3. AFFECTED ENVIRONMENT

This section describes the existing natural resources and environmental conditions within the ROW and immediately adjacent to Section 8B of the Foothills Parkway. The information and data presented in this section provide a baseline description of the environment against which changes to the environment, both positive and negative, resulting from the alternatives described in Sect. 2 are evaluated in Sect. 4.

3.1 GEOLOGY AND SOILS

3.1.1 Regional Geology and Soil Characteristics

The rocks that underlie the Great Smoky Mountains and vicinity comprise part of the western Blue Ridge geologic province in the southern Appalachians (Fig. 2). The geology of the Western Blue Ridge contrasts with that of the adjacent provinces, which include the unmetamorphosed Paleozoic carbonates (limestone, dolomite) and clastic (shale, sandstone, conglomerate) rocks in the Valley and Ridge Province to the west, and the Proterozoic to early Paleozoic high-grade metasedimentary and metaigneous intrusive rocks in the eastern Blue Ridge. The slightly to highly metamorphosed western Blue Ridge rocks of this latitude are divided (based on rock type and geologic age) into three major divisions: the Chilhowee Group, Ocoee Supergroup, and crystalline basement rocks. All are represented in the GSMNP and vicinity (Fig. 2). Rocks of the lower Paleozoic Chilhowee Group comprise an alternating sequence of quartzite and shale that underlies Chilhowee Mountain (Parkway Section 8F), and English, Stone, and other mountains north and east of Parkway Section 8A. Southeast of the mountain front, the foothills and higher peaks of the Great Smoky Mountains are underlain by a thick homogeneous succession of coarse- and fine-grained clastic sedimentary and subordinate carbonate rocks belonging to the late Proterozoic Ocoee Supergroup. These sedimentary rocks overlie crystalline basement rocks composed of Middle Proterozoic gneisses and deformed granitic rocks.

The Great Smoky Mountains are part of the southern Appalachians that formed some 250 million years ago when Africa and North America collided during the final stages of formation of the supercontinent Pangaea (Hatcher 1987). Products of that collision are particularly evident in the vicinity of Wear, Tuckaleechee, and Cades coves which, in geologic terms, are windows (erosional holes in nearly horizontal faults) that expose unmetamorphosed Valley and Ridge carbonate and clastic rocks beneath the cleaved and metamorphosed clastic (and minor carbonate) rocks of the Blue Ridge-Piedmont (Great Smoky) thrust sheet (Fig. 2) (Rodgers 1953; King et al. 1958; Hatcher 1987; Hatcher et al. 1989; Hatcher, Larson, and Neuman 1989). They provide direct evidence of several tens of kilometers of westward transport on the great Blue Ridge-Piedmont thrust sheet (the Great Smoky and Miller Cove thrust blocks) thus formed some 350 km to the southeast; and the rocks southeast of the Miller Cove fault were folded, cleaved, and slightly metamorphosed (some 430–480 million years ago) before being transported westward as part of the Blue Ridge-Piedmont thrust sheet. Subsequent erosion during the past 5 to 20 million years has produced the modern landscape that remains strongly influenced by the composition and structure formed millions of years before (Hack 1982). In particular, the location and size of streams is a

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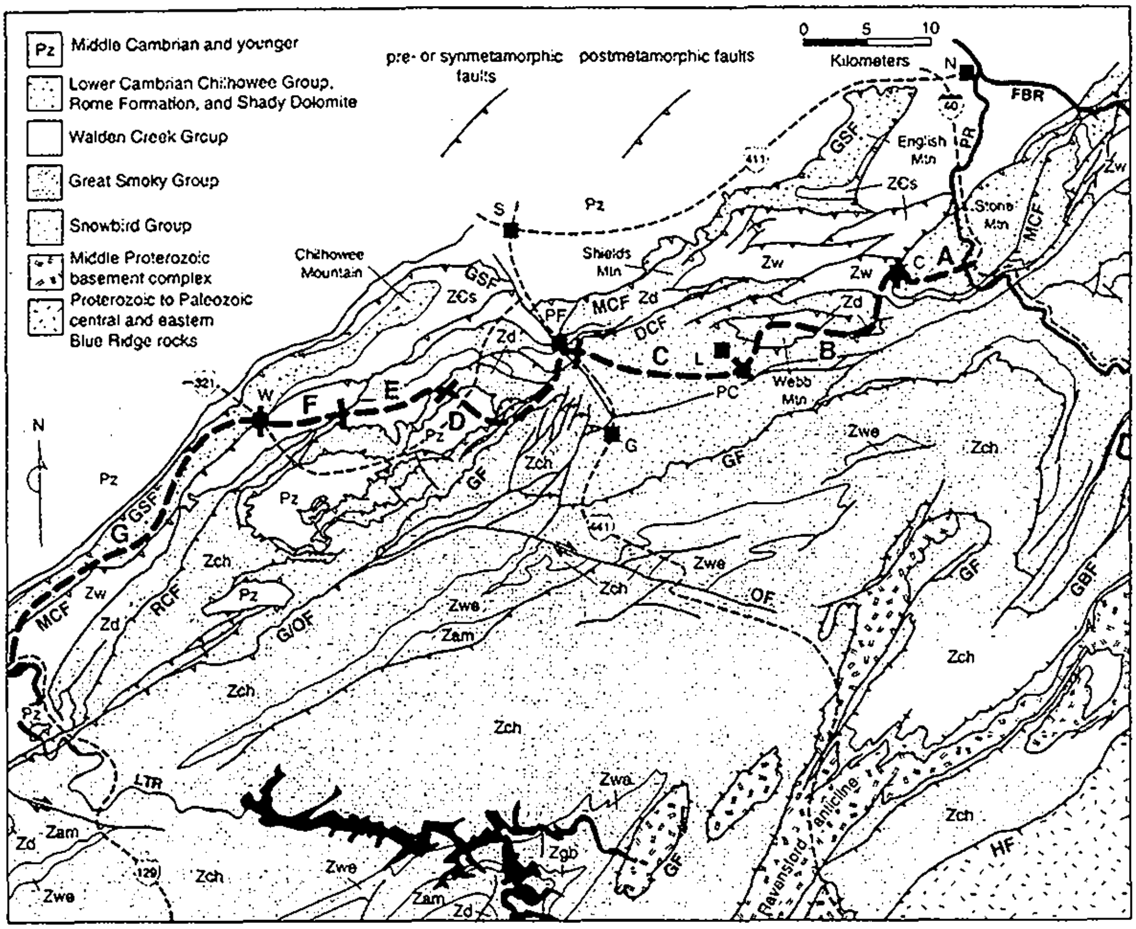

Fig. 2. Regional geologic map of the western Blue Ridge in the vicinity of the Great Smoky Mountains of Tennessee and western North Carolina showing distribution of rock units between the Great Smoky and Hayesville faults. Foothills Parkway indicated by heavy dashed line; bold capital letters indicate segments. Abbreviations of stratigraphic units: ZCs—Sandsuck Formation; Zam—Ammons Formation; Zch—Copperhill Formation; Zd—Dean Formation; Zgb—Grassy Branch Formation; Zw—Wilhite Formation; Zwe—Wehutty Formation. Fault abbreviations: DCF—Dunn Creek fault; GF—Greenbrier fault; G/OF—Greenbrier/ Oconaluftee fault; GSF—Great Smoky fault; HF—Hayesville fault; MCF—Miller Cove fault; OF—Oconaluftee fault; RCF—Rabbit Creek fault. Geographic abbreviations: C—Cosby; FBR—French Broad River; G—Gatlinburg; L—Laurel; LTR—Little Tennessee River; N—Newport; PC—Pittman Center; PF—Pittman Center; PR—Pigeon River; W—Walland. Map modified from King, Neuman, and Hadley (1968), Madley and Neslon (1971), and Connelly (1993).

product of rock composition and structural features (e.g., faults and fracture zones) and the accumulation of colluvial deposits that provide the groundwater reservoirs that sustain streamflow.

King et al. (1958) subdivided the Ocoee Supergroup in the GSMNP and vicinity into three major rock units (groups), subdivided each group into formations, and carefully mapped their areal extent throughout the GSMNP region. The Ocoee Supergroup was divided into (1) Snowbird Group rocks (of which the Pigeon Siltstone constitutes the uppermost formation), which lie stratigraphically above crystalline basement rocks; (2) Great Smoky Group rocks, which overlie Snowbird Group rocks along the Greenbrier fault; and (3) Walden Creek Group rocks, which underlie Chilhowee Group rocks south of Chilhowee, English, and Stone Mountains, Tennessee. The Snowbird Group consists of clean to unclean sandstone (feldspathic sandstone to graywacke), shale, and siltstone; the Great Smoky Group consists of medium to massive beds of unclean sandstone and conglomerate (mostly graywacke) and dark shale (appreciably pyritic); and the Walden Creek Group consists of siltstone, sandstone, conglomerate, and limestone.

More subtle features of the modern landscape were formed by erosion and deposition processes working on somewhat shorter time scales. Rocks and sediments that have been moved from higher-elevation slopes to lower slopes by gravity (e.g., landslides, slumping, or creep) form colluvial deposits. These deposits are like the talus slopes seen at the base of many western mountains, but in this region they are generally covered by forest and have often themselves been highly dissected by streams. Colluvial deposits are very common on the lower slopes of this region. Many of them probably formed during periods of colder and/or wetter climate thousands of years ago. Deposits of sediments left by water are called alluvial deposits and are common as floodplains in the valleys and as bank deposits along many lower-slope streams. A notable example of a combined colluvial and alluvial deposit is the Rocky Flats area near the middle of the Section 8B ROW (Fig. 1B). The present Rocky Flats landscape is the result of a series of large, late Pleistocene mudflows originating from Greenbrier Pinnacle to the south.

Soils that developed on each of the geologic features of the region have characteristics that reflect the underlying bedrock or surficial deposits and that can be used to interpret opportunities for or constraints on the use of that land. Residual soils formed in place from underlying bedrock. Colluvial soils were formed in gravity-transported materials that have moved from upslope; they reflect presently inactive colluvial or mass-movement processes. Alluvial soils were formed in water-transported alluvial deposits and may reflect both ancient or continuing erosional and depositional processes.

3.1.2 Objectives and Data Collection

Existing information on geology and soils along the proposed ROW was compiled and evaluated and supplemental information was collected to characterize the existing environment in order to evaluate potential environmental impacts of the proposed project. Specific objectives of the geology and soils investigations were as follows:

1. to verify and augment published geological and structural data along the proposed route;
2. to map the soils within the ROW using National Cooperative Soil Survey Standards;
3. to comment on engineering properties of the different bedrock types and on constraints associated with soils mapped on the ROW;

4. to locate and study in detail any brittle faults that might cause problems;
5. to collect data on fracture systems present in the bedrock and comment on particular ROW segments that might be affected by combinations of dip of fractures, bedding/cleavage, and rock type;
6. to identify potential construction hazards in karst areas and relationships to groundwater systems;
7. to map bodies of colluvium and alluvium along the ROW to identify potential problem areas related to slope stability and hydrologically important areas and wetlands; and
8. to locate pyritic zones in slates which might impact long-term stability of construction materials and cuts or contribute to stream acidification.

Detailed geologic and soil surveys of the ROW were conducted to verify and augment the existing published data for the area (e.g., King et al. 1958; Hamilton 1961; King 1964; Neuman and Nelson 1965) and the outdated soil survey map for Sevier County (SCS 1956). The geology and soils surveys were conducted using observations during numerous site visits, published U.S. Geological Survey (USGS) maps, and aerial photographs. The information obtained was correlated to USGS topographic quadrangle maps enlarged to 1:12,000 scale and to FHWA maps of the ROW produced at a scale of 1:2000. Detailed findings of the geology and soils investigations are reported in Appendices A (Geology) and B (Soils). The first-order, medium resolution soil map (1:2000 scale) is provided separately. A summary of the geology and soils investigations, including the general 1:12,000-scale soil and parent materials map, is provided in the following sections. Not all soil features can be depicted on the general soil maps (1:12,000), but they are shown on the first-order, medium resolution (1:2000 scale) maps.

3.1.3 Local Geology Along Proposed Section 8B

The Foothills Parkway Section 8B ROW is underlain by four rock units: (1) Pigeon Siltstone, consisting mostly of greenish-gray laminated to thinly banded (<3 cm), locally calcareous, metasiltstone, very fine-grained sandstone, and minor coarse sandstone; (2) a clay slate unit, stratigraphically above rocks of the Pigeon Siltstone, consisting of an interbedded medium gray laminated metaslate to thinly (≤3 cm) banded metasiltstone and fine- to medium-grained feldspathic (i.e., contains feldspar) metasandstone; (3) Great Smoky Group sandstone, a massive unit that underlies Webb Mountain and Big Ridge and consists dominantly of thicker (≤2 m) beds of medium- to coarse-grained feldspathic metasandstone and subordinate granule metaconglomerate; and (4) the Yellow Breeches Member of the Wilhite Formation (Walden Creek Group), consisting dominantly of medium to dark gray calcitic and micaceous slate and metasiltstone, with subordinate interbeds (≤3 m) of medium- to coarse-grained argillaceous (i.e., clay or clay-sized particles) and feldspathic metasandstone (Hamilton 1961) (Fig. 3). Several faults cross the ROW, including the Dunn Creek fault, Webb Mountain fault, a portion of the Gatlinburg fault zone, and several unnamed low-angle and high-angle thrust faults (Fig. 3).

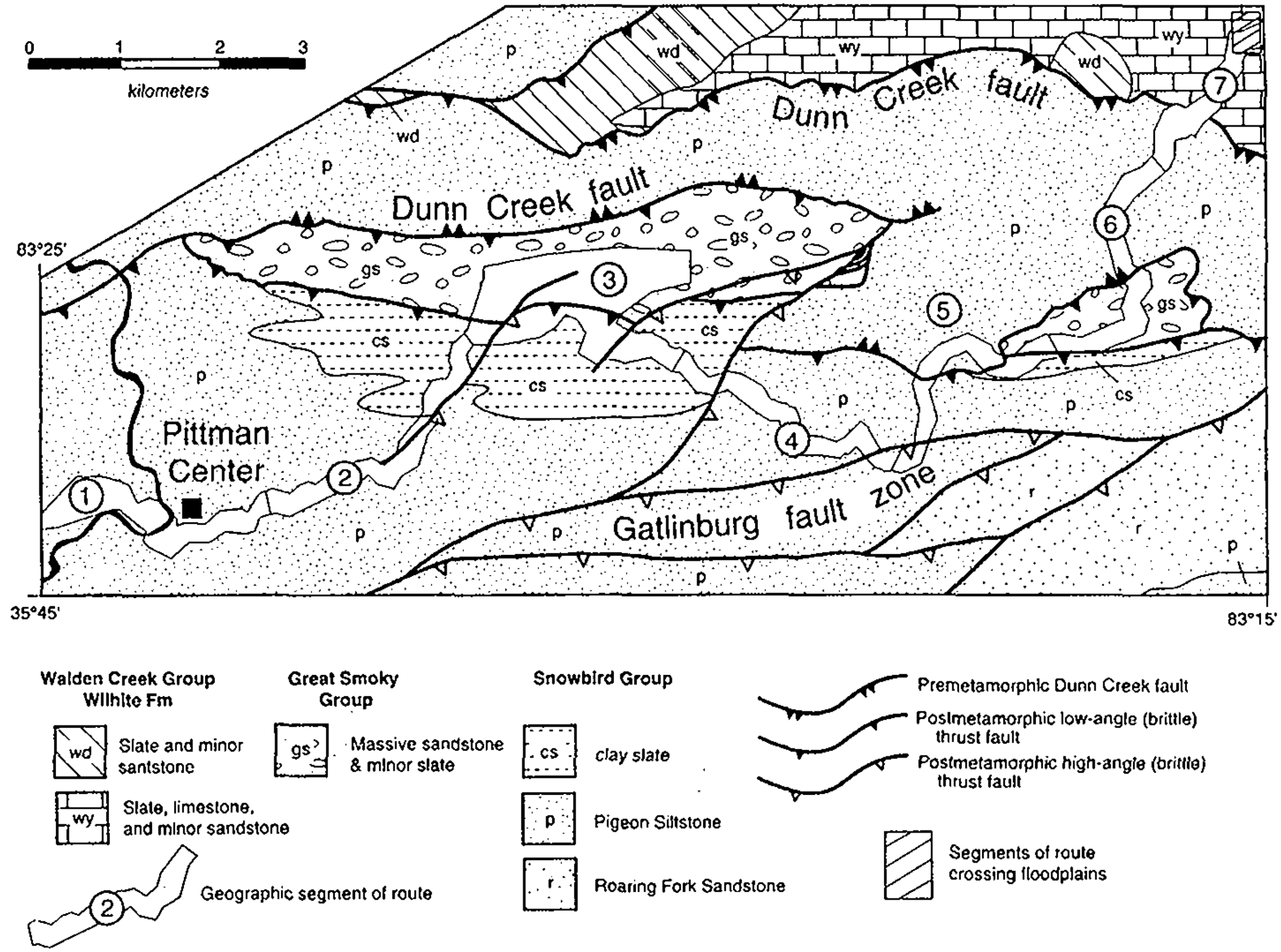

Fig. 3. Simplified geologic map of the Webb Mountain area. Segmented 8B right-of-way is lightly shaded. Numbers indicate geographic segments.

The structural data collected along the ROW include bedding*, slaty cleavage**, joint, fault, and quartz vein orientations; they are presented in Appendix A. A diagram of the rock units of the Foothills Parkway, including other sections in addition to Section 8B, and their engineering and other properties that would affect environmental impacts is provided in Fig. 4. Bedding, cleavage, and joint orientations define rock surfaces that may be problematic to stabilize during road construction. In general, orientation of bedding and slaty cleavage in the vicinity of the Section 8B ROW is very consistent, with bedding having a generally E–W strike with shallow to steep N and S dips, and cleavage having a northeast strike and shallow to moderate southeast dip. Further work is needed to characterize the geotechnical engineering properties of these rock surfaces to fully understand their significance with respect to engineering considerations (e.g., measurements of tensile strength, unconfined compressive strength, shear strength, and characterization of friction angles). Numerous outcrop-scale brittle thrust and strike-slip faults have been encountered during the geologic survey, and many more are expected to be uncovered as development proceeds. A more complete analysis of areas of geologic concern and potential impacts is presented in Appendix A.

3.1.4 Description of Geology and Soils by Segment

The entire Foothills Parkway Section 8B ROW has been subdivided into 7 segments from west to east for the geology and general soils maps (scale of 1:12,000) and descriptions (Fig. 5). Soil mapping units and parent materials are shown in Table 1. Each segment is considered separately in this section.

3.1.4.1 Little Pigeon River Terraces (segment 1)

In segment 1, the ROW traverses the floodplain and terraces of the Little Pigeon River and slopes of the low hills southwest of Webb Mountain. These hills are underlain by Pigeon Siltstone. Bedding generally strikes E–W, with shallow to steep N dips, and cleavage strikes NE–SW and dips moderately SE. The ROW crosses approximately 500 m of Little Pigeon River alluvium of unknown thickness about 0.3 km southwest of Pittman Center. Additionally, the ROW crosses a fault as recognized by Hamilton (1961) about 300 m east of its western terminus. The fault is interpreted to have duplicated Pigeon Siltstone rocks in this area, but tangible surface evidence for it is lacking. The ROW also crosses three streams, Copeland Creek, Lindsey Creek, and Webb Creek in this segment. Copeland Creek has downcut through the Little Pigeon terraces and is now entrenched (Fig. 6).

Alluvial and colluvial soils dominate this segment. Alluvial soils in the Little Pigeon River floodplain and terraces consist of modern floodplain alluvium with high cobble and boulder content and stratified silts and clays that cover older sands and gravels on terraces. Slopes in much of the ROW in this segment are gentle, although there are a few areas of moderately steep slope near the eastern end of the segment (Fig. 7).

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*Bedding-planar surfaces that separate original layers in sedimentary rocks.

**Slaty cleavage-planar structure produced by compressional deformation that mostly results from recrystallization of fine-grained minerals (commonly clays) in a rock. Slate contains slatty cleavage.

AGE		ROCK UNIT/TYPE	PARKWAY SECTION	ESTIMATED ROCK MASS RATING CATEGORIES	OTHER GEOLOGIC ENVIRONMENTAL IMPACTS
Quat.	Stream and slope deposits	Alluvium & colluvium: Unconsolidated sand, gravel, boulders, clay in various degrees of sorting	All	Mostly I, some II	unstable slopes excessive sediment to streams
Paleoz.	Valley and Ridge units	Shale and limestone	8D & E1	sh (F) II–III sh (W) III–IV ls (F) I–II ls (W) II–IV	karst and fracture-controlled cave and ground-water systems
CAMBRIAN AND PRECAMBRIAN (?)	Chilhowee Group	Alternating massive sandstone (+ conglomerate) and brown to gray nonpyritic shale	8G (?)	ss, cgl (F) I–II ss, cgl (W) III–IV sh, sltst (F) II–III sh, sltst (W) III–IV ls (F) I–II ls (W) II–IV	unstable dip slopes
LATE PROTEROZOIC	Ocoee Supergroup – Walden Creek Group	Sandsuck Formation (shale, siltstone, sandstone)	8G (?) & 8F		shale yields excessive sediment to streams
		Wilhite Formation – Yellow Breeches Member (banded siltstone, slate, impure limestone)	8B & F		minor karst
		Wilhite Formation – Dixon Mountain Member (banded siltstone, slate)			slates yield excessive sediment to streams
		Shields Formation (conglomerate, sandstone, shale—some pyritic)	8B & F		Intense fracturing & clay fill in fault zone
		Dunn Creek fault			
	Great Smoky Group	Rocks of Webb Mountain and Big Ridge, Thunderhead Sandstone, Dean Formation Massive graywacke, minor shale (gray to black and pyritic)	8B, C, & D	ss, cgl (F) I–II ss, cgl (W) III–IV sh (F) II–III sh (W) IV	pyritic slate slate yields excessive sediment to streams
		Greenbrier or Dunn Creek fault			
	Snowbird Group	Metcalf Phyllite (W) (phyllite, siltstone, sandstone) Clay slate Pigeon Siltstone (E) (siltstone, phyllite, sandstone)	8B, C, & D	clay sl (F) II–III clay sl (W) IV sltst (F) II–III sltst (W) III–IV ss (F) I–II ss (W) III–IV	pyrite unit near and minor disseminated pyrite in clay shale slate & phyllite yield excessive sediment to streams

RMR = Σ (qu + RQD + Js + Jr + Jw + Jo), where: qu = unconfined compressive strength, RQD = $\frac{\sum \text{Length core pieces} > 10 \text{ cm}}{\text{Total core run length}} \cdot 100$

RMR = Rock mass rating (I – IV) *J = Joint parameters, spacing (Js), roughness (Jr), water content (Jw), and orientation (Jo) (Bieniawski, 1989)*

Fig. 4. Rock units of the Foothills Parkway and their engineering and other properties that would affect environmental impacts.

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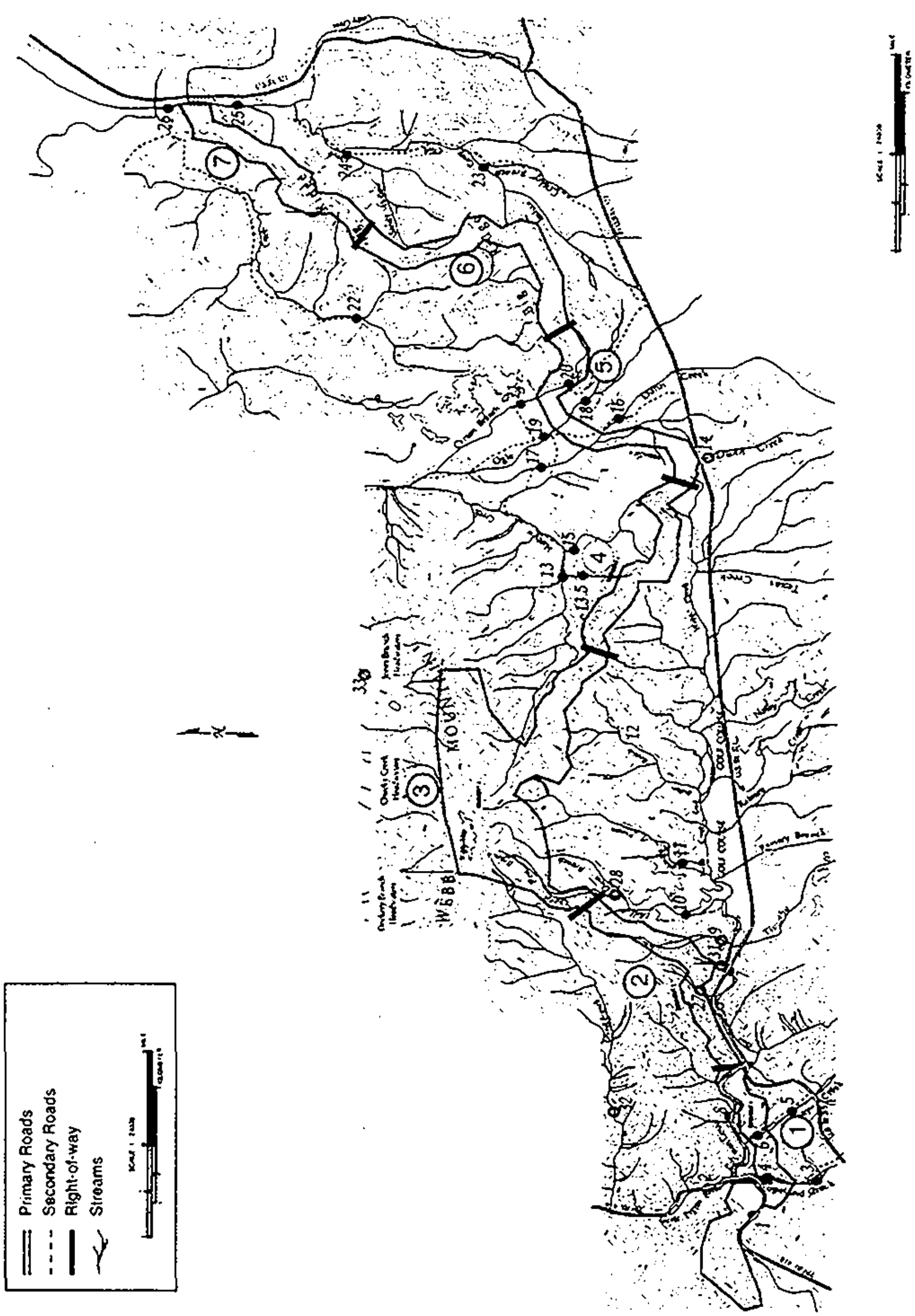

Fig. 5. Map of right-of-way showing the seven segments into which it was divided for presentation of geology and soils characterization.

Table 1. Soil mapping units and parent materials

Number[a]	Soil series name (parent material)
1E, 1F, 1G	Cataska-Citico, siltstone phase, rock outcrop complex (Pigeon siltstone residuum
3D, 3E, 3F	Ranger (pigeon siltstone residuum)
4B	Monongahela (Cosby Creek terrace alluvium)
5A	*Combs-like (Cosby Creek floodplain alluvium)*
6D, 6E, 6F, 6G	Sylco-Citico slaty phase complex (Webb Mountain slate residuum)
7C, 7D, 7E	Junaluska (Pigeon siltstone residuum)
10C, 10D, 10E	Shelocta (Pigeon siltstone colluvium)
20B, 20C, 20D	Braddock (Cosby Creek high terrace alluvium)
21A, 21B, 21C	*Craigsville (local floodplain stony alluvium)*
22C, 22D, 22E, 22F	Maymead (Great Smoky Group sandstone colluvium)
23A	wetlands Fluvaruents (alluvium)
24D, 24E	Nantahala (Webb Mountain slate residuum)
26D	Keener, non-pyritic phase (Webb Mountain slate colluvium)
27A, 27B, 27C, 27D	State (low terrace alluvium)
28B, 28C, 28D	Lost Cove (very stony mudflow alluvium)
33D, 33E	Unicoi-rock outcrop complex (Great Smokies Group sandstone residuum)
36C, 36D, 36E	Brasstown (Great Smoky Group sandstone residuum)
37D, 37E, 37F, 37G	Soco (Great Smoky Group sandstone residuum)
38C	State, high terrace phase (Little Pigeon River terrace alluvium)
39B	Toccoa (Little Pigeon River 2nd bottom alluvium)
Cut and fill	Orthents

[a]Slope class legend:

A 0 to 2%
B 2 to 6%
C 6 to 12%
D 12 to 25%
E 25 to 45% (approximate upper limit for argillic horizons due to slope stability)
F 45 to 65%
G >65% (creep processes become very serious)

Note: Not all of these soils can be shown on the 1:12,000 scale soils map.

3.1.4.2 Webb Creek Ridge (segment 2)

In segment 2, the ROW ascends the southwestern footslope ridges of Webb Mountain. Most of this segment is underlain by Pigeon Siltstone. Bedding generally strikes E–W and dips steeply N, and cleavage strikes NE–SW and dips SE as in segment 1. In the northeastern portion of this segment, west of Mill Dam Branch, the ROW centerline approximately parallels a SE-dipping brittle fault zone (<15 m wide) characterized by anastomosing outcrop-scale brittle faults and crosses the structure in the vicinity of the stratigraphic contact between the Pigeon Siltstone and the lower clay unit (near the northeastern end of the segment between boundary monuments 84 and 152) (Fig. 8).

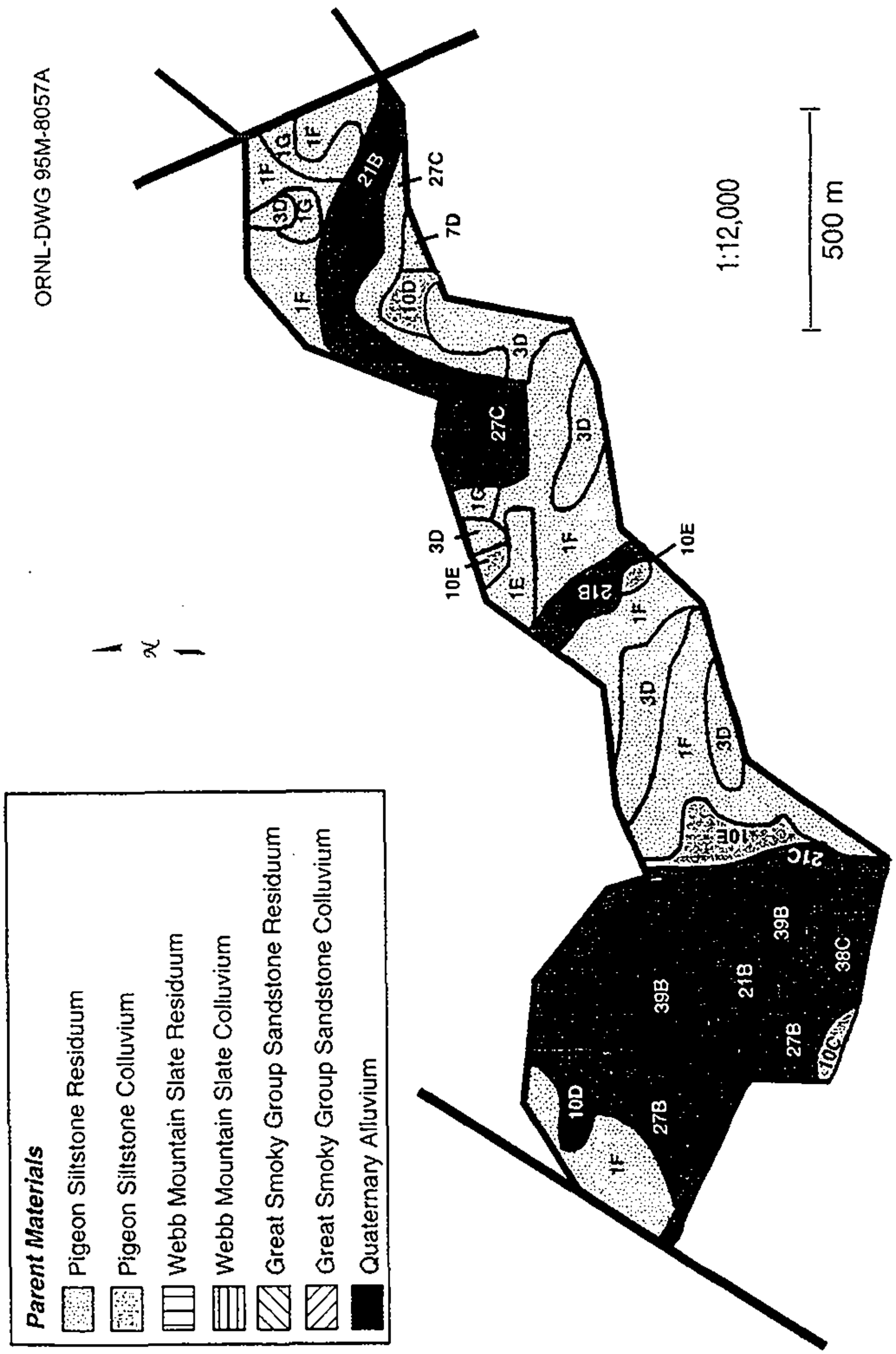

Fig. 6. Parent materials of Segment 1 (Little Pigeon River Terraces).

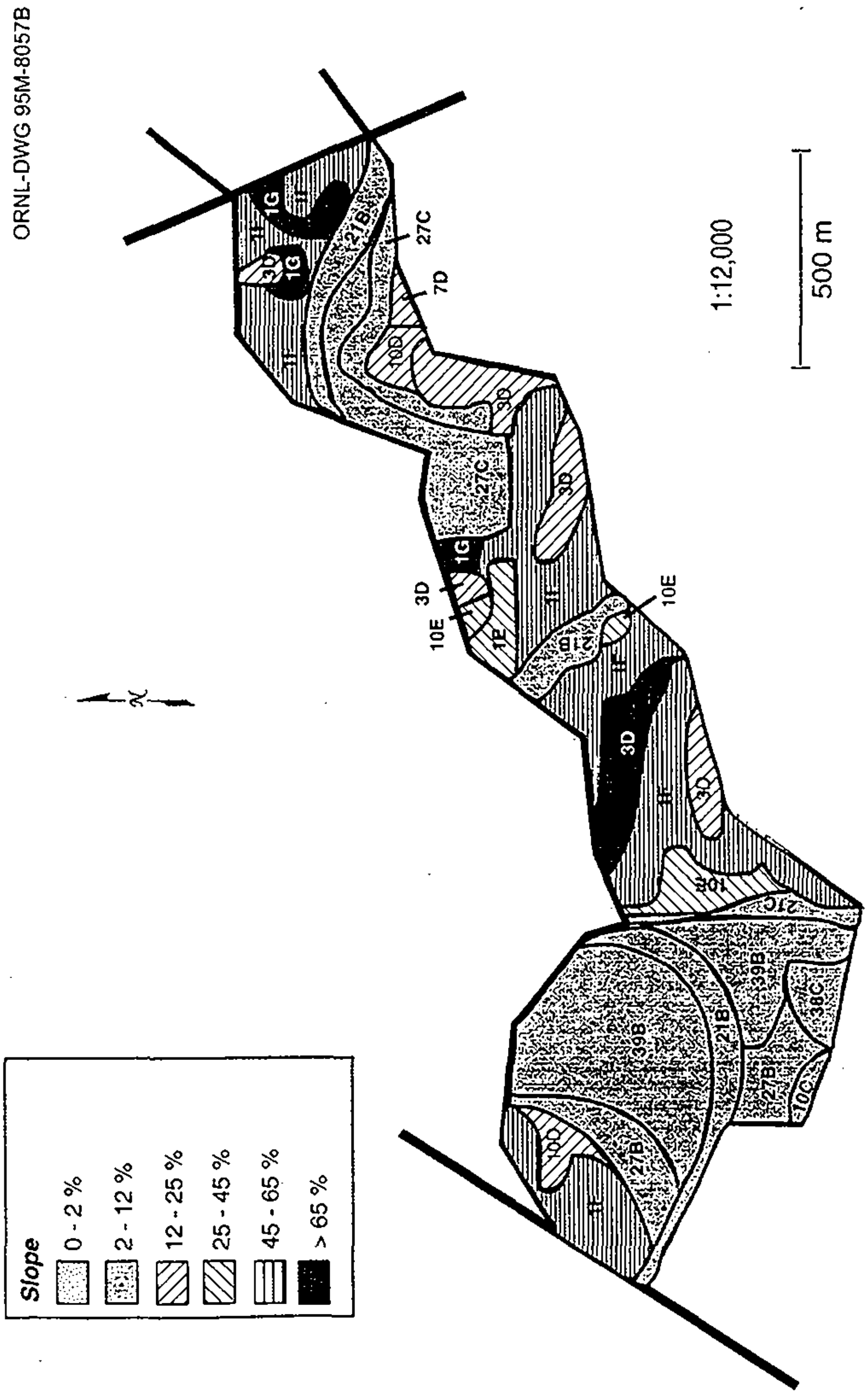

Fig. 7. Slopes of Segment 1 (Little Pigeon River Terraces).

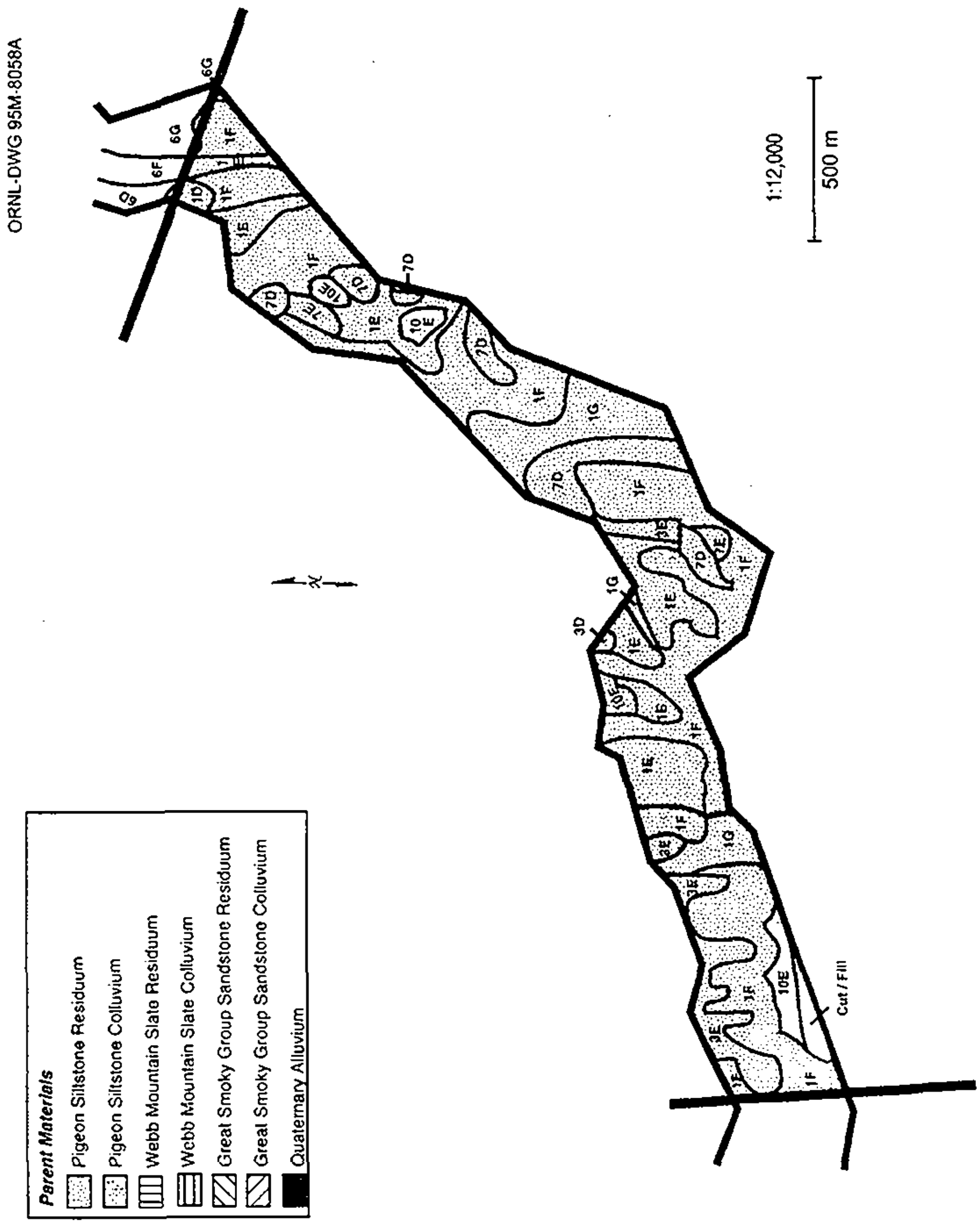

Fig. 8. Parent materials of Segment 2 (Webb Creek Ridge).

Residual soils formed in the Pigeon siltstone dominate this segment. Relatively steep slopes are common, with much of the area having slopes >25%. This segment of the ROW also includes low terraces of Webb Creek along its southwestern edge (Fig. 9).

3.1.4.3 Webb Mountain (segment 3)

In segment 3, the ROW traverses the slopes and ridges of Webb Mountain. The ROW centerline and to the south is wholly underlain by rocks of the clay slate unit (which the soil survey refers to as the Webb Mountain slate). North of the centerline, the ROW on Webb Mountain is underlain by coarser-grained rocks of the Great Smoky Group. The Great Smoky Group rocks underlying Webb Mountain generally do not appear to contain significant pyritic materials. However, the lower slate unit (Webb Mountain slate) contains some finely divided pyrite. Although the pyrite content appears to be low, it may be sufficient to produce significant amounts of acid sulfate as the pyritic material weathers. The presence of the Webb Mountain clay slate unit with its low pyrite content is the most likely reason for the elevated sulfate levels observed in streams draining the south side of Webb Mountain, particularly Warden Branch and its headwater tributaries (see Sect. 3.2.3.2). In particular, a recently constructed road in the upper end of Cobbly Knob area near the southern border of the ROW has probably resulted in fresh exposure of pyritic materials and increased sulfate in streams. Bedding and cleavage orientations are the same as in segment 2 to the west (Fig. 10).

Soils of segment 3 of the ROW are primarily residual soils of the Great Smoky Group in the upper portion (above the centerline) and residual soils of the Webb Mountain slate in the lower portion. Slopes are quite steep in this segment, with many areas exceeding 45% (Fig. 11). Numerous colluvial fields of limited extent (<1 ha) and unknown thickness are located on the midslopes. These are too small, however, to be shown on the general soil maps (see Appendix B and the accompanying first-order soil map for details).

3.1.4.4 Matthew Branch Ridge (segment 4)

In segment 4, the ROW descends the southeastern footslope ridges of Webb Mountain and is underlain by the non-pyritic Pigeon Siltstone (the stratigraphic contact between the Webb Mountain slate and Pigeon Siltstone is approximately at the border between ROW segments 3 and 4). Bedding strikes NW-SE and dips moderately SW in segment 4, whereas cleavage orientations are the same as in the previous segments (Fig. 12).

Soils of segment 4 are primarily residual soils formed from the Pigeon siltstone, although some areas of colluvium were found. Slopes are also relatively steep, although somewhat less steep than in segment 3 (Fig. 13).

3.1.4.5 Rocky Flats (segment 5)

The western one-third of segment 5 consists of the slopes and low hills flanking the southeast side of Webb Mountain and is underlain by rocks of the Pigeon Siltstone (Fig. 14). Bedding strikes E–W and dips steeply N, whereas cleavage orientations are again similar to the previous segments (NE–SW strikes with moderate SE dips). Soils are primarily residual, except for extensive colluvial areas along the eastern edge of the ROW to the west of Rocky Flats. One area of very

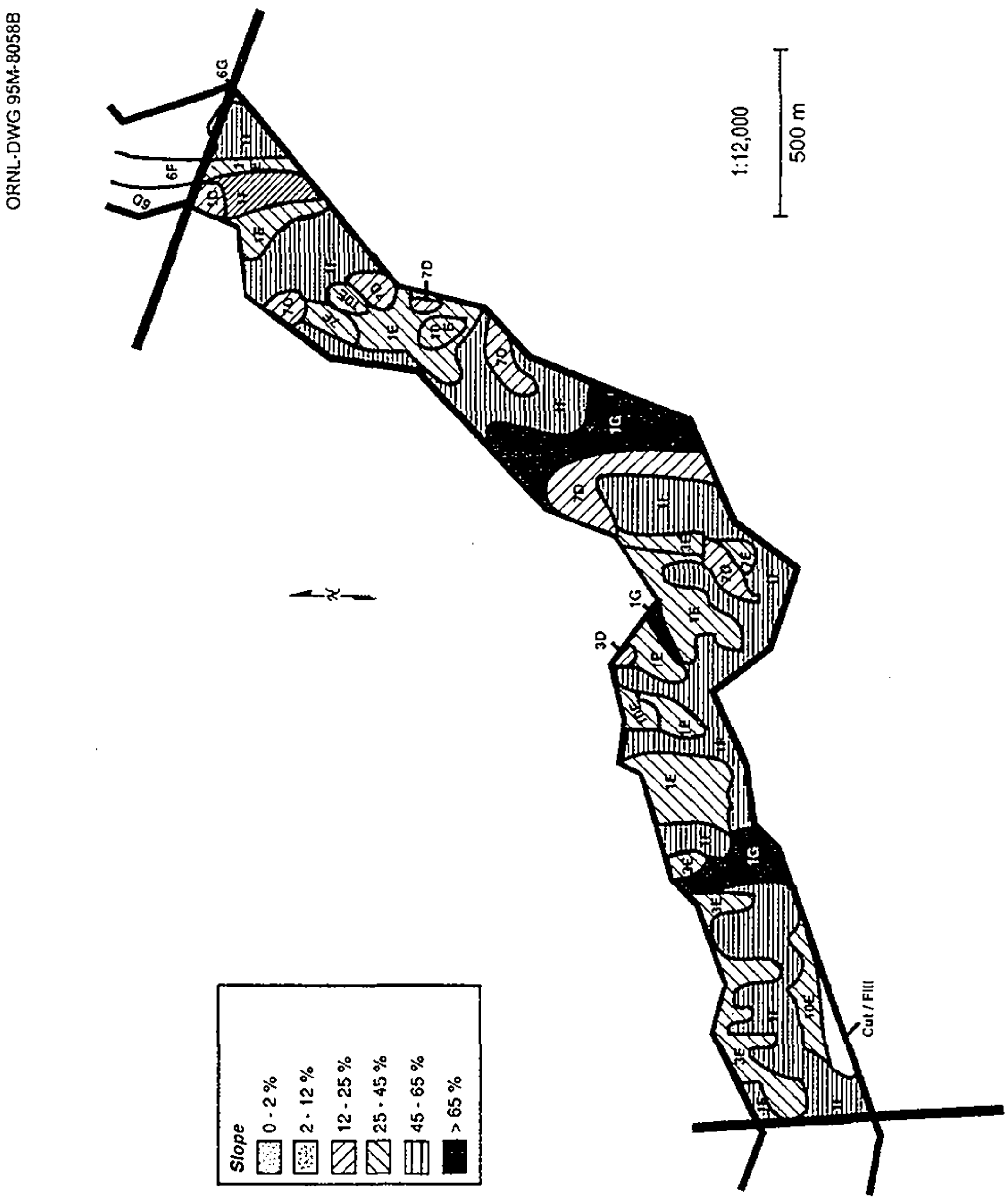

Fig. 9. Slopes of Segment 2 (Webb Creek Ridge).

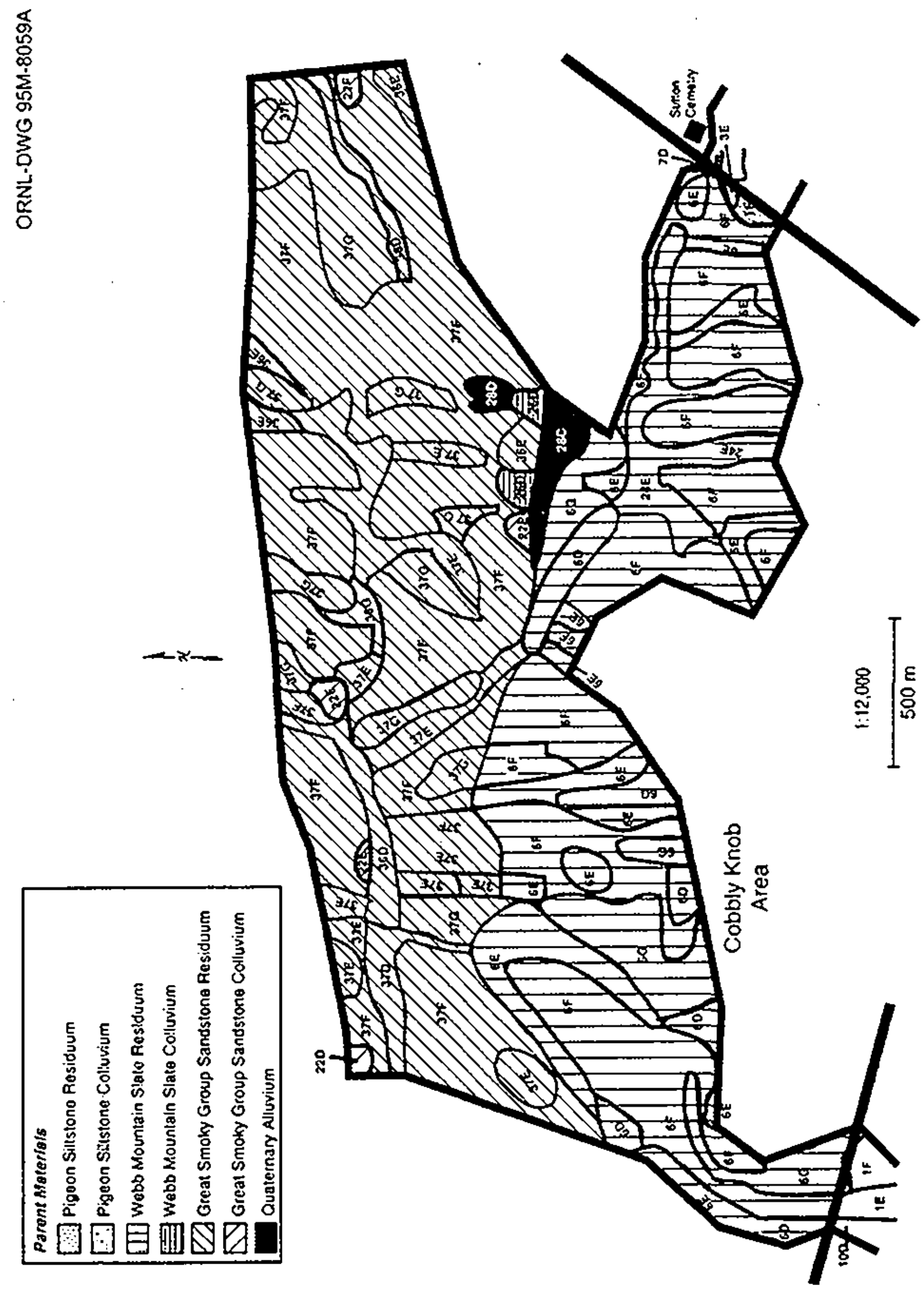

Fig. 10. Parent materials of Segment 3 (Webb Mountain).

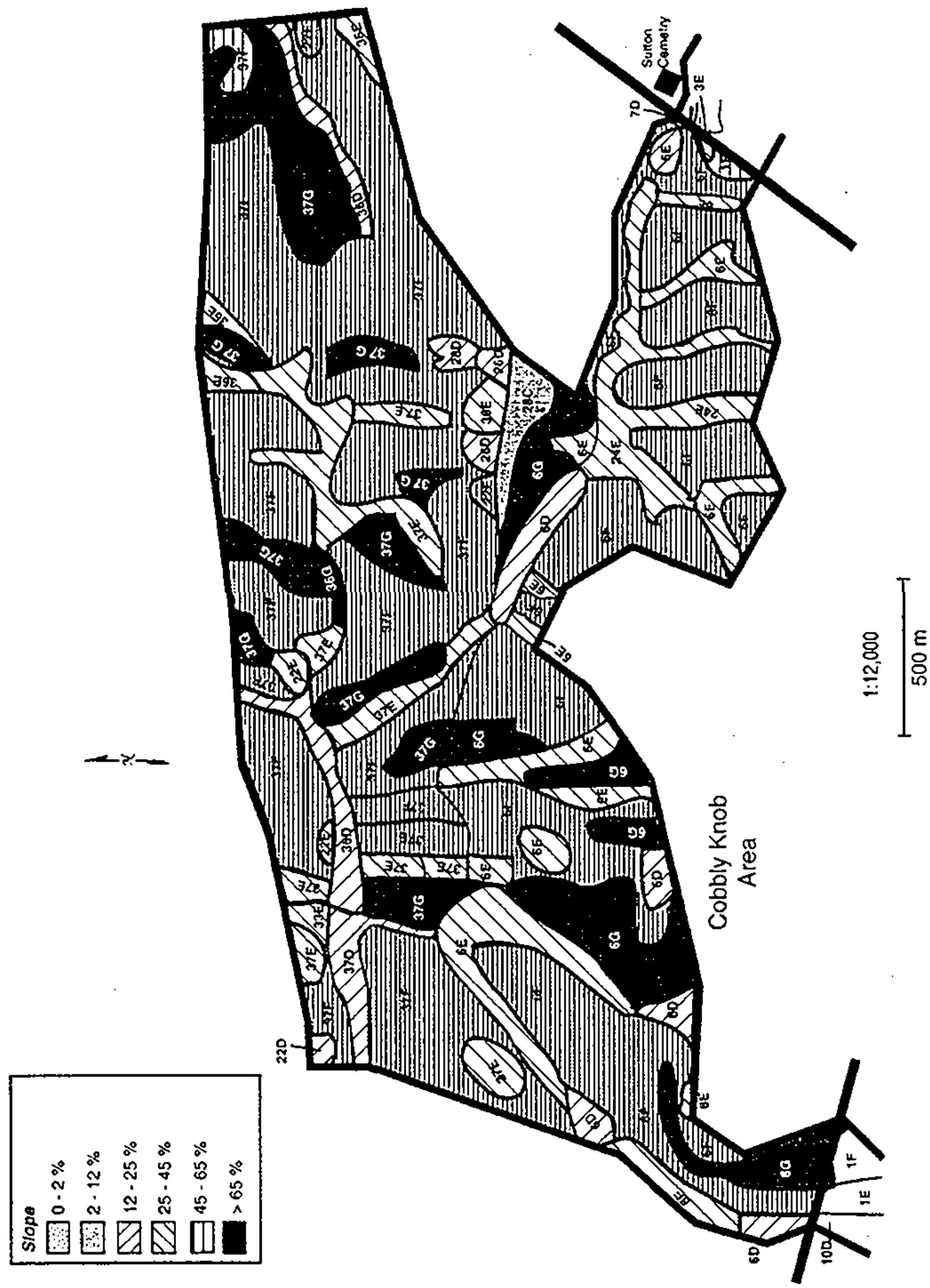

Fig. 11. Slopes of Segment 3 (Webb Mountain).

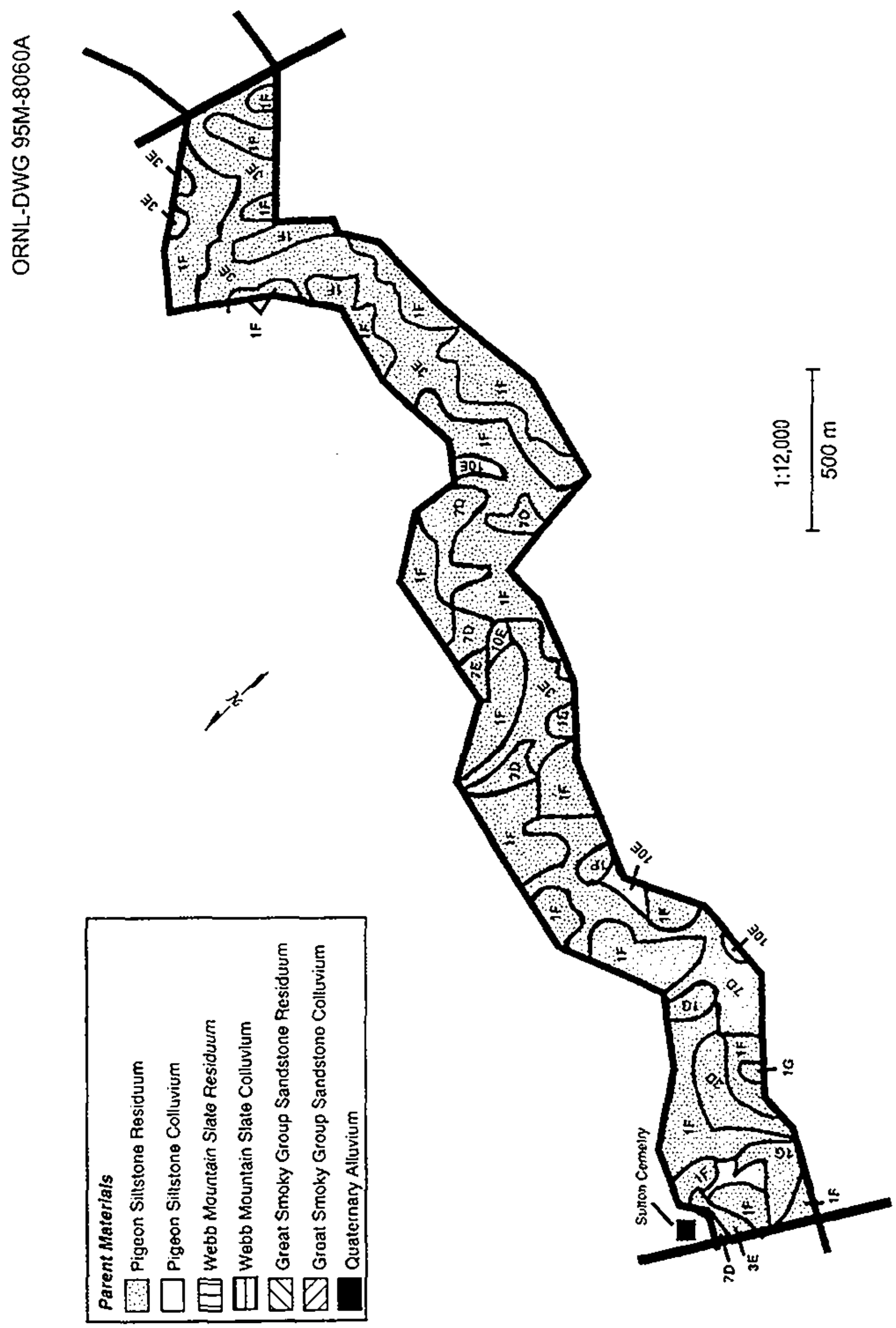

Fig. 12. Parent materials of Segment 4 (Matthew Branch Ridge).

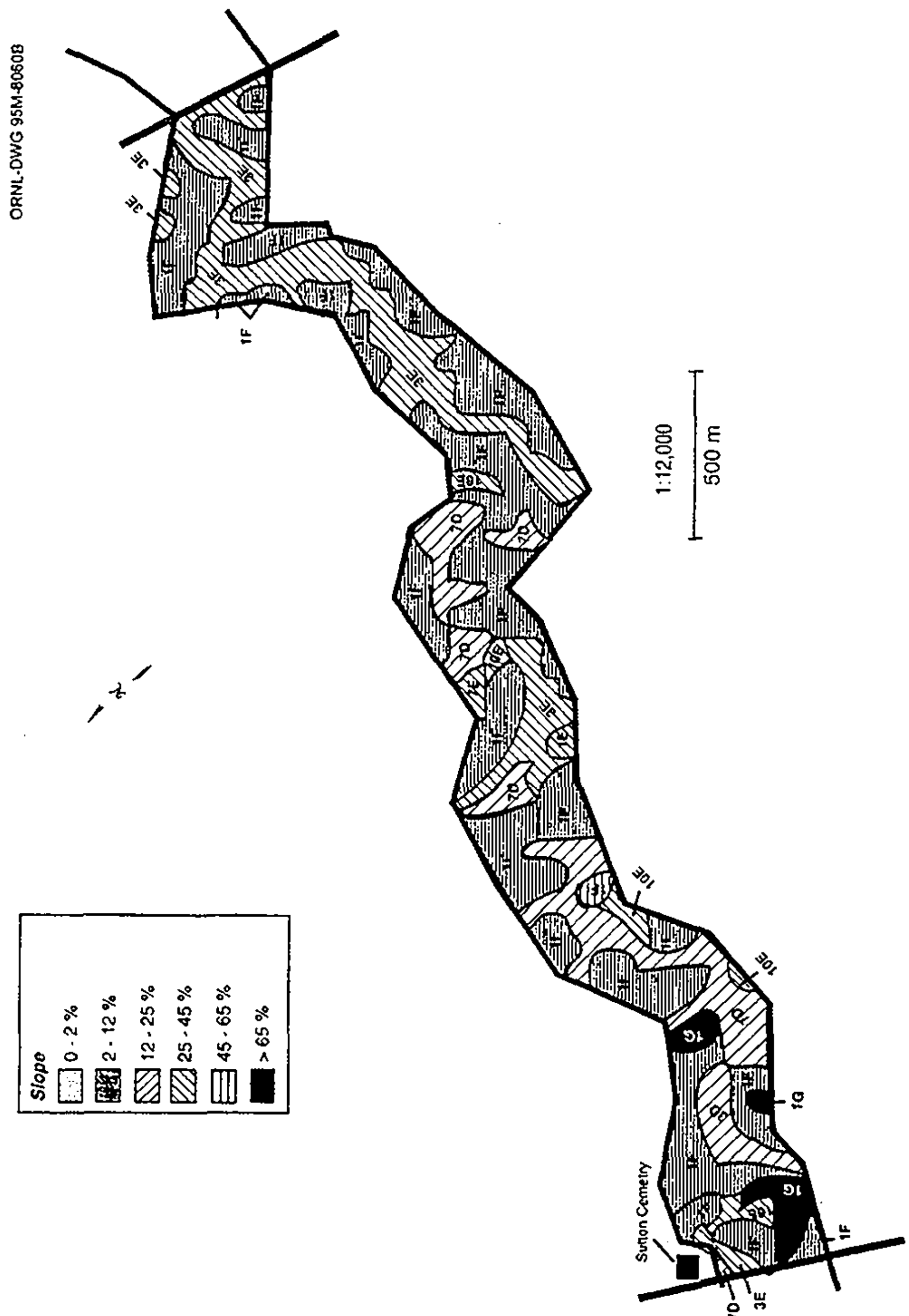

Fig. 13. Slopes of Segment 4 (Matthew Branch Ridge).

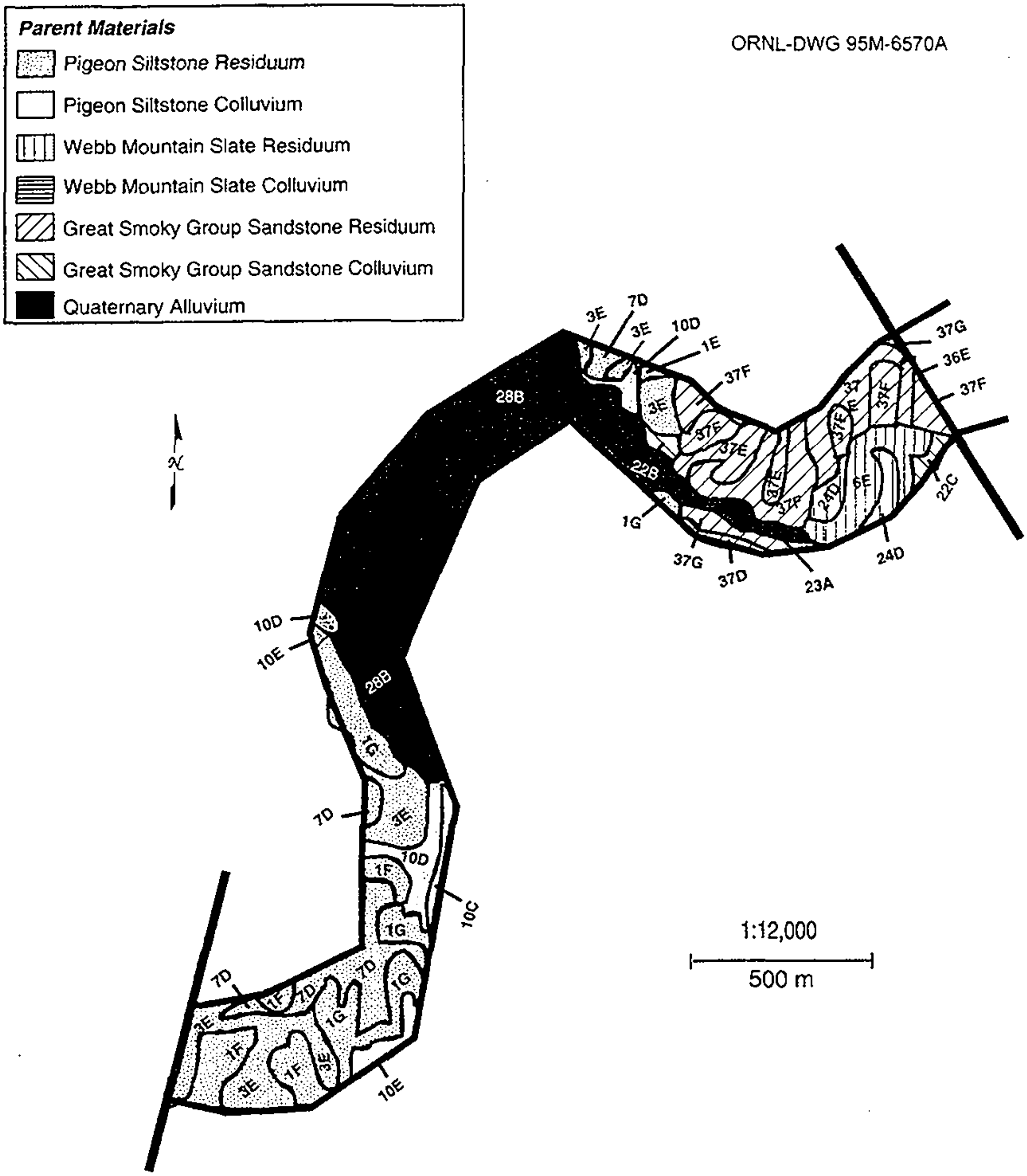

Fig. 14. Parent materials of Segment 5 (Rocky Flats).

steep slope (>65%) borders the lowland Rocky Flats area at the eastern end of this portion of segment 5 (Fig. 15; see 1st order soils map and Appendix B for greater detail).

The middle third of segment 5 consists of the Rocky Flats lowland area, which is the toe of a vast colluvial field of unknown thickness composed of blocks (≤ 3 m^3) of Thunderhead Sandstone (Great Smoky Group) shed from Greenbrier Pinnacle to the south. This area has since been modified extensively by alluvial deposition, stream cuts, and recent agricultural activity. The soils of this area are mapped as alluvium and slopes are gentle, except for a small area of moderately steep residual and colluvial soils formed in Pigeon siltstone to the northeast of Rocky Flats.

The eastern one-third of segment 5 consists of the southwestern slopes of Big Ridge and is mostly underlain by coarse-grained rocks of the Great Smoky Group southeast of the Webb Mountain fault (Fig. 14). To the north of the fault is the Pigeon Siltstone. Hamilton mapped the location of the Webb Mountain fault in this area on the basis of different footwall (Pigeon)/hanging wall (Great Smoky Group) rocks, but surface evidence for a fault is lacking. The soil survey also indicated a stratigraphic contact between the Great Smoky Group rocks and the Webb Mountain slate in the lower eastern portion of segment 5. As described for segment 3, the Webb Mountain slate contains pyritic materials that may produce acid sulfates when exposed and weathered, although streams draining this area do not indicate elevated sulfate levels (see Sect. 3.2.3.2). Bedding and cleavage orientations remain constant from segment 4 across both the fault and the surficial deposits of Rocky Flats (bedding strikes E–W and dips N, cleavage strikes NE–SW and dips SE).

3.1.4.6 Big Ridge (segment 6)

The southern half of segment 6 of the ROW is located close to the top of Big Ridge and is underlain by coarse-grained rocks of the Great Smoky Group (Fig. 16). Bedding and cleavage orientations are similar to those for previous segments (bedding strikes E–W and steep N dips, cleavage strikes NE–SW with moderate SE dips). The coarser sandstone rocks of the Great Smoky Group do not appear to contain pyrite, although thin slate strata within it show some evidence of past pyrite oxidation. Soils are residual and relatively steep (Fig. 17).

The Webb Mountain fault crosses the ROW again near the middle of this segment between boundary monuments 20 and 215/216 (also see Fig. 3), forming the stratigraphic contact between the Great Smoky Group rocks to the south and the Pigeon Siltstone to the north. This fault defines a sharp break in soils and vegetation. To the north are primarily Pigeon siltstone residual soils that, based upon the vegetation differences (white pine and hemlock to the north, virginia pine to the south) may contain higher levels of calcium than the Great Smoky Group soils to the south. In the Pigeon siltstone to the north of the fault, bedding orientations remain constant (E–W strikes with moderate N dips), but cleavage in this area strikes E–W to NW–SE with shallow to moderately steep dips to the S and SW.

3.1.4.7 Cosby Creek Terraces (segment 7)

The southwestern portion of segment 7 of the ROW traverses the upper sideslopes and ridgetop of Big Ridge and is underlain by Pigeon Siltstone (Fig. 18). Soils are formed in siltstone residuum and slopes are moderately steep (Fig. 19). The ROW crosses the Dunn Creek fault on the northeast

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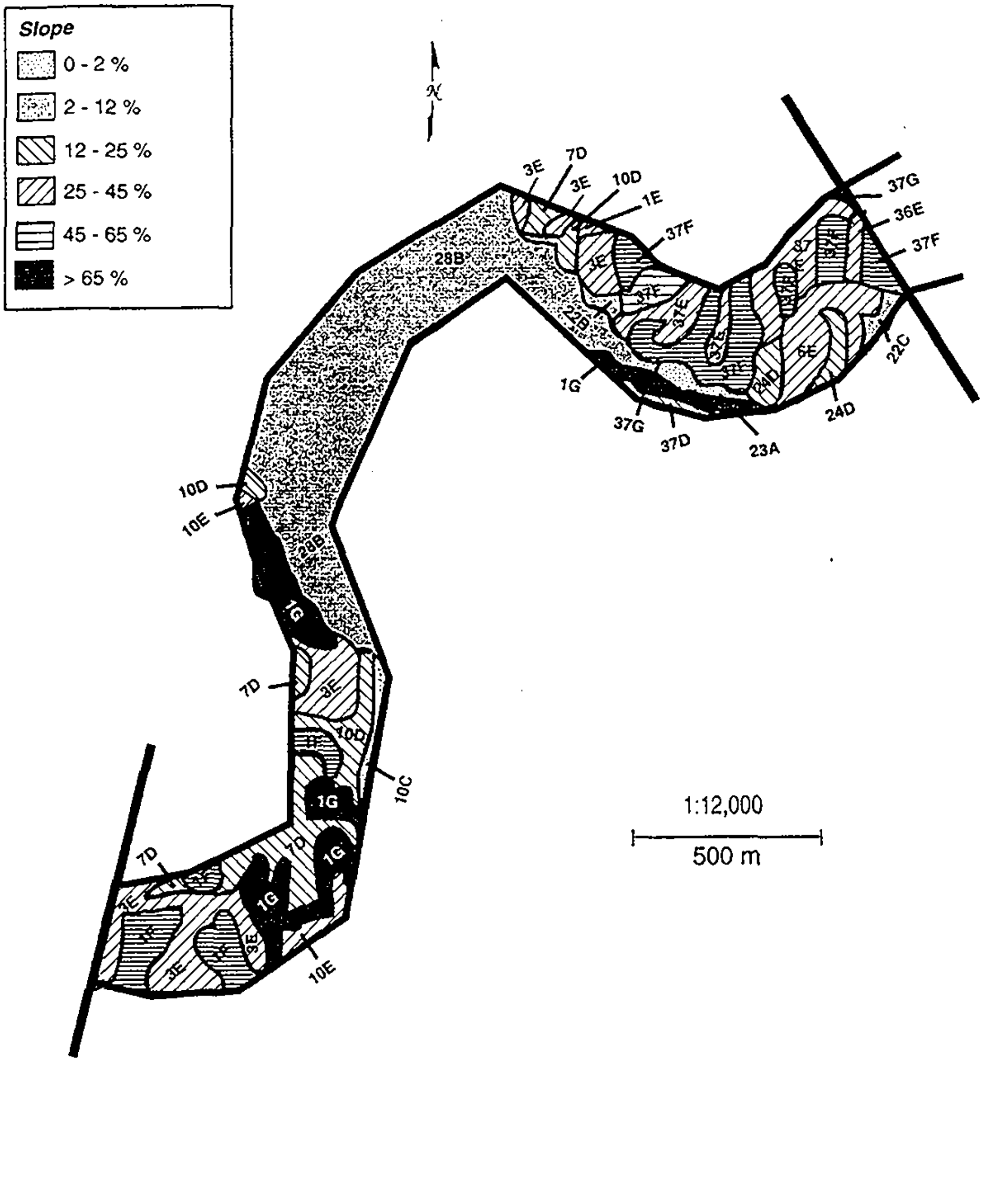

Fig. 15. Slopes of Segment 5 (Rocky Flats).

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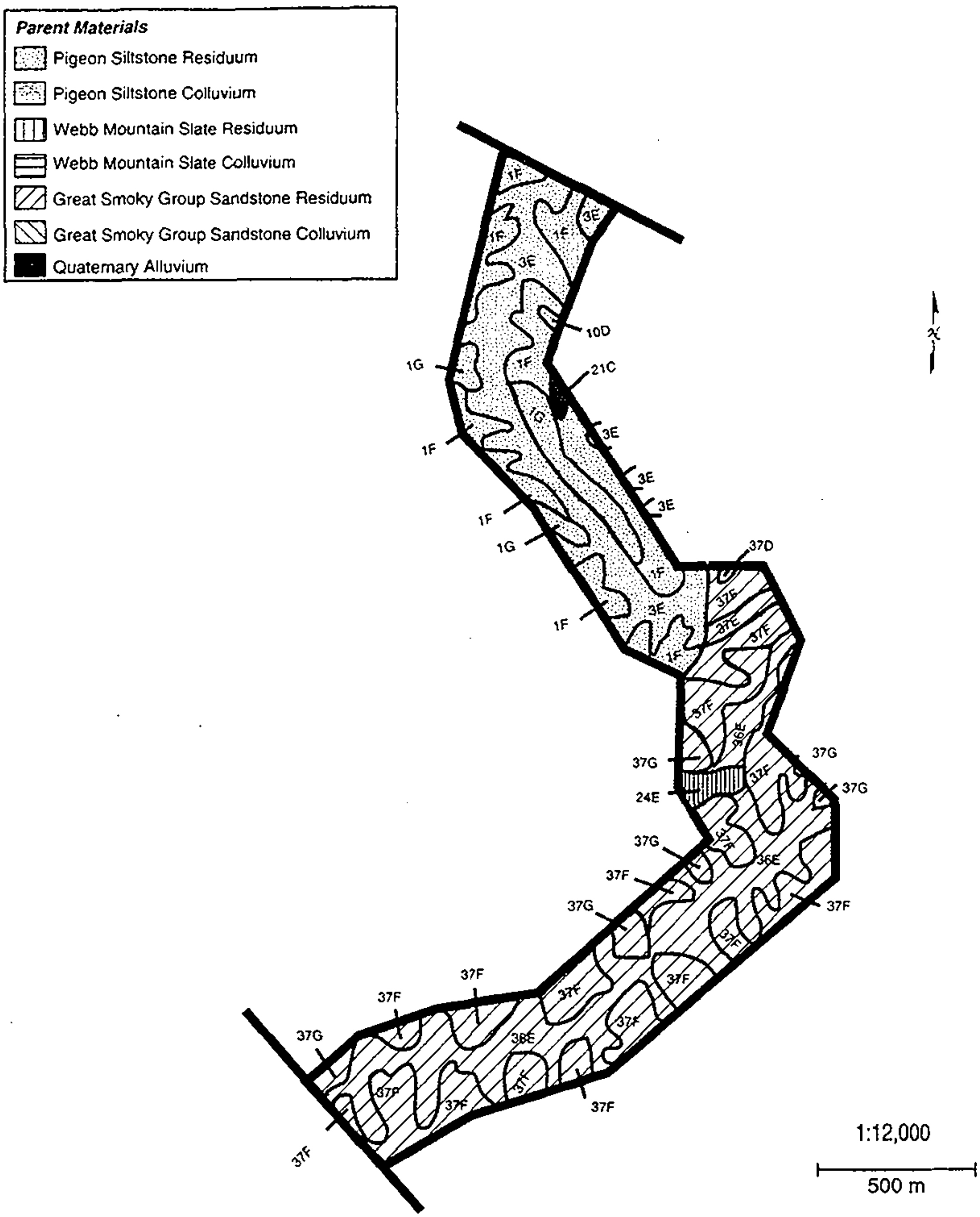

Fig. 16. Parent materials of Segment 6 (Big Ridge).

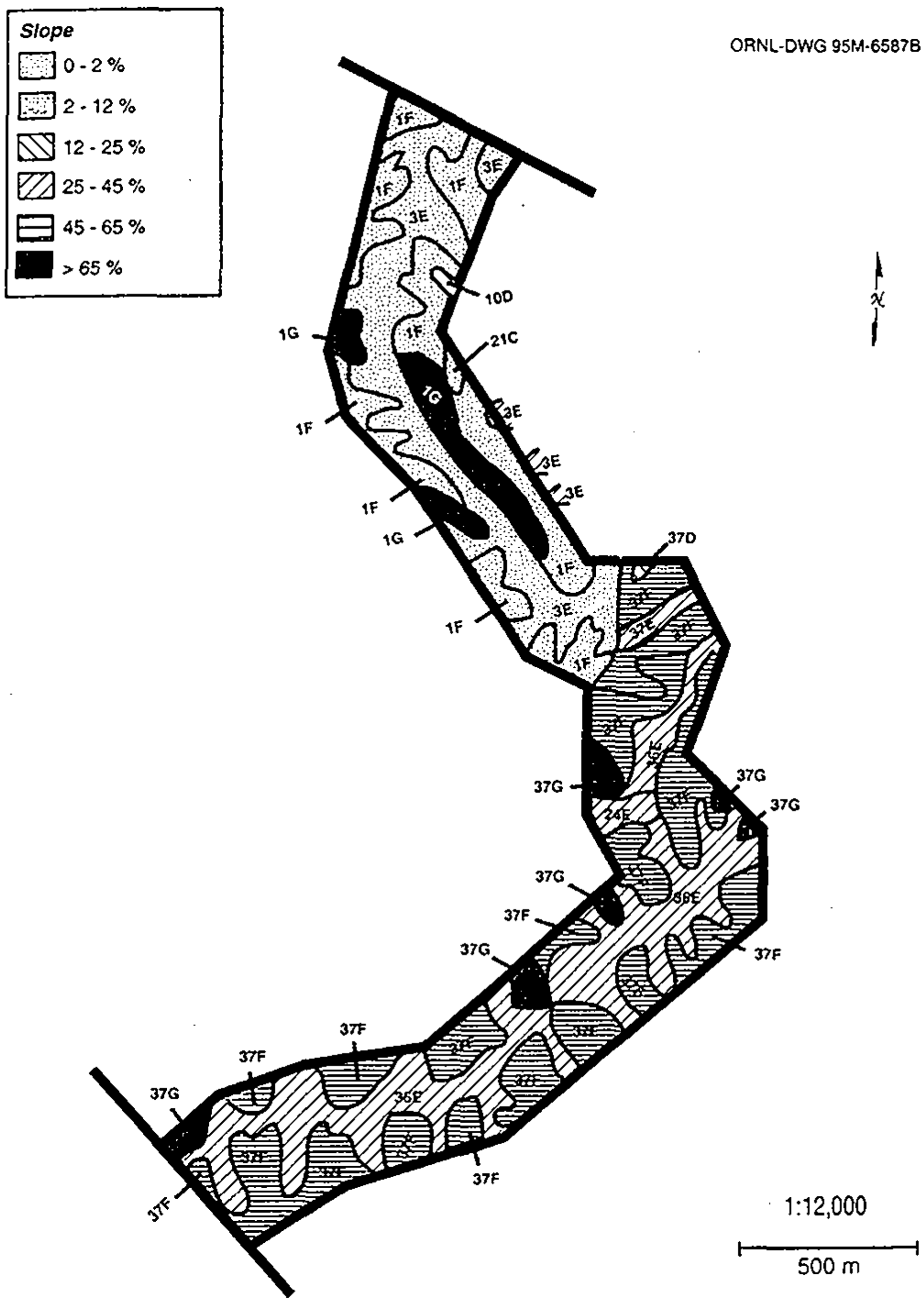

Fig. 17. Slopes of Segment 6 (Big Ridge).

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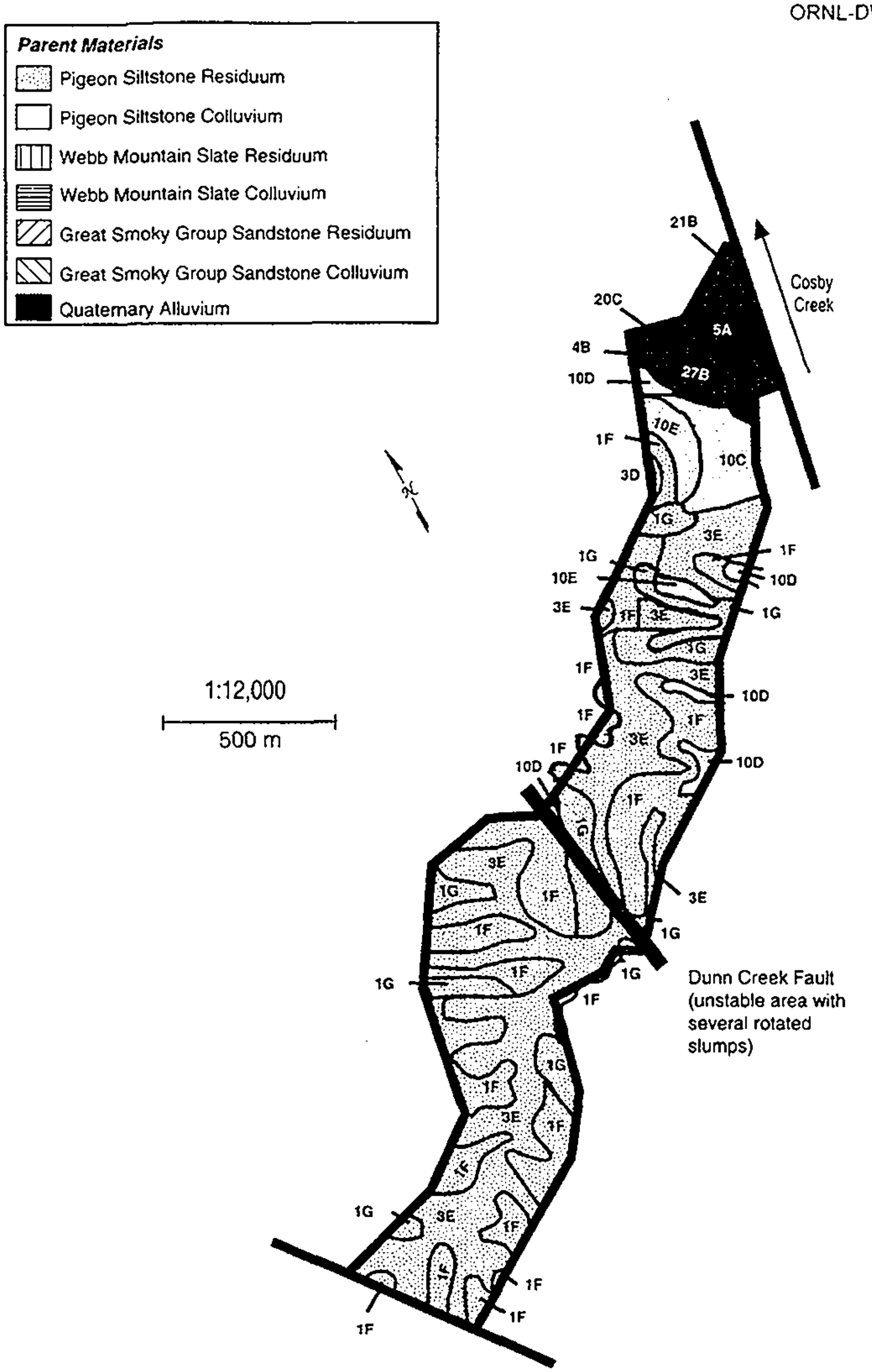

Fig. 18. Parent materials of Segment 7 (Cosby Creek Terraces).

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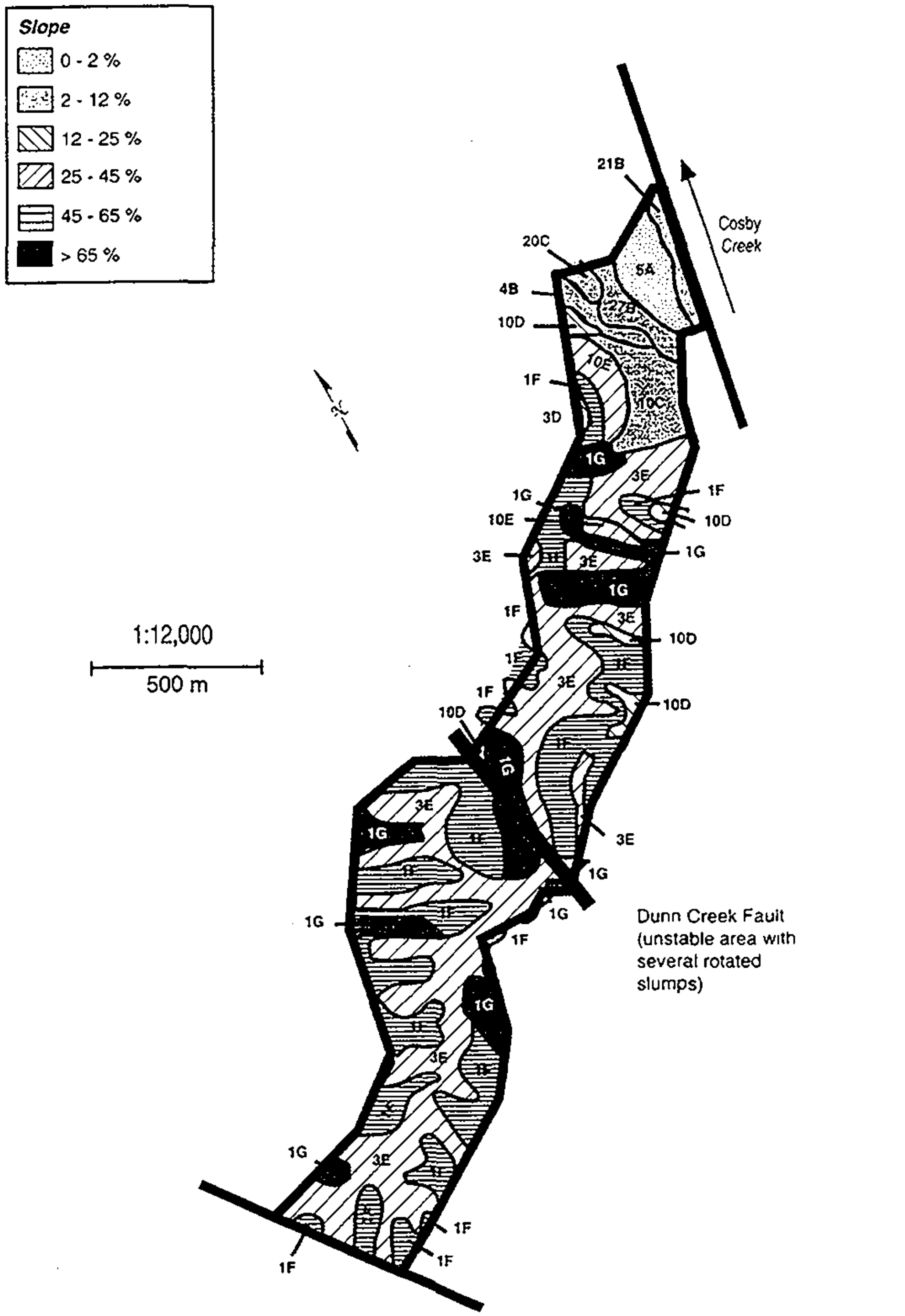

Fig. 19. Slopes of Segment 7 (Cosby Creek Terraces).

end of Big Ridge (between boundary monuments 9 and 227). Here the fault forms the stratigraphic contact between the Pigeon Siltstone to the southwest and rocks of the Yellow Breeches Member of the Wilhite Formation to the northeast. The soils and underlying saprolite on either side of the fault do not have many evident differences, although the Yellow Breeches Member contains more calcium carbonate. The same siltstone-derived residual soils were mapped on both sides of the fault. Soils on the northeast side of the fault were severely eroded, probably by past agricultural activity.

The Dunn Creek fault may present stability problems. The rock on either side of the fault has been extensively fractured and shattered, resulting in very deep weathering. The slopes in this area are steep and there is field evidence of slumps and other geomorphic instabilities near this fault. In the northeastern portion of segment 7, the ROW traverses alluvial deposits of unknown thickness forming the terraces of Cosby Creek.

3.2 WATER RESOURCES

3.2.1 General Description of Surface Waters

The ROW for the proposed parkway extension Section 8B crosses about 30 perennial streams (Fig. 20). The streams in the western end of Section 8B, including those draining the south side of Webb Mountain, either discharge directly to the Little Pigeon River or are tributaries to Webb Creek, which discharges to the Little Pigeon River at Pittman Center. To the east of Webb Mountain, several streams cross the ROW in the low-lying Rocky Flats area. These streams generally flow northward, and some have their headwaters in the GSMNP (e.g., Dunn Creek). Several small wetland areas are found close to streams in the Rocky Flats area (e.g., Carson Branch). To the east of Rocky Flats, streams draining Big Ridge to the north, south, and east discharge to Cosby Creek, a segment of which is crossed by the ROW at the eastern terminus of Section 8B.

Many of the streams studied appear to be affected by human activities, at least in terms of the physical condition of their channels and floodplains. Copeland Creek (near Pittman Center) and Sandy Hollow Creek (draining Big Ridge in the eastern section of the ROW) flow through pasture at the sampling stations, and use of the stream by cattle appears to have resulted in unstable stream banks and siltation of the streambed. Streambed siltation is also evident at the sampling stations on Lindsey Creek in Pittman Center (probably due to residential development adjacent to the stream); Ogle Spring Branch and the lower Carson Branch station in the Rocky Flats area; and Chavis Creek, which drains the north side of Big Ridge (probably as a result of clearing for homes and unpaved roads near the stream channel). Considerable residential development has also occurred in the Webb Mountain area drained by Sheep Pen Branch, Mill Dam Branch, Warden Branch, and Butler Branch (e.g., Cobbly Knob). The roads in this area are mostly paved and many of the homes are on a central sewer system; however, continued home construction in the very steep terrain and runoff from a few new, unpaved roads and cleared residential areas appear to have resulted in minor to moderate siltation impacts in the vicinity of the sampling stations on all of these streams. Webb Creek, which drains much of the south side of Webb Mountain via the streams named earlier, as well as areas to the south of U.S. 321 and Pittman Center, is heavily developed along its length. This development includes a golf course in the Cobbly Knob area, the

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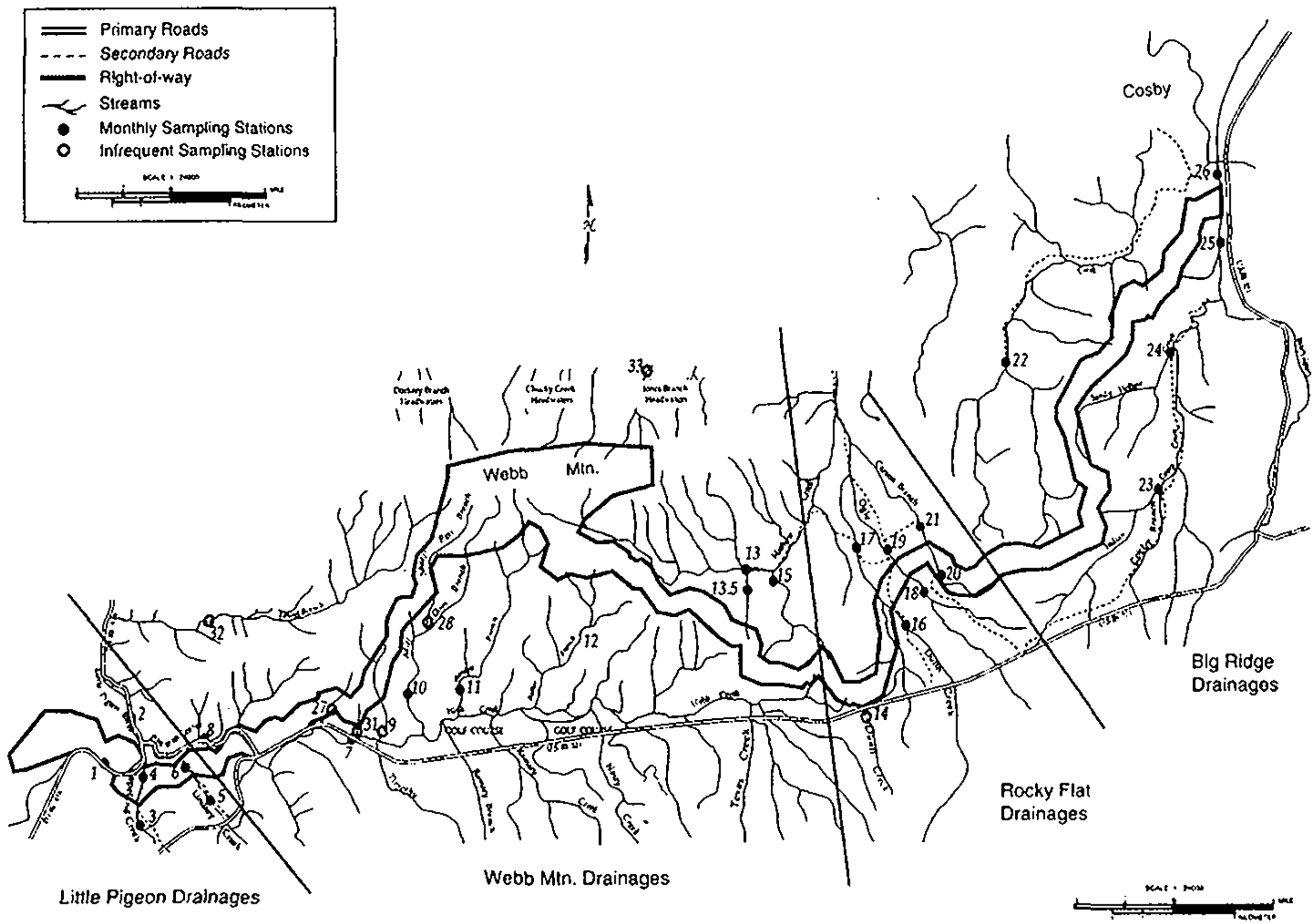

Fig. 20. Map showing the location of all perennial streams and the stream sampling stations for the water quality and aquatic biota studies for Section 8B.

outfall for the sewage treatment plant serving the Cobbly Knob residential area on the south side of Webb Mountain, residential development along U.S. 321 and secondary access roads, and the Pittman Center residential/commercial area. This development has resulted in streambank instability and streambed siltation in some reaches of Webb Creek. The two major rivers receiving drainage from the ROW, the Little Pigeon River to the west and Cosby Creek to the east, have their headwaters in the GSMNP but appear to be affected to a minor degree by residential development in the vicinity of and upstream from the sampling stations in this study.

A few streams draining or crossing the Section 8B ROW appear to be only minimally influenced by human activities, at least in terms of development in their catchments or channel characteristics. Matthew Creek, draining the southeastern portion of Webb Mountain, and the upper portion of Carson Branch, which drains the southwestern portion of Big Ridge, including some wetland areas, appear to have very little current human development in their catchments. Dunn Creek and Indian Camp Creek arise in the GSMNP and appear to have limited residential development upstream of the sampling stations used in this study.

A more extensive presentation of observations of human impacts on channel and near-channel conditions in the vicinity of the sampling stations is provided in Appendix C. Included are photographs of each sampling station.

3.2.2 Tennessee Stream Use Classification

Stream use classifications established by the Tennessee Department of Environment and Conservation have been determined for each stream being sampled. All streams are classified as suitable for fish and aquatic life (FISH), recreation (REC), irrigation (IRR), and livestock watering and wildlife (LW&W). In addition, the Little Pigeon River and Dunn Creek are classified as suitable for domestic (DOM) and industrial (IND) water supply. Each use classification has a set of water quality criteria, with the DOM and FISH classifications generally being the most stringent (Table 2). Seven streams (Little Pigeon River, Copeland Creek, Webb Creek, Dunn Creek, Matthew Creek, Indian Camp Creek, and Cosby Creek) have also been classified as trout waters and have more stringent water temperature ($\leq$20°C) and dissolved oxygen ($\geq$6 mg/L) criteria.

In addition to the parameter-specific water quality criteria, the state of Tennessee has recently added an antidegradation statement to the Tennessee standards (Chapter 1200-4-3-.06) to fully protect existing uses of all surface waters. This antidegradation statement specifies that certain surface waters can be designated as Outstanding National Resource Waters (ONRWs) by the Tennessee Department of Environment and Conservation because (1) they have important habitat for ecologically significant populations (including rare, threatened and endangered species), (2) they offer specialized recreational opportunities, (3) they have outstanding scenic or geologic values, or (4) they have very high existing water quality. If waters are designated as ONRWs, no new or expanded discharges would be allowed unless it is demonstrated that such activity would not degrade existing water quality. Conversations with Tennessee Division of Water Pollution Control personnel indicated that many of the streams in the vicinity of the ROW, particularly in the Pittman Center and Rocky Flats areas, may be considered for designation as ONRWs in the future; and new activities that have a potential to degrade streams would be closely scrutinized (G. Denton, Tennessee Division of Water Pollution Control, personal communication with P. Mulholland, ORNL, December 20, 1994).

Table 2. Tennessee water quality criteria for domestic water supply (DOM) and fish and aquatic wildlife (FISH) use classifications

	Use classification	
Parameter	Domestic	Fish and aquatic life
Dissolved oxygen	NI[a]	≥5.0 mg/L[b]
pH	6.0 to 9.0	6.5 to 8.5
Hardness	NI	—
Total dissolved hardness	500 mg/L	—
Solids, floating material	NI	NI
Turbidity	NI	NI
Temperature	30.5°C	30.5°C[c]
Coliform bacteria	1000/100 mL	—
Taste or odor	NI	NI
Toxic inorganics:[d]		
Antimony	6 μg/L	—
Arsenic, total	50 μg/L	—
Arsenic (III)	—	360 μg/L (max), 190 μg/L (cont)
Barium	2 mg/L	—
Beryllium	4 μg/L	—
Cadmium, dissolved	5 μg/L	1.8 μg/L (max), 0.7 μg/L (cont)
Chlorine (TRC)	—	19 μg/L (max), 11 μg/L (cont)
Chromium, total	100 μg/L	— (max), 100 μg/L (cont)
Chromium, IV	—	16 μg/L (max), 11 μg/L (cont)
Copper, dissolved	—	9.2 μg/L (max), 6.5 μg/L (cont)
Cyanide	200 μg/L	22 μg/L (max), 5.2 μg/L (cont)
Lead, dissolved	5 μg/L	33.8 μg/L (max), 1.3 μg/L (cont)
Mercury	2 μg/L	2.4 μg/L (max), 0.012 μg/L (cont)
Nickel, dissolved	100 μg/L	789 μg/L (max), 87 μg/L (cont)
Selenium	50 μg/L	20 μg/L (max), 5 μg/L (cont)
Silver, dissolved	50 μg/L	1.23 μg/L (max), — (cont)
Thallium	2 μg/L	—
Zinc, dissolved	—	65 μg/L (max), 58.9 μg/L (cont)
Toxic organics[e]		

[a]NI indicates that the criterion is generally one of non-impairment of the usefulness of the water for the designated use.

[b]For streams designated as trout waters, the criterion is ≥6.0 mg/L.

[c]For streams designated as trout waters, the criterion is ≤20°C (68°F).

[d]Concentration criteria for toxic inorganics are given as maximum permissible concentrations. Two values are listed for the FISH classification, a one-hour maximum criterion (max) and a 24-hour average continuous criterion (cont). For dissolved cadmium, copper, lead, nickel, silver, and zinc, the FISH classification criteria vary with total hardness concentrations. The values listed here are for total hardness ≤50 mg/L, typical of most of the study streams. Criteria concentrations for hardness values >50 mg/L would be somewhat larger than these values.

[e]See reference for Toxic Organics criteria.

Source: Rules of the Department of Environment and Conservation, Division of Water Pollution Control, Chapter 1200-4-3 General Water Quality Criteria and Chapter 1200-4-4 Use Classifications for Surface Waters, revised November 1994.)

3.2.3 Water Quality

Water quality is a major issue in the planning for Section 8B of the parkway. Many of the streams in this area are of relatively high water quality, as classified by the state of Tennessee, although water quality degradation due to rapid residential and other development in the area is currently a concern. In addition, the recent construction of Sections 8E and 8F of the parkway, which resulted in major deterioration of water quality in some areas (particularly surface water acidification due to exposure of pyritic materials), has contributed to water quality concerns for Section 8B construction. To develop the information needed to evaluate this issue, a 1-year study of water quality in the area of the Section 8B ROW was conducted to establish existing, baseline conditions. This study establishes only the conditions present during the sampling period (1994–1995), and a follow-up study (over at least 1 full year) should be conducted just before construction to establish pre-construction, baseline conditions with which to compare conditions during and after construction for determining construction effects.

3.2.3.1 Data Collection

Thirty stations (Table 3) located on 21 streams were selected for water quality sampling at intervals ranging from monthly to twice during the period from July 1994 to June 1995. For streams that cross the ROW but originate outside of it, sampling stations were chosen at stations upstream and downstream of the ROW (primarily streams in the Pittman Center and Rocky Flats areas). For streams that originate within the ROW, only a downstream station was selected (e.g., streams draining Webb Mountain and Big Ridge). These water quality sampling stations include most of the stations at which biological sampling was conducted.

Early results from the monthly sampling showed somewhat higher sulfate levels in the three streams draining the central portion of Webb Mountain (Mill Dam Branch, Warden Branch, and Butler Branch). Therefore, a one-time survey sampling of streams draining Webb Mountain was conducted on March 20, 1995. The sampling was designed to locate more specifically the source of the higher sulfate levels in these streams and determine whether they were associated with any known geologic source of sulfate (e.g., pyritic material) that may result in surface water acidification problems during parkway construction in this area. Samples were collected from 12 headwater tributaries of Mill Dam Branch, Warden Branch, Butler Branch, and Matthew Creek draining the south side of Webb Mountain, and from 3 stations in the headwaters of Jones Branch and Chucky Creek draining the north side of Webb Mountain (Fig. 21). A few of these stations were revisited and samples collected again in June 1995.

In addition to the routine water quality sampling described, sampling across the hydrographs of several storms was conducted at four stations (Webb Creek-station 8, Warden Branch-station 11, Matthew Creek-station 13, and Carson Branch-station 21). Samples were collected by automatic samplers triggered by a rise in water level monitored by a pressure transducer placed within a stilling pipe in the stream, and recorded by a datalogger. From 5 to 15 samples were collected across each of 2 or 3 storm hydrographs lasting from 1 to 3 days at each station. The storm sampling was performed to evaluate short-term water quality changes resulting from stormflow in selected streams—changes that would not be detected in results from the monthly sampling. The concentrations of many water quality constituents change markedly during stormflow as a result of changes in the dominant hydrologic flowpaths through soils and bedrock and increases in erosion

Table 3. Water quality sampling stations and sampling frequency [generally listed from west to east (see Fig. 20)]

Site number	Stream name, relationship to ROW	Sampling frequency
	Little Pigeon River/Copeland Creek/Lindsey Creek	
1-LP-A	Little Pigeon River, above ROW	monthly
2-LP-B	Little Pigeon River, below ROW	monthly
3-CP-A	Copeland Creek, above ROW	monthly
4-CP-B	Copeland Creek, below ROW	monthly
5-LN-A	Lindsey Creek, above ROW	monthly
6-LN-B	Lindsey Creek, below ROW	monthly
	Webb Mountain/Webb Creek Drainages	
32-LB-B	Laurel Branch, below ROW	semi-annual
7-WB-A	Webb Creek, above ROW	monthly
8-WB-B	Webb Creek, below ROW	monthly
27-WBT1-B	Webb Creek Tributary 1, below ROW	quarterly
31-WBT3-B	Webb Creek Tributary 3, below ROW	semi-annual
9-WBT2-B	Webb Creek Tributary 2, below ROW	quarterly
28-SP-B	Sheep Pen Branch, below ROW	quarterly
10-MD-B	Mill Dam Branch, below ROW	monthly
11-WR-B	Warden Branch, below ROW	monthly
12-BT-B	Butler Branch, below ROW	monthly
33-JB-B	Jones Branch, below ROW	semi-annual
13-MA-B	Matthew Creek, below ROW	monthly
15-MAT-B	Matthew Creek Tributary, below ROW	monthly
13.5-MAT-B	Matthew Creek Tributary, below ROW	no water quality samples
	Rocky Flat Drainages	
14-DNW-A	Dunn Creek West Branch, above ROW	semi-annual
16-DN-A	Dunn Creek, above ROW	monthly
17-DN-B	Dunn Creek, below ROW	monthly
18-OG-A	Ogle Spring Branch, above ROW	monthly
19-OG-B	Ogle Spring Branch, below ROW	monthly
20-CR-A	Carson Branch, above ROW	monthly
21-CR-B	Carson Branch, below ROW	monthly
	Big Ridge/Cosby Creek Drainages	
22-CH-B	Chavis Creek, below ROW	monthly
23-IC-B	Indian Camp Creek, below ROW	monthly
24-SH-B	Sandy Hollow Creek, below ROW	monthly
25-CB-A	Cosby Creek, above ROW	monthly
26-CB-B	Cosby Creek, below ROW	monthly

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Webb Mountain Stream Survey Sites

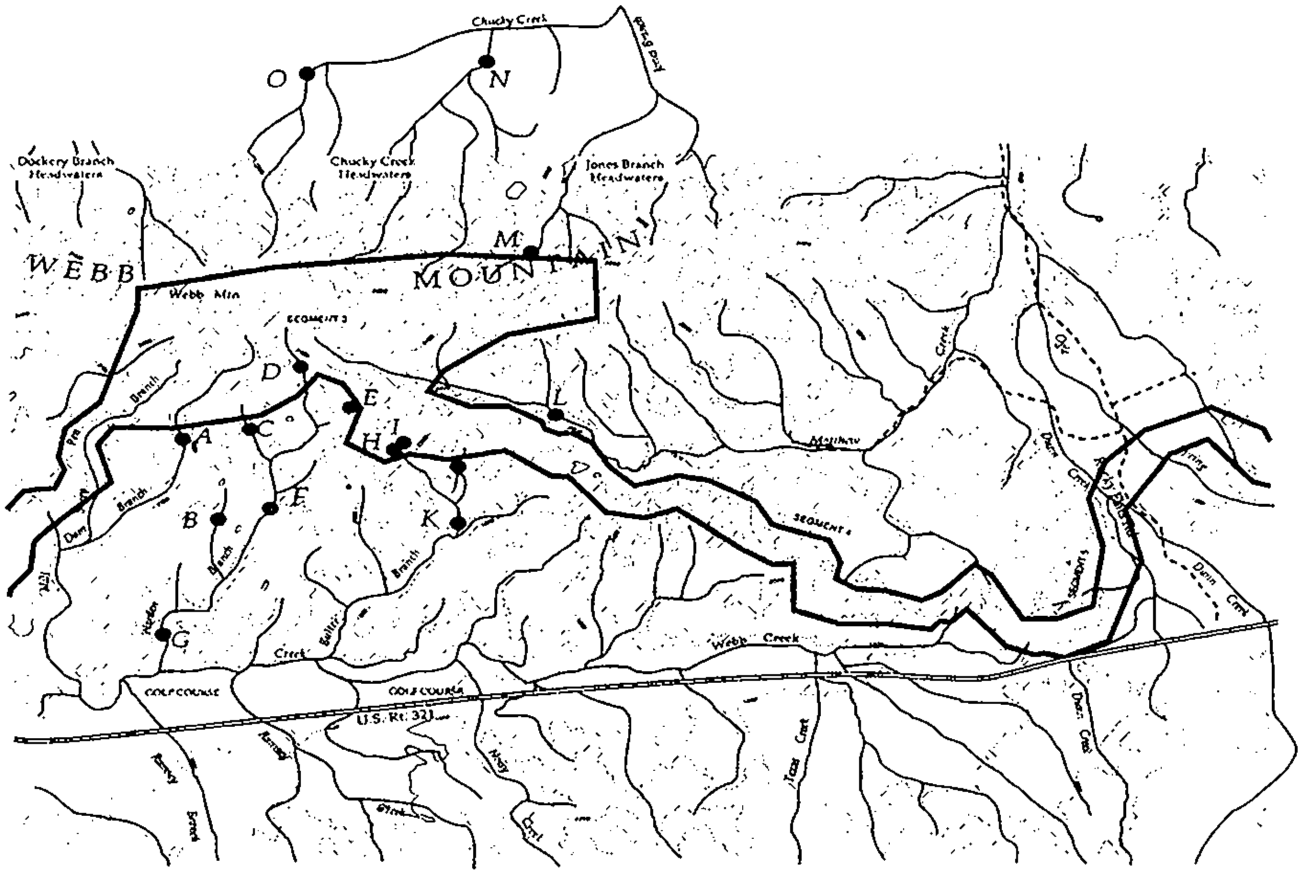

Fig. 21. Map showing the location of stream sampling stations for the Webb Mountain water quality survey conducted on March 20, 1995.

and transport of channel and near-channel sediments. The reasons for selecting these particular stations are as follows:

- Webb Creek, because of the extensive development along its corridor;
- Warden Branch, because of its higher sulfate levels (potential drainage of pyritic materials) and home development in its basin;
- Matthew Creek, because of its relatively undisturbed Webb Mountain catchment; and
- Carson Branch, because of the wetlands within its catchment.

Water quality parameters measured included water temperature, electrical conductance, pH, alkalinity, dissolved oxygen, total suspended sediments, major cations and anions, ammonium, nitrite plus nitrate [referred to as nitrate because very little nitrite is usually present at the high dissolved oxygen concentrations (>8.0 mg/L) found at all stations], soluble reactive phosphorus, trace metals, and mercury. The trace metals and mercury measurements were made only quarterly at each station (September, December, March, June) and only for one or two storms at each storm sampling station. For the Webb Mountain survey, trace metals and mercury were not measured. The water quality measurements were designed to allow inferences regarding conditions for fish and other aquatic biota, current effects of agriculture and other human activities in the catchments of these streams, the likelihood of the presence of pyritic materials in the ROW, and potential effects of parkway construction and operation on the surface waters. Field and laboratory water quality analysis procedures, data, and quality assurance/quality control considerations are presented in Appendix C.

3.2.3.2 Existing Surface Water Quality

Monthly Sampling Results. Water quality data are summarized (means, standard deviations, number of samples) in Tables 4, 5, and 6 for all stream stations sampled. In general, samples collected during the period July to November 1994 and May and June 1995 were during periods of relatively low flow; and samples collected during December 1994 to April 1995 were for somewhat higher flow, but were not representative of stormflow. Considering the physical and bulk chemical parameters (Table 4, Fig. 22), several streams stand out as having low alkalinity (<190 μEquiv/L) and electrical conductance (<37 μS/cm). The Little Pigeon River (stations 1 and 2), Dunn Creek (stations 14, 16, and 17), and Indian Camp Creek (station 23) have their headwaters in the GSMNP; and water quality at the study stations primarily reflects the dilute and poorly buffered character of most GSMNP streams. Laurel Branch (station 32), Mill Dam Branch (station 10), Sheep Pen Branch (station 28), unnamed Webb Creek tributary 3 (station 31), Jones Branch (station 33), and Matthew Branch (station 13), all of which drain Webb Mountain, also are dilute, poorly buffered streams. However, as noted above, Mill Dam Branch and Sheep Pen Branch have some evidence of siltation resulting from development in their catchments. Carson Branch (stations 20 and 21), which originates on the southwest flank of Big Ridge, also has low electrical conductance and alkalinity, although there is evidence of moderate siltation from development at the downstream station (21). All streams had relatively high dissolved oxygen concentrations (>9 mg/L).

Streams with the highest ionic strength and alkalinity are generally those with considerable human disturbance in their catchments (e.g., homes, roads, golf courses, agriculture and livestock). They include Copeland Creek (sites 3 and 4), Lindsey Creek (stations 5 and 6), Webb Creek (stations 7

Table 4. Average physical and bulk chemical characteristics from July 1994 to June 1995

Site	Water temperature (C)	Dissolved oxygen (mg/L)	Conductance (μS/cm)	pH (units)	Alkalinity (μeg/L)	Dissolved organic carbon (mg/L)	Total suspended solids (mg/L)	Organic suspended solids (mg/L)
1-LP-A	9.8 (5.6)	12.1 (3.1)	19.2 (1.5)	6.84 (0.5)	65 (17.1)	1.2 (0.8)	0.9 (0.5)	0.7 (ND)
2-LP-B	9.9 (5.6)	11.6 (1.6)	28.3 (2.9)	6.98 (0.2)	150 (30.3)	1.2 (0.7)	1.4 (0.6)	0.8 (ND)
3-CP-A	10.5 (5.3)	11.1 (1.5)	38.5 (5.3)	7.04 (0.2)	282 (53.7)	0.9 (0.6)	2.6 (1.5)	1.0 (ND)
4-CP-B	10.5 (5.6)	11.3 (1.6)	45.3 (5.9)	7.16 (0.1)	330 (67.1)	1.0 (0.6)	4.0 (2.2)	1.2 (ND)
5-LN-A	12.7 (5.6)	10.3 (1.5)	65.6 (12.6)	7.12 (0.1)	441 (93.4)	1.1 (0.6)	6.8 (4.7)	1.7 (1.3)
6-LN-B	12.3 (5.6)	10.4 (1.5)	65.3 (9.8)	7.28 (0.1)	461 (85.2)	1.0 (0.4)	7.6 (5.5)	1.7 (1.4)
7-WB-A	10.9 (5.7)	11.2 (1.5)	46.9 (9.4)	7.33 (0.1)	298 (68.0)	1.1 (0.6)	3.4 (1.9)	1.2 (ND)
8-WB-B	10.7 (5.8)	11.3 (1.6)	47.0 (8.0)	7.31 (0.2)	321 (79.0)	1.2 (0.9)	3.5 (2.5)	1.1 (ND)
32-LB-B	9.9 (7.2)	12.3 (0.8)	30.3 (3.8)	7.03 (0.1)	186 (42.0)	0.6 (0.2)	6.7 (5.0)	1.3 (0.7)
27-WBT1-B	12.2 (4.3)	10.0 (1.2)	52.7 (5.8)	6.95 (0.1)	382 (68.3)	0.9 (0.3)	4.5 (1.5)	1.4 (ND)
31-WBT3-B	9.3 (NI)	10.6 (NI)	31.1 (NI)	6.64 (NI)	184 (NI)	0.7 (NI)	10.2 (NI)	1.5 (NI)
9-WBT2-B	11.5 (5.5)	10.7 (1.3)	37.0 (5.6)	7.17 (0.1)	245 (55.4)	0.8 (0.3)	5.9 (3.3)	2.2 (1.3)
28-SP-B	12.7 (4.5)	10.1 (0.9)	30.6 (5.6)	6.91 (0.0)	167 (51.1)	0.8 (0.3)	6.4 (5.8)	2.1 (ND)
10-MD-B	10.6 (5.3)	11.2 (1.6)	33.6 (4.4)	7.18 (0.2)	192 (37.2)	1.1 (0.5)	2.4 (1.6)	1.0 (ND)
11-WR-B	10.4 (5.6)	11.1 (1.6)	50.0 (6.2)	7.18 (0.1)	276 (50.5)	0.9 (0.4)	3.6 (2.3)	1.2 (ND)
12-BT-B	11.5 (5.2)	10.2 (1.4)	56.7 (8.5)	7.21 (0.1)	379 (93.1)	0.9 (0.5)	6.0 (2.5)	1.7 (1.1)
33-JB-B	14.2 (4.9)	10.5 (NI)	36.3 (12.4)	7.04 (0.2)	185 (89.1)	0.4 (ND)	2.2 (0.1)	0.6 (ND)
13-MA-B	10.8 (5.4)	10.9 (1.5)	24.3 (2.3)	7.11 (0.2)	134 (20.8)	1.0 (0.4)	1.9 (1.0)	0.9 (ND)
15-MAT-B	11.3 (5.2)	10.8 (1.5)	50.9 (7.6)	7.30 (0.1)	394 (71.8)	0.8 (0.5)	10.5 (5.6)	2.2 (1.4)

Table 4. Continued

Site	Water temperature (C)	Dissolved oxygen (mg/L)	Conductance (μS/cm)	pH (units)	Alkalinity (μeg/L)	Dissolved organic carbon (mg/L)	Total suspended solids (mg/L)	Organic suspended solids (mg/L)
14-DNW-A	12.4 (4.9)	10.8 (N1)	16.7 (3.6)	7.23 (0.4)	118 (31.1)	0.8 (ND)	17.0 (17.2)	3.3 (ND)
16-DN-A	10.4 (5.3)	10.9 (1.4)	20.9 (12.0)	7.01 (0.2)	70 (19.9)	0.9 (0.5)	2.1 (1.2)	1.2 (ND)
17-DN-B	10.8 (5.2)	11.0 (1.5)	24.5 (3.0)	7.09 (0.3)	117 (31.3)	0.9 (0.6)	3.0 (2.2)	1.3 (ND)
18-OG-A	11.7 (5.1)	10.2 (1.7)	56.5 (4.4)	7.00 (0.1)	281 (36.8)	1.3 (0.4)	10.3 (6.0)	3.3 (1.8)
19-OG-B	11.7 (4.9)	10.4 (1.3)	50.9 (2.7)	7.12 (0.1)	267 (36.6)	1.2 (0.4)	6.3 (3.0)	2.4 (1.4)
20-CR-A	11.2 (5.0)	10.6 (1.6)	22.8 (1.9)	6.93 (0.1)	133 (16.5)	0.9 (0.6)	4.1 (2.7)	1.6 (ND)
21-CR-B	11.9 (5.0)	10.3 (1.4)	26.9 (2.8)	6.88 (0.2)	172 (25.1)	1.2 (0.7)	9.7 (5.5)	2.1 (1.3)
22-CH-B	13.7 (5.2)	9.9 (1.3)	40.4 (6.0)	7.06 (0.1)	329 (67.2)	1.0 (0.5)	7.1 (4.1)	1.2 (ND)
23-IC-B	10.8 (4.9)	11.0 (1.6)	31.6 (6.4)	7.07 (0.1)	185 (60.7)	0.9 (0.5)	1.7 (1.2)	1.0 (ND)
24-SH-B	13.8 (5.4)	9.7 (1.3)	37.1 (4.5)	7.13 (0.1)	272 (48.7)	1.3 (0.7)	5.5 (2.8)	1.4 (0.9)
25-CB-A	12.4 (5.2)	10.6 (1.2)	33.5 (4.7)	7.11 (0.3)	214 (58.1)	1.1 (0.7)	2.3 (1.1)	1.0 (ND)
26-CB-B	12.9 (5.4)	10.6 (1.2)	37.2 (4.9)	7.25 (0.2)	234 (58.0)	1.0 (0.4)	2.3 (1.1)	1.0 (ND)

•Results less than the detection limit were set to 1/2 the detection limit to compute the average and standard deviation. The standard deviation is in parentheses following the average. The average is followed by (ND) if more than 50% of the results were below the detection limit. The average is followed by (N1) when only one measurement was made.

Table 5. Average chemical concentrations from July 1994 to June 1995

Site	PO_4 (µg-P/L)	NH_4 (µg-N/L)	NO_3 (µ-N/L)	Cl (mg/L)	SO_4 (mg/L)	Na (mg/L)	K (mg/L)	Ca (mg/L)	Mg (mg/L)	Si (mg/L)
1-LP-A	3 (1.0)	7 (2.1)	323 (101.1)	0.6 (0.1)	2.6 (0.2)	0.9 (0.1)	0.8 (ND)	1.6 (0.1)	0.4 (0.0)	2.6 (0.3)
2-LP-B	9 (1.5)	7 (3.5)	275 (84.4)	0.9 (0.2)	2.6 (0.2)	1.4 (0.2)	0.8 (ND)	2.6 (0.3)	0.6 (0.1)	3.3 (0.3)
3-CP-A	27 (4.3)	5 (1.9)	27 (20.4)	1.4 (0.2)	1.5 (0.3)	2.8 (0.3)	0.7 (ND)	3.0 (0.5)	1.0 (0.2)	6.5 (0.5)
4-CP-B	29 (8.2)	7 (4.3)	46 (14.6)	2.0 (0.2)	1.7 (0.4)	3.0 (0.4)	0.8 (ND)	3.9 (0.5)	1.1 (0.2)	6.4 (0.5)
5-LN-A	29 (29.3)	47 (128.0)	97 (63.2)	4.3 (0.9)	1.9 (0.8)	4.0 (0.7)	0.8 (ND)	5.8 (1.2)	1.7 (0.4)	6.7 (0.8)
6-LN-B	29 (22.8)	34 (95.4)	115 (55.1)	3.8 (0.5)	2.0 (0.8)	3.9 (0.5)	0.8 (ND)	5.8 (0.9)	1.7 (0.3)	6.7 (0.7)
7-WB-A	38 (17.0)	12 (16.3)	349 (114.6)	1.5 (0.3)	2.7 (0.6)	2.4 (0.4)	0.9 (ND)	4.8 (1.0)	0.9 (0.2)	4.7 (0.3)
8-WB-B	28 (8.5)	6 (4.0)	269 (136.7)	1.4 (0.2)	2.4 (0.2)	2.4 (0.3)	0.8 (ND)	4.9 (1.1)	1.0 (0.2)	4.9 (0.3)
32-LB-B	10 (1.7)	8 (10.6)	46 (50.5)	0.5 (0.1)	3.5 (0.4)	2.2 (0.3)	1.2 (ND)	1.9 (0.3)	0.8 (0.1)	6.1 (0.4)
27-WBT1-B	42 (9.5)	7 (3.1)	40 (9.1)	0.7 (0.2)	3.6 (0.5)	4.2 (0.4)	1.1 (ND)	4.0 (0.5)	1.3 (0.1)	9.4 (0.6)
31-WBT3-B	28 (N1)	2 (N1)	13 (N1)	0.7 (N1)	3.7 (N1)	3.1 (N1)	1.0 (ND)	1.6 (N1)	0.8 (N1)	8.1 (N1)
9-WBT2-B	40 (9.9)	3 (2.3)	40 (45.9)	0.5 (0.0)	3.6 (0.4)	3.1 (0.4)	1.1 (ND)	2.4 (0.4)	1.0 (0.1)	7.7 (0.8)
28-SP-B	21 (12.7)	5 (4.0)	41 (39.4)	0.5 (0.1)	3.8 (0.5)	2.5 (0.4)	1.2 (ND)	1.6 (0.3)	0.8 (0.1)	6.9 (1.0)
10-MD-B	25 (4.2)	4 (1.8)	33 (30.6)	0.5 (0.0)	3.8 (0.5)	2.7 (0.3)	0.9 (ND)	2.0 (0.3)	0.9 (0.1)	6.8 (1.6)
11-WR-B	18 (3.3)	3 (1.7)	49 (31.2)	1.0 (0.1)	6.5 (0.7)	3.1 (0.3)	0.9 (ND)	4.0 (0.6)	1.2 (0.2)	7.2 (0.6)
12-BT-B	12 (3.1)	3 (1.3)	172 (66.2)	1.6 (0.3)	4.2 (0.6)	3.1 (0.3)	0.9 (ND)	5.4 (1.1)	1.3 (0.2)	6.8 (0.5)
33-JB-B	10 (3.1)	3 (0.7)	93 (93.4)	0.5 (0.1)	5.3 (0.9)	1.4 (0.3)	1.5 (ND)	3.4 (1.3)	0.8 (0.2)	4.8 (0.7)
13-MA-B	12 (2.0)	3 (1.4)	29 (27.7)	0.5 (0.1)	3.0 (0.3)	1.7 (0.2)	0.9 (ND)	1.3 (0.1)	0.7 (0.1)	5.8 (0.5)
15-MAT-B	28 (3.8)	3 (1.5)	125 (46.5)	1.1 (0.2)	2.2 (0.3)	2.7 (0.3)	0.8 (ND)	5.3 (1.0)	1.1 (0.1)	6.6 (0.4)
14-DNW-A	17 (2.8)	2 (0.6)	41 (48.9)	0.4 (0.0)	1.0 (0.2)	1.6 (0.1)	1.5 (ND)	0.9 (0.2)	0.4 (0.1)	5.0 (0.6)
16-DN-A	5 (1.5)	3 (2.1)	333 (98.8)	0.5 (0.2)	1.9 (0.2)	0.9 (0.1)	0.8 (ND)	1.5 (0.2)	0.3 (0.0)	2.8 (0.2)

Table 5. Continued

Site	PO_4 (μg-P/L)	NH_4 (μg-N/L)	NO_3 (μ-N/L)	Cl (mg/L)	SO_4 (mg/L)	Na (mg/L)	K (mg/L)	Ca (mg/L)	Mg (mg/L)	Si (mg/L)
17-DN-B	8 (2.0)	4 (1.8)	297 (92.5)	1.1 (0.2)	1.9 (0.2)	1.4 (0.2)	0.8 (ND)	2.1 (0.3)	0.5 (0.1)	3.4 (0.3)
18-OG-A	32 (8.1)	16 (14.8)	960 (201.4)	4.1 (0.6)	2.1 (0.2)	3.7 (0.4)	0.9 (ND)	4.5 (0.2)	1.3 (0.1)	5.3 (0.4)
19-OG-B	31 (7.6)	4 (2.0)	726 (224.2)	3.2 (0.4)	2.1 (0.2)	3.4 (0.3)	0.9 (ND)	4.1 (0.5)	1.2 (0.1)	5.5 (0.4)
20-CR-A	14 (3.2)	3 (2.0)	18 (17.0)	0.4 (0.1)	2.5 (0.2)	1.8 (0.1)	0.9 (ND)	1.3 (0.1)	0.6 (0.0)	6.1 (0.4)
21-CR-B	17 (16.9)	4 (2.1)	50 (31.7)	0.5 (0.1)	2.3 (0.2)	2.0 (0.2)	1.0 (ND)	1.8 (0.2)	0.7 (0.1)	6.2 (0.4)
22-CH-B	23 (3.6)	6 (2.6)	29 (18.4)	0.4 (0.1)	1.9 (0.3)	3.2 (0.4)	1.0 (ND)	3.0 (0.5)	1.1 (0.2)	7.8 (0.7)
23-IC-B	20 (15.4)	18 (8.7)	368 (98.0)	0.7 (0.1)	2.1 (0.2)	1.1 (0.1)	0.9 (ND)	3.5 (0.9)	0.6 (0.1)	3.2 (0.2)
24-SH-B	35 (9.4)	11 (11.4)	114 (201.3)	0.6 (0.2)	2.2 (0.5)	3.0 (0.4)	1.1 (ND)	2.4 (0.3)	0.9 (0.1)	7.8 (0.8)
25-CB-A	13 (3.1)	6 (2.3)	281 (152.6)	0.9 (0.2)	2.2 (0.2)	1.6 (0.1)	0.9 (ND)	3.4 (0.6)	0.7 (0.1)	3.7 (0.2)
26-CB-B	13 (2.9)	6 (2.8)	254 (95.6)	0.9 (0.2)	2.5 (0.1)	1.6 (0.2)	0.9 (ND)	3.9 (0.6)	0.8 (0.1)	3.7 (0.2)

•Results less than the detection limit were set to 1/2 the detection limit to compute the average and standard deviation. The standard deviation is in parentheses following the average. The average is followed by (ND) if more than 50% of the results were below the detection limit. The average is followed by (N1) when only one measurement was made.

Table 6. Average trace metal concentrations (mg/L) from July 1994 to June 1995

Site	Aluminum	Arsenic	Cadmium	Chromium	Copper	Iron	Lead
1-LP-A	0.0188 (0.0049)	0.0003 (ND)	0.0001 (ND)	0.0003 (ND)	0.0005 (0.0005)	0.0076 (ND)	0.0001 (ND)
2-LP-B	0.0129 (0.0083)	0.0002 (ND)	0.0001 (ND)	0.0003 (ND)	0.0005 (0.0004)	0.0076 (ND)	0.0001 (ND)
3-CP-A	0.0128 (ND)	0.0004 (ND)	0.0001 (ND)	0.0004 (ND)	0.0003 (ND)	0.0089 (ND)	0.0001 (ND)
4-CP-B	0.0124 (ND)	0.0002 (ND)	0.0001 (ND)	0.0006 (ND)	0.0004 (ND)	0.0219 (ND)	0.0001 (ND)
5-LN-A	0.0107 (ND)	0.0003 (ND)	0.0001 (ND)	0.0004 (ND)	0.0005 (ND)	0.0536 (ND)	0.0001 (ND)
6-LN-B	0.0116 (ND)	0.0002 (ND)	0.0001 (ND)	0.0011 (ND)	0.0005 (ND)	0.0403 (0.0462)	0.0001 (ND)
7-WB-A	0.0110 (ND)	0.0004 (ND)	0.0001 (ND)	0.0004 (ND)	0.0007 (0.0005)	0.0076 (ND)	0.0001 (ND)
8-WB-B	0.0107 (0.0102)	0.0002 (0.0002)	0.0001 (0.0001)	0.0009 (0.0010)	0.0005 (0.0005)	0.0076 (0.0118)	0.0001 (0.0102)
32-LB-B	0.0121 (0.0061)	0.0002 (ND)	0.0001 (ND)	0.0004 (0.0001)	0.0001 (ND)	0.0019 (ND)	0.0000 (ND)
27-WBT1-B	0.0109 (ND)	0.0002 (ND)	0.0001 (ND)	0.0006 (ND)	0.0005 (0.0002)	0.0295 (0.0433)	0.0001 (ND)
31-WBT3-B	0.0300 (N1)	0.0002 (N1)	0.0001 (N1)	0.0005 (N1)	0.0001 (ND)	0.0005 (N1)	0.0002 (N1)
9-WBT2-B	0.0158 (ND)	0.0003 (ND)	0.0001 (ND)	0.0004 (ND)	0.0003 (ND)	0.0076 (ND)	0.0001 (ND)
28-SP-B	0.0166 (ND)	0.0002 (ND)	0.0001 (ND)	0.0008 (0.0007)	0.0004 (ND)	0.0020 (ND)	0.0001 (ND)
10-MD-B	0.0163 (ND)	0.0002 (ND)	0.0001 (ND)	0.0004 (ND)	0.0003 (ND)	0.0076 (ND)	0.0001 (ND)
11-WR-B	0.0145 (ND)	0.0002 (ND)	0.0001 (ND)	0.0006 (ND)	0.0003 (ND)	0.0076 (ND)	0.0002 (ND)
12-BT-B	0.0111 (ND)	0.0002 (ND)	0.0001 (ND)	0.0006 (ND)	0.0003 (ND)	0.0141 (ND)	0.0003 (ND)
33-JB-B	0.0028 (ND)	0.0001 (ND)	0.0000 (ND)	0.0004 (ND)	0.0001 (ND)	0.0003 (ND)	0.0000 (ND)
13-MA-B	0.0109 (ND)	0.0002 (ND)	0.0001 (ND)	0.0003 (ND)	0.0003 (ND)	0.0096 (ND)	0.0001 (ND)
15-MAT-B	0.0123 (ND)	0.0002 (ND)	0.0001 (ND)	0.0005 (ND)	0.0003 (ND)	0.0076 (ND)	0.0001 (ND)
14-DNW-A	0.0225 (0.0106)	0.0002 (ND)	0.0000 (ND)	0.0004 (ND)	0.0001 (ND)	0.0003 (ND)	0.0001 (ND)
16-DN-A	0.0140 (ND)	0.0002 (ND)	0.0001 (ND)	0.0003 (ND)	0.0003 (ND)	0.0076 (ND)	0.0001 (ND)
17-DN-B	0.0125 (ND)	0.0002 (ND)	0.0001 (ND)	0.0003 (ND)	0.0002 (ND)	0.0076 (ND)	0.0002 (ND)
18-OG-A	0.0126 (0.0086)	0.0004 (ND)	0.0001 (ND)	0.0005 (ND)	0.0005 (ND)	0.0196 (ND)	0.0001 (ND)
19-OG-B	0.0128 (ND)	0.0002 (ND)	0.0001 (ND)	0.0007 (0.0005)	0.0006 (ND)	0.0096 (ND)	0.0001 (ND)

Table 6. Continued

Site	Aluminum	Arsenic	Cadmium	Chromium	Copper	Iron	Lead
20-CR-A	0.0203 (ND)	0.0002 (ND)	0.0001 (ND)	0.0033 (0.0052)	0.0006 (0.0005)	0.0141 (ND)	0.0001 (ND)
21-CR-B	0.0198 (ND)	0.0002 (ND)	0.0001 (ND)	0.0014 (ND)	0.0004 (ND)	0.0099 (ND)	0.0010 (ND)
22-CH-B	0.0193 (ND)	0.0002 (ND)	0.0001 (ND)	0.0005 (ND)	0.0004 (ND)	0.0380 (0.0477)	0.0009 (ND)
23-IC-B	0.0124 (0.0087)	0.0002 (0.0002)	0.0001 (0.0001)	0.0004 (0.0001)	0.0003 (0.0002)	0.0076 (0.0118)	0.0001 (0.0087)
24-SH-B	0.0158 (ND)	0.0002 (ND)	0.0001 (ND)	0.0005 (ND)	0.0003 (ND)	0.0276 (ND)	0.0010 (ND)
25-CB-A	0.0129 (ND)	0.0002 (ND)	0.0001 (ND)	0.0004 (ND)	0.0010 (0.0010)	0.0076 (ND)	0.0001 (ND)
26-CB-B	0.0129 (ND)	0.0002 (ND)	0.0001 (ND)	0.0012 (0.0015)	0.0002 (ND)	0.0076 (ND)	0.0001 (ND)

Table 6. Continued

Site	Manganese	Mercury	Nickel	Selenium	Silver	Zinc
1-LP-A	0.0040 (0.0054)	0.00007 (ND)	0.00024 (ND)	0.0003 (ND)	0.00008 (ND)	0.0074 (0.0041)
2-LP-B	0.0021 (0.0012)	0.00008 (ND)	0.00019 (ND)	0.0003 (ND)	0.00008 (ND)	0.0068 (0.0037)
3-CP-A	0.0103 (0.0046)	0.00004 (ND)	0.00019 (ND)	0.0004 (ND)	0.00008 (ND)	0.0035 (0.0024)
4-CP-B	0.0143 (0.0048)	0.00004 (ND)	0.00019 (ND)	0.0004 (ND)	0.00008 (ND)	0.0022 (0.0009)
5-LN-A	0.0253 (0.0095)	0.00004 (ND)	0.00019 (ND)	0.0011 (ND)	0.00008 (ND)	0.0036 (0.0012)
6-LN-B	0.0088 (0.0035)	0.00005 (ND)	0.00102 (ND)	0.0003 (ND)	0.00008 (ND)	0.0021 (0.0019)
7-WB-A	0.0017 (0.0011)	0.00005 (ND)	0.00019 (ND)	0.0008 (ND)	0.00008 (ND)	0.0017 (0.0019)
8-WB-B	0.0020 (0.0011)	0.00003 (.00002)	0.00049 (.00081)	0.0003 (0.0002)	0.00008 (0.0001)	0.0017 (0.0013)
32-LB-B	0.0005 (0.0004)	0.00003 (ND)	0.00009 (ND)	0.0008 (ND)	0.00003 (ND)	0.0005 (0.0004)
27-WBT1-B	0.0308 (0.0093)	0.00005 (ND)	0.00019 (ND)	0.0003 (ND)	0.00008 (ND)	0.0016 (0.0018)
31-WBT3-B	0.0001 (N1)	0.00003 (N1)	0.00013 (N1)	0.0009 (N1)	0.00003 (N1)	0.0021 (N1)
9-WBT2-B	0.0011 (0.0007)	0.00008 (ND)	0.00109 (ND)	0.0003 (ND)	0.00008 (ND)	0.0015 (0.0013)
28-SP-B	0.0009 (0.0004)	0.00005 (ND)	0.00019 (ND)	0.0003 (ND)	0.00008 (ND)	0.0026 (0.0018)
10-MD-B	0.0007 (0.0004)	0.00004 (ND)	0.00019 (ND)	0.0003 (ND)	0.00008 (ND)	0.0024 (0.0018)
11-WR-B	0.0007 (0.0005)	0.00005 (ND)	0.00019 (ND)	0.0003 (ND)	0.00008 (ND)	0.0022 (0.0016)
12-BT-B	0.0011 (0.0013)	0.00004 (ND)	0.00019 (ND)	0.0003 (ND)	0.00008 (ND)	0.0027 (0.0014)
33-JB-B	0.0001 (0.0001)	0.00003 (ND)	0.00008 (ND)	0.0003 (ND)	0.00002 (ND)	0.0005 (0.0004)
13-MA-B	0.0006 (0.0005)	0.00004 (ND)	0.00019 (ND)	0.0003 (ND)	0.00008 (ND)	0.0031 (0.0016)
15-MAT-B	0.0010 (0.0007)	0.00004 (ND)	0.00019 (ND)	0.0011 (ND)	0.00008 (ND)	0.0031 (0.0025)
14-DNW-A	0.0006 (0.0008)	0.00003 (ND)	0.00008 (ND)	0.0003 (ND)	0.00002 (ND)	0.0008 (0.0009)

Table 6. Continued

Site	Manganese	Mercury	Nickel	Selenium	Silver	Zinc
16-DN-A	0.0008 (0.0005)	0.00005 (ND)	0.00019 (ND)	0.0003 (ND)	0.00008 (ND)	0.0034 (0.0027)
17-DN-B	0.0006 (0.0004)	0.00006 (ND)	0.00019 (ND)	0.0003 (ND)	0.00008 (ND)	0.0030 (0.0022)
18-OG-A	0.0049 (0.0031)	0.00010 (ND)	0.00062 (ND)	0.0006 (ND)	0.00008 (ND)	0.0025 (0.0019)
19-OG-B	0.0013 (0.0013)	0.00010 (ND)	0.00332 (ND)	0.0003 (ND)	0.00008 (ND)	0.0043 (0.0052)
20-CR-A	0.0016 (0.0008)	0.00004 (ND)	0.00341 (ND)	0.0003 (ND)	0.00008 (ND)	0.0021 (0.0022)
21-CR-B	0.0034 (0.0018)	0.00006 (ND)	0.00062 (ND)	0.0003 (ND)	0.00008 (ND)	0.0027 (0.0028)
22-CH-B	0.0393 (0.0152)	0.00006 (ND)	0.00019 (ND)	0.0003 (ND)	0.00009 (ND)	0.0029 (0.0022)
23-IC-B	0.0014 (0.0007)	0.00006 (.00005)	0.00019 (.00021)	0.0003 (0.0002)	0.00008 (0.0001)	0.0031 (0.0031)
24-SH-B	0.0105 (0.0051)	0.00006 (ND)	0.00042 (ND)	0.0003 (ND)	0.00008 (ND)	0.0020 (0.0012)
25-CB-A	0.0018 (0.0003)	0.00005 (ND)	0.00019 (ND)	0.0003 (ND)	0.00008 (ND)	0.0020 (0.0018)
26-CB-B	0.0041 (0.0046)	0.00006 (ND)	0.00124 (ND)	0.0003 (ND)	0.00008 (ND)	0.0016 (0.0017)

*Results less than the detection limit were set to 1/2 the detection limit to compute the average and standard deviation. The standard deviation is in parentheses following the average. The average is followed by (ND) if more than 50% of the results were below the detection limit. The average is followed by (N1) when only one measurement was made.

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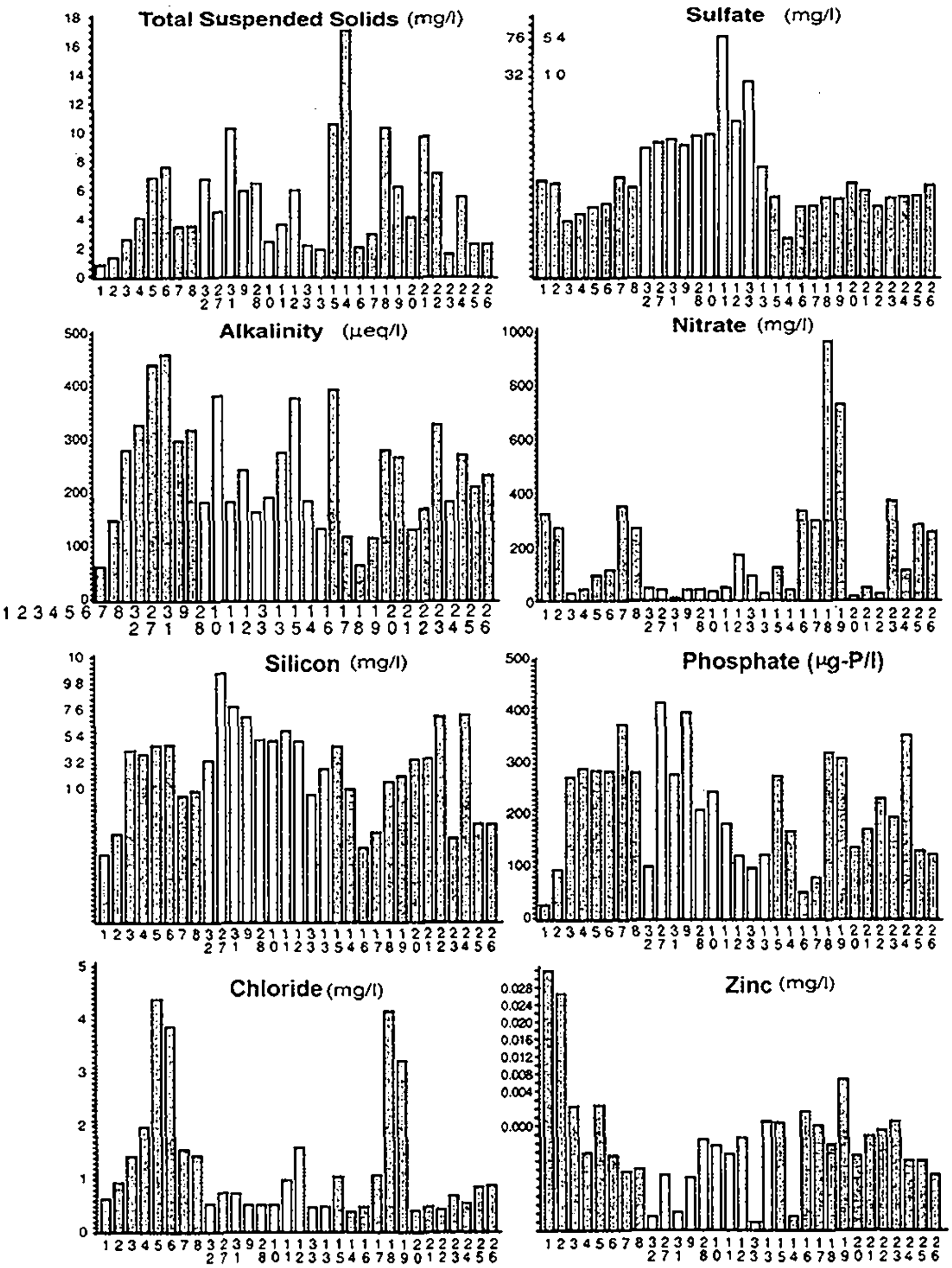

Fig. 22. Variation in the concentrations of selected physical and chemical parameters across sampling stations in the water quality studies. Open bars refer to streams draining Webb Mountain.

and 8) and unnamed Webb Creek tributary 1 (station 27), Warden Branch (station 11), Butler Branch (station 12), a tributary to Matthew Branch (station 15), Ogle Spring Branch (stations 18 and 19), Chavis Creek (station 22), and Sandy Hollow Creek (station 24). Five stations had relatively high total suspended solids (TSS) levels (>9 mg/L): unnamed tributaries to Webb Creek (station 31) and to Matthew Creek (station 15), the upstream station on Ogle Spring Branch (station 18), the downstream station on Carson Branch (station 21), and an upper station on Dunn Creek (station 14). The high TSS for the upper Dunn Creek station was the result of only one sample and is probably not representative of upper Dunn Creek. Each of the other four streams with high TSS is small and has some disturbed areas (gravel roads, cleared homesites) in close proximity to the sampling stations, which may account for the higher TSS values.

The data on nutrient and major ion concentrations (Table 5, Fig. 22) suggest that most streams have reasonably good water quality. Lindsey Creek (stations 5 and 6) and Ogle Spring Branch (stations 18 and 19) appear to be distinctly influenced by human activity, as indicated by relatively high levels of ammonium, nitrate, phosphate, and/or chloride compared with the other stations. Higher concentrations of nitrate, phosphate, and chloride in Webb Creek (stations 7 and 8) also reflect significant human effects, probably from runoff from the golf course and effluent from the sewage treatment plant (serving the Cobbly Knob area) upstream from the sampling stations. Moderately high phosphate concentrations (≥20 μg/L, higher than the 0–10 μg/L typical of undisturbed streams in this region) in Copeland Creek (stations 3 and 4), unnamed Webb Creek tributaries 1, 2, and 3 (stations 9, 27, and 31), Mill Dam Branch (station 10), Sheep Pen Branch (station 28), unnamed Matthew Branch tributary (station 15), Chavis Creek (station 22), Indian Camp Creek (station 23), and Sandy Hollow Creek (station 24) also suggest some effects of human activity. The higher phosphate concentrations in Copeland Creek and Sandy Hollow Creek probably are a result of the extensive pasture in the riparian zone along these streams and access of cows to the streams. Streams that have extensive portions of their catchments in the GSMNP (Little Pigeon River, Dunn Creek, Indian Camp Creek, and Cosby Creek) also have somewhat higher concentrations of nitrate, probably as a result of higher rates of atmospheric nitrate deposition at higher elevations and lower nitrate retention efficiency of the older-aged forests in the GSMNP. Therefore, nitrate concentration alone is not a good indicator of local human impact on streams. Finally, the high sulfate concentrations in streams draining portions of Webb Mountain, particularly Warden Branch (station 11) and Jones Branch (station 33), deserve special note (Fig. 22). These probably reflect a geologic source of sulfate in this area. Although the pH and alkalinity levels in these streams were not particularly low and trace metals were not high, natural sources of alkalinity (e.g., calcium carbonate) or sources related to human disturbance could be obscuring a potential water quality problem associated with geologic sulfides in these catchments. The soil and geology surveys did indicate the presence of sulfide-bearing parent materials in the Webb Mountain area (Sect. 3.1.4.3).

Concentrations of metals (Table 6) were very low and at all times less than the Tennessee water quality criteria (Table 2). Of the metals, only manganese and zinc concentrations were consistently above detection limits (see Appendix C), and mean concentrations of both were relatively low (Mn <0.04 mg/L and Zn <0.004 mg/L). We found no metal values that exceeded Tennessee Water Quality Criteria (Table 3.2-1).

Concentrations of many chemical parameters in these streams showed distinct seasonality (Fig. 23). Concentrations of solutes produced primarily by weathering of parent materials (e.g.,

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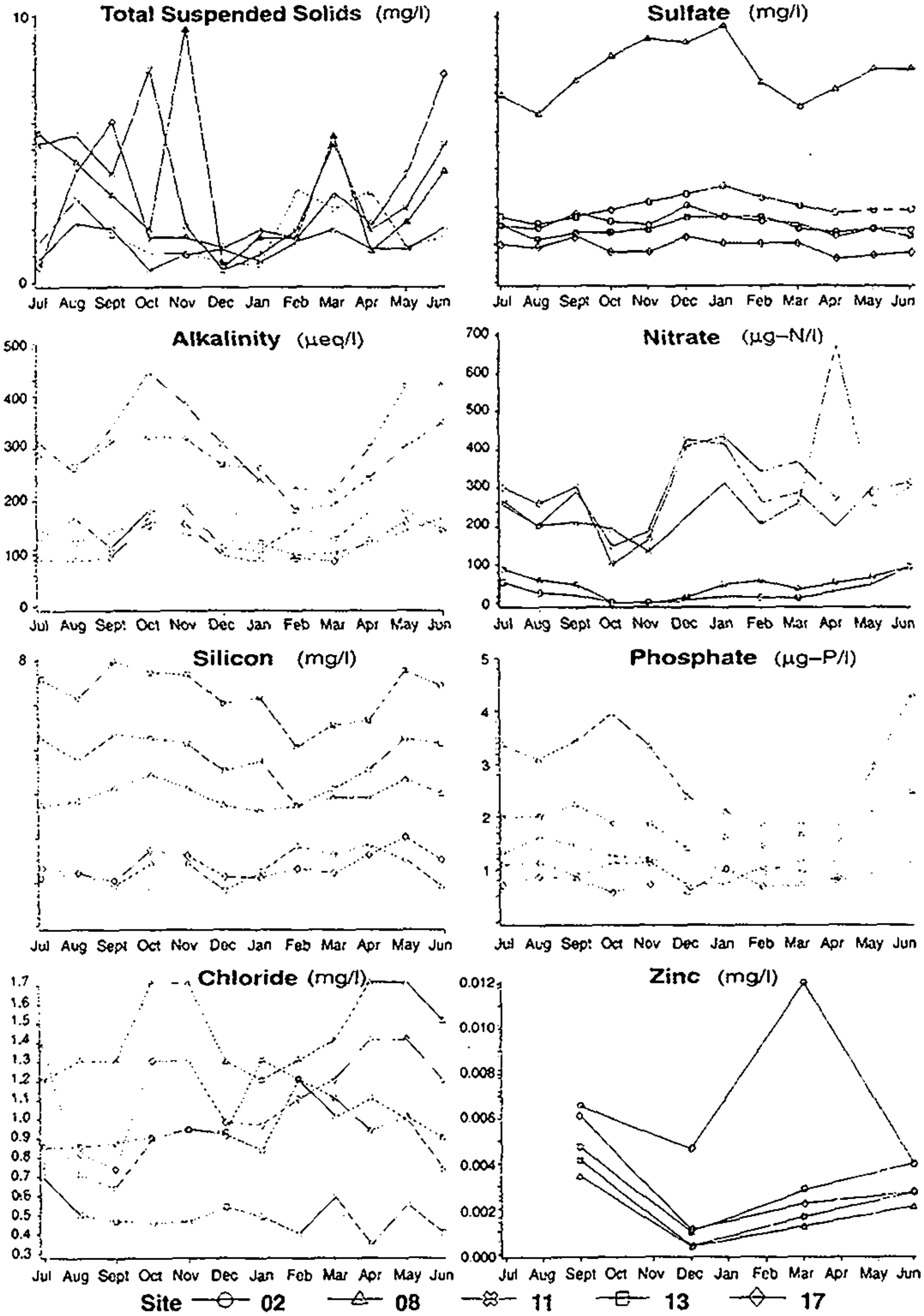

Fig. 23. Seasonal variation in the concentrations of selected physical and chemical parameters for five streams.

silicon, alkalinity) were higher during periods of lower flow in summer and fall, whereas concentrations of solutes primarily leached from surface soils by lateral flow (e.g., sulfate, nitrate) were higher during periods of higher stream flow during winter and early spring.

Webb Mountain Survey Sampling Results. Stream sulfate concentration is of interest as an indicator of the presence of sulfide-bearing parent materials in the catchments of the proposed ROW. Exposure of sulfide-bearing rock during construction of the parkway could allow rapid oxidation of sulfide minerals, which would produce sulfuric acid. Discharges of acidic water to streams could have harmful effects on fish and other aquatic biota.

Sulfate in stream water originates from the weathering of minerals, the degradation of organic material, and wet and dry atmospheric deposition. The concentrations in runoff also may be affected by sulfate adsorption by soils. If the primary source of sulfur input to the area is atmospheric deposition and the soils and parent materials are similar, then the streams draining the area should have similar concentrations of sulfate. The monthly sampling results indicated that many of the streams draining Webb Mountain had noticeably higher sulfate concentrations than other streams along the ROW (Fig. 22), with the highest concentrations found at Warden Branch (station 11) and Jones Branch (station 33).

The results from the Webb Mountain survey indicated that a geologic source of sulfur probably exists on Webb Mountain. Stations D and E in the headwaters of Warden Branch had sulfate concentrations of 6.3 and 16 mg/L, respectively, and stations F and G downstream in Warden Branch also had sulfate concentrations >5 mg/L (Fig. 24). These stations were considerably higher in sulfate than the other Webb Mountain stations (generally 3–4 mg/L, Fig. 24) or most other stations in the monthly sampling (generally <3 mg/L, Table 5 and Fig. 22). Despite the high sulfate concentrations at the Warden Branch headwater stations, the alkalinity of these streams is not low relative to the other streams surveyed (Fig. 24), and pH values were all >6.7 (see Appendix C for complete dataset). Apparently, the acid produced by oxidation of sulfide as it weathers from the parent materials has been neutralized by the weathering of other minerals and soil ion exchange processes. These stations are generally upstream of most residential development, so human activity probably is not responsible for the high sulfate concentrations. However, relatively high concentrations of phosphate in the stream showing the highest sulfate level (E) suggest there is some disturbance effect, although nitrate levels in this stream were very low (Fig. 24). Geologic surveys indicated that sulfate-bearing rock is not present in this area and cannot account for the higher streamwater sulfate concentrations.

Because of the potential for exposing sulfide minerals during construction on Webb Mountain, construction plans may need to include contingencies for mitigating the effects of the disturbance.

Storm sampling results. Changes in streamwater chemistry were monitored during several storms at four stations: Webb Creek downstream (#8), Warden Branch (#11), Matthew Creek (#13), and Carson Branch downstream (#21). Results are presented here for two storms at each of these stations, one storm during winter (January or February) and one storm during spring (May). Tables of the complete chemical analyses for these storms at all four stations, as well as one additional storm at Webb Creek and Warden Branch, are presented in Appendix C.

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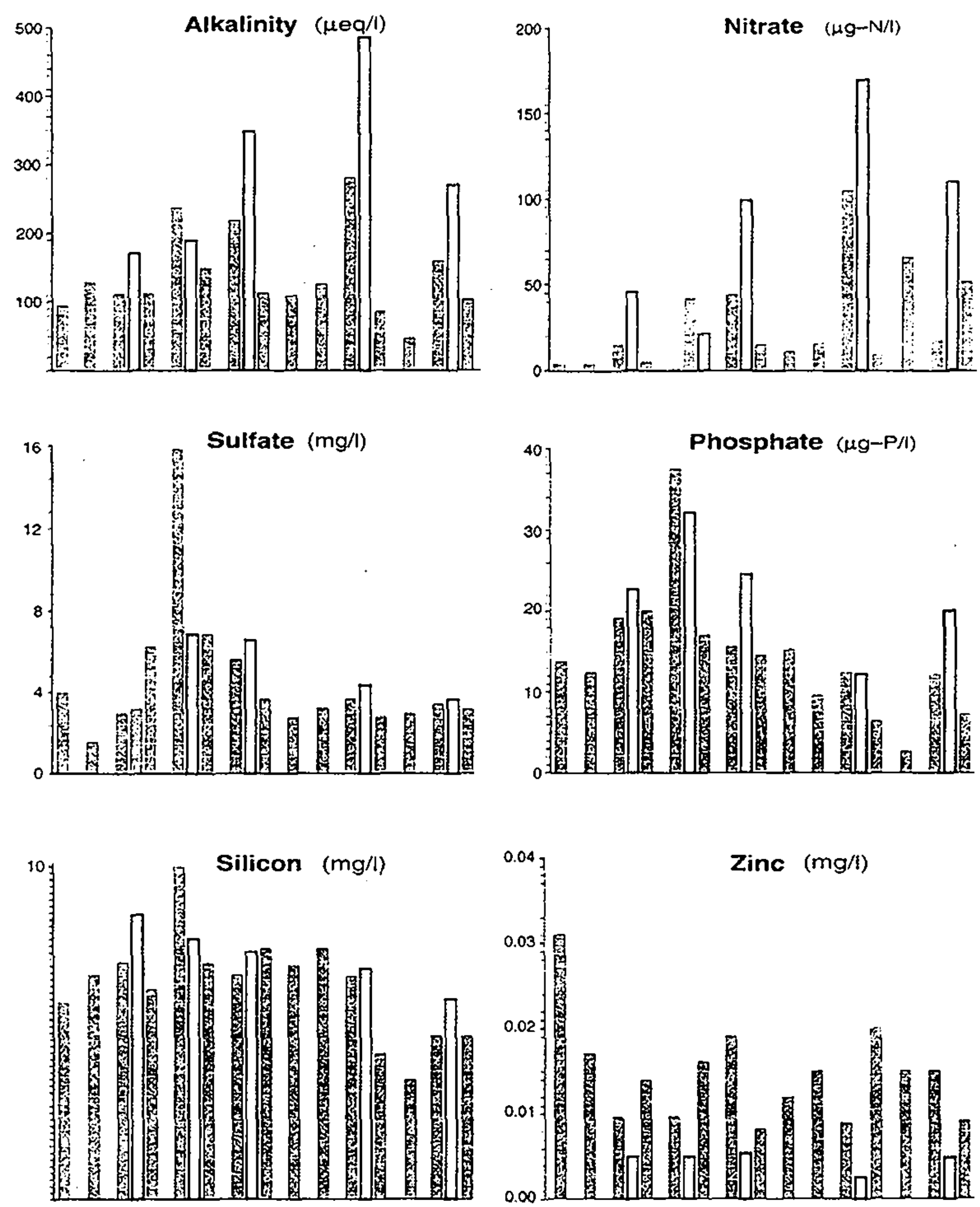

Fig. 24. Variation in the concentrations of selected chemical parameters for streams sampled during the March Webb Mountain survey (open bars are results from a resurvey of a few streams on June 6, 1995). Designations for streams A–O are shown in Fig. 21.

Stream chemistry was monitored at Webb Creek and Warden Branch during a relatively large storm event over a 3-day period on January 14–16, 1995 [rainfall of 50 mm (2 in.), primarily on January 14]. The stage height, which is a reasonably good surrogate for stream discharge, rose 51 cm (20 in.) over 24 hours peaking at 0800 hrs on January 15 at Webb Creek and rose 11 cm (4.3 in.) peaking about 1000 on January 15 at Warden Branch (Figs. 25 and 26). Total suspended solids increased sharply with increasing stage height and peaked prior to the peak in stage (discharge), as is typical in most streams. The peak concentrations of suspended solids were 192 mg/L at Webb Creek and 149 mg/L at Warden Branch. At both stations electrical conductance (not shown, see Appendix C for data), alkalinity, and silicon concentrations decreased with increasing stage height, indicative of a dilution effect of high flow. Values of pH (not shown, see Appendix C for data) also declined slightly in both streams at high flow, from 7.4 to 6.9 in Webb Creek and from 7.3 to 7.0 in Warden Branch. In contrast, nitrate in both streams and sulfate in Webb Creek increased with increasing stage height, indicating a flushing effect and additional sources of these solutes at high flow. Increases in nitrate concentration during stormflow are commonly observed in streams draining catchments influenced by human activities, as is the case with these streams. Increases in sulfate concentrations during storms are commonly observed in most catchments in the southeastern Appalachian region because of flushing of the relatively large sulfate levels in surface soils (due to previous wet and dry deposition) by the shallow water flowpaths that develop in soils during storms. Of particular note was the contrasting sulfate concentration pattern observed in Warden Branch, where sulfate concentration declined as stage increased (the opposite pattern to that observed in most other streams in this area). This stormflow sulfate concentration pattern suggests a dilution effect of a geologic source that masks the usually observed flushing effect from shallow soils. The minimum sulfate concentration during the storm in Warden Branch (5.2 mg/L) was considerably greater than the maximum sulfate concentration in Webb Creek (3.2 mg/L) during peak discharge, further supporting the geological source hypothesis. Thus, these storm sulfate patterns tend to support the Webb Mountain survey results suggesting a geologic source of sulfate in the Warden Branch catchment. Among the metals, only zinc and manganese were consistently above detection limits, and although zinc was somewhat higher at peak stage height than prior to the storm, concentrations were nonetheless low.

Stream chemistry was monitored over a 3-day stormflow period during February 15–17, 1995, in Matthew Creek (station 13) and Carson Branch (station 21) (Figs. 27 and 28). This event deposited 42.5 mm (1.7 in.) of rainfall. At the beginning of the storm, some patches of snow remained on the ground from about 127 mm (5 in.) of snowfall during the previous week. The stage height rose 31 cm (12 in.) over 48 hours peaking at 1100 hours on February 16 at Matthew Creek and rose 21 cm (8 in.) peaking at 1830 hours on February 16 at Carson Branch. The hydrograph at Matthew Creek had two distinct peaks compared with a more diffuse peak at Carson Branch. This may be related to the larger proportion of wetland area along the upper reaches of Carson Branch. Total suspended solids concentrations increased with increasing stage height in both streams, although the peak concentration at Carson Branch (312 mg/L) was considerably higher than the peak concentration in Matthew Creek (183 mg/L). This may be related to the residential development very near the sampling station on Carson Branch (station 21) used for storm sampling. Electrical conductance, alkalinity, and silicon concentrations declined with increasing stage height in Matthew Creek and Carson Branch, indicating dilution of geologic sources, as was observed in Webb Creek and Warden Branch. However, in contrast to the patterns observed in Webb and Warden, nitrate concentrations declined as stage height increased in Matthew and Carson, probably reflecting a minimum of human disturbance in these catchments. Sulfate

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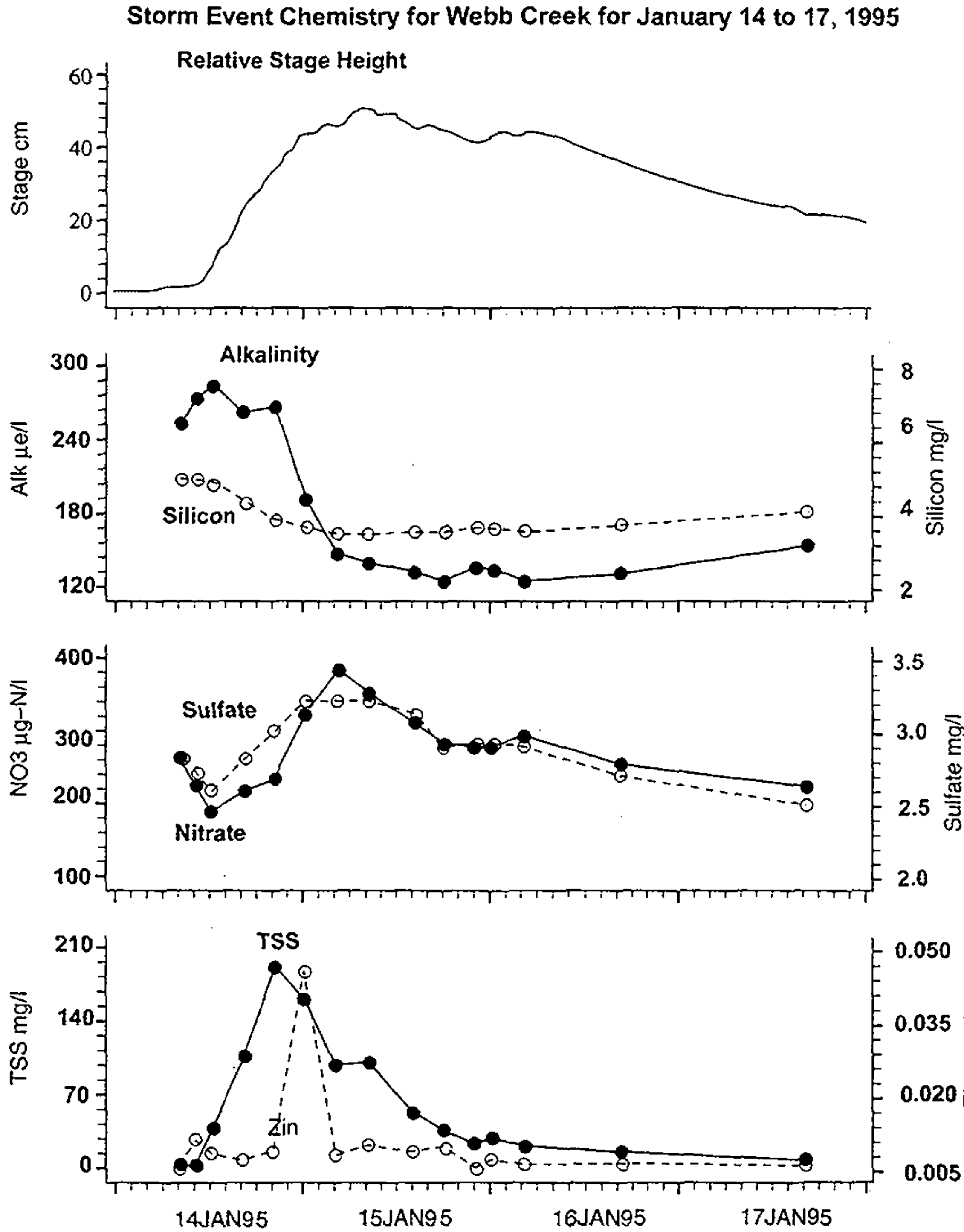

Fig. 25. Concentrations of selected parameters during a storm in January 1995 in Webb Creek (station 8).

ORNL-DWG 95M-8636

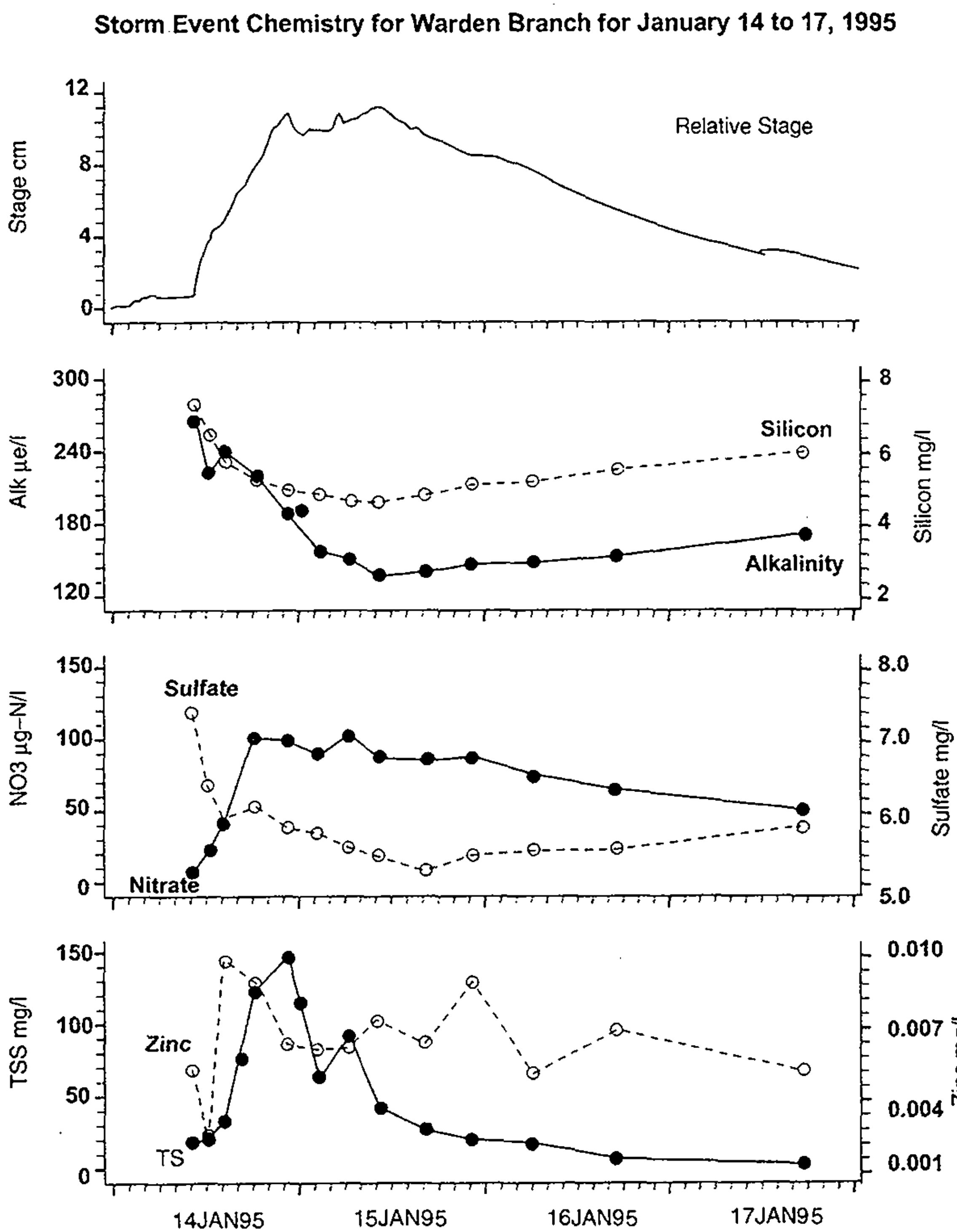

Fig. 26. Concentrations of selected parameters during a storm in January 1995 in Warden Branch (station 11).

ORNL-DWG 95M-8635

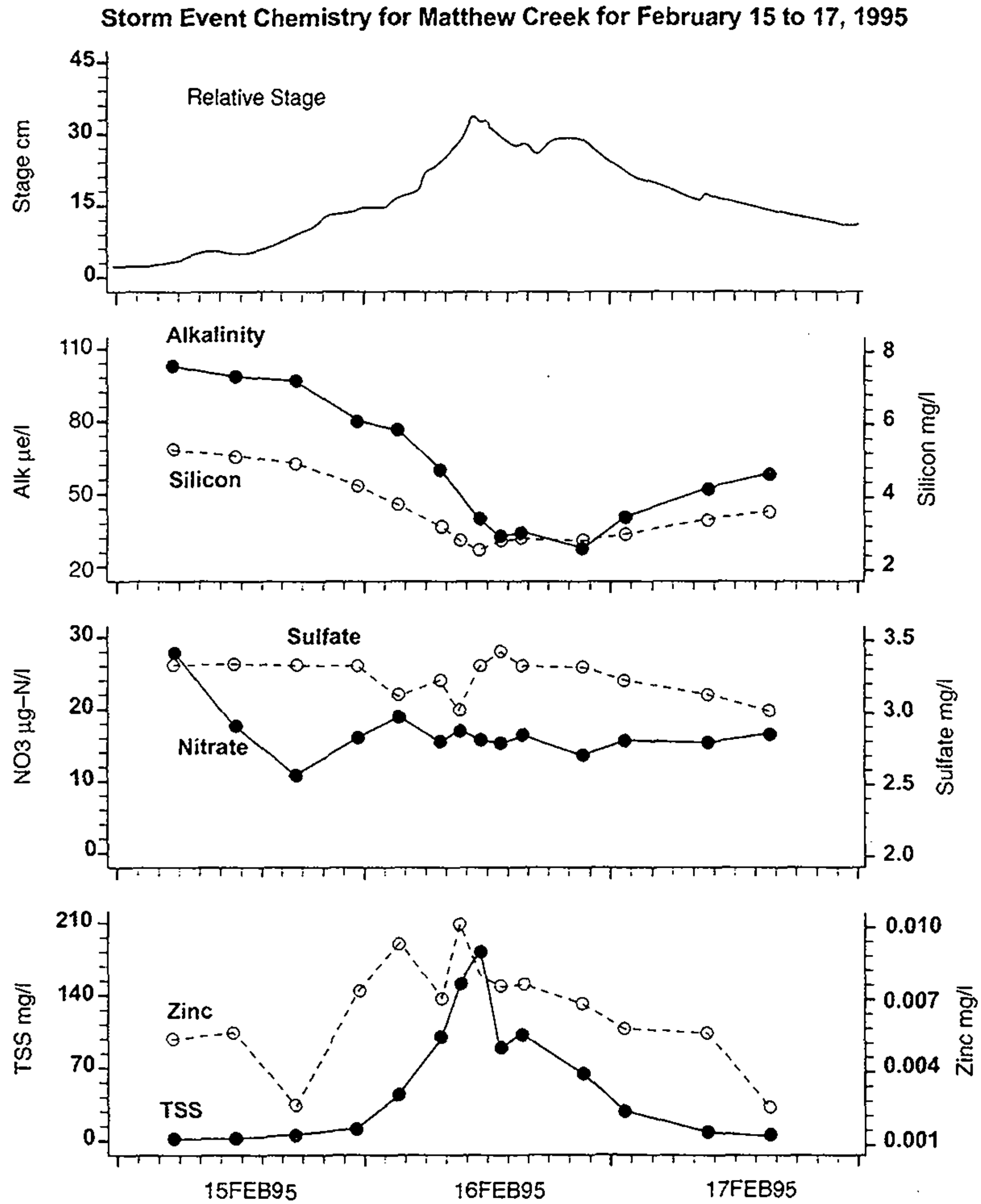

Fig. 27. Concentrations of selected parameters during a storm in February 1995 in Matthew Creek (station 13).

ORNL-DWG 95M-8638

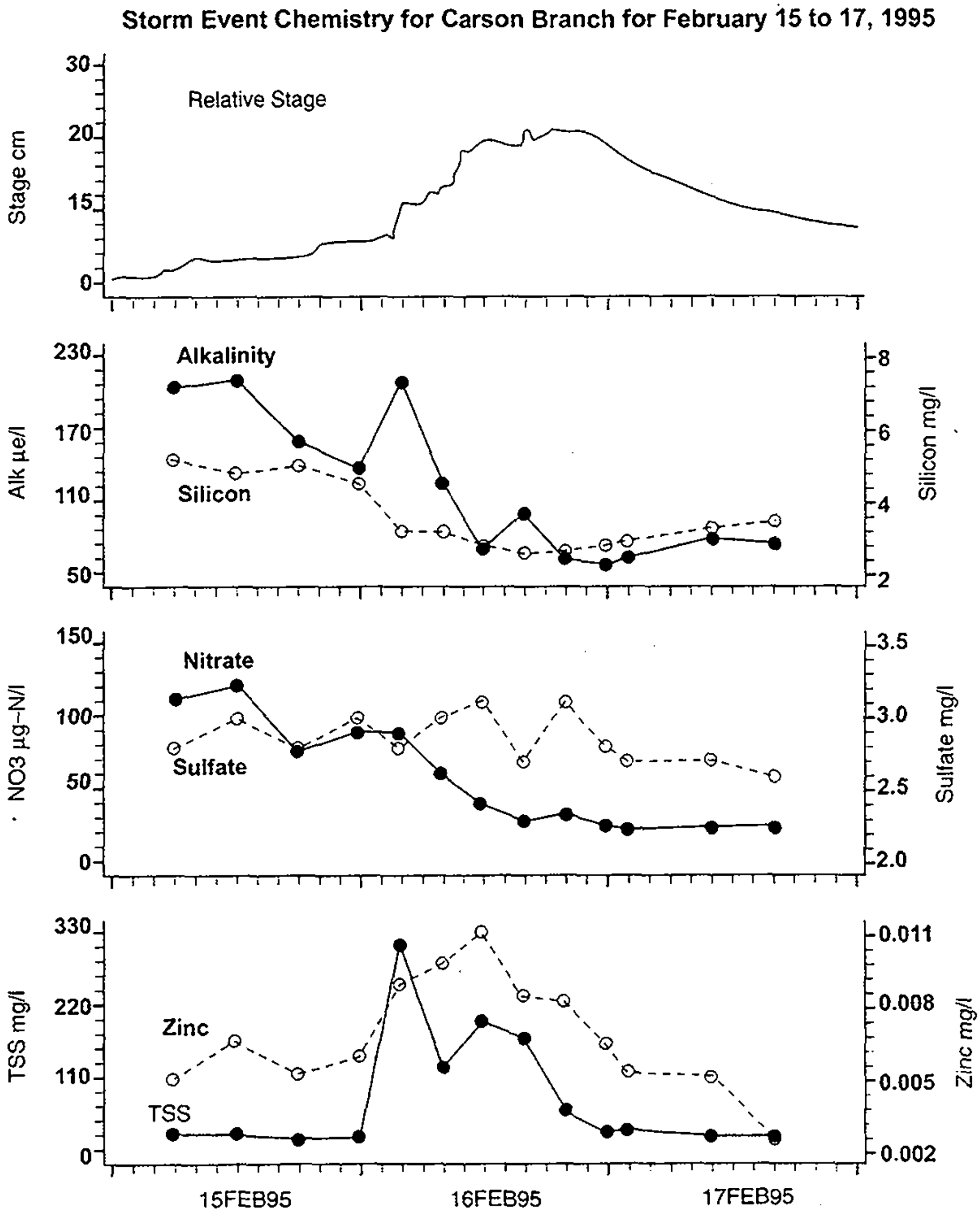

Fig. 28. Concentrations of selected parameters during a storm in February 1995 in Carson Branch (station 21).

concentrations were somewhat variable in Matthew and Carson, although highest concentrations were observed near peak stage height as was the case in Webb Creek. In both Matthew Creek and Carson Branch, pH declined during increasing stage, with values falling from pre-storm values of 6.7 (Matthew) and 6.8 (Carson) to 6.4 at peak stage height in both streams. Metals concentrations were generally below detection limits, except for manganese and zinc. Although zinc concentration increased with increasing stage, concentrations remained relatively low.

In May, there was a much smaller response of stage height during the storms sampled than in the winter, both a result of lower precipitation 20–30 mm (8–12 in.) and lower soil moisture levels after the growing season commenced (Figs. 29, 30, 31, and 32). Patterns in alkalinity and silicon concentration were somewhat different than during the winter storms. Only at Matthew Creek did alkalinity and silicon show a distinct dilution pattern as was observed during the winter (Fig. 31). In the other streams, sharp increases in alkalinity were observed during rising or peak stage heights. Sulfate concentration patterns were less distinct in May than in winter, except for Warden Branch where a distinct dilution pattern was again observed (Fig. 30), further confirming the presence of a geologic source of sulfate in this catchment. Nitrate concentration patterns were also less distinct in Webb Creek and Warden Branch in the May storm compared with the winter storm. In Carson Branch, nitrate concentration increased sharply near the peak and falling limb of the hydrograph (Fig. 32) in contrast to the dilution pattern observed in February. Patterns in storm pH also were somewhat different in May compared with winter in all streams, with pH increasing steadily throughout the storms from pre-storm values ranging from 6.7–7.1 to values on the declining limb of the hydrograph ranging from 7.0 to 7.5 (see Appendix C). Concentrations of metals remained relatively low during the May storms, except for a few high values of zinc observed in Warden Branch (0.015–0.025 mg/L) and in Carson Branch (0.047 mg/L).

In summary, the storm chemistry results show that patterns in solute chemistry observed over the hydrograph are more distinct in winter than in spring, and somewhat different in winter from in spring. The storm results also provide additional evidence of a geologic source of sulfate in the Warden Branch catchment. Finally, the storm results highlight the relatively undisturbed nature of the Matthew Creek and Carson Branch catchments.

3.3 AQUATIC ECOLOGY

3.3.1 Approach

Stream biological surveys have been completed at 31 stream sites to identify aquatic ecological resources potentially impacted by construction and subsequent use of the proposed Section 8B extension of the Foothills Parkway (Fig. 20). The purpose of these surveys is to describe, document, and quantify the existing taxonomic diversity of benthic macroinvertebrates and fish. The sampling strategy for both benthic invertebrates and fish was to survey the different taxa from all available habitats to the extent practicable during single sampling dates. Both qualitative and quantitative collection techniques were used during benthic invertebrate and fish sampling at 31 Section 8B streams (Table 7). The surveys also identified rare and endangered species of concern to the federal and Tennessee governments. The GSMNP has a program to reintroduce some of the Tennessee state endangered species into Abrams Creek but otherwise does not currently have any

ORNL-DWG 95M-8632

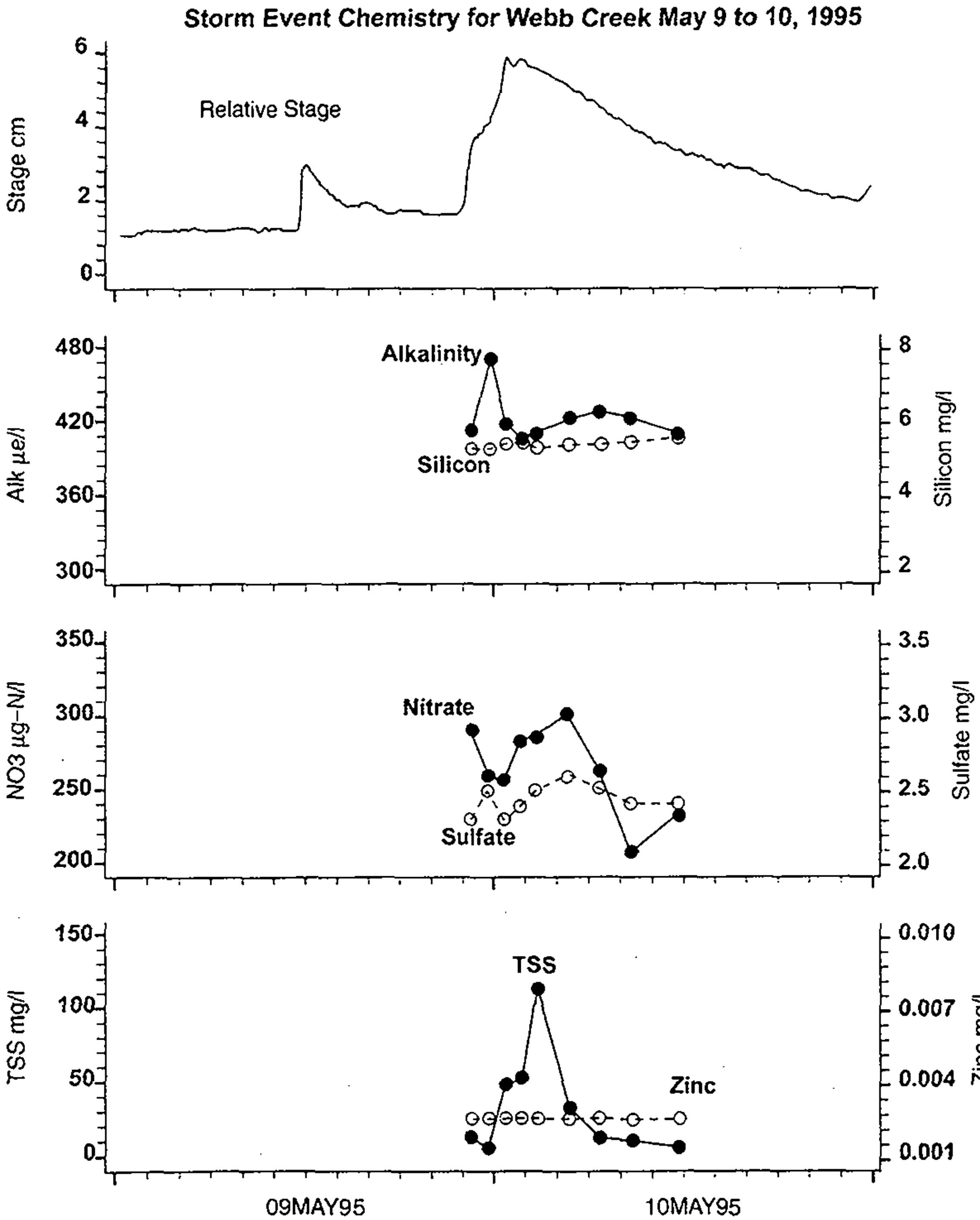

Fig. 29. Concentrations of selected parameters during a storm in May 1995 in Webb Creek (station 8).

ORNL-DWG 95M-8637

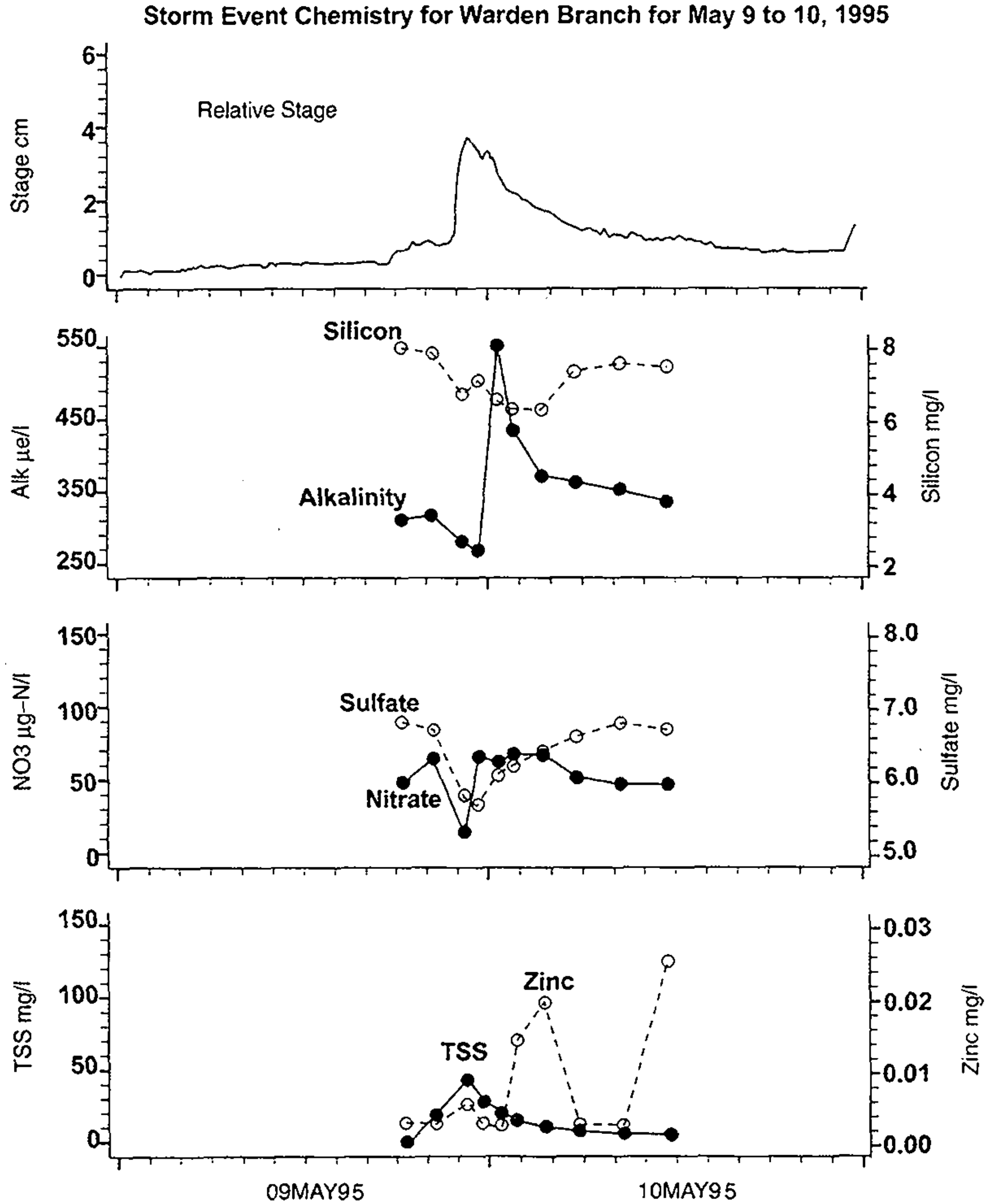

Fig. 30. Concentrations of selected parameters during a storm in May 1995 in Warden Branch (station 11).

ORNL-DWG 95M-8634

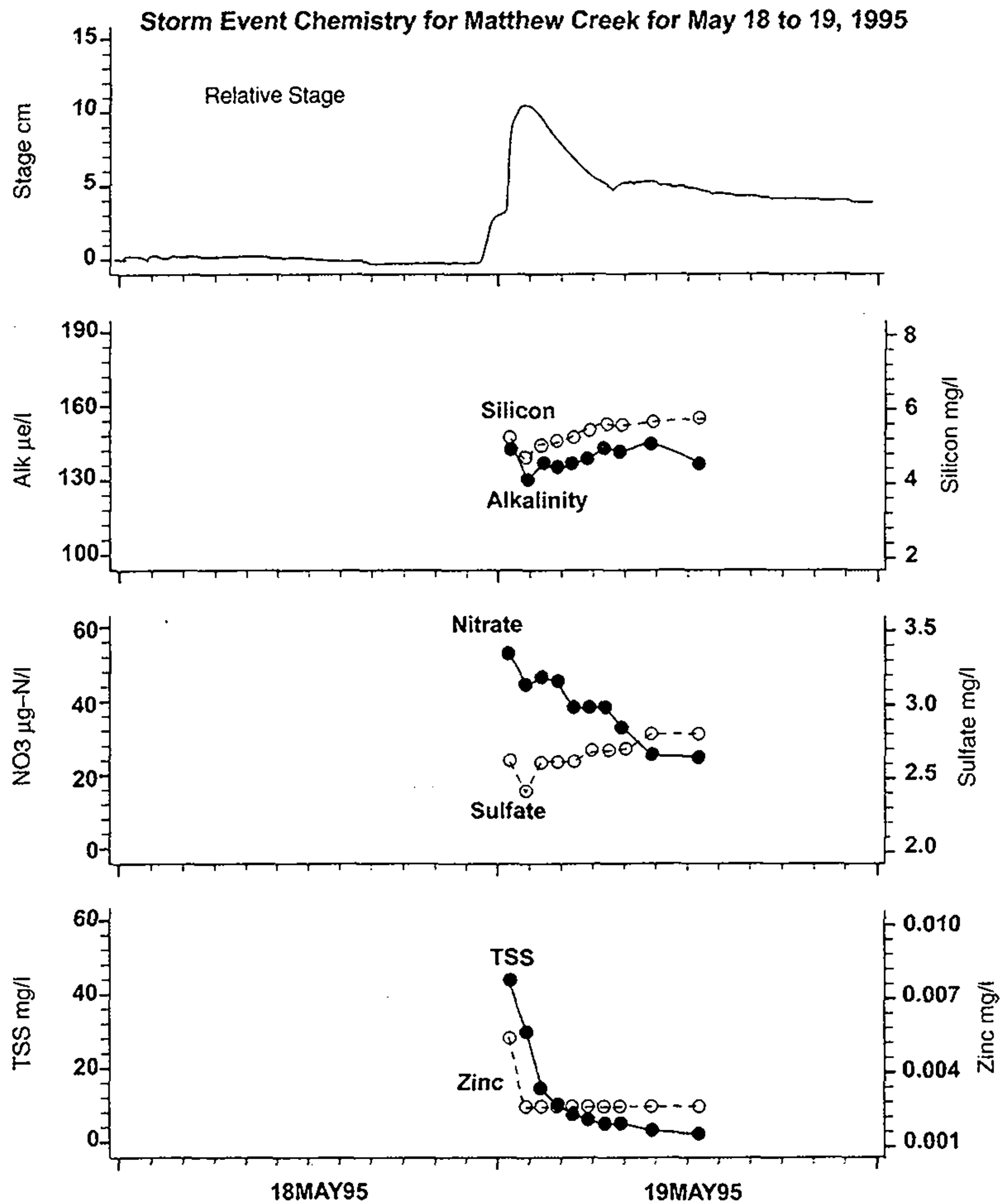

Fig. 31. Concentrations of selected parameters during a storm in May 1995 in Matthew Creek (station 13).

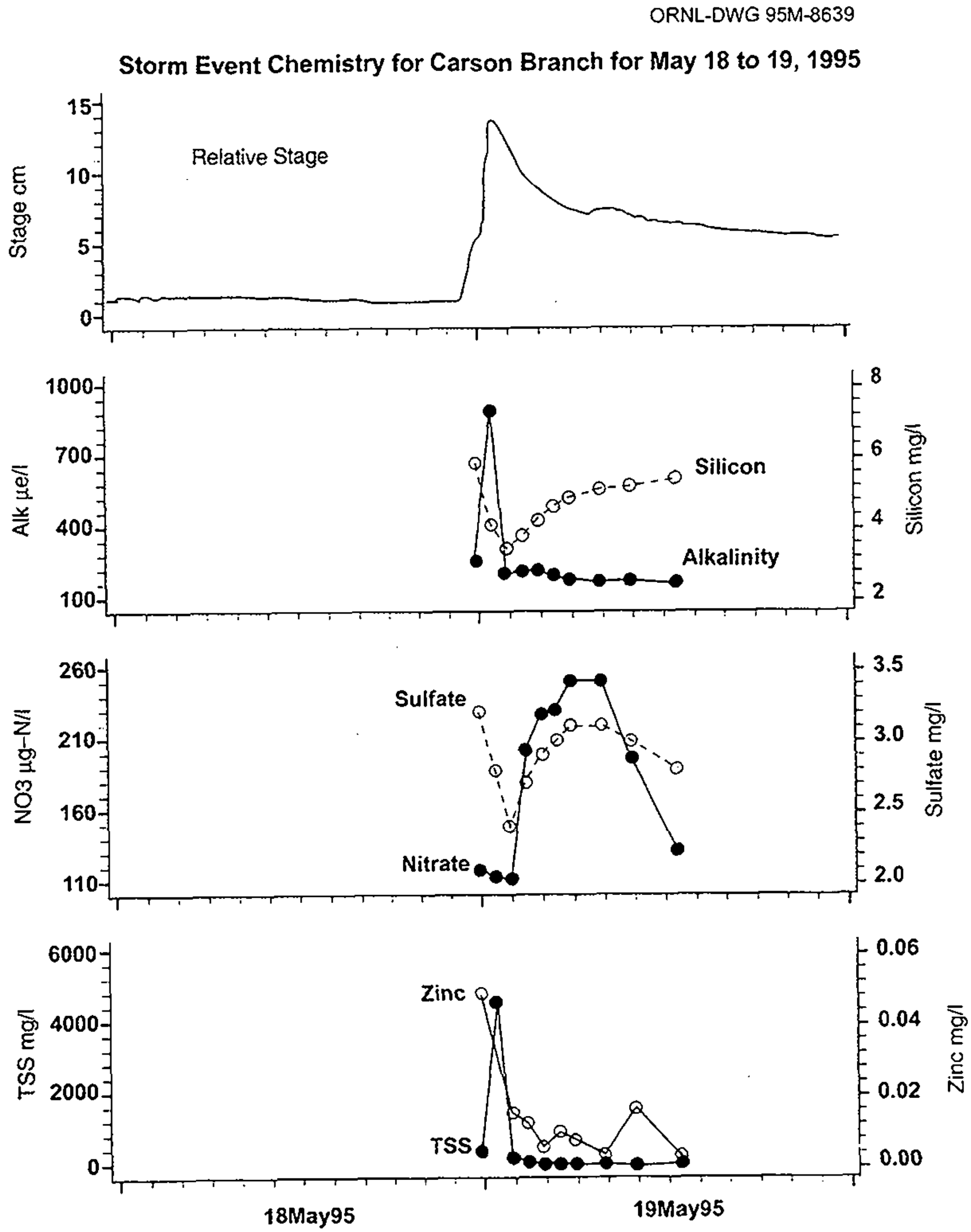

Fig. 32. Concentrations of selected parameters during a storm in May 1995 in Carson Branch (station 21).

Table 7. Sampling sites for the aquatic ecological resources of proposed Section 8B of the Foothills Parkway

Site identifier[a]	Site description	Qualitative benthic macroinvertebrate survey sampling	Quantitative artificial substrate benthic macroinvertebrate sampling	Qualitative fish survey sampling	Quantitative fish survey sampling
	Little Pigeon River/Copeland Creek/Lindsey Creek				
1-LP-A	Little Pigeon River, above right-of-way	X	X	X	
2-LP-B	Little Pigeon river, below right-of-way	X	X		X
3-CP-A	Copeland Creek, above right-of-way	X		X	
4-CP-B	Copeland Creek, below right-of-way	X		X	
5-LN-A	Lindsey Creek, above right-of-way	X		X	
6-LN-B	Lindsey Creek, below right-of-way	X		X	
	Webb Mountain/Webb Creek Drainages				
32-LB-B	Laurel Creek, below right-of-way	X		X	
7-WB-A	Webb Creek, above right-of-way	X	X		X
8-WB-B	Webb Creek, below right-of-way	X	X		X
27-WBT1-B	Webb Creek Tributary, within right-of-way	X		X	
31-WBT3-B	Webb Creek Tributary, below right-of-way	X			

Table 7. continued

Site identifier[a]	Site description	Qualitative benthic macroinvertebrate survey sampling	Quantitative artificial substrate benthic macroinvertebrate sampling	Qualitative fish survey sampling	Quantitative fish survey sampling
9-WBT2-B	Webb Creek Tributary 2, below right-of-way	X		X	
28-SP-B	Sheep Pen Branch, within right-of-way	X		X	
10-MD-B	Mill Dam Br., below right-of-way	x		X	
11-WR-B	Warden Br., below right-of-way	X		X	
12-BT-B	Butler Br., below right-of-way	X		X	
13-MA-B[a]	Matthew Creek, below right-of-way	X		X	
13.5-MAT1-B[b]	Matthew Creek Tributary 1, below right-of-way	X		X	
15-MAT2-B	Matthew Creek Tributary 2, below right-of-way	X		X	
		Rocky Flats Drainages			
14-DNW-A	Dunn Creek West Branch, above right-of-way	X		X	
16-DN-A	Dunn Creek East Branch, above right-of-way	X	X		X
17-DN-B	Dunn Creek, below right-of-way	X	X		X
18-OG-A	Ogle Spring Br., above right-of-way	X		X	
19-OG-B	Ogle Spring Br., below right-of-way	X		X	

Table 7. continued

Site identifier[a]	Site description	Qualitative benthic macroinvertebrate survey sampling	Quantitative artificial substrate benthic macroinvertebrate sampling	Qualitative fish survey sampling	Quantitative fish survey sampling
20-CR-A	Carson Br., above right-of-way	X		X	
21-CR-B	Carson Br., below right-of-way	X		X	
		Big Ridge/Cosby Creek Drainages			
22-CH-B	Chavis Creek, below right-of-way	X		X	
23-IC-B	Indian Camp Creek, below right-of-way	X		X	
24-SH-B	Sandy Hollow Creek, below right-of-way	X		X	
25-CB-A	Cosby Creek, above right-of-way	X	X		X
26-CB-B	Cosby Creek, below right-of-way	X	X		X

[a]The number in the site identifier includes the corresponding water quality site.

[b]These two sites are just above the confluence of Matthew Creek and Matthew Creek Tributary 1, whereas the water quality site is immediately below the confluence.

GSMNP-listed aquatic species beyond the federal and state listed species (S. Moore, personal communication to J. Dickerman, ORNL, August 24, 1995).

These surveys establish a baseline of the existing aquatic ecological resources in 1994 for use in assessing and monitoring the potential environmental impacts of the Section 8B parkway development and operation. Because of the existing human-induced impacts and the trend of continued residential and commercial development within the watersheds of many of the surveyed streams, a reassessment of the baseline aquatic populations just prior to project construction, should that alternative be selected, would be advisable so that potential impacts can be appropriately attributed.

3.3.1.1 Benthic Invertebrate Survey Approach

A standardized qualitative benthic invertebrate collection technique included hand-picking rocks, logs, and leaf packs; coarse screening soft substrates for burrowing organisms; kicking in riffles with a fine-mesh screen as a downstream collecting device; and dip-netting in vegetation, undercut banks, and root mats for a recorded time period for each collector. Concerted efforts with this variety of opportunistic sampling methods in all habitat types are likely to capture from 50 to 70% of the resident benthic invertebrates during any single sampling episode. The remainder of the stream fauna are present in some resting stage (egg or pupa) or are otherwise inaccessible to normal sampling at any single sampling date (Lenat 1987; D. R. Lenat, North Carolina Environmental Management Water Quality Section, Raleigh, method testing memorandum to K. Eagleson, October 18, 1993; Appendix D).

A quantitative benthic macroinvertebrate method was also implemented that used modified Hester-Dendy samplers following the Ohio Environmental Protection Agency (OEPA) protocol (OEPA 1987). These artificial substrate samplers control for substrate variability by offering a standardized surface area for colonization (1 ft^2) that can be replicated. However, these samplers are selective for certain taxa, especially the Chironomids (midges) of the insect order Diptera (true flies). Four upstream-downstream paired sites, consisting of the four largest streams along this section of the ROW, were sampled with replicated Hester-Dendy samplers involving a 6-week incubation period that coincided with the qualitative benthic macroinvertebrate sampling. See Appendix D on Aquatic Ecological Resources on benthic invertebrate collection and identification methods.

3.3.1.2 Fish Survey Approach

All stream sites were sampled, if sufficient water was present, by using electroshocking and/or seining methods for the fish survey. Single-pass electroshock fish sampling, given the conditions in the Section 8B streams, is a qualitative sampling method that provides a nearly complete species listing and an indication of relative dominance of the fish species present (Appendix D). Multiple (triple-pass depletion) electroshock fish sampling in the four upstream-downstream paired sites of the four largest streams along the proposed Section 8B Foothills Parkway permitted calculation of fish population numbers and biomass for these stream sites. See Appendix D for specifics on fish collection and identification methods.

3.3.1.3 Non-Biotic Indicators of Stream Condition

Table 8 compiles information indicative of abiotic anthropogenic impacts on the Section 8B parkway streams. These include the field observations from the water quality and aquatic resources sampling crews on stream siltation and streambank stability. The four water quality parameters of phosphate, ammonia, nitrate, and chloride also indicate whether a stream chemistry value was relatively high compared with pristine water quality values for other streams in this region (Table 8). See Section 3.2 on water quality for more discussion of water chemistry.

Based on Table 8, streams that were identified as having three or more separate indications of human-induced impacts were considered as impacted sites for purposes of stream biota analyses for "affected" and "unaffected" sites. Of the 31 stream sites where both water quality and aquatic resources were sampled, 12 were designated as affected and 19 were designated as unaffected or as pristine stream sites (Table 8). On the basis of this criterion, the 12 affected sites are Copeland Creek (sites 3 and 4), Lindsey Creek (sites 5 and 6), Webb Creek and two of the three Webb Creek tributaries (sites 7, 8, 9, and 27), Ogle Spring Branch (site 18 and 19), the most downstream tributary of Matthew Creek (site 15), and Sandy Hollow Creek (site 24).

3.3.1.4 Biotic Indicators of Stream Condition

The total taxa richness (i.e., the number of taxa per site) of benthic invertebrates is the index of choice for assessment of ecosystem health when monitoring freshwater ecosystems (Reice and Wohlenberg 1993). Generally, total taxa richness decreases with decreasing water quality (Weber 1973; Resh and Grodhaus 1983). Relative abundance of various stress-tolerant and stress-sensitive benthic invertebrate groups (orders, families, genera, and some species) also provides important insights into the conditions and the types of stressors that may be impacting the stream system. An unstressed stream would have a more diverse benthic invertebrate community that contains numerous stress-sensitive and less stress-sensitive taxa.

A comparison of the number of stress-sensitive species and specimens to the total numbers of benthic invertebrate species and specimens is a widely accepted indicator of ecosystem condition that is relatively independent of stream size (Lenat 1988). Three orders—Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies), collectively known as the EPT—are recognized as stress-sensitive benthic invertebrate orders. Within these three orders, the stoneflies (Plecoptera) are generally considered the most sensitive group, followed closely by the mayflies (Ephemeroptera), and lastly the caddisflies (Trichoptera).

Within another insect order, the Diptera (true flies), one subfamily—Orthocladiinae of the Chironomidae family (midges)—is generally recognized as a stress-tolerant subfamily (Wiederholm 1984; Wojtowicz Report 1982). Therefore, a comparison of species and specimens in the Orthocladiinae subfamily relative to all chironomid species and specimens is another indicator of ecosystem stress. The higher the number of taxa and specimens in the subfamily Orthocladiinae, especially in the genera *Cricotopus* and *Orthocladius*, the more indicative of a stressed site. Some other specific taxa are also considered indicators of pollution problems (primarily organic enrichment) and their presence, especially if in abundance in a stream survey, is noted. These taxa include the chironomid *Microtendipes*, the caddisfly *Hydropsyche betteni/depravata*, and the

Table 8. Indications of anthropogenic effects on the streams in the proposed Section 8B of the Foothills Parkway: abiotic indicators of stream condition

Site identifier	"Affected" stream site	Streambed siltation evident[a]	Streambank stability compromised[a]	Phosphate relatively high[b]	Ammonia relatively high[c]	Nitrate relatively high[d]	Chloride relatively high[e]
1-LP-A						•	
2-LP-B						•	
3-CP-A	♦	•	••	•			
4-CP-B	♦	•	••	•			•
5-LN-A	♦	•		•	•		••
6-LN-B	♦	••		•	•		•
32-LB-B							
7-WB-A	♦	•	•	•		•	
8-WB-B	♦	•	•	•		•	
27-WBT1-B	♦	•		••			
31-WBT3-B		•		•			
9-WBT2-B	♦	•		••			
28-SPB		•		•			
10-MD-B		•		•			
11-WR-B		•					
12-BT-B		•					
13-MA-B							
13.5-MAT1-B							
15-MAT-B	♦	••		•			
14-DNW-A							
16-DN-A						•	
17-DN-B						•	
18-OG-A	♦	••		•		••	••
19-OG-B	♦	•		•		••	•
20-CR-A		•					
21-CR-B		••					
22-CH-B		•		•			
23-IC-B							
24-SH-B	♦	•	••	•			

Table 8. Continued

Site identifier	"Affected" stream site	Streambed *siltation* evident[a]	Streambank *stability* compromised[a]	Phosphate *relatively* high[b]	Ammonia *relatively* high[c]	Nitrate *relatively* high[d]	Chloride *relatively* high[e]
25-CB-A							
26-CB-B							

[a]Impacts visually evident in the stream water, stream substrate and/or stream bank condition as noted by water quality and aquatic resources field crews. "Some" and "moderate" = •; "Considerable" = ••.

[b]Indicates relatively high levels of phosphate (>20 μg/L) in these generally pristine mountain streams. See Table 3.2-4 and Sect. 3.2.3.2.

[c]Indicates relatively high levels of ammonia (>30 μg/L) in these generally pristine mountain streams. See Table 3.2-4 and Sect. 3.2.3.2.

[d]Indicates relatively high levels of nitrate (>250 μg/L) in these generally pristine mountain streams. See Table 3.2-4 and Sect. 3.2.3.2.

[e]Indicates relatively high levels of chloride (>2 μg/L) in these generally pristine mountain streams. See Table 3.2-4 and Sect. 3.2.3.2.

• = single bullet indicates that mean value is equal to or greater than the threshold values for relatively high levels.
•• = double bullet indicates that mean value is equal to or greater than twice the threshold values for relatively high levels.

mayfly *Stenacron interpunctatum*. The indications of biotic anthropogenic effects for Section 8B are listed in Table 9.

Some of the effects of mild enrichment and siltation on stream benthic macroinvertebrates are known to alter certain populations. Mild enrichment of streams (e.g., from agricultural and yard fertilizers and laundry detergents) tends to increase populations of some mayflies, black flies, caddisflies, and chironomids. Prolonged siltation is known to reduce species richness and specimen density and would alter populations to favor burrowing and deposit-feeding insect forms (e.g., some chironomids; Wiederholm 1984).

3.3.2 Benthic Macroinvertebrates and Fish: Results and Discussion

The following subsections describe and discuss the results of the 31 stream biotic survey sites in four geographically-grouped stream drainages from west to east along the proposed Section 8B Foothills Parkway (Fig. 20). The largest stream in each of the four stream drainage clusters is discussed in more detail, while the smaller associated streams of the drainages are summarized.

Stream discussions include physical stream characteristics (Table 10); benthic macroinvertebrate taxa richness (Tables 10 and 11; Fig. 33); abiotic and biotic indicators of stream condition, especially as they relate to human-induced impact (Tables 8 and 9; Figs. 34 and 35); and the fish survey results (Table 10; Fig. 33).

The biotic indicators of stream condition include the relative abundance of stress-sensitive and stress-tolerant taxonomic groups including EPTs (stress-sensitive taxa; Fig. 36), the relative contribution of each order within the EPT (Fig. 37), EPT to total benthic taxa ratios (Fig. 34), and

Table 9. Indications of anthropogenic effects on the streams in the proposed Section 8B of the Foothills Parkway: biotic indicators of stream condition

Site identifier	Ratio of EPT taxa to total invertebrate taxa[a]	Ratio of orthoclad taxa to chironomid[b]	Number of pollution indicating species present[c]	More than one pollution indicating species present
1-LP-A	0.5	0.63	4	♦
2-LP-B	0.5	0.49	3	♦
3-CP-A	0.48	0.48	4	♦
4-CP-B	0.47	0.35	4	♦
5-LN-A	0.41	0.35	2	♦
6-LN-B	0.46	0.35	1	
32-LB-B	0.54	0.63	1	
7-WB-A	0.5	0.61	4	♦
8-WB-B	0.46	0.48	6	♦
27-WBT1-B	0.39	0.5	0	
31-WBT3-B	0.44	0.5	0	
9-WBT2-B	0.48	0.5	0	
28-SPB	0.5	0.62	0	
10-MD-B	0.6	0.57	0	
11-WR-B	0.51	0.61	0	
12-BT-B	0.45	0.6	0	
13-MA-B	0.46	0.67	1	
13.5-MAT1-B	0.51	0.67	0	
15-MAT-B	0.55	0.75	0	
14-DNW-A	0.56	0.82	0	
16-DN-A	0.48	0.62	4	♦
17-DN-B	0.51	0.65	2	♦
18-OG-A	0.48	0.38	0	
19-OG-B	0.53	0.55	1	
20-CR-A	0.47	0.68	0	
21-CR-B	0.47	0.5	0	
22-CH-B	0.53	0.48	3	♦
23-IC-B	0.48	0.58	2	♦
24-SH-B	0.5	0.5	4	♦

Table 9. Continued

Site identifier	Ratio of EPT taxa to total invertebrate taxa[a]	Ratio of orthoclad taxa to chironomid[b]	Number of pollution indicating species present[c]	More than one pollution indicating species present
25-CB-A	0.46	0.58	5	♦
26-CB-B	0.43	0.5	5	♦

[a]EPT taxa to total taxa ration—compares the number of taxa in EPT orders [Ephemeroptera (mayflies), Plecoptera (stoneflies), Tricoptera (caddisflies)] that contain insects that are generally known to be sensitive to pollutants with total taxa present, assuming that the higher the proportion of sensitive taxa, the healthier the ecosystem.

[b]Ratio of Subfamily Orthocladiinae taxa to total Family Chironomidae taxa—compares the number of taxa in the generally stress-tolerant Orthocladiinae to the total chironomids (non-biting midges). Higher relative numbers of stress tolerant taxa generally indicate the presence of stress factors in the stream environment.

[c]Pollution-indicating species include the chironomids *Cricotopus, Orthocladius,* and *Microtendipes*; the caddisfly *Hydropsyche betteni/depravata*; and the mayfly *Stenacron interpunctatum.*

orthoclad taxa (stress-tolerant taxa) and orthoclad to total chironomid taxa ratios (Tables 10 and 11; Fig. 38). Comparisons with other stream survey results in this region are made when the streambed substrate, stream width, and collection methods allow such comparisons. It is hoped that these comparisons help develop a larger context for the relative evaluation of the status of Section 8B stream aquatic ecological resources.

Section 3.3.2.5 summarizes the general findings of the Section 8B stream survey results.

3.3.2.1 Little Pigeon River/Copeland Creek/Lindsey Creek

Three of the Section 8B streams intercept the ROW in the Pittman Center valley at the westernmost end of Section 8B. Most notably, these include the largest stream in the Section 8B study—Little Pigeon River (Fig. 20). The other two streams in this valley are Copeland Creek, a small primary tributary to Little Pigeon River, and Lindsey Creek, a secondary tributary to the Little Pigeon River by way of Webb Creek.

The **Little Pigeon River** at sites 1 and 2 is approximately 18 m (59 ft) wide with a maximum depth of 150 cm (5 ft). The two small tributaries, Copeland and Lindsey Creeks (sites 3, 4, 5, and 6) are both about 2 m (6 ft) with maximum depths of around 60 cm (2 ft)] (see Fig. 20, Table 10). Little Pigeon sites were approximately 10 to 20% canopy-covered with a stream bed substrate predominantly comprised of boulder and cobbles (70%) with gravel (20%), and the remainder consisting of bedrock and silt. With 25 total fish taxa and 174 different invertebrate taxa collected in the surveys, site 1 and the very similar site 2 (24 total fish taxa; 174 total invertebrate taxa) not only are the most taxonomically rich sites sampled in Section 8B (Table 10, Fig. 33), but also compare very favorably with other temperate region sites. For example, Abrams Creek is a nearby GSMNP stream site of comparable substrate and size [about 0.40 km (0.25 mile) below Abrams Creek Campground]. The May 1993 sample for Abrams Creek (using identical collection methods exclusive of chironomid taxa) was 106 total invertebrate taxa and 59 EPT taxa. This

Table 10. Stream width and depth and total numbers of benthic macroinvertebrates and fish taxa collected from the stream sampling sites along the proposed Section 8B of the Foothills Parkway

Site identifier	Mean stream width (m)	Maximum depth (cm)	Total benthic taxa	Total EPT taxa	Total orthoclad taxa	Total fish taxa
Little Pigeon River/Copeland Creek/Lindsey Creek						
1-LP-A	18	100	174	88	21	24
2-LP-B	18	150	174	87	19	25
3-CP-A	3	60	130	62	14	6
4-CP-B	2.5	70	115	54	8	10
5-LN-A	1	50	79	32	7	4
6-LN-B	1.5	60	78	36	6	4
Webb Mountain/Webb Creek Drainages						
32-LB-B	4	80	94	51	12	4
7-WB-A	11	100	137	68	16	15
8-WB-B	12	100	160	73	17	15
27-WBT1-B	1	50	71	28	3	4
31-WBT3-B	0.5	20	27	12	2	0
9-WBT2-B	1.8	40	82	39	8	1
28-SPB	1.2	20	68	34	5	0
10-MD-B	2.5	70	100	51	8	1
11-WR-B	2	50	106	54	11	2
12-BT-B	2	45	86	39	9	1
13-MA-B	1.8	15	109	70	18	4
13.5-MAT1-B	0.6	40	73	37	8	0
15-MAT-B	1.5	40	87	48	9	2

Table 10. Continued

Site identifier	Mean stream width (m)	Maximum depth (cm)	Total benthic taxa	Total EPT taxa	Total orthoclad taxa	Total fish taxa
Rocky Flat Drainages						
14-DNW-A	1.5	20	91	51	9	0
16-DN-A	6	60	135	65	23	7
17-DN-B	6	75	113	58	15	9
18-OG-A	1.5	20	87	42	5	2
19-OG-B	3	50	99	52	11	2
20-CR-A	1.5	30	106	50	15	1
21-CR-B	1.5	30	95	45	7	2
Big Ridge/Cosby Creek Drainages						
22-CH-B	1.5	45	99	52	21	6
23-IC-B	8	60	90	43	14	7
24-SH-B	2	30	109	54	11	0
25-CB-A	12	120	162	75	21	13
26-CB-B	15	60	163	70	21	18

Table 11. Benthic macroinvertebrate survey taxa and specimen comparisons of various stress-sensitive and stress-tolerant taxonomic groupings from the stream sampling sites along the proposed Section 8B of the Foothills Parkway

Site identifier	Ratio of EPT taxa to total benthic taxa[b,c]	Mayflies (E) of EPT	Stoneflies (P) of EPT	Caddisflies (T) of EPT	Ratio of EPT specimens to total benthic specimens[b]	Total EPT specimens[b]	Total benthic specimens	Ratio of orthoclad taxa to total chionomid taxa	Total orthoclad taxa	Total chironomid taxa
Little Pigeon River/Copeland Creek/Lindsey Creek										
1-LP-A	0.5	34	19	35	0.65	1493	2296	0.63	21	33
2-LP-B	0.5	38	15	34	0.69	2054	2966	0.49	19	39
3-CP-A	0.48	29	10	23	0.64	1160	1818	0.48	14	29
4-CP-B	0.47	30	8	16	0.64	814	1266	0.35	8	23
5-LN-A	0.41	12	6	14	0.63	708	1117	0.35	7	20
6-LN-B	0.46	16	8	12	0.71	804	1132	0.35	6	17
Webb Mountain/Webb Creek Drainages										
32-LB-B	0.54	22	10	19	0.74	1088	1477	0.63	12	19
7-WB-A	0.5	30	16	22	0.69	1524	2215	0.61	16	26
8-WB-B	0.46	34	18	21	0.64	1704	2676	0.48	17	35
27-WBT1-B	0.39	8	6	14	0.57	337	590	0.5	3	6
31-WBT3-B	0.44	5	2	5	0.66	64	97	0.5	2	4
9-WBT2-B	0.48	14	7	18	0.72	873	1211	0.5	8	16
28-SPB	0.5	9	13	12	0.73	540	1737	0.62	5	8
10-MD-B	0.6	21	9	21	0.63	736	1163	0.57	8	14
11-WR-B	0.51	22	11	21	0.6	976	1624	0.61	11	18
12-BT-B	0.45	17	7	15	0.63	556	888	0.6	9	15
13-MA-B	0.46	22	13	15	0.65	840	1294	0.67	18	27

Table 11. Continued

Site identifier	Ratio of EPT taxa to total benthic taxa[b,c]	Mayflies (E) of EPT	Stoneflies (P) of EPT	Caddisflies (T) of EPT	Ratio of EPT specimens to total benthic specimens[b]	Total EPT specimens[b]	Total benthic specimens	Ratio of orthoclad taxa to total chionomid taxa	Total orthoclad taxa	Total chironomid taxa
13.5-MAT1-B	0.51	15	8	14	0.79	622	784	0.67	8	12
15-MAT-B	0.55	23	10	15	0.81	1098	1356	0.75	9	12
Rocky Flat Drainages										
14-DNW-A	0.56	19	13	19	0.75	876	1170	0.82	9	11
16-DN-A	0.48	26	18	21	0.75	1475	1976	0.62	23	37
17-DN-B	0.51	31	12	15	0.73	1034	1407	0.65	15	23
18-OG-A	0.48	15	6	21	0.64	641	996	0.38	5	13
19-OG-B	0.53	25	8	19	0.78	943	1227	0.55	11	20
20-CR-A	0.47	19	12	19	0.68	1315	1929	0.68	15	22
21-CR-B	0.47	18	8	19	0.66	611	927	0.5	7	14
Big Ridge/Cosby Creek Drainages										
22-CH-B	0.53	23	12	17	0.6	742	1233	0.48	21	10
23-IC-B	0.48	18	11	14	0.46	365	787	0.58	14	24
24-SH-B	0.5	24	11	19	0.66	833	1343	0.5	11	22
25-CB-A	0.46	33	19	23	0.71	1692	2384	0.58	21	36
26-CB-B	0.43	29	21	20	0.61	1408	2306	0.5	21	42

[a]These numbers are combined totals for both the spring and fall benthic invertebrate qualitative surveys.
[b]EPT = Ephemeroptera (mayflies), Plecoptera (stoneflies), Tricoptera (caddisflies).
[c]EPT to total ratio—compares the number of taxa in orders (or number of specimens in those orders) that contain insects that are generally known to be sensitive to pollutants with the total taxa present, assuming that the higher the proportion of sensitive taxa, the healthier the ecosystem.

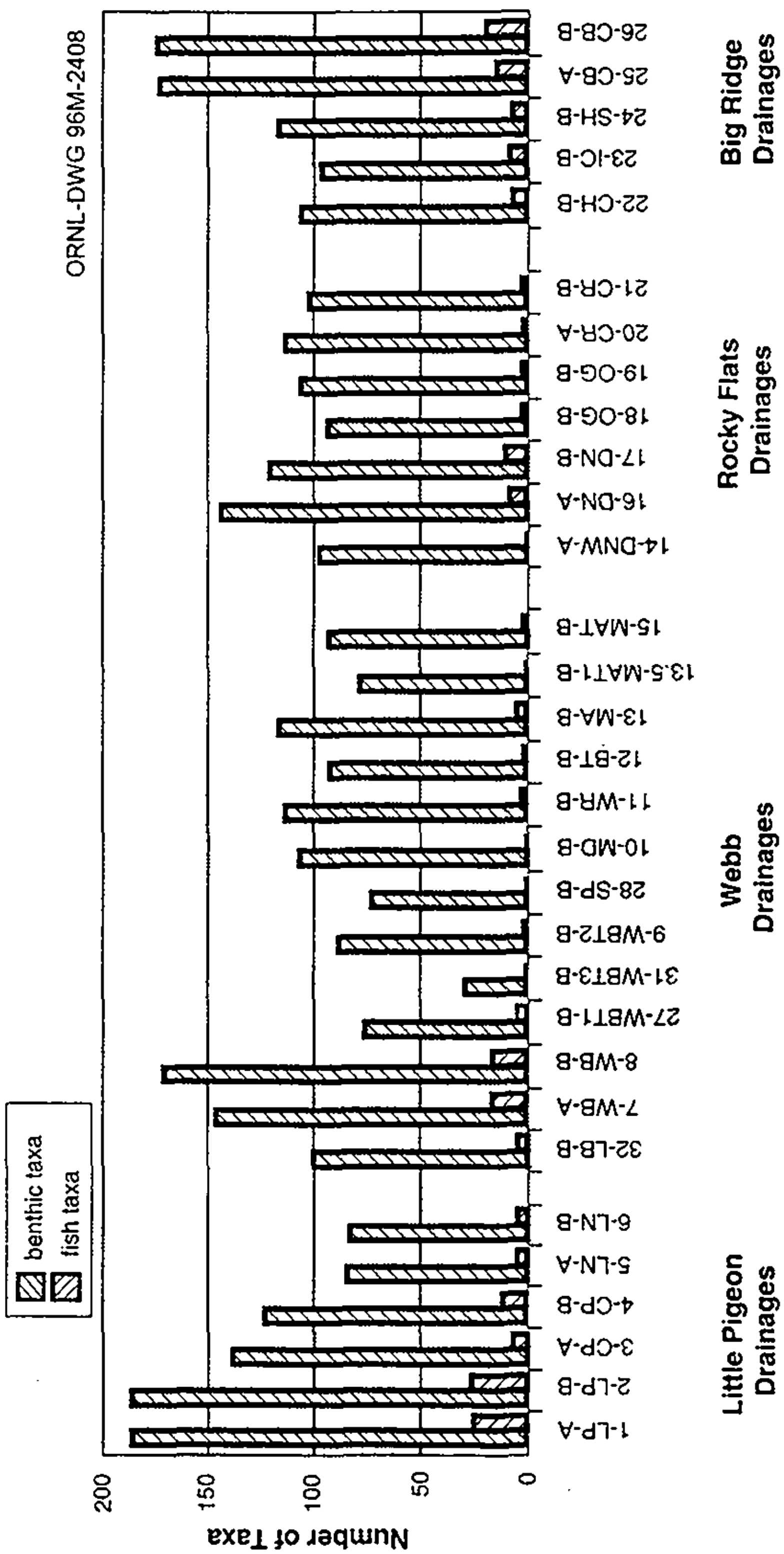

Fig. 33. Total number of taxa for benthic macroinvertebrates and fish at the stream biological survey sites for Section 8B of the Foothills Parkway.

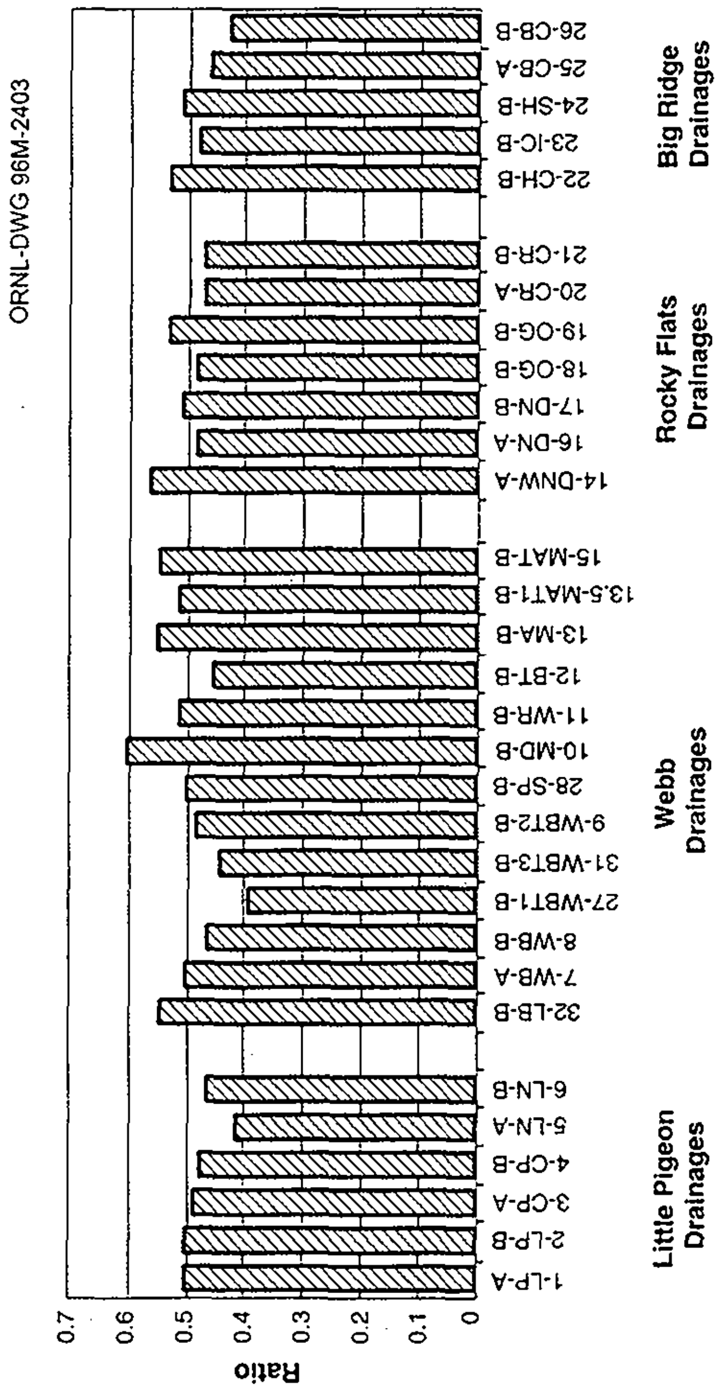

Fig. 34. Ratio of EPT taxa to total benthic macroinvertebrate taxa at the stream biological survey sites for Section 8B of the Foothills Parkway.

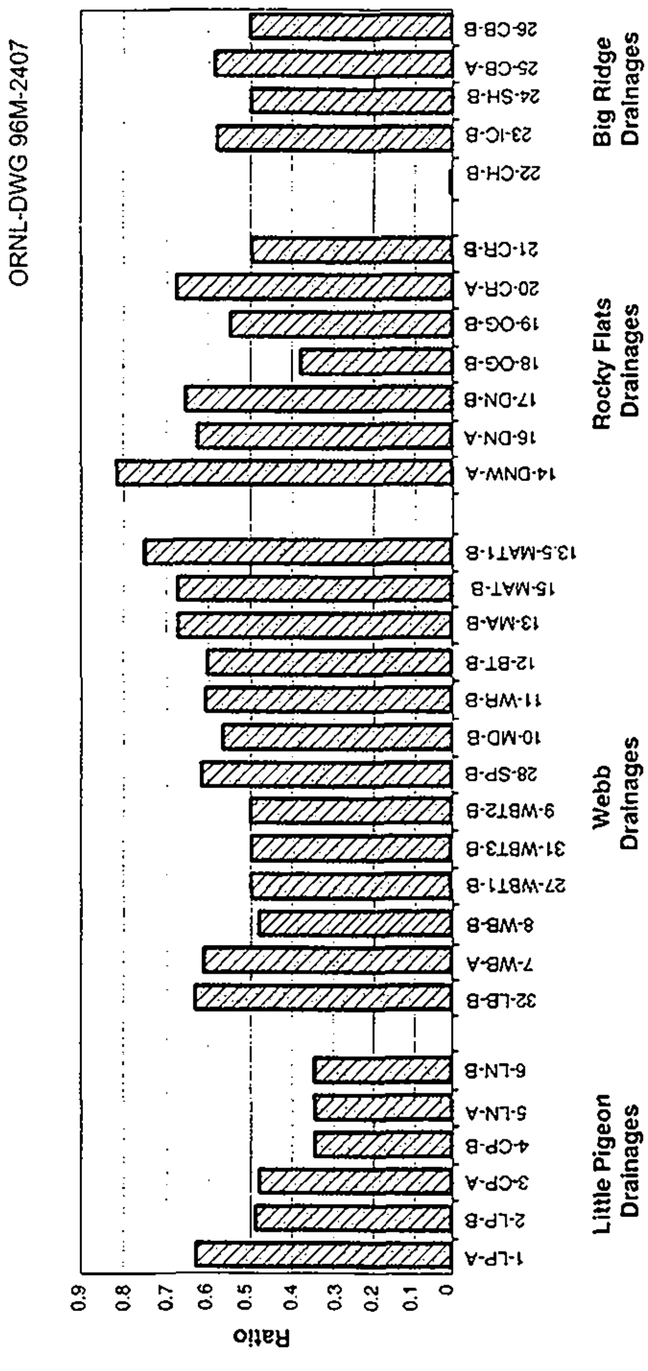

Fig. 35. Ratio of Orthocladiinae taxa to total Chironomidae taxa at the stream biological survey sites for Section 8B of the Foothills Parkway.

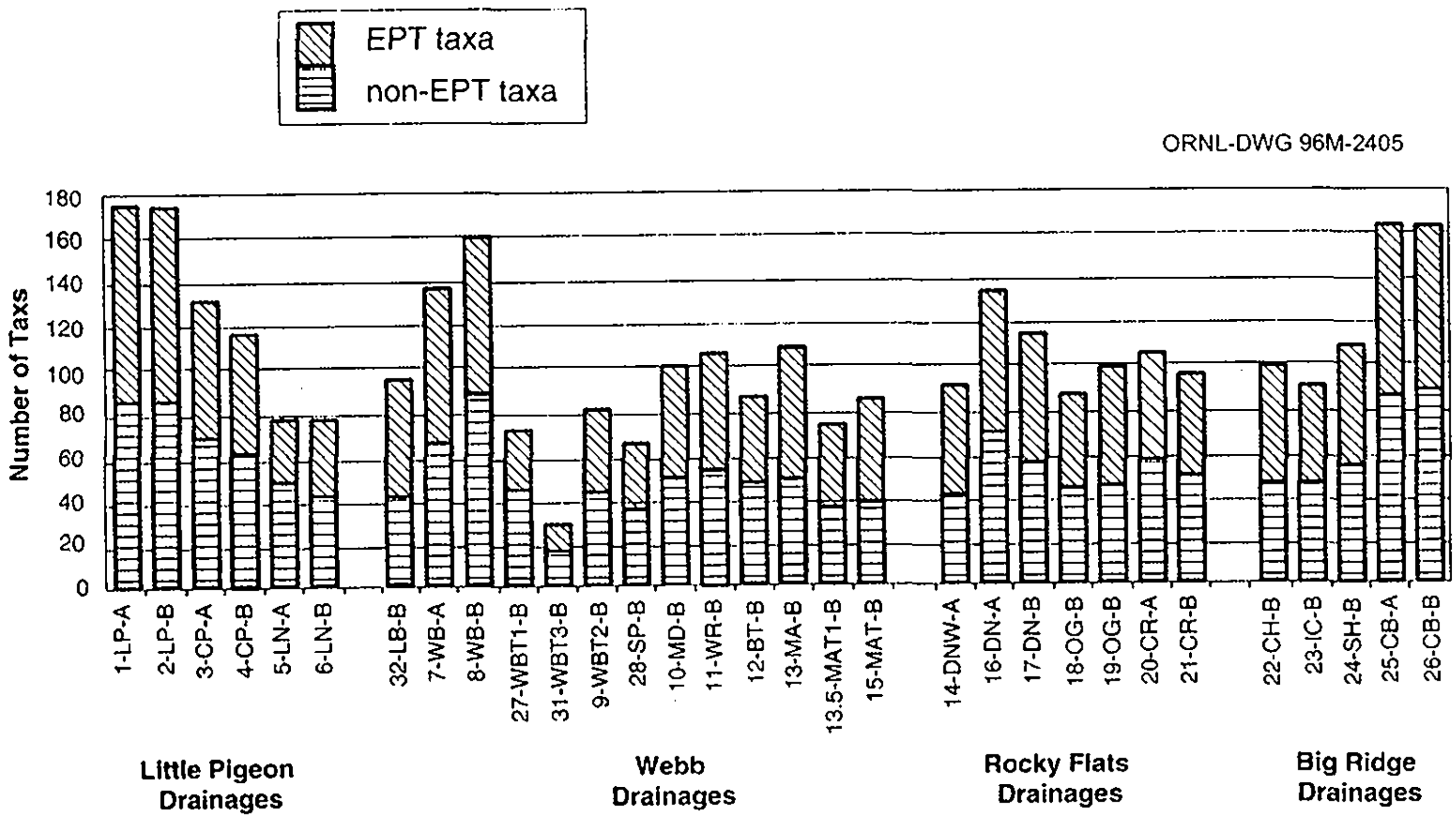

Fig. 36. Number of Ephemeroptera, Plecoptera, and Tricoptera (EPT) taxa and non-EPT taxa at the stream biological survey sites for Section 8B of the Foothills Parkway.

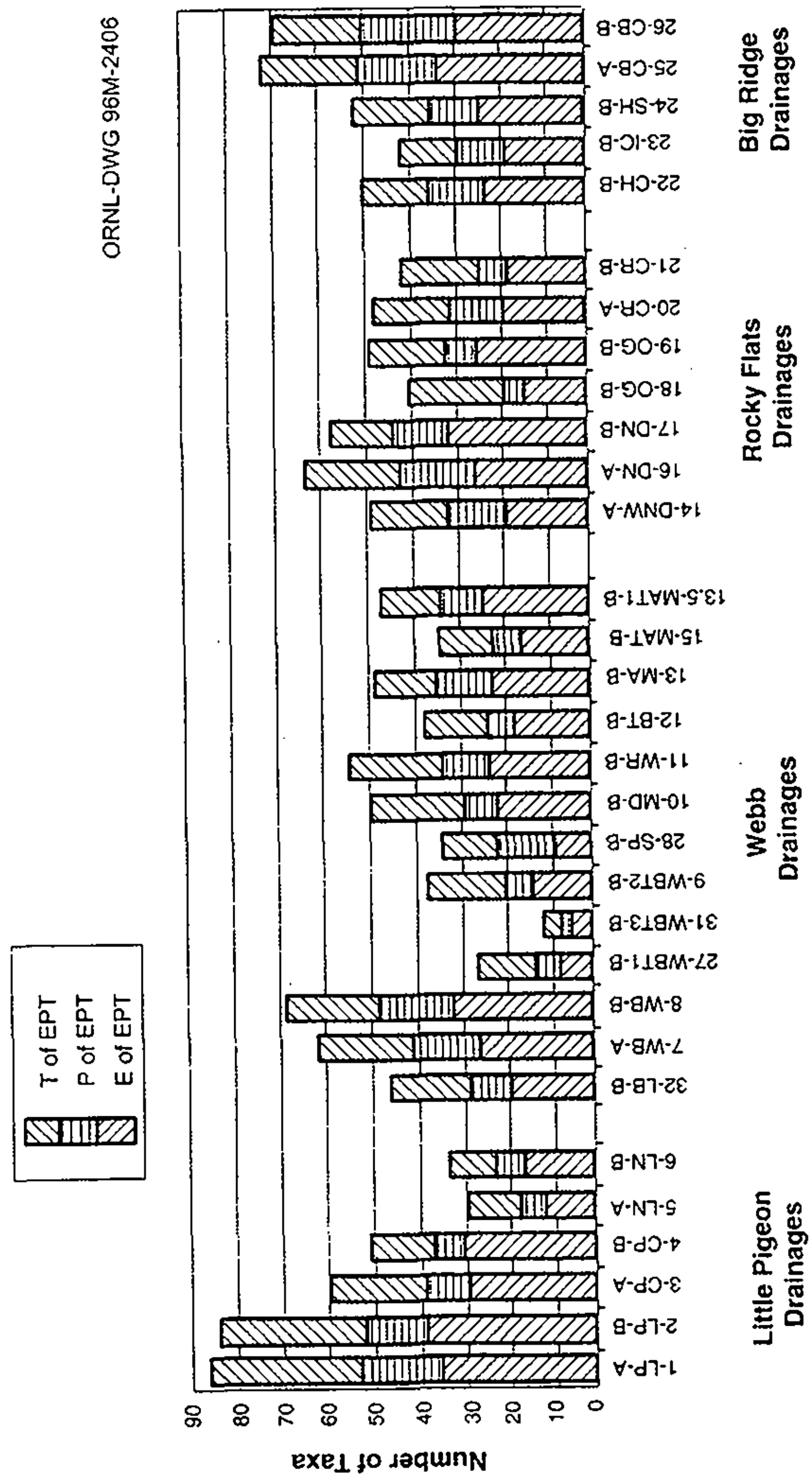

Fig. 37. Relative contribution of Ephemeroptera, Plecoptera, and Tricoptera (EPT) to the EPT total taxa at the stream biological survey sites for Section 8B of the Foothills Parkway.

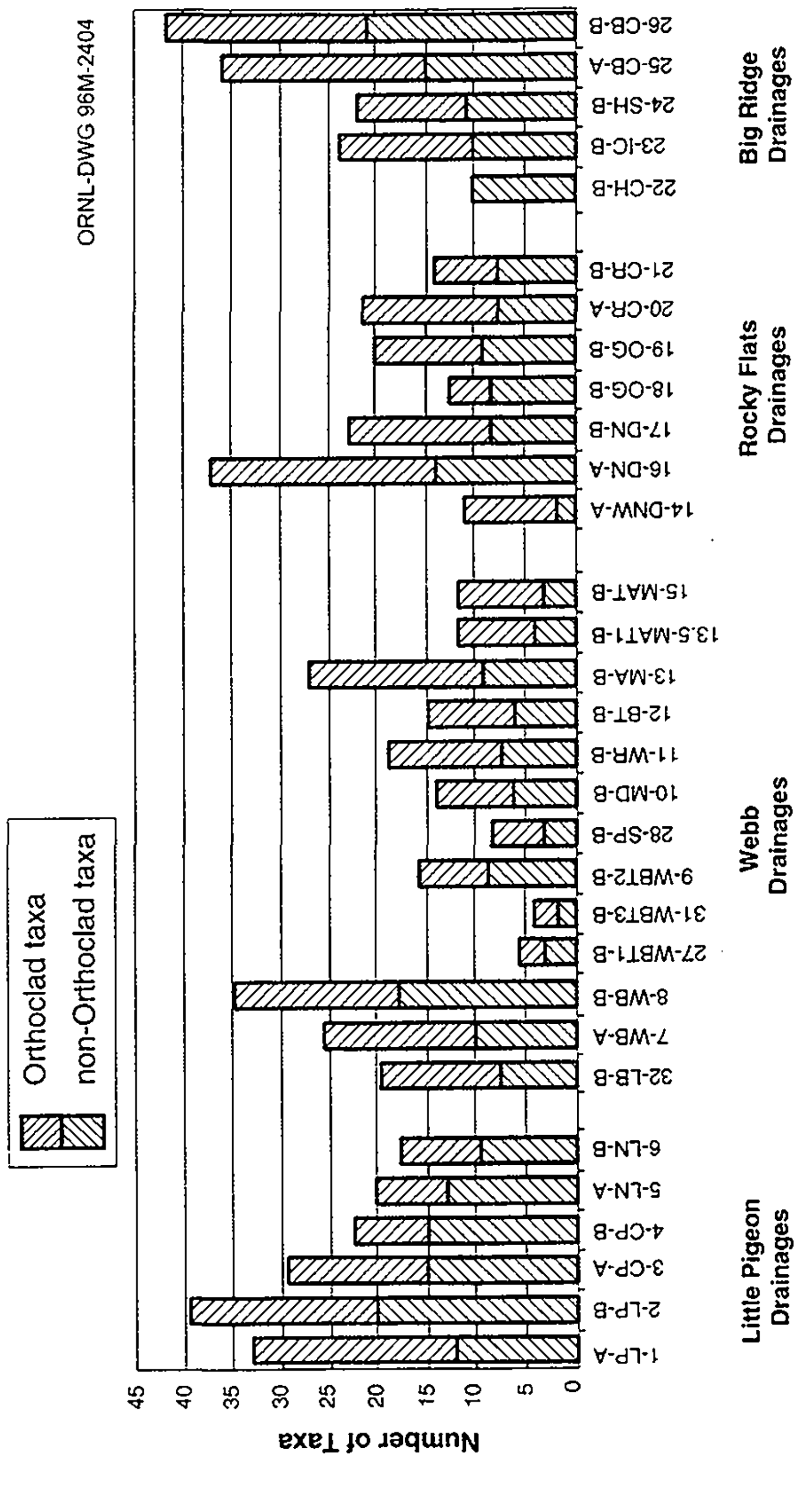

Fig. 38. Numbers of Orthocladiinae and non-Orthocladiinae taxa at the stream biological survey sites for Section 8B of the Foothills Parkway.

sample compares favorably with 100 non-chironomid taxa for the site 1 and 2 spring sample, including 88 EPT taxa (D. Etnier, personal communication to J. Dickerman, January 20, 1995).

The Little Pigeon River sites were rated as pristine according to the abiotic indicators of stream condition. Only one of six possible abiotic human-induced impact indicators—relatively high nitrate levels—applied to this site. This particular indicator, when occurring without other abiotic human-induced indicators, is not considered supportive of anthropogenic impact (see Sect. 3.2.3.2 discussion). All the biotic data of stream condition indicate that the Little Pigeon River sites have very rich taxonomic assemblages with diverse specimen abundances (see Appendix D). Half of the benthic invertebrate taxa were from the stress-sensitive EPT taxonomic groups, and 60% of those EPT taxa belonged to the two most sensitive orders (E and P) within the EPT groups (Tables 10 and 11, Fig. 38). The chironomid fauna were also exceptionally diverse and abundant with 50 to 60% of the chironomid taxa within the most stress-tolerant orthoclad group (Table 11, Figs. 35 and 38). The Little Pigeon River sites had three and four different species of pollution-indicating genera, *Cricotopus* and *Orthocladius*, respectively. But these taxa occurred in very low numbers, only about 30 specimens (from a total of 2 to nearly 3000 thousand specimens) in the benthic invertebrate combined surveys at these Little Pigeon River sites (Table 11; Appendix D).

Fish communities at both Little Pigeon River sites were dominated by stonerollers (*Campostoma anomalum*), accounting for an estimated 50% and 31% of the total number of fish collected at sites 1 and 2, respectively. Warpaint shiners (*Luxilus coccogenis*) and Tennessee shiners (*Notropis rubricroceus*) were the next most commonly collected fish, accounting for the same percentages of total fish at both sites—15% and 12%, respectively. At Little Pigeon River (site 10), collection efforts also yielded 12 specimens identified as hybrids between the Tennessee shiner and saffron shiner (*Notropis rubricroceus*). This hybrid is not uncommon where these species co-occur (Appendix D).

Copeland and Lindsey Creeks (sites 3, 4, 5, and 6) are small creeks with substrate consisting predominantly of gravel and cobble (80%–95%). The Copeland Creek sites are located in a cow pasture with 0% to 5% high canopy (consisting of a few large trees), while slightly smaller Lindsey Creek sites are adjacent to a small road and several residences in Pittman Center with around 10% canopy coverage of larger trees and 40% canopy coverage from shrubs (Fig. 20). The upstream watersheds are more forested with less residential development.

The Copeland Creek sites are similar in size, substrate, and fish taxa to Section 8D stations Machine Branch and Rymel Branch (MB-3M and MB-3R) just above their confluence in Wears Cove (ORNL 1992). Copeland Creek has greater richness for both total benthic and EPT taxa (total benthic taxa 130 and 115; EPT taxa 62 and 54), while Machine Branch and Rymel Branch have 99 and 71 total benthic taxa and 35 and 29 EPT taxa, respectively. These Section 8D sites also had a larger proportion of orthoclad taxa in their chironomid taxa. For example, Machine Branch site (MB-3M) had 17 orthoclads among 26 chironomid taxa, with 6 of these taxa being either *Cricotopus* or *Orthocladius* species; Copeland Creek had 8 to 14 orthoclad taxa in 23 to 29 chironomid taxa, with 3 of these taxa being either *Cricotopus* or *Orthocladius species*. The Copeland Creek survey results also indicated 44 specimens of the pollution-indicating taxa *Hydropsyche betteni/depravata* out of a total of about 3000 specimens from both Copeland Creek sites (Table 11).

Both Copeland and Lindsey Creek, with four separate abiotic indicators of human-induced stress, were designated as affected sites (Table 8). Both creeks showed evidence of stream bed siltation and relatively high phosphate and chloride levels. Copeland Creek had compromised stream bank stability while Lindsey Creek water had relatively high ammonia levels. The biotic indicators of stream condition also suggested some organic loading, especially in Lindsey Creek (Table 9 and Appendix D). Lindsey Creek site 5—with 32 EPT taxa and 41% EPT taxa in the benthic invertebrate total of 79 taxa—was among the lowest EPT percentage in the Section 8B stream biotic survey. The presence of *Stenacron interpunctatum* (8 specimens) and the dominance of *Hydropsyche betteni/depravata* with 70 specimens further indicates an organically enriched environment. Even so, the overall benthic taxa richness (115 to 130 for Copeland Creek and 78 to 79 for Lindsey Creek) indicates a fairly healthy benthos. The small creek fish communities for both Copeland Creek and Lindsey Creek included creek chubs (*Semotilius atromaculatus*) and blacknose dace (*Rhinichthys atractulus*) as frequently collected members of the fish community (Table 10, Appendix D).

3.3.2.2 Webb Mountain/Webb Creek Drainages

Thirteen of the 31 Section 8B stream sites are associated with the Webb Mountain drainages. Webb Creek is the third largest stream along the Section 8B ROW and the main stream of this drainage (Fig. 20). Webb Creek (sites 7 and 8) collects the surface waters from the southern slopes of Webb Mountain and receives the waters from seven other study sites (9, 10, 11, 12, 27, 28, and 31). Matthew Creek (site 13) drains the eastern slope of Webb Mountain and receives the waters of site 13.5 and 15, two small tributaries. One other moderately-sized stream, Laurel Branch (site 32), drains the western slope of Webb Mountain.

Webb Creek sites (7 and 8) have a mean width of about 12 m (40 ft) and a maximum depth of 100 cm (3 ft) with 30 to 50% mixed canopy of trees and shrubs along a stream bed substrate predominantly composed of 50 to 60% boulder and cobble and 30 to 45% gravel (Appendix D). Webb Creek, the third largest stream in Section 8B, is also the third most taxonomically rich site for benthic invertebrate taxa (137 and 160 taxa, sites 7 and 8 respectively) and fish taxa (15 taxa for each site) in Section 8B (Table 10). Around half of the total benthic taxa were from the stress-sensitive EPT groups (68 and 73 taxa, sites 7 and 8 respectively) with the two most stress-sensitive EPT orders (P and E) together contributing over 68 to 71% of the EPT group taxa (Tables 10 and 11, Fig. 37). The stress-tolerant orthoclads in the chironomid group contributed 16 and 17 taxa to the chironomid total taxa of 26 and 35, and 3 and 5 of these taxa were either *Cricotopus* or *Orthocladius* species. Webb Creek site 8 biota, more so than the other Webb Creek site, reflects an organically enriched stream as evidenced by the higher *Cricotopus* and *Orthocladius* species count (55 specimens) as well as the considerable number of *Microtendipes* specimens (110). It would appear that enrichment from runoff has been sufficient to increase stream productivity without reducing taxonomic richness.

The abiotic indicators of human-induced stress support the biotic indicators of organic enrichment. The Webb Creek sites were classified as affected sites because four separate abiotic indicators met the criteria of human-induced stress (Table 8). There was evidence of compromised stream bank stability and siltation along with relatively high phosphate and nitrate levels.

Fifteen fish taxa were collected at both Webb Creek sites (7 and 8). The five most dominant populations of fish, on the basis of numbers of individuals and their percentage contribution to the fish community are stonerollers (29, 12%), warpaint shiners (15, 10%), river chubs (*Nocomis micropogon*; 7, 11%), saffron shiners (22, 18%), and sculpins (*Cottus carolinae and C. bairdi*, 12, 37%). Game fish were not abundant (Appendix D).

These Webb Creek sites are similar to Mill Creek just above Abrams Creek in Cades Cove, GSMNP (Etnier Report in Appendix D). An early May 1994 survey, using identical collection methods, collected 53 EPT taxa out of a total (not including chironomids) of 79 benthic taxa. The spring Webb Creek (site 7) survey, also excluding chironomid taxa, collected 53 EPT taxa out of total taxa of 96. The higher Webb Creek taxa totals may be explained by the enrichment effect from the sewage and fertilizer input to this stream. This enrichment effect was evidenced in the abiotic and biotic indicators and may have actually increased the taxonomic richness. However, further increases of the anthropogenic impacts are likely to reduce the taxonomic richness within the stream community.

The seven Webb Creek tributaries range in mean width from 0.5 to 2.5 m (1 to 8 ft) with maximum stream depth ranging from 20 to 70 cm (0.5 to 2 ft; Table 20). Six of the seven tributaries flow through heavily forested areas with canopy coverage typically from 80 to 90%. Warden Branch (site 10), however, had considerably less canopy with 25 to 50% coverage. Stream bed substrates—in five of the seven streams—were composed mainly of gravel (40 to 85%); cobbles and boulders were generally the next most common substrate (15 to 35%). Bedrock (40 to 50%), however, was the dominant substrate for Warden Branch and Mill Dam Branch (sites 11 and 10, respectively; Appendix D).

All seven Webb tributaries had evidence of stream impacts, in particular stream siltation. These Webb tributaries flow down Webb Mountain, often along very steep gradients. The Butler Branch (site 12) stream had the most siltation, apparently from nearby residential construction and input from the adjacent dirt road. All Webb tributaries, except Warden Branch and Butler Branch (sites 11 and 12), had high levels of phosphate in their waters (Table 8). On the basis of the abiotic indicators of stream condition, however, only two of the seven tributaries were designated as affected because those two streams, Webb Creek Tributaries 2 and 1 (sites 9 and 27, respectively) had very high levels of phosphate in addition to the stream siltation.

Webb Creek tributaries varied widely on the basis of their taxonomic richness. Three of these tributaries had the lowest values for total benthic and EPT taxa for several different reasons. Webb Creek Tributary 2 (site 27), an anthropogenically affected site, reflects these impacts; this site had the lowest number of EPT taxa (28) and the lowest percentage of EPT taxa compared with total benthic taxa (39%) for those streams containing water throughout the year. Webb Creek Tributary 1 (site 31), the smallest stream in Section 8B, was the only intermittent stream in this survey; it was dry during the fall and consequently yielded the lowest total benthic taxa (27), lowest EPT taxa (12), and no fish (Table 10). Sheep Pen Branch (site 28) had the lowest number of total benthic taxa (68) for permanent streams. While there was no evidence of human-induced impact, the absence of moss on rocks at this site indicates that the site had been recently scoured before the spring 1994 survey, although the stream was heavily shaded (75%) (Appendix D). For the permanent Webb tributaries, the total number of benthic taxa ranged from 68 to 106, while the total number of EPT taxa ranged from 28 to 54. The orthoclad taxa ranged from 3 to 11, while the chironomid taxa varied from 4 to 18. None of these tributaries had any *Cricotopus* or *Orthocladius* taxa. All these tributaries had many taxa found only in cool, clean water; and, for their size, the taxa richness and specimen abundance indicated fairly good (Mill Dam Branch, site 10) to very healthy assemblages of stream benthic biota (Warden Branch, site 11; Appendix D).

Where fish were present in the Webb Creek tributaries, blacknose dace populations dominated; this involved five of the seven tributaries. One stream collection yielded four fish taxa (Webb Creek Tributary 1, site 27), another stream yielded two fish taxa, while three other streams each had only blacknose dace (see Table 10 and Appendix D).

Both Mill Dam Branch (site 10) and Butler Branch (site 12) can be compared with the Caney Creek station (CC-3) from the 1991 survey of Section 8D. They are similar in size, substrate, and fish taxa, although site 12 is slightly more silty. Caney Creek had 86 total benthic taxa with 44 EPT taxa (ORNL 1992). Butler Branch has the same number of total benthic taxa with 39 EPT taxa, while Mill Dam Branch (near a swimming pool and golf course) had higher total benthic and EPT taxa (100 and 51, respectively). The Caney Creek survey found 15 chironomid taxa, 8 being orthoclads with no *Cricotopus* or *Orthocladius* specimens. Butler Branch and Mill Dam Branch were very similar with 14 and 15 chironomid taxa, respectively, and 8 and 9 orthoclad taxa, respectively. Neither had any *Cricotopus* or *Orthocladius* specimens.

While Matthew Creek (site 13) and Matthew Creek Tributary 1 (site 13.5) are similar in maximum stream depth [each 40 cm (6 in.)], Matthew Creek and Matthew Creek Tributary 2 (site 15) have similar stream widths, 1.5 to 1.8 m (5 to 6 ft). Matthew Creek proper and Tributary 1 are higher up on Webb Mountain and consequently more forested (80 to 90% forested canopy). Tributary 2, farther down Webb Mountain, is located in a more developed area with an estimated 25 to 50% canopy (Appendix D). Cobble-sized slabrock constitutes most (40 to 65%) of the two Matthew Creek tributaries substrate, and gravel comprises the rest. The Matthew Creek stream bed is nearly equal gravel and cobbles (40 to 45% each). Also noteworthy is a 85-m subsurface channel for Matthew Creek Tributary 1 that resurfaces just 15 m before its confluence with Matthew Creek (Appendix D).

Matthew Creek Tributary 2 (site 15) is considered as affected anthropogenically on the basis of heavy stream bed siltation and relatively high phosphate levels. The other two sites were relatively pristine, with no evidence of human-induced impact on stream condition. The biotic stream survey results indicate that all three of these sites have high taxonomic richness ranging from 109 total benthic taxa in Matthew Creek to 87 taxa at site 15 and 73 taxa at the narrowest stream, site 13.5. All three sites had many cool-, clean-water taxa (see Wojtowicz discussion in Appendix D). The percentage of EPT taxa ranged from 46 to 55%. Most chironomid taxa, however, were orthoclad taxa, 67% at sites 13 and 13.5 and 75% (second highest value recorded at Section 8B sites) at site 15. Even so, only one of these sites, site 13, had any *Cricotopus* or *Orthocladius* specimens (one taxa with 3 specimens), indicating that there was no significant representation of individual taxa indicative of pollution problems (Table 11; Appendix D).

The Matthew Creek Tributary 2 (site 15) can also be appropriately compared with the Caney Creek station (CC-3) of the 1991 Section 8D survey. With 48 EPT taxa and 87 total benthic taxa, site 15 is strikingly similar to the Caney Creek station (44 EPT and 86 total taxa). The orthoclad and chironomid taxa (8 and 15 for CC-3) are also very comparable to Matthew Creek (9 and 12 at site 15), with no *Cricotopus* or *Orthocladius* at either site.

While site 13.5 had no fish taxa collected in the fall survey, the other two streams had four and two taxa of fish (sites 13 and 15, respectively; Table 10). Both streams had mainly blacknose dace and mottled sculpin populations (*Cottus bairdi*; Appendix D).

Laurel Branch site 32 is a medium-sized stream in the Section 8B survey with a mean stream width of 4 m (13 ft), 80 cm (2.5 ft) maximum depth, and an estimated 60% canopy coverage. The stream bed consists primarily of cobbles and boulders with 15% gravel, 10% bedrock, and the remainder silt and sand. This stream appeared to be pristine with no stream bank or water quality impairment. The biota consisted of 51 EPT taxa comprising 54% of the 94 benthic invertebrate taxa total. Nineteen total chironomid taxa were collected, including 12 orthoclad taxa. Blacknose dace were the most common of the four fish species collected, and rainbow trout (*Oncorhynchus mykiss*) were second most common. Only single specimens of longnose dace (*Rhinichthys cataractae*) and stonerollers were found in Laurel Branch.

3.3.2.3 Rocky Flats Drainages

In the Rocky Flats valley between Webb Mountain and Big Ridge Mountain, four streams were sampled in conjunction with the Section 8B ROW. Dunn Creek is the largest of these streams and the direct recipient of waters from the other three streams, as well as the Matthew Creek waters discussed in the preceding paragraphs (Fig. 20). Dunn Creek eventually flows into the Little Pigeon River farther to the north and west. This valley remains heavily forested with deciduous trees near the ROW, although there are strips of residential development near some portions of these streams. The canopy for Dunn Creek (sites 16 and 17) and the Dunn Creek West Branch (site 14) reflects the undisturbed surroundings for these two streams at 100% and 70% coverage. The canopy coverage for the other two streams—Ogle Spring Branch (sites 18 and 19) and Carson Branch (sites 20 and 21) ranges from 80% to 30%. While the stream bed substrates for the Dunn Creek and Ogle Spring Branch sites primarily consisted of boulders and cobbles (85 to 50%), Carson Branch substrate was more evenly divided between boulders and cobbles (30 to 35%), gravel (30 to 35%), and silt and sand (30 to 40%). The Dunn Creek West Branch substrate primarily consisted of cobble (65%), some gravel (20%), and bedrock (10%) (Fig. 20, Appendix D).

Dunn Creek is the fifth largest stream in the Section 8B stream survey with a mean stream width of 6 m (20 ft) and maximum stream depth of 60 to 75 cm (2 ft). The other streams all had a mean stream width of 1.5 m (5 ft), except the lower Ogle Spring Branch (site 19) with a maximum stream depth ranging from 20 to 50 cm (1 to 1.5 ft).

Both Ogle Spring Branch sites (18 and 19) were designated as affected sites (Table 8 and Sect. 3.2.1). Both sites had four separate abiotic indications of human-induced stream impact—siltation (heavy at site 18), high phosphate levels, very high nitrate levels, and high chloride levels (very high for site 18). Although the other streams are designated as pristine on this basis, very heavy siltation was noted in Carson Branch at site 21 where new construction and a nearby dirt road were noted (Appendix D).

These benthic invertebrate assemblages exhibited healthy, rich taxa with many cool-, clean-water species. The total benthic invertebrate taxa ranged from 135 taxa at Dunn Creek site 16—reflecting very pristine, virtually unimpacted stream conditions—to 87 in site 18, one of the affected sites. The chironomid taxa were somewhat less taxonomically rich with 12, 13, and 14 taxa at Dunn Creek West Branch (site 14), Ogle Branch (site 18), and Carson Branch (site 21), respectively. The other more taxonomically-enriched sites ranged from 20 to 37 taxa for the chironomids. The percent of orthoclad taxa in the chironomid taxa ranged from 82% at site 14 (the highest value for all Section 8B) to 38% at site 18 (the lowest value for all Section 8B) (Table 11). While neither site 14 or 18 or the Carson Branch sites had any *Cricotopus* or *Orthocladius* or other taxa indicative of pollution problems, the two Dunn Creek sites (16 and 17) did have two and three *Cricotopus* or *Orthocladius* species from 20 and 13 specimens, respectively (Appendix D).

The number of fish species varied from seven and nine in Dunn Creek down to no fish captured at Dunn Creek West Branch (site 14). Blacknose dace was the most commonly captured fish at sites with fish, comprising 33 to 38% of the captured fish in the Dunn Creek sites, 96 to 97% in the Ogle Spring Branch sites, and 98 to 100% in the Carson Branch sites. Other fish identified in Dunn Creek included mottled sculpin at 33 to 34% and stonerollers at 12 to 13% of the fish community (Appendix D).

Both Dunn Creek sites (16 and 17) can be compared to other similar streams in this region. Dunn Creek site 16, virtually unimpacted, compared very favorably with two other stream sites in Cades Cove in the GSMNP. These GSMNP sites, also considered pristine, are the upper Mill Creek site at Parsons Branch Road and Anthony Creek just above the horse camp near the Cades Cove campground. The winter 1994 survey of the two Cades Cove sites collected 41 and 45 EPT taxa out of 65 and 62 total taxa, as compared with 47 EPT and 72 total taxa for Dunn Creek (site 16) (comparison exclusive of chironomid taxa; see Etnier discussion in Appendix D). Site 16 taxonomic counts were slightly higher than at these pristine sites. Another comparison can be made between Dunn Creek site 17 and the Section 8D Wears Cove station MC-5, both with similar size stream size and fish community structure. Station MC-5 contained 112 total benthic taxa and 52 EPT taxa; 12 of 23 chironomid taxa were orthoclads, including two *Cricotopus* or *Orthocladius* species. The analogous data for site 17 are 113 total benthic taxa with 58 EPT taxa; 15 of 23 chironomid taxa were orthoclads, including two *Cricotopus* or *Orthocladius* species. Both of these sites are interpreted as being rich, healthy, and very slightly impacted by silt.

3.3.2.4 Big Ridge/Cosby Creek Drainages

Four streams were sampled at the eastern-most end of the Section 8B ROW. The largest of these streams, and the second largest stream in the Section 8B stream survey, is Cosby Creek. This creek is also the recipient of the waters from the three other streams—Indian Camp Creek, Sandy Hollow Creek, and Chavis Creek (Fig. 20). Cosby Creek eventually flows into the Pigeon River farther to the north and east. This area is a mixture of deciduous forests interlaced with developed strips of land. Trees along the stream embankment comprised the canopy for Cosby Creek, which varied from 50 to 5%. The canopy coverage for the other smaller streams varied from 30 to 100% coverage depending on whether the stream was adjacent to a bridge, field, or forest. The stream bed substrate for larger streams consisted primarily of cobbles and boulders (Cosby Creek—85%;

Indian Camp Creek—70%), while the smaller streams have primarily gravel (Chavis Creek—70%; Sandy Hollow Creek—60%; Appendix D).

Cosby Creek, the second largest stream in the survey, varied in width from 12 to 18 m (40 to 60 ft) with a maximum depth of 120 cm (4 ft) at site 25. Indian Camp Creek, also a rather large stream, has a width that ranges from 6 to 9 m (20 to 30 ft) with a maximum depth of 60 cm (2 ft). Both Chavis Creek and Sandy Hollow Creek are much smaller streams [1.5 to 2 m (5 to 7 ft)] with maximum depths of 45 and 30 cm (1.5 to 1 ft), respectively (Table 10).

In this group of streams, only Sandy Hollow Creek (site 24) was considered an affected site on the basis of abiotic indicators of stream condition (Table 8 and Sect. 3.2.1). This site had considerable stream bank instability, stream bed siltation, and relatively high phosphate levels. While Chavis Creek had some stream bed siltation and relatively high levels of phosphate, neither Indian Camp Creek nor Cosby Creek sites exceeded any of the six different abiotic criteria; they were therefore considered unaffected sites.

On the basis of biotic indicators of stream condition, all of these streams appeared to exhibit some evidence of human impact, although all sites also had healthy, taxonomically-rich assemblages of benthic invertebrates (i.e., ranging from a total benthic invertebrate taxa of 90 to 163 with 43 to 53% EPT taxa) (Tables 9, 10, and 11). A hint of organic enrichment was noted at the Cosby Creek sites 25 and 26 by the presence of five different species of *Cricotopus* or *Orthocladius* species. The Cosby Creek sites had the highest number (19 and 21) of stonefly taxa—generally considered the most stress-sensitive order—for any of the Section 8B sites. The Cosby Creek sites also had the largest number of infrequently collected chironomids, five different species, of any of the Section 8B sites (Appendix D; see summary below). A moderate amount of organic enrichment was evidenced in the benthic invertebrate data at Chavis Creek. Half of the chironomid taxa belonged to the orthoclad group, including three species of *Cricotopus* or *Orthocladius*; one species, *Cricotopus bicinctus,* contributed 20 of the 65 midge specimens in the fall sample. The very stress-tolerant caddisfly, *Hydropsyche betteni/depravata,* was also present.

In Indian Creek, the diversity and abundance of biota were impoverished, indicating some disturbance greater than the spring 1994 flooding. Only 23 EPT taxa and a total of 59 benthic invertebrate taxa were collected, which is 25 to 50% lower than would be expected. In contrast, Dunn Creek yielded 54 EPT taxa and 100 benthic invertebrate taxa in the spring survey. The Indian Creek fall survey (34 EPT and 67 total benthic taxa) showed somewhat less disparity with the Dunn Creek survey results (47 EPT taxa and 97 total benthic taxa), perhaps indicating a recovery in progress. Sandy Hollow Creek, affected on the basis of abiotic indicators, exhibited some evidence of eutrophication by the presence of three taxa of *Cricotopus* and the stress-tolerant caddisfly, *Hydropsyche betteni/depravata.*

The number of fish species varied from 18 and 13 collected at the Cosby Creek sites, to a total of 6 and 7 captured in the other three smaller survey streams. Stonerollers were the most commonly captured fish in Cosby Creek comprising 40 and 44% of the captured fish. Saffron shiners, the second most commonly captured fish, comprised 18 and 38%, and mottled sculpins contributed 11 and 15% of the fish identified. In Chavis Creek (site 22) and Sandy Hollow Creek (site 24), the dominant fish population was the blacknose dace, comprising 82% in both of these streams. Mottled sculpins (48%) and longnose daces (32%) accounted for 80% of the fish surveyed in

Indian Camp Creek (site 23; see Appendix D). The seven fish taxa collected in the survey at Indian Camp Creek were fewer than would be expected for a stream of this size, 6 to 9 m (20 to 30 ft), in this region in which the water quality indicates a pristine condition.

The Cosby Creek sites (25 and 26) were similar in EPT taxa and total benthic taxa richness to Webb Creek (site 8) in the Webb Mountain/Webb Creek Drainages. These sites can also be compared to several Abrams Creek watershed sites in the GSMNP: Mill Creek just above Abrams Creek, Abrams Creek just below the confluence of Mill Creek in Cades Cove, and lower Abrams Creek below the Abrams Creek campground. Total benthic invertebrate taxa (exclusive of chironomids) and EPT taxa for these Abrams Creek sites (from a May 1994 survey) were 79 and 53, 98 and 63, 106 and 59, respectively.

3.3.2.5 Summary

Evaluation of the Section 8B benthic invertebrate surveys yielded several general findings. First, the Section 8B study streams in 1994 had a taxonomically rich benthic fauna ranking among the richest in the Appalachian region (Appendix D, Part 1 and Part 3). For the 31 Section 8B stream survey sites, the numbers of benthic invertebrate taxa ranged from 68 to 174 in streams ranging in width from 1 to 18 m (3 to 59 ft; Fig. 39). By way of comparison, the Section 8D benthic macroinvertebrate survey, which used the same methods and included 23 stream sites with stream widths ranging from 1.2 to 7.6 m (4 to 25 ft), had taxa values ranging from 54 to 112. If we compare only the Section 8B study streams that range in width from 1.0 to 6 m (3 to 20 ft), their taxa values range from 68 to 135, slightly higher than the Section 8D survey results. Another benthic survey at Abrams Creek in the GSMNP reports maximum taxa value for a single sampling date of 106 (exclusive of chironomid data). This value is comparable to the Little Pigeon River Section 8B sites for taxa richness of 105 for a single sampling date (also exclusive of chironomid data).

Second, this level of taxonomic richness extended through both the EPT and chironomid groups, indicating these streams, as a group, are relatively unaffected by human-induced impacts (Fig. 40). Because these streams are relatively unimpacted and have taxonomically rich assemblages of macroinvertebrates, use of the EPT to total benthic taxa ratios and the orthoclad to total chironomid taxa ratios was not definitive in differentiating sites among the Section 8B survey streams (Fig. 40). Rather, the presence of specific genera and species considered pollution-indicating taxa (e.g., *Cricotopus, Orthocladius, Microtendipes, Hydropsyche betteni/depravata,* and *Stenacron interpunctatum*), especially if numerous specimens were found, was more useful in defining the status of these streams.

Third, the number of fish and benthic invertebrate taxa increased with increasing stream size up to the largest stream surveyed—Little Pigeon River [mean width 18 m (59 ft); Fig. 39]. This site had 25 fish taxa and 174 different benthic macroinvertebrate taxa when the spring and fall survey data were combined. Cosby Creek and Webb Creek, the two next largest streams in this survey [mean stream width around 12 m (40 ft)], had 15 to 18 fish taxa and 137 to 163 different benthic macroinvertebrate taxa, respectively (Table 10).

Stream conditions. On the basis of abiotic indicators of stream condition, 12 sites were defined as affected by either physical or chemical human-induced impacts (Fig. 41). The chemical indicators

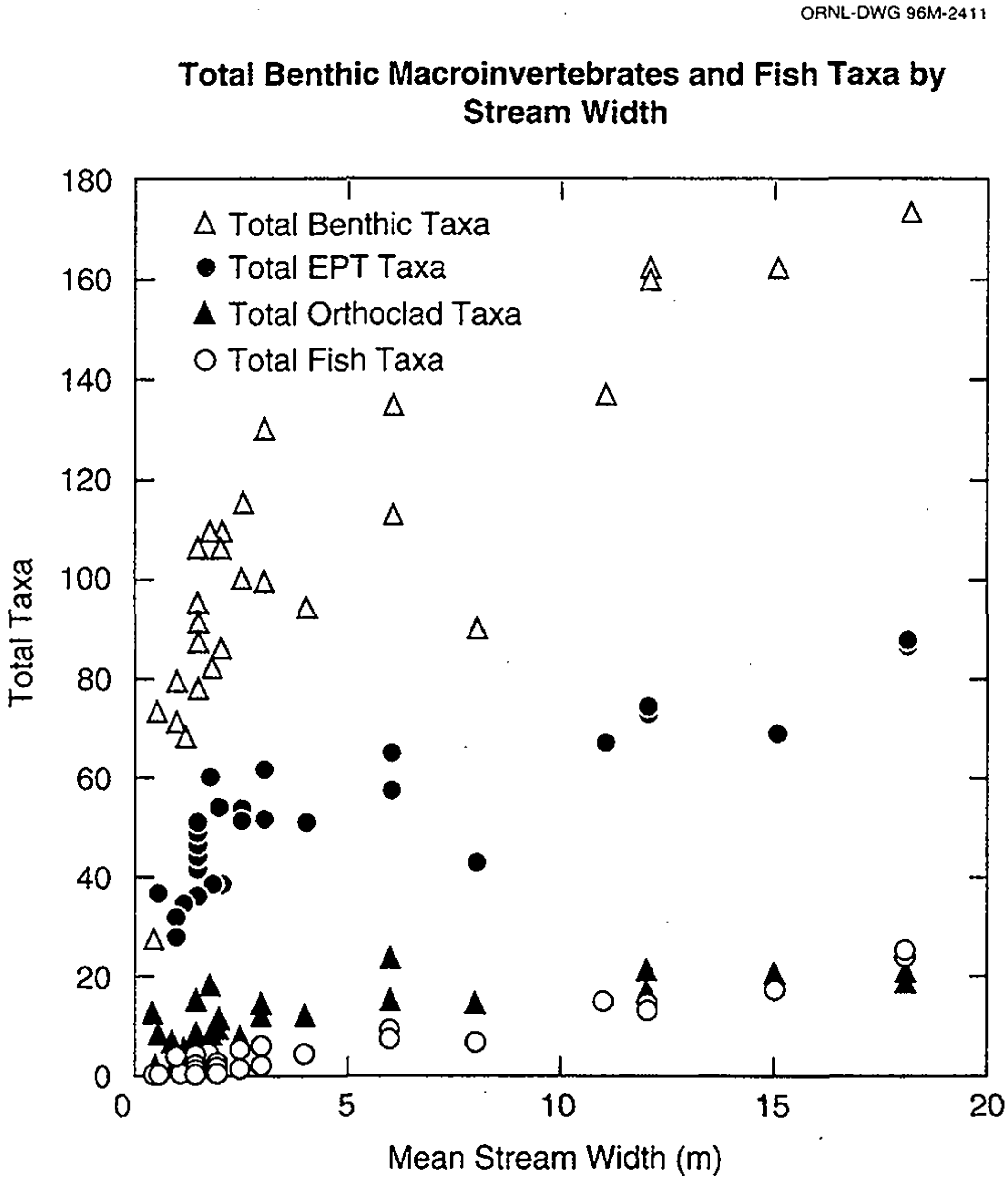

Fig. 39. Total benthic invertebrates, EPTs, orthoclads, and fish taxa versus mean stream width at the stream biological survey sites for Section 8B of the Foothills Parkway.

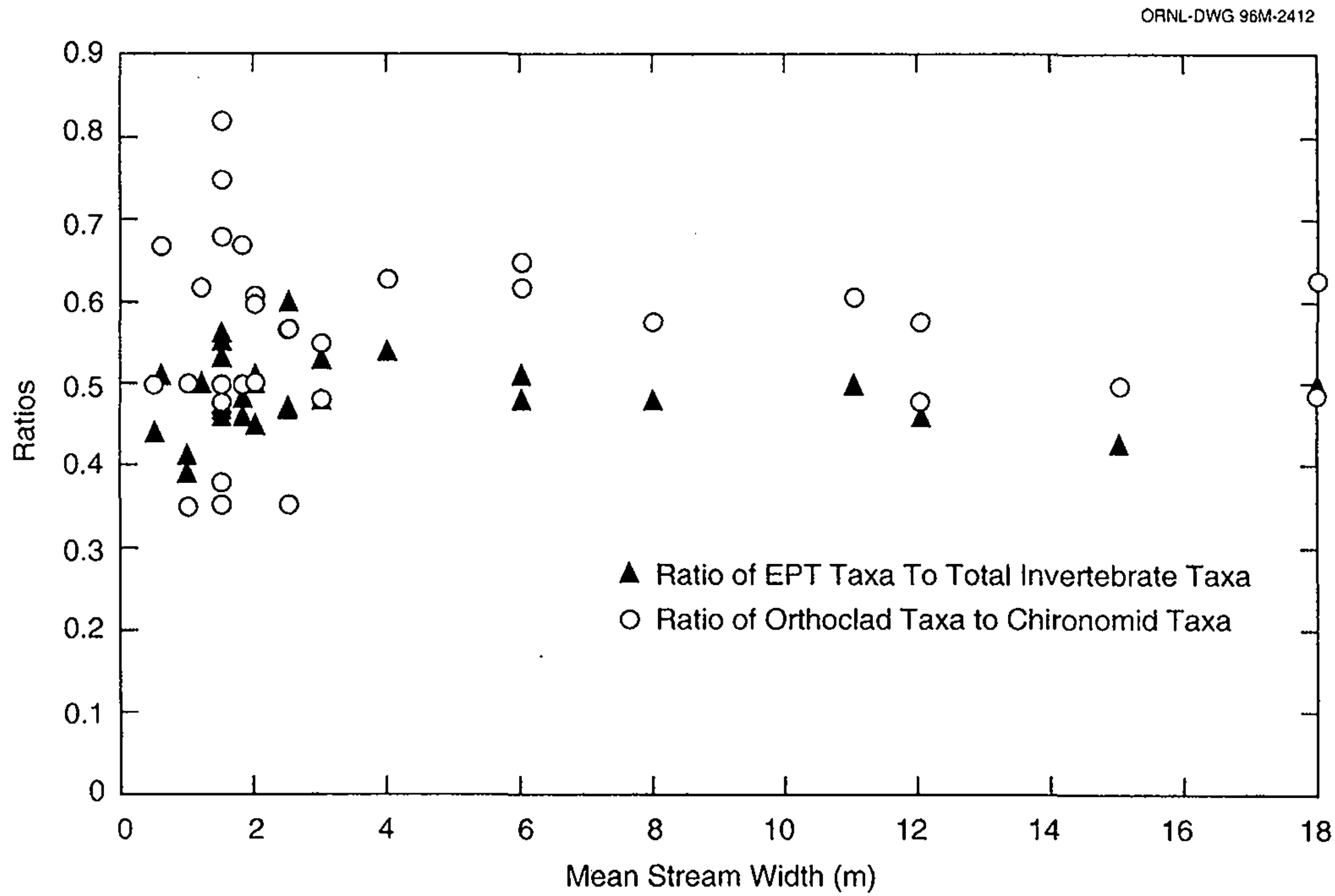

Fig. 40. Benthic invertebrate ratios of EPT taxa to total taxa and orthoclad taxa to chironomid taxa versus mean stream width at the stream biological survey sites for Section 8B of the Foothills Parkway.

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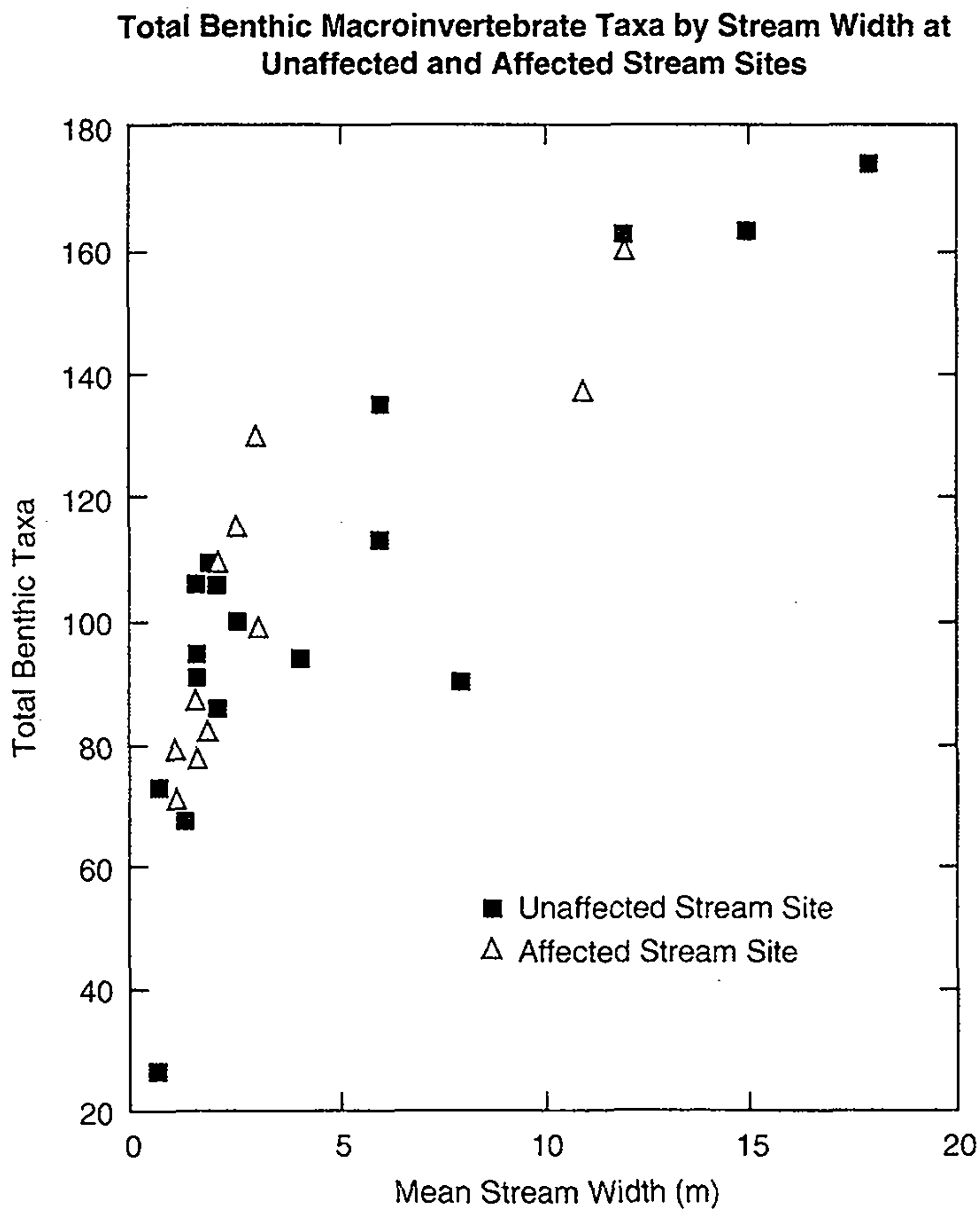

Fig. 41. Total benthic macroinvertebrates taxa by stream width at unaffected and affected stream sites in the stream biological survey sites at Section 8B of the Foothills Parkway.

are relative because the overall water quality in this survey is good (see Sect. 3.2). The most useful differentiating biotic indicators of stream condition were the pollution-indicating genera and species. On this basis, the survey sampling at all five of the widest streams [18 to 6 m (59 to 20 ft)] found some species specifically associated with organic enrichment (Fig. 42). Cosby Creek and Webb Creek had the highest abundance of these pollution-indicator species. There were also five smaller streams [4 to 1.5 m (13 to 5 ft)] that had pollution-indicating species. These streams were most notably Copeland Creek and the smaller Big Ridge/Cosby Creek Drainage streams (see Sects. 3.3.2.1 and 3.3.2.4 for more detail).

Listed species. While no federal or state listed endangered or threatened fish or macroinvertebrate species were found at any of the sites, there was one former federal candidate species and one state species of special concern. The Allegheny snaketail dragonfly (*Ophiogomphus incurvatus allegheniensis*), the formerly C2 federal candidate species for listing under the Endangered Species Act, was found in six of the stream survey sites. *Percina aurantiaca*, the tangerine darter, was found at two stream survey sites. It is a Tennessee state special concern species (Starnes and Etnier 1980) and deemed in need of management (Hatcher 1994).

Newly identified species. There are several other noteworthy taxonomic findings (see Appendix D). Some specimens are tentatively identified as newly collected mayfly (Ephemeroptera) species in the family Heptageniidae (collected at two sites) and an undescribed species in the caddisfly genera *Ceratopsyche* and *Mystacides* (collected at ten sites). There are also several other new distributional records for the state of Tennessee in the caddisfly order (Trichoptera) and stonefly order (Plecoptera) at multiple stream survey sites. There are also five infrequently collected chironomids that were identified in eight different streams in the Section 8B stream survey, with all five of these chironomids occurring together at one of the stream sites.

3.4 TERRESTRIAL RESOURCES

Except for areas near the Little Pigeon River, Rocky Flats, and Cosby Creek, the 22.7 km (14.2 miles) ROW in Section 8B is primarily on south-east facing slopes of Webb Mountain and Big Ridge. Elevations range from about 400 m (1300 ft) in the lowlands to 950 m (3100 ft) at the highest point of Webb Mountain. The terrain is generally rugged, with very steep slopes on Webb Mountain and steeply undulating terrain on Big Ridge.

Field surveys for vegetation and wildlife were conducted to determine the presence of federal and state listed, federal candidate, park-rare, and non-native (exotic) species; sensitive habitats (including biologically significant wetlands); and general characterization of biota on the ROW (Somers 1989; 58 *Fed. Regist.* 51143–89; 59 *Fed. Regist.* 49848–59; 59 *Fed. Regist.* 58981–9028; Rock and Langdon 1991). The field surveys were also done for vascular plants, small mammals, salamanders, and reptiles; birds; and bryophytes as identified in the Section 8B Study Plan. A summary of results of these surveys and a general description of vegetation and wildlife are presented in this report. In general, biota along the Section 8B section are similar to those in the GSMNP below about 920 m (3000 ft).

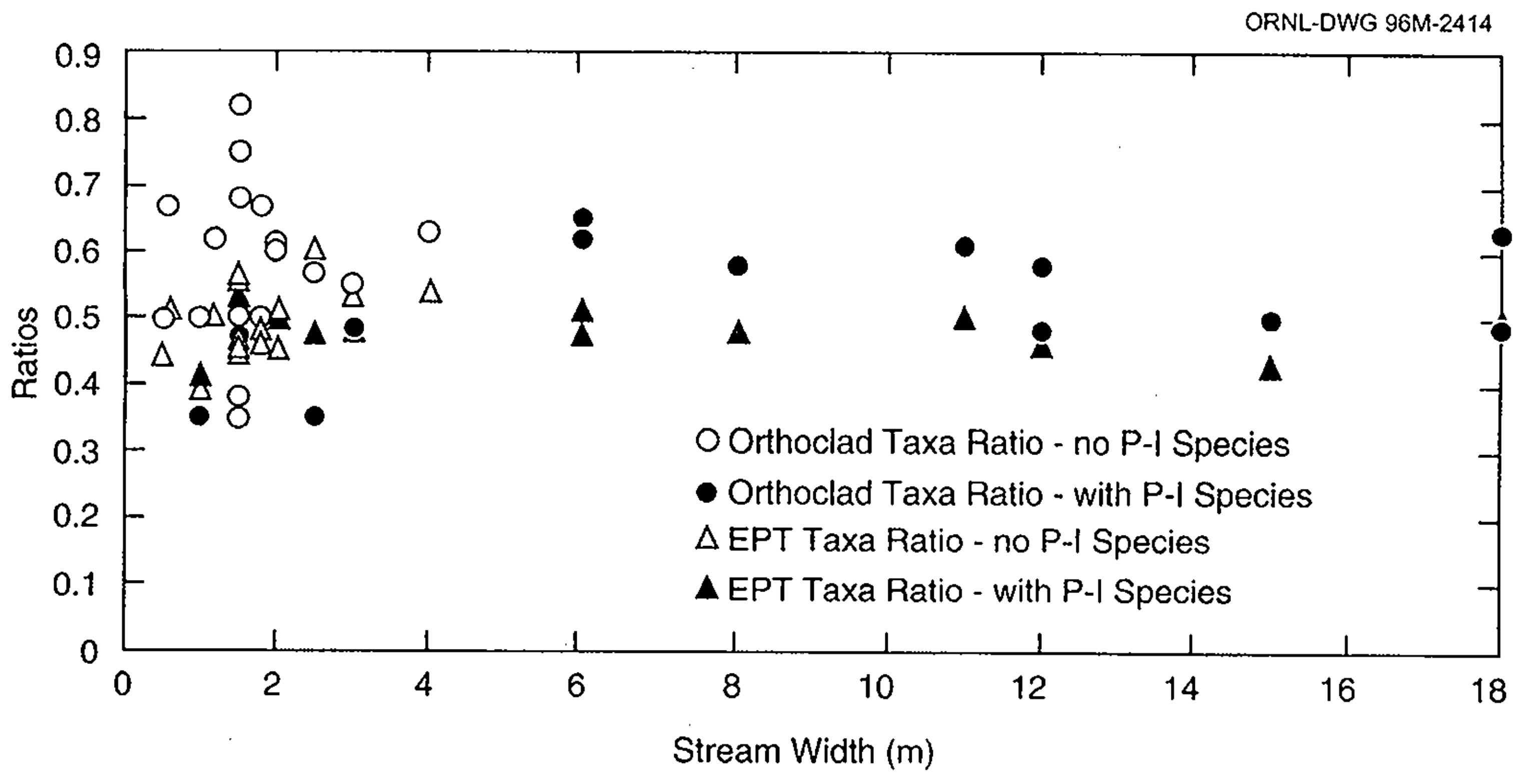

Fig. 42. Benthic invertebrate ratios versus mean stream width at sites with and without more than one pollution indicating species in the stream biological survey sites for Section 8B of the Foothills Parkway.

3.4.1 Vegetation

Distribution of plant communities on the ROW is complex as a result of interactions of slope, elevation, soil types, and a varied history of land use and fire. The general descriptions that follow are based on past vegetation surveys and observations during the current field surveys (see Appendix B, Appendix E, and Appendix F).

In an earlier survey (Baron and Mathews 1977), 26 vegetation plots were sampled along Sections 8B, 8C, 8D, and 8E over a distance of 65 km (40.4 miles). The vegetation map prepared for the 1977 environmental analysis divided Section 8B into two general vegetation types: (1) open field to successional around Pittman Center and Cosby and (2) dry pine/oak/maple through the Webb Mountain and Big Ridge areas. In the 1977 survey, much of the ROW west of Webb Mountain was characterized as old field or successional. These areas are now primarily young, dry, pine-oak forest.

Vegetation along the ROW is generally similar to the vegetation in the rest of GSMNP below 920 m (3000 ft) elevation (Whittaker 1956; Harmon, Bratton, and White 1983; MacKenzie 1991). None of the ROW is old-growth forest. Most of the area has been logged or burned, and some areas were farmed (Baron and Mathews 1977). The ROW is currently mostly forested (Fig. 43, Appendix E), is crossed by few roads, and does not contain other types of clearings. All-terrain vehicle use is common in some areas and evidence of previous disturbance is common along the ROW. Forest populations range in age from young saplings to mature trees. In this study, eight vegetation types were identified as useful for delineating habitats of plant and animal species of concern (Table 12).

Most of the vegetation along the ROW can be classified as either dry pine, mixed pine/hardwood, or more mesic (rich and moist) areas of mixed hemlock and hardwoods. Because of past disturbance, some parts of the ROW are predominantly young forest, usually with abundant pine. These areas were apparently cleared in the past and used for crops or pasture. Pines on the ROW are either Table Mountain and pitch pine (*Pinus pungens* and *P. rigida*), especially on Webb Mountain, or Virginia pine (*Pinus virginiana*), which is especially common on the ROW southwest of Webb Mountain in old field areas. The pine or pine/hardwood vegetation type ranges from nearly pure pine stands to mostly hardwood with some pine and is comparable to the xeric oak, pine-oak, and pine vegetation types of the GSMNP (MacKenzie 1991). Common hardwoods found in xeric oak and oak-pine vegetation types include chestnut oak (*Q. prinus*), scarlet oak (*Q. coccinea*), sourwood (*Oxydendron arboreum*), dogwood (*Cornus florida*), and red maple (*Acer rubrum*).

Mesic areas of hardwoods and hemlock on the ROW fall into three types: (1) sheltered, rich coves; (2) sheltered slopes and ravines; (3) mesic upper slopes. The first two types have many overstory species in common: red oak (*Quercus rubra*), basswood (*Tilia heterophylla*), tulip poplar (*Liriodendron tulipifera*), buckeye (*Aesculus octandra*), beech (*Fagus grandifolia*), and black cherry (*Prunus serotina*) are usually present; sweet birch *(Betla lenta)* is also present. Sheltered slopes and ravines often have hemlock (*Tsuga canadensis*) and rhododendron (*Rhododendron maximum*) along stream drainages. Mesic upper slope forests are of two types: (1) mixed hardwood or (2) mixed hemlock, white pine (*Pinus strobus*), and hardwoods. Hardwoods include several oak species, red maple, tulip poplar, and several other less abundant species. Herbaceous

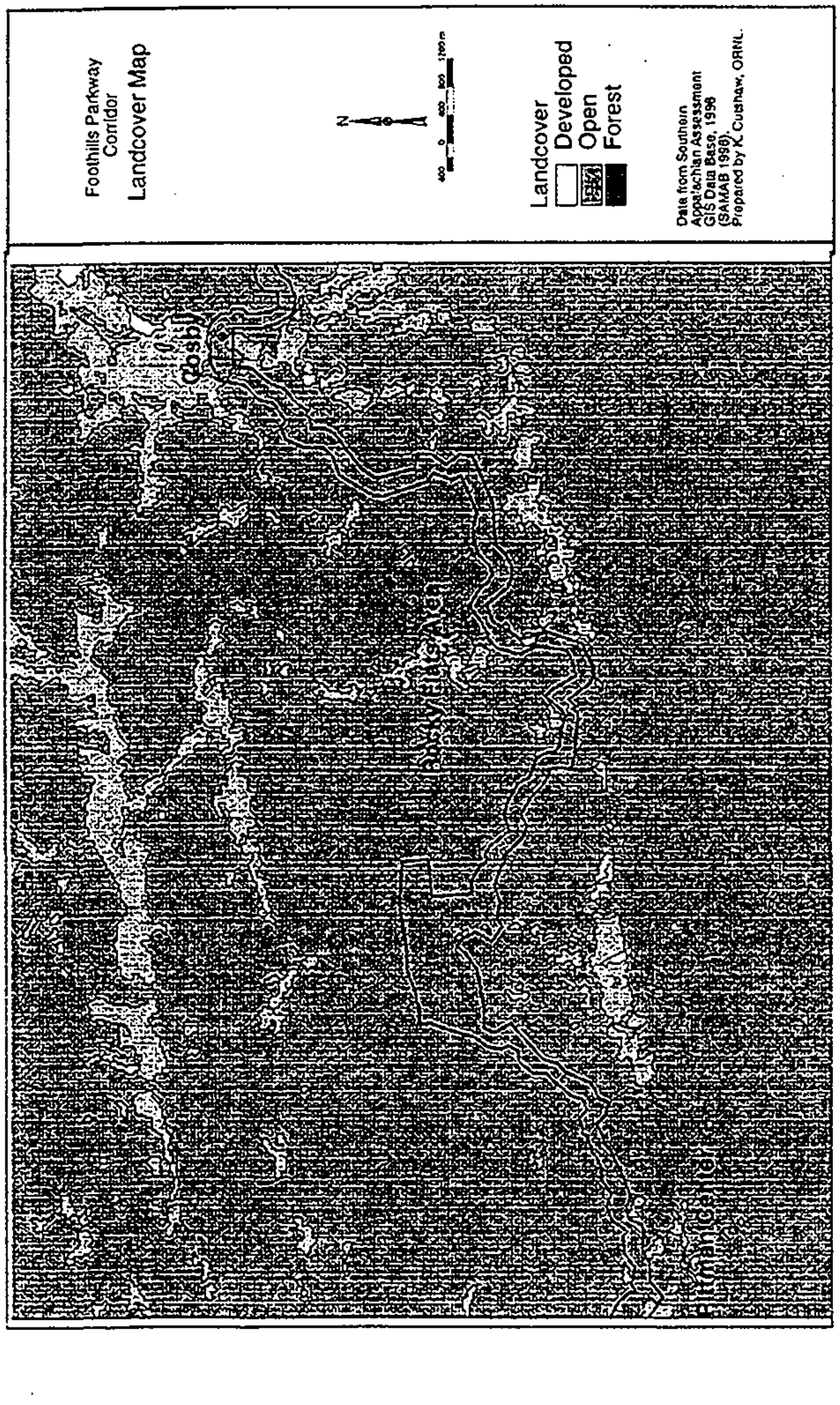

Fig. 43. Landcover in the approximately 130 mi^2 (335 km^2) region surrounding the ROW.

Table 12. Important vegetation types for delineating habitats of plant and animal species of concern along Section 8B

Forest	
	Young forest in old fields—usually with abundant pine
	Pine or oak-pine
	Mesic mixed hardwoods
	Mesic mixed hemlock, white pine, and hardwoods on uplands
	Sheltered upland hardwoods with hemlock along stream drainages
	Bottomland hardwoods
Other	
	Wetlands
	Open areas

vegetation is often more variable than overstory species. Mesic hardwoods on the ROW are comparable to the mesic oak, mixed mesic, and cove hardwoods (MacKenzie 1991) or northern hardwoods, cove hardwoods, hemlock hardwoods, and oaks (Eager 1984) of the GSMNP. Pines are mixed with tulip poplar in some old field areas; these areas are comparable to the tulip poplar type of GSMNP (Eager 1984; MacKenzie 1991).

Extensive floodplain vegetation is limited to two areas of the ROW. These areas contain forests composed of many bottomland tree species including sycamore (*Platanus occidentalis*), box elder *(Acer negundo)*, red maple, ironwood (*Carpinus caroliniana*), tulip poplar, hemlock, and many herbs and shrubs typical of disturbed floodplain areas. Giant cane (*Arundinaria gigantea*), old field vegetation, including dense stands of native blackberry *(Rubus* sp.) mowed powerline ROW, and some pasture for cattle are also in these areas.

The division of the ROW into segments is the same as that used in Sect. 3.1.4 and shown in Fig. 5.

Segment 1—Little Pigeon River Terraces. Vegetation in the vicinity of the Little Pigeon River reflects disturbances due to flooding of the river and farming activities in the lower, more level slopes. Currently part of this area is in mixed, open floodplain forest, including a substantial grove of butternut, and some pasture land.

Segment 2—Webb Creek Ridge. Very young forest, with many Virginia pines, is common on this segment of the ROW, especially on more level slopes and ridge tops. Xeric mixed pine and pine-hardwood forest is found on steeper south-facing slopes. Some areas of dead pine and mountain laurel (*Kalmia latifolia*) are present on small exposed ridgetops. Approaching Webb Mountain, especially in the Sheep Pen Branch area, more mesic, mature hardwood forest is found on sheltered slopes and ravines. Some hemlock is also found in this area.

Segment 3—Webb Mountain. Mixed pine and pine-hardwood stands with Table Mountain and pitch pines are common on the steep, south-facing slopes of Webb Mountain. Most of the mature pines on Webb Mountain have been killed within the last few years by southern pine beetle outbreaks. Sheltered slopes and ravines with mesic hardwoods, hemlock, and rhododendron are also found in this area. An extensive stand of American chestnut (*Castanea dentata*) sprouts is on the crest of Webb Mountain near Jones Gap.

Segment 4—Matthew Branch Ridge. Most of the vegetation on this segment of the ROW is similar to that on the lower slopes of Webb Mountain and the older forests of Webb Creek Ridge. West of Blackgum Gap, the northern slopes include some areas of mesic hardwoods containing a few red spruce (*Picea rubens)* and striped maple (*Acer pennsylvanica*). On most of this segment, however, pines are the dominant forest species, especially east of Blackgum Gap. Dead and fallen trees are abundant. Understory vegetation is primarily mountain laurel, huckleberry (*Gaylussacia* sp.), or blueberry (*Vaccinium* sp.).

Segment 5—Rocky Flats. Vegetation in this segment of the ROW is highly diverse, ranging from open old fields and old field pine stands to wetlands, mesic forests, and coves. A maintained powerline ROW crosses the parkway ROW in this segment.

Segment 6—Big Ridge. Vegetation in this segment is similar to that in the Matthew Branch Ridge segment and older forests of Webb Creek Ridge, consisting of a mosaic of dry, mixed pine and pine-hardwood forest on steeper south-facing slopes and more mesic, mature hardwood forest, often with hemlock and sweet birch, on sheltered slopes and ravines. Unlike most of the Matthew Branch Ridge and Webb Creek Ridge vegetation, that on some uplands in this segment is a mixture of hemlock, white pine, and hardwoods (Appendix B).

Segment 7—Cosby Creek Terraces. Vegetation in this segment is highly diverse and has mostly been affected by previous human disturbance. Young forests in old field areas near the north end of the ROW are mostly tulip poplar and pine. Young dogwood and hemlock are also present. The forest is patchy and contains floodplain species typical of eastern Tennessee. Giant cane, old field vegetation, and mowed powerline ROW are also in this segment.

3.4.2 Wildlife

Wildlife on the ROW probably includes most animals common at middle to low elevations of the GSMNP (Linzey and Linzey 1971; Stupka 1963; Huheey and Stupka 1967). White-tailed deer (*Odocoileus virginianus*), red fox (*Vulpes fulva*), grey fox (*Urocyon cinereoargenteus*), raccoon (*Procyon lotor*), and bobcat (*Lynx rufus*) are among the larger animals likely to be present on the ROW. Black bears (*Ursus americanus*) could be present on the ROW, but no evidence of black bears was observed during surveys. No large den trees are present on the ROW. Bears may use parts of the ROW, but present use appears to be intermittent at most. Although the non-native European wild boar (*Sus scrofus*) is abundant in parts of GSMNP, no evidence of boars was seen during any of the field surveys. The coyote (*Canis latrans*) has expanded its range into east Tennessee, but none was seen during surveys of the ROW.

Small mammals commonly occurring in the area of the ROW include gray squirrel (*Sciurus carolinensis*), eastern chipmunk (*Tamias striatus*), striped skunk (*Mephitis mephitis*), woodchuck

(*Marmota monax*), opossum (*Didelphis marsupialis*), long-tailed weasel (*Mustela frenata*), and eastern cottontail (*Sylvilagus floridanus*). Spotted skunk (*Spilogale putorius*), though not common to the area, may also be present. Habitat along Cove Creek and other streams is suitable for mink (*Mustela vison*) and muskrat (*Ondatra zibethicus*). Four species of shrews; four species of mice, including jumping mice; a bog lemming; and two species of bats were captured on the ROW during the field surveys for small mammals (Appendix G).

Alsop (1991) lists 29 commonly occurring species of birds in hardwood forests at middle and low elevations of the GSMNP and another 21 that are common in fields and pastures. Most of these species probably use the ROW. Sixty-three species were seen on the ROW during the bird survey in 1995 (Table 13 and Appendix F). Species commonly seen in openings, oldfields, and forest edges include northern cardinal, indigo bunting, American crow, Carolina wren, song sparrow, rufous-sided towhee, eastern phoebe, and northern bobwhite. Commonly seen forest-dependent species include hooded warbler, black and white warbler, worm-eating warbler, black-throated green warbler, northern parula, ovenbird, red-eyed vireo, wood thrush, black-capped and Carolina chickadees, blue-gray gnatcatcher, yellow-billed cuckoo, tufted titmouse, and pileated woodpecker. Sixteen additional species were observed during two previous surveys in the vicinity: (1) the

Breeding Bird Survey census for the Compone route, stop number 10 (page 5) near Pittman Center in the Little Pigeon River Terraces segment of the ROW and (2) the 1988 Tennessee Ornithological Society Breeding Bird Atlas survey of the USGS Jones Cove map quadrangle (Nicholson 1994), which includes most of the ROW.

Common amphibians in the area include the American toad (*Bufo americanus*), several salamanders (*Desmognathus* sp., *Plethodon* sp., *Eurycea* sp.), and several species of frogs, such as the northern cricket frog (*Acris crepitans*), tree frogs (*Hyla* sp.), upland chorus frog (*Pseudacris triseriata*), green frog (*Rana clamitans*), and wood frog (*Rana sylvatica*). Amphibians found on the ROW include the southern leopard frog (*R. sphenocephalous*) (Appendix B), Appalachian seal salamander (*Desmognathus monticola monticola*), black-bellied salamander (*D. quadramaculatus*), Blue Ridge Mountain salamander (*D. ochrophaeus carolinensis*), slimy salamander (*Plethodon glutinous glutinous*), red-backed salamander (*P. cinereus cinereus*), black-chinned red salamander (*Pseudotriton ruber schenchi*), and long-tailed salamander (*Eurycea longicauda longicauda*) (Harvey 1995).

The eastern box turtle (*Terrapene carolina*) is common in the area. Other widespread reptiles are the northern fence lizard (*Sceloporus undulatus hyacinthinus*), skink (*Eumeces* sp.), water snake (*Nerodea sipedon*), eastern garter snake (*Thamnophis sirtalis*), northern ring-neck snake (*Diadophis punctatus*), eastern worm snake (*Carphophus amoenus*), black rat snake (*Elaphe obsoleta*), and northern copperhead (*Agkistrodon contortrix mokesson*).

3.4.3 Protected Rare Species

3.4.3.1 Vascular Plant Species

Federal (58 *Fed. Regist.* 51143–89; 59 *Fed. Regist.* 49848–59), state (Somers 1989), and GSMNP (Rock and Langdon 1991) lists of rare species were used to determine those which could potentially occur on the ROW. These provided an initial list of species with federal or state legal

Table 13. Birds of the right-of-way[a]

Scientific name	Common name	Habitat[b]				
		O	M	F	L	W
Butorides striatus	green-backed heron[c]					x
Anas platyrynchos	mallard					x
Cathartes aura	turkey vulture	x	x	x		
Buteo jamaicensis	red-tailed hawk	x	x			
Accipiter cooperi	Cooper's hawk		x	x		
Bonasa umbellus	ruffed grouse		x	x		
Colinus virginianus	northern bobwhite	x	x			
Charadrius vociferus	killdeer[c]	x				
Columba livia	rock dove	x				
Zenaida macroura	mourning dove	x				
Coccyzuz americanus	yellow-billed cuckoo		x	x		
Bubo virginianus	great horned owl	x	x	x		
Chaetura pelagica	chimney swift	x	x			
Archilochus colubris	ruby-throated hummingbird[c]	x	x			
Cercyle alcyon	belted kingfisher					x
Melanerpes carolinus	red-bellied woodpecker		x			
Picoides pubescens	downy woodpecker	x	x	x		
Picoides villosus	hairy woodpecker		x	x		
Colaptes auratus	northern flicker		x			
Dryocopus pileatus	pileated woodpecker		x	x	x	
Sayornis phoebe	eastern phoebe	x	x			
Contopus virens	eastern wood-pewee		x	x		
Empidonax virescens	Acadian flycatcher			x	x	x
Myiarchus crinitus	great crested flycatcher[c]			x	x	
Progne subis	purple martin[c]	x				
Stelgidopteryx serripennis	northern rough-winged swallow[c]	x	x			
Hirundo rustica	barn swallow	x	x			
Cyanocitta cristata	blue jay		x			
Corvus brachyrhynchos	American crow	x	x	x		

Table 13. Continued

Scientific name	Common name	Habitat[b]				
		O	M	F	L	W
Parus atricapillus	black-capped chickadee		x	x		
Parus carolinensis	Carolina chickadee		x	x		
Parus bicolor	tufted titmouse		x	x		
Sitta canadensis	red-breasted nuthatch		x	x		
Sitta carolinensis	white-breasted nuthatch		x	x		
Thryothorus ludovicianus	Carolina wren		x	x		
Polioptila caerulea	blue-gray gnatcatcher		x	x	x	
Sialia sialis	eastern bluebird[b]	x	x			
Hylocichla mustelina	wood thrush			x	x	
Turdus migratorius	American robin		x	x		
Dumetella carolinensis	gray catbird		x	x		
Mimus polyglottos	northern mockingbird	x	x			
Toxostoma rufum	brown thrasher		x			
Bombycilla cedrorum	cedar waxwing[c]	x	x			
Sturnus vulgaris	European starling[d]	x	x			
Vireo griseus	white-eyed vireo	x	x			
Vireo solitarius	solitary vireo		x	x		
Vireo flavifrons	yellow-throated vireo[c]					
Vireo olivaceous	red-eyed vireo			x	x	
Parula americana	northern parula			x	x	x
Dendroica pinus	pine warbler			x		
Dendroica petechia	yellow warbler	x	x			x
Dendroica caerulea	cerulean warbler[d]				x	
Dendroica virens	black-throated green warbler			x		
Dendroica magnolia	yellow-rumped warbler	x	x			
Dendroica fusca	blackburnian warbler			x		
Mniotilta varia	black and white warbler			x	x	
Helmitheros vermivorus	worm-eating warbler			x	x	
Seiurus motacilla	Louisiana waterthrush			x	x	x

Table 13. Continued

Scientific name	Common name	Habitat[b] O	M	F	L	W
Seiurus aurocapillus	ovenbird			x	x	
Opoprornis formosus	Kentucky warbler			x	x	
Geothylpis trichas	common yellowthroat	x				
Wilsonia citrina	hooded warbler			x	x	
Icteria virens	yellow-breasted chat	x				
Pheucticus ludovicianus	rose-breasted grosbeak		x	x	x	
Piranea rubra	summer tanager[c]			x	x	
Piranga olivacea	scarlet tanager[c]			x	x	
Cardinalis cardinalis	northern cardinal		x			
Guiraca caerulea	blue grosbeak[c]	x	x			
Passerina cyanea	indigo bunting	x	x			
Pipilo erythrophthalmus	rufous-sided towhee		x			
Spizella passerina	chipping sparrow[c]	x	x			
Zonotricia leucophrys	white-throated sparrow	x	x			
Melospiza melodia	song sparrow	x				
Agelaius phoeniceus	red-winged blackbird					x
Sturnella magna	eastern meadowlark	x				
Quiscalus quiscula	common grackle	x	x			
Molothrus ater	brown-headed cowbird	x	x			
Icterus spurius	orchard oriole[c]		x			
Carduelis tristis	American goldfinch	x	x			

[a]Unless otherwise noted, all birds were observed on the ROW during 1994–1995.

[b]O = openings, fields, and brushy areas; M = mixed forest and openings, edges, open woods; F = forest; L = optimal habitat is large blocks of contiguous forest; W = water (i.e., in or near streams and wetlands). Habitat information is from Scott 1987, Robbins et al. 1989, Alsop 1991, and Appendix F.

[c]Observed during the Breeding Bird Survey (BBS) census or the Tennessee Ornithological Society (TOS) Breeding Bird Atlas survey (Nicholson 1994). The BBS survey data used for this table were for 1989, 1990, 1992, and 1993 from the Compone (previously Walland) route. Data are from page 5 of the BBS route which includes locations near Pittman Center in the vicinity of the Little Pigeon River Terraces segment of the ROW. The TOS data used are for the 1988, 1990, and 1991 surveys of the USGS Jones Cove map quadrangle, which is in the vicinity of Webb Mountain.

[d]One individual was reported in the 1988 TOS Breeding Bird Atlas survey. None was reported otherwise.

status that were targeted for field surveys. Topographic maps and information from the Tennessee Department of Environment and Conservation data base were used to further refine the list of rare target species (Appendix E). In addition to state and federal candidate, proposed, and listed species, target species included those that might be placed on these lists (e.g., plants not previously recorded for Tennessee). Other target species of interest to GSMNP staff are discussed in Sect. 3.4.4. The search for target species was conducted along the proposed ROW and includes adjacent areas that could be affected by the construction and operation of the parkway, particularly areas downslope from the ROW. The survey encompassed one growing season, April through October 1994.

Species with federal status. No species with federal status were found growing on the ROW. The ROW falls within the known range of the federally endangered small whorled pogonia (*Isotria medeoloides*). This inconspicuous orchid is most often found in relatively open areas in deciduous hardwoods, and suitable habitat ranges from dry, rocky slopes to moist streambanks. Although a careful survey for this species was conducted along the ROW, it was not found.

Species with state status. Three species previously listed as federal candidates and six additional state protected vascular plant species were found growing on the ROW and are listed in Table 14. The distribution by segments of these nine species, as well as fourteen additional species new or rare in GSMNP, are shown in Table 15.

Table 14. Protected vascular plant species growing on the right-of-way

Species	Common name	Federal status[a]	State status[b]
Juglans cinerea	Butternut	C2	T
Silene ovata	Ovate catchfly	C2	T
Abies fraseri	Fraser fir	C2	T
Carex howei	Howe's sedge		E
Cypripedium acaule	Pink lady's-slipper		E
Trillium rugelli	Southern nodding trillium		E
Panax quinquefolius	Ginseng		T
Thermopsis fraxinifolius	Ash-leaved bush-pea		T
Heuchera longiflora var aceroides	Maple-leaf alumroot		S

[a]C2—species previously under review for listing (61 *Fed. Regist.* 64481–85; 58 *Fed. Regist.* 51143–89).

[b]E—endangered, T—threatened, S—special concern (Somers 1989), Division of Natural Heritage 1995. Special concern means species are either (1) rare in Tennessee because the state represents the limit or near-limit of their geographic range, or (2) their status is undetermined because of insufficient information.

The state threatened butternut grows in two locations on floodplains within the ROW. In this region, typical habitat for this species is floodplains. The populations consist of about 30 individuals ranging in size from saplings to mature trees. Some trees appear to have been cut during the centerline surveys, and others may have been poached (cut stumps and tops are present but logs are missing). Trees on the ROW are infected with butternut canker, an introduced fungus that threatens to eliminate butternut by killing many, but not all trees, over a period of years.

Table 15. Vascular plant distribution, traversing Section 8B of the right-of-way from southwest to northeast, of state and previous federal candidate species and species new or rare in Great Smoky Mountains National Park
(excluding exotic species)

Species	Common name	PRT[a]	WM	MBR	RF	BR	CCT
Juglans cinerea	Butternut	X					
Silene ovata	Ovate catchfly		X				
Abies fraseri	Fraser fir				X		
Carex howei	Howe's sedge				X	X	
Cypripedium acaule	Pink lady's slipper		X			X	
Trillium rugelli	Southern nodding trillium					X	
Panax quinquefolius	Ginseng		X			X	
Thermopsis fraxinifolius	Ash-leaved bush-pea		X				
Heuchera longiflora var aceroides	Maple-leaf alumroot		X				
Aronia arbutifolia	Red chokeberry				X		
Asclepias amplexicaulis	Clasping milkweed		X				
Aster sagittifolius	Arrow-leaved aster		X				
Carex prasina	Drooping sedge				X		
Carex austrocaroliniana	South Carolina sedge					X	
Carex debilis var. pubera	Sedge			X			
Carex atlantica	Atlantic sedge			X	X		

Table 15. Continued

Species	Common name	PRT[a]	WM	MBR	RF	BR	CCT
Cyperus brevifoliodes	Pasture flatsedge	X					
Danthonia epilis	Wild oatgrass					X	
Dryopteris celsa	Log fern						x
Eclipta alba	Yerba-de-tajo	X					
Juncus diffusissimus	Slimpod rush				X		
Muhlenbergia tenufolia	Slender muhly		X				
Tradescantia virginiana	Virginia spiderwort	X					

[a]PRT = Pigeon River Terraces, WM = Webb Mountain, MBR = Matthew Branch Ridge, RF = Rocky Flats, BR = Big Ridge, CCT = Cosby Creek Terraces. No species were found in the Webb Creek Ridge segment.

Three flowering stems of the state threatened ovate catchfly were found in hardwood forest in two stream drainages. The hardwood forest habitat of the ovate catchfly is a common habitat on Section 8B of the ROW. This species may be present in other parts of the ROW, but intensive survey of this extensive habitat type is beyond the current scope of this project.

One 6-foot-tall sapling of the state threatened Fraser fir was found on the ROW growing in an area of abandoned homesteads in mixed hardwood and hemlock. The natural habitat of this species is high elevation, where it is threatened by the Balsam wooly adelgid, an exotic insect pest. However, it is commonly grown commercially for Christmas trees and as a landscaping ornamental at lower elevations. The presence of this individual in such an atypical location is not considered ecologically significant.

State endangered Gray's saxifrage (*Saxifraga caroliniana*), state threatened Smoky Mountain manna grass (*Glyceria nubigena*), state threatened Rugel's ragwort (*Cacalia rugelia*), state endangered Cain's reed grass (*Calamagrostis cainii*), and state threatened mountain bittercress (*Cardamine clematitis*) are additional species that may occur in the vicinity of the parkway that were previously federal candidate species under review for possible listing. All except the saxifrage are found only at high elevations, were not expected to occur on this section of the ROW, and were not seen during the survey. Suitable habitat for the saxifrage, which grows on steep, rocky terrain with dense shade and abundant moisture (e.g., steep, moist, moss-covered rocks, cliffs, and seepage slopes) is not present on this section of the ROW. Other potentially occurring previously federal candidate plant species include state threatened piratebush (*Buckleya distichophylla*), state endangered Frasier's loosestrife (*Lysimachia fraseri*), and state threatened sweet pinesap (*Monotropsis odorata*). None of these species was found on the ROW.

The state endangered southern nodding trillium grows in a north-facing stream drainage on the ROW. Southern nodding trillium is a southern Appalachian endemic species. This species is endangered in Tennessee but is more common in North Carolina.

The endangered Howe's sedge grows in two wetland seep areas on the ROW. This species is sometimes considered by taxonomists to be a subspecies of *Carex atlantica*; however, both taxa (*C. atlantica howei* and *C. atlantica*) are present in this location. It is associated with several mosses (*Polytrichum commune*, *Thuidium delicatulum*, and *Climacium americanum* var *kindbergii*) in a boggy area and has not been previously reported in Tennessee east of the Cumberland Plateau.

The endangered pink lady slipper, which is found throughout the ROW, is more common than is normally the case for a Tennessee listing. It and the threatened ginseng are listed because of the potential threat from commercial exploitation. There are several populations of pink lady slipper on the ROW, mostly in dry pine forest. Some were also found in dry, oak-pine forest. Two populations of ginseng are in mesic forest sites.

The threatened ash-leaved bush-pea was found on the ROW at three sites. Two populations are in open, dry mixed forest containing pine killed by southern pine beetle. The other population is in oak forest in a ravine. It is possible that other populations are present on the ROW. There are large areas of potential habitat for this species on the ROW, and an intensive search of this habitat type was beyond the scope of this survey. This species was previously known in the GSMNP only on Section 8D of the ROW.

The maple-leaf alumroot, a state species of special concern, was found in two locations on the ROW and one location downslope from the ROW on non-calcareous sites. Plants were scattered over a fairly large area and may be present in other areas of hardwood forest on the Webb Mountain segment. This species has been previously reported in rich calcareous woods (Radford, Ahles, and Bell 1968) and calcareous shales or bluffs (Wofford 1981). It has previously been reported only in Greene and Cocke counties and may be a new finding for Sevier County.

No other state listed vascular plant species were found on the ROW (Appendix D).

3.4.3.2 Bryophyte and Lichen Species

The bryophyte and lichen survey was conducted by Dr. David Smith of the University of Tennessee and his graduate students during the fall of 1994 and winter and early spring of 1995. Field surveys and identifications were completed for all segments of the ROW. Bryophytes and lichens do not currently have protected legal status in Tennessee and no federally endangered, threatened, or previously candidate species have been identified.

3.4.3.3 Animal Species

Federal (59 *Fed. Regist.* 58981–9028; 59 *Fed. Regist.* 49848–59) lists of rare species were used to determine which rare animal species might occur on the ROW. This list provided an initial list of species with federal or state legal status that were targeted for field surveys. Information from the Tennessee Department of Environment and Conservation data base and GSMNP staff were used to further refine the list of rare target species. From these lists and examination of topographic maps, lists of small mammal (Appendix G) and bird species of concern to GSMNP that are likely to be present in the study area were developed.

Mammals, reptiles, and upland salamanders. The small mammal, reptile, and upland salamander survey was conducted by Dr. Michael Harvey of Tennessee Technological Institute and his assistants in late summer and fall of 1994. No endangered or threatened species, or candidate species for listing as endangered or threatened, was captured (Appendix G).

Species with federal status. Three listed endangered mammal species could occur on the ROW: the Indiana bat (*Myotis sodalis*), the gray bat (*M. grisescens*), and the Carolina northern flying squirrel (*Glaucomys sabrinus coloratus*) (Appendix G). The largest known hibernating colony of the Indiana bat in the GSMNP region (about 8500) occupies Whiteoak Blowhole Cave in the northwestern section of GSMNP [about 35 to 45 km (22 to 28 miles) from the study area]. Another small colony of about 200 bats hibernates in Bull Cave, also in the northwestern section of GSMNP. Although not seen during field surveys, the endangered Indiana bat might be present along the ROW in summer. Despite protection of important hibernacula—usually limestone caves—where Indiana bats winter, populations of this species have continued to decline (Rommé, Tyrell, and Brack 1995). Important components of summer habitat include maternity roost and foraging habitat. Female Indiana bats establish nursery colonies or roosts in dead trees or under loose bark of large mature hardwoods. Open subcanopy space over streams provides an open travel corridor where bats concentrate, but Indiana bats eat primarily terrestrial insect species (Rommé, Tyrell, and Brack 1995). Upland and riparian hardwood forest are foraging and maternity roost habitat for this species.

The gray bat occurs primarily in areas of abundant caves and is not known in GSMNP. It is unlikely that it is present in the vicinity of the ROW. No suitable habitat for the Carolina northern flying squirrel, which has previously been found only above 1230 m (4000 ft) elevation, is present on the ROW.

Species with state status. Seven small mammal species, one snake, and two salamanders that were previously candidates for federal listing could occur on the ROW (Appendix G), but none were observed. Suitable habitat is present on the ROW for state "in need of management" Rafinesque's big-eared bat (*Corynorhinus rafinesquii*), the eastern small-footed bat (*Myotis leibii*), southeastern bat (*Myotis austroriparius*), eastern woodrat (*Neotoma floridana*), southern water shrew (*Sorex palustris punctulatus*), southern rock vole (*Microtus chrotorrhinus carolinensis*), and Appalachian cottontail (*Sylvilagus obscurus*). The big-eared bat is apparently one of the most common bats in the GSMNP and was found on the Section 8D ROW about 20 to 35 km (12.5 to 22 miles) away. It is probably present on the Section 8B ROW during summer. The small-footed bat is apparently rare in the GSMNP region. There is a single record from Greenbrier Cove in GSMNP [about 6 to 17 km (4 to 11 miles) from the ROW]; and it is possible, but not probable, that this bat would occur along the ROW during summer. There are no records of the southeastern bat in the GSMNP, and it is unlikely to be present on the ROW.

The woodrat is found up to elevations of 800 m (2500 ft) and is likely to be present on the ROW, especially in rocky areas. The other three species are generally found at higher elevations and are uncommon in the GSMNP. Some of the streams on the ROW are similar habitat to areas where the water shrew has been found; however, the shrew has been found only at elevations above 1138 m (3700 ft) and is unlikely to be present on the ROW (Appendix G). The rock vole has been reported in the GSMNP only above 815 m (2650 ft) (Appendix G). It could possibly occur in the higher-elevation rocky areas in the Webb Mountain segment of the ROW. Although the Appalachian cottontail was not captured during the field study, cottontails were seen on the ROW (Appendix G). It was not possible to determine whether they were Appalachian cottontails or the more common eastern cottontail (*Sylvilagus floridanus*) but suitable habitat is present in the higher elevations of the Webb Creek Ridge, Webb Mountain, and Matthew Branch Ridge segments of the ROW.

Neither of the potentially occurring upland species which were previously federal candidates, state "in need of management" Junaluska salamander (*Eurycea junaluska*) and green salamander (*Aneides aeneus*), or the state threatened northern pine snake (*Pituophis melanoleucas melanoleucas*) was observed during the survey (Appendix G). The Junaluska salamander is currently known only in the Cheoah River Valley in Graham County, North Carolina, and in the GSMNP about 14 to 30 km (9 to 19 miles) away (Appendix G). Although the green salamander is known historically in Sevier County at Cherokee Orchard near Gatlinburg about 12 to 26 km (7.5 to 16 miles) away, no suitable cave or cliff habitat is on the ROW. This species is unlikely to be present. The pine snake has been historically reported from GSMNP and was not thought to be uncommon in the western regions of the park below about 600 m (2000 ft) (Huheey and Stupka

1967). Suitable habitat is present throughout the ROW where this relatively secretive snake may be present.

The state "in need of management" hellbender (*Cryptobranchus alleganiensis*), also previously a candidate for federal listing, has been reported in the Little Pigeon River drainage system (J. Widlak, USFWS, Cookeville, Tennessee, telephone conversation with L. Mann, ORNL, April 11, 1994).

Five species listed by the state of Tennessee as in need of management (Tennessee Wildlife Resources Commission 1994) were captured (Table 16). The masked and smoky shrews are probably throughout the ROW, but other need of management species are probably more localized in damp areas. The meadow jumping mouse and bog lemming are found in grassy areas and the woodland jumping mouse in wooded areas. Although not observed on the Section 8B ROW, the "in need of management" hairy-tailed mole was found on Section 8A of the ROW in 1995 (K. Langdon, GSMNP, Gatlinburg, Tennessee, telephone conversation with L. Mann, ORNL, Aug. 11, 1995).

Table 16. Mammals captured on the Section 8B of the right-of-way that were listed as "In Need of Management" by the state of Tennessee[a]

Species	Common name	Segment of right-of-way
Sorex cinereus	Masked shrew	Webb Mountain, Matthew Branch Ridge
Sorex fumeus	Smoky shrew	Webb Mountain, Matthew Branch Ridge
Zapus hudsonius	Meadow jumping mouse	Cosby Creek Terraces
Napaeozapus insignis	Woodland jumping mouse	Matthew Branch Ridge, Rocky Flats
Synaptomys cooperi	Southern bog lemming	Cosby Creek Terraces

[a]Species "in need of management" need data to determine management measures necessary to sustain populations Hatcher (1994).

Bird species with federal status. No federally listed birds are known to occur on the ROW. According to the U.S. Fish and Wildlife Service, the only bird species of possible concern on the ROW is the threatened peregrine falcon (*Falco peregrinus*). Historically, the American peregrine falcon (*F. peregrinus anatum*) occurred in the vicinity of the parkway; transients and occasional migrants are still seen, but no recent sitings are on record (J. Widlak, USFWS, Cookeville, Tennessee, telephone conversation with L. Mann, ORNL, April 11 and June 1, 1994). The peregrine is being successfully reintroduced to the southern Appalachians (WWF 1990) and was hacked in the GSMNP (Henry 1988) at a hack site about 7 to 14 km (5 to 9 miles) from the ROW. Peregrines prefer cliffs for nest sites, but reintroduced birds also regularly nest on tall buildings and bridges (WWF 1990; Henry 1988). Birds often travel up to 11 km (7 miles) from the nest site to hunt in a variety of habitats, including grasslands and open country. They tend especially to hunt near water, along large lakes and rivers (WWF 1990; Eagar and Hatcher 1980). They may range as far as 30 km (20 miles) (R. M. Hatcher, Tennessee Dept. of Conservation, Nashville, Tennessee, telephone conversation with L. Mann, ORNL, 1991).

Two other listed species of birds, the threatened American bald eagle (*Haliaeetus leucocephalus*) and the endangered red-cockaded woodpecker (*Picoides borealis*), could occur on the ROW. According to Stupka (1963), the American bald eagle was historically an irregular and infrequent visitor to the GSMNP despite nearby water impoundments. It is highly unlikely that this species would be found on the ROW. The nearest historically known population of red-cockaded woodpeckers is near Fontana, about 60 km (38 miles) south of the study area. Suitable habitat for this species is on the ROW, but nest trees, which are conspicuous, were not seen.

Bird species with state status. Three species of birds that were previously candidates for federal listing and are either state threatened or endangered occur on the ROW. These species are the state threatened Appalachian Bewick's wren (*Thryomanes bewickii altus*), the loggerhead shrike (*Lanius ludovicianus*), and state endangered Bachman's sparrow (*Aimophila aestivalis*).

Appalachian Bewick's wren, the loggerhead shrike, and Bachman's sparrow prefer open pastures and old fields. Historically, Bewick's wren was a very uncommon summer resident and a rare winter visitor in the GSMNP (Stupka 1963). The wren was somewhat more frequent at low altitudes and often occupied old homesites (Eagar and Hatcher 1980). It has been reported in the past in the Pigeon Forge area (Stupka 1963). Bachman's sparrow has been an uncommon spring migrant and a scarce summer resident in GSMNP (Stupka 1963). Preferred habitat for this species is open pastures and old fields, usually with some woody brush and briars. This species has abundant unused habitat in Tennessee and does not appear to be habitat-limited (Eagar and Hatcher 1980). The loggerhead shrike is a winter resident near the GSMNP and breeds in Sevier County (R. J. Shelley, NPS, letter to R. M. Reed, ORNL, March 24, 1992).

No species of concern at the federal level were seen during the survey, but Cooper's hawk, a species "deemed in need of management" (Hatcher 1994) in Tennessee was seen in the Webb Mountain segment of the ROW (Appendix F).

3.4.4 Additional Species of Interest to the NPS

Park-rare species. Because one of the purposes of national parks is conservation of biotic diversity, the GSMNP staff is concerned with protecting its rare species. The park maintains a data base of plant species similar to that of the Heritage Program, which ranks species according to rarity. In the park, species with five or fewer small populations (P1 status) or with six to 20 small populations (P2 status) are most vulnerable to extinction. The search for rare vascular plants and bryophytes on the ROW included these P1 and P2 species (Rock and Langdon 1991; Smith, McFarland, and Davison 1991).

Vascular plants. Seven species new to GSMNP, seven P1 species, and three P2 species were found on the ROW (Table 17). Their distributions are shown in Table 15. The slimpod rush was new to both GSMNP and East Tennessee. Of the new or rare species in the GSMNP, all but the two exotic species (coltsfoot and ivy-leaved speedwell) and three species growing on Webb

Table 17. Vascular plants found during surveys on Section 8B of the right-of-way which were either new or considered rare in GSMNP, other than state and federally listed species in Table 14

Species	Common name	Park status[a]
Aronia arbutifolia	Red chokeberry	P2
Asclepias amplexicaulis	Clasping milkweed	P1
Aster sagittifolius	Arrow-leaved aster	P1
Carex prasina	Drooping sedge	P2
Carex austrocaroliniana	South Carolina sedge	P2
Carex debilis var. pubera	Sedge	P1
Carex howeii	Howe's sedge	New
Carex atlantica	Atlantic sedge	New
Cyperus brevifoliodes	Pasture flatsedge	P1
Danthonia epilis	Wild oatgrass	New
Dryopteris celsa	Log fern	P1
Eclipta alba	Yerba-de-tajo	P1
Juncus diffusissimus	Slimpod rush	New
Muhlenbergia tenufolia	Slender muhly	P1
Tradescantia virginiana	Virginia spiderwort	New
Tussilago farfara	Coltsfoot	New (exotic)
Veronica hederifolia	Ivy-leaved speedwell	New (exotic)

[a]New = previously not reported in GSMNP (exotic species are non-native to the region); P1 = extremely rare in GSMNP; P2 = rare in GSMNP (Rock and Langdon 1991).

Mountain (clasping milkweed, arrow-leaved aster, and slender muhly) were found in wetlands or the Little Pigeon River floodplain. This abundance of GSMNP rare wetland species may be a result of the relative rarity of wetland and floodplain habitats in the park and the quality of wetlands present on the ROW. The plant in the Cosby Creek floodplain identified as log fern, a P1 species, may be of hybrid origin. Dr. Murray Evans of the Botany Department at the University of Tennessee, concluded that it is best assigned to *Dryopteris celsa* but it may have some genes from *D. cristata* as a result of hybridizing (M. Evans, University of Tennessee, personal communication with L. Pounds, Jaycor, Dec. 1994). *D. cristata*, a state listed species of special concern, was not found during the field searches.

Bryophyte and lichens. Of the 43 liverwort species, 106 moss species, and 2 hornwort species identified on the ROW, 14 park-rare and one state-rare liverwort species and 29 park-rare moss species were found (Appendix H). A rare aquatic hornwort (*Megaceros aenigmaticus*), previously known globally in only one stream in North Carolina in the GSMNP and in the Tellico River drainage in Tennessee, was found in one of the streams in the Rocky Flats segment. Although not currently listed, this species is globally rare enough to be considered for protection (K. Langdon, GSMNP, telephone conversation with L. Mann, ORNL, 1995).

Five species (three mosses, one liverwort, and one hornwort) rare in both GSMNP and in Tennessee (P1, S1) (Smith, McFarland, and Davison 1991; Appendix H) were found. Two of the mosses (*Brachethelium rutabulum* and *Fissidens appalachensis*) and the hornwort (*Megaceros aenigmaticus*) were in or near streams and wetlands. The other moss (*Fissidens bushii*) was growing on disturbed soil, and the liverwort (*Frullania kunzei*) was growing on boulders in mesic woods. An additional 23 species rare in GSMNP (P1, P2) but more common elsewhere in Tennessee were also growing on the ROW. Nine of these species were on bark, five were in streams or wetlands, three were on rock, one was on wet, decaying wood, and three were on disturbed soils. Three taxa were new to GSMNP: two liverworts (*Frullania eboracensis* subsp. *virginica* and *F. ericoides*) and a moss (*Dicranum spurium*). No new state records resulted from this study. A sphagnum (*Sphagnum affine*, P1, P2) bog was found during the vascular plant survey (Appendix E).

Small mammals. Three small mammal species that are considered to be rare in the GSMNP were captured on the ROW: the northern long-eared bat (*Myotis septentrionalis*) in the Little Pigeon Terraces segment, the pygmy shrew (*Sorex hoyi*) in the Big Ridge segment, and the golden mouse (*Ochrotomys nuttalli*) in the Cosby Creek Terraces segment (Appendix G). One individual of each of these species was caught. The pygmy shrew was previously only reported from one high-elevation site in the park.

Birds. Because of apparent population declines in neotropical migratory songbirds (Askins 1995; Robinson et al. 1995), many of which are dependent on large blocks of unfragmented forest, these birds are of concern to GSMNP. They are particularly vulnerable to medium-sized mammalian predators (e.g., raccoons and opossums) and egg-eating birds (e.g., American crows and blue jays), and to parasitism by brown-headed cowbirds. These predators and parasites thrive in fragmented forests in landscapes containing abundant forest edge and field vegetation. Although some migrant songbirds experiencing population declines (e.g., the cerulean warbler, Kentucky warbler, and wood thrush) breed only in large blocks of contiguous forest, some non-forest migrants (e.g., the northern prairie warbler) also seem to be declining in some regions of the United States (Hunter et al. 1993; Hunter, Pashley, and Escano 1993). Conservation Concern Scores have been developed by the Southeast Management Working Group for Partners in Flight as preliminary priorities for conservation of migratory songbirds (Hunter et al. 1993; Hunter, Pashley, and Escano 1993; Roedel, Miles, and Ford 1996). These scores were developed using 7 criteria, with each given from 1 to 5 points (low to extremely high concern). The criteria are (1) global abundance, (2) global breeding distribution, (3) global wintering distribution, (4) threats during breeding season, (5) threats during non-breeding migration and wintering season, (6) local population trend, and (7) importance of the area compared with other distribution. In the Blue Ridge Physiographic province, 16 species of neotropical migrants and one temperate migrant of very high concern, or vulnerable and likely in need of management and/or monitoring were observed on or near the ROW (Table 18 and Appendix F).

Table 18. Songbirds identified by the Southeast Management Working Group for Partners in Flight as preliminary priorities in need of increased conservation attention in the Southeastern United States and Blue Ridge Physiographic Province (Hunter et al. 1993a, b; Roedel et al. 1996) which were observed on or near the right-of-way (Appendix F; Nicholson 1994)

Species		Habitat
Neotropical migrants		
Cerulean warbler[a]	*Dendroica cerulea*	Forest
Blackburnian warbler	*Dendroica fusca*	Forest
Worm-eating warbler	*Helmitheros vermivorous*	Forest
Hooded warbler	*Wilsonia citrina*	Forest
Kentucky warbler	*Oporornis formosus*	Forest
Black-throated green warbler	*Dendroica virens*	Forest
Ovenbird	*Seiurus aurocapillus*	Forest
Wood thrush	*Hylocichla mustelina*	Forest
Acadian flycatcher	*Epidonax virescens*	Forest
Scarlet tanager	*Piranga olivacea*	Forest
Northern parula	*Parula americana*	Forest, streams
Louisiana waterthrush	*Seiurus motacilla*	Forest, streams
Yellow-throated vireo	*Vireo flavifrons*	Forest, open woods
Eastern wood-pewee	*Contopus virens*	Forest, open woods
Northern prairie warbler	*Dendroica discolor discolor*	Fields, edges
Gray catbird	*Dumetella carolinensis*	Fields, edges
Temperate migrants		
Field sparrow	*Spizella pusilla pusilla*	Fields

[a]Observed during the Tennessee Ornithological Society (TOS) Breeding Bird Atlas survey (Nicholson 1994). The TOS data used were for the 1988, 1990, and 1991 surveys of the USGS Jones Cove map quadrangle, which is in the general vicinity of Webb Mountain.

One of these species, the cerulean warbler (*Dendroica cerulea*), was previously a candidate for federal listing. Cerulean warblers are undergoing precipitous population declines throughout their range. They nest in large tracts of mature hardwood forest on hilly to steep slopes in the mountains, with greatest reported abundance in the central Cumberland Mountains (Hamel 1992). Breeding density of this species is low in the Parkway ROW area and it is described as rare in northeast Tennessee (Robinson 1990). Although one cerulean warbler was reported from the 1988 Breeding Bird Survey in or near the Webb Mountain segment of the ROW (Nicholson 1994), Stupka (1963) reported it as "very uncommon" in GSMNP even before population declines were reported. This species might nest on the ROW, but it is not likely to occur as more than an occasional breeding pair and was not observed during an extensive search for this species during the 1995 bird survey of the ROW.

Many of these species require large tracts of forest for successful nesting. Most of the Section 8B ROW is contained within tracts of deciduous forest larger than about 400 ha (1000 acres) (Fig. 1). Tracts of this size were identified by the Southern Appalachian Assessment as suitable habitat for birds requiring interior deciduous forest (SAMAB 1996).

Several species that breed at high elevations in the park were observed on the ROW during the 1995 survey. The rose-breasted grosbeak, black-capped chickadee, red-breasted nuthatch, solitary vireo, and blackburnian warbler are considered high elevation species, usually found above about 1100 m (3500 ft) (Alsop 1995). All but the rose-breasted grosbeak are reported by other sources as breeding as low as 600 m or 900 m (2000 or 3000 ft) in or near the park (Stupka 1963). These species were all observed on or near Webb Mountain (Appendix F), whose peak of 950 m (3100 ft) is the highest elevation on the ROW. The individual rose-breasted grosbeak may have been a visitor from nearby higher elevations (Stupka 1963).

The rock dove, also known as the pigeon of urban areas, was found in the Webb Creek Ridge segment of the ROW. It was the only bird species observed during the 1995 survey that is considered rare in GSMNP (Alsop 1995). This species is not of concern to GSMNP.

Non-native (exotic) invasive species. The presence of non-native or exotic plant species on and near the ROW is important to staff of GSMNP because aggressive non-native species compete with native species and detract from the GSMNP visitor experience (Clebsch and Wofford 1989; Remaley 1996). Vegetation on most of the ROW is native, although a few areas are infested with aggressive, non-native species, especially in disturbed areas and up drainage systems from disturbed areas outside the ROW (Table 19). Other non-native species may be present on the ROW but were not included as part of this study.

The greatest exotic plant threat to native vegetation on the ROW is from privet (*Ligustrum vulgare*), which is spreading along streams into relatively undisturbed areas, especially along the tributaries to Webb Creek west of Mill Dam Branch. Although not currently abundant on the ROW, Japanese grass (*Microstegium vimineum*) is another aggressive exotic species found in shaded moist areas. Garlic mustard (*Allialaria petiolata*) was not found on the ROW, but it grows nearby and may invade mesic forest areas. Coltsfoot (*Tussilago farfara*) and ivy-leaved speedwell (*Veronica hederaefolia*) are new exotic species for the GSMNP. The potential effects of these species on natives is unknown. Coltsfoot dominates bare ground on roadside banks and is not a threat for any of the rare species found in this section of the ROW.

Table 19. Non-native (exotic) species growing on or near Section 8B of the right-of-way

Species	Common name	Section of right-of-way
Microstegium vimineum	Japanese grass	Along streams
Alliaria petiolata	Garlic mustard	Rocky Flats Road, south of right-of-way
Lonicera japonica	Japanese honeysuckle	In many locations, especially those with past history of disturbance
Veronica hederaefolia	Ivy-leaved speedwell	Along Dunn Creek
Ligustrum vulgare	Privet	In disturbed areas and drainages above disturbed areas
Broussonetia papyrifera	White mulberry	Seen previously by NPS staff—location unknown; not relocated during survey
Vinca minor	Periwinkle	On ROW in vicinity of Chavis Road
Dioscorea batatas	Cinnamon vine, Chinese yam	Little Pigeon River and Cosby Creek floodplains; near Chavis Road
Pueraria lobata	Kudzu	Vicinity of Chavis Road
Tussilago farfara	Coltsfoot	Branam Hollow Road
Rosa Multiflova	Multiflora rose	Near Webb Creek, Crosby Creek, and Little Pigeon River

Mimosa (*Albizzia julibrissin*), princess tree (*Pawlonia tomentosa*), catalpa (*Catalpa speciosa*), and wineberry (*Rubus phoenicolasius*) were not found on the ROW. Mimosa is common in the general area, and the princess tree is locally abundant in some other sections of the ROW and on other roadsides, such as on I-40 north of Cosby. Catalpa is neither common nor considered an aggressive exotic species in this area (K. Langdon, GSMNP, telephone conversation with L. Mann, ORNL, 1995).

3.4.5 Unique or Sensitive Habitats Including Wetlands

For purposes of this ER, unique or sensitive habitats are defined as fairly discrete landscape units that provide habitat for one or more species of plants or animals that are of interest to the GSMNP; that are listed, proposed, or candidates for listing by state or federal governments; or that are plant communities recognized as globally or nationally threatened or endangered (Noss, LaRoe, and Scott 1995).

Such biologically important habitats on the ROW include floodplains, boulder slopes, mesic slopes, and wetlands. All are of limited extent in the region as a result of either the rare occurrence of physical features or increasing conversion of native landscapes to urbanization, land clearing, or agricultural use.

Wetlands. National Wetlands Inventory (NWI) maps were examined initially to identify possible locations of wetlands along the ROW. Although potential wetlands were identified along the Little Pigeon River, Copeland Creek, Webb Creek, and Cosby Creek in the Little Pigeon Terraces, Webb Creek Ridge, Rocky Flats, and Cosby Creek Terraces segments of the ROW, these maps proved inadequate to locate other wetlands on the ROW. Wetlands discussed in this section were identified during soil, vegetation, and aquatic surveys. A detailed wetlands survey was conducted in 1994 and 1995 for several of the more extensive wetlands on the Little Pigeon River, Webb Creek, Dunn Creek, and Carson Branch (Appendix I). Most other wetlands were smaller than 1 ha (0.5 acres).

Although small areas of wetlands are found along most of the stream drainages crossing the ROW, the high gradient of the streams and their rocky nature result in little wetland development. Areas of more extensive wetlands are on cobble bars of the Little Pigeon River in the Little Pigeon Terraces segment, along a tributary to Webb Creek in the Webb Creek Ridge segment, and near seeps and streams along Dunn Creek and Carson Branch in the Rocky Flats segment. Vegetation in most of these larger wetland areas is similar to vegetation in smaller [less than 9 m^2 (100 ft^2)] wetlands types found throughout the ROW along small streams and drainages. Typical wetland (e.g., hydrophytic) vegetation includes several species of sedges, fowl manna grass (*Glyceria striata*), ferns, spotted touch-me-not (*Impatiens capensis*), and Japanese grass. In areas without standing water, Japanese grass often forms a dense ground cover, obscuring native vegetation. Smooth alder (*Alnus serrulata*), ironwood, elderberry (*Sambucus canadensis*), and black willow (*Salix nigra*) are typical hydrophytic shrubs in open, shrub-dominated wetlands. Typical forest vegetation in larger wetlands includes sycamore, red maple, sweetgum (*Liquidambar styriciflua*), and elm (*Ulmus americana*). In small wetlands, the overstory canopy is often formed by the surrounding forest rather than by trees that are actually growing in the wetland. Hemlock, oaks, red maple, tulip poplar, and rhododendron often grow near these drainages. The soils in small wetland areas are typical wetland, hydric soil types (either Aquolls, Aquepts, or Aquents) (see Appendix B).

Biologically important wetlands are present on the ROW in three drainages containing fairly extensive networks of seeps. One is in a steep-sided, narrow ravine in mesic forest. The area containing the seeps is about 30 m (100 ft) long and 3 to 6 m (10 to 20 ft) wide. This mountain wetland seep contains a diverse flora, including several sedges (*Carex atlantica*, previously unknown in the GSMNP; *C. debilis*, P1 or the most rare category for GSMNP; *C. scabrum*; and *C. crinata*), a wetland grass (*Sphenopholis pennsylvanicum*), and yellow fringed orchid (*Platanthera ciliaris*).

Another biologically important seepage area originates at the base of a steep slope below a roadcut. Many small pools and boggy areas occur under pine and mixed pine-hardwood canopy, as well as under a mowed area paralleling the creek. This wetland complex contains a moss bog and a diverse wetland flora, including the state endangered Howe's sedge; slimpod rush, new to the park; and red chokeberry, a park P2 species.

The third biologically important wetland area consists of small seeps in multiple tributaries of a stream system. These wetlands contain wild oatgrass (a species new to the park), and the state endangered Howe's sedge.

Floodplain and other unique habitats. Despite disturbance from flooding and human activity, the Little Pigeon River and Cosby Creek floodplains contain assemblages of native bottomland species representative of large streams and small rivers in the region, including a population of the federal candidate butternut. Although no listed species are known to be present on the Cosby Creek floodplain, there is a small stand of giant cane (*Arundinaria gigantea*). Canebrake communities in the Southeast are among those listed by Noss, LaRoe, and Scott (1995) as critically endangered ecosystems (more than 98% of such communities have been lost). Native riparian or floodplain communities are threatened by urban development and agricultural use throughout the region and are threatened (70 to 84% decline) throughout the United States (Noss, LaRoe, and Scott 1995).

A well developed cobble bar with mostly native vegetation is also present in the Little Pigeon River. No listed plant species have been observed in this frequently flooded habitat, but Yerba-de-tajo and pasture flatsedge, both rare species of disturbed sites in the park, were found there.

Boulder or talus slopes and rocky areas are present on the ROW in the Webb Mountain segment. One of these rocky areas is habitat for the federal candidate ovate catchfly. At present, no other listed species are known to be present in these sites.

The vegetation in one area of the ROW on the Big Ridge segment is somewhat different from the rest of the ROW. Redbud (*Cercis canadensis*), glade fern (*Athyrium pycnocarpon*), and the state endangered southern nodding trillium are species often found in calcareous areas, or areas of basic to neutral soil. Therefore, the geology of this area may be less acidic than that of the rest of the ROW. Some of this general area is highly disturbed and contains extensive kudzu (*Pueraria lobata*), but the relative rarity of calcareous soils in the GSMNP makes this an area of ecological interest to the park.

3.4.6 Summary

Of the 14 species with federal or state endangered, threatened, previous candidate, or special concern status, the populations of the state threatened ovate catchfly and ash-leaved bush-pea are of greatest concern because of their potential global rarity. Of the sensitive habitats and protected species identified or found on the ROW, those of greatest concern are the floodplains of the Little Pigeon River and Cosby Creek; Webb Mountain, including drainages and slopes; wetlands and streams in the Rocky Flats area; and some upper drainages on Big Ridge. Although not currently protected, the globally rare population of hornwort is also of concern.