Hydrologic Benchmark Network Stations in the Western U.S. 1963-95 (USGS Circular 1173-D)

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Elder Creek near Branscomb, California (Station 11475560)

This report details one of the approximately 50 stations in the Hydrologic Benchmark Network (HBN) described in the four-volume U.S. Geological Survey Circular 1173. The suggested citation for the information on this page is:

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All of the tables and figures are numbered as they appear in each circular. Use the navigation bar above to view the abstract, introduction and methods for the entire circular, as well as a map and list of all of the HBN sites. Use the table of contents below to view the information on this particular station.

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Site Characteristics and Land Use

The Elder Creek HBN Basin is located on the west slope of the southern section of the Pacific Border physiographic province in northern California (Figure 4. *Map showing the study area in the Elder Creek Basin and photograph showing the forest cover in the* *basin*). The 16.8-km2 basin ranges in elevation from 424 to 1,290 m and drains a landscape of steep hillslopes and narrow canyons. The HBN station is located 8.5 km northwest of the town of Branscomb, Calif., at latitude 39°43'47" and longitude 123°38'34". Elder Creek is a headwater tributary that flows westward into the South Fork Eel River, a tributary of the Eel River, and has a channel length of about 8.0 km upstream from the HBN station and an average stream gradient of 80 m/km. Streamflow is highly variable during storms because of surface runoff from the steep hillslopes but is well sustained by springs during periods of low rainfall. Mean monthly discharge varies from a minimum of 0.03 m3/s in September to 1.9 m3/s in January, and average annual runoff from the basin was 129 cm for 1968 through 1995 (Friebel and others, 1996). The area has a Mediterranean-type climate, with cool, wet winters and warm, dry summers. Average daily air temperatures range from 6°C in January to as much as 31°C in August. Cold air often drains down the valleys, creating strong temperature inversions. Average annual precipitation is about 215 cm, most of which falls as rain during intense frontal storms occurring from December through March (Herring, 1997). A solar-powered weather station was installed in 1990 just outside the Elder Creek Basin by The Nature Conservancy where data are collected on precipitation amount, air temperature, and solar radiation (Herring, 1997).

The basin is located in the Sierran Steppe-Mixed Forest-Coniferous Forest-Alpine Meadow ecoregion (Bailey and others, 1994), and vegetation grows in a mosaic of mixed forest, oak woodland, mixed chaparral, riparian, and grassland communities (Herring, 1991, 1997). The mixed forest is dominated by old-growth Douglas-fir as well as tan oak and madrone (Rundel and others, 1977; Herring, 1991). Understory plants in the mixed forest include mountain dogwood, chinquapin, and California bay. Oak woodland is present in various settings; Oregon white oak line the river terraces, black oak grows on ridges, and interior live oak and canyon live oak are dispersed throughout the basin. Chaparral communities are mostly on dry southern slopes and consist of chamise, manzanita, and ceanothus (Rundel and others, 1977). The riparian community is dominated by white alder, bigleaf maple, and Oregon ash. Coastal redwoods grow along river banks and in forest swells. Grassland species include native oatgrass and rushes. Soils in the basin are classified as Inceptisols and Ultisols and primarily belong to the Hugo and Josephine soil series (Herring, 1997). These series consist of deep, well-drained soils that formed in material weathered from sedimentary rocks. Soils usually range in depth from 100 to 150 cm, have base saturations ranging from 35 to 50 percent, and contain between 15 and 35 percent rock fragments.

The basin is underlain by rocks of the Yager terrain, which consists of thinly bedded arkosic sandstone and argillite of Paleocene or Eocene age (Ogle, 1953; Blake and others, 1985; Jayko and others, 1989). The mineralogy of the sediments in the Yager terrane includes quartz, biotite, chlorite, and feldspar. Interbedded limy siltstone also is present in the Yager terrane. The Yager terrane is the easternmost of three terranes in the Coastal Franciscan Belt and may have formed as a trench-slope deposit that accumulated in its present location (Underwood, 1983; Bachmann, 1994).

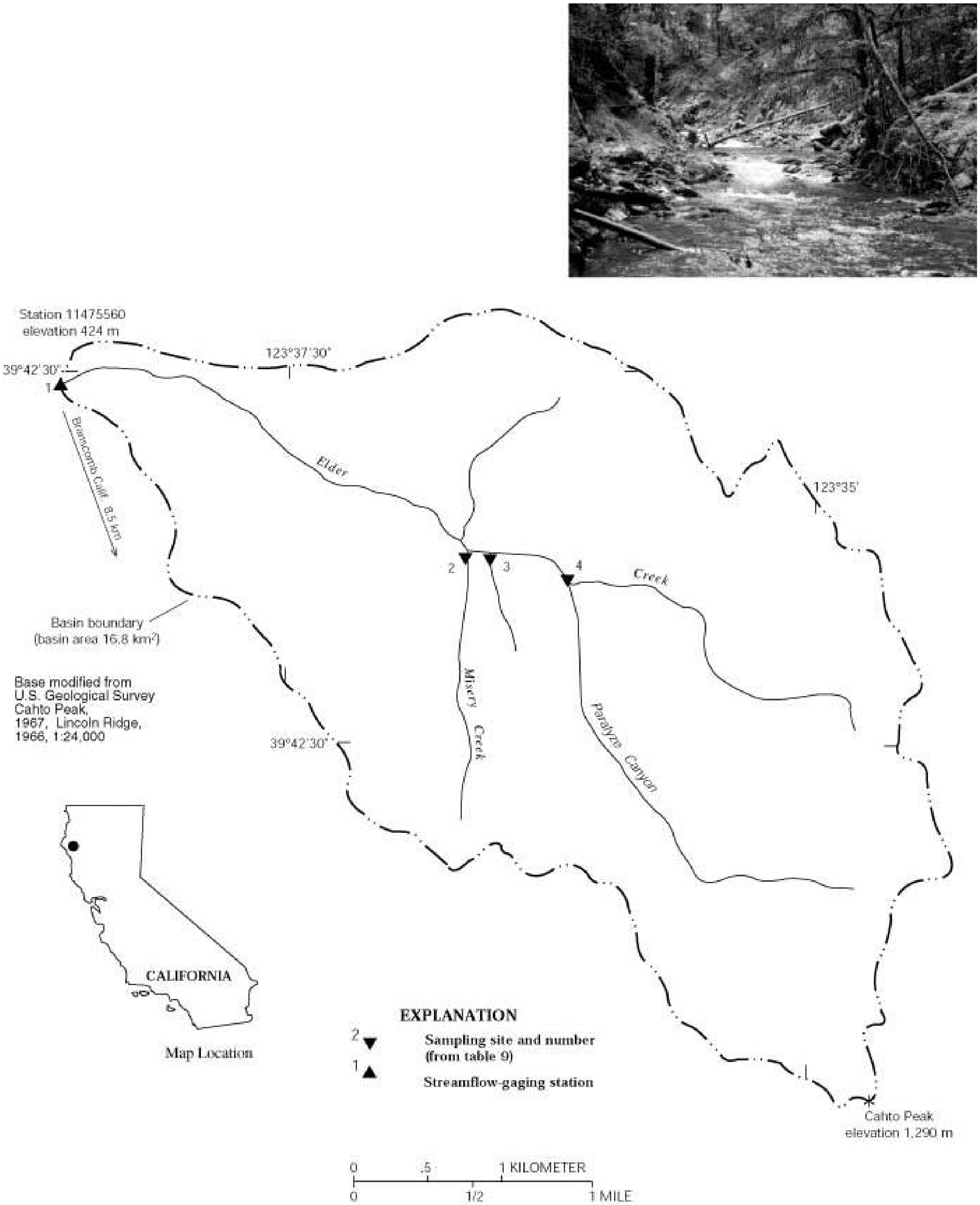

Figure 4. *Map showing the study area in the Elder Creek Basin and photograph showing the forest cover in the basin*

Land in the Elder Creek Basin is part of the Angelo Coast Range Reserve, which was established in 1959 as The Nature Conservancy's first preserve west of the Mississippi. Since then, the reserve has been protected from development and operated by the University of California for research in freshwater ecology and old-growth forest ecosystems (Ruggiero, 1991). In 1994, the ownership of the reserve was transferred to the University of California's Natural Reserve System, which provides secure field sites for ecological study used to support university-level teaching and research. Entry to the nature reserve by the public is tightly restricted, and research is allowed to the extent that it does not damage the ecosystem or habitats. Limited logging may have occurred in the basin in the late 19th and early 20th centuries, but beginning in 1931, land in the Elder Creek Basin began to be acquired and protected by homesteaders. No grazing, mining, or logging has occurred in the basin since at least 1959, when the homesteaders sold the land to The Nature Conservancy. A small diversion upstream from the Elder Creek HBN station provides water for the dwelling used by the reserve caretakers. Access to the basin is limited to an access road that is maintained by The Nature Conservancy; the road is used by caretakers and researchers but is closed to the public. Cahto Peak can be reached through a gated gravel road from the east.

Historical Water-Quality Data and Time-Series Trends

The data set for the Elder Creek HBN station analyzed for this report includes 195 water-quality samples that were collected from February 1968 through September 1995. Sampling frequency ranged from 8 to 12 times per year from 1969 to 1982, then was decreased to quarterly from 1983 to 1995. Samples from the early part of the period of record probably were analyzed at a USGS district laboratory in Sacramento, Calif. (Durum, 1978). After establishment of the central laboratory system, samples were analyzed at the Salt Lake City, Utah, laboratory from 1973 to 1975 and at the NWQL in Arvada, Colo., from 1976 through 1995. Daily discharge records for Elder Creek (station 11475560) are available beginning in October 1967. Daily water temperature at the HBN station was measured from October 1968 through September 1979, and a precipitation gage was operated at the station from October 1968 through March 1996.

Calculated ion balances for 190 samples that have complete major-ion analyses are shown in figures 5a and 5b. *Graphs showing temporal variation of discharge, field pH, major-ion concentrations, and ion balance in Elder Creek, California.* Ion balances ranged from -14 to +15 percent, and 85 percent of the samples had values within the ±10 that the analytical results were of good quality. The average ion balance was 0.5 percent, indicating that unmeasured constituents, such as organic anions, do not seem to contribute substantially to the ionic composition of stream water at this HBN station. Time- series plots of the major dissolved constituents were inspected for evidence of method-related effects. The most notable pattern was the considerable decrease in scatter of sulfate concentrations beginning in 1983 (fig. 5). This pattern probably was caused by a change in the analytical technique for sulfate from a colorimetric to a turbidimetric technique in 1983 (Office of Water Quality Technical Memorandum No. 83.07, Analytical methods: Sulfate determinations, issued February 25, 1983, at URL http://water.usgs.gov/admin/memo/). A period of uniform sulfate concentrations in 1982

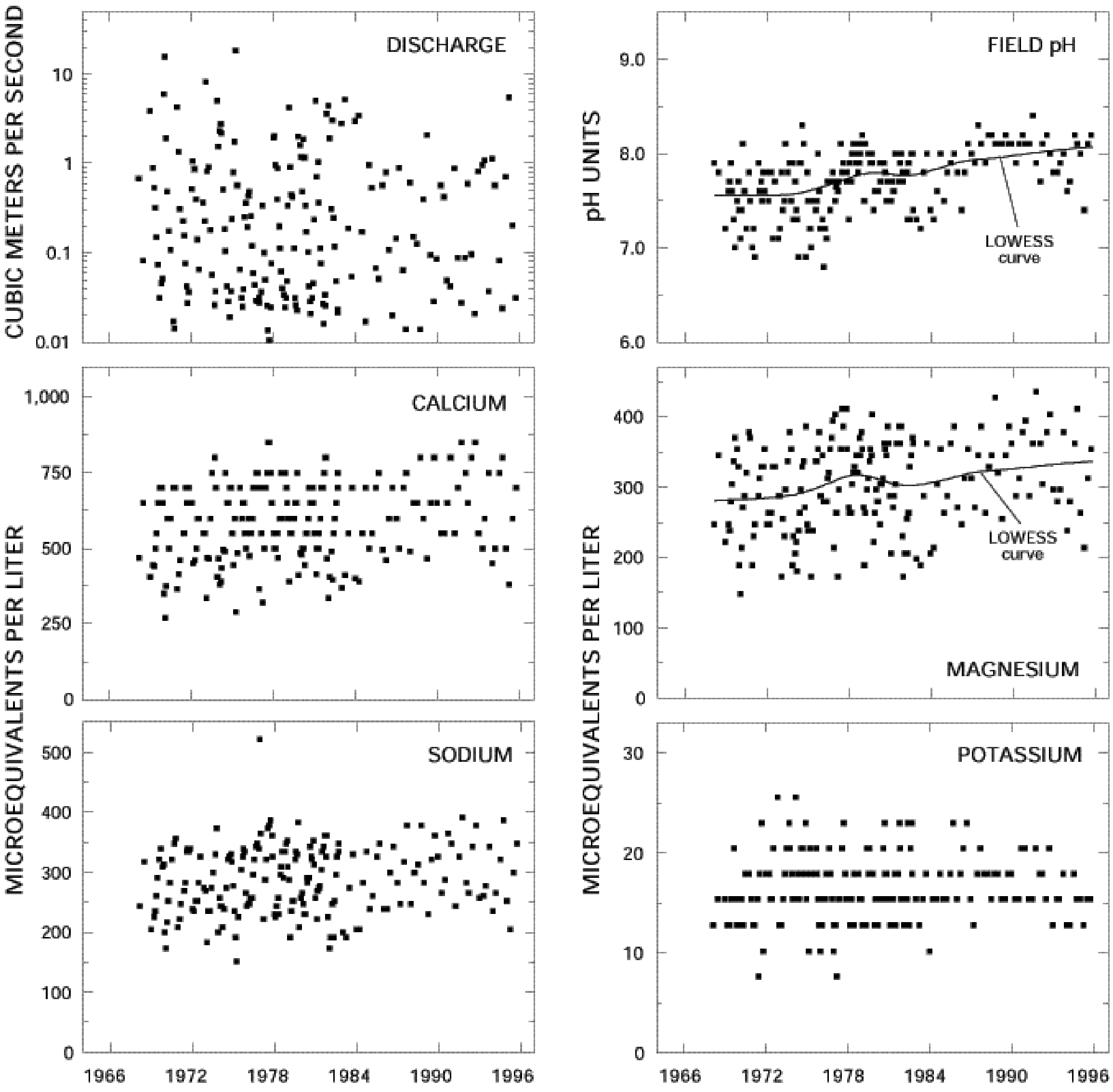

Figure 5a. *Graphs showing temporal variation of discharge, field pH, major-ion concentrations, and ion balance in Elder Creek, California*

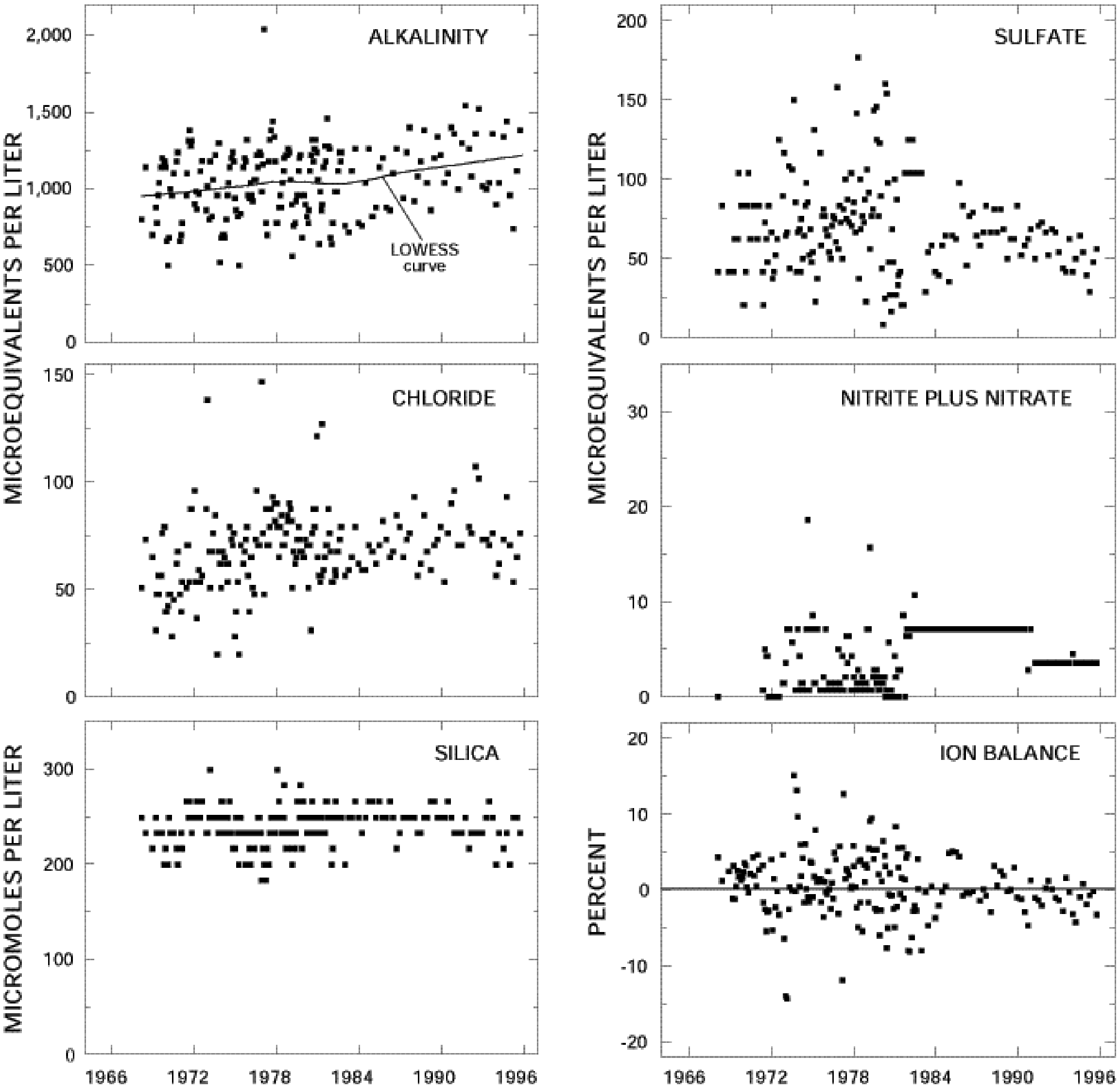

Figure 5b. *Graphs showing temporal variation of discharge, field pH, major-ion concentrations, and ion balance in Elder Creek, California- Continued*

and 1983, which reflects a change in the analytical reporting limit for sulfate to 5 mg/L (104 meq/L) during those 2 years, also is shown in figure 5. The temporal pattern in concentrations of nitrite plus nitrate at this station also was affected by changes in the reporting limit for this constituent that occurred in 1982 and again in 1991.

Table 6. Minimum, first quartile, median, third quartile, and maximum values of physical properties and major dissolved constituents measured in water-quality samples from Elder Creek, California, February 1968 through September 1995, and volume-weighted mean concentrations in wet precipitation collected at the Hopland Station, California

[Concentrations in units of microequivalents per liter, discharge in cubic meters per second, specific conductance in microsiemens per centimeter at 25 degrees Celsius, pH in standard units, and silica in micromoles per liter; n, number of stream samples; VMW, volume-weighted mean; inst., instantaneous; spec. cond., specific conductance; <, less than; --, not reported]

Parameter	Stream water						Precipitation VWM[a]
	Minimum	First quartile	Median	Third quartile	Maximum	n	
Discharge, inst.	0.010	0.042	0.17	0.81	18	195	--
Spec. cond., field	49	96	120	130	190	195	5.4
pH, field	6.8	7.5	7.8	8.0	8.4	190	5.4[b]
Calcium	270	500	600	700	850	195	1.8
Magnesium	150	260	300	350	440	195	3.7
Sodium	150	240	280	330	520	194	16
Potassium	7.7	15	15	18	36	194	.5
Ammonium	<.7	<.7	1.4	3.0	9.3	80	3.0
Alkalinity, laboratory	500	880	1,060	1,220	2,040	193	--
Sulfate	8.3	50	67	85	230	195	6.0
Chloride	20	57	71	78	160	194	18
Nitrite plus nitrate	<.7	.7	3.6	7.1	19	169	4.1[c]
Silica	180	230	250	250	300	195	--

[a] Values are volume-weighted mean concentrations for 1979-95.

[b] Laboratory pH.

[c] Nitrate only.

The median concentrations and ranges of major dissolved constituents in stream water collected at the HBN station and VWM concentrations in wet-only precipitation measured at the Hopland NADP station are presented in table 6. Precipitation chemistry at the NADP station, which is about 90 km south of the HBN station, is dilute and slightly acidic and had a VWM pH of 5.4 for 17 years of record. The predominant cation in precipitation was sodium, which contributed 55 percent of the total cation charge, and the predominant anion was chloride, which accounted for 64 percent of the total anion charge. The predominance of these ions in precipitation reflects the proximity of this station to the Pacific Ocean and the influence of marine aerosols on precipitation chemistry at this site. Stream water in Elder Creek is moderately concentrated and well buffered; specific conductance ranged from 49 to 190 mS/cm, and alkalinity ranged from 500 to 2,040 meq/L (table 6). The major cation in stream water was calcium and the major anion was bicarbonate. The predominance of these solutes in stream water is attributed to the weathering of carbonate cements in the underlying arkosic sandstones, argillites, and siltstones. The median chloride (71 meq/L) and sulfate (67 meq/L) concentrations in stream water were substantially greater than the VWM concentrations of chloride (18 meq/L) and sulfate (6.0 meq/L) in precipitation, indicating that these solutes primarily are derived from sources other than wet deposition. Because land-use activities in the basin are minimal, the most plausible source of these solutes is weathering of salt and sulfate minerals in the marine sedimentary rocks and dry deposition of marine aerosols. Concentrations of inorganic nitrogen species in stream water generally were less than the VWM concentrations in precipitation, indicating that most atmospheric nitrogen is retained by vegetation and soils in the basin.

Table 7. Spearman rank correlation coefficients (rho values) showing the relation among discharge, pH, and major dissolved constituents, Elder Creek, California, 1968 through 1995

[Q, discharge; Ca, calcium; Mg, magnesium; Na, sodium; K, potassium; Alk, alkalinity; SO_4, sulfate; Cl, chloride; Si, silica]

	Q	pH	Ca	Mg	Na	K	Alk	SO_4	Cl
pH	-0.357	--	--	--	--	--	--	--	--
Ca	-.874	0.469	--	--	--	--	--	--	--
Mg	-.880	.442	0.929	--	--	--	--	--	--
Na	-.940	.414	.874	0.897	--	--	--	--	--
K	-.498	.226	.524	.476	0.480	--	--	--	--
Alk	-.882	.428	.879	.879	.902	0.448	--	--	--
SO_4	-.272	.110	.287	.273	.236	.177	0.187	--	--
Cl	-.529	.387	.572	.582	.537	.330	.528	0.210	--
Si	.042	.191	.034	.039	.041	.228	.048	-.058	0.038

Table 8. Results of the seasonal Kendall test for trends in discharge and unadjusted and flow-adjusted pH and major dissolved constituents, Elder Creek, California, February 1968 through September 1995

[Trends in units of microequivalents per liter per year, except for discharge in cubic meters per second per year, pH in standard units per year, and silica in micromoles per liter per year; <, less than; --, not calculated]

Parameter	Unadjusted		Flow adjusted	
	Trend	p-value	Trend	p-value
Discharge	0.001	0.465	--	--
pH, field	.02	.000	0.02	0.000
Calcium	<.1	.083	2.3	.000
Magnesium	1.3	.006	1.3	.000
Sodium	.7	.097	.7	.000
Potassium	<.1	.875	<.1	.590
Alkalinity, laboratory	6.5	.001	6.9	.000
Sulfate	-.6	.013	-.6	.019
Chloride	4	.024	.4	.027
Nitrite plus nitrate	(a)	--	--	--
Silica	<.1	.466	<.1	.649

The solute composition of stream water was further evaluated by analyzing correlations between solutes and stream discharge (table 7). Most weathering-derived solutes had strong inverse correlations with stream discharge, particularly sodium (rho = -0.940), alkalinity (rho = -0.882), magnesium (rho = -0.880), and calcium (rho = -0.874). These results are consistent with a hydrologic system where weathering-enriched base flow is diluted by water from shallow or surficial sources during periods of increased discharge. For the solutes, the strongest correlations were found among calcium, magnesium, sodium, and alkalinity. Correlations among calcium, magnesium, and alkalinity are consistent with the weathering stoichiometry of carbonate cements in the sedimentary rocks. The strong correlation between sodium and alkalinity and the lack of correlation with silica indicates that sodium perhaps is released from exchange reactions with marine clays rather than from weathering of feldspar minerals in the arkosic sandstones.

The results of the seasonal Kendall test for trends in discharge and major dissolved constituents are listed in table 8. Statistically significant upward trends were detected in field pH and unadjusted magnesium and alkalinity concentrations at the 0.01 probability level. Trends were similar for the unadjusted and flow-adjusted concentrations, indicating that the trends were not caused by variations in stream discharge. Statistically significant upward trends also were detected in the flow-adjusted calcium and sodium concentrations at the 0.01 probability level. The LOWESS curves in figure 5 show that most of the increase in field pH and in magnesium and alkalinity concentrations occurred after the mid-1980's. Although not shown in figure 5, LOWESS curves through the flow-adjusted calcium and sodium concentrations show a similar pattern of increasing concentrations beginning about 1984. The cause of the upward trends in stream-water chemistry at this HBN station could not be identified, although the similarity in the timing of the trends indicates that they may have been caused by a similar factor. Method-related factors probably were not the cause of the trends, given that the significance of most of the trends increased after adjusting for flow. Environmental factors that may have affected stream-water chemistry include changes in atmospheric deposition, land-use activities, and climate. The stream-water trends at this station probably were not related to changes in atmospheric deposition, considering the dilute chemistry of precipitation at the NADP station compared to the stream (table 6). Similarly, changes in land use probably were not an important factor because the basin has been free of human activities since it was purchased by The Nature Conservancy in 1959. Perhaps the most plausible explanation for the trends in water quality is climate variability. Although a detailed analysis of climate variability is beyond the scope of this report, long- term precipitation records indicated that there was an extended period of drought that persisted in the northwestern part of California from 1984 through 1994 (National Climatic Data Center at URL http://www.ncdc.noaa.gov).

Synoptic Water-Quality Data

Chemical results of the surface-water synoptic sampling of August 6, 1991, are listed in table 9, and locations of sampling sites are shown in figure 4. During the synoptic sampling, discharge at the HBN station was about 0.05 m3/s compared to the median daily discharge of 0.03 m3/s for August (Lawrence, 1987), indicating that the basin was sampled during normal flow conditions for that time of year. Most of the solute concentrations measured at the HBN station (site 1) during the synoptic sampling were equal to or greater than the third-quartile values reported for the station during the entire period of record, except for the sulfate concentration, which was less than the median value (table 6). Stream water at the upstream sampling sites were similar in composition to stream water at site 1; calcium was the predominant cation and bicarbonate was the predominant anion. Ion balances for the synoptic samples ranged from -1.4 to 4.2 percent and averaged 0.5 percent, indicating that organic anions probably were not an important component of stream water during the sampling period. The results in table 9 indicate that the concentrations of the major solutes, particularly the weathering-derived solutes, did not vary markedly among the sampling sites. For example, calcium concentrations ranged from 650 to 750 meq/L, magnesium ranged from 370 to 440 meq/L, and alkalinity ranged from 1,130 to 1,410 meq/L. This uniformity in stream- water composition most likely reflects the small size of the basin and the relatively homogenous composition of the underlying bedrock. Sulfate and chloride had a slightly wider range of concentrations; sulfate ranged from 50 to 140 meq/L and chloride ranged from 51 to 93 meq/L, perhaps due to local variations in bedrock mineralogy or differences in evapotranspiration among the sites. Nitrate concentrations at all of the sampling sites were less than the analytical reporting limit of 3.6 meq/L, which is consistent with the minimal amount of land use in the basin.

Table 9. Physical properties and major dissolved constituents from surface-water sampling sites in the Elder Creek Basin, California, collected August 6, 1991

[Site locations shown in fig. 4; Q, discharge in cubic meters per second; SC, specific conductance in microsiemens per centimeter at 25 degrees Celsius; pH in standard units; Ca, calcium; Mg, magnesium; Na, sodium; K, potassium: Alk, alkalinity; SO4, sulfate; Cl, chloride; NO3, nitrate; Si, silica; concentrations in microequivalents per liter, except silica in micromoles per liter; <, less than; --, not reported]

Site	Station number	Q	SC	pH	Ca	Mg	Na	K	Alk	$S0_4$	Cl	NO_3	Si	Criteria[a]
1	11475560	0.048	150	8.2	750	370	360	18	1,350	65	93	<3.6	250	--
2	394311123363800	--	147	7.9	700	420	360	17	1,410	50	87	<3.6	300	T
3	394311123363300	.0011	140	8.0	650	440	340	17	1,130	140	51	<3.6	320	T
4	394306123361100	--	150	8.1	750	380	350	18	1,320	83	79	<3.6	250	MC

[a] Criteria used in selection of sampling sites: MC = main channel, T = tributary.

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Appendix A. List of Map References

a. U.S. Geological Survey Topographic Maps:

- Cahto Peak, California (1:24,000), 1967
- Lincoln Ridge, California (1:24,000), 1966, HBN gaging station on this quadrangle
- Covelo, California (1:100,000), 1981

b. Geologic Maps:

- Collins, K.A., 1979, Geology of the Northern Coast Range Preserve, Mendocino County, California: The Natural Conservancy, 44 p.
- Jayko, A.S., Blake, M.C., Jr., McLaughlin, R.J., Ohlin, H.N., Ellen, S.D., and Kelsey, H., 1989, Reconnaissance geologic map of the Covelo 30- by 60-minute quadrangle, northern California: U.S. Geological Survey Miscellaneous Field Studies Map MF-2001, scale 1:100,000.

c. Soil Surveys:

- U.S. Department of Agriculture, 1991, Soil survey of Mendocino County, eastern part, and Trinity County, southwestern part, California: U.S. Department of Agriculture Soil Conservation Service in cooperation with U.S. Department of Agriculture Forest Service.

d. Miscellaneous Maps:

- Herring, M.L., 1997, Heath and Marjorie Angelo Coast Range Reserve: Oakland, University of California, 8 p. including vegetation map.

Appendix B. NWIS Site-Identification Numbers

Table B-1. NWIS site-identification numbers and site names for water-quality sampling sites.

Site	Identification Number	Site Name
1	11475560	ELDER CR NR BRANSCOMB, CA
2	394311123363800	MISERY CR NR BRANSCOMB, CA
3	394311123363300	MERCY CR NR BRANSCOMB, CA
4	394306123361100	UPPER ELDER CR NR BRANSCOMB, CA