Integrated Monitoring of Hydrogeomorphic, Vegetative, and Edaphic Conditions in Riparian Ecosystems of Great Basin National Park, Nevada

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U.S. Department of the Interior
U.S. Geological Survey

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By Erik Beever and David A. Pyke
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Integrated Monitoring of Hydrogeomorphic, Vegetative, and Edaphic Conditions in Riparian Ecosystems of Great Basin National Park, Nevada

By Erik A. Beever and David A. Pyke[1]

Abstract

In semiarid regions such as the Great Basin, riparian areas function as oases of cooler and more stable microclimates, greater relative humidity, greater structural complexity, and a steady flow of water and nutrients relative to upland areas. These qualities make riparian area's attractive not only to resident and migratory wildlife, but also to visitors in recreation areas such as Great Basin National Park in the Snake Range, east-central Nevada. To expand upon the system of ten permanent plots sampled in 1992 (Smith et al. 1994) and 2001 (Beever et al. *in press*), we established a collection of 31 cross-sectional transects of 50-m width across the mainstems of Strawberry, Lehman, Baker, and Snake creeks. Our aims in this research were threefold: a) map riparian vegetative communities in greater detail than had been done by past efforts; b) provide a monitoring baseline of hydrogeomorphology; structure, composition, and function of upland- and riparian-associated vegetation; and edaphic properties potentially sensitive to management; and c) test whether instream conditions or physiographic variables predicted vegetation patterns across the four target streams.

In each of the four watersheds, we performed walking transects from the lower-elevation boundary of the park along creek mainstems to a point well above the point at which vehicle access stopped. In these transects, we ranked, by cover, the riparian and upland woody species on each side of the creek, in 0.32-km segments. These walking transects also facilitated selection of a suite of cross-sectional transects that might serve as an early-warning signal of change for natural (e.g., aggradative) and anthropogenic changes (e.g., due to visitor impacts or climate change). At each cross-sectional transect, we used several methods: a) measurement of the number, approximate volume, and total length of instream logs greater than 10 cm in diameter that were within 5 m up- or downstream of the transect; b) counts of pebbles by size class, following Wolman (1954); c) line-point intercepts, which provided various measures of percent cover; d) gap-intercept transects, following Herrick et al. (*in press*), to measure susceptibility of uplands to erosion by wind or water; e) 1-m^2 quadrats, to obtain frequency of woody species; f) nested-frequency plots, to measure frequency of all plant species in quadrats of varying size; g) a field-based soil aggregate stability test following Herrick et al. (2001); and h) an impact penetrometer, to measure penetration resistance of soil horizons.

We used species-accumulation curves to assess the ability of our methods to detect the majority of plant species at sites, using the most species-rich and species-poor sites as illustrations. We compared characteristics of hydrogeomorphic valley types (designated by Frissell and Liss 1993), vegetation types, and creeks individually and, using multivariate analyses for the first two 'types,' simultaneously. For the latter, using both the nested-frequency and 1-m^2 frequency data, we first used nonmetric multidimensional scaling (NMS) to assess relationships of plant communities among sites. Secondly, we used multi-response permutation procedures (MRPP) to test whether plant-community differences existed among either hydrogeomophic valley types or vegetation types. To increase the value of these comparisons for management, we used indicator species analyses to quantify the indicator value of each individual plant species for separating groups.

In contrast to the more incised riparian channels of central Nevada, we observed knickzones, downcutting, and incision only rarely and usually with limited extent in the walking surveys. Downcutting occurred most frequently and extensively in Strawberry and Snake creeks, due in part to their more erodible soils. According to a hydrogeomorphologist with extensive experience in Great Basin riparian systems, the sediment-delivery and hydrologic systems appeared relatively undisturbed in most reaches, with respect to grazing animals and other types of anthropogenic alteration. Site elevation of the 31 transects ranged from 1,950-2,987 m, and stream slope (i.e., gradient) was relatively steep (mean = 9.3%, range 3-16%). Strawberry Creek averaged the lowest maximum water depth, and correspondingly had greatest width/depth ratios. Baker Creek sites averaged the smallest amount of tree-canopy gaps, whereas Snake Creek sites on average had the largest proportion of gaps in understory vegetation. Sites in terrace-bound valley types averaged the lowest slope in the

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channel as well as the least cover of trees, litter, and vegetation overall, whereas alluviated, boulder-bed canyon sites averaged the greatest widths of the active channel. Sites in Lehman Creek averaged nearly twice as much coarse woody debris as sites from any other creek, whereas Baker Creek sites averaged greatest tree cover (mean = 67%, range 40 – 96%) and species richness (mean = 17.3 species). Multivariate ordinations suggested that sites in leveed outwash valleys and alluvial-fan-influenced valleys had the greatest inter-site heterogeneity in plant composition, whereas sites in incised moraine-filled valleys appeared most homogeneous. Differences among homogeneity of sites within vegetation types were less pronounced, but sites dominated by either aspen and Woods' rose or narrow-leaved cottonwood had the most similar plant communities among sites of the same vegetation type. A number of species were faithful indicators of various valley and vegetation types, using either set of plant-frequency data. We estimate that all 31 sites could be subsequently re-sampled in 14-18 field days by individuals possessing familiarity of the riparian flora of the southern Snake Range. As with any research, monitoring-focused investigations must balance the concerns for number of ecosystem attributes measured, extensiveness in time and space of sampling periods and locations, and the time and cost of sampling.

Introduction

In semiarid regions such as the Great Basin, riparian areas serve as the interface between aquatic and terrestrial ecosystems, and represent the product of hydraulic forces, historic and contemporary anthropogenic influences, and underlying geomorphology. Riparian geomorphology and, consequently, riparian vegetation are intrinsically dynamic in that aggradation and degradation are natural processes expected within some geophysical units along a stream (Auble and Scott 1998). In some cases, the magnitude of natural channel evolution that occurs due to residual effects of paleological influences can eclipse changes due to management or that are otherwise human-induced (Chambers et al. 1998, Miller et al. 2001). Many plant taxa require bank scouring or other aspects of peak-flow events for their establishment and subsequent germination. Timing, magnitude, and duration of rare peak-flow events may have dominant effects on steam geomorphology in arid and semiarid regions (Baker 1977).

In concert with these natural disturbances, a host of anthropogenic influences have altered the structure, composition, and function of riparian ecosystems in the western United States. In the Great Basin in particular, water diversions, nearby roads, historic and contemporary mining, logging, conversion to agriculture, local eradication of beaver, heavy recreational use, introduction of exotic plant and animal species, fire exclusion, dams, and improper livestock management have all affected riparian ecosystems (Skovlin 1984, Lee et al. 1997, Belsky et al. 1999, Trombulak and Frissell 2000). Of these factors, many authors have charged improper livestock grazing as the most pervasive source of upland and riparian habitat degradation in the western United States (Elmore and Kauffman 1994, Ohmart 1996, Belsky 1999). Recovery from improper grazing management in arid and semiarid ecoregions can be protracted, occurring only after sometimes significant time lags (Buckhouse et al. 1981, Ohmart 1996, Sarr et al. 1996).

Although riparian areas comprise one of the most drastically altered community types over the last 150 years on federal lands in the Intermountain West of North America, they remain the most biologically diverse (Hessburg et al. 1999). Because of their relatively abundant shade, water, and nutrients, riparian zones act as focal points for many taxa that occupy these habitats either obligately or facultatively (Bull 1978, Thomas 1979, Gregory et al. 1991). However, authors have only recently acknowledged the importance of riparian habitat for birds, fishes, and other taxa in the context of adjacent uplands and the surrounding matrix, and consequently have argued for simultaneous monitoring of riparian and adjacent upland communities that incorporates both physical and vegetative parameters (Murphy and Meehan 1991, Block and Brennan 1993, Belsky et al. 1999).

In Great Basin National Park (GBNP), riparian areas and the taxa that inhabit them constitute one of the main management and monitoring foci in the park (Williams et al. 1999), in part due to recent efforts to reintroduce Bonneville cutthroat trout populations. Smith et al. (1994) performed ordination of 229 stands in eight park watersheds, and found that woody vegetative composition was highly correlated with site elevation and slope as well as channel pattern, terrace width, and flow state. Furthermore, controls on vegetative composition varied among the Baker, Big Wash, Lehman, and Snake watersheds when stands within a single watershed were analyzed independently with TWINSPAN (Smith et al. 1994). In these analyses of individual streams, aspect, flow conditions, valley form, and texture of the valley fill alternatively determined stand composition in various watersheds, but elevation was the strongest determinant of vegetation across all four watersheds (Smith et al. 1994). Frissell and Liss (1993) mapped valley segments (defined as "the stream channels and the portion of the adjacent valley floor and slopes with which the channels interact over a time frame of thousands or tens of thousands of years") in nine streams in the park as a result of sampling at 191 sites and subsequent map interpretation. Despite this work, riparian vegetation has not been explicitly mapped in park watersheds, and soils for all riparian areas are classified into a single soil series. Repeat sampling in 2001 of ten permanent plots established by Smith et al. (1994) proved to be of limited use (Beever et al. *in press*), because results were confounded by potential differences in the methods, which were vaguely stated originally. Furthermore, ten plots across four watersheds provide the park with little statistical power to detect concerted change in park riparian systems over time.

Thus, the objectives of this research program were to: 1) map riparian vegetative communities in greater detail than had been done by past GAP projects or by Smith et al. (1994); 2) provide, within dominant geomorphic and vegetative strata, a monitoring baseline of hydrogeomorphology; structure, composition and function of upland- and riparian-associated vegetation; and potentially management-sensitive edaphic properties; and 3) test whether instream conditions and physiographic covariates clearly predicted accompanying vegetation patterns across the four target streams. Secondarily, we sought to consider, to the extent possible, the magnitude of change in stream conditions that may be detected with different levels of sampling intensity.

Study Area: Geologic, Geomorphic, and Ecological Setting

The hydrographic Great Basin of western North America consists of a series of north-south trending mountain ranges between the Sierra Nevada and Rocky Mountains, where the entire area drains internally rather than flowing to an ocean. Each mountain range contains a unique mix of coniferous trees, birds, butterflies, montane mammals, poorly dispersing herbaceous plants, and a diversity of other taxa (Brown 1971, Johnson 1978, Wilcox et al. 1986, Charlet 1996, Lawlor 1998). On a percentage basis, the Great Basin contains more public lands than any other ecoregion in the contiguous United States, and consequently it represents an important opportunity for conservation of biological diversity. This fact, combined with the large number and spatial extent of wilderness and roadless areas in and adjacent to the Basin, suggest that the region may be increasingly relied upon as a reservoir of biodiversity in future decades (Newmark 1995, Holling and Meffe 1996).

The Snake Range contains some of the highest areas of the interior Great Basin, and has a relief of nearly 2,500 m. The north-south-trending ridge is cut roughly in half by Hwy 50, with the southern portion dominated by Great Basin National Park, which was established as a National Park Service unit in 1981. The range encompasses extensive areas of talus, several groves of long-lived bristlecone pine trees, a diversity of insects, a distinctive flora with strong Rocky-Mountain influence (e.g., Charlet 1996), patches of limestone substrates, and impressive geologic features. Additionally, riparian areas of the range are distinct from the more severely incised streams dominant in the interior Great Basin. Sheep grazing has been reported to have been heavy across the eastern edge of Nevada during 1890-1920 (Young and Sparks 2002), and plenty of evidence of Basque sheepherders' presence in the park remains etched in trunks of aspen (*Populus tremuloides*) trees (E. Beever, *pers. obs.*, Mallea-Olaetxe 2000). Cattle grazing occurred in the area of the park from the 1860s (Eddleman and Jaindl 1994) until the National Park Service terminated grazing permits in 1999 due to conflicts with other park uses. Domestic sheep were similarly considered for removal from the park around 2002, but had yet to be removed as of September 2004 (G. Baker [Ecologist, GBNP], *pers. comm.*).

Research was conducted at 31 transects across streams in four watersheds on the eastern side of the southern Snake Range in east-central Nevada, in the park. Transects were established along Strawberry, Lehman, Baker, and Snake creeks, because roads adjacent to these streams should facilitate re-sampling over time. However, given that not all stream segments in the park are near roads, this may mean that the sampled transects are not representative of all streams in the park. Preliminary sampling for mapping vegetation associations ranged in elevation from 1,890 to 3,080 m (with transects located from 1,950 to 3,000 m), but elevations within these drainages vary from 3,968 m at Wheeler Peak down to the Snake Valley floor at 1,510 m. Stream gradients of all four creeks were similar, and were in the range of A- and B-type streams in Rosgen's (1985) classification system. The hydrogeomorphology for the upper reaches of three of the four creeks was that of an incised moraine-filled valley, whereas Strawberry Creek was classified as an alluvial system and resembled the downstream reaches of Snake and Baker creeks (Table 1, Figure 1). Active channel width in mid-summer averaged from 1-3 m, but the channel was significantly braided in many locations (E. Beever, *pers. obs.*). Precipitation on the east side of the Snake Range varies from 65.5 cm/yr at 3,182 m elevation to 33.3 cm/yr at 2,081 m elevation to 19.3 cm/yr at the valley floor (Garrison, UT; 1,518 m elevation) (Western Regional Climate Center online data, Reno, NV). Much of the winter precipitation falls as snow.

Although watersheds varied in plant species composition, upland vegetation bordering riparian corridors typically transitioned from salt-scrub to big sagebrush communities below the park boundary, to pinyon-juniper-big sagebrush, ponderosa pine, white fir-douglas fir, mountain mahogany, aspen, and Engelman spruce communities as elevation increased (Figure 1; scientific names for these species occur in Appendix A). Soils in the park generally, and in the study watersheds in particular, are derived primarily from granitic or limestone parent rock material (SCS 1992). Although the Brokit Series encompassed only 0.6% of the park area, it was assigned to all riparian areas in the park, despite notable spatial heterogeneity in riparian vegetation and likely in associated soils (Smith et al. 1994; E. Beever, *pers. obs.*).

Table 1. Physiographic and hydrogeomorphic characteristics of each transect, and averages of values in each of four target watersheds in Great Basin National Park, Snake Range, NV. Julian sampling date followed the calendar year, beginning at Day 1 on 1 January 2002. Drainage area was calculated in ARC/INFO, as delineated in the text.

Transect	Hydrogeomorphic classification[a]	Dominant canopy species	Classification of vegetation types	Elevation (m)	Elevation (ft)	Tag # attached to rebar endpoint
BK1	ACB	POTR/PIEN/ABCO	5	2664	8740	28
BK2	ACB	POTR/PIEN/ABCO	5	2634	8641	29
BK3	LOV	POTR/ABCO	4	2486	8157	30
BK4	LOV	POTR/ABCO	4	2487	8160	31
BK5	LOV	BEOC/POTR/ABCO	4	2303	7557	25
BK6	LOV	BEOC/POTR	6	2286	7500	24
BK7	ACB/LOV	POTR/ABCO/SALsp/PIMO	4	2204	7230	27
BK8	ACB	PIMO/POTR/ROWO/ARTR	1	2160	7085	26
Mean, Baker Creek sites				2403	7884	
LM1	IMV	PIEN/POTR/PIFL	5	2947	9670	18
LM2	IMV	PIEN/POTR/PIFL	5	2987	9800	19
LM3	LOV	POTR/SALSP/PJ/ROWO	2	2204	7230	20
LM4	LOV	POTR/PJ/ROWO	2	2219	7280	21
LM5	LOV	ABCO/POTR	4	2551	8370	22
LM6	LOV	POTR/ABCO (ARTR/CELE upland)	4	2356	7730	23
Mean, Lehman Creek sites				2544	8347	
SN1	TBV	POAN - PJ/ARTR	3	1950	6397	4
SN2	TBV	POAN/ROWO/BEOC	3	1950	6399	5
SN3	AFV	PIEN/ABCO/PIFL/POTR	5	2563	8410	6
SN4	AFV	PIEN/ABCO/PIFL/POTR	5	2593	8508	7
SN5	ACG	POTR/ROWO/POAN/ABCO	2	2304	7559	8
SN6	ACG	POTR/ROWO/POAN/ABCO (PJ/ARTR upland)	2	2592	8505	9
SN7	AFV	POAN/BEOC/PJ/ARTR	3	2048	6720	10
SN8	AFV	POAN/BEOC/PJ/ARTR	3	2041	6696	11
Mean, Snake Creek sites				2255	7399	
ST1	AFV	PIMO/POTR/BEOC/ROWO	1	2351	7714	1
ST2	AFV	PIMO/POTR/BEOC/ROWO	1	2381	7812	2
ST3	AFV	PIMO/POTR/BEOC/ROWO	1	2353	7720	3
ST4	ACG	POTR/PIEN/ARTR	5	2580	8465	12
ST5	ACG	POTR/PIEN/ABCO	5	2576	8450	13
ST6	AFV	POTR/ABCO (ARTR uplnd)	4	2399	7870	14
ST7	AFV	POTR/PIMO/BEOC/SALSP/ARTR	1	2317	7600	15
ST8	AV	BEOC/SALSP (PJ/ARTR)	6	2148	7048	16
ST9	AV	BEOC/SALSP (PJ/ARTR/ROWO)	6	2216	7270	17
Mean, Strawberry Creek sites				2369	7772	
GRAND MEAN				**2382**	**7816**	

[a] Classification of valley segment, following Frissell and Liss (1993). **ACB** = alluviated canyon, boulder-bed; **ACG** = alluviated canyon, gravel-cobble-bed; **IMV** = incised moraine-filled valley; **TBV** = terrace-bound valley; **LOV** = leveed outwash valley; **AV** = alluvial valley; **AFV** = alluvial fan-influenced valley.

[b] No water aboveground; piped for agriculture to valley below.

Table 1. Physiographic and hydrogeomorphic characteristics of each transect, and averages of values in each of four target watersheds in Great Basin National Park, Snake Range, NV. Julian sampling date followed the calendar year, beginning at Day 1 on 1 January 2002. Drainage area was calculated in ARC/INFO, as delineated in the text.—Continued

Transect	Hydrogeomorphic classification[a]	Julian sampling date, 2002	Stream aspect (deg)	Transect aspect (deg)	Slope gradient (%), upstream	Slope gradient (%), downstream	Avg. slope gradient (%)
BK1	ACB	225	105	197	10	14.5	12.25
BK2	ACB	225	76	158	15	10	12.5
BK3	LOV	226	85	170	15	14	14.5
BK4	LOV	226	30	125	9	7	8
BK5	LOV	223	74	156	13	11	12
BK6	LOV	225	114	185	7		7
BK7	ACB/LOV	224	70	153	4.5	3	3.75
BK8	ACB	224	169	238	4	15	9.5
Mean, Baker Creek sites		224.8			9.7	10.6	9.9
LM1	IMV	220	96	184	12.5	12	12.25
LM2	IMV	220	28	125	11	13	12
LM3	LOV	221	57	145	12	8	10
LM4	LOV	221	61	128	8	7	7.5
LM5	LOV	222	124	35	14	18	16
LM6	LOV	222	116	18	10	7	8.5
Mean, Lehman Creek sites		221		106	11.3	10.8	11.0
SN1	TBV	209	68	344	5	6	5.5
SN2	TBV	209	16	282			
SN3	AFV	210	102	208	8	10	9
SN4	AFV	210	310	233	14	13	13.5
SN5	ACG	211	350	274	1	5	3
SN6	ACG	211		196	12	3	7.5
SN7	AFV	212	288	200	8	6	7
SN8	AFV	212	307	222.5	5	7	6
Mean, Snake Creek sites		210.5			7.6	7.1	7.4
ST1	AFV	206	279	14	7	9	8
ST2	AFV	207	279	14	7	9	8
ST3	AFV	208	75	1	8	7	7.5
ST4	ACG	217	200	114	13	15	14
ST5	ACG	217	7	112	11	12	11.5
ST6	AFV	218		109	3.5	14	8.75
ST7	AFV	218	120	11	10	10	10
ST8	AV	219	73	357	6	6	6
ST9	AV	219	113	352	8	8	8
Mean, Strawberry Creek sites		214.3			8.2	10.0	9.1
GRAND MEAN		**217.3**			**9.1**	**9.6**	**9.3**

[a] Classification of valley segment, following Frissell and Liss (1993). **ACB** = alluviated canyon, boulder-bed; **ACG** = alluviated canyon, gravel-cobble-bed; **IMV** = incised moraine-filled valley; **TBV** = terrace-bound valley; **LOV** = leveed outwash valley; **AV** = alluvial valley; **AFV** = alluvial fan-influenced valley.

[b] No water aboveground; piped for agriculture to valley below.

Table 1. Physiographic and hydrogeomorphic characteristics of each transect, and averages of values in each of four target watersheds in Great Basin National Park, Snake Range, NV. Julian sampling date followed the calendar year, beginning at Day 1 on 1 January 2002. Drainage area was calculated in ARC/INFO, as delineated in the text.—Continued

Transect	Hydrogeomorphic classification[a]	Drainage area (ha)	Active channel width (m)	Channel width, bankfull (m)	Max. water depth (m)	Width/depth ratio [active channel]	Width/depth ratio [bankfull]
BK1	ACB	1442.3	3.6	4.31	0.234	15.41	18.44
BK2	ACB	1450.5	7.42	9.56	0.305	24.34	31.36
BK3	LOV	1468.0	3.88	8.43	0.241	16.08	34.94
BK4	LOV	2263.6	4.65	5.94	0.267	17.44	22.27
BK5	LOV	2629.5	1.52	4.12	0.191	7.98	21.63
BK6	LOV	2639.6	3.38	4.05	0.146	23.14	27.73
BK7	ACB/LOV	3271.8	2.98	6.75	0.298	9.99	22.62
BK8	ACB	3287.7	4.21	7.00	0.338	12.46	20.72
Mean, Baker Creek sites		2306.6	3.96	6.27	0.252	15.85	24.96
LM1	IMV	471.2	2.51	4.63	0.152	16.47	30.38
LM2	IMV	451.7	4.4	6.07	0.117	37.66	51.95
LM3	LOV	2188.8	2.83	5.90	0.244	11.61	24.20
LM4	LOV	2162.7	3.85	4.80	0.286	13.47	16.80
LM5	LOV	1251.2	2.74	4.02	0.257	10.68	15.67
LM6	LOV	1964.0	4.25	6.15	0.267	15.94	23.06
Mean, Lehman Creek sites		1414.9	3.40	5.30	0.200	17.64	27.01
SN1	TBV	5335.5	1.18	4.47	0.160	7.37	27.93
SN2	TBV	449.2	1.97		0.133	14.77	0.00
SN3	AFV	5339.6	1.79	4.22	0.150	11.94	28.16
SN4	AFV	449.2	1.39	4.15	0.112	12.44	37.13
SN5	ACG	2554.3	0[b]	4.85	0[b]	N/A	N/A
SN6	ACG	2559.7	0[b]	4.95	0[b]	N/A	N/A
SN7	AFV	4345.7	2.59	4.40	0.191	13.60	23.01
SN8	AFV	4360.1	2.16	3.00	0.210	10.31	14.32
Mean, Snake Creek sites		3174.2	1.85	4.29	0.159	11.74	21.77
ST1	AFV	1245.8	4.23	4.97	0.054	78.37	92.08
ST2	AFV	1212.9	0.77	3.47	0.061	12.63	56.92
ST3	AFV	1241.3	0.64	3.44	0.044	14.40	77.39
ST4	ACG	551.4	1.55	3.30	0.044	34.87	74.24
ST5	ACG	552.7	2.61	3.12	0.032	82.21	98.27
ST6	AFV	747.6	1.73	9.32	0.053	32.43	174.73
ST7	AFV	1295.7	1.05	4.10	0.044	23.62	92.24
ST8	AV	1843.3	1.29	3.50	0.089	14.51	39.37
ST9	AV	1675.2	1.64	4.65	0.080	20.50	58.12
Mean, Strawberry Creek sites		1151.8	1.72	4.43	0.056	34.84	84.82
GRAND MEAN			**2.72**	**5.05**	**0.165**	**21.26**	**43.30**

[a] Classification of valley segment, following Frissell and Liss (1993). **ACB** = alluviated canyon, boulder-bed; **ACG** = alluviated canyon, gravel-cobble-bed; **IMV** = incised moraine-filled valley; **TBV** = terrace-bound valley; **LOV** = leveed outwash valley; **AV** = alluvial valley; **AFV** = alluvial fan-influenced valley.

[b] No water aboveground; piped for agriculture to valley below.

Figures 1a,b,c. Map of transects sampled in a) Strawberry, b) Baker and Lehman creeks, and c) Snake Creek, Great Basin National Park, southern Snake Range, Elko Co. Nevada. The image is derived from binned GAP vegetation data overlaid on a digital orthophotoquad image, supplemented by GIS coverages of hydrography and roads. Valley segments within stream corridors are divided into hydrogeologic units mapped for the creeks by Frissell and Liss (1993). Our plots from 2001 (denoted with "PP#") and 2002 sampling appear in all four watersheds.

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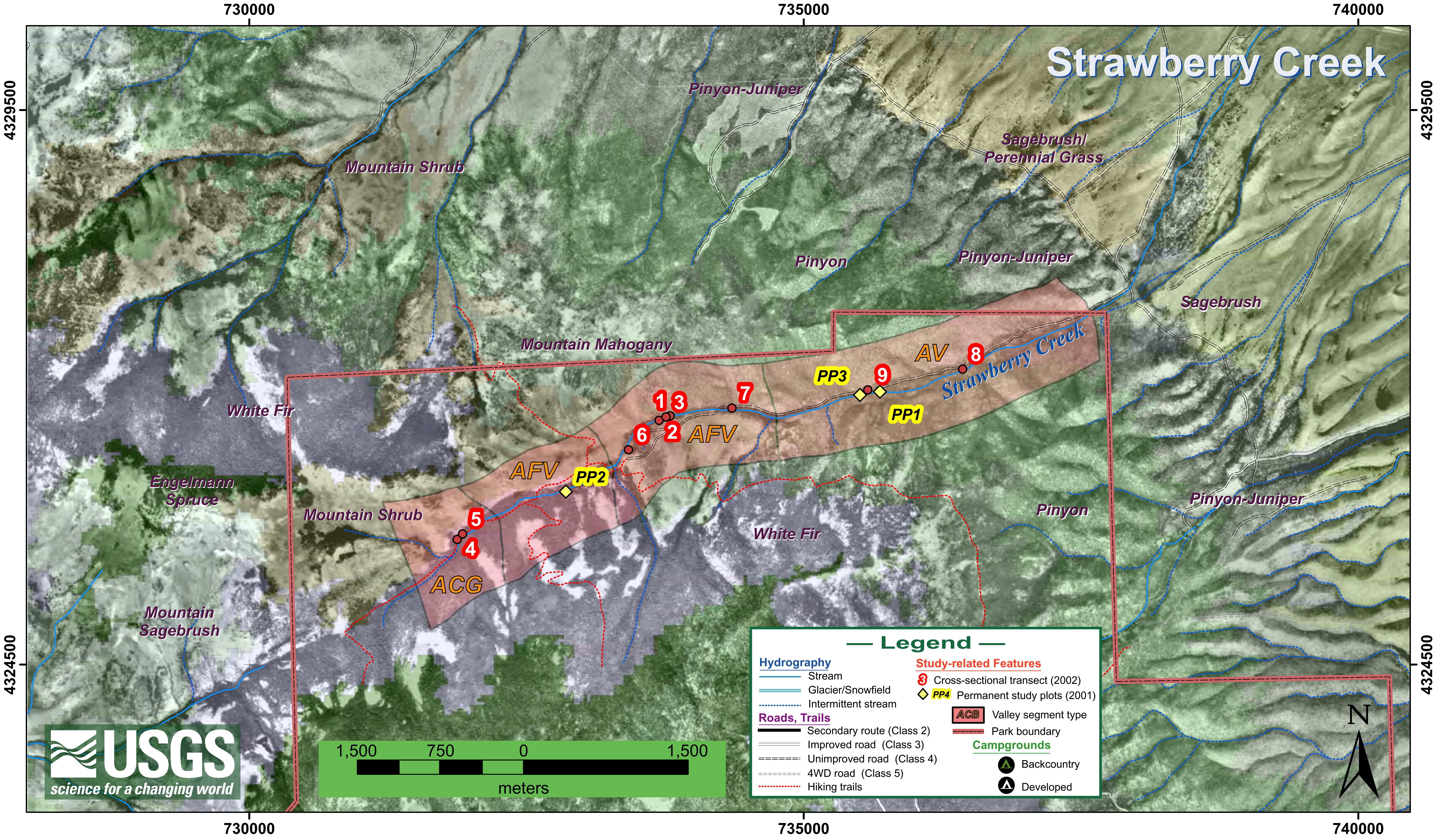

Figures 1a,b,c. Map of transects sampled in a) Strawberry, b) Baker and Lehman creeks, and c) Snake Creek, Great Basin National Park, southern Snake Range, Elko Co. Nevada. The image is derived from binned GAP vegetation data overlaid on a digital orthophotoquad image, supplemented by GIS coverages of hydrography and roads. Valley segments within stream corridors are divided into hydrogeologic units mapped for the creeks by Frissell and Liss (1993). Our plots from 2001 (denoted with "PP#") and 2002 sampling appear in all four watersheds.—Continued

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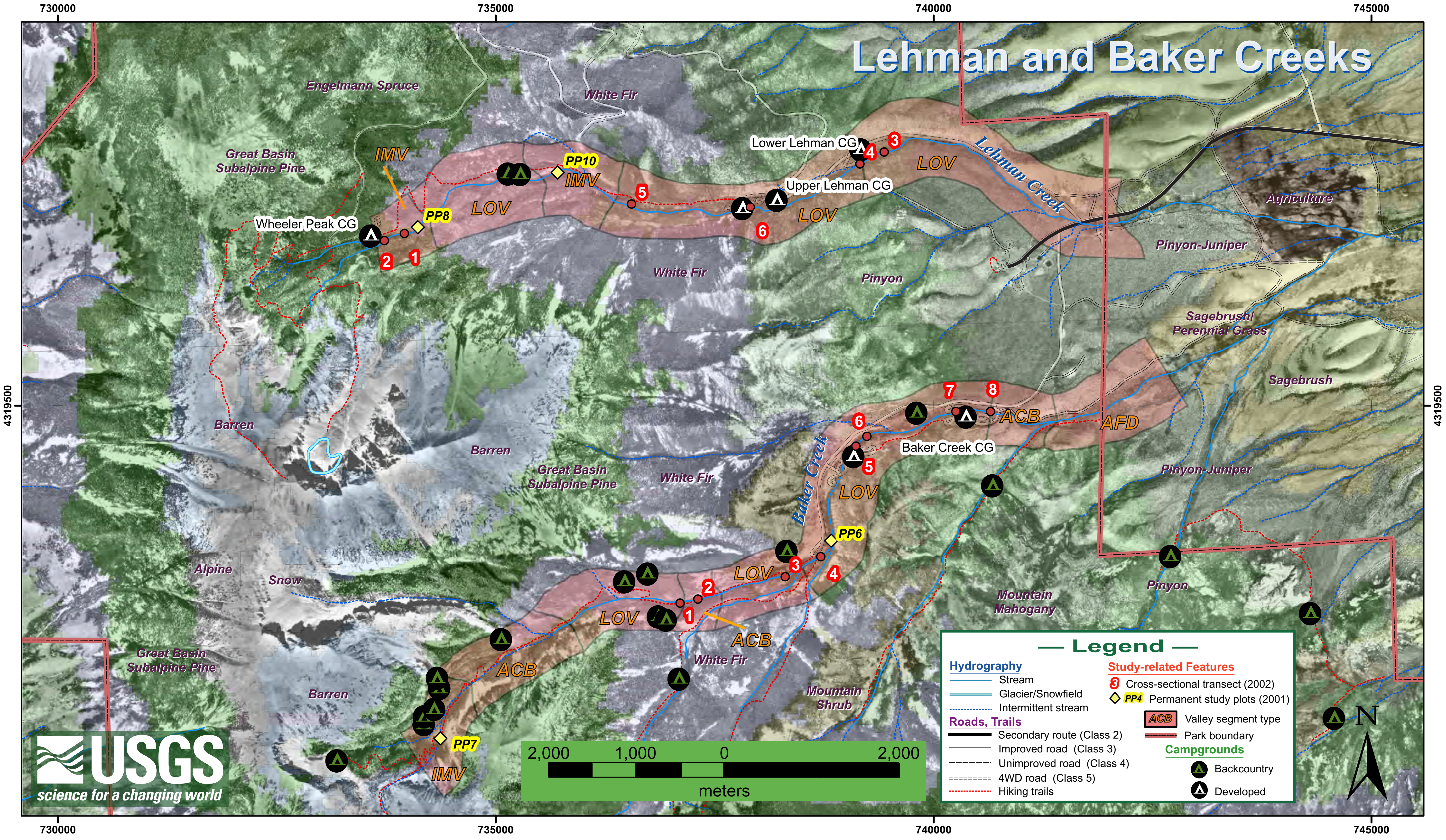

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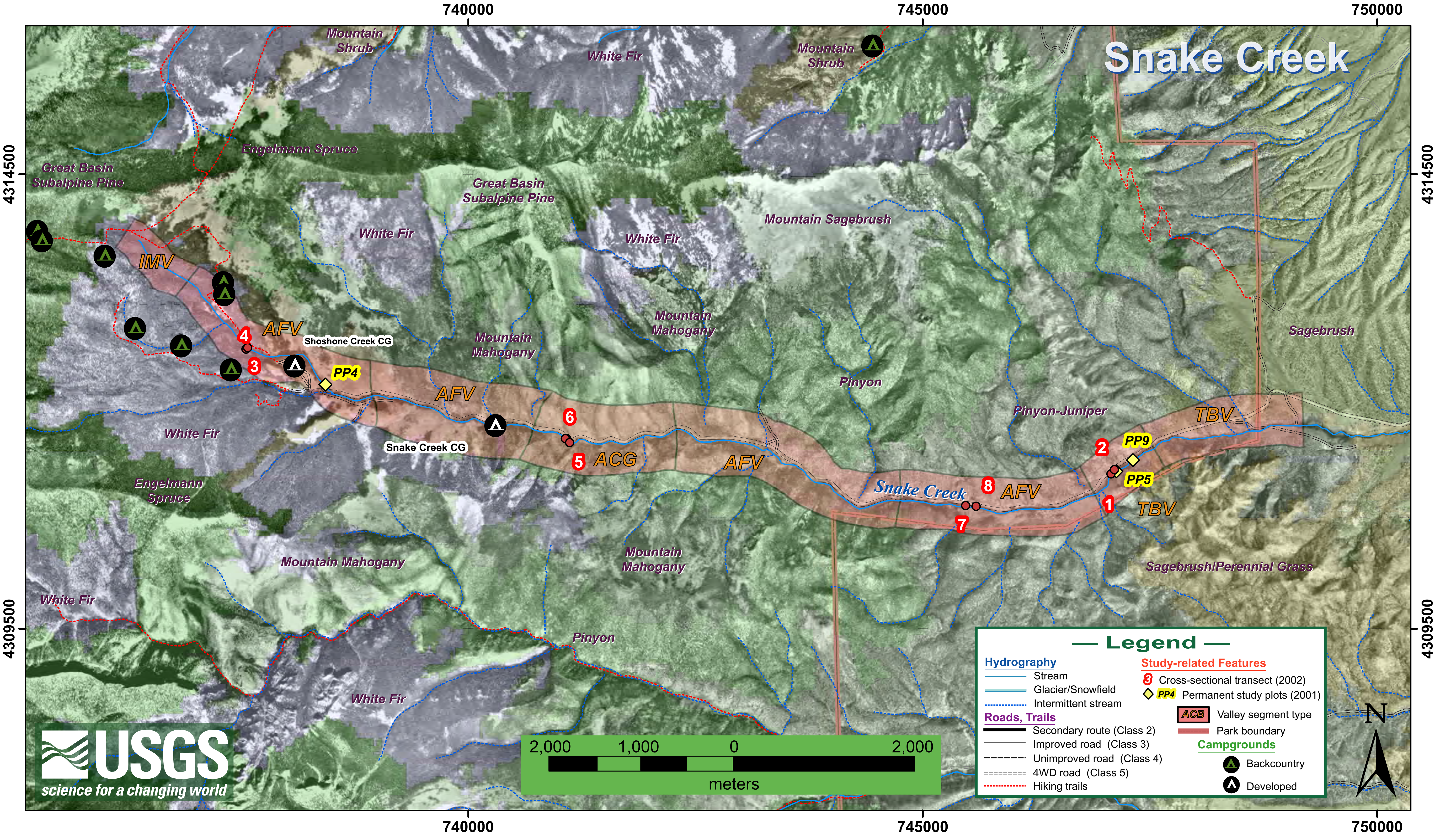


Methods

Walking surveys of target watersheds

We used several methods to allocate our sampling among the various vegetative and geomorphic units present in our four watersheds. We first attempted to define sampling units by comparing aerial photographic images (orthophotoquads) with a mapped GAP vegetation GIS coverage. This proved to be too coarse-grained to extract meaningful information, and was instead used solely to confirm and corroborate selections derived from other methods.

We thus performed walking transects in each of Strawberry, Lehman, Baker, and Snake Creek watersheds, starting from the lower-elevation boundary of the park and continuing to either the headwaters or as far as logistics permitted surveying. Each stream was divided into sections of approximately 0.32 km. In Strawberry Creek, we used the vehicle odometer along the road that runs adjacent to the stream to delineate 0.32-km segments. In the remaining creeks, we began sampling at the low-elevation park boundary, and used a handheld global positioning system (GPS) unit (Magellan Map 330; not differentially corrected) to ascertain when we had traveled an additional 0.32 km from the start point. Distances for this latter method were all measured from the first start point, rather than segment-by-segment. Because both methods use straight-line distance, increased stream sinuosity or changes in stream azimuth mean that distances strictly along the watercourse exceed 0.32 km. However, mainstems for all four creeks are nearly linear, minimizing the importance of this difference. Sampling occurred during 18-26 July and 13 August 2002.

We sampled only along the mainstem in each of the four watersheds, identified by 1:100,000-scale maps and Frissell and Liss' (1993) sampling. Within each segment, we used ocular estimation to rank by cover the dominant shrub and tree species, independently on each side of the stream. We merged data across sides of the stream if there was no heterogeneity in plant composition from one side to the other and where there was no aboveground water flow. Because our cross-sectional sampling in these watersheds spans from the waterway through the riparian corridor to the surrounding uplands, we divided species into riparian-associated species (usually 3 to 5 m from water's edge, depending on channel and bank morphology) and upland species (usually from 3-5 m to 30 m from water's edge). In addition to using known riparian obligates to distinguish the two groups of species, riparian zones tended to remain green throughout the summer, due to their connection via their roots to the stream or hyporheic zone. Two exceptions to this distinction were *Rhus aromatica* var. *trilobata* and *Rosa woodsii*, which often occurred at distances 3-8 m from the stream edge. We included these two species in riparian lists, because they often penetrated the outer edge of the zone of riparian-associated species. These data appear in Appendix A, as do the position and elevation of most segment endpoints. We also noted the lowest-elevation occurrence that we encountered for each tree species in each watershed (Appendices A, B) and notable features along each mainstem (Appendix B).

Site selection: location of transects

These vegetation surveys identified locations along streams where there occurred detectable shifts in vegetative community, particularly in dominant species. To establish cross-sectional transects, we first allocated samples among different hydrogeomorphic units mapped in our target watersheds by Frissell and Liss (1993). We sought to maximize the diversity of hydrogeomorphic units that we sampled, rather than sample repeatedly the same unit in the same drainage that occurred in several elevational bands. Within these bands, we avoided boundary areas between adjacent hydrogeomorphic units, and secondarily placed transects well within one or two of the dominant vegetative communities located within the selected hydrogeomorphic units. At finer scales, because we sought to provide an early-warning monitoring perspective, we often placed transects where bank erosion had already begun or where significant recreation influence might be expected in current and future years.

To address the adequacy of different sampling intensities within a hydrogeomorphic-vegetative combination, we sampled from two (in most cases) to five transects in these combinations. Transects were placed to represent vegetative conditions throughout the combination, and were located at least 50 m from other transects except in the five-transect combination. At the finest scale, transects were placed perpendicular (or nearly so) to the stream in riffle sections of reaches. In total, we sampled eight transects from four vegetative-hydrogeomorphic strata in each of Snake and Baker creeks, six transects from three vegetative-hydrogeomorphic strata in Lehman Creek, and nine transects from three vegetative-hydrogeomorphic strata in Strawberry Creek.

Sampling methods for transects

Our sampling integrated information on hydrogeomorphology, vulnerability of slopes to erosion by wind and water, stream-obligate vegetation, and upland vegetation. Methods we employed generally followed Harrelson et al. (1994) and Herrick et al. (*in press*).

Cross-sections – In order to track hydrogeomorphic evolution over time within the channel, we mapped an approximation of cross-sectional stream geometry using the height from a permanently marked reference point to both the water surface and channel bottom (following Herrick et al. *in press*). We placed the transect endpoints well outside the 100-yr floodplain (and usually more than 2 m from the stream edge). We determined this floodplain following Harrelson et al. (1994), using characteristics such as existing terraces. Endpoints consisted of 3/8”-diameter, 4’ long rebar pounded into the soil as far as feasible yet still permitting a nylon string to travel taut between the endpoints at the same height. We marked the height of the string on each endpoint with a notch from a hacksaw blade, and used a clinometer at string level on one endpoint to choose the height of the notch on the second rebar. A third observer 5-10 m upstream confirmed that the string was level. The 0-m end of the transect occurred on the south side of the stream; transect length varied from 4 to 17.5 m. Beginning at the 0-m end, and every 20 cm across the transect, we measured distance from the string to the water surface and to the bottom of the channel (or simply to the soil surface if not over water). We also noted the location along the string of the wetted edge and bankfull position on both the north and south edges of the stream, following Harrelson et al. (1994). To obtain width/depth ratios, we additionally noted the position along the string of the maximum water depth and the corresponding heights (to water surface and channel bottom). Due to logistical and financial constraints, we did not measure elevations with a surveyor's level, as suggested by Harrelson et al. (1994). We argue, however, that the method employed was suitable to achieve the study objectives, and permitted more extensive sampling in the small amount of field time available. Graphical, quantitative representations of these cross-sections appear in Appendix E.

50-m integrated transect – To permit monitoring of dynamics of both riparian and adjacent upland vegetation, we used duct tape to secure the center (25-m point) of a 50-m fiberglass reel tape to the center of the cross-sectional string. We then pulled taut the ends of the 50-m tape along the same azimuth of the short transect and pounded in another piece of 3/8"-diameter rebar to 15-25 cm height (above ground) at each end of the 50-m transect. When necessary, we threaded the tape under vegetation to minimize its height above the ground. We measured the azimuth of the transect and of the 10-m segment of the stream centered at the transect with a handheld compass.

All four pieces of rebar were topped with a small yellow rebar cap and their locations recorded with a differentially corrected GPS unit. We wrapped pink-and-black-striped ribbon around many endpoints to facilitate their relocation. Furthermore, we noted distance from three prominent landmarks (thoroughly described in our notes, which are summarized in Appendix C, right column) to further assist in plot re-location. GPS locations of each piece of rebar, generally four per site, appear in Appendix C. Following Harrelson et al. (1994), we took six digital photographs per transect as photo points of the stream, each 5 m from the point of interest. Each point of interest was accompanied by a 1.5-m-tall PVC pole with 10-cm alternating black-and-white stripes to provide a reference scale. Four of these photopoints consisted of the four rebar endpoints, photographed 5 m further from the stream than the rebar; the remaining two photopoints included upstream and downstream views of the transect centerpoint, each 5 m away.

To measure percent cover of litter, woody vegetation, and total vegetative cover, as well as minimum estimates of plant species richness, we used ***point-intercept transects*** (Herrick et al. *in press*). Beginning at the 0-m mark and each 1 m thereafter, we recorded each species that touched a sampling pin (10-gauge rod) placed vertically at the point. The sampling pin extended upwards to include all tree species (using a clinometer to determine whether questionable trees occurred above the meter mark or not), understory shrubs and herbaceous species. The pin was also extended downward to include basal cover categories (e.g., plant base, moss, lichens, water, rock, litter, cryptobiotic crust, gravel, or soil). We defined t**otal cover** as the proportion of the 50 points that intercepted anything organic (i.e., anything except solely water, rock, soil, or gravel). **Total canopy cover** represented the percentage of the 50 points that intercepted at least one rooted plant, dead or live. **Litter** was defined as any unrooted material derived from organic sources, and the **minimum estimate of species richness** simply represented the count of different species that appeared anywhere in the transect.

We sought to characterize soil characteristics amenable to monitoring using impact penetrometers (to measure penetration resistance, a surrogate of soil compaction) and soil-stability kits, both following Herrick et al. (*in press*). Unfortunately, however, neither method appeared to be appropriate for use in park riparian cross-sections. ***Impact penetrometers*** require that soils be dried to field capacity to the depth to which compaction might be expected. This did not happen during 2002, due to the frequent precipitation that kept upland soils moist. Penetrometer measurements also require that soils be relatively rock- and boulder-free, which is generally not true in park riparian areas and lateral slopes (Frissell and Liss 1993, E. Beever, *pers. obs.*). We did not continue ***soil-stability*** sampling after pilot sampling found that extensiveness of plant litter and subsurface rocks prevented repeatable sampling at regularly spaced intervals (Appendix D).

Gap-intercept transects (*sensu* Herrick et al. *in press*) measure the number and extent of gaps in vegetative canopy or plant bases along a line transect, thus indexing a site's vulnerability to erosion by wind or water, respectively.
The minimum-length criterion was defined to be 20 cm for ***understory*** (grasses, forbs, shrubs, and tree biomass occurring below 3 m height) ***canopy gaps***. The end of gaps was defined as any vegetation which covered at least 50% of a 3-cm segment. We recorded starting and ending positions of gaps to the nearest cm along the 50-m transect by sliding a sampling pin (10-gauge rod, ~1 m long) along the left edge of the tape while walking from 0 to 50 m on the right side of the tape. Starting and ending points of ***tree-canopy gaps*** were recorded to the nearest 0.1 m by looking directly above the line (at 90°) with a clinometer. Minimum-length criterion for tree-canopy gaps was 1.0 m. ***Basal gaps*** were measured by dragging the sampling pin along the ground on the left edge of the tape. Minimum gap length was again 20 cm, and a gap was ended by interception of any plant base under one side of the transect line (i.e., shrub base, tree root, any herbaceous stem at ground level). Past research (e.g., Lavee and Poesen 1991, Herrick et al. 2002) has shown that the larger the gap size, the greater the vulnerability to erosion by wind or water. Consequently, we

measured the proportion of the line occupied by gaps greater than the threshold lengths of 25 cm, 50 cm, 1 m, and 2 m (following Herrick et al. *in press*).

Within the bankfull channel, we performed ***pebble counts*** (Wolman 1954) in the riffle zone near the transect to characterize the grain size of the bed and bank material. Because of the narrow width of the channel (within which we sampled approximately three-fourths of our pebbles), we used a random-walk path rather than a step-toe procedure. After each step (in a random direction), we picked up the particle first touched when reaching 20 cm to the side of the boot tip, alternating to the left and right of the tip at each step. We measured length of the intermediate axis of the particle using a gravelometer with $^1/_2$ phi values for class intervals, for a total of 15 size classes (< 2 mm to > 180 mm). We measured 100 pebbles per transect, and did not replace pebbles immediately after sampling to ensure that pebbles were not re-counted. Because pebble counts and other monitored variables determine the stream's gradient (Hack 1957, Ritter et al. 2002), we used a handheld clinometer to obtain the channel slope from the center-point of the transect to points 10 m up- and downstream. We used the clinometer to also measure the lateral angle of the stream from the transect center to the endpoints of the 50-m transect.

Because of the strong role played by ***coarse woody debris*** in both fish-bearing and high-gradient streams as well as in affecting macroinvertebrates and other elements of aquatic biodiversity (Richmond and Fausch 1995, Hildebrand et al. 1997, Doloff and Warren 2003, Wondzell and Bisson 2003), we measured occurrence of logs greater than 10 cm in diameter that spanned more than $^1/_2$ of the width of the channel that was 'wet' at time of measurement within 5 m up- or downstream of the transect. Diameter was measured in the middle of the stream, and log length was measured as that portion of the log in or above the stream within the wetted edges of the stream (i.e., the part of the channel that was 'wet' at the time of sampling). Because flow volume in these streams will vary during the year with respect to the last occurrence of a rainfall-runoff event, these debris measurements are applicable only to this portion of the year. At worst, our estimates will underestimate the volume of woody debris that would be involved at peak flows. Nonetheless, we suspect that in most cases our debris variables would vary only slightly across the year, given the cross-sectional geometry of the streams.

To assess the ***frequency of woody species*** at transect locations, we noted which shrub and tree species occurred ***within*** 25 ***1-m²*** ***quadrats*** along each of two transects that ran parallel to the main 50-m transect, each 2 m either up- or downstream of the main transect. On each line, we alternated (synchronously between lines) whether the quadrat was placed on the right or left side of the secondary transect, such that the quadrats sampled areas from 1 to 3 m from the main transect. We started (at the 0-m point) and ended (at 50 m) on the left side, as one looked from the 0-m end towards the 50-m end. In practice, it was easier to define the sampling area by using two adjacent 1 m x 0.5 m quadrats rather than one 1-m by1-m quadrat.

To measure frequency of all plant species in park target streams and vegetative-hydrogeomorphic strata, we used nested-frequency plots (NFP) (Mueller-Dombois and Ellenberg 1974, McCawley and Smith 1986). The nested areas were 10 x 10 cm, 20 x 20 cm, 20 x 40 cm, and 40 x 40 cm. Measurements were again made on alternating sides of secondary transects 2 m up- and downstream from the main transect, synchronously on both transects. The smallest plot was always placed to the right side. The six points on the frame, used to calculate an overall summary of the relative proportions of basal vegetation, vegetative canopy, litter, bare ground, gravel or rocks, and cryptogamic crust, were the outermost corner of each of the four ends of PVC emanating from the base plus the two bottom outside corners of the frame. Species were only considered to occupy a given area if they were **rooted** within that plot. We placed the bottom part of the frame at the sampling mark, and the rest of the plot toward the 50-m end. On both lines, we started at 0 m on the left side (looking from 0 to 50 m), on the right side at 2 m, left side at 4 m, until sampling on the right side at 48 m. At Strawberry 1, the first transect sampled, we only measured plots to 38 m.

To assess the adequacy of our sampling effort to detect plant species at each site, we created species-accumulation curves at both our most species-rich and most species-poor transect for the NFP and 1-m² sampling techniques. The most species-rich and species-poor transects were selected by ranking among sites the average of the values of species richness obtained by the line-point-intercept, 1-m² frequency, and NFP (largest frame size) sampling techniques. Because the cross-sectional nature of our sampling dictated that new species were often found towards the end of the 50-m transects (given the stratification of the riparian zone and across-stream differences in upland vegetation community), we randomized the order of transects before creating each curve. Thus, we assessed the effect of increasing sampling effort rather than change of position among vegetative strata. Our amount of sampling seemed sufficient to detect species in the 1-m² sampling, because at least 83% of woody species were detected at the most species-rich site overall (BK5), most species-poor site (BK8), and most species-rich 1-m² site (SN6) within the first 19-28 samples (Appendix F). Species-accumulation curves for NFP sampling also suggested that our sampling effort was adequate, because curves tended to plateau around the middle range of sampling effort (although slightly less so for larger plot sizes at BK5 (Appendix F).

To explore correlations between variables hypothesized to be interrelated, we used correlations and Fisher's r to Z statistics to assess significance of the correlation. To assess which groups differed significantly from others in ANOVAs, we used Bonferroni-Dunn *post-hoc* comparisons, thus adjusting the critical alpha to reflect the multiple comparisons.

Multivariate analyses – We sought to assess the relationships of plant communities among sites, using NFP and 1-m² frequency data as the main data sources, with multivariate ordinations. Ordination is an analytical technique that condenses information from multiple-variable datasets into a small number of continuous composite variables (or axes) that express much of the information in the original data (McCune and Grace 2002). In our research, these datasets were composed of frequency of many individual species at each of the 31 sites, and the ultimate goal was to describe the strongest patterns in species composition. We chose nonmetric multidimensional scaling (NMS; Kruskal 1964, Mather 1976) to ordinate sites in species space using PC-ORD v4.0 (MjM Software, Gleneden Beach, OR).

We used the quantitative version of the Sørensen coefficient as our distance measure for the matrix of dissimilarity coefficients. In a preliminary analysis, we determined the dimensionality of the data set by exploring the first six axes, using an instability criterion of 0.0005, and compared 50 runs using the real data with 30 runs using randomized data (where data are shuffled within columns after each run) using a Monte Carlo test at each dimensionality. From a scree plot of final stress versus the number of dimensions, we selected the number of dimensions beyond which additional dimensions only slightly reduced stress. We then ran the analysis again using the selected dimensionality and the starting configuration that produced the lowest final stress, with one real run and no randomized runs.

NMS was preferable to other methods because of its three strengths: a) it is robust to data that are non-normal or on arbitrary or discontinuous scales; b) it uses ranked rather than absolute distances, and, therefore, it does not suffer from the "zero-truncation" problem; and c) it allows the use of any distance measure or relativization (McCune and Grace 2002). NMS works as an iterative search for the best positions of samples (sites) on *k* dimensions (axes) that minimizes the "stress" of the *k*-dimensional configuration (McCune and Grace 2002). Before ordinating the NFP and 1-m^2 frequency data, we removed species that occurred at less than 5% of sites (with $N = 31$, this meant species that occurred at only one site). These "singleton" species should not affect the relationships among sites, given that they are not shared by any sites.

We then desired to relate the graphical relationships among sites (i.e., the ordination scores) to a suite of topographic and hydrogeomorphic (hereafter, physical) variables. We achieved this using joint plots in PC-ORD, which are overlaid on ordinations. The angle of the line associated with each variable is defined by

$$\alpha = \arccos\,(r_x \bullet |r_x|)\ , \qquad (1)$$

where r_x is the correlation of the variable with the horizontal axis. The length of the variable line is proportional to a function of the r^2 values with the two axes:

$$h \propto [(r^2_x)^2 + (r^2_y)^2]^{-0.5} \qquad (2)$$

We used the default threshold criterion of $r^2 \geq 0.200$ to display a physical variable in the joint plots. We used orthogonal (rigid) rotation of the ordination in 5-degree increments to orient elevation (a dominant determinant of vegetation in Great Basin mountains; Beever 1999) parallel to one of the two axes. Such rotation changes the correlations of variables with ordination axes and the variance represented by individual axes, but does not change either the geometry of the constellation of points in ordination space or the cumulative variance represented by the axes (McCune and Grace 2002). We additionally helped interpret the meaning of NMS axes by performing Pearson and Kendall correlations of the ordination axes with species scores in the main site-by-species matrix.

Secondarily, we sought to test whether composition of plant communities differed between hydrogeomorphic valley types or between our vegetation types, using either the NFP or 1-m^2 frequency data as main data sources. Hydrogeomorphic types for each site were taken from maps in Frissell and Liss (1993). One site (BK7) was intended to be placed within the ACB type, but ended up being placed on the border between the ACB and LOV types; because this was the only site of this type, it was removed for MRPP analyses, as within-group distances could not be produced. Vegetation type at each site was assigned to one of six types we created from our characterization of overstory dominants at sites and confirmed with our walking transect surveys.

For both types of groups, we used multi-response permutation procedures (MRPP; Mielke 1984, Mielke and Berry 2001) to test the hypothesis of no difference in species composition among the different hydrogeomorphic types as well as among the different vegetation types. MRPP is the nonparametric equivalent of discriminant analysis and MANOVA, and differs in that it doesn't require the distributional assumptions of multivariate normality and homoscedasticity, which are rarely met with ecological community data (McCune and Grace 2002). To maintain consistency with the NMS analyses, we again used the Sørensen (Bray-Curtis) distance measure to calculate the distance matrix. In addition, for calculating δ (delta; the weighted mean within-group distance), we defined C_i as

$$\mathrm{n}_i / \Sigma \mathrm{n}_i \qquad (3)$$

to weight groups. The test statistic, *T,* describes the separation between groups, and is defined by

$$(\text{observed } \delta \text{ - expected } \delta) \ / \ \text{SD of expected } \delta \qquad (4)$$

When all items within groups are identical, $A_{\max} = 1$, and $A < 0$ when there is more heterogeneity within groups than expected by chance. In addition to finding the measure of effect size provided by MRPP, we also explored differences between groups by overlaying the variables defining groups onto the NMS ordinations of NFPand 1-m^2 frequency data (e.g., Figures 3-5).

Because this randomization technique provides little information other than the measure of "effect size" (i.e., the chance-corrected within-group agreement, A, defined as [1 – (observed δ/ expected δ)]), we used indicator species analysis (Dufrêne and Legendre 1997) to describe the indicator value of each individual species for separating the groups. Indicator species analysis is a companion test to MRPP in that it supplements the test of no multivariate difference between groups with a description of how well each species separates among groups (McCune and Grace 2002). The method combines information from both the concentration of species abundance in a particular group with the faithfulness of occurrence of a species in that group. A perfect indicator species for a group is always present at sites within that group (i.e., is faithful), but is exclusive to that group, never occurring in other groups. We used 1000 randomizations in a Monte Carlo test to determine significance of indicator values for each species. Because NFP data had so many more species than 1-m^2 data ($N = 98$ vs. 26 spp.), we used a more stringent criterion of alpha to identify significant indicator species ($P < 0.0125$ for NFP, $P < 0.05$ for 1-m^2).

Results

Walking surveys of target watersheds

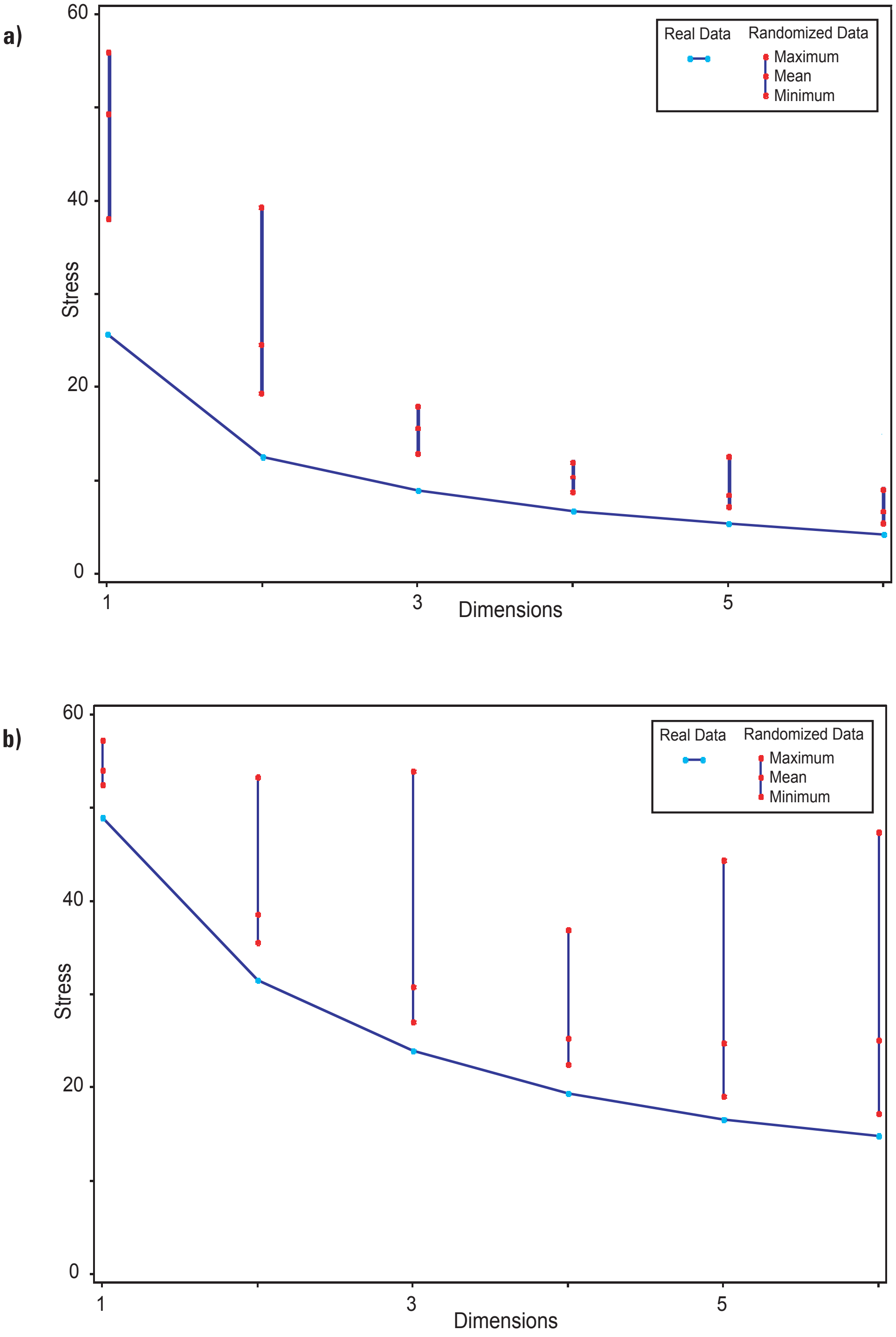
We conducted surveys on 101 stream segments, each approximately 0.32 km long, producing ranked characterizations of woody vegetation within 5.5 – 12.6 km of riparian corridor in each of the various drainages. Upland vegetation types progressed relatively consistently across watersheds with increasing elevation, as mentioned in the "Study Area" section. In contrast, vegetation along riparian corridors was more patchy and exhibited numerous discontinuities, especially in the species *Betula occidentalis*, *Salix* spp., and *Populus tremuloides*. Woody vegetation generally exhibited significant variability across the two sides of the stream, especially in species other than the single-most abundant species (Appendix A). Exceptions to this cross-stream heterogeneity included upland areas dominated by *Pinus monophylla* at the lowest sampled elevations, upland and riparian areas dominated by *P. engelmannii* at highest elevations, and aspen stands (Appendix A).

As Smith et al. (1994) also found, we observed variability in elevational distribution of some tree species across watersheds. In contrast to the findings of Smith et al. (1994), however, we observed greater homogeneity in the lowest-elevation occurrence of *Picea engelmannii* (all within 180 m of each other elevationally)*, P. tremuloides* (within 100 m), *Abies concolor* (within 50 m), and *Pinus monophylla* (within 125 m). Similarly, *Pinus flexilis* was detected as low as 2,300 – 2,315 m in Baker, Lehman, and Snake creeks, but was not detected in Strawberry Creek, although it remains possible we simply did not find it. The lower elevational bound of *Pseudotsuga menziesii* differed erratically from results of Smith et al. (1994) in our four target watersheds, increasing by 100 – 350 m in two drainages, and decreasing by 100 – 200 m in the other two. This may have resulted from the species' superficial similarity to *A. concolor*, and consequent misidentifications by field crews of Smith et al. (1994) or this research. Although *P. engelmannii* exhibited similar lower-elevation bounds across watersheds in 2002, they were 175 – 200 m higher than in 1992 sampling in three of the four target drainages. In similar fashion, *Populus angustifolia* exhibited an apparently higher high-elevation boundary in 2002 compared to 1991-1993 sampling, being found 200 m higher in Baker Creek and 700 m higher in Lehman Creek. It should be noted that some of these differences (especially the last) may have occurred because sampling in 1991-1993 was not continuous along riparian corridors, but only at regularly spaced sites.

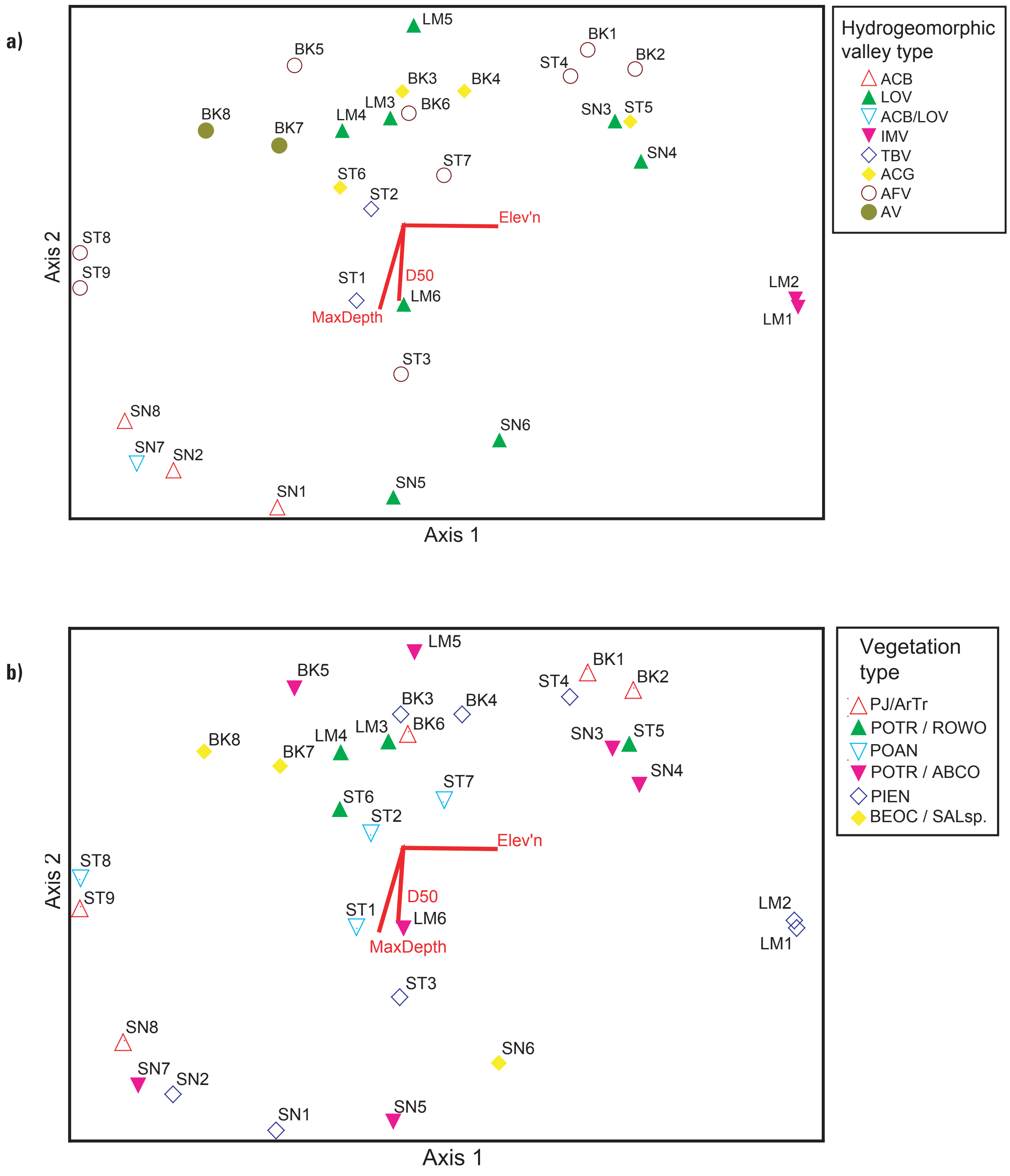
Geomorphically, stream reaches in our four target watersheds within GBNP were straight and narrow, and only a few segments ($N = 8$ locations in Lehman, 4 in Baker, and 3 in Strawberry creeks; total length = 1.7 km) possessed significantly long bifurcations (Appendix B). True channel braiding was rare, however, and was noted only at two locations in Baker Creek (Appendix B). In contrast to the more incised riparian channels of central Nevada (e.g., in the Toiyabe Range), we observed knickzones, downcutting, and incision only rarely and usually with limited extent (often ≤ 5 m long and < 1 m high; Appendix B). Although not reflected in Appendix B, downcutting occurred most frequently and extensively in Strawberry and Snake creeks. From on-site surveys of scattered locations in our target watersheds during 17-18 June 2002, the sediment-delivery and hydrologic systems appeared relatively undisturbed in most reaches, at least with respect to grazing animals and other types of anthropogenic alteration (D. Germanoski, Dept. of Geosciences, Lafayette College, *pers. comm.*). Banks generally appeared stable, and high vertical bank walls (indicative of past incision) were rare. Across the watersheds, localized downcutting occurred at bends in the stream channel, near smaller-diameter culverts in the stream channel, and where the stream was close to roads, campgrounds, or other recreational features.

Cross-sectional transects

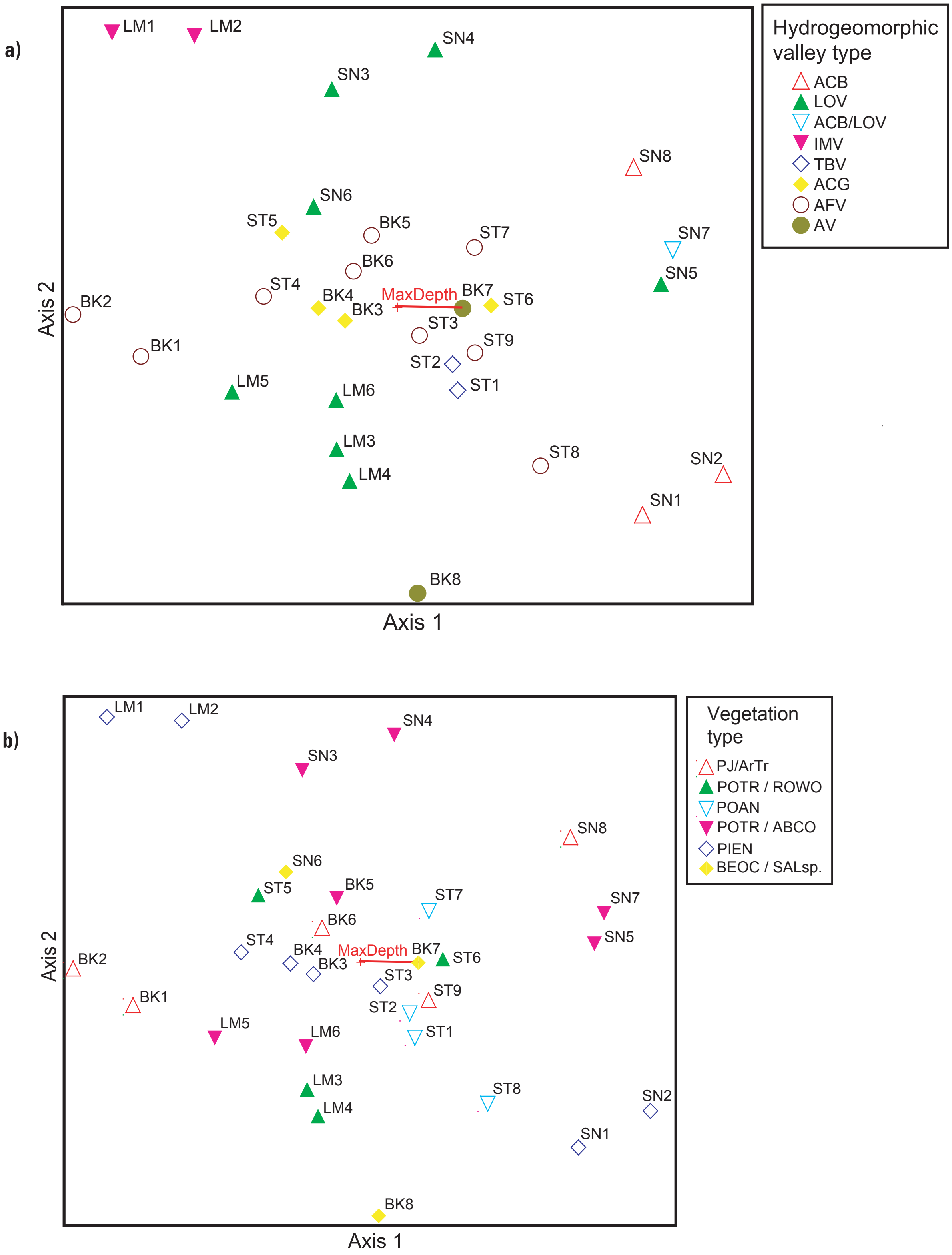
The 31 transects were distributed such that each drainage contained between six and nine transects (Table 1). Because park managers were not interested in focusing attention on any particular community, we placed two transects in each hydrogeomorphic-vegetative sampling stratum. The only exception to this was one stratum on Strawberry Creek, which had five transects in the AFV (alluvial-fan-influenced valley) hydrogeomorphic type, four of which were dominated by



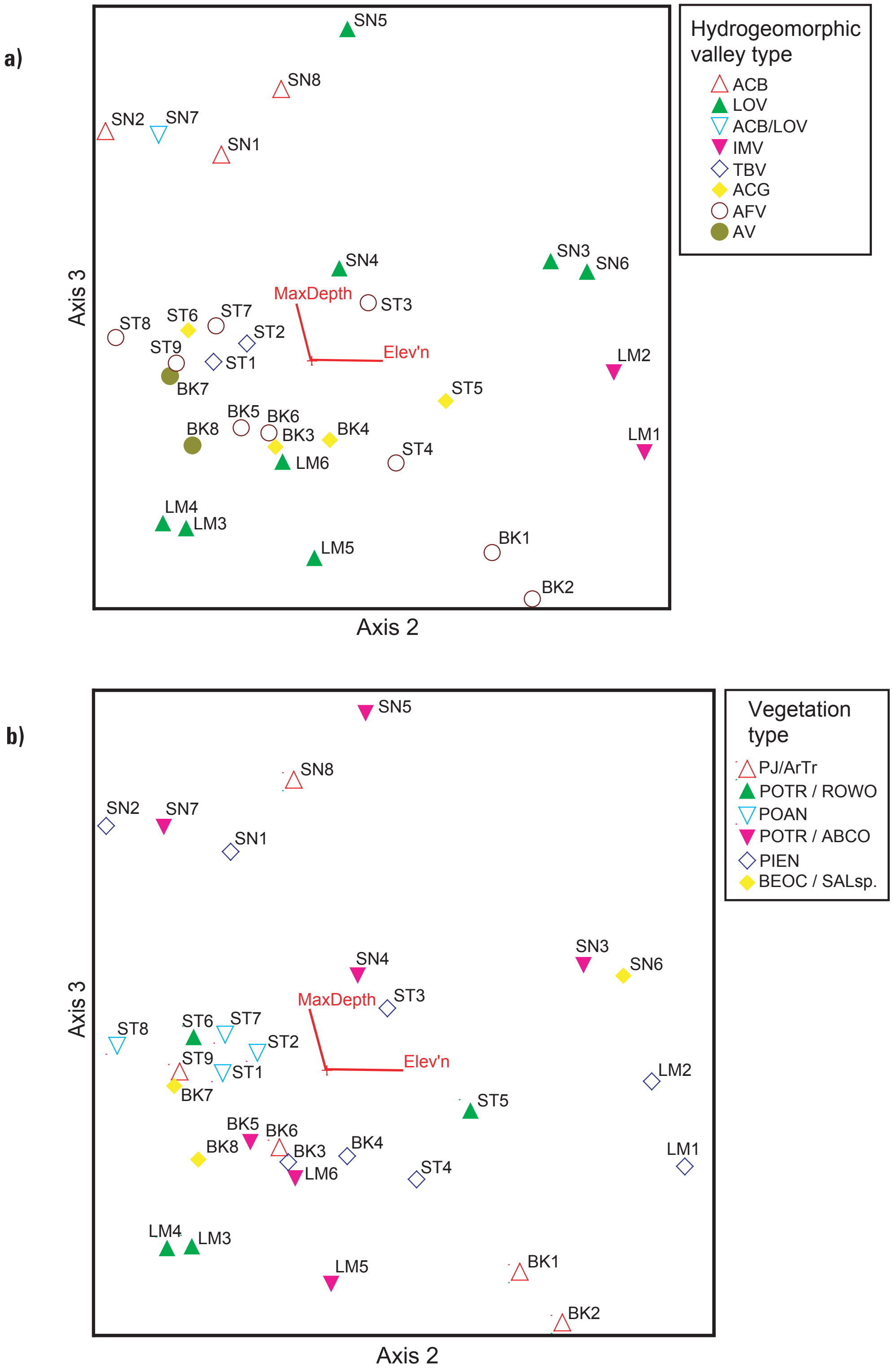
Figures 2a,b. Scree plots used to determine the correct dimensionality of ordination solutions for nonmetric multidimensional scaling (NMS) analyses of frequency data from a) 1-m^2 and b) nested-frequency plot (NFP) sampling. Stress is an inverse measure of fit to the data, and can be described as the departure from monotonicity in the plot of distance in the original *n*-dimensional space (dissimilarity) vs. distance in the ordination space. Species that occurred at only one site were removed, but frequency values were not log-transformed before ordination. The 'randomized data' are obtained by shuffling cover values of species within each site before each run, and are analyzed as a null model for comparison with the real data. Selecting the correct dimension involves balancing two conflicting goals: 1) using enough dimensions to minimize stress, where additional dimensions reduce stress only slightly; and 2) using as few dimensions as possible, to maximize interpretability of results. A two-dimensional solution was recommended and adopted in a), whereas a three-dimensional solution was recommended for the NFP data in b).



Figures 3a,b. Results of 2-dimensional NMS ordination of 31 sites in four watersheds from 1-m^2 frequency data (woody species only). Species that occurred at only one site were removed, but frequency values were not log-transformed before ordination. In both plots, joint plots are overlaid at the centroid of the ordination space to demonstrate the correlations of the ordination points with environmental variables. Length of the arrow reflects the magnitude of the correlation with the two ordination axes, and direction the relative correlation with each axis. Thus, for example, the elevation of sites moves from lower to higher from left to right, and from lower to higher D_{50} values from the top to the bottom portion of the graphs. In a), sites are identified by the hydrogeomorphic valley type in which they occur (following types of Frissell and Liss (1993), abbreviations of which are defined in Tables 1 and 3), and in b), by the vegetation type (defined in Tables 1 and 7) in which they occur. Note that relative positions of sites in ordination space are equivalent in both graphs—sites are simply classified differently.



Figures 4a,b. Results of the first two dimensions of NMS ordination of 31 sites in four watersheds from nested-frequency plot (NFP) data (all plant species). Species that occurred at only one site were removed, but frequency values were not log-transformed before ordination. In a), sites are identified by the hydrogeomorphic valley type in which they occur, and in b), by the vegetation type in which they occur. Joint plots occur and site types are defined as in Figure 3.



Figures 5a,b. Ordination results of the second and third dimensions of an NMS ordination of 31 sites in four watersheds from nested-frequency plot (NFP) data. In this analysis, more of the variability in ordination distances in the *n*-dimensional space (i.e., sites in species space) was described by axis 1, yet nearly equal amounts by axes 2 and 3. Specifically, coefficients of determination for the correlations between ordination distances and distances in the original *n*-dimensional space were: axis 1, $r^2 = 0.384$; axis 2, $r^2 = 0.236$, and axis 3, $r^2 = 0.234$. See text (bottom of pg. 30) for r^2 values for each axis for the correlations for this (orthogonally rotated) representation of the sites. In a), sites are identified by the hydrogeomorphic valley type in which they occur, and in b), by the vegetation type in which they occur. All conventions and conditions follow those of Figures 3 and 4.

P. monophylla. Transects occurred from 1,950 – 2,987 m, though only LM1 and LM2 occurred above 2,665 m. We sampled hydrogeomorphic types generally in accord with their linear extent within our target watersheds; this produced sampling of only one pair of sites within alluvial valley (AV), incised moraine-filled valley (IMV), and terrace-bound valley (TBV) types, and two pairs each in (ACB) and (ACG) types (Table 1). In contrast, we sampled at eight sites within leveed outwash valleys (LOV) and nine sites within alluvial-fan-influenced valleys (AFV). This allocation of sites agrees with the relative abundance of the types within the entire park (Table 1 of Frissell and Liss 1993), except that we sampled AFV areas about twice as heavily as their abundance in the entire park would suggest. After transects were established, sampling of all methods required 2.5 – 4.5 hr/site, which meant that we never sampled more than two sites per day.

Although the mainstem in all four drainages generally flows from west to east (aspect approximately 90°), examination of the values for stream aspect demonstrate that there exists much small-scale variation in stream aspect, both within and across drainages (Table 1). Other than one low-gradient (3%) site on Snake Creek, slope ranged from 6 – 14.5% (Table 1). The average slope from our sites was within 1.1% (absolute values) of the average gradient for the entire creek derived from geographic-information-system calculations of [rise / run] for each of the four drainages (Table 1; Beever et al. *in press*). Maximum water depth varied from 3.2 – 29.8 cm across all sites, with Strawberry Creek sites exhibiting noticeably smaller maximum depths (and consequently larger width/depth ratios) than sites of other drainages (Table 1). Although we observed a fair amount of channel braiding throughout the target watersheds during walking surveys, active channel width at our 31 sites was greater than 4.7 m at only one site, and averaged greater widths in Baker and Lehman creeks than in Snake and Strawberry creeks (Table 1). Although Snake Creek had a drainage area two to three times larger than each of the other creeks (Beever et al. *in press*), active channel width at our Snake Creek sites averaged only slightly greater than the width at our sites in Strawberry Creek (Table 1), the smallest-area drainage of the creeks. Surface water was absent for approximately 4.06 km of Snake Creek (Appendices A, B).

Gap-intercept data suggested that sites were relatively productive (i.e., vegetation-rich), and relatively resistant to erosion by wind or water. This was especially true in the few meters adjacent to the stream course, but inconsistently so more distant from streams. At many sites, there were no basal gaps for spans of 1- 12 m. Nonetheless, at the smallest threshold for gap size ($\geq$ 25 cm), from 22.5 – 99.0% (for an average of 75.9%) of the 50-m transect was occupied by gaps across all sites (Table 2). Snake Creek sites generally had few plant bases under the transect, whereas Strawberry Creek sites supported the highest abundances of plants, as suggested by their greater number of plant bases (Table 2). The proportion of the line in basal gaps declined only slightly when switching the minimum gap length from 25 cm to 50 cm, but declined more strongly across all transects at minimum gap lengths of 1 m and especially 2 m (Table 2).

All other things being equal, greater numbers of plants (as indexed by number of plant bases) should produce greater amounts of litter. This truism was fairly well supported, as the proportion of the line in basal gaps tended to correlate with litter cover, especially at greater threshold gap sizes ($-0.34 \leq r \leq -0.29$, $0.06 < P < 0.12$). Across all 31 sites, proportions of basal and understory gaps were not correlated with amount of tree gaps ($r > -0.30$ for all gap thresholds), but were strongly correlated with each other across all gap thresholds ($r > 0.50$, $P \leq 0.003$). Within individual watersheds, the latter relationship held true only in Baker Creek ($r > 0.82$, $P < 0.01$).

In contrast, transects at sites were notably more interrupted by occurrences of understory vegetation $\geq$ 1.5 cm long (Table 2). Understory canopy gaps more than 25 cm long occupied more than 55% of the transect at only 3 of the 31 sites, and averaged 30.7% of the transect across all sites (Table 2). Sites generally had few large (> 2 m) gaps, averaging 11.1% occupation of the transect across all sites and occupying more than 25% of the transect at only two sites (Table 2). Sites ranged from a near-total lack of tree-canopy cover (SN1, 88% tree gaps) to a completely closed canopy at LM5 (Table 2). Tree cover was greatest in ACB-valley sites (average = 15.5% gap) and sparsest in TBV- (70.3% gaps) and IMV-valley sites (53.4% gaps; Table 3). Not surprisingly, fine-scale assessment of tree cover from gap measurements agreed well ($r = -0.90$, $P < 0.0001$) with measurement of tree cover in point intercepts.

Because of the greater time required to measure 20 cm with a ruler in alternating directions from the boot toe, we instead visually estimated 20 cm. This may have had the effect of undersampling the smallest-diameter particles, as technicians may often have reached for a particle that was easy to pick up (i.e., small pebbles are difficult to process rapidly). Among the mountain-valley segment types (i.e., IMV, TBV, LOV, AV, and AFV), sites in alluvial segments (AFV and AV) had finer-texture bed materials than did sites in other types (Table 3), as suggested by Frissell and Liss (1993). Across all watersheds, D_{50} values revealed that bed particle sizes were largest at the site at the ACB-LOV interface and only slightly lower in ACB (alluviated canyon, boulder-bed) valley segments, compared to in LOV (leveed outwash valley) and other segment types (Table 3). Mirroring comparisons in active channel width and maximum water depth, D_{50} values revealed that sites in Strawberry Creek averaged the smallest bed particle sizes, followed closely by Snake Creek, but more distantly by Lehman and Baker creeks (Table 4). To demonstrate the magnitude of difference, only one of the nine Strawberry sites had a median-particle size above 35 mm, whereas all eight Baker sites had $D_{50} \geq 45$ mm (Table 4). In a forward-step stepwise regression on D_{50} values (*F*-to-enter = 4.000) across all sites, maximum water depth at the site entered the model but average slope of the stream and drainage area above the transect did not.

At all but one Lehman-Creek site, sites sampled within the target watersheds had fewer than 10 logs over or in the

Table 2. Proportion of a 50-m transect occupied by gaps at three structural levels in the system: tree canopy (an index of the width of the riparian corridor); basal (an index of vulnerability to erosion by water); and understory canopy (an index of vulnerability to erosion by wind). For the latter two measures, proportion of the line in gaps is reported for four minimum threshold lengths for gaps—in both cases, larger gap lengths have potential for more serious erosion.

	Tree gap	Understory-canopy gaps			
Transect	**Proportion of line in tree gaps > 1 m**	**Proportion of line in gaps > 25 cm**	**Proportion of line in gaps > 50 cm**	**Proportion of line in gaps > 1 m**	**Proportion of line in gaps > 2 m**
BK1	0.052	0.865	0.850	0.795	0.420
BK2	0.152	0.990	0.990	0.990	0.931
BK3	0.202	0.878	0.818	0.668	0.480
BK4	0.263	0.948	0.934	0.825	0.582
BK5	0.392	0.225	0.213	0.124	0.050
BK6	0.590	0.416	0.384	0.334	0.334
BK7	0.264	0.711	0.651	0.576	0.453
BK8	0.262	0.952	0.945	0.898	0.723
Mean, Baker Creek sites	0.2721	0.7480	0.7232	0.6512	0.4967
LM1	0.484	0.915	0.900	0.793	0.612
LM2	0.584	0.855	0.825	0.691	0.627
LM3	0.354	0.419	0.379	0.310	0.095
LM4	0.304	0.747	0.675	0.509	0.427
LM5	0.000	0.954	0.931	0.824	0.549
LM6	0.414	0.591	0.494	0.330	0.130
Mean, Lehman Creek sites	0.3567	0.747	0.7007	0.5759	0.4067
SN1	0.886	0.963	0.906	0.853	0.656
SN2	0.520	0.898	0.882	0.861	0.626
SN3	0.294	0.966	0.931	0.919	0.831
SN4	0.444	0.582	0.569	0.495	0.457
SN5	0.755	0.846	0.775	0.616	0.437
SN6	0.344	0.987	0.977	0.958	0.904
SN7	0.392	0.887	0.822	0.762	0.658
SN8	0.272	0.951	0.930	0.903	0.745
Mean, Snake Creek sites	0.4885	0.8849	0.8489	0.7958	0.6642
ST1	0.462	0.364	0.343	0.264	0.219
ST2	0.554	0.913	0.859	0.726	0.359
ST3	0.480	0.850	0.769	0.598	0.572
ST4	0.186	0.739	0.639	0.566	0.375
ST5	0.332	0.875	0.850	0.850	0.663
ST6	0.462	0.232	0.146	0.064	0.000
ST7	0.206	0.521	0.458	0.272	0.143
ST8	0.370	0.776	0.722	0.591	0.379
ST9	0.404	0.703	0.681	0.609	0.424
Mean, Strawberry Creek sites	0.3840	0.6636	0.6074	0.5045	0.3483
Grand mean (*N* = 31 sites)	**0.3632**	**0.7726**	**0.7342**	**0.6531**	**0.5068**

Table 2. Proportion of a 50-m transect occupied by gaps at three structural levels in the system: tree canopy (an index of the width of the riparian corridor); basal (an index of vulnerability to erosion by water); and understory canopy (an index of vulnerability to erosion by wind). For the latter two measures, proportion of the line in gaps is reported for four minimum threshold lengths for gaps—in both cases, larger gap lengths have potential for more serious erosion.—Continued

	Basal gaps			
Transect	**Proportion of line in gaps > 25 cm**	**Proportion of line in gaps > 50 cm**	**Proportion of line in gaps > 1 m**	**Proportion of line in gaps > 2 m**
BK1	0.418	0.363	0.237	0.069
BK2	0.631	0.581	0.520	0.493
BK3	0.296	0.254	0.185	0.125
BK4	0.274	0.182	0.103	0.066
BK5	0.036	0.036	0.000	0.000
BK6	0.054	0.029	0.000	0.000
BK7	0.253	0.230	0.127	0.044
BK8	0.377	0.377	0.316	0.220
Mean, Baker Creek sites	0.2922	0.2564	0.1861	0.1271
LM1	0.159	0.133	0.086	0.000
LM2	0.232	0.175	0.125	0.056
LM3	0.243	0.176	0.130	0.054
LM4	0.147	0.121	0.057	0.000
LM5	0.432	0.405	0.341	0.174
LM6	0.073	0.047	0.032	0.000
Mean, Lehman Creek sites	0.2143	0.1763	0.1286	0.0474
SN1	0.550	0.459	0.367	0.164
SN2	0.354	0.287	0.217	0.071
SN3	0.551	0.434	0.205	0.179
SN4	0.296	0.249	0.232	0.051
SN5	0.333	0.221	0.132	0.052
SN6	0.463	0.362	0.257	0.163
SN7	0.275	0.261	0.199	0.177
SN8	0.193	0.166	0.040	0.040
Mean, Snake Creek sites	0.3769	0.3050	0.2061	0.1123
ST1	0.189	0.154	0.108	0.108
ST2	0.230	0.205	0.123	0.064
ST3	0.202	0.202	0.202	0.128
ST4	0.714	0.674	0.611	0.289
ST5	0.656	0.609	0.521	0.500
ST6	0.212	0.179	0.091	0.043
ST7	0.156	0.096	0.052	0.052
ST8	0.342	0.227	0.067	0.042
ST9	0.170	0.105	0.055	0.000
Mean, Strawberry Creek sites	0.3190	0.2723	0.2033	0.1363
Grand mean (*N* = 31 sites)	**0.3264**	**0.2776**	**0.2054**	**0.1337**

Table 3. Comparisons of the mean and standard error (SE) several physical, geomorphic, and biotic variables between different hydrogeomorphic valley types, as defined by Frissell and Liss (1993). *F*- and *P*-values refer to the test of no difference among groups using a 1-way ANOVA.

	Valley type [abbreviation used elsewhere] (*N*)				
	Alluviated canyon, boulder-bed [ACB] (3)		ACB/LOV (1)	Alluviated canyon, gravel-cobble-bed [ACG] (4)	
Indicator metric	Mean	SE	Value	Mean	SE
Average % slope gradient of stream channel, within 5 m of transect	11.42	0.96	3.75	9	2.41
Drainage area in watershed above the x-s transect	2,060	614	3,272	1,555	579
Total volume of coarse woody debris over stream	0.125	0.077	0	0.354	0.164
Median particle size (mm) of bed material (D_{50})	63.8	8.9	71.4	35.7	9.4
Mean percentage of particles with intermediate axis length < 2 mm	0.667	0.667	0	2.5	1.5
Active channel width (m)	5.08	1.19	2.98	2.08	0.53
Maximum water depth (m)	0.292	0.031	0.298	0.038	0.006
Width/depth ratio, active channel	17.4	3.57	9.99	58.54	23.67
Julian sampling date	224.7	0.3	224	214	1.7
Proportion of line in tree gaps	0.155	0.061	0.264	0.404	0.122
Proportion of line under plant canopy	0.86	0.069	0.88	0.82	0.039
Proportion of point-intercepts that possess litter	0.727	0.024	0.76	0.8	0.055

Table 3. Comparisons of the mean and standard error (SE) several physical, geomorphic, and biotic variables between different hydrogeomorphic valley types, as defined by Frissell and Liss (1993). *F*- and *P*-values refer to the test of no difference among groups using a 1-way ANOVA.—Continued

	Valley type [abbreviation used elsewhere] (*N*)					
	Alluvial-fan-influenced valley [AFV] (9)		Alluvial valley [AV] (2)		Incised moraine-filled valley [IMV] (2)	
Indicator metric	Mean	SE	Mean	SE	Mean	SE
Average % slope gradient of stream channel, within 5 m of transect	8.64	0.72	7	1	12.13	0.13
Drainage area in watershed above the x-s transect	2,249	623	1,759	84	462	10
Total volume of coarse woody debris over stream	0.226	0.089	0.024	0.016	0.365	0.365
Median particle size (mm) of bed material (D_{50})	26.2	4.4	23.7	7.7	40.5	1.3
Mean percentage of particles with intermediate axis length < 2 mm	5.44	1.4	2.5	2.5	0	0
Active channel width (m)	1.82	0.37	1.47	0.18	3.46	0.95
Maximum water depth (m)	0.102	0.02	0.084	0.004	0.135	0.018
Width/depth ratio, active channel	23.3	7.28	17.5	2.99	27.06	10.59
Julian sampling date	211.2	1.5	219	0	220	0
Proportion of line in tree gaps	0.396	0.038	0.387	0.017	0.534	0.05
Proportion of line under plant canopy	0.867	0.026	0.85	0.03	0.61	0.01
Proportion of point-intercepts that possess litter	0.827	0.021	0.87	0.07	0.74	0.02

Table 3. Comparisons of the mean and standard error (SE) several physical, geomorphic, and biotic variables between different hydrogeomorphic valley types, as defined by Frissell and Liss (1993). *F*- and *P*-values refer to the test of no difference among groups using a 1-way ANOVA.—Continued

	—Valley type [abbreviation used elsewhere] (*N*)—					
	Leveed outwash valley [LOV] (8)		Terrace-bound valley [TBV] (2)			
—Indicator metric—	Mean	SE	Mean	SE	*F*	*P*
Average % slope gradient of stream channel, within 5 m of transect	10.44	1.2	5.5	0	1.61	0.18
Drainage area in watershed above the x-s transect	2,071	176	2,892	2,443	0.65	0.71
Total volume of coarse woody debris over stream	0.366	0.118	0.051	0.051	0.78	0.61
Median particle size (mm) of bed material (D_{50})	54.0	5.6	34.5	5.3	4.5	0.003
Mean percentage of particles with intermediate axis length < 2 mm	1	0.756	3.5	0.5	1.97	0.11
Active channel width (m)	3.39	0.35	1.58	0.4	3.79	0.008
Maximum water depth (m)	0.237	0.016	0.147	0.013	10.14	< 0.0001
Width/depth ratio, active channel	14.54	1.66	11.07	3.7	2.01	0.10
Julian sampling date	223.3	0.8	209	0	15.33	< 0.0001
Proportion of line in tree gaps	0.315	0.061	0.703	0.183	2.57	0.041
Proportion of line under plant canopy	0.902	0.022	0.592	0.092	6.25	0.0004
Proportion of point-intercepts that possess litter	0.819	0.028	0.563	0.037	3.89	0.006

Table 4. Number of particles (out of 100) whose median axis measured a length in each of 15 size classes, at each of 31 sites. Particl were sampled from within the active channel, and lengths were measured with a gravelometer. Classes were defined based on $^{1}/_{2}$-phi values. D_{50} values represent the median length of the intermediate axis, and were calculated following Harrelson et al. (1994).

Transect	< 2 mm	< 2.8 mm	< 4 mm	< 5.6 mm	< 8 mm	< 11 mm	< 16 mm	< 22.6 mm
BK1	2	1	0	0	1	0	1	5
BK2	0	0	0	0	1	1	0	3
BK3	0	0	0	0	0	1	5	12
BK4	0	0	1	0	0	0	4	3
BK5	0	0	0	0	0	1	2	8
BK6	2	0	0	2	1	4	3	14
BK7	0	0	0	0	0	5	10	3
BK8	0	0	0	1	2	4	9	9
Mean, Baker Creek sites	0.5	0.1	0.1	0.4	0.6	2.0	4.3	7.1
LM1	0	0	0	2	1	4	8	11
LM2	0	0	1	0	5	5	7	13
LM3	0	0	0	2	2	2	1	9
LM4	6	0	0	1	0	4	12	8
LM5	0	0	0	0	0	0	1	5
LM6	0	0	1	2	2	0	3	7
Mean, Lehman Creek sites	1	0	0.3	1.2	1.7	2.5	5.3	8.8
SN1	4	1	1	1	2	3	7	14
SN2	3	0	0	0	3	9	12	16
SN3	12	3	8	9	4	4	6	10
SN4	2	3	0	3	2	1	6	10
SN5	4	2	3	3	4	4	7	11
SN6	3	2	3	4	6	5	8	8
SN7	7	5	3	6	4	7	11	5
SN8	6	0	4	2	5	9	10	7
Mean, Snake Creek sites	5.1	2.0	2.8	3.5	3.8	5.3	8.4	10.1
ST1	10	0	12	5	4	6	3	3
ST2	7	6	4	8	14	10	10	8
ST3	5	2	4	10	11	8	12	15
ST4	4	2	7	12	8	6	10	17
ST5	1	0	0	5	0	4	9	10
ST6	0	0	3	6	4	7	10	11
ST7	0	2	4	9	13	11	12	15
ST8	0	2	2	7	7	8	6	6
ST9	5	1	4	8	7	13	12	22
Mean, Strawbewrry Creek sites	3.6	1.7	4.4	7.8	7.6	8.1	9.3	11.9
Grand mean	**2.5**	**1.0**	**2.0**	**3.3**	**3.5**	**4.5**	**6.6**	**9.2**

Table 4. Number of particles (out of 100) whose median axis measured a length in each of 15 size classes, at each of 31 sites. Particles were sampled from within the active channel, and lengths were measured with a gravelometer. Classes were defined based on $^1/_2$-phi values. D_{50} values represent the median length of the intermediate axis, and were calculated following Harrelson et al. (1994).—Continued

Transect	< 32 mm	< 45 mm	< 64 mm	< 90 mm	< 128 mm	< 180 mm	> 180 mm	D_{50} (mm)
BK1	8	13	13	18	15	15	8	72.7
BK2	6	18	16	15	13	12	15	72.7
BK3	12	20	10	10	15	5	10	45.0
BK4	3	5	9	14	13	22	26	52.0
BK5	5	13	18	23	18	5	7	67.4
BK6	14	9	17	20	5	3	6	46.1
BK7	8	8	12	14	15	7	18	71.4
BK8	13	11	22	12	5	3	9	45.9
Mean, Baker Creek sites	8.6	12.1	14.6	15.8	12.4	9.0	12.4	59.1
LM1	14	18	7	7	8	8	12	39.2
LM2	16	4	6	2	9	0	32	41.8
LM3	18	28	17	6	5	8	2	39.4
LM4	15	10	12	13	9	8	2	37.2
LM5	5	14	17	11	25	10	12	82.9
LM6	9	16	11	11	10	12	16	62.3
Mean, Lehman Creek sites	12.8	15	11.7	8.3	11	7.7	12.7	50.5
SN1	11	10	9	4	9	10	14	39.8
SN2	10	12	9	6	7	8	5	29.2
SN3	6	7	2	6	9	4	10	18.6
SN4	11	8	9	4	7	17	17	53.4
SN5	7	13	12	8	10	8	4	37.0
SN6	18	8	18	11	4	2	0	28.3
SN7	12	9	5	8	2	7	9	24.2
SN8	6	5	5	8	12	11	10	34.6
Mean, Snake Creek sites	10.1	9.0	8.6	6.9	7.5	8.4	8.6	33.1
ST1	7	7	10	4	7	16	6	32.0
ST2	9	16	5	1	0	2	0	11.5
ST3	13	7	6	2	1	3	1	15.2
ST4	5	10	6	6	5	2	0	16.6
ST5	9	7	6	11	17	13	8	60.8
ST6	10	11	12	17	6	3	0	31.1
ST7	13	8	6	3	0	1	3	15.6
ST8	13	10	9	13	9	7	1	31.3
ST9	21	6	1	0	0	0	0	16.0
Mean, Strawbewrry Creek sites	11.1	9.1	6.8	6.3	5.0	5.2	2.1	25.6
Grand mean	**10.3**	**11.4**	**10.6**	**9.6**	**9.0**	**7.8**	**8.9**	**41.0**

active channel within 5 m up- or downstream of the cross-sectional transect, and 14 of the 31 sites had one or no logs (Table 5). Across all watersheds, all three variables (number of instream logs within 5 m of the transect, total instream length of logs, and approximate total log volume) were highly correlated with each other ($r > 0.80$, $P < 0.0001$). Sites in Lehman Creek averaged more than double the number, length, and volume of logs than in any other stream, and Baker Creek sites averaged the least in all three measures (Table 5). However, it was Strawberry Creek whose sites possessed four of the six largest log diameters (all ≥ 28.0 cm). Neither number nor volume of logs correlated strongly with measurements of tree cover from the point-intercept method ($r \geq -0.25$, $P > 0.17$ for both).

Similar to results from our sampling of these watersheds in 2001 (Beever et al. *in press*) and once again in contrast to the findings of Smith et al. (1994), cover of litter was abundant, occupying less than 60% at only one site (SN2, 53%) and averaging 79% across all sites (Table 6). Amount of tree cover varied slightly among vegetation types, averaging the most cover at aspen-white fir and Englemann spruce sites and least cover at pinyon-juniper and *Populus angustifolia*-dominated sites ($F_{5,25} = 1.81$, $P = 0.15$). If gap-intercept data suggested that sites exhibited high standing biomass, point-intercept data on canopy cover confirmed this. Sites averaged 83.4% cover of plants across watersheds, and only one site (SN1) had less than 60% cover of plants (Table 6). Total cover was always 82% or greater, and averaged 94.8% across all sites (Table 6).

Pooled across watersheds, NFP sampling identified a maximum of 179 species within the sampled areas, including 8 tree, 18 shrub, no more than 46 grass, and no more than 106 forb species. Uncertainty regarding the number of species in the last two groups stemmed from our inability to identify plants to species; in some cases, these plants may have belonged to another species we encountered. The 81 singleton (i.e., single-occurrence) species removed before ordinating the data included 8 shrub, 18 grass, and 55 forb species. By far the most commonly encountered tree species were white fir and aspen, which were found at nearly half of all sites. Among shrub species, *Rosa woodsii* (Woods' rose) and *Symphoricarpos oreophilus* (snowberry) were the most widely distributed, followed by sagebrush (*Artemisia tridentata*—usually *A.t. wyomingensis* at low elevations, but *A.t. vaseyana* and *A.t. tridentata* also occur in the park) and *Chrysothamnus viscidiflorus* (green rabbitbrush). Across all species within each life-form, individual tree species occurred at an average of 5.9 (of the 31) sites, shrub species at an average of 5.1 sites, grasses at 4.5 sites, and forbs at 3.5 sites.

When pooled across watersheds, sampling with 1-m^2 quadrats (woody species only) detected a total of 15 tree and 23 shrub species, of which 2 and 10 species were "singletons," respectively (thus leaving $N = 26$ species for ordination). In contrast to the NFP sampling, individual tree species occurred at an average of 8.2 sites, and shrubs at 6.7 sites in the 1-m^2 sampling. The three most widely distributed shrubs in 1-m^2 quadrats were the same as in sampling of NFP, though their order changed slightly. Among trees, aspen and white fir were again the most pervasive species, but were followed closely by *Pinus monophylla* (single-leaf pinyon pine).

Multivariate analyses

NMS. – Although an NMS (nonmetric multidimensional scaling) scree plot demonstrated that real runs with 1-m^2 data produced significantly less stress than randomly shuffled data at all six axes, stress was reduced only slightly after the first two axes (Figure 2a). Thus, a two-dimensional solution was selected for the final run, which produced a stress of 12.32 with a final instability of 0.00030. Correlations between the ordination differences and distances in the original 26-dimensional space (from the original site-by-species frequency matrix) showed that the r^2 for axis 1 was 0.598 and 0.302 for axis 2. Thus, the ordination captured 90.0% of the variation in the original matrix in its two axes. Although sites within the same hydrogeomorphic-vegetation stratum often paired off in the ordination (Figure 3), all sites within watersheds were not distinct from sites of other watersheds, especially in comparison to the ordination with NFP data incorporating all plant species.

After the orthogonal rotation, elevation was positively associated with axis 1, and median particle size and maximum depth of water were negatively associated with axis 2 (Figure 3). Drainage area of each site was the only other physical variable that exhibited $r^2 > 0.1$ with either axis. Species that exhibited strongest relationships to axis 1, in descending order of r, included *R. woodsii* (negative correlation coefficient), *P. engelmannii* (positive), *P. flexilis* (positive), *P. monophylla* (negative), *J. communis* (positive), and *B. occidentalis* (negative). These associations are intuitive given the strong positive correlation of axis 1 with elevation. For axis 2, strongest relationships were exhibited by *P. tremuloides* on the positive (upper) side and *A. tridentata*, *P. angustifolia*, *C. viscidiflorus*, and *R. aromatica* on the negative (lower) side of the axis.

As with the 1-m^2 data, real runs with data from NFP produced significantly less stress than randomly shuffled data at all six axes, although a three-dimensional solution was recommended because additional axes further reduced stress only slightly (Figure 2b). The final run produced a stress of 11.46 with a final instability of 0.00050 for the three-dimensional solution. After orthogonal rotation, correlations between the ordination differences and distances in the original 98-dimensional space showed that the r^2 for axis 1 was 0.268, 0.314 for axis 2, and 0.271 for axis 3. Thus, the ordination captured 85.4% of the variation in the original matrix in its three axes. Although sites from different watersheds were well mixed in ordinations involving axis 1, a plot of sites in relation to axes 2 and 3 showed sites generally clustered by watershed except that two pairs of sites diverged along axis 2 (LM1 and LM2 as well as BK1 and BK2). These sites were 400 m (for Lehman) and 150 m (for Baker) higher than any other site within their

Table 5. Measurements of coarse woody debris (CWD) within 5 m up- or downstream of each of 31 transects from four watersheds Great Basin National Park, Snake Range, eastern NV. Logs were counted only if their diameter exceeded 10 cm and if they spanned more than half of the active stream channel. Volume was calculated using the log diamter at the middle of the active channel. See text for more detailed description of methods.

Transect	Total # logs	Total length of logs between wetted edges (m)	Total CWD volume over stream (m^3)
BK1	0	0	0.000
BK2	2	7.1	0.265
BK3	0	0	0.000
BK4	2	9.82	0.236
BK5	2	6.22	0.168
BK6	2	6.92	0.387
BK7	0	0	0.000
BK8	2	9.2	0.108
Mean, Baker Creek sites	1.25	4.91	0.146
LM1	0	0	0.000
LM2	3	17.66	0.729
LM3	18	48.55	0.928
LM4	9	24.76	0.810
LM5	2	7.44	0.099
LM6	1	2.4	0.299
Mean, Lehman Creek sites	5.5	16.8	0.477
SN1	0	0	0.000
SN2	1	1.92	0.102
SN3	1	1.28	0.028
SN4	2	5.32	0.129
SN5	2	5.5	0.177
SN6	6	42.39	0.764
SN7	1	3.89	0.199
SN8	0	0	0.000
Mean, Snake Creek sites	1.6	7.54	0.175
ST1	7	21.78	0.703
ST2	6	13.23	0.650
ST3	3	4.71	0.195
ST4	1	1.68	0.458
ST5	1	1.32	0.016
ST6	3	5.2	0.116
ST7	1	1.23	0.013
ST8	3	3.45	0.040
ST9	1	1.02	0.008
Mean, Strawberry Creek sites	2.9	5.96	0.244
Grand mean (all sites)	**2.6**	**8.19**	**0.246**

Table 6. Proportion of points occupied by four types of cover, based on sampling at 50 locations on a point-intercept transect at each of 31 sites. Minimum estimate of species richness reflected the count of different species encountered in the transect. Definitions for the four categories of cover occur in the text.

Transect	Total canopy cover	Total cover	Tree cover	Litter cover	Minimum estimate of species richness
BK1	0.98	0.98	0.96	0.76	14
BK2	0.86	0.94	0.72	0.74	14
BK3	0.88	0.94	0.74	0.7	15
BK4	0.88	0.92	0.72	0.76	16
BK5	1	1	0.62	0.72	24
BK6	0.9	1	0.4	0.9	24
BK7	0.88	0.94	0.58	0.76	22
BK8	0.74	0.86	0.64	0.68	9
Mean, Baker Creek sites	**0.89**	**0.948**	**0.67**	**0.75**	**17.3**
LM1	0.62	0.88	0.46	0.76	8
LM2	0.6	0.82	0.3	0.72	10
LM3	0.88	0.98	0.48	0.88	16
LM4	0.8	0.94	0.4	0.86	14
LM5	0.974	1	0.842	0.868	12
LM6	0.9	1	0.54	0.86	19
Mean, Lehman Creek sites	**0.796**	**0.937**	**0.504**	**0.825**	**13.2**
SN1	0.5	0.82	0.16	0.6	11
SN2	0.684	0.816	0.342	0.526	13
SN3	0.76	0.98	0.66	0.98	10
SN4	0.96	1	0.48	0.76	13
SN5	0.72	0.88	0.16	0.82	10
SN6	0.8	0.86	0.66	0.64	11
SN7	0.86	0.94	0.6	0.8	14
SN8	0.84	0.9	0.44	0.8	17
Mean, Snake Creek sites	**0.766**	**0.899**	**0.44**	**0.74**	**12.4**
ST1	0.84	0.96	0.46	0.86	17
ST2	0.88	0.94	0.44	0.8	17
ST3	0.76	0.88	0.52	0.8	15
ST4	0.86	0.98	0.7	0.86	16
ST5	0.9	0.94	0.68	0.88	13
ST6	0.92	0.98	0.44	0.84	12
ST7	0.98	0.98	0.8	0.8	15
ST8	0.88	0.98	0.64	0.94	13
ST9	0.82	0.9	0.56	0.8	18
Mean, Strawberry Creek sites	**0.87**	**0.95**	**0.58**	**0.84**	**15.1**
Grand mean (all sites)	**0.84**	**0.93**	**0.56**	**0.79**	**14.5**

watersheds, and a joint plot showed that axis 2 was positively correlated with site elevation. Other than the two variables that appeared in the joint plot (Figures 5a, 5b), median particle size was the strongest of the remaining correlations of the physical variables with any axis, nearly missing the joint-plot criterion for its association with axis 3. Species that exhibited the strongest correlation with axis 2, which was positively associated with elevation, included *R. woodsii* (negative correlation coefficient) as it was with the 1-m^2 data, as well as *S. jamesii*, *C. scopulorum*, *P. nervosa*, *Juniperus* sp., and *S. lettermanii* (all positively corelated). Notable correlations of species with ordination axis 3 included a negative association with *M. repens* and positive correlations with *P. angustifolia*, *C. viscidiflorus*, and *R. aromatica*. For axis 1, *B. tectorum* (cheatgrass) and *Agropyron desertorum* were positively associated, while *Carex limnophila* was negatively associated.

Comparisons between vegetative and hydrogeomorphic groups. – Multi-response permutation-procedure (MRPP) analyses of 1-m^2 data suggested that species composition differed strongly between hydrogeomorphic types ($A = 0.206$. $P = 0.0000274$). Sites in IMV (incised moraine-filled valley) types were the most tightly clustered, followed by sites in AV, ACB, ACG, and TBV types; in contrast, the AFV and LOV types were more dispersed (Table 7, Figure 3a). In contrast, analyses of 1-m^2 data suggested that woody-species composition was not different between our categories of vegetation types ($A = -0.000475$, $P = 0.47$). Only two vegetation types, aspen-Woods' rose and *P. angustifolia*-dominated sites, had average within-group distances within the range of distance values for geomorphic valley types; all four other vegetation types had higher within-group distances (Table 7, Figure 3b).

As with the 1-m^2 data, MRPP analyses of frequency data from NFP sampling also showed a greater difference in species composition between different hydrogeomorphic types than between different vegetation types. Plant species composition again appeared to differ markedly between hydrogeomorphic valley types ($A = 0.124$, $P = 0.0000274$). Although sites in IMV valley types were again tightly clustered, the pair of TBV sites from Strawberry Creek was even more clustered, though only slightly (Table 7, Figures 4a, 5a). Other than the ACG valley type, sites from other hydrogeomorphic groups were much more highly dispersed (Table 7). Species composition again did not differ significantly between sites of different vegetation types ($A = 0.009$, $P = 0.27$), as sites from all different vegetation types were well interspersed (Figures 4b, 5b).

Indicator species analysis of 1-m^2 data at sites revealed that 8 of the 26 woody species were relatively faithful indicators of a particular hydrogeomorphic group ($P < 0.05$; Table 8). Of these, *Juniperus communis*, *Cornus sericea*, and *Cercocarpus ledifolius* were the only species found at sites within only one valley type, though only *J. communis* was noted at all sites within its corresponding type. Other relatively strong indicator species included *P. angustifolia, P. menziesii*, *A. tridentata*, *Prunus virginiana*, and *R. aromatica*. Four of the eight woody species were indicators for the ACB (alluviated canyon, boulder-bed) valley type.

Reflecting the lack of difference in community composition between vegetation types demonstrated by MRPP analyses, only three (of 26) woody species were strong indicators of any particular vegetation type using 1-m^2 data. These species included *B. occidentalis*, *C. viscidiflorus,* and *P. virginiana*. Of the 12 instances in which a species occurred in all sites within a given vegetation type, 10 occurred in the two vegetation types that were the types that species indicated for in Table 8.

Indicator species analysis of data from NFP revealed that 7 of 98 sites were significant indicators of a particular hydrogeomorphic type ($P < 0.0125$), while another 13 species (8 forb, 4 grass, and 1 shrub) exhibited a somewhat weaker but still notable indicator value for a particular type ($0.0125 < P < 0.05$). Sixteen of the 98 species that occurred in NFPs at two or more sites occurred in only one hydrogeomorphic type, but only three species occurred at every site within the only type they occupied (Indicator Value = 100; Table 8).

Of the 10 plant species that occurred in only one vegetation type, six occurred in the high-elevation, Englemann spruce-dominated type. An unidentified hawksbeard (*Crepis* sp.) was the most pervasive species across sites, occurring at 75% or more of sites in every vegetation type, followed by *Poa pratensis*, which was detected in NFP sampling at 22 sites. Of the 98 species, none acted as a significant indicator of any particular vegetation type, although six species exhibited weak ($0.0125 < P < 0.05$) indicator value for a particular type.

Discussion

In semiarid ecosystems such as the interior Great Basin, riparian areas constitute a landscape resource of far greater importance than would be predicted by their limited spatial extent, due to their provision of the often-limiting resources of water, nutrients, shade, and a lush, diverse riparian vegetative canopy (Gregory et al. 1991). Because of these attractive qualities, riparian areas are often used disproportionately heavily by both humans as well as resident and migratory wildlife. Due in part to this concentration of uses in such a small area, riparian areas are often heavily altered or degraded in arid and semiarid regions of the western United States. On the other hand, especially relative to adjacent upland systems, riparian systems are dynamic and can recover relatively quickly from disturbance if thresholds have not been crossed (Yount and Niemi 1990, Krueper et al. 2003). Although monitoring trends in riparian areas is important for these and other reasons, condition of riparian areas may not indicate trends in other communities of Great Basin mountain ranges. Thus, we recommend riparian monitoring as one part of a more comprehensive assessment of protected areas that includes a greater diversity of soils and vegetation types.

Table 7a, b. Number of transects (*N*) in and average distance between points within the same a) hydrogeomorphic or b) vegetation type, in nonmetric multidimensional scaling (NMS) ordinations of plant-community data from 1-m^2 frequency sampling (woody species only; *N* = 26 spp.) and nested-frequency-plot (NFP) sampling (*N* = 98 spp.). Also included in a) is a cross-walk from the types of Frissell and Liss (1993) to those defined by Rosgen (1985), which was made originally by Frissell and Liss (1993).

a)

			Average within-group distance	
Hydrogeomorphic types (per Frissell and Liss [1993])	***N***	**Equivalent Rosgen (1985) stream classification types**	**1-m^2**	**NFP**
Alluviated canyon, boulder-bed [ACB]	3	B1	0.416	0.732
Leveed outwash valley [LOV]	8	D1	0.575	0.794
Incised moraine-filled valley [IMV]	2	A3, B1	0.109	0.342
Terrace-bound valley [TBV]	2	C1-1	0.446	0.333
Alluvial fan-influenced valley [AFV]	9	C3	0.599	0.705
Alluvial canyon, gravel-cobble-bed [ACG]	4	B2, B3, B4	0.432	0.513
Alluvial valley [AV]	2	C1, C2, C3	0.375	0.769

b)

		Average within-group distance	
Vegetation types	***N***	**1-m^2**	**NFP**
PICENG, etc.[1]	8	0.717	0.775
POPTRE / ABICON[2]	7	0.668	0.809
BETOCC, etc.[3]	3	0.626	0.88
PINMON, POPTRE, ROSWOO[4]	5	0.708	0.771
POPTRE / ROSWOO[5]	4	0.433	0.683
POPANG[6]	4	0.498	0.548

[1] High-elevation sites, dominated or co-dominated by PICENG

[2] Sites co-dominated by POPTRE and ABICON

[3] Low-elevation sites with strong presence of BETOCC

[4] Sites co-dominated by PINMON, POPTRE, and ROSWOO

[5] Sites co-dominated by POPTRE and ROSWOO

[6] Sites with strong presence of POPANG

Tables 8a, b. Results of indicator species analysis for determining which plant species most strongly created differences observed in MRPP comparisons between either hydrogeomorphic valley types or vegetation types, using data either from a) 1-m^2, or b) nested-frequency-plot (NFP) sampling. Valley types follow Frissell and Liss (1993), and are defined in Table 1. Indicator values (IV) range from 0-100%, and denote the % of perfect indication. They are a function of the species' relative abundance in a group (i.e., the mean abundance of the species in a given group of sites over the mean abundance of the species in all site) with the species' relative frequency in a group (i.e., the % of sites in the group at which the species is present). *P*-values represent the proportion of 1,000 Monte-Carlo randomized trials that had an IV $\geq$ the highest observed IV.

a) 1-m² frequency data

				IV from randomized groups		
Species	**Life-form**	**Valley type with highest IV**	**Observed IV**	**Mean**	**SD**	***P***
Cercocarpus ledifolius	T	LOV	50.0	25.2	12.9	0.040
Cornus sericea	T	ACB	66.7	25.1	14.8	0.017
Juniperus communis	T	IMV	100.0	25.2	13.2	0.004
Populus angustifolia	T	ACB	86.6	25.6	13.2	0.001
Pseudotsuga menziesii	T	ACG	51.9	25.6	13.9	0.040
Artemisia tridentata	S	ACB	45.0	29.3	8.5	0.047
Prunus virginiana	S	AV	54.2	28.2	11.7	0.036
Rhus aromatica	S	ACB	95.2	26.9	14.8	0.001

				IV from randomized groups		
Species	**Life-form**	**Vegetation type with highest IV**	**Observed IV**	**Mean**	**SD**	***P***
Betula occidentalis	T	POAN, etc.	48.0	22.2	8.9	0.018
Chrysothamnus viscidiflorus	S	POAN, etc.	42.1	22.9	8.8	0.037
Prunus virginiana	S	BEOC, etc.	53.7	26.2	9.8	0.012

Tables 8a, b. Results of indicator species analysis for determining which plant species most strongly created differences observed in MRPP comparisons between either hydrogeomorphic valley types or vegetation types, using data either from a) 1-m^2, or b) nested-frequency-plot (NFP) sampling. Valley types follow Frissell and Liss (1993), and are defined in Table 1. Indicator values (IV) range from 0-100%, and denote the % of perfect indication. They are a function of both the species' relative abundance in a group (i.e., the mean abundance of the species in a given group of sites over the mean abundance of the species in all site) and the species' relative frequency in a group (i.e., the % of sites in the group at which the species is present). *P*-values represent the proportion of 1,000 Monte-Carlo randomized trials that had an IV $\geq$ the highest observed IV.—Continued

b) NFP frequency data

Species	Life-form	Valley type with highest IV	Observed IV	IV from randomized groups Mean	SD	*P*
Populus tremuloides	T	TBV	53.3	26.0	9.4	0.003
Carex scopulorum	CJ	IMV	100.0	24.5	13.0	0.004
Poa nervosa	G	IMV	100.0	24.5	13.0	0.004
Crepis sp.	F	ACG	35.2	23.8	3.7	0.002
“Unidentified dead forb 3	F	TBV	90.0	25.8	12.0	0.003
Phlox stansburyi	F	TBV	100.0	25.4	14.7	0.005
Smilacina stellata	F	ACB	85.4	25.9	13.4	0.003

Species	Life-form	Vegetation type with highest IV	Observed IV	IV from randomized groups Mean	SD	*P*
None at $P < 0.0125$.						

Walking surveys of target watersheds

Although there was some variation in elevational distributions of some species, we observed relatively systematic progression of vegetation types from the valley floor up to headwaters across our four watersheds (Appendix A, Figure 1). In addition to the fact that all four watersheds are east-facing, they are located within 15 km or less of each other. Thus, all watersheds probably experience similar weather patterns on average, leading to similar evolutionary pressures on, and consequently similar physiological tolerances of, the dominant canopy species. Given that seed-bearing cones are abundant and easily found by highly vagile dispersal agents such as birds, it is likely that dominant canopy species are rarely dispersal-limited. This was confirmed by comparison of NMS ordinations of woody-species-only (1-m^2) and all-species (nested-frequency plot) frequency data. Sites from the same watershed appeared indistinguishable from sites of other watersheds and were clustered together only when they were subsamples of the same hydrogeomorphic-vegetative stratum in ordinations of woody-species data. In contrast, ordinations of NFP (all-species) data much more clearly discriminated different watersheds (Figures 2, 3). At smaller spatial scales, cross-stream heterogeneity and patchiness in species distributions likely result from the collective effects of small-scale variability in surface and upper-horizon soil conditions; differences in aspect, shading, and insolation; allelopathy; and vicariance of seed dispersal and small-scale catastrophes (e.g., treefalls).

Elevational distributions of canopy species generally did not differ consistently and meaningfully from distributions noted in 1991-1993 (by Smith et al. 1994), and most differences may have resulted from species misidentifications, the point-specific nature of the Smith et al. (1994) sampling compared to our continuous sampling, or deaths of individual trees between the two sampling periods. One notable exception to this was *Picea engelmannii,* a high-elevation tree whose lower elevational bound was 175-200 m higher in 2002 sampling compared to 1993 sampling (Beever et al. *in press*). Furthermore, magnitude of change in abundance of the species in four 0.5 km^2 (50-m x 10-m) plots was strongly predicted by plot elevation, with greatest declines occurring at lowest elevations ($F_{1,3} = 269.2$, $r^2 > 0.99$, $P = 0.004$; Beever et al. *in press*). This trend is consistent with a climate-change scenario of increasing temperatures.

Overall, at least in comparison to riparian systems in central Nevada, extent and severity of downcutting was limited in our four target watersheds. Tree roots were not frequently exposed in the channel (as would occur with significant bank erosion); channel and floodplain features appeared adequate to dissipate energy of high-stream-power events; lateral stream movement had recently occurred in numerous locations; and riparian vegetation generally exhibited diverse composition and age structure—all attributes of properly functioning watersheds (following criteria of BLM 1993). Concern for trends over the long term may be merited, however, because the system no longer possesses beavers as it did in the past, and we did not observe any evidence of the riparian zone widening at lower elevations (two additional attributes of proper-functioning condition: BLM 1993). D. Germanoski noted, from the distribution of some terraces, that streams may have experienced significant alterations at some point between 80-200 years ago. The younger end of this range corresponds to the period of intensive sheep grazing in eastern Nevada (1890-1920s). However, tree coring should be used to further investigate the dynamics of these more distant time periods by providing ages of trees at different distances from current channel boundaries.

In our target watersheds, the occurrence of one to four terraces may be good indications of incision in degrading stream reaches. Higher-elevation floodplains from past times, particularly their relation to the current channel, may also indicate recent incision. The common occurrence of root flares (especially on the more energetic outside edge of channel bends) and root exposure are another type of evidence suggesting changes over time. However, a few exposed tree roots are not necessarily an indication of downcutting; roots in truly unstable systems are additionally separated by some measurable height from the channel. An overbank accumulation of fines may also suggest recent disturbance. In contrast, the presence of decades-old trees rooted right at the edge of the stream channel suggests stability in the system. For most of the length of our walking transects, the state of all of these indicators suggested that these four watersheds, at least the mainstem reaches, are generally stable.

Our observation of more frequent point incisions and bank sloughing in Snake and Strawberry creeks compared to the other two watersheds is consistent with the mapping of valley segments and interpretation by Frissell and Liss (1993). They stated that in Snake and Strawberry creeks, the softer shales and limestones that weather rapidly into smaller-sized particles are more easily transported by fluvial processes than are the hard, granitic boulder- and cobble-dominated geology of Lehman and Baker creeks (Frissell and Liss 1993). In our research, this conclusion was further supported by the pebble-count data, which showed smaller D_{50} values on average, as well as greater proportions of the smallest-diameter (< 2 mm) particles, at Strawberry and Snake sites (Table 4). Frissell and Liss (1993) suggest that streams dominated by alluvial segment types are additionally likely to be more sensitive to the effects of climate change. Bank angle (i.e., slope of the bank) is a common indicator of riparian condition, and is evaluated by the assumption that as stream banks recover, bank angle generally declines (Herrick et al. *in press*). Although banks in Lehman and Baker creeks were usually vertical, this was due to the lack of any detectable bank erosion, rather than deep incision (D. Germanoski and E. Beever, *pers. obs.*). This apparent contradiction persisted in this system because: a) banks were armored against erosion by cobbles, boulders, and tree roots; b) height of the bank above the water suface was generally very small (i.e., vertical banks were not tall); and c) lower width-depth ratios (except at BK2, BK6, and LM2) meant that sites may have been more vulnerable to undercutting than downcutting.

Perhaps because grazing had been terminated 32 months before our 2002 sampling (G. Schenk, Ecologist, GBNP, *pers. comm.*.) and vegetation may have re-colonized denuded patches, we had difficulty detecting widespread evidence of livestock influence on stream channels mentioned by Smith et al. (1994) and Frissell and Liss (1993). Smith et al. (1994) considered livestock grazing the most pervasive influence on biotic integrity in the park's riparian areas, whereas Frissell and Liss (1993) and Eddleman and Jaindl (1994) noted significant spatial variability in the level of grazing impact. Frissell and Liss (1993) concluded that grazing impact was most severe and extensive in alluvial valleys, alluvial-fan-influenced valleys, and bajada-filled canyons, but rarely affected stream banks in leveed outwash valleys and canyons. Eddleman and Jaindl (1994) found grazing impacts to be greatest at heavily used springs and seeps, and at areas where animals were at high stocking rates or not properly moved seasonally. Our anecdotal field observations agree, however, with the conclusion of Frissell and Liss (1993) that grazing impact appeared to be positively correlated with extent of grassland, and negatively correlated with forest (especially coniferous) cover and mean size of bed and bank materials. Thus, cobbles and boulders not only are resistant to natural scour processes and peak-flow events, but also armor banks better and prevent entry of cattle into stream channels. We observed livestock trails in adjacent uplands at a number of locations, but correlation of these occurrences with greater incision was not readily apparent (nor frequent enough to quantitatively test robustly).

Greater occurrence of bank sloughing at stream meanders agrees with the hydrological models presented by Brotherton (1979), wherein particle deposition occurs at the inside of the bend and in low-gradient reaches whereas erosion of banks on the outside of the meander is due to shear stress and other fluvial forces.

One potential cause of sedimentation in our watersheds is the occurrence of dirt roads often in very close proximity to stream channels. D. Germanoski noted the extensive erosion of the road adjacent to Strawberry Creek, and E. Beever later followed this gulleying in the road eventually into the stream at several points. Similar diversions of road particles into the stream channel also were evident at selected points along Snake Creek where the road was very near the water's edge. Across the western United States, increased sediment loads are the most widespread water-pollution problem in forests (Binkley and Brown 1993). Unpaved roads have been shown to transport fine sediments to adjacent streams and thereby increase their turbidity (Reid and Dunne 1984), reducing productivity and growth or survival of fishes (Newcombe and Jensen 1996). Although problem-causing roads have been remediated in more mesic systems than those in the park to reduce future erosion potential (e.g., Weaver et al. 1987, Harr and Nichols 1993), effects of past sediment delivery can be long-lasting and cumulative, not able to be effectively mitigated, and can be distributed long distances from the site of the road incursion (Richardson et al. 1975, Hagans et al. 1986). Roads can also alter woody-debris dynamics and natural habitat development, create localized alterations in flow patterns and consequent erosion (which we observed in Strawberry Creek), and act as barriers to movement of salmonids and other fishes (reviewed in Trombulak and Frissell 2000).

Cross-sectional transects

The occurrence of small bed-particle sizes in alluvial valley types was supported by our comparison of median particle sizes among hydrogeomorphic types (Table 3). *Post hoc* comparisons showed that particle sizes at sites in ACB valley types were significantly larger than at alluvial valley (AV) and alluvial-fan-influenced (AFV) sites. Although proportion of smallest-diameter (< 2 mm) bed particles was correspondingly smaller at ACB sites than at AV and ADV sites, large variability in values in each type prevented statistical significance. It is likely that sampling either at more sites or using more particles per site would confirm this difference statistically. We suspected that significantly lower values of canopy cover in terrace-bound valley (TBV) and IMV compared to both AFV and leveed outwash valley (LOV) hydrogeomorphic types were confounded by elevation, but in fact, canopy (vegetative) cover was not correlated with elevation ($r^2 = 0.001$, $P = 0.89$). Instead, the smaller particles deposited by alluvial valleys (including during peak-flow events) may provide more suitable sites for colonization by plants (*sensu* Yount and Niemi 1990). The fact that D_{50} is correlated to neither channel slope nor basin area is surprising, given that slope is usually a function of D_{50} and basin area. This can mean that the grain size of the material found in the channel is a function of past geomorphic events (J. Miller, *pers. comm.*). However, the strength of this relationship alternatively may have been eroded by artifacts of our pebble-sampling technique, and our data do not allow us to test this possibility with confidence.

Although width/depth ratios in ACG (alluviated canyon, gravel-cobble-bed) valley types averaged greater than twice that of other types, the nature of this canyon type does not suggest that this should be so. Consequently, we suggest this as a question to be addressed by future research. The fact that volume of coarse woody debris did not differ among hydrogeomorphic types in spite of significant differences in tree cover (as indexed by tree gaps) between types, as well as a lack of correlation between these two measures ($r = 0.25$, $P = 0.18$) suggests that either the sampling area (10 m x the stream width) is too small to properly measure debris, or, perhaps more likely, that different tree species vary widely in their average age to senescence and vulnerability to windthrow.

Lower flow values, as evidenced by lower active-channel widths and maximum depths, in Snake Creek than would be expected based on hypsography and basin area are due in large part to extensive diversion of water from the creek for irrigation in the Snake Valley below. We were surprised to find that drainage area (derived from digital-elevation models) correlated only weakly with maximum water depth and not with active channel width. However, removing Snake Creek sites from the analysis multiplied the correlation of drainage area with maximum width by 11.5 times, and the correlation with maximum depth by 2.8 times (thus increasing the absolute value of r^2 by 0.263).

Geomorphic and ecological consequences of this could be seen in several parameters. First, cross-sections of the two sites we sampled in the "dry" reaches of Snake Creek (Appendix E) demonstrate that banks are more deeply incised than nearly any other locations in our target watersheds. This likely occurs because of the disconnection of the water table with bankside vegetation, which consequently often becomes less abundant (Bendix 1994, Chambers et al. 2004). In turn, banks become more vulnerable to peak-flow pulses. Second, the minimum estimate of species richness averaged 2.5 species lower at 'dry' sites than at sites with aboveground flow, likely following the model just described. Finally, coarse woody debris accumulated in these segments, and number, length, and volume of logs were higher at both 'dry' sites than at any other Snake Creek site with aboveground flow (except for one site that had slightly greater volume than one of the 'dry' sites).

Mirroring results from more-intensive sampling of riparian vegetation by Smith et al. (1994) and Beever and Pyke (2002), the index of species richness from point-intercept measurements across all sites was strongly predicted by a second-order regression of elevation, with maximum richness occurring at intermediate elevations ($r^2 = 0.25$, $P < 0.02$). Along two large rivers in northern Sweden, Nilsson et al. (1989) found that ruderal species increased monotonically downstream. However, total species richness was unrelated to position but instead increased with substrate heterogeneity and was highest at intermediate levels of substrate fineness. In contrast, species richness at our sites was not predicted in either a first-order or second-order regression on median particle size within stream channels. However, size distributions of stream particles may not necessarily correlate well with soil texture on adjacent streambanks.

Because they incorporate many elements of stream-channel evolution, width-depth ratios are often used as an indicator of geomorphic condition in riparian areas. These ratios are primarily an indicator of the nature of the sediment transported by the stream, and the mode through which it is moved (Knighton 1998). Width and depth tend to increase as one travels downstream in the basin (due to greater drainage areas), although the relative rates of change of the two differs from one another and is a function of existing flow conditions in the channel. Peak-flow events that approach or even exceed bankfull levels produce the greatest stream power and often define riparian characteristics for years to come (Auble et al. 1994, Friedman et al. 1996, Friedman and Lee 2002); thus, width-depth ratios using bankfull widths may provide a more important (although difficult to measure unequivocally; Harrelson et al. 1994) monitoring indicator.

The impact of peak-flow events on stream morphology of riparian areas in the interior Great Basin, independent of anthropogenic effects, was supported by evidence from Myers and Swanson (1996). Their analysis of rare, peak-flow flooding events indicated that 8 of 30 streams from north-central Nevada surveyed from 1979-1993 exhibited major changes at some point, regardless of Rosgen (1985) stream type. More importantly, the two streams most and least damaged by ungulates remained unchanged after flooding. In addition, research in central Nevada riparian systems has suggested that, at least in some watersheds, effects of current management practices (such as grazing management) are overshadowed by residual effects of past (paleo- and historic) climate change on hillslope processes and sediment regimes (Chambers et al. 1998, Miller et al. 2001).

Although gap-intercept data may be useful for monitoring trends in upland communities in the park, it is not clear that they would have equal utility for the areas within the riparian corridor. Litter was widespread within the portions of the riparian corridor under tree canopy, and often constituted a thick layer (3-10 cm). Especially when combined with the patches of extremely dense graminoids we frequently encountered, the extensiveness of litter cover (mean = 79% across all sites) could be a strong deterrent of erosion of topsoil by either water or wind. Wind erosion within the corridor is assumed to be even less likely, given the physical protection provided by the tree canopy. As we have currently designed the sampling and analysis, the data are not easily divided into riparian and upland gap values, especially since the boundary between these two zones is fuzzy at many sites. Unfortunately, this may lessen their utility and interpretability as monitoring indicators in this system.

Although values for proportion of basal gaps seem very high (averaging 76.5% across all sites), when compared with averages of 96-99.5% gaps from Mojave National Preserve (Beever and Pyke 2002), which is < 500 km distant, park sites have a relative abundance of plant bases. Re-sampling of transects in subsequent decades may reveal whether greater variability in gap-intercept indicators, and greater sensitivity to environmental changes, than our current results suggest in fact exists. Greater correlation among basal and understory-canopy gap indicators than with the tree-canopy gap metric suggests that while dynamics are tightly linked in understory structure, reliance solely on tree canopy as a monitoring indicator may not detect changes in sites' small-scale vulnerability to erosion. The conclusion from gap-intercept data that park riparian zones are characterized by high standing biomass and high structural complexity was supported in parallel fashion by our finding of high vegetative cover (mean = 83.4%) across all sites.

Between-creek differences in number, length, and volume of logs within active stream channels is not easily interpretable, especially given the fact that neither number nor volume of logs correlated with measures of tree cover ($r \geq -0.25$). Because some of our Baker plots occur near campgrounds, it is possible that either management or recreationalists have locally altered distribution of debris, for convenience of fishing or to lower the risk of inundation of campgrounds. Assuming that this was not the case, lower occurrence of instream logs in Baker Creek may be due to the re-lining of the stream in the early 1960s with bentonite (G. Schenk, *pers. comm.*), a generally impervious substance that may have altered soil structure or chemistry and movement of trees into the stream. The concentration of the largest-diameter trees within the channel at Strawberry Creek sites likely results from the drainage's smaller area and lower slope gradient, and thus, lower stream power.

Multivariate analyses

We threw out 81 species that occurred at only one site before performing ordinations on data from NFP, and 12 singleton species from the 1-m^2 data. This technique should not alter results of ordinations or our other multivariate analyses (McCune and Grace 2002) because these species are not shared with any other sites and thus do not change relationships in ordination space. Interestingly, however, the large percentages of these infrequently occurring species suggest that, especially for poorly dispersed forbs and grasses, there may be even stronger watershed-specific signatures in species composition when all species are considered collectively. Across both data sets, sites that were in both the same hydrogeomorphic valley type and the same vegetation association were most likely to appear similar to each other in ordination space (Figures 3-5). This suggests the possibility of continuous variation in vegetation communities as one moves up or down a watershed or distance-based divergence of vegetative communities based on a factor other than elevation.

Ordinations were effective at reducing the complexity of the *n*-dimensional space created by frequency data of all species at all sites, and captured 90% of the variability in the 1-m^2 dataset ($N = 26$ species) in the first two axes and > 85% of the variability in the NFP dataset ($N = 98$ species) in the first three axes. These results suggest that the community data are not exceedingly complex, if two or three orthogonal axes, each of which may represent a complex of environmental factors but is dominated by the factors identified in join plots, can reflect the variability in the original data.

NMS ordinations as well as MRPP analyses of both woody-species (1-m^2) and NFP (all-species) data suggested that vegetative communities differed much more strongly among hydrogeomorphic types than among vegetation types (Figures 3, 5). Greater importance of hydrogeomorphology in determining vegetation communities at sites is perhaps not surprising, given that both extent and density of riparian vegetation depend largely on local geomorphic and hydrologic controls (Kondolf et al. 1987, Harris 1988). Vegetative differences may have arisen from the strong differences among hydrogeomorphic valley types in a number of physical as well as biotic variables that we measured (Table 3), as well as from differences in other variables (such as number of terraces and lateral slope) detected in past comparisons in the interior Great Basin (e.g., Frissell and Liss 1993, Chambers et al. 2004). Lack of difference among vegetative types could have resulted from the manner in which we assigned sites to different types. Although dominant canopy species may be easily recognizable, they may not define vegetation associations as strongly as elevationally based, broadly occurring categories.

Baker (1989a) used cluster analysis and Bray-Curtis ordination to classify 115 stands that were "as free as possible of postsettlement and land-use effects" in montane and subalpine zones in Colorado. Although that work identified 16 vegetative associations in five habitat types (including montane forests, subalpine forests, wetlands, and two types of carrs), it provided no quantitative analysis of which species distinguished the different associations, or what method they used to decide the number of groups into which to divide the stands. In a related analysis, Baker (1989b) related scores of sites in Bray-Curtis ordination to a suite of environmental variables. As we found, his first ordination axis was correlated strongly with elevation, but he also found correlation with drainage basin variables (especially area, length, relief, and ruggedness), and channel width. Baker (1989b) suggested that non-linearities and multi-scale effects combine in such a way that different forces are driving dynamics at different spatial and temporal scales, a view congruent with paradigms suggested by the hierarchical paradigm of stream organization proposed by others (Frissell et al. 1986, Gregory et al. 1991, Naiman et al. 1993).

Both Kruskal (1964) and Clarke (1993) gave rules of thumb to evaluating the reliability of final ordination solutions based on values of stress. Kruskal's (1964) thresholds are considered reasonable for sociological data (for which they were developed), but overly stringent for ecological community data. From this perspective, values between 10-20 are considered "fair," in contrast to "excellent" (2.5), good (5), and poor (≥ 20) final-stress values (Kruskal 1964). Clarke (1993) suggested that values less than 5 were rarely achieved, but would constitute an excellent representation with no prospect of misinterpretation; values 5-10 constituted a good ordination with no real risk of drawing false inferences; and values 10-20 could still correspond to a usable picture, although values at the upper end have a potential to mislead. McCune and Grace (2002) note that in their experience, most ecological community data sets have stress values between 10-20, and that while values approaching or exceeding 20 are cause for concern, values from 10-15 are quite satisfactory. Since final stress tends to increase with increasing sample size (number of sites) and with increasing number of original species (with more pervasive species exhibiting more influence) (McCune and Grace 2002), our finding of slightly lower stress with the 1-m^2 data relative to the NFP data is not surprising.

NMS is fundamentally different from other ordination techniques in that it iteratively optimizes the solution to beyond a selected threshold criterion. The technique has been shown to perform well with simulated gradients in species composition, even when beta diversity is high or gradient strengths are unequal (Fasham 1977, McCune 1994). NMS is being increasingly used as a robust analytical tool to examine community data, and we recommend its use for future analyses of multiple-site vegetation data within riparian zones and in other systems. The appearance of cheatgrass as a species that exhibited significantly nonrandom presence at sites (i.e., a significant correlation with axis 1) may be of interest, particularly since axis 1 was not correlated with elevation ($r^2 = 0.017$).

In both the NMS ordinations and in the corresponding MRPP analyses, we often observed for sites in TBV and especially IMV types both greater within-group homogeneity and greater distinctness from other sites than in other valley types (Figures 3a, 4a, 5a, Table 7). Both of these types occur at the elevational extremes of our sampling units. In these types, species richness is lower than at intermediate elevations, thus minimizing within-group heterogeneity. Furthermore, many of the plant species do not occur in many of the other valley types, thus increasing their distance in *n*-dimensional space from other valley types. This was evidenced by indicator species analyses of the more species-rich NFP data, in which five of the seven strongest indicator species indicated either TBV and IMV valley types. This was not true for the 1-m^2 data (except for *Juniperus communis*, which was a perfect indicator of the high-elevation IMV type), because these types possessed so few woody species, and the few that **were** found there do not have narrow elevational distributions (Table 7).

The careful observer may have noted that *P*-values for the data sets from NFP were much smaller, relative to the *A*-values, when compared to the 1-m^2 data sets. In MRPP, as the number of species being compared between groups increases, so does the likelihood of a statistically significant test-statistic, regardless of the chosen alpha. Consequently, statistical significance may result even when the effect size (*A*) is small (McCune and Grace 2002).

Further Management Implications

Beschta and Platts (1986), in their review of studies on small streams across the United States, concluded that management actions using in-stream engineered structures may appear to improve conditions at the site of application, but often degrade conditions upstream or downstream of the ‘improvement.’ They further concluded that channel morphology must be matched with the hydraulic, geologic, and vegetative constraints of the managed location, and that vegetation is probably the most important constraint from a management perspective. Thus, they suggested that more resources should be directed toward encouraging and maintaining vegetation and channel characteristics associated with natural riparian ecosystems and less towards altering them.

In terms of the observed effects of roads adjacent to stream channels, and suspended sediment particles resulting from their erosion, management of travel intensity and, more importantly, road construction and maintenance may strongly influence channel morphology and distribution of particle sizes, which may in turn impact fish populations. Roth et al. (1996) found that indices of biotic integrity of habitat and fish assemblages were highly correlated, and that habitat quality and stream biotic integrity were negatively correlated with extent of agriculture but positively correlated with extent of wetlands and forest. However, they found that correlations were strongest at the broadest spatial scales, and became less strong at more local scales.

Alterations in flow regime, due to diversions, dams, and other developments, have received extensive coverage in the ecological literature. Riparian species occur at different distances from and elevations above the mean active channel, and these distributions result from the frequency of flood disturbance that each ‘zone’ experiences (Harris 1986). Altered flow regimes can thus lead to changes in species composition in previously scoured zones, reduced sediments and nutrients as well as lower soil moisture conditions in intermediate zones, and altered area, density, composition, and species diversity of riparian vegetation in terms of its distance from the stream (Harris 1986, Kondolf et al. 1987). Auble et al. (1994) used TWINSPAN to define three vegetative cover types among 133 1-x-2-m rectangular plots in five gravel bars in a national monument along the Gunnison River by clustering plots according to species occurrence. They used a hydraulic model to determine the discharge necessary to inundate each plot, a flow-duration curve (from the hydrologic record) to determine inundation duration, and estimated quantitative changes in cover types based on three hypothetical flow regimes. They concluded that riparian vegetation is particularly sensitive to changes in minimum and maximum flows, and that, because species respond individualistically to environmental change, species-level (rather than community-level) monitoring would be (1) most likely to exhibit detectable change, and (2) most appropriate for understanding details of a spatio-temporally complex response (Auble et al. 1994).

Kondolf et al. (1987), using a hydrologic approach that linked streamflow and availability of water to riparian plants, similarly concluded that autecology of individual species would define a community’s response to changes in flow regime. They advocated four methods for collecting relevant hydrologic data, and found that width of the riparian corridor was more variable in a U-shaped glacial valley than in alluvial fans, which were often in hydrologically losing reaches (i.e., losing water to groundwater; Kondolf et al. 1987). In similar fashion, Richter et al. (1996) outlined 32 biologically relevant hydrologic parameters, based on magnitude, timing, frequency, and duration of water condition (especially droughts and floods), as well as the rate of change in water condition, for assessing hydrologic alteration.

In this research, we have chosen to sample many aspects of not only the riparian corridor and its associated plant species, but also the adjacent upland communities. Several of the methods proved to be either difficult to implement (e.g., aggregate soil stability, penetration resistance) or generally not appropriate for riparian systems of the Snake Range (e.g., basal-gap intercepts). Even without completing these methods at all sites, this research involved intensive sampling at each cross-sectional site. The cost of this for researchers is a sacrifice of statistical power that could be achieved by sampling fewer or less-time-intensive methods at a greater number of sites, as has been done by other researchers (e.g., Baker 1989, Frissell and Liss 1993, Smith et al. 1994). From an optimistic perspective, given that the transects are already established and locations of each of four pieces of rebar per cross-section have been recorded with a differentially corrected global positioning system unit, we suspect that all 31 sites could be subsequently re-sampled in 14-18 full field days by individuals possessing familiarity with the riparian flora of the southern Snake Range. As with any research, monitoring-focused investigations must balance the concerns of number of ecosystem attributes measured, extensiveness in time and space of sampling periods and locations, with the time and cost of sampling.

Because most of our sampling strata contained only two replicate cross-sectional sites, this baseline has very little statistical power to detect even relatively large changes within any particular stratum of valley type and vegetation type. Following discussions with park staff about desired monitoring foci before we began the site selection, instead of providing the park with very detailed information about one hydrogeomorphic type or one drainage, we have provided a baseline that can serve as a repeatable template (using methods clearly stated in this publication) for future studies on status and trend of riparian resources of the park. Because we have more than 30 potential response variables (each of which demonstrated unique variability and CVs), eight hydrogeomorphic types, and approximately 6 vegetation types, *a posteriori* power analyses to assess the robustness of our sampling would serve little value. Such analyses are often used to determine, after research has been completed and a null hypothesis was failed to be rejected, how many sample units it would have taken to be able to detect a trend of, say, 50% (or 25%, or 10%) with a 95% degree of confidence, given the observed variability in the indicator variable. We would advocate such analyses after either management or future researchers decide to narrow the scope of the research and focus on key questions and drivers in these systems.

While the relatively high productivity of riparian systems can allow for comparatively rapid recovery of these systems from disturbances (Yount and Niemi 1990), other authors have argued that succession of vegetation may occur only after significant time lags (Buckhouse et al. 1981), or may be highly influenced by "climatic" factors such as nutrient chemistry (Fisher 1990). Fisher (1990) further argued that, at least for desert streams, the idea of succession should be replaced by the paradigm of stability theory because succession often does not result in a climax state. Much remains to be learned about recovery from disturbance in lotic ecosystems. Among other aspects, researchers have highlighted the need to better understand consequences of homogeneous versus heterogeneous distributions of disturbance; how the local extent of disturbance relates to the patch's regional context; critical versus noncritical patches (in terms of size and location) of disturbance at different spatial and temporal scales; delineation of reversible and nonreversible processes; and physical and biological constraints on the time frame for recovery (Gore et al. 1990).

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Appendix A Walking surveys of target watersheds

Ranked cover data for woody species in 0.32-km (0.20-mile) segments along each of four creek mainstems on east-facing slopes in Great Basin National Park, Snake Range, White Pine Co., NV. When a superscripted number follows a species' abbreviation, only the superscripted number of individuals were observed within that 0.32-km stream reach. Taxonomic names and life-forms follow Hickman (1993) and abbreviations are defined at the end of this appendix. In cases where a species occurs as both a tree and a shrub, we used our judgment to select the most appropriate form to approximate the species' structure and physiognomy in the Park. Perhaps the most contentious life-forms are our designation of all willows and *Prunus virginiana* as shrubs.

Snake Creek watershed; sampled 21 and 24 July 2002

0.0 - 0.2 mi from USFS-NPS boundary

Location of 0.0 mi: 11 748603 E, 4311698 N — Elevation: 6177 ft. (1893 m)

Riparian species								
N side:	POPANG	RHUARO	ROSWOO	CORSER	SARVER	SYMORE	SALIsp.	BETOCC
S side:	POPANG	RHUARO	CORSER	ROSWOO	BETOCC	PINMON	JUNOST	
Upland species								
N side:	PINMON	JUNOST	ARTTRI	EPHVIR	SARVER	SYMORE		
S side:	PINMON	JUNOST	ARTTRI	CHRVIS	CERLED	AMELsp.	SYMORE	EPHVIR

Notes: first (lowest-elevation) BETOCC in park detected 0.15 mi from boundary, at 6,230' elev.

0.2 - 0.4 mi from USFS-NPS boundary

Location of 0.2 mi: 11 748292 E, 4311629 N — Elevation: 6230 ft. (1899 m)

Riparian species							
N side:	POPANG	RHUARO	ROSWOO	SALEXI	BETOCC	SEROCC	CHRVIS
S side:	POPANG	BETOCC	CORSER	RHUARO	ROSWOO	JUNOST	
Upland species							
N side:	JUNOST	PINMON	ARTTRI	EPHVIR	SARVER	CERLED	CHRVIS
S side:	PINMON	JUNOST	ARTTRI	SYMORE	EPHNEV	Elym cine	CHRVIS

0.4 - 0.6 mi from USFS-NPS boundary

Location of 0.4 mi: 11 747977 E, 4311586 N — Elevation: 6294 ft. (1918 m)

Riparian species								
N side:	POPANG	RHUARO	BETOCC	SALEXI	CORSER	ROSWOO	SARVER	EQUIspp.
S side:	POPANG	BETOCC	CORSER	RHUARO	SALEXI	JUNOST	PINMON	
Upland species								
N side:	JUNOST	PINMON	ARTTRI	CHRNAU	GUT sp.	EPHVIR	GRAESP	
S side:	PINMON	JUNOST	ARTTRI	CHRVIS	EPHNEV	ATRCON	TETRsp.	

Notes: lowest-elevation *Equisetum* detected in this segment; present along stream up to 5.4 mi from boundary

Snake Creek watershed; sampled 21 and 24 July 2002—Continued

0.6 - 0.8 mi from USFS-NPS boundary

Location of 0.6 mi: 11 747643 E, 4311556 N — Elevation: 6290 ft. (1917 m)

Riparian species

N side:	POPANG	RHUARO	BETOCC	ROSWOO	EQUIspp.	CORSER	SALEXI	
S side:	POPANG	CORSER	RHUARO	BETOCC	ROSWOO	SALEXI	EPHVIR	

Upland species

N side:	PINMON	JUNOST	CHRVIS	EPHNEV	ARTTRI	SARVER	SALEXI	RHUARO
S side:	ARTTRI	PINMON	JUNOST	SARVER	CHRVIS	CHRNAU		

0.8 - 1.0 mi from USFS-NPS boundary

Riparian species

N side:	POPANG	ROSWOO	RHUARO	SALEXI	BETOCC	EQUIspp.	CORSER
S side:	POPANG	BETOCC	CORSER	ROSWOO	RHUARO	SALEXI	AMELsp.[1]

Upland species

N side:	PINMON	JUNOST	CHRNAU	ARTTRI	RHUARO	SARVER	
S side:	PINMON	ARTTRI	POPANG	CHRVIS	SARVER	CHRNAU	SYMORE

1.0 - 1.2 mi from USFS-NPS boundary

Location of 1.0 mi: 11 747077 E, 4311185 N — Elevation: 6425 ft. (1958 m)

Riparian species

N side:	POPANG	RHUARO	ROSWOO	CORSER	PSEMEN	PINMON	JUNOST	SARVER	SALEXI
S side:	POPANG	ROSWOO	CORSER	RHUARO	AMELsp.				

Upland species

N side:	PINMON	JUNOST	ARTTRI	CHRNAU	CERLED	EPHVIR	RHUARO	SARVER	SYMORE
S side:	POPANG	PINMON	ARTTRI	CHRVIS	CERLED	JUNOST	SYMORE	EPHVIR	CHRNAU
		SARVER							

1.2 - 1.4 mi from USFS-NPS boundary

Location of 1.2 mi: 11 746817 E, 4310948 N — Elevation: 6779 ft. (2066 m)

Riparian species

N side:	POPANG	ROSWOO	RHUARO	CORSER	CHRVIS	EQUIspp.	
S side:	POPANG	ROSWOO	CORSER	RHUARO	JUNOST	JUNIsp.	BETOCC*

Upland species

N side:	PINMON	JUNOST	ARTTRI	CHRVIS	CHRNAU	POPANG
S side:	ARTTRI	CHRNAU	JUNOST	CHRVIS		

*(all in upper 1/3 of transect)

1.4 - 1.6 mi from USFS-NPS boundary

Location of 1.4 mi: 11 746517 E, 4310822 N — Elevation: 6530 ft. (1990 m)

Riparian species

N side:	POPANG	ROSWOO	RHUARO	BETOCC	SALEXI	PINMON	JUNOST	EQUIspp.
S side:	POPANG	BETOCC	SALEXI	RHUARO	ROSWOO	JUNOST	PINMON	

Upland species

N side:	PINMON	JUNOST	ARTTRI	CHRYSsp.	POPANG	SARVER
S side:	JUNOST	ARTTRI	CHRVIS	PINMON	CHRYSsp.	

Snake Creek watershed; sampled 21 and 24 July 2002—Continued

1.6 - 1.8 mi from USFS-NPS boundary

Location of 1.6 mi: 11 746177 E, 4310812 N — Elevation: 6555 ft. (1998 m)

Riparian species								
N side:	POPANG	ROSWOO	BETOCC	SALEXI	RHUARO	EQUIspp.		
S side:	POPANG	BETOCC	SALEXI	JUNOST	RHUARO	ROSWOO	CORSER	AMELsp.[1]
Upland species								
N side:	PINMON	JUNOST	ARTTRI	CHRVIS	SARVER	(or GRAESP)		
S side:	ARTTRI	PINMON	JUNOST	CHRYSsp.	SARVER*			

*only in highest-elevation portion of the 0.2 mi segment

1.8 - 2.0 mi from USFS-NPS boundary

Location of 1.8 mi: 11 745860 E, 4310753 N — Elevation: 6615 ft. (2016 m)

Riparian species								
N side:	POPANG	BETOCC	ROSWOO	RHUARO	SALEXI	EQUIspp.		
S side:	POPANG	BETOCC	PINMON	ROSWOO	SALEXI	RHUARO		
Upland species								
N side:	PINMON	JUNOST	ARTTRI	CHRVIS	SARVER	EPHVIR		
S side:	ARTTRI	SARVER	CHRYSsp.	PINMON	JUNOST	SYMORE	CHRNAU	TETRsp.

2.0 - 2.2 mi from USFS-NPS boundary

Location of 2.0 mi: 11 745499 E, 4310829 N — Elevation: 6670 ft. (2033 m)

Riparian species									
N side:	POPANG	BETOCC	SALEXI	ROSWOO	RHUARO				
S side:	BETOCC	RHUARO	POPANG	ROSWOO	SALEXI	JUNOST	EQUIspp.		
Upland species									
N side:	PINMON	JUNOST	ARTTRI	CHRYSsp.	SARVER	POPANG	EPHVIR	CHRNAU	CERLED
		EPHNEV[1]							
S side:	PINMON	JUNOST	ARTTRI	CHRNAU	RHUARO	SARVER			

2.2 - 2.4 mi from USFS-NPS boundary

Location of 2.2 mi: 11 745155 E, 4310864 N — Elevation: 6752 ft. (2058 m)

Riparian species							
N side:	POPANG	BETOCC	ROSWOO	RHUARO	CORSER	SALEXI	EQUIspp.
S side:	BETOCC	RHUARO	POPANG	ROSWOO	CORSER	PINMON	JUNOST
Upland species							
N side:	JUNOST	PINMON	ARTTRI	RHUARO	SARVER	CHRVIS	
S side:	PINMON	JUNOST	ARTTRI	CHRNAU	POPANG	ROSWOO	

Notes: stream not evident at surface above 2.25 mi

2.4 - 2.6 mi from USFS-NPS boundary, surveyed largely from road [no surface water]

Riparian species									
	POPANG	ROSWOO	POPTRE	BETOCC	RHUARO	ABICON	EPHVIR	CERLED	CORSER
		AMELsp.							
Upland species									
	PINMON	JUNOST	ARTTRI	CHRNAU	POPANG	RHUARO	ROSWOO		

Snake Creek watershed; sampled 21 and 24 July 2002—Continued

2.6 - 2.8 mi from USFS-NPS boundary, surveyed largely from road [no surface water]

Location of 2.6 mi: 11 744474 E, 4310901 N — Elevation: 6883 ft. (2098 m)

Riparian species

POPANG BETOCC POPTRE CORSER ROSWOO RHUARO ABICON

Upland species

PINMON JUNOST ARTTRI CHRVIS EPHVIR POPANG RHUARO

2.8 - 3.0 mi from USFS-NPS boundary, surveyed largely from road [no surface water]

Location of 2.8 mi: 11 744139 E, 4310961 N — Elevation: 6948 ft. (2118 m)

Riparian species

POPANG POPTRE CORSER BETOCC ROSWOO RHUARO ABICON CERLED SALEXI
RIBESsp. SYMORE

Upland species

PINMON JUNOST ARTTRI RHUARO CHRVIS POPANG POPTRE CHRNAU

Notes: stream evident at surface briefly in segment

3.0 - 3.2 mi from USFS-NPS boundary, surveyed largely from road [no surface water]

Location of 3.0 mi: 11 743795 E, 4311146 N — Elevation: 7029 ft. (2142 m)

Riparian species

POPANG BETOCC POPTRE ROSWOO CORSER SALEXI RHUARO ABICON

Upland species

PINMON JUNOST ARTTRI POPANG CERLED RHUARO ROSWOO CHRVIS CHRNAU

3.2 - 3.4 mi from USFS-NPS boundary, surveyed largely from road [no surface water]

Location of 3.2 mi: 11 743441 E, 4311399 N — Elevation: 7111 ft. (2167 m)

Riparian species

SALEXI POPANG BETOCC ABICON RHUARO ROSWOO CHRVIS CHRNAU PRUVIR

Upland species

PINMON JUNOST ARTTRI CHRVIS CHRNAU

Note: no trees observed between 3.20 - 3.36 mi

3.4 - 3.6 mi from USFS-NPS boundary, surveyed largely from road [no surface water]

Location of 3.4 mi: 11 743111 E, 4311567 N — Elevation: 7180 ft. (2188 m)

Riparian species

POPANG PINMON JUNOST BETOCC ABICON CORSER ROSWOO SYMORE

Upland species

PINMON JUNOST ARTTRI CHRVIS CHRNAU

3.6 - 3.8 mi from USFS-NPS boundary, surveyed largely from road [no surface water]

Location of 3.6 mi: 11 742790 E, 4311600 N — Elevation: 7249 ft. (2209 m)

Riparian species

PINMON JUNOST ABICON CORSER POPANG ROSWOO SYMORE POPTRE PSEMEN

Upland species

PINMON JUNOST ARTTRI EPHVIR CHRNAU SYMORE CERLED

3.8 - 4.0 mi from USFS-NPS boundary, surveyed largely from road [no surface water]

Location of 3.8 mi: 11 742468 E, 4311648 N — Elevation: 7337 ft. (2236 m)

Riparian species

POPANG PINMON JUNOST BETOCC ABICON CORSER ROSWOO SYMORE POPTRE

Upland species

PINMON JUNOST ARTTRI CERLED RHUARO CHRVIS

Snake Creek watershed; sampled 21 and 24 July 2002—Continued

4.0 - 4.2 mi from USFS-NPS boundary, surveyed largely from road [no surface water]

Location of 4.0 mi: 11 742147 E, 4311623 N — Elevation: 7390 ft. (2252 m)

Riparian species

POPANG ABICON PINMON ROSWOO POPTRE BETOCC JUNOST RHUARO

Upland species

PINMON JUNOST CERLED ARTTRI CHRVIS POPTRE PSEMEN[2] EPHVIR

4.2 - 4.4 mi from USFS-NPS boundary, surveyed largely from road [no surface water]

Location of 4.2 mi: 11 741822 E, 4311609 N — Elevation: 7400 ft. (2256 m)

Riparian species

POPTRE BETOCC ABICON ROSWOO CORSER SYMORE POPANG RHUARO

Upland species

PINMON JUNOST CERLED ARTTRI EPHVIR CHRVIS RIBESsp. RHUARO

4.4 - 4.6 mi from USFS-NPS boundary, surveyed largely from road [no surface water]

Location of 4.4 mi: 11 741506 E, 4311568 N — Elevation: 7468 ft. (2276 m)

Riparian species

ABICON POPTRE PINMON POPANG BETOCC CORSER ROSWOO SYMORE

Upland species

PINMON JUNOST CERLED CHRVIS ARTTRI ROSWOO POPANG RHUARO

Note: lowest-elevation individual *P. flexilis* in Snake Creek observed in this segment

4.6 - 4.8 mi from USFS-NPS boundary, surveyed largely from road [no surface water]

Location of 4.6 mi: 11 741180 E, 4311578 N — Elevation: 7524 ft. (2293 m)

Riparian species

POPTRE CORSER ROSWOO SYMORE RIBESsp. POPANG ABICON BETOCC

Upland species

PINMON JUNOST CERLED CHRVIS PSEMEN ARTTRI SYMORE EPHVIR CHRNAU ROSWOO

4.8 - 5.0 mi from USFS-NPS boundary, surveyed largely from road [no surface water]

Location of 4.8 mi: 11 740854 E, 4311686 N — Elevation: 7588 ft. (2313 m)

Riparian species

POPTRE ABICON POPANG BETOCC CORSER PICENG

Upland species

PINMON JUNOST CERLED ARTTRI CHRVIS PSEMEN PINFLE SYMORE ROSWOO

Note: lowest-elevation (7,609’) individual *P. englemanii* in Snake Creek observed in this segment

Note 2: water again evident above the surface at and above 4.92 mi

5.0 - 5.2 mi from USFS-NPS boundary

Location of 5.0 mi: 11 740532 E, 4311772 N — Elevation: 7611 ft. (2320 m)

Riparian species

N side: ABICON BETOCC POPTRE PINPON CORSER JUNCOM SALEXI SALspp. ROSWOO

S side: BETOCC POPTRE ABICON CORSER SYMORE ROSWOO PINPON JUNOST PICENG EQUIspp.

Upland species

N side: PINMON JUNOST SYMORE PSEMEN POPTRE POPANG PICENG

S side: POPANG ABICON SYMORE PINMON JUNOST ROSWOO

Note: lowest-elevation (7,611’) individual *P. ponderosa* in Snake Creek observed in this segment

Snake Creek watershed; sampled 21 and 24 July 2002—Continued

5.2 - 5.4 mi from USFS-NPS boundary

Location of 5.2 mi: 11 740211 E, 4311751 N — Elevation: 7672 ft. (2338 m)

N side:	POPTRE	BETOCC	POPANG	ABICON	CORSER	SALspp.		
S side:	BETOCC	CORSER	POPTRE	ABICON	SYMORE	ROSWOO	POPANG	
Upland species								
N side:	POPTRE	CERLED	ARTTRI	ROSWOO	CHRNAU	AMELsp.	SYMORE	JUNCOM
S side:	POPTRE	ABICON	ARTTRI	SYMORE	ROSWOO	PICENG	PINMON	CHRNAU

5.4 - 5.6 mi from USFS-NPS boundary, surveyed largely from road [no N-S heterogeneity]

Location of 5.4 mi: 11 739890 E, 4311778 N — Elevation: 7657 ft. (2334 m)

Riparian species									
	BETOCC	ABICON	SALspp.	POPTRE	ROSWOO	SALEXI	AMELsp.		
Upland species									
	ABICON	ARTTRI	CERLED	ROSWOO	PINMON	JUNOST	SYMORE	SALEXI	CHRVIS

Note: *P. tremuloides* absent from 5.43 - 5.58 mi

5.6 - 5.8 mi from USFS-NPS boundary, surveyed largely from road [no N-S heterogeneity]

Location of 5.6 mi: 11 739566 E, 4311951 N — Elevation: 7859 ft. (2395 m)

Riparian species									
	BETOCC	ABICON	SALspp.	ROSWOO	POPTRE	JUNOST	SALEXI	PRUVIR	PICENG
Upland species									
	CERLED	POPTRE	ARTTRI	PINMON	SYMORE	ABICON	CHRVIS	AMEALN	

Note: lowest-elevation individual *P. engelmanii* in Snake Creek observed in this segment

Note 2: *Equisetum* spp. present along stream from 5.4 - 6.8 mi

5.8 - 6.0 mi from USFS-NPS boundary, surveyed largely from road [no N-S heterogeneity]

Location of 5.8 mi: 11 739238 E, 4312046 N — Elevation: 7923 ft. (2415 m)

Riparian species									
	BETOCC	ABICON	POPTRE	SALspp.	ROSWOO	PICENG			
Upland species									
	ARTTRI	CERLED	PINMON	AMELsp.	SALEXI	SYMORE	ROSWOO	CHRVIS	PRUVIR

6.0 - 6.2 mi from USFS-NPS boundary, surveyed largely from road [no N-S heterogeneity]

Location of 6.0 mi: 11 738927 E, 4312083 N — Elevation: 7977 ft. (2431 m)

Riparian species								
	POPTRE	BETOCC	ABICON	PICENG	SALspp.	PINFLE	ROSWOO	AMELsp.
Upland species								
	ARTTRI	CERLED	CHRVIS	ROSWOO	SYMORE	AMELsp.	JUNOST	

6.2 - 6.4 mi from USFS-NPS boundary, surveyed largely from road [no N-S heterogeneity]

Location of 6.2 mi: 11 738597 E, 4312086 N — Elevation: 8043 ft. (2452 m)

Riparian species								
	BETOCC	PICENG	POPTRE	ROSWOO	ABICON	SYMORE	SALspp.	
Upland species								
	POPTRE	ARTTRI	SYMORE	ROSWOO	CERLED	JUNOST	ABICON	PINMON

Snake Creek watershed; sampled 21 and 24 July 2002—Continued

6.4 - 6.6 mi from USFS-NPS boundary [no N-S heterogeneity]

Location of 6.4 mi: 11 738278 E, 4312091 N — Elevation: 8126 ft. (2477 m)

Riparian species

POPTRE BETOCC SALIsp. PICENG ABICON PINFLE PINPON

Upland species

ARTTRI POPTRE SYMORE CHRVIS MAHREP JUNOST

6.6 - 6.8 mi from USFS-NPS boundary [no N-S heterogeneity]

Location of 6.6 mi: 11 737978 E, 4312517 N — Elevation: 8312 ft. (2533 m)

Riparian species

PICENG POPTRE ABICON SYMORE AMEALN SALspp. ROSWOO *Carex* spp.

Upland species

POPTRE ARTTRI ABICON PINFLE SYMORE CERLED JUNCOM PINPON ARCPAT

6.8 - 7.0 mi from USFS-NPS boundary [no N-S heterogeneity]

Location of 6.8 mi: 11 737651 E, 4312550 N — Elevation: 8385 ft. (2556 m)

Riparian species

PICENG SALIsp. POPTRE *Carex* spp.

Upland species

POPTRE PICENG ABICON PINPON SYMORE MAHREP BETOCC

7.0 - 7.2 mi from USFS-NPS boundary [no N-S heterogeneity]

Location of 7.0 mi: 11 737333 E, 4312836 N — Elevation: 8582 ft. (2616 m)

Riparian species

PICENG POPTRE SALIsp. ABICON PINFLE *Carex* spp.

Upland species

POPTRE PICENG SYMORE PINPON JUNCOM MAHREP ARCPAT RIBESsp. ABICON PSEMEN AMELsp.

7.2 - 7.4 mi from USFS-NPS boundary [no N-S heterogeneity]

Location of 7.2 mi: 11 737006 E, 4312642 N — Elevation: 8759 ft. (2670 m)

Riparian species

PICENG POPTRE PINPON ABICON *Carex* spp.

Upland species

POPTRE PICENG PINPON SYMORE SALspp. ABICON MAHREP AMELsp. JUNCOM ARCPAT

7.4 - 7.6 mi from USFS-NPS boundary [no N-S heterogeneity]

Location of 7.4 mi: 11 736693 E, 4312595 N — Elevation: 8922 ft. (2719 m)

Riparian species

PICENG ABICON POPTRE *Carex* spp.

Upland species

PICENG PINPON ABICON MAHREP PSEMEN SYMORE JUNCOM ARCPAT SAMBsp. PINFLE

Snake Creek watershed; sampled 21 and 24 July 2002—Continued

7.6 - 7.8 mi from USFS-NPS boundary [no N-S heterogeneity]

Location of 7.6 mi: 11 736376 E, 4312711 N — Elevation: 9158 ft. (2791 m)

Riparian species									
	PICENG	PSEMEN	ABICON	PINFLE	POPTRE	*Carex* spp.			
Upland species									
	POPTRE	MAHREP	ARCPAT	PINFLE	PSEMEN	JUNCOM	SYMORE	AMELsp.	ROSWOO
		RIBESsp.							

Strawberry Creek watershed; sampled 18 July 2002

0.0 - 0.2 mi from USFS-NPS boundary

Riparian species							
N side:	BETOCC	PINMON	POPTRE	SALEXI	JUNOST	ROSWOO	ABICON.
S side:	BETOCC	SALEXI	ROSWOO	PINMON			
Upland species							
N side:	PINMON	ARTTRI	CHRNAU	JUNOST			
S side:	PINMON	ARTTRI	CHRNAU	JUNOST		.	

Notes: first (lowest-elevation) ABICON in park detected in this segnent.

0.2 - 0.4 mi from USFS-NPS boundary

Riparian species					
N side:	BETOCC	SALEXI	ROSWOO	PINMON	
S side:	BETOCC	ROSWOO	PINMON	POPTRE	SALspp.
Upland species					
N side:	PINMON	ARTTRI	ROSWOO	ABICON	JUNOST
S side:	PINMON	ARTTRI	CHRNAU		

0.4 - 0.6 mi from USFS-NPS boundary

Riparian species								
N side:	BETOCC	SALspp.	ABICON					.
S side:	BETOCC	SALspp.	PINMON	ABICON[1]				
Upland species								
N side:	PINMON	ROSWOO	ARTTRI	JUNOST	CHRNAU			
S side:	PINMON	ROSWOO	CHRVIS				.	

0.6 - 0.8 mi from USFS-NPS boundary

Riparian species							
N side:	BETOCC	SALIsp.	POPTRE*				
S side:	BETOCC	SALEXI	POPTRE*				

*(upper 100 m of segment only)

Upland species							
N side:	PINMON	ROSWOO	CHRNAU	JUNOST			
S side:	PINMON	SALEXI	ROSWOO	ARTTRI	SYMORE[1]	CHRVIS	Elym cine

Strawberry Creek watershed; sampled 18 July 2002—Continued

0.8 - 1.0 mi from USFS-NPS boundary

Riparian species

N side:	BETOCC	SALEXI	ROSWOO	PINMON	SALIsp.
S side:	BETOCC	SALEXI	ROSWOO	PINMON	

Upland species

N side:	PINMON	ROSWOO	ABICON	JUNOST	CHRNAU	ARTTRI
S side:	PINMON	JUNOST				

1.0 - 1.2 mi from USFS-NPS boundary

Riparian species

N side:	BETOCC	SALEXI	ABICON	SALIsp.	
S side:	BETOCC	SALIsp.	PINMON	ROSWOO	SALEXI

Upland species

N side:	PINMON	ROSWOO	JUNOST	SALEXI	ABICON[1]
S side:	PINMON	ROSWOO	CHRNAU	ARTTRI	

1.2 - 1.4 mi from USFS-NPS boundary

Location of 1.2 mi: 11 735314 E, 4326881 N — Elevation: 7356 ft. (2242 m)

Riparian species

N side:	BETOCC	POPTRE	SALIsp.	SALEXI	ROSWOO
S side:	BETOCC	PINMON	POPTRE	ABICON	

Upland species

N side:	PINMON	ROSWOO	JUNOST	ABICON	CHRVIS	ARTTRI
S side:	PINMON	ROSWOO	ARTTRI	PSEMEN		

Notes: lowest-elevation PSEMEN observed at 1.40 mi

1.4 - 1.6 mi from USFS-NPS boundary

Riparian species

N side:	BETOCC	POPTRE	SALIsp.	ROSWOO	CORSER
S side:	POPTRE	BETOCC	ROSWOO	ABICON	PSEMEN[1]

Upland species

N side:	POPTRE	ROSWOO	ABICON	PINMON	CORSER
S side:	PINMON	ARTTRI	CHRNAU	SYMORE	

1.6 - 1.8 mi from USFS-NPS boundary

Riparian species

N side:	POPTRE	BETOCC	ROSWOO	SALIsp.	SALEXI	CORSER
S side:	POPTRE	ROSWOO	BETOCC	ABICON		

Upland species

N side:	POPTRE	PINMON	ROSWOO	ABICON	CHRNAU	ARTTRI	PURTRI	SYMORE
S side:	POPTRE	CORSER	ABICON	ROSWOO	PSEMEN[1]			

1.8 - 2.0 mi from USFS-NPS boundary

Riparian species

N side:	POPTRE	BETOCC	SALspp.	ABICON		
S side:	BETOCC	POPTRE	SYMORE	CORSER	ROSWOO	SALEXI

Upland species

N side:	PINMON	SYMORE	ROSWOO	CERLED	ARTTRI	CHRVIS	CHRNAU
S side:	BETOCC	ABICON	PSEMEN				

Strawberry Creek watershed; sampled 18 July 2002—Continued

2.0 - 2.2 mi from USFS-NPS boundary						
Riparian species						
N side:	POPTRE	ABICON	BETOCC	SALspp.		
S side:	BETOCC	POPTRE	ROSWOO	SALIsp.		
Note: POPTRE dominant in upper half, BETOCC in lower half						
Upland species						
N side:	PINMON	ROSWOO	SYMORE	ARTTRI	CERLED[1]	Elym cine
S side:	POPTRE	PINMON	ROSWOO	CHRNAU	ARTTRI	
2.2 - 2.4 mi from USFS-NPS boundary						
Riparian species						
N side:	POPTRE	BETOCC	SALspp.	ABICON	PINMON	
S side:	POPTRE	ROSWOO	BETOCC	SYMORE		
Upland species						
N side:	PINMON	ROSWOO	SYMORE	Elym cine	CHRNAU	
S side:	PINMON	POPTRE	ABICON	ARTTRI	CHRVIS	
2.4 - 2.6 mi from USFS-NPS boundary						
Riparian species						
N side:	POPTRE	ROSWOO	ABICON	SALIsp.	SYMORE	
S side:	POPTRE	ROSWOO	SYMORE	SALIsp.		
Upland species						
N side:	POPTRE	ARTTRI	ROSWOO	PINMON		
S side:	POPTRE	ROSWOO	PINMON	ABICON		
2.6 - 2.8 mi from USFS-NPS boundary						
Location of 2.6 mi: 11 733466 E, 4326650 N — Elevation: 7839 ft. (2389 m)						
Riparian species						
N side:	POPTRE	SALIsp.	ROSWOO	BETOCC[1]		
S side:	POPTRE	SALIsp.	ROSWOO			
Upland species						
N side:	POPTRE	ABICON	ARTTRI	ROSWOO		
S side:	POPTRE	ROSWOO	ABICON	SYMORE		
2.8 - 3.0 mi from USFS-NPS boundary						
Riparian species						
N side:	POPTRE	ROSWOO	SALIsp.	ABICON		
S side:	POPTRE	ROSWOO	ABICON	SYMORE	BETOCC	SALIsp.
Upland species						
N side:	POPTRE	ABICON	ARTTRI	ROSWOO	SYMORE	CHRNAU
S side:	POPTRE	ROSWOO	SYMORE	PINMON	ABICON	
3.0 - 3.2 mi from USFS-NPS boundary						
Riparian species						
N side:	ABICON	POPTRE	SALspp.	BETOCC		
S side:	ABICON	POPTRE	SALIsp.	BETOCC		
Upland species						
N side:	POPTRE	ABICON	SYMORE	ARTTRI	ROSWOO	
S side:	ABICON	POPTRE	ROSWOO	SYMORE		

Strawberry Creek watershed; sampled 18 July 2002—Continued

3.2 - 3.4 mi from USFS-NPS boundary

Location of 3.2 mi: 3.2 mi: 11 732715 E, 4326087 N — Elevation: 8096 ft. (2468 m)

Riparian species						
N side:	ABICON	POPTRE	SALspp.	PICENG	ROSWOO	BETOCC
S side:	ABICON	POPTRE	ROSWOO	SALIsp.	PICENG	
Upland species						
N side:	POPTRE	ABICON	SYMORE	ARTTRI		
S side:	POPTRE	ABICON	ROSWOO	PICENG		

3.4 - 3.6 mi from USFS-NPS boundary

Location of 3.4 mi: 11 732071 E, 4325816 N — Elevation: 8464 ft. (2579 m)

Riparian species					
N side:	POPTRE	ABICON	PICENG		
S side:	PICENG	POPTRE	SALIsp.		
Upland species					
N side:	POPTRE	ABICON	SYMORE	ARTTRI	CERLED
S side:	POPTRE	ABICON	SYMORE	PSEMEN	

Baker Creek watershed; sampled 23 July and 13 Aug 2002

0.0 - 0.2 mi from USFS-NPS boundary

Location of 0.0 mi: 11 741947 E, 4319471 N — Elevation: 6745 ft. (2056 m)

Riparian species									
N side:	POPANG	SALEXI	ROSWOO	POPTRE	BETOCC	RHARO	RIBESsp.		
S side:	ROSWOO	POPANG	BETOCC	SALEXI	POPTRE	PINMON	JUNIsp.		
Upland species									
N side:	PINMON	JUNOST	CERLED	ARTTRI	MAHREP	EPHVIR	PRUVIR	PINPON	JUNSCO
		CHRVIS							
S side:	PINMON	ARTTRI	CERLED	RHUARO	OPUNsp.	MAHREP	EPHNEV	PURTRI	

0.2 - 0.4 mi from USFS-NPS boundary

Location of 0.2 mi: 11 741625 E, 4319382 N — Elevation: 6779 ft. (2066 m)

Riparian species									
N side:	POPTRE	SALEXI	ROSWOO	PRUVIR	SALIsp.	POPANG			
S side:	POPTRE	ROSWOO	SALEXI	PRUVIR	POPANG	SYMORE	RHUARO	PINMON	JUNIsp.
		ABICON							
Upland species									
N side:	PINMON	JUNOST	ARTTRI	CERLED	EPHVIR	MAHREP	ABICON	CHRVIS	CHRNAU
		RHUARO							
S side:	ARTTRI	PINMON	JUNIsp.	EPHVIR	CHRVIS	RHUARO	SYMORE	OPUNsp.	RIBESsp.

Notes: lowest-elevation *A. concolor* detected in this segment

Baker Creek watershed; sampled 23 July and 13 Aug 2002—Continued

0.4 - 0.6 mi from USFS-NPS boundary

Location of 0.4 mi: 11 741323 E, 4319316 N — Elevation: 6853 ft. (2089 m)

Riparian species									
N side:	BETOCC	ROSWOO	PRUVIR	POPTRE	POPANG	SALIsp.			
S side:	BETOCC	ROSWOO	SALIsp.	PRUVIR	CERLED	ABICON	PINMON	SAMBsp.	
Upland species									
N side:	PINMON	JUNOST	CERLED	ABICON	MAHREP	ARTTRI	CHRNAU	EPHVIR	RIBESsp.
		PURTRI	HOLOsp.	SAMBsp.	CHRVIS				
S side:	PINMON	ARTTRI	EPHVIR	JUNIsp.	CERLED	SYMORE	RHUARO	OPUNsp.	AMELsp.
		PURTRI	SARVER						

0.6 - 0.8 mi from USFS-NPS boundary

Location of 0.6 mi: 11 740996 E, 4319310 N — Elevation: 6948 ft. (2118 m)

Riparian species									
N side:	BETOCC	PRUVIR	ROSWOO	POPTRE	SALEXI	SALIsp.			
S side:	BETOCC	SALIsp.	ROSWOO	PRUVIR	POPTRE	ABICON	CERLED	RIBESsp.	CORSER
		MAHREP	EPHVIR	JUNIsp.	PINMON				
Upland species									
N side:	PINMON	JUNOST	CERLED	EPHVIR	ARTTRI	CHRVIS	RHUARO	PURTRI	MAHREP
S side:	PINMON	JUNOST	EPHVIR	ARTTRI	SARVER	AMELsp.	CERLED	RHUARO	CHRVIS
		SYMORE							

0.8 - 1.0 mi from USFS-NPS boundary

Location of 0.8 mi: 11 740655 E, 4319428 N — Elevation: 7027 ft. (2142 m)

Riparian species									
N side:	POPTRE	BETOCC	ROSWOO	EQUIspp.					
S side:	POPTRE	SALIsp.	ROSWOO	PRUVIR	BETOCC	JUNIsp.			
Upland species									
N side:	PINMON	JUNOST	CERLED	ARTTRI	PRUVIR	EPHVIR	MAHREP	CHRVIS	PURTRI
		JUNCOM							
S side:	PINMON	ARTTRI	CERLED	EPHVIR	PRUVIR	JUNIsp.	OPUNsp.	PURTRI	MAHREP
		RIBESsp.	RUBIDA						

1.0 - 1.2 mi from USFS-NPS boundary

Location of 1.0 mi: 11 740332 E, 4319468 N — Elevation: 7156 ft. (2181 m)

Riparian species									
N side:	POPTRE	BETOCC	ROSWOO	SALIsp.	SALEXI				
S side:	SALIsp.	BETOCC	ROSWOO	POPTRE	ABICON	JUNIsp.	PINMON	CORSER	
Upland species									
N side:	PINMON	JUNOST	ARTTRI	EPHVIR	ABICON	MAHREP	PRUVIR	SYMORE	CHRNAU
S side:	PINMON	ARTTRI	CERLED	JUNIsp.	MAHREP	SYMORE			

Baker Creek watershed; sampled 23 July and 13 Aug 2002—Continued

1.2 - 1.4 mi from USFS-NPS boundary

Location of 1.2 mi: 11 740014 E, 4319379 N — Elevation: 7235 ft. (2205 m)

Riparian species									
N side:	BETOCC	POPTRE	SALEXI	ROSWOO	PRUVIR				
S side:	POPTRE	ROSWOO	SALEXI	BETOCC	SALIsp.	ABICON	PINMON		
Upland species									
N side:	PINMON	JUNOST	CERLED	ARTTRI	MAHREP	ABICON	POPANG		
S side:	POPTRE	ROSWOO	JUNIsp.	PINMON	RIBESsp.	SALIsp.	ARTTRI	SALEXI	PRUVIR
		CHRNAU	SYMORE	MAHREP					

1.4 - 1.6 mi from USFS-NPS boundary

Location of 1.4 mi: 1 739702 E, 4319172 N — Elevation: 7348 ft. (2240 m)

Riparian species								
N side:	BETOCC	ROSWOO	POPTRE	PRUVIR				
S side:	SALIsp.	POPTRE	ROSWOO	POPANG	PRUVIR	BETOCC		
Upland species								
N side:	PINMON	CERLED	ARTTRI	POPTRE				
S side:	ARTTRI	PINMON	POPANG	CHRNAU	SYMORE	RIBESsp.	ABICON	JUNIsp.

1.6 - 1.8 mi from USFS-NPS boundary

Location of 1.6 mi: 11 739380 E, 4319162 N — Elevation: 7465 ft. (2275 m)

Riparian species									
N side:	BETOCC	POPTRE	SALEXI	ROSWOO					
S side:	BETOCC	SALspp.	POPTRE	*Carex-Junc*	ROSWOO				
Upland species									
N side:	PINMON	CERLED	ABICON	JUNOST	PINPON	ARTTRI	MAHREP	RHUARO	PRUVIR
		PURTRI							
S side:	POPTRE	ABICON	PINMON	JUNOST	Elym cine	SYMORE*			
*trace									

1.8 - 2.0 mi from USFS-NPS boundary

Location of 1.8 mi: 11 739083 E, 4318970 N — Elevation: 7548 ft. (2301 m)

Riparian species								
N side:	POPANG	POPTRE	BETOCC	ROSWOO				
S side:	ABICON	POPTRE	SALspp.	BETOCC	ROSWOO	CORSER	*Carex-Junc*	PINFLE[1]
Upland species								
N side:	ABICON	PINMON	CERLED	ARTTRI	MAHREP	SYMORE	RIBESsp.	
S side:	ABICON	POPTRE	PINMON	JUNOST	SYMORE	MAHREP		.

2.0 - 2.2 mi from USFS-NPS boundary

Location of 2.0 mi: 11 738855 E, 4318561 N — Elevation: 7670 ft. (2338 m)

Riparian species									
N side:	POPTRE	BETOCC	POPANG	ROSWOO	PICENG	SALIsp.			
S side:	POPTRE	ABICON	BETOCC	SALIsp.	PRUVIR	ROSWOO			
Upland species									
N side:	ABICON	PINMON	PICENG	JUNOST	ARTTRI	RIBESsp.	MAHREP	SYMORE	JUNCOM
S side:	ABICON	POPTRE	JUNCOM	PINMON	JUNIsp.	PICENG	ROSWOO	SYMORE	RIBESsp.

Baker Creek watershed; sampled 23 July and 13 Aug 2002—Continued									
2.2 - 2.4 mi from USFS-NPS boundary									
Location of 2.2 mi: 11 738809 E, 4318561 N — Elevation: 7909 ft. (2411 m)									
Riparian species									
N side:	POPTRE	ROSWOO	POPANG						
S side:	POPTRE	POPANG	ABICON	ROSWOO	PICENG	BETOCC	PRUVIR		
Upland species									
N side:	PICENG	PINMON	JUNOST	ARTTRI					
S side:	POPTRE	PICENG	ABICON	ARTTRI	SYMORE	RIBESsp.	JUNOST	JUNSCO	
2.4 - 2.6 mi from USFS-NPS boundary									
Location of 2.4 mi: 11 738512 E, 4317629 N — Elevation: 8031 ft. (2448 m)									
Riparian species									
	POPTRE	SALIsp.	ABICON						
Upland species									
	ARTTRI	ABICON	PINMON	POPTRE	SALspp.*	ROSWOO	JUNIsp.		
*on side strm only									
2.6 - 2.8 mi from USFS-NPS boundary									
Location of 2.6 mi: 11 738223 E, 4318223 N — Elevation: 8111 ft. (2472 m)									
Riparian species									
	ABICON	POPTRE	SALIsp.	PSEMEN					
Upland species									
	ARTTRI	ABICON	CERLED	POPTRE*	MAHREP	SYMORE	SALIsp.		
*more on S side									
2.8 - 3.0 mi from USFS-NPS boundary, surveyed largely from road [no surface water]									
Location of 2.8 mi: 11 737889 E, 4317480 N — Elevation: 8229 ft. (2508 m)									
Riparian species									
	POPTRE	ABICON	SALspp.	PINPON	PICENG	PSEMEN	ROSWOO	RUBIDA	PRUVIR
Upland species									
	POPTRE	ABICON	SYMORE	MAHREP					
Notes: stream evident at surface briefly in segment									
3.0 - 3.2 mi from USFS-NPS boundary, surveyed largely from road [no surface water]									
Location of 3.0 mi: 11 737580 E, 4317394 N — Elevation: 8500 ft. (2591 m)									
Riparian species									
	POPTRE	PICENG	ABICON	CARNEB	SALEXI				
Upland species									
	POPTRE	PICENG	ABICON	PSEMEN	MAHREP	RUBIDA	CERLED	ARTTRI	CHRVIS
Note: last 3 spp. occurred >35 m from stream edge, and were more common on N side									
3.2 - 3.4 mi from USFS-NPS boundary, surveyed largely from road [no surface water]									
Location of 3.2 mi: 11 737268 E, 4317313 N — Elevation: 8669 ft. (2642 m)									
Riparian species									
	POPTRE	PICENG	ABICON	PINPON	CARNEB	ANGKIN			
Upland species									
N side:	POPTRE	PICENG PINMON	CERLED*	ARCPAT	ABICON	MAHREP	PINFLE	ARTTRI*	CHRVIS*
S side:	POPTRE	PICENG	MAHREP	ARCPAT	PINPON				
***C.ledifolius* and last 3 spp. occurred >25 m from stream edge on N side									

Lehman Creek watershed; sampled 25-26 July 2002

0.07 below - 0.13 mi above USFS-NPS boundary; 5.4 - 5.2 mi from stream emergence below Teresa Lk.

Location of 5.2 mi: 11 741562 E, 4321620 N — Elevation: 6582 ft. (2006 m)

Riparian species

N side:	SALEXI	SALIsp.	ROSWOO				
S side:	SALEXI	ROSWOO	*Carex-Junc*	SALIsp.			

Upland species

N side:	Poaceae	ARTTRI	ROSWOO	JUNOST	CHRVIS	PINMON	CHRNAU
S side:	ARTTRI	ROSWOO	PINMON	JUNOST	*Carex-Junc*	CHRNAU	CHRVIS*

*relatively near rip. area

0.13 - 0.33 mi above USFS-NPS boundary; 5.2 - 5.0 mi from stream emergence below Teresa Lk.

Location of 5.0 mi: 11 741230 E, 4321742 N — Elevation: 6625 ft. (2019 m)

Riparian species

N side:	POPANG	BETOCC	ROSWOO	SALEXI	PINMON				
S side:	*Carex-Junc*	ROSWOO	POPANG	BETOCC	SALEXI	SALIsp.	PINMON	POPTRE	RHUARO
		AMELsp.[1]	CHRVIS	MAHREP					

Upland species

N side:	PINMON	ARTTRI	JUNOST	POPANG	RHUARO	CHRNAU	CHRVIS
S side:	ARTTRI	PINMON	Elym cine	JUNOST	RHUARO	CHRNAU	PURTRI

0.33 - 0.53 mi above USFS-NPS boundary; 5.0 - 4.8 mi from stream emergence below Teresa Lk.

Location of 4.8 mi: 11 740860 E, 4322035 N — Elevation: 6795 ft. (2071 m)

Riparian species

N side:	POPTRE	SALEXI	ROSWOO	POPANG			
S side:	ROSWOO	POPTRE	SALEXI	POPANG	BETOCC	PINMON	JUNOST

Upland species

N side:	PINMON	ARTTRI	PURTRI	JUNOST	CHRNAU	EPHVIR	CHRVIS	SYMORE	EPHNEV
S side:	PINMON	ARTTRI	JUNOST	EPHVIR	OPUNsp.	PURTRI	CHRVIS		

0.53 - 0.73 mi above USFS-NPS boundary; 4.8 - 4.6 mi from stream emergence below Teresa Lk.

Location of 4.6 mi: 11 740489 E, 4322400 N — Elevation: 6899 ft. (2103 m)

Riparian species

N side:	ROSWOO	POPANG	SALEXI	BETOCC	EQUIspp.		
S side:	ROSWOO	SALIsp.	SALEXI	BETOCC	PINMON	JUNOST	PINPON

Upland species

N side:	PINMON	ARTTRI	JUNOST	CHRNAU	EPHVIR	MAHREP	PINPON	
S side:	PINMON	ARTTRI	JUNOST	EPHVIR	OPUNsp.	RIBESsp.	MAHREP	CHRVIS

Notes: lowest-elevation *P. ponderosa* for Lehman Crk. detected in this segment

0.73 - 0.93 mi above USFS-NPS boundary; 4.6 - 4.4 mi from stream emergence below Teresa Lk.

Location of 4.4 mi: 11 740128 E, 4322512 N — Elevation: 7020 ft. (2140 m)

Riparian species

N side:	ROSWOO	*Carex-Junc*	POPTRE	SALEXI	PINMON	PINPON	SALIsp.	ABICON[1]	CERLED[1]
S side:	ROSWOO	POPTRE	PINPON	SALIsp.	JUNOST	ABICON	PINMON		

Upland species

N side:	PINMON	ARTTRI	POPTRE	JUNOST	ROSWOO	EPHVIR	CHRNAU	PURTRI[1]	RIBESsp.[1]
S side:	PINMON	ARTTRI	JUNOST	OPUNsp.	CHRVIS	MAHREP	AMELsp.		

Notes: lowest-elevation *A. concolor* for Lehman Crk. detected in this segment (4.58 mi); upland CHRNAU present because of road

Lehman Creek watershed; sampled 25-26 July 2002—Continued

0.93 - 1.13 mi above USFS-NPS boundary; 4.4 - 4.2 mi from stream emergence below Teresa Lk.

Location of 4.2 mi: 11 739501 E, 4322414 N — Elevation: 7081 ft. (2158 m)

Riparian species

N side:	POPTRE	SALEXI	ROSWOO	SALIsp.	RHUARO			
S side:	POPTRE	ROSWOO	SALEXI	SALIsp.	BETOCC	PINMON	JUNOST	ABICON

Upland species

N side:	PINMON	ARTTRI	JUNOST	CHRNAU			
S side:	PINMON	JUNOST	ARTTRI	MAHREP	PURTRI	CHRNAU	ROSWOO

1.13 - 1.33 mi above USFS-NPS boundary; 4.2 - 4.0 mi from stream emergence below Teresa Lk.

Location of 4.0 mi: 11 739501 E, 4322414 N — Elevation: 7201 ft. (2195 m)

Riparian species

N side:	POPTRE	ROSWOO	SALEXI	SALIsp.				
S side:	POPTRE	ROSWOO	PINMON	SALEXI	BETOCC	JUNOST	ABICON	AMELsp.

Upland species

N side:	PINMON	ARTTRI	JUNOST	MAHREP	ABICON					
S side:	PINMON	ARTTRI	CERLED	JUNOST	ROSWOO	CHRNAU	PURTRI	MAHREP	EPHVIR	OPUNsp.

1.33 - 1.53 mi above USFS-NPS boundary; 4.0 - 3.8 mi from stream emergence below Teresa Lk.

Location of 3.8 mi: 11 739196 E, 4321181 N — Elevation: 7291 ft. (2222 m)

Riparian species

N side:	POPTRE	ROSWOO	SALIsp.	SALEXI			
S side:	POPTRE	SALIsp.	SALEXI	ROSWOO	JUNOST	ABICON	PINPON

Upland species

N side:	PINMON	JUNSCO	ARTTRI	MAHREP	ABICON	CHRVIS	CERLED		
S side:	PINMON	ABICON	POPTRE	CERLED	JUNOST	ARTTRI	CHRNAU	ROSWOO	MAHREP

1.53 - 1.73 mi above USFS-NPS boundary; 3.8 - 3.6 mi from stream emergence below Teresa Lk.

Location of 3.6 mi: 11 738882 E, 4322113 N — Elevation: 7388 ft. (2252 m)

Riparian species

N side:	POPTRE	ROSWOO	SALIsp.	BETOCC	EQUIspp.				
S side:	POPTRE	ABICON	SALIsp.	ROSWOO	BETOCC	JUNOST	*Carex-Junc*	SALEXI	EQUIspp.

Upland species

N side:	PINMON	JUNOST	ABICON	ARTTRI	CERLED	MAHREP	
S side:	PINMON	POPTRE	ABICON	JUNOST	CERLED	JUNOST	JUNCOM

1.73 - 1.93 mi above USFS-NPS boundary; 3.6 - 3.4 mi from stream emergence below Teresa Lk.

Location of 3.4 mi: 11 738602 E, 4321921 N — Elevation: 7489 ft. (2283 m)

Riparian species

N side:	POPTRE	BETOCC	ROSWOO	RIBESsp.
S side:	POPTRE*	ABICON*	BETOCC	

*these two species co-dominant

Upland species

N side:	PINMON	CERLED	ABICON	JUNOST	MAHREP	SYMORE		
S side:	ABICON	POPTRE	JUNSCO	PINMON	MAHREP	PINFLE[1]	SYMORE	.

Lehman Creek watershed; sampled 25-26 July 2002—Continued

1.93 - 2.13 mi above USFS-NPS boundary; 3.4 - 3.2 mi from stream emergence below Teresa Lk.

Location of 3.2 mi: 11 738297 E, 4321790 N — Elevation: 7594 ft. (2315 m)

Riparian species

N side: POPTRE SALIsp. BETOCC *Carex* spp. SYMORE
S side: ABICON POPTRE BETOCC ROSWOO SALspp.

Upland species

N side: ABICON JUNOST CERLED MAHREP PINPON
S side: ABICON POPTRE PINPON JUNSCO MAHREP

2.13 - 2.33 mi above USFS-NPS boundary; 3.2 - 3.0 mi from stream emergence below Teresa Lk.

Location of 3.0 mi: 11 737968 E, 4321767 N — Elevation: 7580 ft. (2310 m)

Riparian species

N side: BETOCC SALIsp. ROSWOO POPTRE
S side: ABICON POPTRE SALspp. BETOCC *Carex-Junc*

Upland species

N side: ABICON PINPON JUNOST MAHREP
S side: ABICON POPTRE PINPON PINMON JUNspp. SYMORE PINFLE[1] PRUVIR[1] AMELsp.[1]

2.33 - 2.53 mi above USFS-NPS boundary; 3.0 - 2.8 mi from stream emergence below Teresa Lk.

Location of 2.8 mi: 11 737654 E, 4321733 N— Elevation: 7768 ft. (2368 m)

Riparian species

N side: POPTRE BETOCC ROSWOO
S side: ABICON POPTRE BETOCC *Carex-Junc* ROSWOO SALspp.

Upland species

N side: PINMON ABICON ARTTRI CERLED JUNIsp. CHRVIS SYMORE PINFLE
S side: ABICON POPTRE SYMORE

2.53 - 2.73 mi above USFS-NPS boundary; 2.8 - 2.6 mi from stream emergence below Teresa Lk.

Location of 2.6 mi: 11 737327 E, 4321743 N — Elevation: 7947 ft. (2422 m)

Riparian species

N side: POPTRE ROSWOO SALIsp. JUNSCO EQUIspp.
S side: POPTRE ABICON BETOCC ROSWOO SALIsp. JUNIsp.

Upland species

N side: CERLED PINMON JUNIsp. ABICON PICENG MAHREP
S side: PICENG* POPTRE* ABICON* SYMORE* CERLED* JUNIsp.*

*all spp. except PICENG occur >30 m from stream edge

2.73 - 2.93 mi above USFS-NPS boundary; 2.6 - 2.4 mi from stream emergence below Teresa Lk.

Location of 2.4 mi: 11 736999 E, 4321724 N — Elevation: 8073 ft. (2461 m)

Riparian species

N side: POPTRE SALIsp. PRUVIR ROSWOO
S side: SALIsp. POPANG POPTRE ABICON ROSWOO JUNIsp. PRUVIR

Upland species

N side: CERLED PINMON JUNIsp. ABICON MAHREP SYMORE JUNCOM
S side: PRUVIR SYMORE RIBESsp. PINMON JUNIsp. MAHREP PICENG JUNCOM
ARTTRI* CERLED*

*these 2 spp. occur >30 m from stream edge

Lehman Creek watershed; sampled 25-26 July 2002—Continued										
2.93 - 3.13 mi above USFS-NPS boundary; 2.4 - 2.2 mi from stream emergence below Teresa Lk.										
Location of 2.2 mi: 11 736649 E, 4321803 N — Elevation: 8290 ft. (2527 m)										
Riparian species										
N side:	SALIsp.	ROSWOO	POPTRE							
S side:	SALIsp.	POPANG	ROSWOO	PINMON	PICENG	JUNIsp.				
Upland species										
N side:	CERLED	JUNIsp.	PINMON	ABICON	SAMBsp.	ARTTRI	PRUVIR	CHRVIS	PICENG	MAHREP
S side:	ABICON	POPTRE	JUNIsp.	PRUVIR	JUNCOM	MAHREP	ROSWOO			
3.13 - 3.33 mi above USFS-NPS boundary; 2.2 - 2.0 mi from stream emergence below Teresa Lk.										
Riparian species										
N side:	POPTRE	POPANG	ROSWOO							
S side:	SALIsp.	POPANG	ABICON	ROSWOO	POPTRE					
Upland species										
N side:	PINMON	JUNIsp.	CERLED	ABICON	ARTTRI	SYMORE	MAHREP	RIBESsp.	PRUVIR	CHRVIS
S side:	POPTRE	ABICON	ROSWOO	SYMORE	MAHREP	JUNCOM	JUNIsp.	RIBESsp.	PRUVIR	SAMBsp.
3.33 - 3.53 mi above USFS-NPS boundary; 2.0 - 1.8 mi from stream emergence below Teresa Lk.										
Location of 1.8 mi: 11 735862 E, 4322214 N — Elevation: 8757 ft. (2669 m)										
Riparian species										
N side:	POPTRE	ROSWOO	SALIsp.	POPANG	PRUVIR					
S side:	SALIsp.	ABICON	POPANG	PICENG	ROSWOO					
Upland species										
N side:	CERLED	ABICON	PINMON	PICENG	ARTTRI	MAHREP	PSEMEN	SYMORE	JUNIsp.	
S side:	ABICON	POPTRE	ROSWOO	SYMORE	PRUVIR	CERLED				
3.53 - 3.73 mi above USFS-NPS boundary; 1.8 - 1.6 mi from stream emergence below Teresa Lk.										
Location of 1.6 mi: 11 735540 E; 4322121 N — Elevation: 8871 ft. (2704 m)										
Riparian species										
N side:	POPTRE	ROSWOO	SALIsp.							
S side:	SALIsp.	POPANG	PICENG	POPTRE	ROSWOO					
Upland species										
N side:	PINMON	PINFLE	ARTTRI	PICENG	CERLED	MAHREP	PSEMEN	SYMORE	ARCPAT	JUNCOM
S side:	PICENG	POPTRE	ABICON	ARCPAT	ROSWOO	SYMORE				
3.73 - 3.93 mi above USFS-NPS boundary; 1.6 - 1.4 mi from stream emergence below Teresa Lk.										
Location of 1.4 mi: 11 735204 E; 4322099 N — Elevation: 9113 ft. (2778 m)										
Riparian species										
N side:	POPTRE	ROSWOO	SALIsp.	RIBESsp.						
S side:	POPTRE	SALIsp.	PICENG	ABICON	PINFLE	ROSWOO				
Upland species										
N side:	PICENG	PINMON	MAHREP	JUNCOM	PINFLE	SYMORE	PSEMEN			
S side:	PICENG	POPTRE	JUNCOM	SYMORE	ROSWOO	RIBESsp.	MAHREP	AMELsp.		

Lehman Creek watershed; sampled 25-26 July 2002—Continued

3.93 - 4.13 mi above USFS-NPS boundary; 1.4 - 1.2 mi from stream emergence below Teresa Lk.

Location of 1.2 mi: 11 734912 E; 4321940 N — Elevation: 9250 ft. (2819 m)

Riparian species

N side: POPANG SYMORE ROSWOO RIBESsp.

S side: *Carex* spp. POPTRE PICENG JUNCOM

Upland species

N side: POPTRE PICENG ABICON PINFLE JUNCOM MAHREP PSEMEN

S side: POPTRE

Note: JUNCOM intermediate between riparian zone and upland community

4.13 - 4.33 mi above USFS-NPS boundary; 1.2 - 1.0 mi from stream emergence below Teresa Lk.

Location of 1.0 mi: 11 734548 E; 4321951 N — Elevation: 9292 ft. (2832 m)

Riparian species

N side: *Carex* spp.

S side: *Carex* spp. PICENG POPTRE JUNCOM PINFLE

Upland species

N side: PICENG POPTRE PINFLE MAHREP

S side: POPTRE PICENG PINFLE ARCPAT MAHREP JUNCOM ROSWOO ARTTRI*

*>30 m from stream

4.33 - 4.53 mi above USFS-NPS boundary; 1.0 - 0.8 mi from stream emergence below Teresa Lk.

Location of 0.8 mi: 11 734303 E; 4321712 N — Elevation: 9407 ft. (2867 m)

Riparian species

N side: *Carex* spp. MAHREP

S side: *Carex* spp. PICENG POPTRE PINFLE

Upland species

N side: POPTRE PICENG PINFLE JUNCOM MAHREP SYMORE

S side: PICENG POPTRE PINFLE JUNCOM MAHREP

4.53 - 4.73 mi above USFS-NPS boundary; 0.8 - 0.6 mi from stream emergence below Teresa Lk.

Location of 0.6 mi: 11 734072 E; 4321478 N — Elevation: 9579 ft. (2920 m)

Riparian species

N side: *Carex* spp. SYMORE

S side: *Carex* spp. PICENG RIBESsp.

Upland species

N side: PICENG POPTRE PINFLE JUNCOM

S side: PICENG POPTRE JUNCOM RIBESsp. PINFLE

4.73 - 4.93 mi above USFS-NPS boundary; 0.6 - 0.4 mi from stream emergence below Teresa Lk.

Location of 0.4 mi: 11 733739 E; 4321399 N — Elevation: 9820 ft. (2993 m)

Riparian species

N side: POPTRE *Carex* spp. RIBESsp.

S side: *Carex* spp. PICENG

Upland species

N side: POPTRE PICENG PINFLE

S side: PICENG PINFLE JUNCOM RIBESsp. POPTRE

Lehman Creek watershed; sampled 25-26 July 2002—Continued

4.93 - 5.13 mi above USFS-NPS boundary; 0.4 - 0.2 mi from stream emergence below Teresa Lk.					
Location of 0.2 mi: 11 733458 E; 4321250 N — Elevation: 9847 ft. (3001 m)					
Riparian species					
N side:	POPTRE	*Carex* spp.			
S side:	*Carex* spp.	PICENG			
Upland species					
N side:	PICENG	POPTRE	JUNCOM	PINFLE	
S side:	PICENG	JUNCOM	RIBESsp.		
5.13 - 5.33 mi above USFS-NPS boundary; 0.2 - 0.0 mi from stream emergence below Teresa Lk.					
Location of 0.0 mi: 11 733175 E; 4321094 N — Elevation: 10081 ft. (3073 m)					
N side:	*Carex* spp.	POPTRE			
S side:	*Carex* spp.	PICENG	POPTRE		
Upland species					
N side:	PICENG	JUNCOM	RIBESsp.	POPTRE	PINFLE
S side:	PICENG	JUNCOM	RIBESsp.		

Key to taxonomic abbreviations:

Note: Abbreviations of tree species are in bold type face.

ABICON = *Abies concolor* (Gordon & Glend.) Lindl. (white fir)
AGOGLA = *Agoseris glauca*-“weed”
AGRDES = Agropyron desertorum-“crested wheatgrass
AGRSPI = *Agropyron spicatum*-“bluish grass”
AMELsp. = *Amelanchier* sp. [probably *A. utahensis* (Nutt.) Nutt] (service-berry)
ANTMIC = *Antennaria microphylla*-“Antennaria sp.”
ARADRU = *Arabis drummondii*-“star lanceolate”
ARCPAT = *Arctostaphylos patula* E. Greene (manzanita)
ARNCOR = *Arnica cordifolia*-“viola sp.”, “Hairy spade”
ARTTRI = *Artemisia tridentata* Nutt. (sagebrush)
ASTASC = *Aster ascendens*-“orange stem aster”
ASTEAT = Aster eatonii-“purple aster”
ATRCON = *Atriplex confertifolia* (Torrey & Frémont) S. Watson (saltbush)
BERAQU = *Berberis aquifolium* Pursh (oregon-grape, barberry) [*Mahonia repens* in Smith et al.]
BETOCC = *Betula occidentalis* Hook. (water birch)
BROCIL = *Bromus ciliatus*-“lm roadgrass”
CALNEG = *Calamagrostis neglecta*-“puffy/poofy grass”
CARBRE = *Cardamine breweri*
Carex-Junc = unidentified graminoids, mostly *Carex* spp. and *Juncus* spp.
CARLIM = *Carex limnophila*
CARMIC = *Carex microptera*-“carex doug”
CARNEB = *Carex nebrascensis* Dewey (Nebraska sedge)
CARPRE = *Carex praegracilis*-“Juncus sp.”
CERLED = *Cercocarpus ledifolius* Nutt. (curl-leaf mountain-mahogany)
CHRNAU = *Chrysothamnus nauseosus* (Pallas) Britton (rubber rabbitbrush)
CHRVIS = *Chrysothamnus viscidiflorus* (Hook.) Nutt. (yellow rabbitbrush)
CHRYSsp. = tall, unidentified *Chrysothamnus*-like shrub
COMUMB = *Comandra umbellatum* ssp. *pallida*-“thick lf forb”
CORSER = *Cornus sericea* L. ssp. *sericea* (American dogwood)
CREPsp. = *Crepis sp*.
DESCES = *Deschampsia cespitosa*-“golden tip”
DESELO = *Deschampsia elongata*-“skinny stream grass”
DODALP = *Dodecatheon alpinum*-“dodecatheon, long narrow forb”
Elym cine = *Leymus* (AKA *Elymus*) *cinereus* (Scribner & Merr.) A. Löve (Great Basin wildrye)
EPHVIR = *Ephedra viridis* Cov. (green ephedra)
EPHNEV = *Ephedra nevadensis* S. Watson (grey ephedra, mormon tea)
EPICIL = *Epilobium cilatum* ssp. *glandulosum*-“redstem”
EPIGLA = *Epilobium glaberrimum*-“pink mustard”
EQUIsp. = *Equisetum* sp. (horsetail)
ERIJON = *Erigeron jonesii*-“fuzzy basal lfs”

ERIRAC = *Eriogonum racemosum*-“fuzzy lf forb”, AND “pressed eriog/eriog jones”
GLYSTR = *Glyceria striata*-“droopy grass”
HOLOsp. = *Holodiscus* sp. (ocean-spray)
HYPSCO = *Hypericum scouleri*-“yellow flower forb”
JUNCOM = *Juniperus communis* L. (common juniper)
JUNENS = *Juncus ensifolious ssp. Montana*-“carex compound”
JUNIsp. = *Juniperus* sp.
JUNOST = *Juniperus osteosperma* (Torrey) Little (Utah juniper)
JUNSCO = *Juniperus scopulorum* Sarg. (Rocky Mountain juniper)
LUZPAR = *Luzula parviflora*-“brown droopy”
MACCAN = *Machaeranthera canescens*-“forbx”
MENARV = *Mentha arvensis*-“mint”
MERFRA = *Mertensia franciscana*-“forked starflower”
OENPAL = *Oenothera pallida*-“woody stem forb”
OPUNsp. = *Opuntia* sp. (cactus)
[[this may be incorrect; Clifton’s key identifies other spp. of Cactaceae NOT in *Opuntia*]]
OSMDEP = *Osmorhiza depauperata*
PENLEI = *Penstemon leiophyllus* ssp. *francisci-penellii*-“Hershey forb”
PHLPRA = *Phleum pratense*
PINFLE = *Pinus flexilis* James (limber pine)
PINMON = *Pinus monophylla* Torrey and Frémont (singleleaf pinyon pine)
PINPON = *Pinus ponderosa* ssp. *scopulorum* S. Wats. (Weber) (ponderosa pine)
POANER = *Poa nervosa*-“purple node grass”
POPANG = *Populus angustifolia* James (narrow-leaved cottonwood)
POPTRE = *Populus tremuloides* Micheaux (quaking aspen)
PRUVIR = *Prunus virginiana* L. (western choke-cherry)
PSEMEN = *Pseudotsuga menziesii* (Mirbel) Franco (Douglas fir)
PURTRI = *Purshia tridentata* (Pursh) DC (antelope bush; bitterbrush)
RHUARO = *Rhus aromatica* Ait. var. *trilobata* (Nutt.) A. Gray (squawbush; skunkbush)
ROSWOO = *Rosa woodsii* Lindl. var. *ultramontanus* (S. Wato.) Jeps. (Intermountain rose)
RHUARO = *Rhus aromatica* Ait. Ssp. *trilobata*-“rhus”
RIBESsp. = *Ribes* sp. [probably *R. aureum* var. *aureum*] (currant, gooseberry)
RUBIDA = *Rubus idaeus* L. ssp. *strigosus* (Michx) Maxim (raspberry)
RUMACE = *Rumex acetosella*- “red lumpy”
SALEXI = *Salix exigua* Nutt. (narrow-leaved willow; coyote willow)
SAMBsp. = *Sambucus* sp. (elderberry)
SARVER = *Sarcobatus vermiculatus* (Hook.) Torrey (greasewood)
SAXODO = *Saxifraga odontaloma*-“heart shaped viola”
SCIMIC = *Scirpus microcarpus*-“funky carex”
SMISTE = *Smilacina stellata* (L.) Desf. (false Solomon’s seal)
STEEXI = *Stephanomeria exigua* Nutt. var. *exigua*-“wire lettuce”
STELON = *Stellaria longipes*-“Stellaria-like”
STESPI = Stephanomeria spinosa-“spinyforb”
SYMORE = *Symphoricarpos oreophilus* (snowberry, waxberry)
TETRsp. = *Tetradymia* sp. (cotton-thorn, horsebrush)
THERID = Thermopsis ridifolia ssp. Montana-“thermopsis
TRIGYM = *Trifolium gymnocarpon* T&G ssp. *gymnocarpon*-“trifolium”
TRISPI = *Trisetum spicatum*
URTDIO = *Urtica dioica* L. ssp. *angustifolia* Schlecht

Appendix B Notable features from walking surveys

Notable elements in 0.32-km (0.20-mile) stream surveys that were not reported in file Appendix A, within each of our four target watersheds in the Great Basin National Park Snake Range. Whereas distances for Strawberry Creek were measured with a vehicle odometer on the gravel road adjacent to the mainstem (starting at the low-elevation Park boundary), distances for other creeks were continuously walked along the stream (and not re-set after each segment) from the 0.0-mile point (at the low-elevation Park boundary, except in Lehman Creek).

STRAWBERRY CREEK

- 0-0.20 mi – lots of ARTTRI on south side of creek; lowest ABICON observed
- 0.20-0.40 mi – POPTRE is absent; it stopped @ 0.40 mi
- 0.60-0.80 mi – approx. 100-m stand of POPTRE
- 0.80-1.00 mi – wide meadow 1/3 way up the riparian corridor; channel very wide at beginning, due to bifurcated (braided) channel
- 1.00-1.20 mi – wide, grassy meadow on south side of stream dotted with ROSWOO, ARTTRI, and PINMON; lateral angle steep
- 1.40-1.60 mi – many beaver-felled trees at lower end; stream channel narrows, road borders north side of stream transition between BETOCC to POPTRE/ABICON
- 1.40 mi – wide meadow, bifurcated channel
- 1.60 mi – fence crossing stream
- 1.60-1.80 mi – counted six small tributaries arising on south side of main channel
- 2.60-2.80 mi – wet, grassy meadow borders north side
- 2.80 mi – road crosses stream

SNAKE CREEK

- 0.31 mi – USGS cadastral survey marker “AP10”
- 0.32 mi – huge (1.93-m) rock in stream
- 0.39 mi – cattle trails in uplands notable
- 0.42 mi – USGS cadastral survey marker “AP9”, 1.5-m stretch of incision on south side at marker
- 0.43 mi – cattle-induced loss of vegetation; heavily used upland just upstream
- 0.53 mi – USGS cadastral survey marker “AP8”
- 0.60-0.80 mi – dominant tree along stream is POPANG; switches at 0.7 mi to BETOCC
- 0.67 mi – USGS cadastral survey marker “AP5”
- 0.69 mi – trailing from past cattle movements is evident in upland
- 0.76 mi – point incision
- 0.78 mi – USGS cadastral survey marker “AP4”
- 0.79 mi – permanent plot 9 end (Smith et al. (1994) study, UNLV)
- 0.80-1.00 mi – stream veg corridor broadens; road runs parallel to stream on north side, 10 m from stream; riparian veg crosses road in some places, lots of BROTEC along roadsides/campsites
- 0.87 mi – point incision on north bank, apparently due to campground road
- 0.88 mi – channel has migrated, BETOCC distant from active channel here
- 0.98 mi – 2-m incision at bend
- 1.05 mi – many large rocks > 7 m in diameter
- 1.06 mi – USGS cadastral survey marker survey sec. 17/18
- 1.09 mi – stream is >3 m below surface of adjacent upland on north side
- 1.12 mi – USGS cadastral survey marker “AP10”

- 1.15 mi – south-side bank almost 4 m above stream
- 1.16 mi – USGS cadastral survey marker “AP9”
- 1.20 mi – USGS cadastral survey marker “AP8”
- 1.20 mi – dirt road crosses creek
- 1.35 mi – USGS cadastral survey marker “AP7”
- 1.41 mi – USGS cadastral survey marker “AP6”
- 1.43 mi – USGS cadastral survey marker “AP5”
- 1.49 mi – broad, low terrace
- 1.50 mi – beginning to see cryptogamic crusts
- 1.54 mi – significant downcutting below PINMON that fell into stream
- 1.58 mi – USGS cadastral survey marker “AP4”
- 1.79 mi – USGS cadastral survey marker “AP2”
- 1.90 mi – 1.5-m long downcut
- 1.91 mi – USGS cadastral survey marker “AP1”
- 2.08 mi – grassy meadow
- 2.25 mi – stream goes underground
- 2.60-2.80 mi – heavy cattle usage
- 4.60-4.80 mi – lots of BROTEC along stream bank
- 4.80-5.00 mi – lowest elev. PICENG (2,319 m)
- 6.10 mi – 15 small-diameter fallen trunks across stream
- 6.72 mi – lateral angle becomes steep
- 6.80-7.00 mi – several tree falls originating from inside the stream and ending away from the channel
- 6.85-6.88 mi – wet meadow
- 6.91 mi – channel erosion in tributary
- 6.97 mi – persistent downcutting in side stream
- 7.60-7.69 mi – high-gradient stream in main channel
- 7.69 mi – stream flattens out; oxbow present on flat bench
- 7.70 mi – cow pies on flat grassy meadows beyond oxbow; width of *Carex*/herbaceous zone = 0.5-1.0 m

BAKER CREEK

- 0.03 mi – lowest-elevation PINPON in Park
- 0.10 mi – lowest-elevation ABICON in Park
- 0.22 mi – potential location of transect 1; wide channel above rock bridge; meadow
- 0.23-0.31 mi – stream bifurcated
- 0.29 mi – pretty good fence
- 0.33 mi – Pole Canyon trailhead bridge
- 0.40-0.60 mi – cliff narrows stream channel; defines riparian zone on south side
- 0.51 mi – point incision (2.5 m long); well armored
- 0.60-0.80 mi – more POPTRE after culvert
- 0.74 mi – stream runs under road
- 0.75-0.78 mi – small bifurcation runs on south side
- 0.80 mi – bank incision: 6 m long, ~ 1 m tall
- 0.83 mi – bank incision: 4 m long, ~ 60 cm tall
- 0.93 mi – big (wide) wood debris dam
- 0.96 mi – campground road crosses stream
- 1.08 mi – point incision (north side only): 15-20 m long, 0.5 - >2.0 m tall
- 1.13 mi – point incision: 3 m long, 1.25 m tall; broad dry meadow in upland
- 1.18 mi – point incision (offset, but present on both sides): 3.5 m long, 1.4 m tall
- 1.20–1.30 mi and beyond – stream too densely vegetated to easily observe; some broad dry meadows exist; channel has been split for a long time, and is ± braided
- 1.42 mi – wet meadow 100 m to south of stream
- 1.40-1.54 mi – lots of wet and dry meadows to south of stream
- 1.00 mi –> unspecified location: beaver-created stumps
- Broad-leaved *Populus* individuals at 2,271 m elevation; seem too broad to be *P. angustifolia*
- 1.68 mi – stream splits
- 1.68–1.80 mi – braided channel
- 1.83 mi – lowest-elevation PINFLE at 2,317 m
- 1.76 mi – Baker Crk. CG first observed

- 1.87 mi – Baker Crk. campsite #16
- 1.92 mi – road to “Exit” crosses stream
- 1.93-1.99 mi – stream splits
- 2.07 mi – triangular shed and cattle guard

LEHMAN CREEK

(distances are miles from the headwaters of mainstem of Lehman Crk.)

- 5.00-5.20 mi – lots of cow pies present; BROTEC, ARTTRI, and CHRVIS extend down into stream bed at some points
- 4.99 mi – green house with antenna
- 4.96 mi – point bank-sloughing
- 4.90 mi – point bank-sloughing: <3 m long
- 4.75 mi – point bank-sloughing: <3 m long (occurs at bend in the stream)
- 4.70 mi – point bank-sloughing: 8 m long, 2 m high (occurs at bend in the stream)
- 4.92–4.93 mi – several large treefalls
- 4.73–4.91 mi – small stream has been separated from and running parallel to main channel to the north
- 4.69 mi –short bifurcation of stream
- 4.61–4.63 mi – longer bifurcation (division into 2) of stream
- 4.54 and 4.55 mi – lots of branches over stream
- 4.38 mi – huge pile of branches
- 4.18 and 4.19 mi – logs across stream
- 4.16–4.17 mi – stream bifurcated (2 main channels); lots of downed logs throughout
- 4.09 mi – lots of downed logs
- 4.07 mi – stream splits into two
- 4.04 mi – 3-way split of stream
- 3.82 mi – Lower Lehman campground site #10
- 3.69 mi – campsite access (road?)
- 3.66–3.68 mi – stream split into two
- 3.57 mi – island of *Salix* sp.
- 3.54 mi – pile of downed logs
- 3.52 mi – stream forks
- 3.48 mi – smaller fork in stream
- 3.47 mi – dead willow treefall splits stream; another stream runs parallel on north side
- 3.45 mi – stream crosses road
- 3.41 mi – treefall
- 3.34 mi – island of *Betula* trees divides and broadens stream
- 3.23 mi – stream forks again
- 3.17 and 3.18 mi – campsites located between two branches of streams
- 3.14 mi – northernmost channel splits
- (Recreational trail runs on south side of northern channel)
- 3.05 mi – campsites on north and south sides of northern channel
- 3.03 mi – campsites on south side of northern channel
- 2.95 mi – small tributary enters mainstem from the south
- 2.89 mi – Upper Lehman campground campsite
- 2.85 mi – road meets stream

2.81 mi – second-highest-elevation campsite in Upper Lehman CG (#23?)

Appendix C Transect (rebar) locations

Location and elevation of each of the four transect endpoints (pieces of rebar) at each of 31 transects in the four target watersheds, in both metric and English units. Nomenclature of point names: a) the first three characters refer to the transect identity; b) XS refers to the (narrower) cross-sectional transect immediately outside the bankfull (N on the northernmost side of the stream, and S on the southernmost side of the stream); c) 50M refers to the 50-m transect endpoints. WAAS (wide-area augmentation system) is a system of ground reference stations and geostationary satellites, which allow precision in point-location estimates of 3-7 m. The rightmost column provides another set of reference points for re-locating transect endpoints.

Transect and rebar	LOCATION (Decimal °)		ELEV	LOCATION (UTM)		ELEV	WAAS?	
	Lat (N)	Long (W)	(ft)	x	y	(m)	Y/N	PLOT-LOCATION INFORMATION:
BK1 XSN	38.97212	-114.26310	8740	737105.0	4317245.6	2664.0	N	(i) 50MN rebar to POPTRE w/ “NP & GB”, 2 m from rebar, DBH 13.4 cm 196° from rebar to tree.
BK1 XSS	38.97205	-114.26312	8730	737103.8	4317238.1	2660.9	N	
BK1 50MN	38.97222	-114.26308	8741	737106.1	4317256.7	2664.3	N	(ii) XSN rebar 1.99 m from POPTRE, DBH 37.3 cm @ stream edge, 145° (stake to tree center).
BK1 50MS	38.97197	-114.26317	8743	737099.7	4317228.7	2664.9	N	
BK2 XSN	38.97247	-114.26075	8559	737307.4	4317290.5	2608.8	N	(i) 50MN rebar to POPTRE at edge of trail says “BS X 57”, 11.21 m, DBH 23.3 cm at 171°.
BK2 XSS	38.97238	-114.26067	8508	737314.9	4317281.5	2593.2	N	
BK2 50MN	38.97262	-114.26082	8628	737301.2	4317307.0	2629.8	N	(ii) 4.55 m from XSN rebar to closest root of downed Douglas fir, 204° from tree to rebar.
BK2 50MS	38.97225	-114.26060	8580	737321.2	4317266.9	2615.2	N	
BK3 XSN	38.97450	-114.24915	8142	738305.7	4317546.5	2481.7	N	(i) From 50MN stake to “V”-shaped POTR (branching begins at 0.93 m hgt. DBH of N-most (L) trunk is 32.6 cm, DBH of S-most (Rt) trunk is 35.9 cm. 3.75 m @ 31°.
BK3 XSS	38.97447	-114.24912	8175	738308.7	4317542.9	2491.7	N	
BK3 50MN	38.97472	-114.24920	8149	738300.7	4317570.5	2483.8	N	(ii) From 50MS stake to rock of width 65.0 cm, length 106 cm, surrounded by PRUVIR [DIGPIC]; 6.19 m to rocks highest pt @ 270°.
BK3 50MS	38.97425	-114.24912	8174	738309.4	4317518.9	2491.4	N	
BK4 XSN	38.97645	-114.24440	7980	738710.7	4317775.4	2432.3	N	(i) 50MN rebar to hinge of bathroom door is 31.99 m, 275°.
BK4 XSS			8082			2463.4	N	(ii) 50MN rebar to POPTRE “CS77”; 12.97 m to base of tree, DBH 32.7 cm at 320° (rebar to tree).
BK4 50MN	38.97652	-114.24470	7988	738684.5	4317782.0	2434.7	N	
BK4 50MS	38.97628	-114.24425	8013	738724.3	4317757.3	2442.4	N	(iii) XSS rebar to big POPTRE, 5.91 m, DBH 52 cm, 120° (rebar to tree).
BK5 XSN	38.98770	-114.23933	7570	739111.8	4319037.5	2307.3	N	(i) XSN rebar to POPTRE, “Aleis + grandma”, 6.2 m, DBH 25.7 cm, 43°, from rebar to tree.
BK5 XSS	38.98763	-114.23930	7565	739114.9	4319030.1	2305.8	N	
BK5 50MN	38.98787	-114.23953	7557	739093.9	4319055.4	2303.4	N	(ii) 50MN rebar to POPTRE “MIX MU”, 4.06 m, 33°, from tree to rebar, DBH 32.7 cm.
BK5 50MS	38.98747	-114.23918	7567	739125.6	4319012.0	2306.4	N	

Transect and rebar	LOCATION (Decimal °)		ELEV	LOCATION (UTM)		ELEV	WAAS?	
	Lat (N)	Long (W)	(ft)	x	y	(m)	Y/N	PLOT-LOCATION INFORMATION:
BK6 XSN	38.98867	-114.23785	7519	739237.1	4319148.7	2291.8	N	(i) 4.97 m, DBH 22.6 cm 15° (tree to rebar) from XSN rebar to POPTRE.
BK6 XSS	38.98860	-114.23787	7534	739235.8	4319141.2	2296.4	N	
BK6 50MN	38.98885	-114.23783	7514	739237.9	4319169.1	2290.3	N	(ii) 5.93 m to base of POPTRE scar from XSN rebar.
BK6 50MS	38.98838	-114.23785	7522	739238.0	4319117.2	2292.7	N	(iii) 43.6 cm DBH, 292° tree to rebar.
BK7 XSN	38.99095	-114.22605	7217	740251.5	4319433.2	2199.7	N	(i) 50MN rebar to picnic table (south most corner) of campsite, 27.32 m, 54°.
BK7 XSS	38.99082	-114.22598	7201	740257.8	4319418.6	2194.9	N	
BK7 50MN	38.99103	-114.22608	7217	740248.4	4319442.4	2199.7	N	(ii) 50MN rebar to ABICON of DBH 61.8 cm (very large girth) 3.81 m @ 181°.
BK7 50MS	38.99065	-114.22592	7201	740264.1	4319400.3	2194.9	N	
BK8 XSN	38.99085	-114.22148	7084	740647.5	4319434.2	2159.2	N	(i) From XSS stake to large boulder in stream by swim hole, 8.58 m @ 20°.
BK8 XSS	38.99080	-114.22153	7087	740643.3	4319428.5	2160.1	N	(ii) From 50MS stake to NW corner seat of picnic table (Greycliffs cmpgrnd) 20.21 m @ 202°.
BK8 50MN	38.99093	-114.22128	7120	740664.5	4319443.9	2170.2	N	(iii) Trx runs just upstream from artificial rock dam.
BK8 50MS	38.99072	-114.22177	7097	740623.4	4319418.61	2163.2	N	
LM1 XSN	39.01095	-114.29795	9661	733957.4	4321465.7	2944.7	Y	(i) 5.05 m @ 313°. From S-side XS stake to dwnstrm white corner (top) of stream gauging apparatus.
LM1 XSS	39.01090	-114.29797	9727	733956.1	4321460.1	2964.8	Y	(ii) 5.05 m @ 241°. From N-side XS stake to same pt.
LM1 50MN	39.01113	-114.29788	9684	733962.5	4321486.2	2951.7	Y	
LM1 50MS	39.01072	-114.29803	9732	733950.9	4321439.6	2966.3	Y	
LM2 XSN	39.01028	-114.30060	9814	733730.1	4321384.9	2991.3	N	(i) From XSN stake to PICENG of DBH 54.2 cm (tallest of 4 on island in center of stream) 5.69 m @ 41° to center of base.
LM2 XSS	39.01015	-114.30052	9727	733737.7	4321370.3	2964.8	N	(ii) From N-side 50M stake to dead gnarly (v.large) PICENG of DBH 114.5 cm, 5.76 m to center of base @ 41°.
LM2 50MN	39.01038	-114.30073	9839	733718.2	4321395.7	2998.9	N	
LM2 50MS	39.01007	-114.30035	9870	733752.4	4321361.5	3008.4	N	
LM3 XSN	39.01785	-114.23443	7240	739434.6	4322396.9	2206.8	Y	(i) Plot @ same elevation as first turnout on S-side of rd. below lowest Lower Lehman exit (~1.6 mi from JCT w/ road to VC).
LM3 XSS	39.01792	-114.23438	7281	739438.7	4322404.5	2219.2	Y	
LM3 50MN	39.01800	-114.23455	7194	739424.0	4322413.3	2192.7	Y	
LM3 50MS	39.01780	-114.23432	7281	739444.8	4322391.7	2219.2	Y	

Transect and rebar	LOCATION (Decimal °)		ELEV	LOCATION (UTM)		ELEV	WAAS?	
	Lat (N)	Long (W)	(ft)	x	y	(m)	Y/N	PLOT-LOCATION INFORMATION:
LM4 XSN	39.01670	-114.23768	7266	739157.0	4322260.7	2214.7	Y	(i) From N-side 50MXS stake to E-most corner of concrete slab of women's restroom lower lehman campground. site #8; 6.02 m @ 297°. (ii) From N-side XSN stake to center of base of tall PINMON of DBH 38.2 cm (next to skinny dead one); 10.45 m @ 280°.
LM4 XSS	39.01672	-114.23765	7319	739159.8	4322262.7	2230.8	Y	
LM4 50MN	39.01685	-114.23785	7271	739142.1	4322277.0	2216.2	Y	
LM4 50MS	39.01657	-114.23752	7309	739171.9	4322246.4	2227.8	Y	
LM5 XSN	39.01328	-114.26792	8224	736550.4	4321802.4	2506.7	N	(i) From N-side XSN stake to POTR of DBH 21.4 cm, says "46" on bark; 6.46 m @ 77°.
LM5 XSS	39.01320	-114.26777	8292	736563.7	4321793.6	2527.4	N	
LM5 50MN	39.01337	-114.26775	8283	736564.6	4321812.1	2524.7	N	
LM5 50MS	39.01305	-114.26790	8293	736552.7	4321776.6	2527.7	N	
LM6 XSN	39.01262	-114.25228	7747	737906.5	4321769.2	2361.3	Y	(i) From N-side 50 m stake to western most corner of "parking only" post in lower loop of Upper Lehman cmpgrnd. 14.01 m @ 91°. (ii) From N-side XSN stake to POTR of DBH 16.5 cm w/ "M" written on it @ waist height; 4.49 m @ 78°.
LM6 XSS	39.01252	-114.25227	7716	737908.2	4321758.1	2351.8	Y	
LM6 50MN	39.01282	-114.25222	7750	737911.6	4321791.6	2362.2	Y	
LM6 50MS	39.01233	-114.25235	7691	737901.6	4321737.6	2344.2	Y	
SN1			6397	11 747072 E	4311202 N	1949.8	*	i) From the closest point where the rock outcrop (~7 m x 8 m) meets the road, looking south to XSN is 175˚ azimuth and 21.3 m. ii) Highest point of outcrop is 1.25 m from 50MN rebar.
SN2			6399	11 747108	4311249 N	1950.4	*	i) 11.70 m at 162˚ from high point of squarish-shaped large white rock along road to XSN. ii) 14.44 m at 241˚ from same point to stake at 6 m, near road. iii) 2.92 m downstream of downstreammost point of BETOCC clump.
SN3			8410	11 737554 E	4312575 N	2563.4	*	i) ~0.56 km (~0.35 mi) above Shoshone CG, and just below extensive meadow on south side of stream. ii) 11.24 m at 115˚ azimuth from XSN rebar to POPTRE (26.4 cm DBH, says "DW 1941" on uphill side of trunk. iii) 11.62 at 80˚ from XSN to POPTRE (25.4 cm, says "R" on downhill side).
SN4			8508	11 737573 E	4312591 N	2593.2	*	i) 6.55 m at 268˚ from XSN to 2 POPTRE growing together on N side of creek (60.8 cm diameter at V in trunk).
*These points were differentially corrected and thus more accurate (within approximately 0.75 - 1.50 m of the actual point on the earth).								
SN5 XSN	38.92013	-114.21940	7544	741067.6	4311590.3	2299.4	N	**XSN stake is**: a) 1.10 m at 58° from orange stake w/ "BP# 4972" downhill from forked POPANG); b) 6.96 m @ 156° from upstream middle of base of POPTRE w/ "Keith Taylor June 21 1954", 24.8 cm DBH; c) 8.05 m @ 320° from top of pipe in mid-stream marked w/ black X; d) immediately dwnstrm., of 10-cm diameter stump, 25 cm tall; and e) towards & a bit downstream of POPANG w/ 189 tag.
SN5 XSS								
SN5 50MN								
SN5 50MS	38.92017	-114.21970	7546	741041.5	4311593.2	2300.0	N	

Transect and rebar	LOCATION (Decimal °)		ELEV	LOCATION (UTM)		ELEV	WAAS?	PLOT-LOCATION INFORMATION:
	Lat (N)	Long (W)	(ft)	x	y	(m)	Y/N	
SN6 XSN	38.91973	-114.21887	7513	741115.2	4311547.3	2290.0	N	(i) 18.91 m @ 319° to center of 23.95 cm DBH POPTRE on S side of road w/ stump cut like a V. (ii) 17.12 m @ 74° to water pipe upstream of trx; both positions are from 50M endpoint on N side of road.
SN6 XSS	38.91972	-114.21890	7531	741112.4	4311545.4	2295.4	N	
SN6 50MN	38.91990	-114.21878	7544	741121.9	4311566.0	2299.4	N	
SN6 50MS	38.91957	-114.21890	7560	741112.9	4311528.7	2304.3	N	
SN7 XSN	38.91228	-114.16890	6714	745473.6	4310853.8	2046.4	N	(i) From rock at south edge of road looking south to N rebar, 141°, 9.9 m rock is by CHRNAU. (ii) From 50MN rebar to standing snake rock spire, 138°.
SN7 XSS	38.91223	-114.16893	6727	745470.9	4310848.1	2050.4	N	
SN7 50MN	38.91233	-114.16865	6720	745495.1	4310860.0	2048.3	N	
SN7 50MS	38.91207	-114.16907	6727	745459.9	4310829.3	2050.4	N	
SN8 XSN	38.91218	-114.16760	6696	745586.7	4310846.2	2040.9	N	(i) 25.5 m @ 299° to center of lone JUOS on N side of road, that has a very rounded crown, from 50MN rebar. (ii) 3.83 m from 50MN rebar to crest of road burm, perpendicular to the road berm. (iii) 0.3 m up the road (W) from western terminus of EPHNEV to 50MN rebar.
SN8 XSS								
SN8 50MN	38.91233	-114.16745	6696	745599.2	4310861.4	2040.9	N	
SN8 50MS	38.91200	-114.16792	6692	745559.8	4310825.0	2039.7	N	
ST1			7714	11 733796 E	4326741 N	2351.2	*	No plot-location information.
ST2			7812	11 733696 E	4326701 N	2381.1	*	i) 8.46 m at 221˚ from XSS rebar to center of ABICON tree (43.6 cm DBH, >15 m tall). ii) 17.86 m at 86˚ azimuth from XSS to NPS-RM survey point (yellow stake – just W of small tributary of width 30 cm).
ST3			7720	11 733758 E	4326731 N	2353.1	*	i) ~5-15 m upstream from exclosure on N side of dirt road. ii) ~5 m upstream from downed log of DBH 35.8 cm; log occurs @ 45˚ from stream. iii) 7.04 m at 121˚ from XSS to POPTRE (32.1 cm DBH, ┌┘ shape).

*These points were differentially corrected and thus more accurate (within approximately 0.75-1.50 m of the actual point on the earth).

Transect and rebar	Lat (N)	Long (W)	ELEV (ft)	x	y	ELEV (m)	WAAS? Y/N	PLOT-LOCATION INFORMATION:
ST4 XSN	39.04897	-114.32055	8465	731875.9	4325627.6	2580.1	N	(i) 14.10 m from XSS rebar to broken off edge of PICENG, 256° from tree edge to rebar. (ii) POPTRE that has Palomo engraved, it is across from location 1, 280° (tree to rebar), 3 m.
ST4 XSS	39.04888	-114.32047	8503	731883.4	4325618.5	2591.7	N	
ST4 50MN	39.04903	-114.32072	8511	731861.2	4325634.5	2594.2	N	
ST4 50MS	39.04882	-114.32028	8498	731899.5	4325611.6	2590.2	N	
ST5 XSN	39.04940	-114.31998	8467	731923.5	4325677.1	2580.7	N	(i) 8.19 m from POPTRE to N-side stream stake @ 188°, DBH 36.05 cm, “Clark Neilson 1958” at BH on E-side of road (~2 m). (ii) 15.11 m from POPTRE to S-side stream stake @ 15.11 m from POPTRE to S-side stream stake @ BH on E-side of road (~1 m).
ST5 XSS	39.04925	-114.32012	8455	731912.5	4325660.1	2577.1	N	
ST5 50MN	39.04933	-114.32035	8480	731892.0	4325668.8	2584.7	N	
ST5 50MS	39.04913	-114.31998	8459	731924.4	4325647.5	2578.3	N	

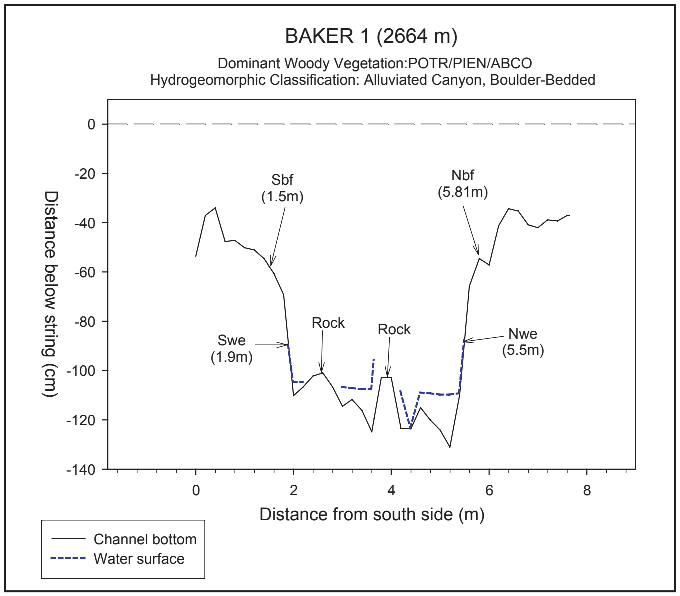
Transect and rebar	LOCATION (Decimal °)		ELEV	LOCATION (UTM)		ELEV	WAAS?	
	Lat (N)	Long (W)	(ft)	x	y	(m)	Y/N	PLOT-LOCATION INFORMATION:
ST6 XSN	39.05583	-114.30245	7871	733419.8	4326436.1	2399.1	N	(i) Base of POPTRE, DBH 33.2 cm, NNW of 5 m wide rock pile, 11.43 m to 50MN stake, 208° tree to stake. (ii) ABICON DBH 49.0 cm, 24.6 m @ 220° from base of ABICON to 50MN stake. (iii) Group of 4 POPTRE, 1.50 m from XSS stake to center V of upstrm pr., @ 44° NE of stake.
ST6 XSS	39.05588	-114.30270	7889	733398.0	4326441.0	2404.6	N	
ST6 50MN								
ST6 50MS	39.05563	-114.30082	8467	733561.9	4326418.1	2580.7	N	
ST7 XSN	39.05897	-114.29155	7589	734352.8	4326811.9	2313.1	N	(i) 2.52 m from XSN rebar to center base of POPTRE, DBH is 50.6 cm, @ 10°. (POPTRE has dark crusty base, branching into 3 prominent trunks @ ~ 2 m high). (ii) 12.44 m from XSN rebar to center base of POPTRE, DBH 34.3 cm @ 306°, says "PB" on upslope side.
ST7 XSS	39.05888	-114.29155	7599	734353.1	4326802.7	2316.2	N	
ST7 50MN	39.05912	-114.29153	7586	734353.8	4326828.6	2312.2	N	
ST7 50MS								
ST8 XSN	39.06157	-114.26742	7049	736432.6	4327163.1	2148.5	N	(i) 50MS rebar to hightest point of E-most rock (pair 60-65 cm diam.) 1.60 m @ 236°. (ii) 50MN rebar to EPHNEV (center of base), 6.59 m at 355°.
ST8 XSS	39.06148	-114.26737	7064	736437.2	4327154.0	2153.1	N	
ST8 50MN	39.06153	-114.26718	7048	736452.9	4327160.0	2148.2	N	
ST8 50MS	39.06132	-114.26747	7058	736429.1	4327135.2	2151.3	N	
ST9 XSN	39.06012	-114.27735	7269	735577.8	4326976.3	2215.6	N	(i) XSS stake to rebar w/ yellow cap says "straw" (faded), 3.65 m @ 114°. (ii) XSN stake to PINMON L-shaped stump of 16 cm diam. 1-2 m from road edge, 15.55 m @ 303°.
ST9 XSS	39.06002	-114.27732	7261	735581.1	4326965.3	2213.2	N	
ST9 50MN	39.06017	-114.27723	7305	735587.8	4326982.2	2226.6	N	
ST9 50MS			7266			2214.7	N	

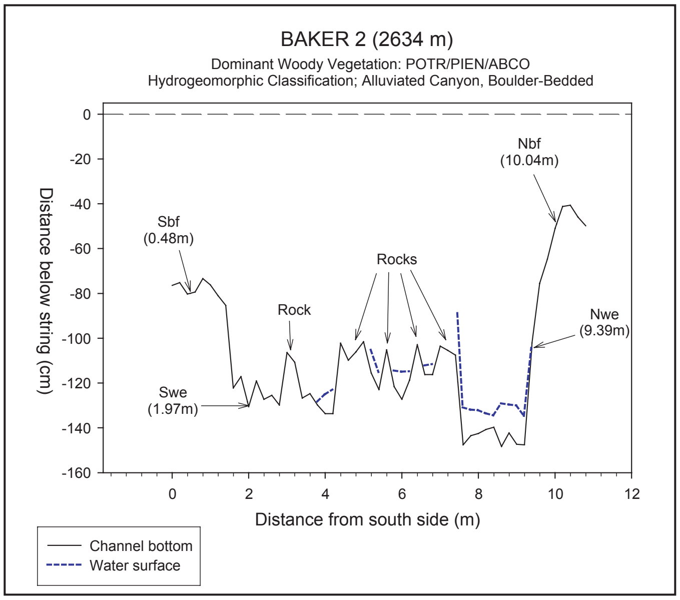
Appendix D Reasons why monitoring of aggregate soil stability is not recommended for riparian areas of Great Basin National Park.

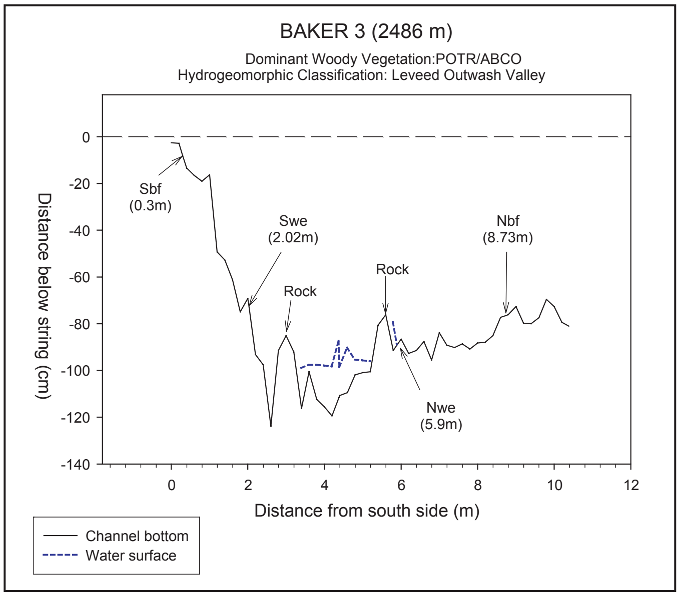
1. The number of bare spaces with no litter is often very limited, and exactly how one removes this litter to get a surface sample will greatly influence the stability value. This is difficult to standardize for comparability across replicated measurements through time.
2. The soil is too rocky to sample easily in a defensible and repeatable manner.
3. It is very difficult to get to the soil surface under shrubs, due to large amounts of duff and surface roots.
4. There is too much fine-root mass in upper soil horizons to permit soils to become unstable over time, thus obviating the need to monitor soil stability.
5. The method may not be repeatable enough to be rigorous for monitoring purposes. Detecting change can be confounded by observer bias.
6. It is not a rigorously quantitative method, but rather categorical, which limits its precision.
7. Give the combination of factors above, we suspect that the response variable will not change enough over time to be detected by divergent observers, even if methods are very explicit (e.g., exactly where to sample, how to clear off litter, how to pare down soil sample to standard size, etc.).

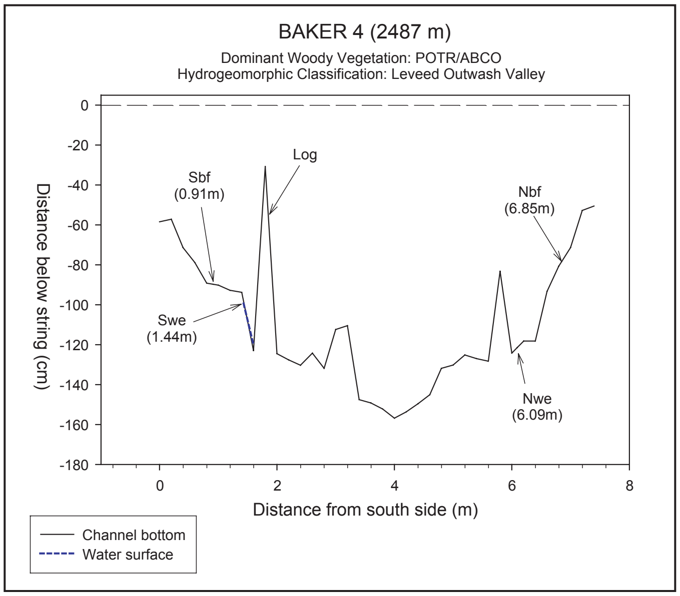
Appendix E Cross sections

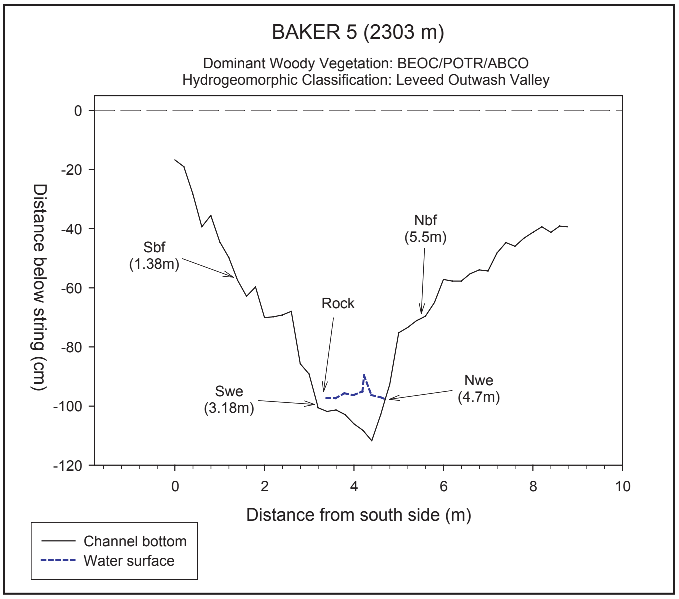
Elevations of the water surface and the bottom of the channel, relative to a string pulled between points on inner pieces of rebar indicated by hacksaw marks (following Herrick et al. *in press*). Measurements occurred at each 20-cm interval between bankfull endpoints. **Sbf** = bankfull on southernmost edge of stream; **Nbf** = northern bankfull; **Nwe** = wetted edge on northernmost side of the stream at the time of sampling; and **Swe** = southern wetted edge. Hydrogeomorphic valley types follow Frissell and Liss (1993).

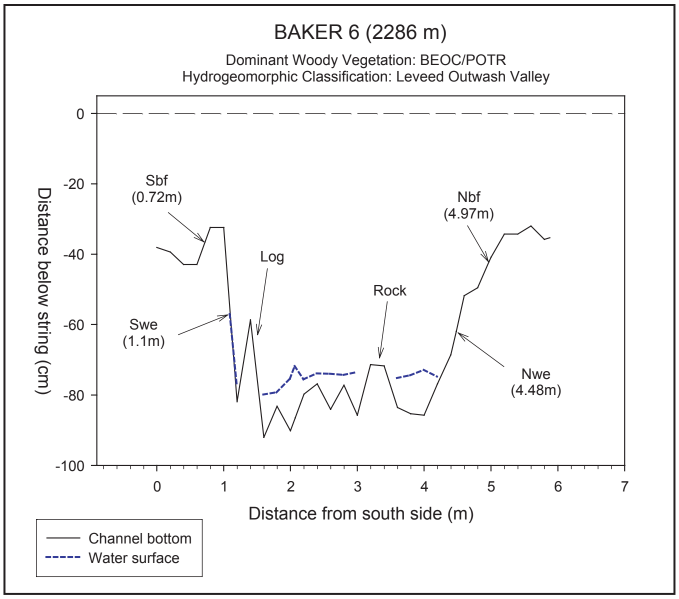


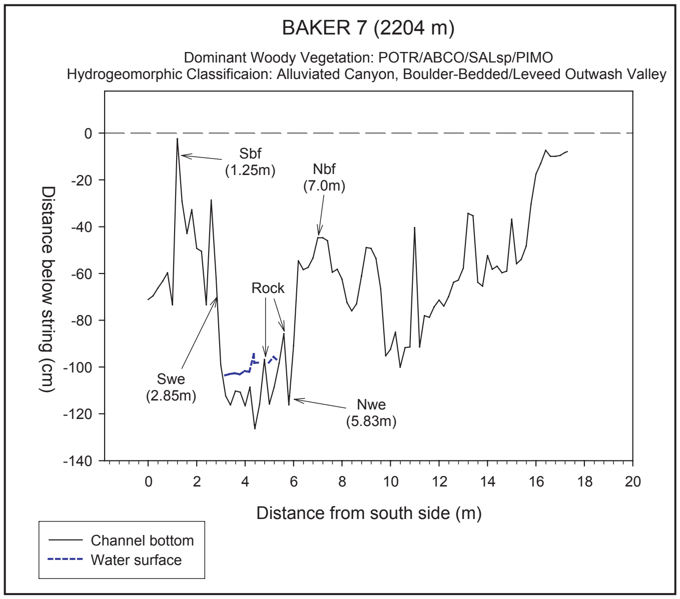


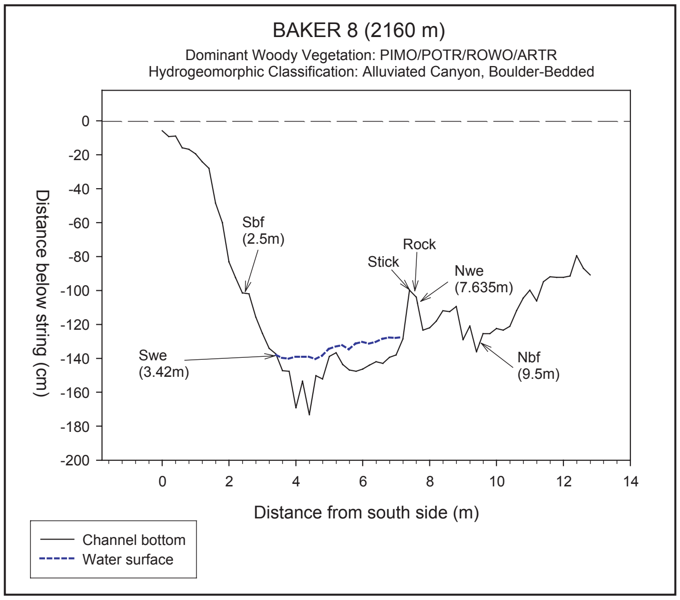


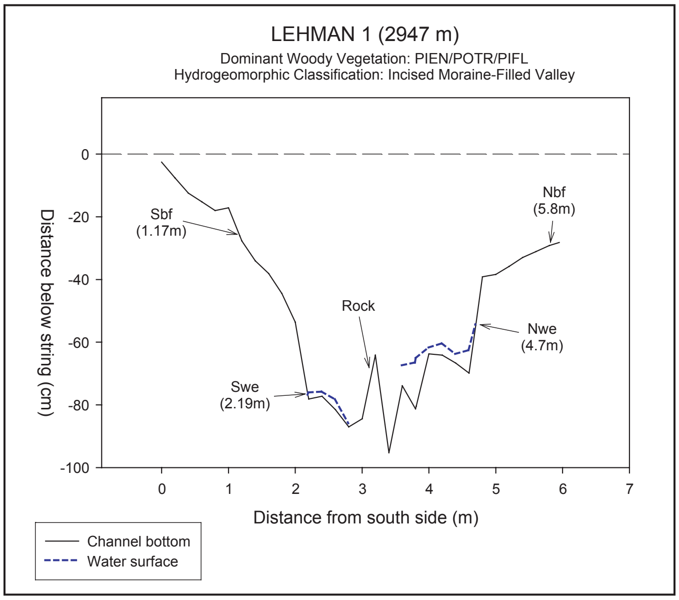


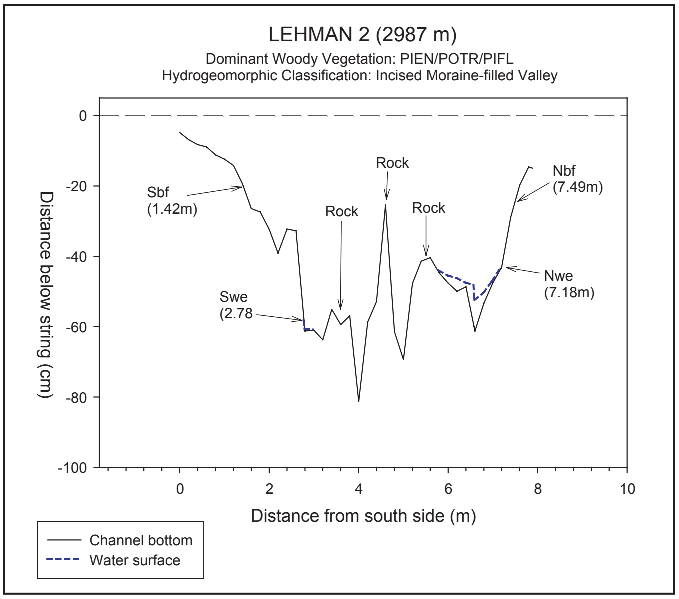

BAKER 5 (2303 m)
Dominant Woody Vegetation: BEOC/POTR/ABCO
Hydrogeomorphic Classification: Leveed Outwash Valley
Distance below string (cm)
0
-20
-40
-60
-80
-100
-120
Sbf
(1.38m)
Nbf
(5.5m)
Rock
Swe
(3.18m)
Nwe
(4.7m)
0
2
4
6
8
10
Distance from south side (m)
Channel bottom
Water surface

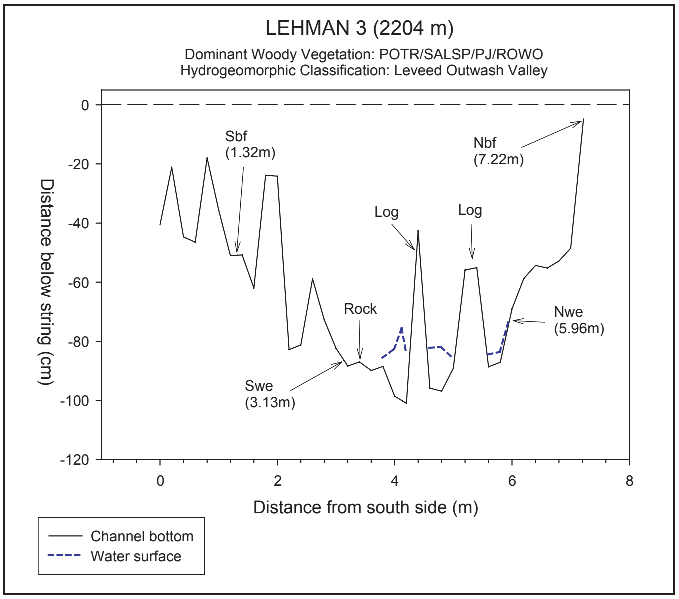

BAKER 6 (2286 m)
Dominant Woody Vegetation: BEOC/POTR
Hydrogeomorphic Classification: Leveed Outwash Valley
Distance below string (cm)
0
-20
-40
-60
-80
-100
Sbf
(0.72m)
Nbf
(4.97m)
Log
Rock
Swe
(1.1m)
Nwe
(4.48m)
0
1
2
3
4
5
6
7
Distance from south side (m)
Channel bottom
Water surface

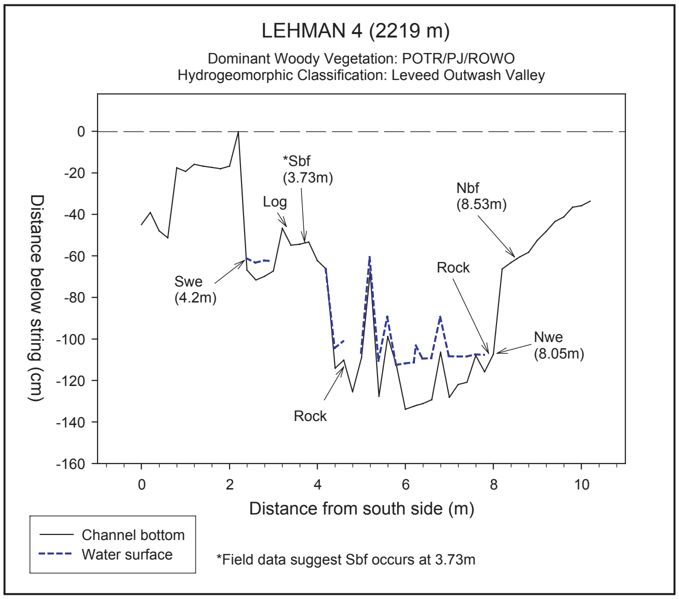

BAKER 7 (2204 m)
Dominant Woody Vegetation: POTR/ABCO/SALsp/PIMO
Hydrogeomorphic Classificaion: Alluviated Canyon, Boulder-Bedded/Leveed Outwash Valley
Distance below string (cm)
0
-20
-40
-60
-80
-100
-120
-140
Sbf
(1.25m)
Nbf
(7.0m)
Rock
Swe
(2.85m)
Nwe
(5.83m)
0
2
4
6
8
10
12
14
16
18
20
Distance from south side (m)
Channel bottom
Water surface

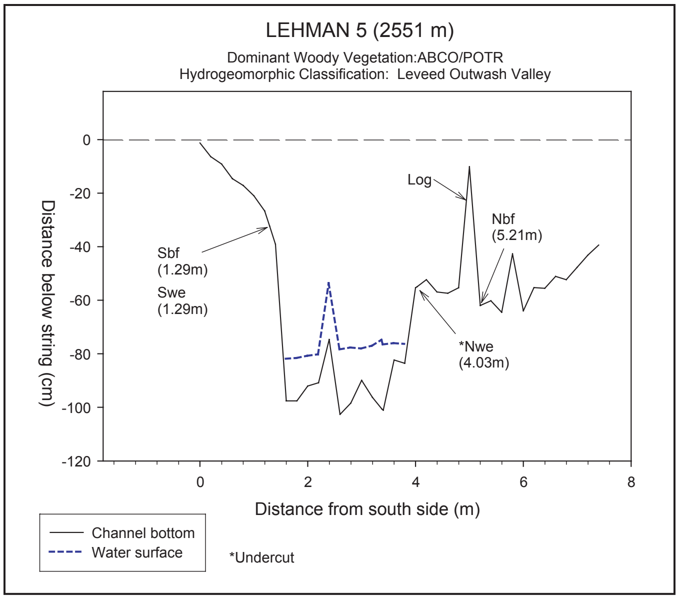

BAKER 8 (2160 m)
Dominant Woody Vegetation: PIMO/POTR/ROWO/ARTR
Hydrogeomorphic Classification: Alluviated Canyon, Boulder-Bedded
Distance below string (cm)
0
-20
-40
-60
-80
-100
-120
-140
-160
-180
-200
Sbf
(2.5m)
Rock
Stick
Nwe
(7.635m)
Swe
(3.42m)
Nbf
(9.5m)
0
2
4
6
8
10
12
14
Distance from south side (m)
Channel bottom
Water surface

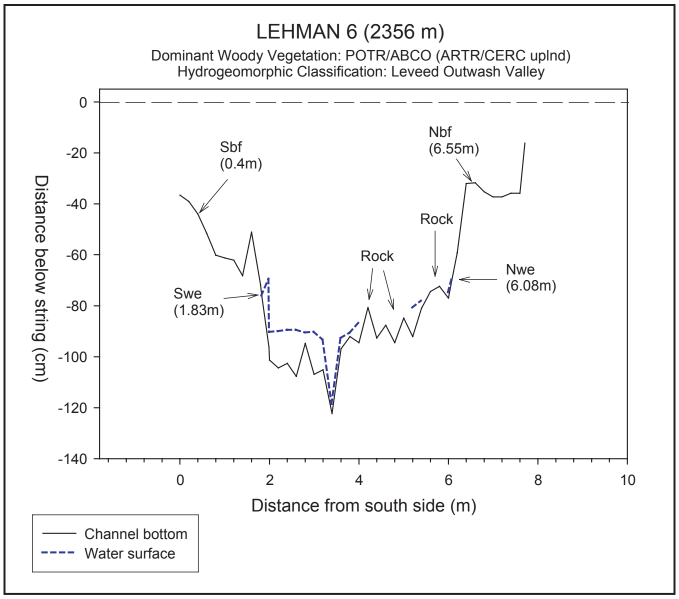

LEHMAN 1 (2947 m)
Dominant Woody Vegetation: PIEN/POTR/PIFL
Hydrogeomorphic Classification: Incised Moraine-Filled Valley
Distance below string (cm)
0
-20
-40
-60
-80
-100
Sbf
(1.17m)
Nbf
(5.8m)
Rock
Nwe
(4.7m)
Swe
(2.19m)
0
1
2
3
4
5
6
7
Distance from south side (m)
Channel bottom
Water surface

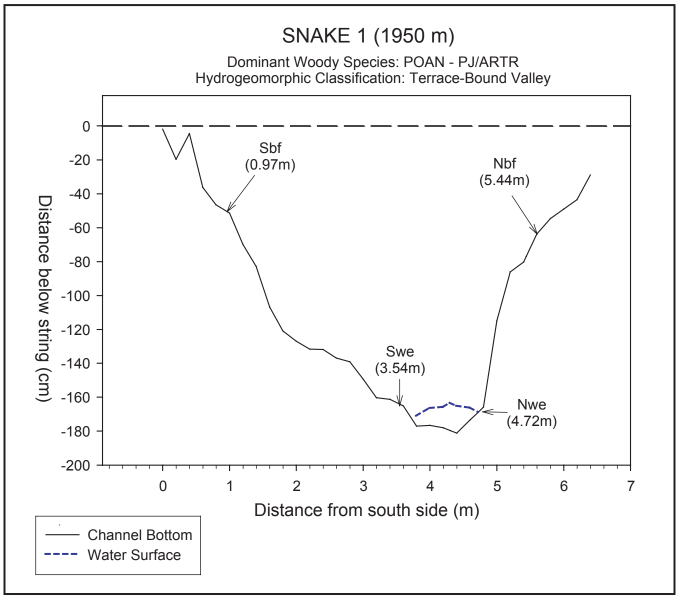

LEHMAN 2 (2987 m)
Dominant Woody Vegetation: PIEN/POTR/PIFL
Hydrogeomorphic Classification: Incised Moraine-filled Valley
Distance below string (cm)
0
-20
-40
-60
-80
-100
Sbf
(1.42m)
Rock
Rock
Rock
Nbf
(7.49m)
Nwe
(7.18m)
Swe
(2.78
0
2
4
6
8
10
Distance from south side (m)
Channel bottom
Water surface

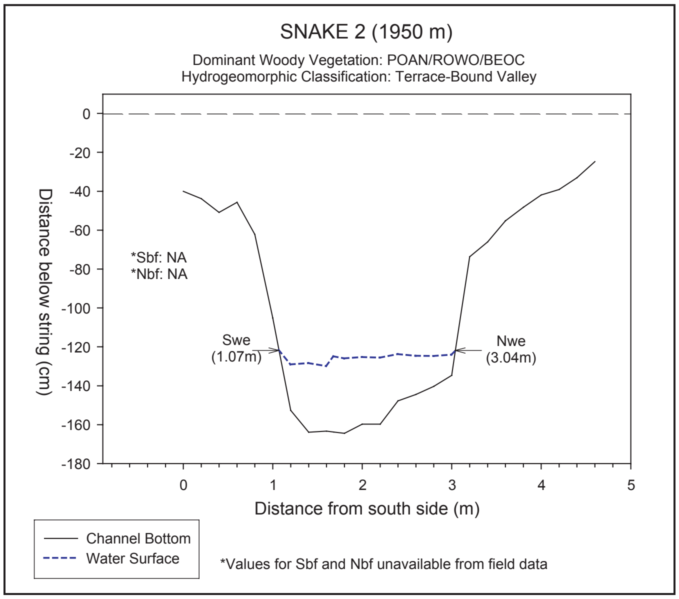

LEHMAN 3 (2204 m)
Dominant Woody Vegetation: POTR/SALSP/PJ/ROWO
Hydrogeomorphic Classification: Leveed Outwash Valley
Distance below string (cm)
0
-20
-40
-60
-80
-100
-120
Sbf
(1.32m)
Nbf
(7.22m)
Log
Log
Rock
Nwe
(5.96m)
Swe
(3.13m)
0
2
4
6
8
Distance from south side (m)
Channel bottom
Water surface

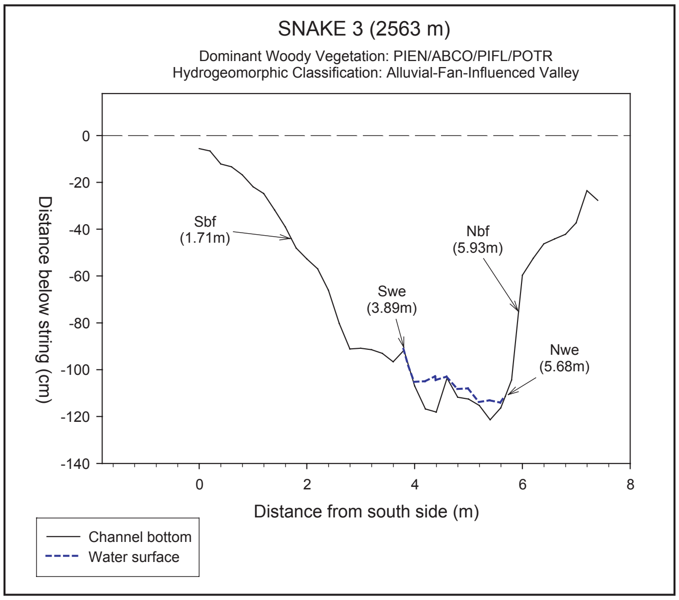

LEHMAN 4 (2219 m)
Dominant Woody Vegetation: POTR/PJ/ROWO
Hydrogeomorphic Classification: Leveed Outwash Valley
Distance below string (cm)
0
-20
-40
-60
-80
-100
-120
-140
-160
*Sbf
(3.73m)
Log
Nbf
(8.53m)
Swe
(4.2m)
Rock
Nwe
(8.05m)
Rock
0
2
4
6
8
10
Distance from south side (m)
Channel bottom
Water surface
*Field data suggest Sbf occurs at 3.73m

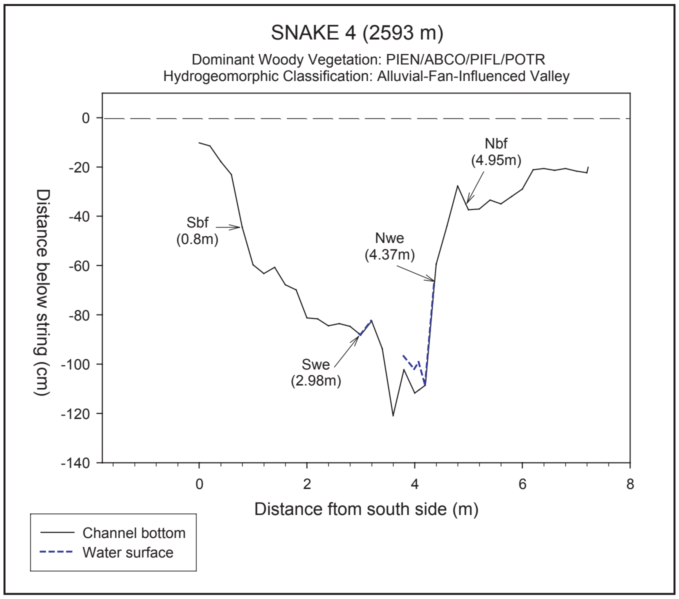

LEHMAN 5 (2551 m)
Dominant Woody Vegetation:ABCO/POTR
Hydrogeomorphic Classification: Leveed Outwash Valley
Distance below string (cm)
0
-20
-40
-60
-80
-100
-120
Distance from south side (m)
0
2
4
6
8
Log
Nbf
(5.21m)
Sbf
(1.29m)
Swe
(1.29m)
*Nwe
(4.03m)
Channel bottom
Water surface
*Undercut

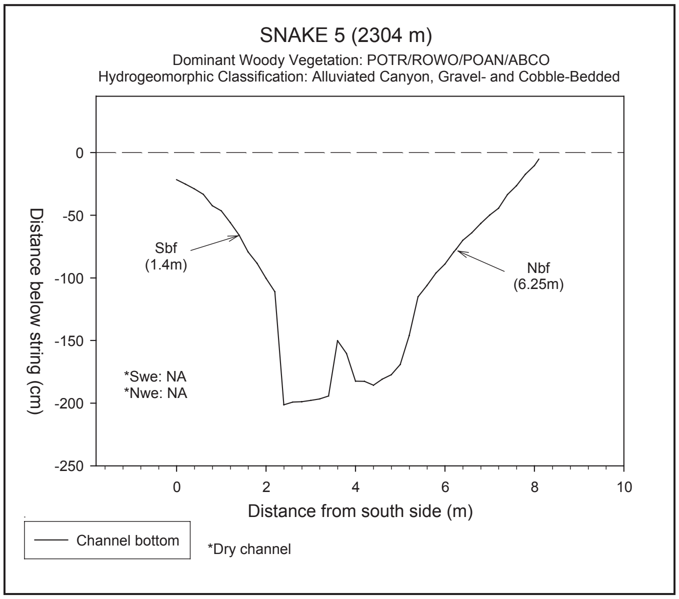

LEHMAN 6 (2356 m)
Dominant Woody Vegetation: POTR/ABCO (ARTR/CERC uplnd)
Hydrogeomorphic Classification: Leveed Outwash Valley
Distance below string (cm)
0
-20
-40
-60
-80
-100
-120
-140
Distance from south side (m)
0
2
4
6
8
10
Sbf
(0.4m)
Nbf
(6.55m)
Rock
Rock
Nwe
(6.08m)
Swe
(1.83m)
Channel bottom
Water surface

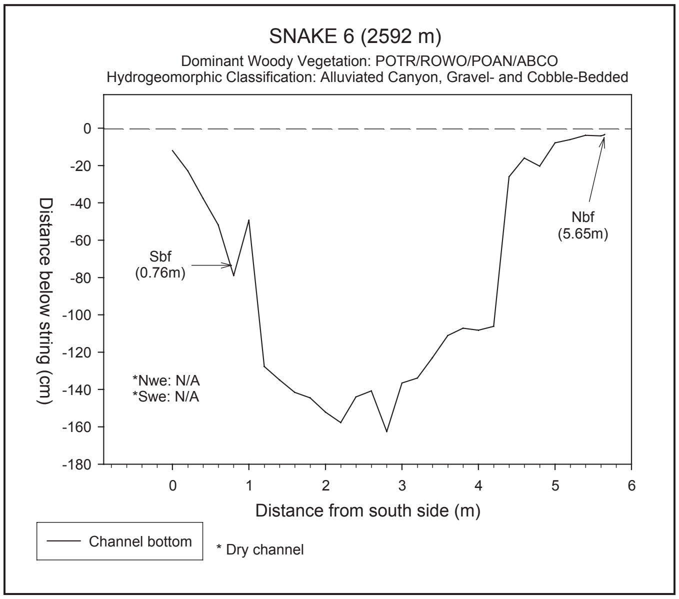

SNAKE 1 (1950 m)
Dominant Woody Species: POAN - PJ/ARTR
Hydrogeomorphic Classification: Terrace-Bound Valley
Distance below string (cm)
0
-20
-40
-60
-80
-100
-120
-140
-160
-180
-200
Distance from south side (m)
0
1
2
3
4
5
6
7
Sbf
(0.97m)
Nbf
(5.44m)
Swe
(3.54m)
Nwe
(4.72m)
Channel Bottom
Water Surface

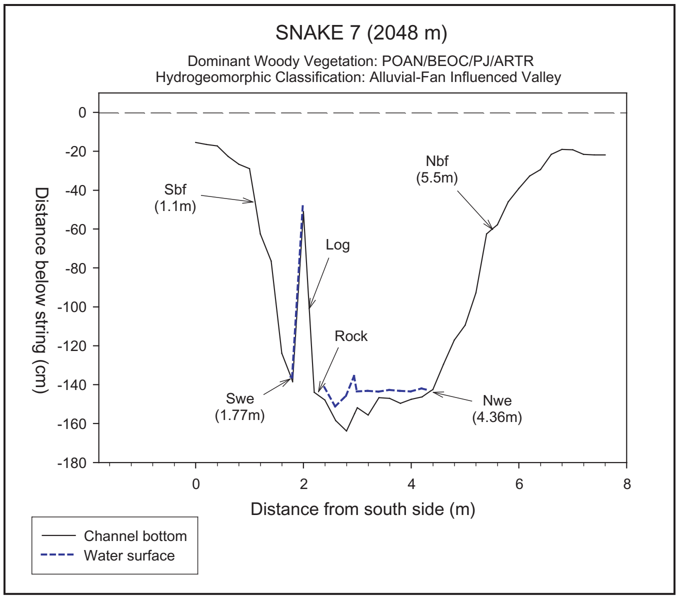

SNAKE 2 (1950 m)
Dominant Woody Vegetation: POAN/ROWO/BEOC
Hydrogeomorphic Classification: Terrace-Bound Valley
Distance below string (cm)
0
-20
-40
-60
-80
-100
-120
-140
-160
-180
Distance from south side (m)
0
1
2
3
4
5
*Sbf: NA
*Nbf: NA
Swe
(1.07m)
Nwe
(3.04m)
Channel Bottom
Water Surface
*Values for Sbf and Nbf unavailable from field data

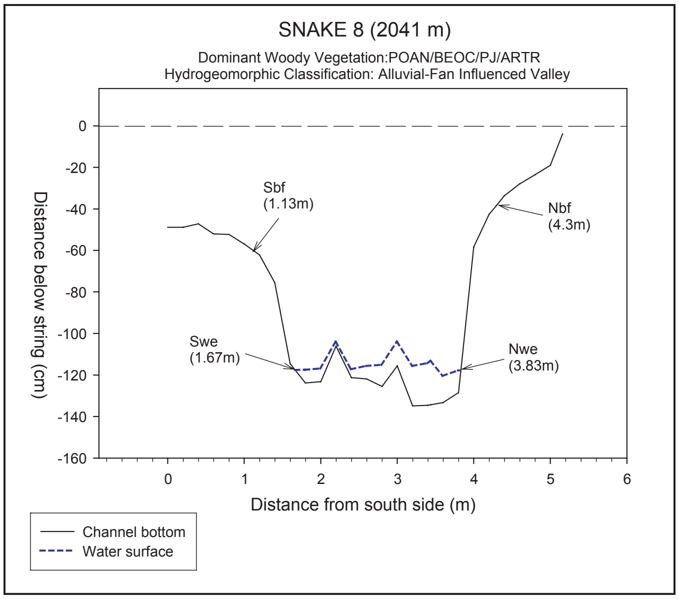

SNAKE 3 (2563 m)
Dominant Woody Vegetation: PIEN/ABCO/PIFL/POTR
Hydrogeomorphic Classification: Alluvial-Fan-Influenced Valley
Distance below string (cm)
0
-20
-40
-60
-80
-100
-120
-140
Distance from south side (m)
0
2
4
6
8
Sbf (1.71m)
Nbf (5.93m)
Swe (3.89m)
Nwe (5.68m)
Channel bottom
Water surface

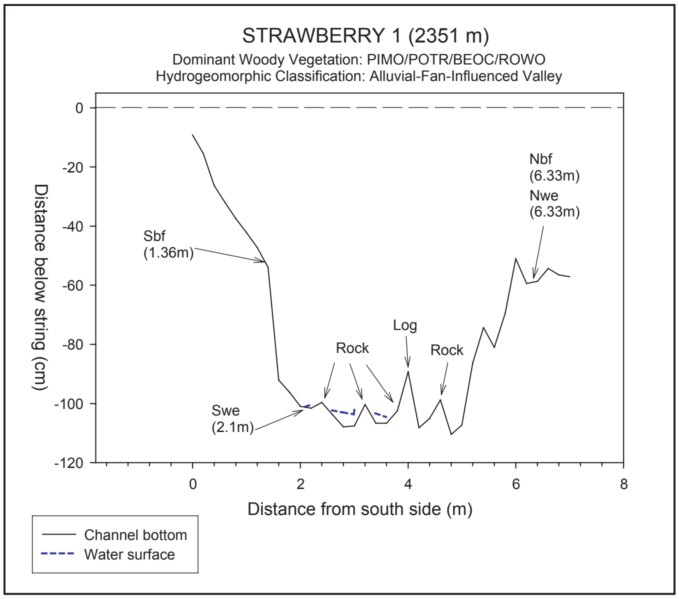

SNAKE 4 (2593 m)
Dominant Woody Vegetation: PIEN/ABCO/PIFL/POTR
Hydrogeomorphic Classification: Alluvial-Fan-Influenced Valley
Distance below string (cm)
0
-20
-40
-60
-80
-100
-120
-140
Distance ftom south side (m)
0
2
4
6
8
Nbf (4.95m)
Sbf (0.8m)
Nwe (4.37m)
Swe (2.98m)
Channel bottom
Water surface

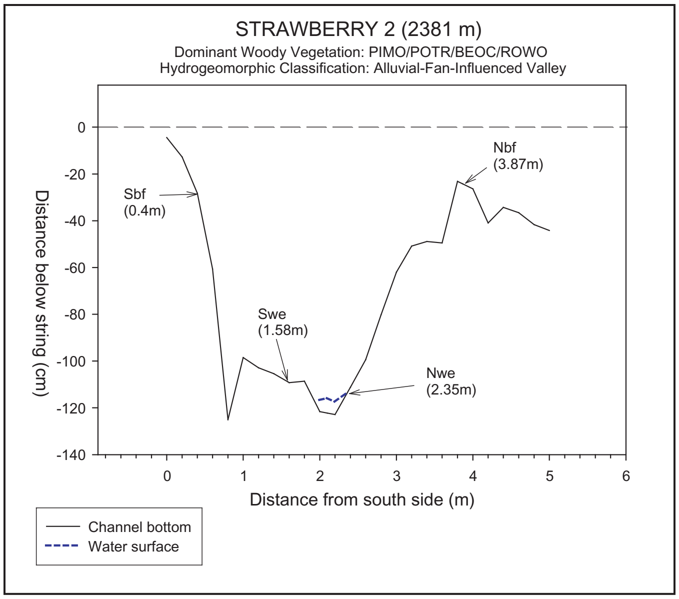

SNAKE 5 (2304 m)
Dominant Woody Vegetation: POTR/ROWO/POAN/ABCO
Hydrogeomorphic Classification: Alluviated Canyon, Gravel- and Cobble-Bedded
Distance below string (cm)
0
-50
-100
-150
-200
-250
Distance from south side (m)
0
2
4
6
8
10
Sbf (1.4m)
Nbf (6.25m)
*Swe: NA
*Nwe: NA
Channel bottom
*Dry channel

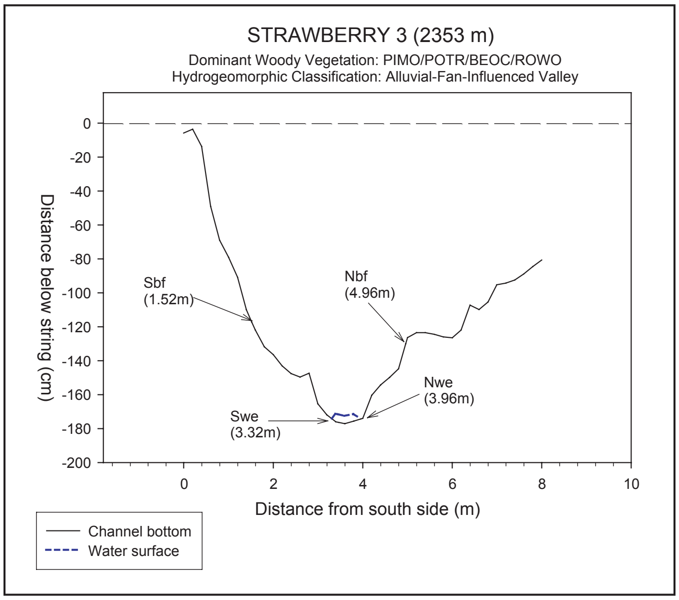

SNAKE 6 (2592 m)
Dominant Woody Vegetation: POTR/ROWO/POAN/ABCO
Hydrogeomorphic Classification: Alluviated Canyon, Gravel- and Cobble-Bedded
Distance below string (cm)
0
-20
-40
-60
-80
-100
-120
-140
-160
-180
Distance from south side (m)
0
1
2
3
4
5
6
Sbf (0.76m)
Nbf (5.65m)
*Nwe: N/A
*Swe: N/A
Channel bottom
* Dry channel

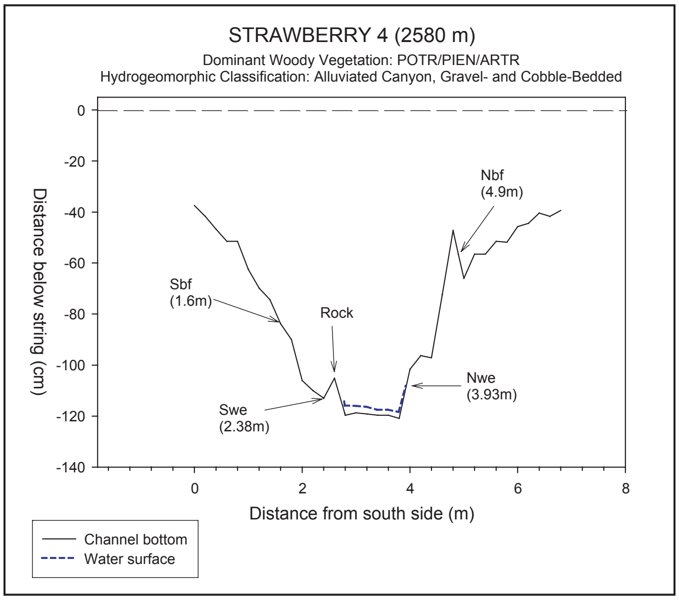

SNAKE 7 (2048 m)
Dominant Woody Vegetation: POAN/BEOC/PJ/ARTR
Hydrogeomorphic Classification: Alluvial-Fan Influenced Valley
Distance below string (cm)
0
-20
-40
-60
-80
-100
-120
-140
-160
-180
Sbf
(1.1m)
Log
Rock
Nbf
(5.5m)
Swe
(1.77m)
Nwe
(4.36m)
0
2
4
6
8
Distance from south side (m)
Channel bottom
Water surface

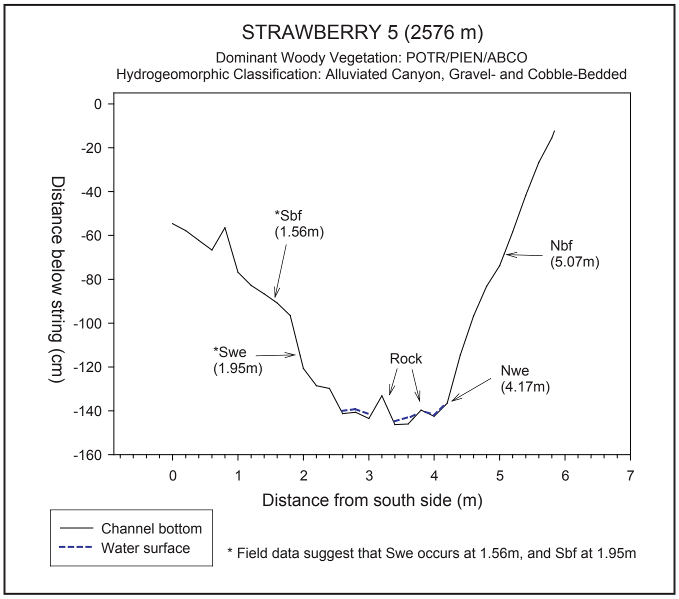

SNAKE 8 (2041 m)
Dominant Woody Vegetation:POAN/BEOC/PJ/ARTR
Hydrogeomorphic Classification: Alluvial-Fan Influenced Valley
Distance below string (cm)
0
-20
-40
-60
-80
-100
-120
-140
-160
Sbf
(1.13m)
Nbf
(4.3m)
Swe
(1.67m)
Nwe
(3.83m)
0
1
2
3
4
5
6
Distance from south side (m)
Channel bottom
Water surface

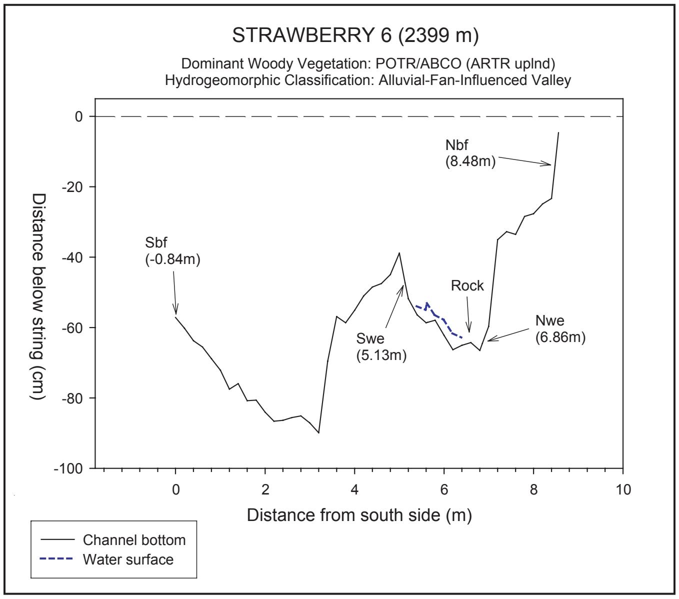

STRAWBERRY 1 (2351 m)
Dominant Woody Vegetation: PIMO/POTR/BEOC/ROWO
Hydrogeomorphic Classification: Alluvial-Fan-Influenced Valley
Distance below string (cm)
0
-20
-40
-60
-80
-100
-120
Nbf
(6.33m)
Nwe
(6.33m)
Sbf
(1.36m)
Log
Rock
Rock
Swe
(2.1m)
0
2
4
6
8
Distance from south side (m)
Channel bottom
Water surface

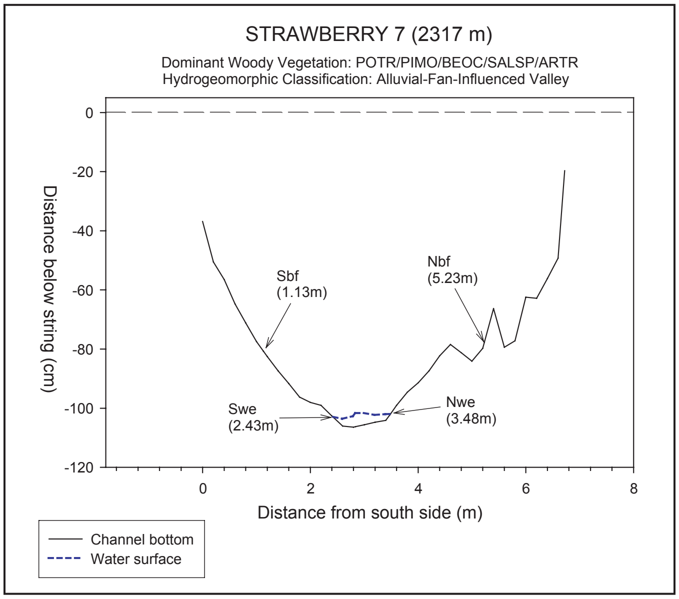

STRAWBERRY 2 (2381 m)
Dominant Woody Vegetation: PIMO/POTR/BEOC/ROWO
Hydrogeomorphic Classification: Alluvial-Fan-Influenced Valley
Distance below string (cm)
0
-20
-40
-60
-80
-100
-120
-140
Nbf
(3.87m)
Sbf
(0.4m)
Swe
(1.58m)
Nwe
(2.35m)
0
1
2
3
4
5
6
Distance from south side (m)
Channel bottom
Water surface

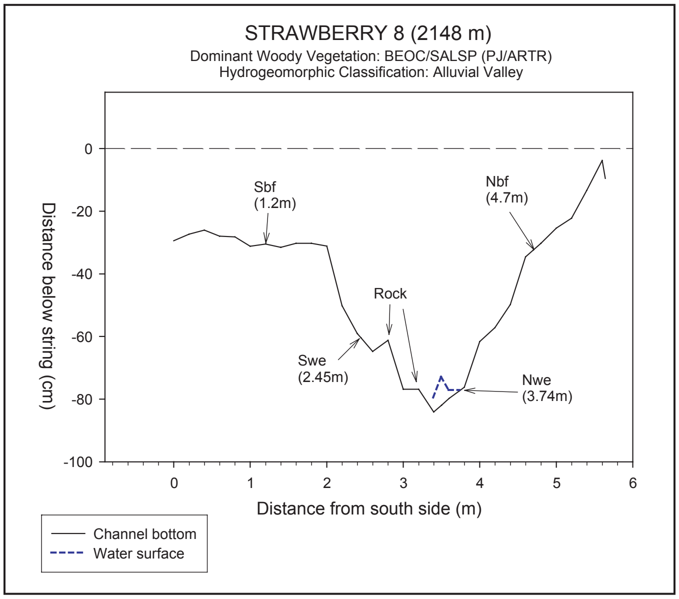

STRAWBERRY 3 (2353 m)
Dominant Woody Vegetation: PIMO/POTR/BEOC/ROWO
Hydrogeomorphic Classification: Alluvial-Fan-Influenced Valley
Distance below string (cm)
0
-20
-40
-60
-80
-100
-120
-140
-160
-180
-200
Sbf (1.52m)
Nbf (4.96m)
Nwe (3.96m)
Swe (3.32m)
0
2
4
6
8
10
Distance from south side (m)
Channel bottom
Water surface

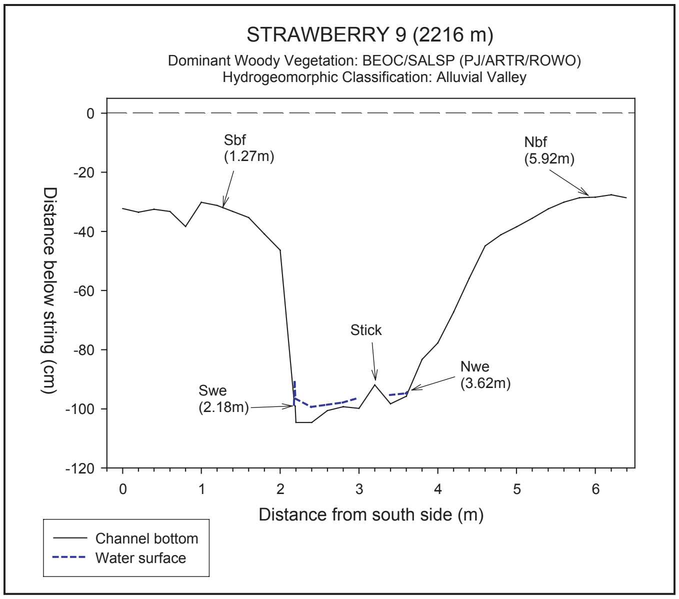

STRAWBERRY 4 (2580 m)
Dominant Woody Vegetation: POTR/PIEN/ARTR
Hydrogeomorphic Classification: Alluviated Canyon, Gravel- and Cobble-Bedded
Distance below string (cm)
0
-20
-40
-60
-80
-100
-120
-140
Nbf (4.9m)
Sbf (1.6m)
Rock
Nwe (3.93m)
Swe (2.38m)
0
2
4
6
8
Distance from south side (m)
Channel bottom
Water surface


STRAWBERRY 5 (2576 m)
Dominant Woody Vegetation: POTR/PIEN/ABCO
Hydrogeomorphic Classification: Alluviated Canyon, Gravel- and Cobble-Bedded
Distance below string (cm)
0
-20
-40
-60
-80
-100
-120
-140
-160
*Sbf (1.56m)
Nbf (5.07m)
*Swe (1.95m)
Rock
Nwe (4.17m)
0
1
2
3
4
5
6
7
Distance from south side (m)
Channel bottom
Water surface
* Field data suggest that Swe occurs at 1.56m, and Sbf at 1.95m


STRAWBERRY 6 (2399 m)
Dominant Woody Vegetation: POTR/ABCO (ARTR uplnd)
Hydrogeomorphic Classification: Alluvial-Fan-Influenced Valley
Distance below string (cm)
0
-20
-40
-60
-80
-100
Nbf (8.48m)
Sbf (-0.84m)
Rock
Nwe (6.86m)
Swe (5.13m)
0
2
4
6
8
10
Distance from south side (m)
Channel bottom
Water surface

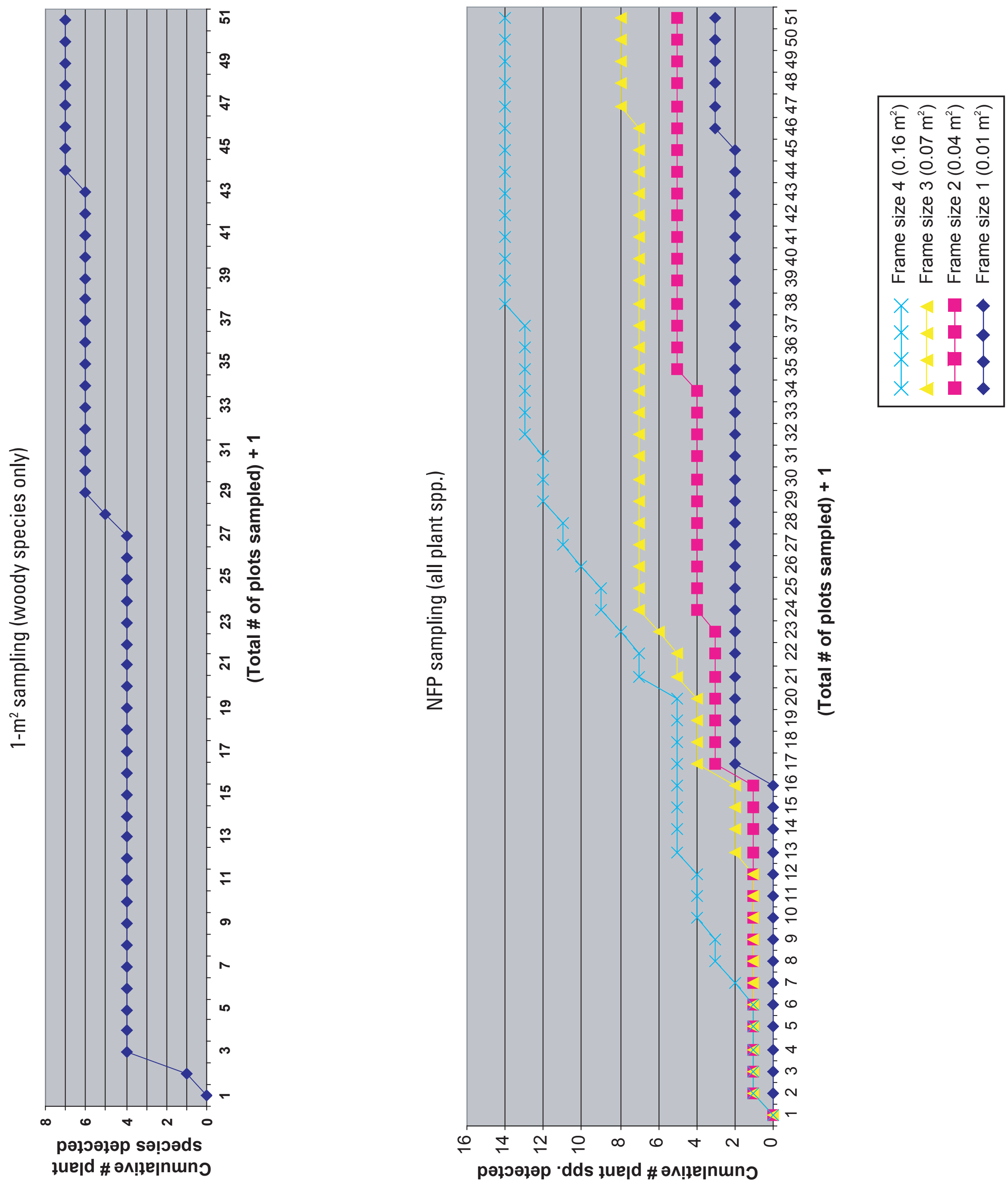

STRAWBERRY 7 (2317 m)
Dominant Woody Vegetation: POTR/PIMO/BEOC/SALSP/ARTR
Hydrogeomorphic Classification: Alluvial-Fan-Influenced Valley
Distance below string (cm)
0
-20
-40
-60
-80
-100
-120
Sbf (1.13m)
Nbf (5.23m)
Swe (2.43m)
Nwe (3.48m)
0
2
4
6
8
Distance from south side (m)
Channel bottom
Water surface


STRAWBERRY 8 (2148 m)
Dominant Woody Vegetation: BEOC/SALSP (PJ/ARTR)
Hydrogeomorphic Classification: Alluvial Valley
Distance below string (cm)
0
-20
-40
-60
-80
-100
Sbf (1.2m)
Nbf (4.7m)
Rock
Swe (2.45m)
Nwe (3.74m)
0
1
2
3
4
5
6
Distance from south side (m)
Channel bottom
Water surface


STRAWBERRY 9 (2216 m)
Dominant Woody Vegetation: BEOC/SALSP (PJ/ARTR/ROWO)
Hydrogeomorphic Classification: Alluvial Valley
Distance below string (cm)
0
-20
-40
-60
-80
-100
-120
Sbf (1.27m)
Nbf (5.92m)
Stick
Swe (2.18m)
Nwe (3.62m)
0
1
2
3
4
5
6
Distance from south side (m)
Channel bottom
Water surface

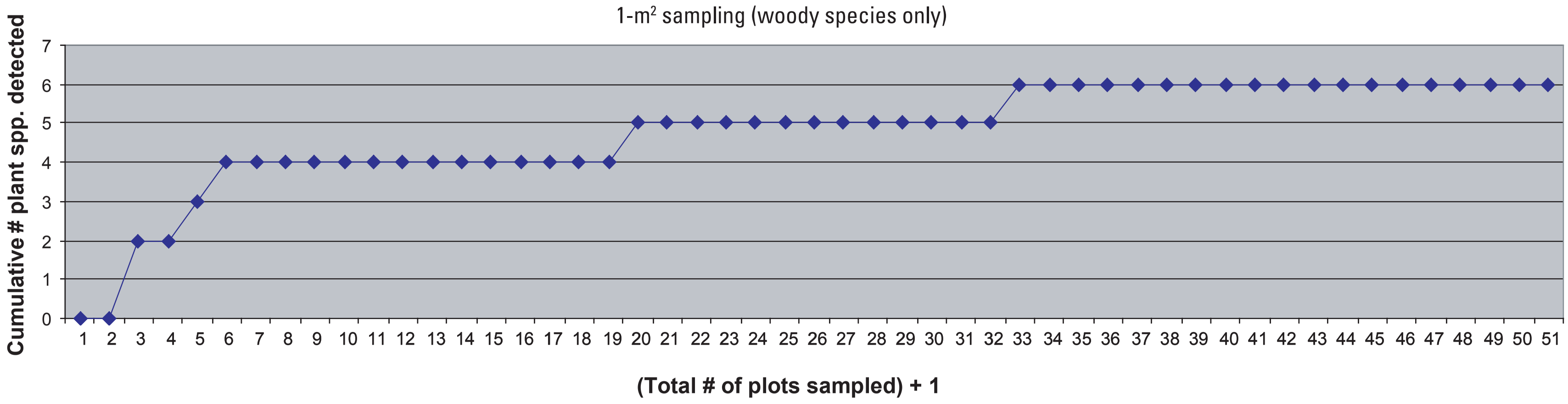
Appendix F Species-accumulation curves

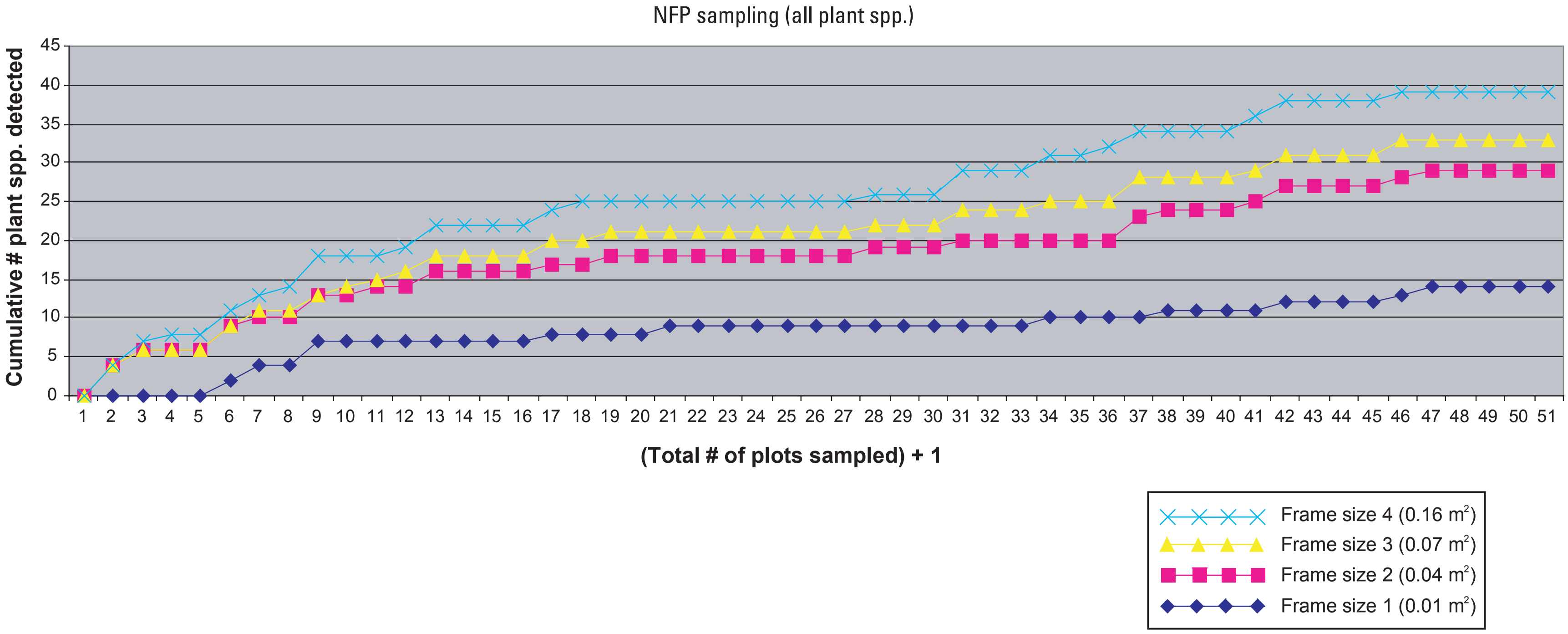
Curves that were used to assess the adequacy of our various methods for detecting plant species. Due to the distinctly ordered (stratified) nature of vegetation across a stream, we randomized the order of transects once before plotting curves. BK8 represented the most species-poor transect we encountered. In contrast, BK5 was the most species-rich transect, across all methods. We detected the most woody plant species at SN6, and thus provide a curve only for the 1- m^2 sampling method at that site.


1-m^2 sampling (woody species only)

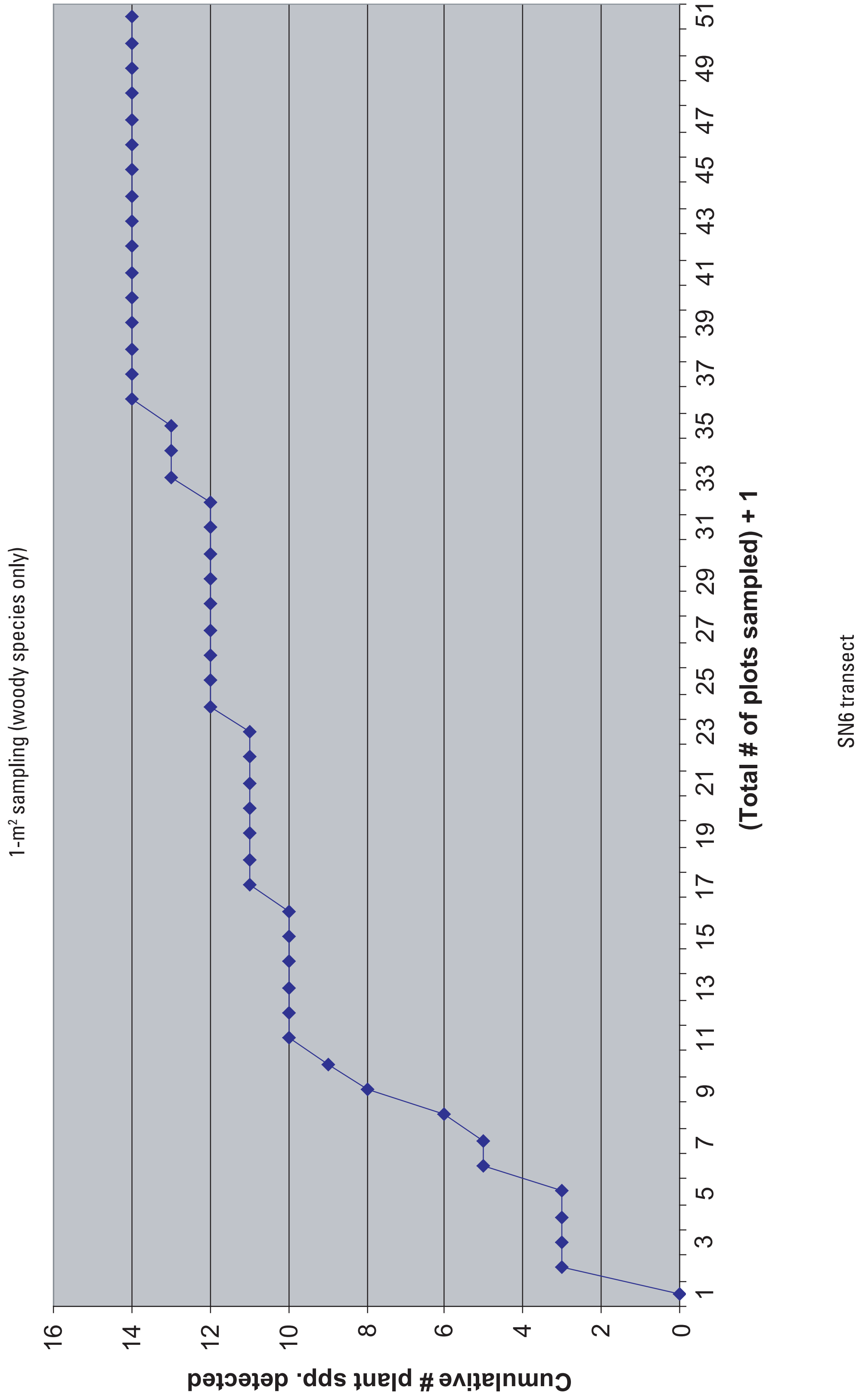
NFP sampling (all plant spp.)

BK8 transect


1-m² sampling (woody species only)


NFP sampling (all plant spp.)

BK5 transect


1-m² sampling (woody species only)
Cumulative # plant spp. detected
0
2
4
6
8
10
12
14
16
(Total # of plots sampled) + 1
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
31
33
35
37
39
41
43
45
47
49
51
SN6 transect