ANALYSIS
of
EROSION TRENDS

Of the Sedimentary Deposits
In the Grand Canyon

by

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MEMORANDUM

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SEDIMENTARY DEPOSITS IN THE GRAND CANYON

I. Introduction

This report summarizes the results of our analyses of the impact of the 1980 (June) high water releases (∿50,000 cfs) from Glen Canyon Dam on the sedimentary deposits (beaches) along the Colorado River in the Grand Canyon. The data base for the study included a set of color aerial photos of selected sites in the canyon taken on 27 June 1980, topographic profiles taken during a summer float trip (17 June-30 June), and a second set of profiles taken at the same sample sites in late October.

Both the aerial photographs and the profiles were compared with previous studies of erosion rates based on similar data sets collected between 1973 and 1979. Our specific work statement was:

> "Prepare a report on beach changes along the Colorado River in the Grand Canyon based upon analysis of aerial photographs taken before construction of Glen Canyon Dam, after construction in 1973, and a June 1980 set supplied by the Water and Power Resources Service. The erosion data are to be summarized in the report and in graphic (map) form. The results of the aerial photo analysis will be compared (calibrated) with the field surveys."

II. Background

The impact of the regulated flows from Lake Powell on the sedimentary deposits in the Grand Canyon can be divided into changes in river bank morphology below the present high-water level and modifications of pre-dam flood terraces that are now above high water level. This report will be concentrated on the fine-grained (sand-size or smaller) flood terraces which are both the most dynamic of the fluvial deposits and the most frequent sites used for camping. Cobble bars and tributary fan deposits are relatively inhospitable for camping, and are much more stable under the present river regime.

The sediments found on the terraces in the Grand Canyon can be classified according to age (pre- or post-dam), agent of deposition (floods, eolian action, or fluvial reworking in the zone below present normal high water), and grain size (cohesive silts, dominantly silt with a small percentage of clay; silt-sand with about 30 percent silt content; and sands with negligible silt), (Howard and Dolan, 1975). Table 1 lists associations between these classifications, and Figure 1 illustrates their spatial relationships. Several generalities can be made about these deposits, and their response to different processes:

1) Pre- and post-dam flood terraces are usually silt-sand.
2) Pre-dam eolian deposits are but little coarser than the flood terraces from which they are derived.
3) Pre-dam cohesive silt was deposited by summer floods and runoff. These deposits seldom extend more than a few feet above present high water levels, and because of the abundance of water and the fine substrate, they have been covered by a dense vegetative growth since the dam.
4) Post-dam beach deposits, reworked by small waves and current, are dominantly sand, with noticeable silt content only along the wide, quiet sections of the river. These deposits are well-sorted, and are the predominant source for post-dam eolian deposits.

Fine-grained deposits below the present high water are being reworked by the river. The rate of change of these sediments depends upon grain size. Cohesive silts are being slowly cut back, forming steep, vegetated banks with numerous

Table 1. Classification of Fine-Grained Deposits

Age of Deposit	Depositional Agent	Grain Size
Pre-Dam	Spring Flood Terrace	Silt-Sand
	Eolian	
	Summer Flood Terrace	Cohesive Silt
	Flood Terrace	Silt-Sand
Post-Dam	Eolian	Sand
	Beach Deposits	

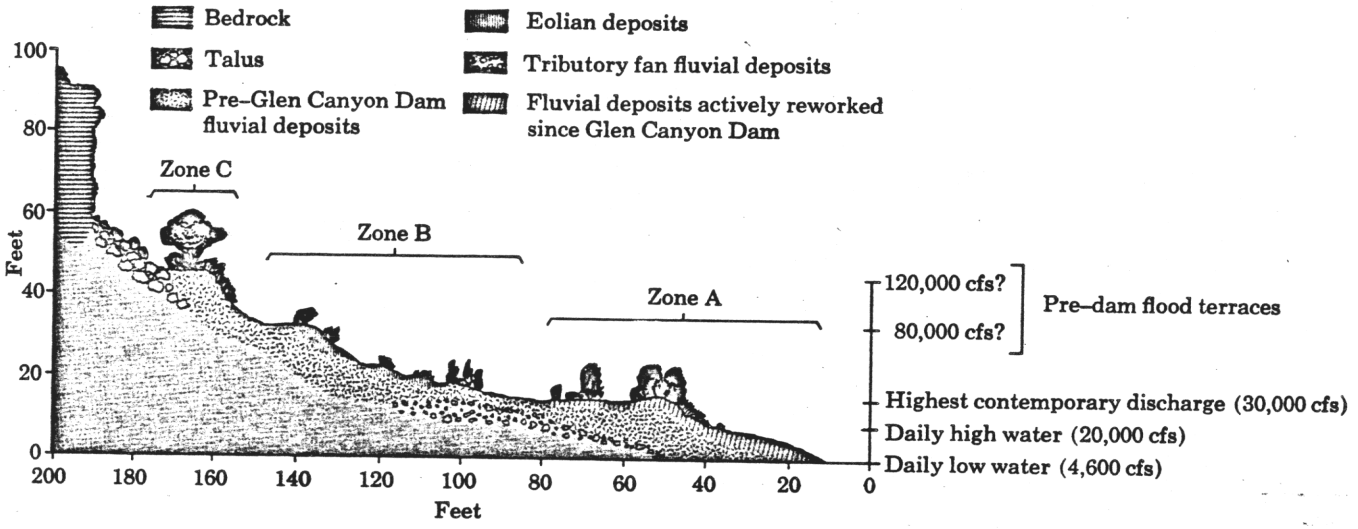

Bedrock
Talus
Pre–Glen Canyon Dam fluvial deposits
Eolian deposits
Tributory fan fluvial deposits
Fluvial deposits actively reworked since Glen Canyon Dam
Zone C
Zone B
Zone A
Feet
100
80
60
40
20
0
200
180
160
140
120
100
80
60
40
20
0
Feet
120,000 cfs?
80,000 cfs?
Pre–dam flood terraces
Highest contemporary discharge (30,000 cfs)
Daily high water (20,000 cfs)
Daily low water (4,600 cfs)

Figure 1

exposed roots which give the appearance of rapid erosion. The slow rate of erosion is due to the heavy vegetation cover and the cohesion of the silts. However, unlike the coarser deposits, the fine silts and clays, once eroded, stay in suspension.

Pre-dam flood terraces and post-dam deposits of sand and silt-sand are more easily entrained by present day flows. The changes measured over several years at our bench mark profiles in this coarser-grained sediment are variable, but they show rates of lateral erosion averaging about 1.0 meters per year (Table 2). Since the measurements were made at commonly used campsites, human impact contributes to this figure.

Lateral erosion is not uniform along the fine-grained beaches. The short-term measurements indicate rates of erosion ranging from a high of 4.9 m/yr to .7 m/yr of deposition (Table 2). Similarly, our aerial photographic analysis shows rates of erosion of up to 3 m/yr with 10 m/yr at scattered locations. A few sites have expanded through deposition.

The average rate of lateral erosion from the previous photo analysis is .3 meters per year (Table 3). However, the great variability of erosion rates makes average figures of little use. Therefore each continuous sand deposit (a beach) was classified according to the maximum change recorded by the aerial photo analysis. The beaches so

Table 2. CHANGES TO FINE-GRAINED FLUVIAL DEPOSITS MEASURED BY RESURVEY OF BASE-LINE PROFILES (After Howard and Dolan, 1975)

A. Maximum Changes

Beach Location (mile)	Cross-Section Identification Number	Interval Between Resurveys (years)	Location on Beach [1]	Dominant Grain Size of Beach	Average Gradient	Maximum Lateral Change (meters) [2]	Maximum Vertical Change (meters)
L19.5	1	2	Beach Face	Silt-sand	.091	-4.9	-.8
L19.5	2	2	Beach Face	Silt-sand	.190	-4.0	-.9
L34.7	1	1	Beach Face	Sand	.040	-4.3	+0.7
L34.7	2	1	Beach Face	Sand	.160	0	0
R53.0	1	2	Beach Face	Silt-sand	.152	-1.3	-.2
R53.0	1	2	Camp Area	Sand	.125	-0.9	-.1
R53.0	2	2	Beach Face	Cohesive silt	.200	0	0
R72.2	1	1	Beach Face	Sand	.124	-4.0	-.7
R72.2	2	1	Beach Face	Cohesive silt	.73	0	0
R151.6	1	1	Beach Face	Cohesive silt	.40	+0.7	+.15
R151.6	2	1	Beach Face	Silt-sand	.133	-1.8	-.55
L208.8	1	2	Beach Face	Cohesive silt	.244	-0.8	-.18
L208.8	2	2	Beach Face	Cohesive silt	.400	0	0

B. Average Rates of Change of Beach Face

Dominant Grain Size	Average Gradient	Average Vertical Change (meters/yr) [3]	Average Lateral Change (meters/yr) [4]	Number of Profiles Sampl
Cohesive silt	.39	0	0	5
Silt-sand	.14	-.16	-1.19	4
Sand	.11	-.10	- .67	3

Explanation:

1) Beach Face: Portion of profile below present high water.
Camp Area: Portion of profile no longer inundated. Note: Changes in camp areas are not listed if amount of change recorded is less than survey errors.

2) Maximum change observed on resurveyed profile. Zeros are entered if change is less than expected magnitude of survey errors.

3) Calculated by dividing the total areal change of portion of profile below high water by 1) the lateral extent of the profile, and by 2) the number of years between resurveys. Figures quoted are averaged over all profiles.

4) Calculated as above but divided by the vertical extent of the profile.

Table 3 - POST-DAM SHORELINE CHANGES OF THE COLORADO RIVER, 1965-1973, USING AERIAL PHOTOGRAPHY *

Miles	Average Channel Width (meters)	Total Shoreline Length (meters)		Net Areal Change (meters)²		Average Shoreline Change (meters)		Number of Severe 1) Erosion
		Fan Deltas	Fine Alluvium	Fan Deltas	Fine Alluvium	Fan Deltas	Fine Alluvium	
0.5	138.5	0	1560	0	8855	0	+5.68	
2.1	101.5	955	1225	81	-5645	+0.08	-4.61	1
3.6	74.5	145	1570	0	-6871	0	-4.38	1
4.6	98.5	395	815	0	516	0	+0.63	2
6.0	88.0	385	550	2581	1452	+6.70	+2.64	1
7.2	97.0	640	590	677	677	+1.06	+1.15	2
8.7	78.5	405	1160	613	1065	+1.51	+0.92	0
10.0	62.5	105	1135	0	-290	0	-0.26	1
11.3	57.0	680	730	1790	-323	+2.63	-0.44	1
12.8	41.5	755	400	484	-516	+0.64	-1.29	1
14.2	46.0	410	115	306	0	+0.75	0	0
15.4	57.5	575	685	0	-355	0	-0.52	1
16.7	66.5	640	655	1806	371	+2.82	+0.57	1
18.0	59.0	585	790	1242	742	+2.12	+0.94	1
19.4	59.5	730	1035	1355	3532	+1.86	+3.41	0
20.5	54.0	185	580	2613	1274	+14.12	+2.20	0
29.9	64.0	670	930	323	306	+0.48	+0.33	0
31.2	65.0	665	900	0	-3210	0	-3.57	1
33.0	65.0	275	1340	81	-2065	+0.29	-1.54	1
34.4	80.5	310	1110	371	-6758	+1.20	-6.09	3
35.5	70.5	425	1150	161	-5758	+0.38	-5.01	4
36.9	78.5	375	1125	1903	-3242	+5.07	-2.88	3
38.1	83.5	330	1365	919	-2935	+2.78	-2.15	2
39.7	85.0	260	1695	387	-9339	+1.49	-5.51	4
40.9	88.5	260	1565	387	-1968	+1.49	-1.26	3
42.2	94.5	65	490	0	-1226	0	-2.50	0
43.8	81.0	570	2305	3145	-9210	+5.52	-4.00	8
45.3	95.5	285	1155	806	-7113	+2.83	-6.16	4
46.7	104.5	700	1320	645	-11952	+0.92	-9.05	5
48.1	102.0	565	1495	694	-7468	+1.23	-5.00	5
49.5	110.0	530	1200	0	-8500	0	-7.08	3
50.7	93.5	210	1295	0	-10903	0	-8.42	4
52.5	113.5	800	1985	2258	-2790	+2.82	-1.41	4
129.5	50.0	290	210	1984	500	+6.84	+2.38	3
130.8	58.0	285	845	0	-1774	0	-2.10	4
132.2	49.0	515	1080	81	-9903	+0.16	-9.17	1
133.5	60.5	825	1375	355	-6806	+0.43	-4.95	2
135.0	48.0	415	1205	597	-5548	+1.44	-4.60	3
136.4	48.0	430	1285	0	-5613	0	-4.37	2
137.7	63.0	690	1315	48	-1952	+0.07	-1.48	2
139.4	56.5	700	1135	887	-4984	+1.27	-4.39	2
140.5	51.0	880	900	0	-3613	0	-4.01	1
142.0	55.5	0	270	0	0	0	0	0
143.4	56.0	385	170	5726	-613	+14.87	-3.61	0
155.8	42.8	265	210	565	0	+2.13	0	0
157.3	45.0	345	220	613	-677	+1.78	-3.08	1
158.8	44.0	210	390	371	0	+1.77	0	0
160.4	48.5	155	415	0	1016	0	+2.45	0
161.5	50.5	150	420	323	+81	+2.15	+0.19	0
163.2	54.5	395	475	565	-403	+1.43	-0.84	1
164.8	63.5	220	1160	565	242	+2.57	+0.21	0
166.5	65.5	285	1180	0	500	0	+0.42	0
167.7	76.5	335	1615	806	-4661	+2.41	-2.89	3
169.4	68.0	105	585	0	0	0	0	0
170.8	65.0	430	950	1016	2581	+2.12	+2.72	2
172.3	72.5	155	1560	65	-7081	+0.42	-4.54	4
173.5	68.0	680	1265	2097	2823	+3.08	+2.23	1
175.1	69.5	425	1195	565	-3548	+1.33	-2.97	1
176.4	81.5	160	595	0	-2097	0	-3.52	2
	68.9	24,665	57,030	42,857	-141,177	+1.738	-2.476	100
	(226 ft)				Change/yr	+.217	-.310	
							Percent of Total	16

Explanation

1) Maximum lateral erosion of fine-grained shoreline segment greater than 15 meters in 8 years (50 ft. or 6 feet per year).

2) Maximum lateral change between 0 and 15 meters of erosion.

3) Maximum lateral change between 0 and 15 meters of deposition.

4) Greater than 15 meters deposition.

*After Howard and Dolan, 1975.

Table 3 (continued)

Grained Shoreline Segments with Indicated Maximum Changes					Number of Fan Deltas with Indicated Maximum Changes			
State 2) tion	No Change	Moderate 3) Deposition	Pronounced 4) Deposition	Total Cases	No Change	Moderate Deposition	Severe Deposition	Total Cases
1	1	1	2	6	0	0	0	0
1	5	4	0	13	7	1	0	8
3	3	4	0	12	3	0	0	3
1	4	2	1	9	4	0	0	4
0	2	0	0	4	3	1	2	6
3	1	3	0	7	2	2	0	4
1	4	3	2	11	4	1	0	5
1	8	2	0	12	1		0	1
3	6	1	0	10	2	1	1	4
1	4	2	0	8	3	2	0	5
0	3	0	0	3	2	1	0	3
2	4	1	1	9	5	0	0	5
1	4	1	2	9	1	1	3	5
1	7	0	1	9	2	4	0	6
3	7	5	3	18	4	3	1	8
0	5	2	0	7	0	0	1	1
1	3	1	1	6	6	1	0	7
6	4	3	0	14	9	0	0	9
3	9	1	0	14	4	1	0	5
6	0	1	0	10	2	1	1	4
3	6	0	0	13	4	2	0	6
2	6	0	0	11	2	0	1	3
4	5	2	1	14	1	2	1	4
1	6	0	1	12	2	1	0	3
2	3	0	2	10	1	1	0	2
3	1	1	0	5	1	0	0	1
2	2	2	2	16	3	1	1	5
0	7	1	0	12	1	0	1	2
0	6	1	1	13	5	0	1	6
1	9	0	0	15	5	0	1	6
1	6	0	0	10	5	0	0	5
0	5	1	0	10	3	0	0	3
2	3	0	1	10	2	1	1	4
0	5	0	1	6	0	1	2	3
4	2	3	1	14	4	0	0	4
8	6	2	0	17	5	1	0	6
5	4	1	0	12	8	1	0	9
6	3	2	0	14	4	2	0	6
3	10	1	0	16	5	0	0	5
5	7	0	0	14	6	1	0	7
2	7	0	0	11	3	2	0	5
5	4	0	0	10	9	0	0	9
2	0	1	0	3	0	0	0	0
1	0	1	0	2	1	0	1	2
0	5	0	0	5	3	1	0	4
0	4	0	0	5	4	1	1	6
0	7	0	0	7	3	1	0	4
0	9	0	1	10	2	0	0	2
0	8	0	0	8	1	1	0	2
1	4	1	0	7	6	0	1	7
0	17	1	0	18	1	1	0	2
1	13	1	1	16	3	0	0	3
1	14	0	1	19	2	0	1	3
0	7	0	0	7	1	0	0	1
0	3	0	3	8	1	0	1	2
2	10	1	0	17	1	1	0	2
4	6	1	2	14	6	0	2	8
0	8	4	4	17	2	1	0	3
	6	0	1	12	1	0	0	1
2	318	65	36	631	18	43	25	249
	50	10	6	100	73	17	10	100

defined occur with an average density of about 8 per mile. About 16 percent of these beaches underwent severe erosion between 1965 and 1973 (defined as an average rate exceeding 2 meters per year) while only 6 percent underwent an equivalent rate of deposition (Table 3). The unavoidable problems in estimating discharge during the times of the various sets of aerial photography used in the analysis have affected these figures by increasing the number of cases of extreme erosion and deposition, but they would have had less effect upon the average rates. Therefore the actual number of cases of severe erosion is less than 16 percent of the total, perhaps considerably less. The management implication remains the same, however. Severe lateral erosion sufficient to affect camping activities over the next few years will be rare and of localized occurrence if water releases continue in the 5,000 to 20,000 cfs range. Over the long run, measured in decades, coupled with higher water releases, the progress of erosion will gradually reduce the number of sandy beaches. The rate of this process cannot be reliably estimated from the aerial photo analysis.

Erosion rates will, of course, decrease when the coarse-grained substrate beneath the terrace (bedrock, talus, alluvial fan debris, or Colorado River gravels) becomes exposed. Exposure of the cohesive silts also

reduces erosion rates, and sandy beaches that are deeply inset between headlands or resistant rock are protected from strong currents and wave action. Finally, the input of sediment from the Paria River, the Little Colorado River, and ungaged tributaries below Lee's Ferry may eventually be sufficient to sustain an equilibrium between supply and removal of sand-size sediment before the beaches are completely eroded away.

The pre-dam terrace deposits above present-day high water have been modified by three natural processes, eolian transport, rainfall runoff, and vegetation. Eolian sand movement occurs mostly where vegetation is sparse and the local winds are strong. Under such circumstances, rates of vertical erosion or deposition may exceed a meter/yr. Eolian transport is greatly diminished by even a sparse vegetation cover.

Rainfall and associated runoff also erode the pre-dam terraces on a localized basis. Two types of runoff erosion occur; slope wash and tributary canyon flooding. Heavy rainfall causes runoff and local gullying. Because of the high infiltration capacity of the terrace deposits and the rarity of intense, long-duration rainfall, this type of erosion is only important locally and is difficult to forecast. Erosion is also influenced by human use of the beaches. Of the fine-grained deposits, the silt-sands are the most easily eroded. The cohesive silts are less

easily detached by running water and are commonly protected by a vegetative cover. Coarse sand, on the other hand, is highly permeable, so that a very heavy rain is necessary before erosion takes place.

The other erosional process is the flooding of tributary streams that flow across the alluvial fans mantled with fine-grained deposits. When in flood the tributary streams cause wide-scale erosion of the fine-grained mantle.

The absence of large floods since Glen Canyon Dam has resulted in a decreased competency of the post-dam river. Because almost all of the major rapids have resulted from deposition of coarse debris brought by the flooding of tributary canyons, the smaller post-dam river may be forced into a gradient as much as twice its pre-dam value if a major side-canyon flood occurs. However, in order for the river to be so narrowed and steepened, the tributary must flood. The aerial photographic study indicates that 27 percent of tributary fans in the study sites have built outward, but narrowing of the river by more than 15 meters has occurred on only 10 percent of the fans (Table 3). Catastrophic narrowing and steepening of rapids is very uncommon, the most notable example being the creation of a major rapid at Crystal Creek (Mile 98.2) in the mid-1960's.

Constriction of the river by tributary floods can have two effects upon human use of the river. Firstly, rapids may become impassable to river traffic. Secondly,

Table 4. Grand Canyon Data Base Surveyed Profiles

		1974	1975	1980a	1980b
8S	Badger Creek	-	-	-	-
19N	House Rock	✓		✓	✓
29S	Silver Grotto	-	-	-	-
44S	Pres Harding Upper	-	-	-	-
47N	Saddle Canyon	-	-	-	-
52N	Nankoweap	✓	✓	✓	✓
61N	61.8 Lower LC	-	✓	✓	-
66S	Chuar Rapid	✓	-	✓	✓
72N	Unkar	-	✓	✓	✓
75S	Nevillis	-	-	-	-
76S	Hance	-	-	-	-
81S	Grapevine	✓	-	-	✓
87S	Suspension Bridge	✓	-	✓	✓
93S	Granite Rapid	-	-	-	-
103N	Lower Bass	✓	-	✓	✓
109N	109 Mile	-	-	-	-
112N	Walthenberg	-	✓	-	✓
114N	114 Mile Camp	-	-	-	-
120N	Blacktail	-	✓	-	✓
131N	Bedrock	✓	-	✓	✓
132N	Dubendorff	-	-	-	-
136S	Deer Creek Falls	-	-	-	✓
137S	Panchos Kitchen	-	-	-	-
140S	140 Mile (Fishtail?)	-	-	-	-
146S	Olo	-	-	-	-
152N	Ledges	-	-	-	-
166S	National	-	✓	✓	✓
174N	Cole Canyon	-	-	-	✓
179S	Lava Falls	-	-	-	-
180N	Lower Lava (left side)	-	-	-	-
181N	181 Mile	✓	-	-	✓
185N	185 Mile	-	-	-	-
190S	190 Mile	-	✓	✓	✓
198N	198L	-	-	-	-
198S	Parashont	-	-	-	-
209S	Granite Park	✓	✓	✓	✓
219N	219 Mile Camp	-	-	-	-
220N	220 Mile Camp	-	-	-	✓

a. June 1980

b. October 1980

deposition of coarse material in the river, steepening its gradient, can increase the total fall through the rapids and back up the river upstream, raising the water level of the river by several feet a mile or more upstream. The backwater effect, of course, could drown out beaches formerly used for camping. Such major floods are rare and unpredictable in specific occurrence, and even their frequency of occurrence along the river is uncertain. Human adjustment to any such major flood will have to be done on an after-the-fact basis. However, the likelihood of occurrence of a flood of sufficient magnitude to create an impassable river over the next several decades seems remote.

III. Aerial Photographic and Base-line Surveys

We have established study sites at 38 camping beaches (Table 4) between Lee's Ferry (River Mile 0) and Diamond Creek (River Mile 225). Twenty of these sites, with 38 surveyed profiles were established in 1974 and 1975, and in 1975 and 1976 twelve of the 30 profiles were resurveyed to provide some quantitative data on lateral erosion and deposition. These same profiles were re-surveyed in June, 1980, and again during late October, 1980. (Table 4).

In 1973 aerial photography at a scale of 1:7000 was flown along the Colorado River from Lee's Ferry to Lake Mead. When compared to similar photography flown in 1965, the 1973 photography provides an excellent record of eight years of changes in the geomorphology and vegetation since

Table 5. Grand Canyon Data Base Aerial Photos

		1932	1952	1963	1965	1973	1980
8S	Badger Creek	-	✓	-	✓	✓	-
19N	House Rock	-	✓	-	✓	✓	✓
29S	Silver Grotto	-	-	-	-	✓	✓
44S	Pres Harding Upper	-	✓	✓	✓	✓	✓
47N	Saddle Canyon	-	✓	✓	✓	✓	✓
52N	Nankoweap	-	-	-	-	✓	✓
61N	61.8 Lower LC	-	-	-	-	✓	-
66S	Chuar Rapid	-	-	-	-	✓	-
72N	Unkar	-	-	✓	-	✓	✓
75S	Nevillis	✓	-	-	-	✓	✓
76S	Hance	-	-	-	-	✓	✓
81S	Grapevine	✓	-	-	-	✓	✓
87S	Suspension Bridge	✓	-	-	-	✓	-
93S	Granite Rapid	-	-	-	-	✓	-
103N	Lower Bass	-	-	-	-	✓	✓
109N	109 Mile	-	-	-	-	✓	-
112N	Walthenberg	-	-	-	-	✓	-
114N	114 Mile Camp	-	-	-	-	✓	-
120N	Blacktail	-	-	-	-	✓	✓
131N	Bedrock	-	✓	✓	✓	✓	-
132N	Dubendorff	✓	✓	✓	✓	✓	-
136S	Deer Creek Falls	✓	✓	✓	✓	✓	-
137S	Panchos Kitchen	-	-	✓	✓	✓	-
140S	140 Mile (Fishtail?)	-	✓	✓	✓	✓	-
146S	Olo	-	-	-	-	✓	-
152N	Ledges	-	-	-	-	✓	-
166S	National	-	-	✓	✓	✓	✓
174N	Cole Canyon	-	-	✓	✓	✓	✓
179S	Lava Falls	-	-	-	-	✓	-
180N	Lower Lava (left side)	-	-	-	-	✓	-
181N	181 Mile	-	-	-	-	✓	-
185N	185 Mile	-	-	-	-	✓	-
190S	190 Mile	-	-	-	-	-	-
198N	198L	-	-	-	-	✓	-
198S	Parashont	-	-	-	-	✓	-
209S	Granite Park	-	-	-	-	✓	✓
219N	219 Mile Camp	-	-	-	-	✓	✓
220N	220 Mile Camp	-	-	-	-	✓	✓

the regulation of the river. Additional photo coverage of portions of the canyon are also available for 1932, 1953, 1963, and 1965 at scales ranging from 1:20,000 to 1:37,000 (Table 5).

We have used this photography to record two types of changes: lateral movement of the shoreline (erosion and deposition) along the terrace deposits and the build-up of the tributary fan. However, any mapping from aerial photos is complicated in the Grand Canyon because water levels vary from one set of photos to the next and during the course of an individual flight. The differences cause apparent erosion and/or deposition. For the rapidly varying discharges of the 1973 flight, it has been necessary to route the water releases from the dam to determine discharge at each point along the river. Furthermore, in our previous studies, we were limited to mapping portions of the canyon where pre-dam photography was available for both lower and higher discharges than those of the 1973 flight. These criteria limited us to detailed shoreline comparison to less than 40 percent of the river (Table 3).

The 1980 photography was taken on 27 June 1980, at 1:4800 when water was being released at a rate of ∿37,000 cfs. However, given the fact that there is a two-day delay in water reaching the lower canyon, the water level varies along the flight line from the 37,000 cfs to ∿40,000 cfs plus.

The Aerial Photographic Analyses. The data maps appended to this report represent the fundamental information base for this investigation. We show on each map the shorelines or river stage water lines for each photographic date. However, there is not total photographic coverage for the 38 sample beaches for any of the overflights. The most complete coverage is the 1973 flight.

Table 5 provides a quick reference to the photo coverage available for the 38 research beaches. We have 4 beaches with 5 sets of photography, 5 beaches with 4 sets, 5 with 3, 9 beaches with 2 sets, and 14 beaches with just one set of photos. Therefore, the photo coverage is limited to 23 sites for temporal comparisons.

The maps provide positions of the shorelines for the aerial photographic dates for each of our 38 sample beaches. When coupled with the surveyed profiles (next section), estimates of erosion are possible. In addition, when compared, the shorelines provide an estimate of the flooded zone associated with the 1980 high water.

Two scales of maps are offered. A smaller scale shows the shoreline patterns of the 38 sample beaches and adjacent areas along the river; the larger scale maps are enlargements of the campsite beaches.

The Surveyed Beach Profiles. Accompanying the photo shoreline maps are plots of the surveyed profiles. These

surveys were initiated in 1974 and re-surveyed in 1976 (some) and again in June, 1980 and October, 1980. The profile data base includes 2 beach sample sites with a sequence of 3 surveys, 5 beaches with 2 surveys, and 3 with only one survey (Table 4).

IV. Results

Table 6 summarizes my interpretation of erosion patterns from the surveyed profile data. As can be seen, only 4 of the sample beaches with surveyed profiles have undergone what I consider to be major erosion since our surveys were initiated in 1964. Five of the 15 beaches with adequate survey data for comparisons show evidence of modest erosion, and 7 others show minor changes.

The aerial photo shoreline maps are more difficult to interpret without associated ground surveys. However, the maps do suggest that erosion is only a serious problem in about 10% of the sample beaches, a modest problem in about 50% and of minor significance in the remaining 40%. Overall then one can conclude from these analyses that over the past 7 years erosion has not been a very serious problem on our 38 sample beaches. Nevertheless, even with modest rates of change the beaches will loose significant amounts of sand over periods of 15, 20, or 50 years.

Another conclusion worth special consideration is that much of the erosion (serious and modest) occurred in association

Table 6. Changes in the Surveyed Beach Profiles

		Major Changes (several feet)	Modest Changes (1 to 2 feet)	Minor Changes (less than 1 ft)
19N	House Rock	✓		
52N	Nankoweap			✓
61N	61.8 Lower LC		✓	
66S	Chuar Rapid	✓		
72N	Unkar	✓		
81S	Grapevine		✓	
87S	Suspension Bridge			✓
103N	Lower Bass			✓
112N	Walthenberg			✓
120N	Blacktail			✓
131N	Bedrock		✓	
136S	Deer Creek Falls	Only one survey		
166S	National			✓
174N	Cole Canyon	Only one survey		
181N	181 Mile		✓	
190S	190 Mile	✓		
209S	Granite Park		✓	
220N	220 Mile Camp	Only one survey		
		4	5	6

with the single release of high water in June of 1980. This is not to suggest that erosion at high rates would continue indefinitely with higher water releases. After a period of rapid adjustments to a new water release regime, I believe erosion would resume at rates similar to those of the past decade. In fact, the data suggest that much of the erosion may, in fact, be re-distribution of sand from the higher elevations on the beaches to the water line at lower water levels.

Perhaps of equal importance is the magnitude of the flooded zone on the campsites. This can be easily measured from the shoreline sweep zone. Table 7 is my estimate of the land areas that will be flooded by the three water levels suggested for planned increases in power production by Glen Canyon Dam.

V. Conclusions

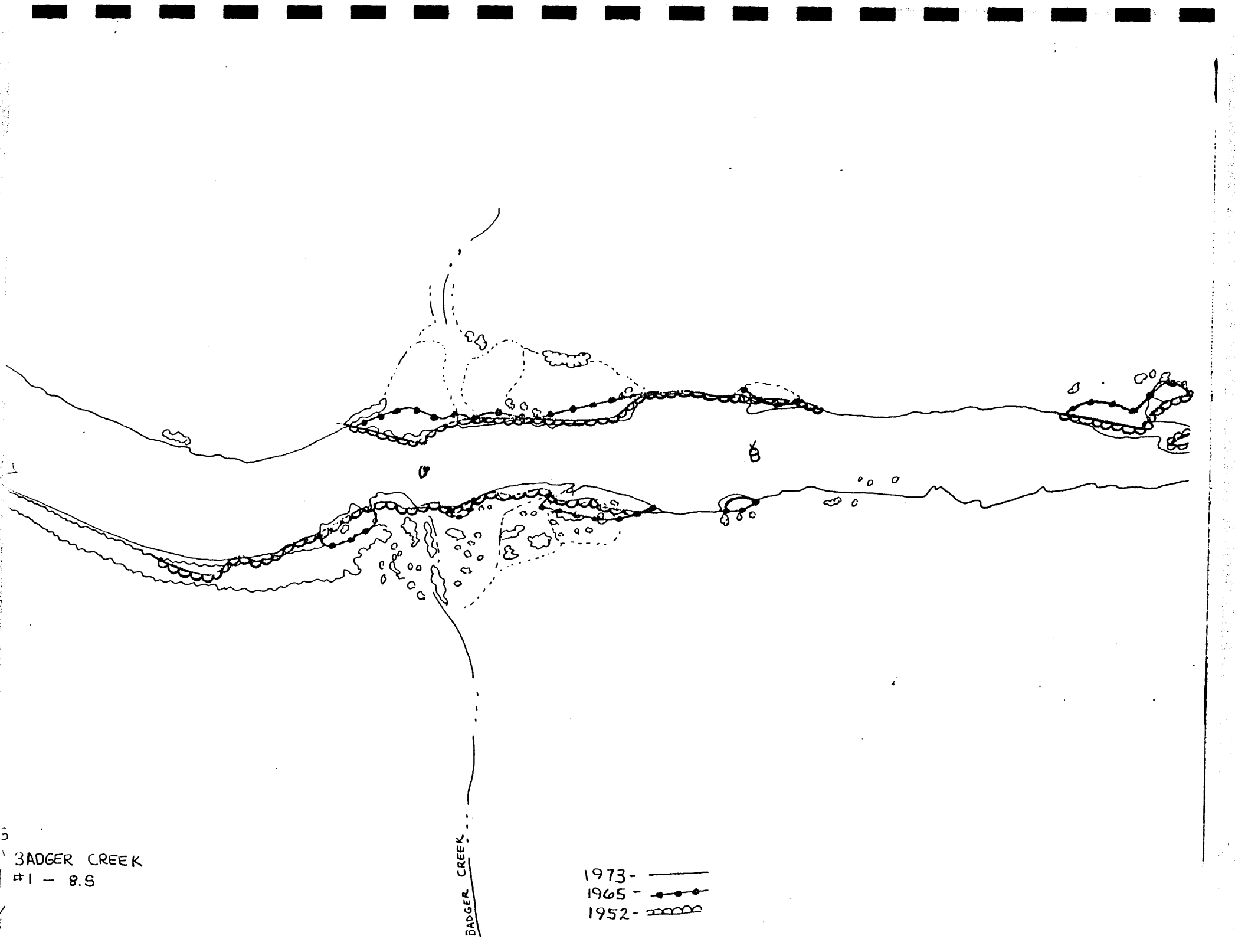
Are the beaches along the Colorado River of the Grand Canyon undergoing significant change? Will higher water releases result in irreversible change? My evidence suggests that the answer to these questions is yes. However, what this means to management cannot be answered in equally definite terms. The Colorado River alluvial system below Glen Canyon Dam is clearly adjusting to the post-dam altered river regime. Further adjustments to higher water releases will be superimposed onto the longer term trend.

Table 7. Estimates of Beach Campsite Flooding Associated With Three Water Levels
(Based on photo maps, profiles, and field observations)
(Numbers in % of total beach area)

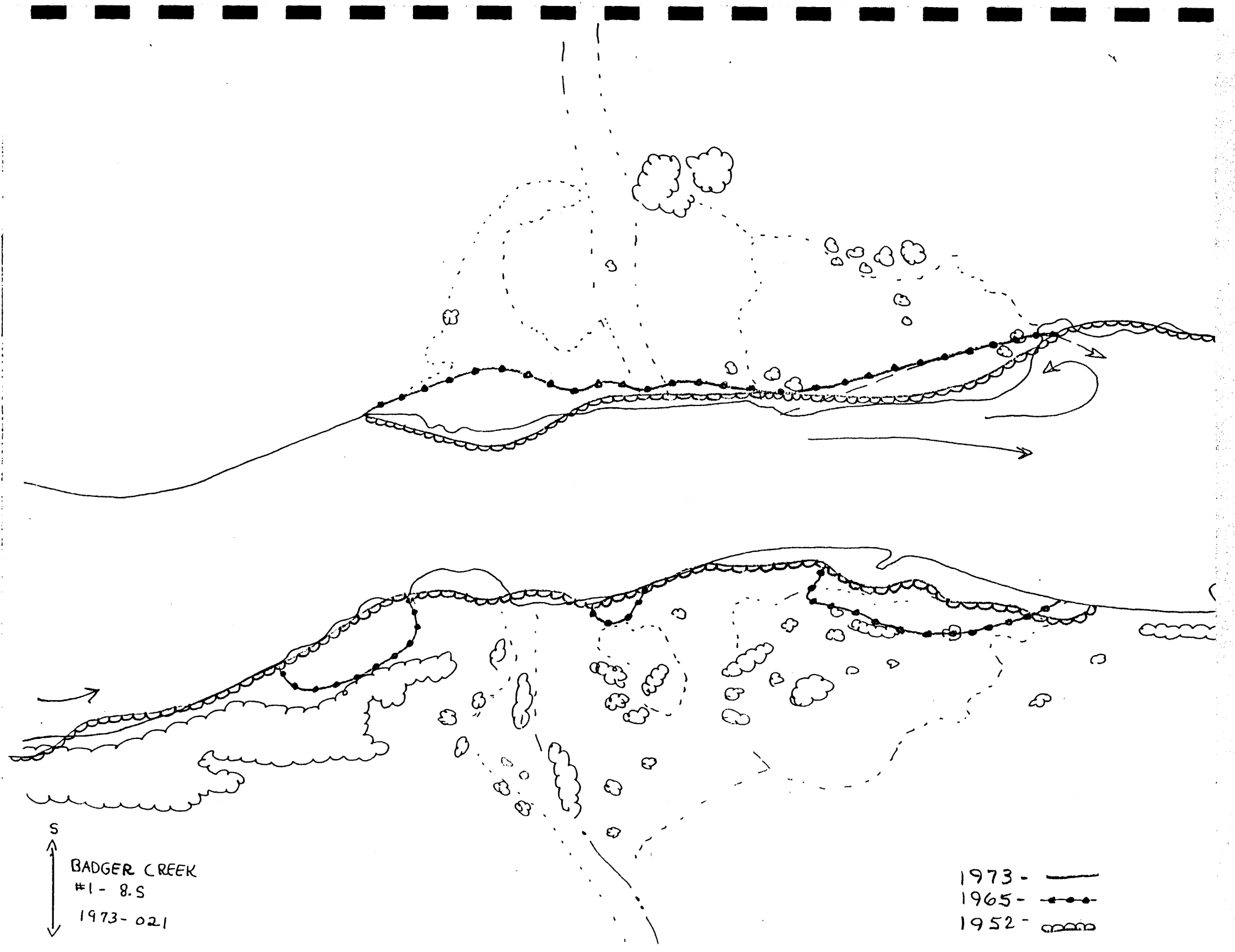
		30,000 cfs	37,000 cfs	40,000 cfs
8S	Badger Creek	10	15	35
19N	House Rock	20	25	35
29S	Silver Grotto	10	15	25
44S	Pres Harding Upper	20	25	30
47N	Saddle Canyon	10	15	20
52N	Nankoweap	10	20	30
61N	61.8 Lower LC	30	50	100
66S	Chuar Rapid	10	15	18
72N	Unkar	5	10	15
75S	Nevillis	10	15	20
76S	Hance	5	10	15
81S	Grapevine	40	60	100
87S	Suspension Bridge	5	10	12
93S	Granite Rapid	40	75	100
103N	Lower Bass	15	25	30
109N	109 Mile	60	100	100
112N	Walthenberg	60	90	100
114N	114 Mile Camp	10	20	25
120N	Blacktail	10	15	20
131N	Bedrock	20	35	80
132N	Dubendorff	50	100	100
136S	Deer Creek Falls	20	25	30
137S	Panchos Kitchen	15	20	25
140S	140 Mile (Fishtail?)	15	20	25
146S	Olo	15	40	75
152N	Ledges	15	20	40
166S	National	25	45	75
174N	Cole Canyon	30	40	50
179S	Lava Falls	10	30	50
180N	Lower Lava (left side)	10	25	30
181N	181 Mile	10	15	20
185N	185 Mile	10	12	15
190S	190 Mile	30	35	40
198N	198L	5	10	15
198S	Parashont	5	10	15
209S	Granite Park	5	10	20
219N	219 Mile Camp	25	50	80
220N	220 Mile Camp	10	25	35

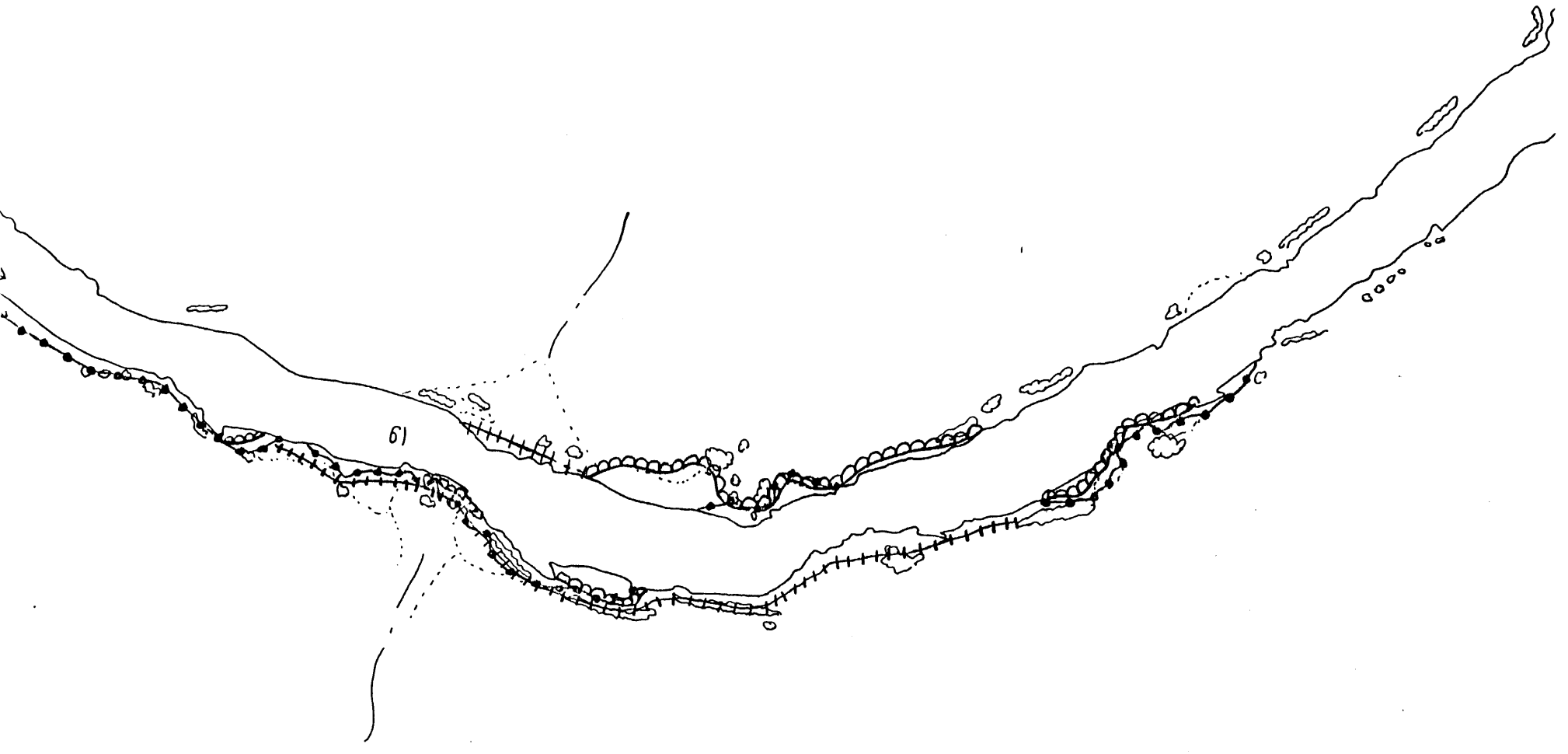
Alterations of the beaches are of two types: 1) addition or removal of sediment by natural processes, and 2) alteration of the sand deposits by human impact associated with camping activities. The data I have collected indicate that over the next several years the removal of fine sediment from the beaches (by high water) will have minor impact upon the number of campsites. A few beaches may become less desirable due to exposure of the underlying coarse rocks or bedrock at the mooring or camping sites. Over a longer period (several decades) this erosion may force appreciable readjustment to a diminishing supply of campable beaches. However, the high water will have significant impact on the beach campsites by flooding.

The changes brought about by the Glen Canyon Dam, including the proposed high water releases, will occur slowly, but erosion of the terraces is cumulative. Because these changes occur over a wide range of processes, my estimates of change are subject to a degree of uncertainty. These uncertainties are due mostly to the short period of observation. Trends established from one, two, or five years of measurement may not be representative, and the amounts of change are in some cases less than the surveying errors. The aerial photographic comparisons are also subject to errors, particularly in the estimate of discharge at the time of the photography.



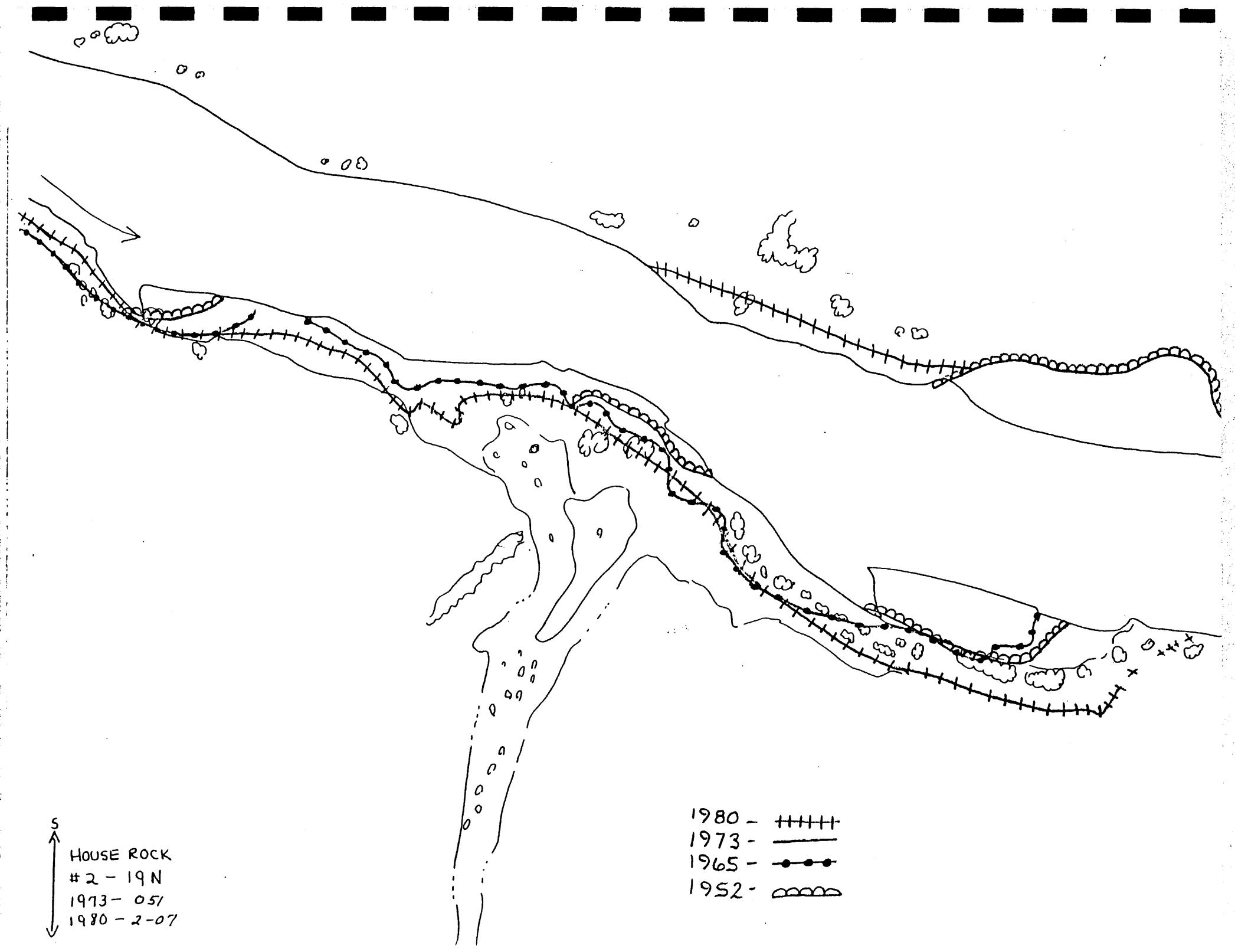
BADGER CREEK
#1 – 8.5


S
BADGER CREEK
#1 - 8.S
1973-021
1973 -
1965 -
1952 -

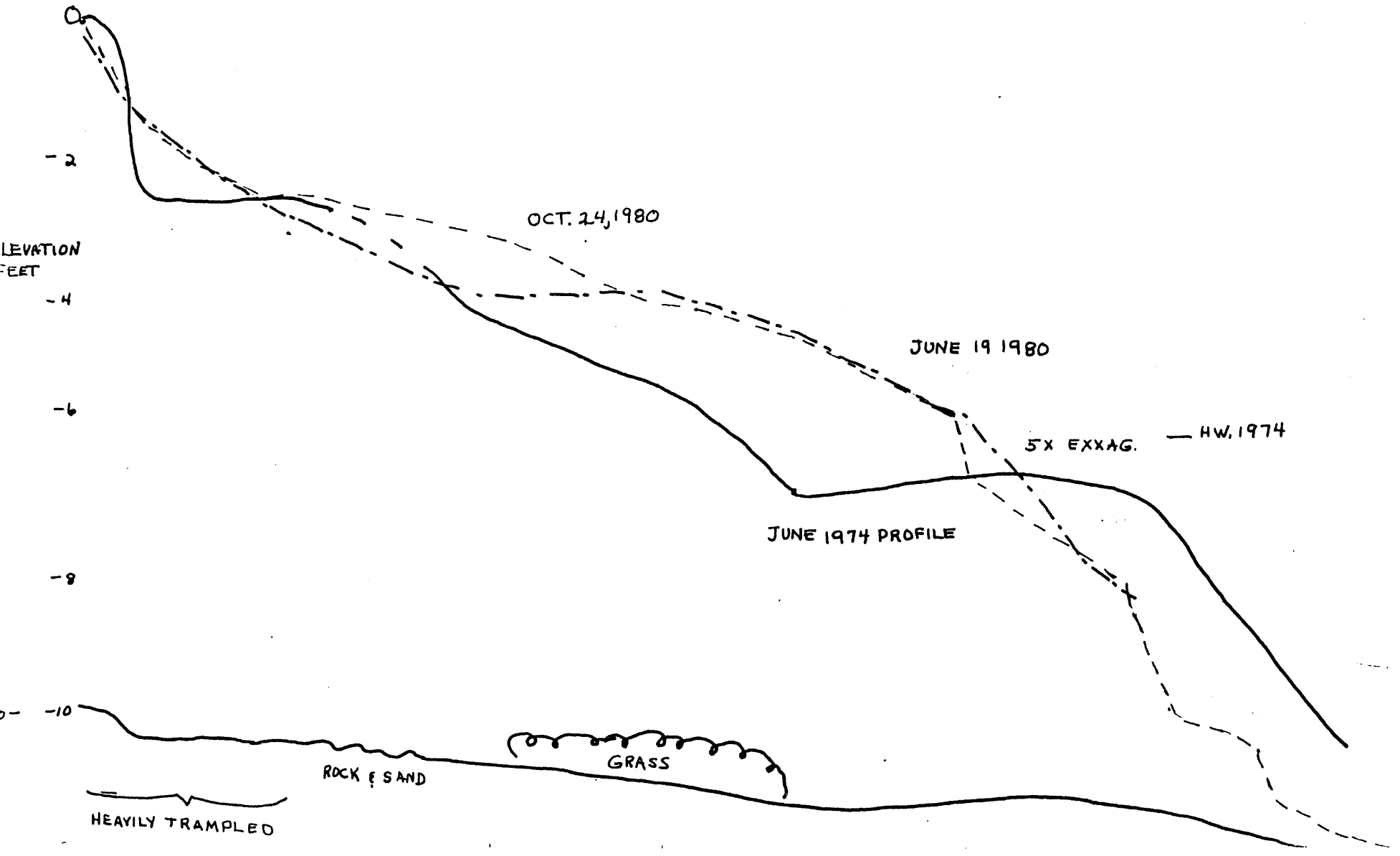


HOUSE ROCK
#2 - 19N

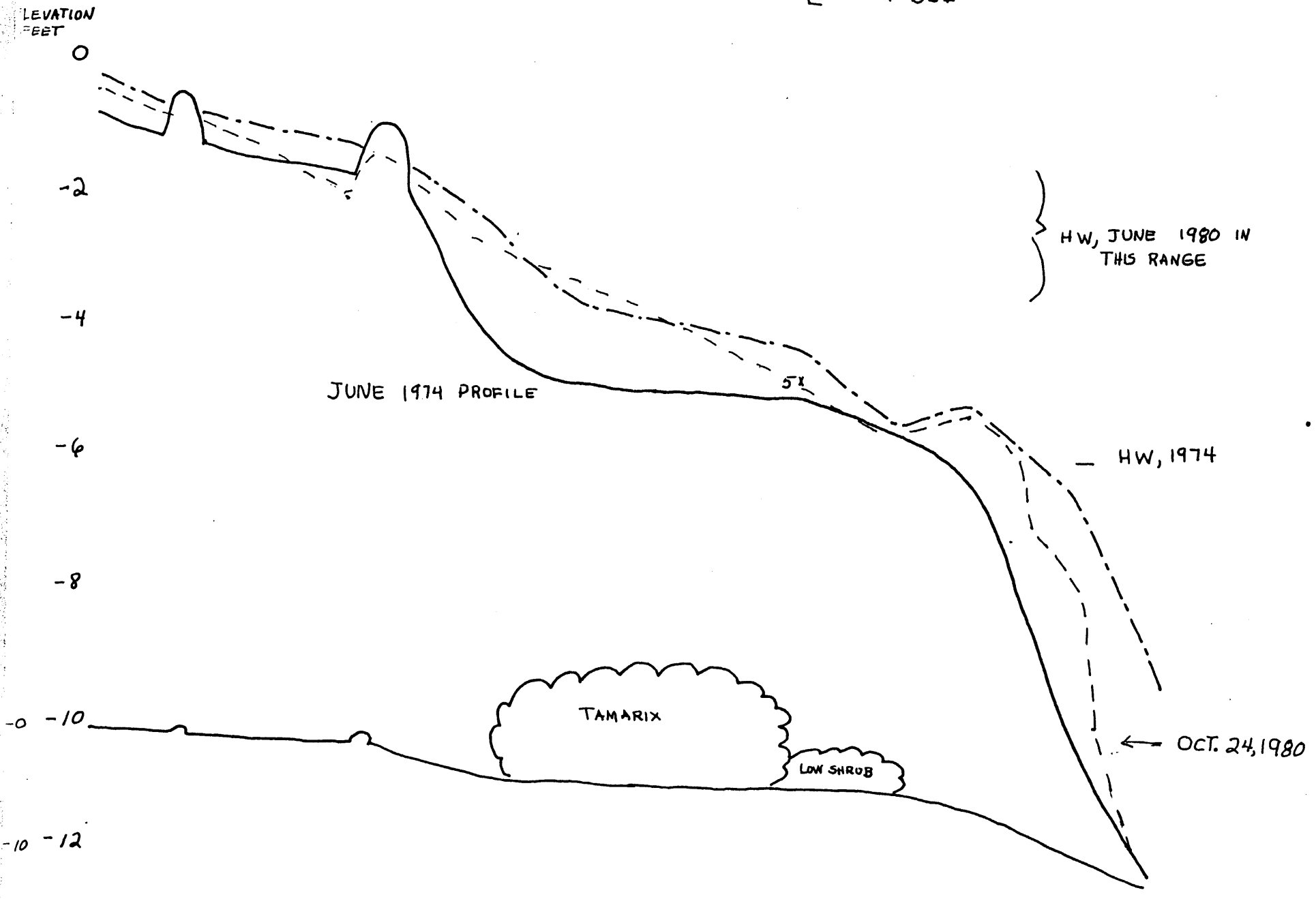
1980-
1973-
1965-
1952-

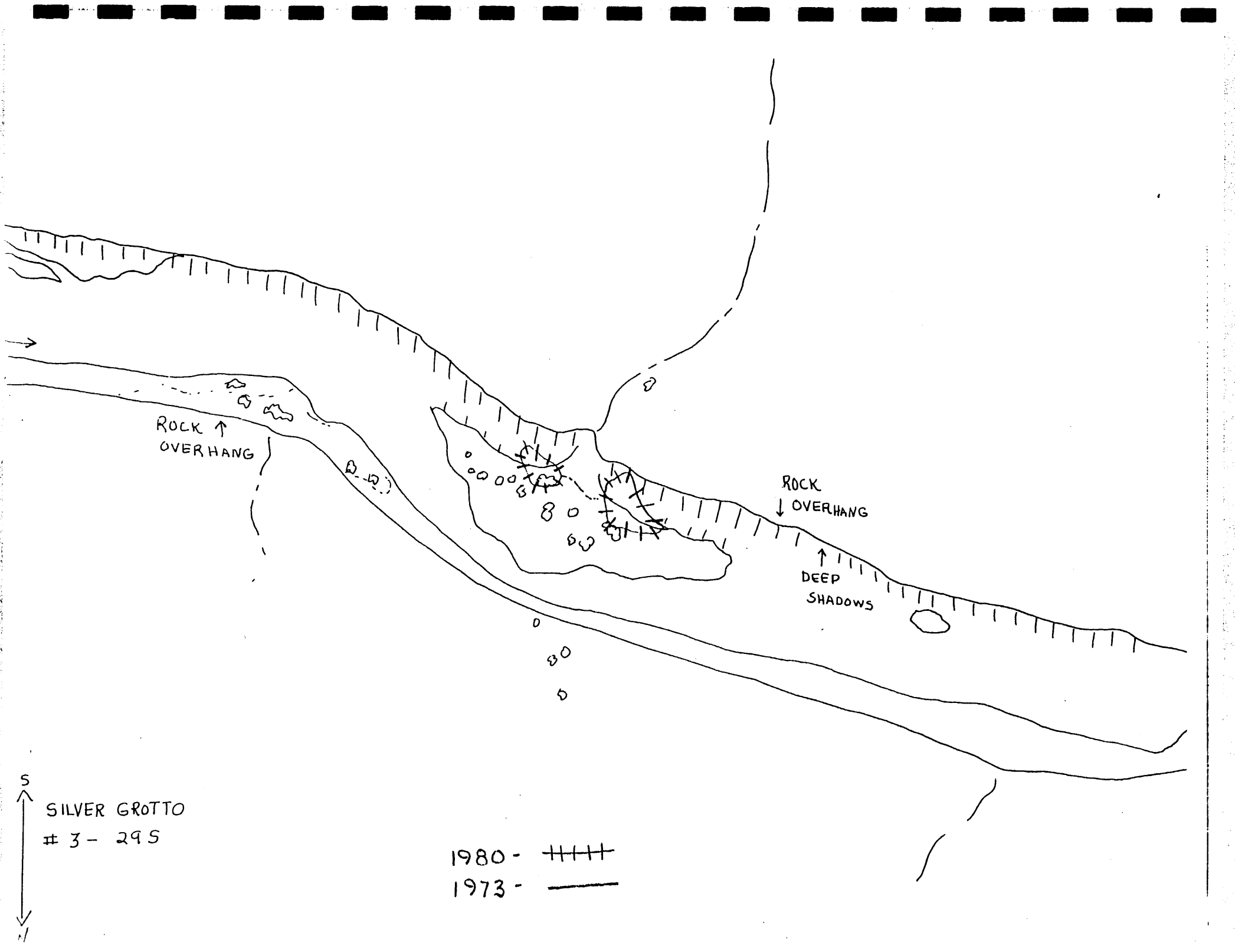

S
HOUSE ROCK
#2 - 19N
1973 - 051
1980 - 2-07
1980 -
1973 -
1965 -
1952 -

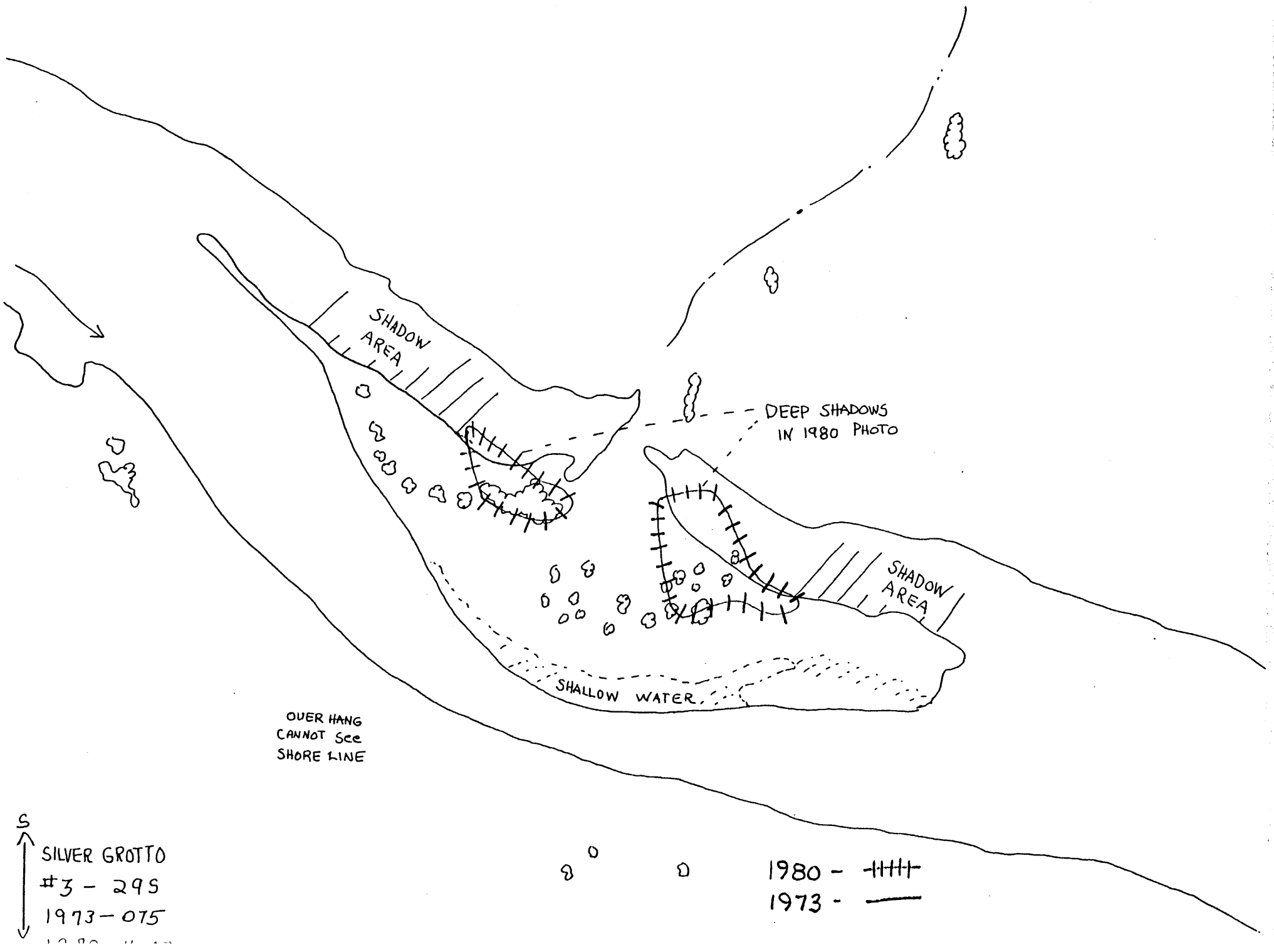
L19.3: CROSS-SECTION #1, FROM BS2 AT ANGLE OF 107°40' CLOCKWISE FROM BS2
ELEVATION DATUM. TOP OF FLAT ROCK 7' ALONG BASE LINE FROM BS1

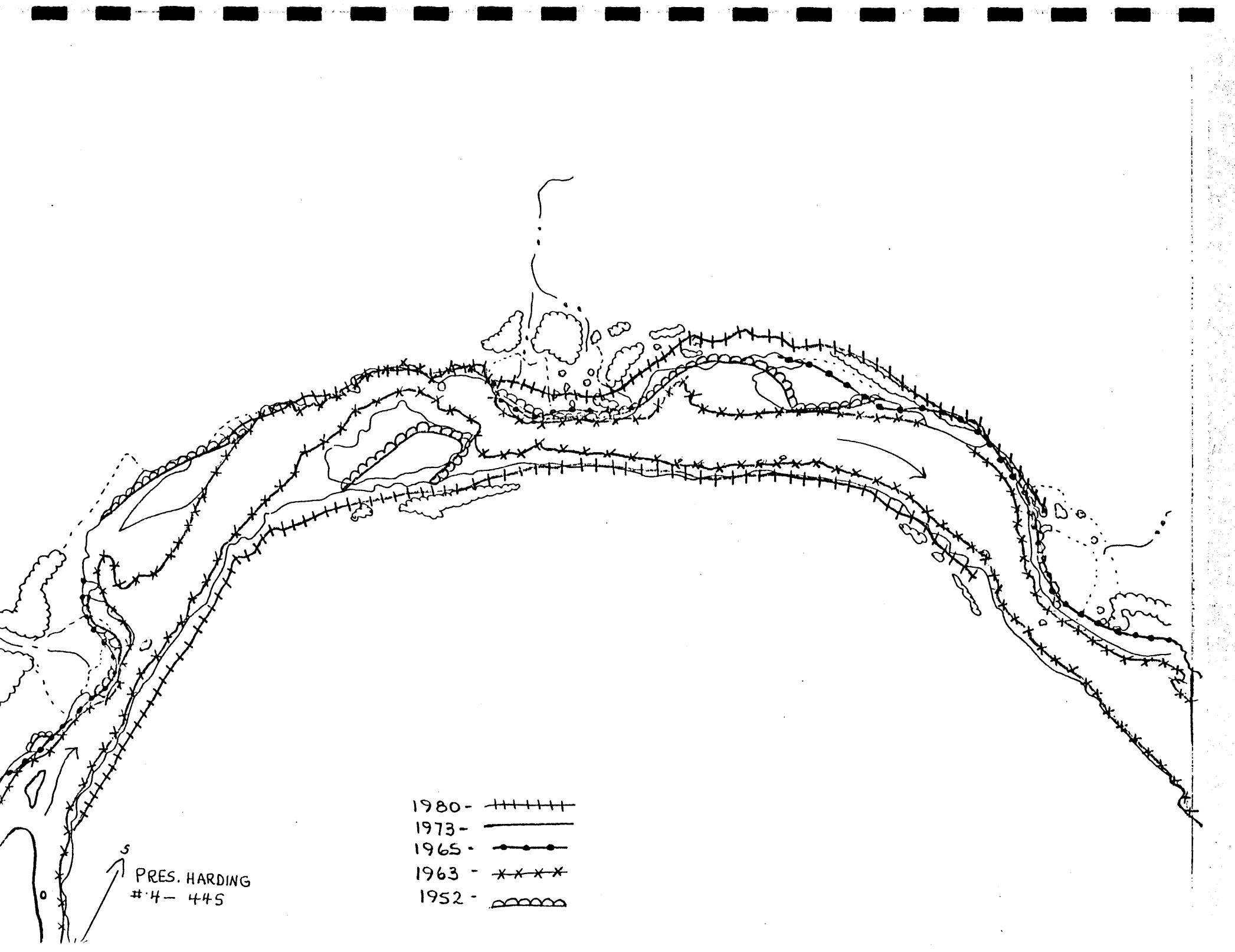


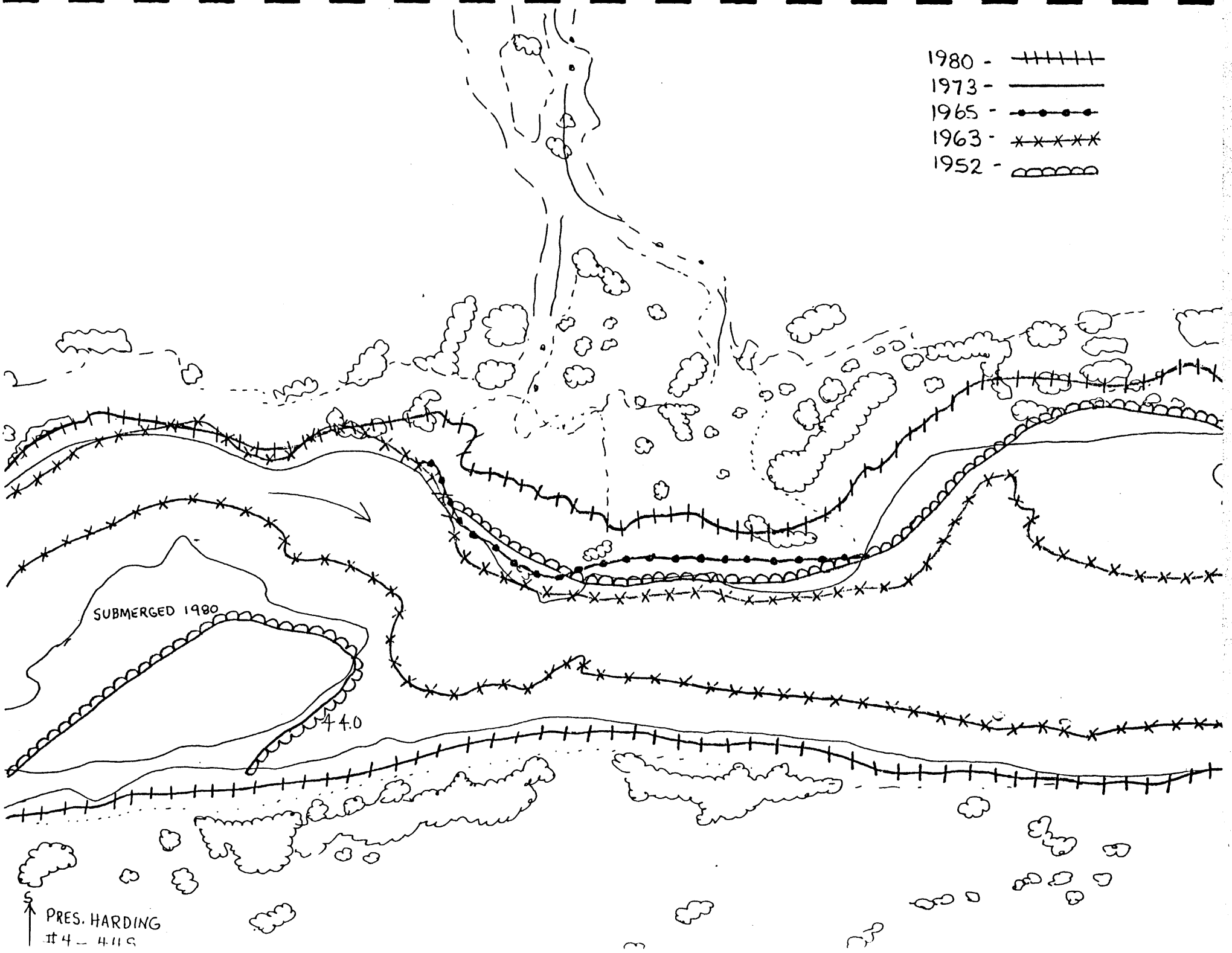
L.193 L1.3 CROSS SECTION #2, LOCATED 18'0" ALONG ℄ FROM BS1, AT ANGLE OF 30° 55' CLOCKWISE FROM BS1
· ELEVATION DATUM: TOP OF FLAT ROCK 7' ALONG ℄ FROM BS1

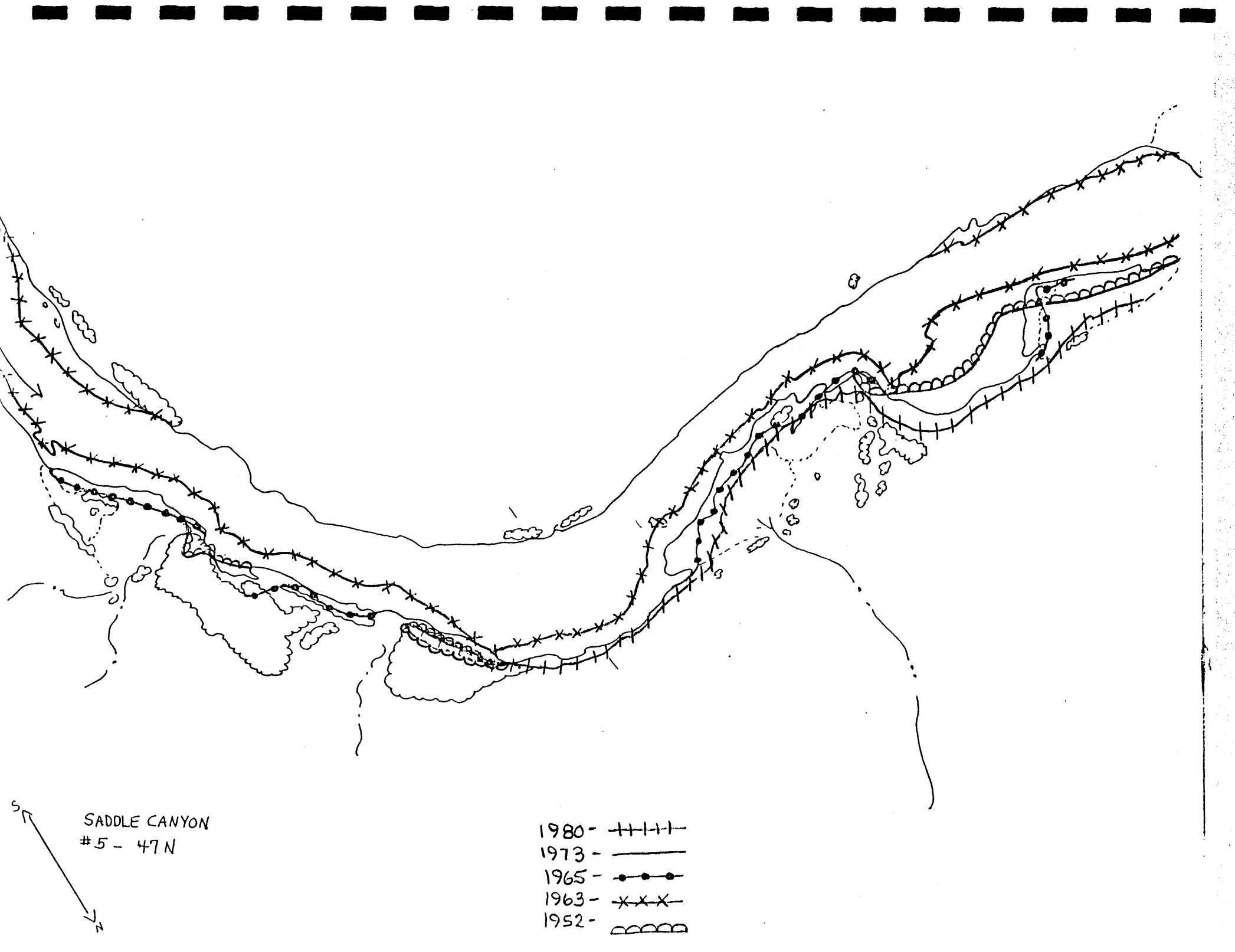


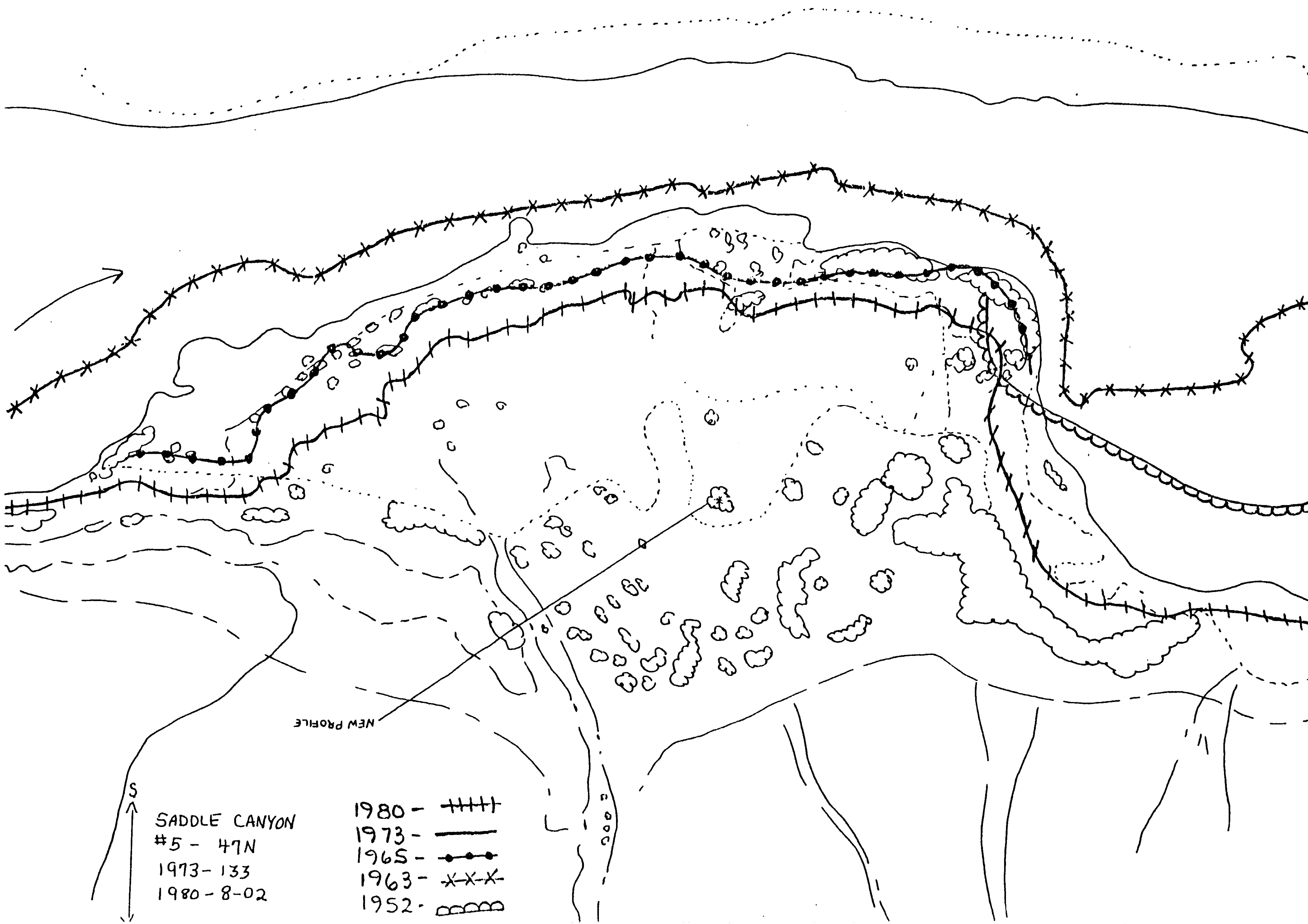

ROCK
OVERHANG
ROCK
OVERHANG
DEEP
SHADOWS
S
N
SILVER GROTTO
3 - 29 S
1980 -
1973 -

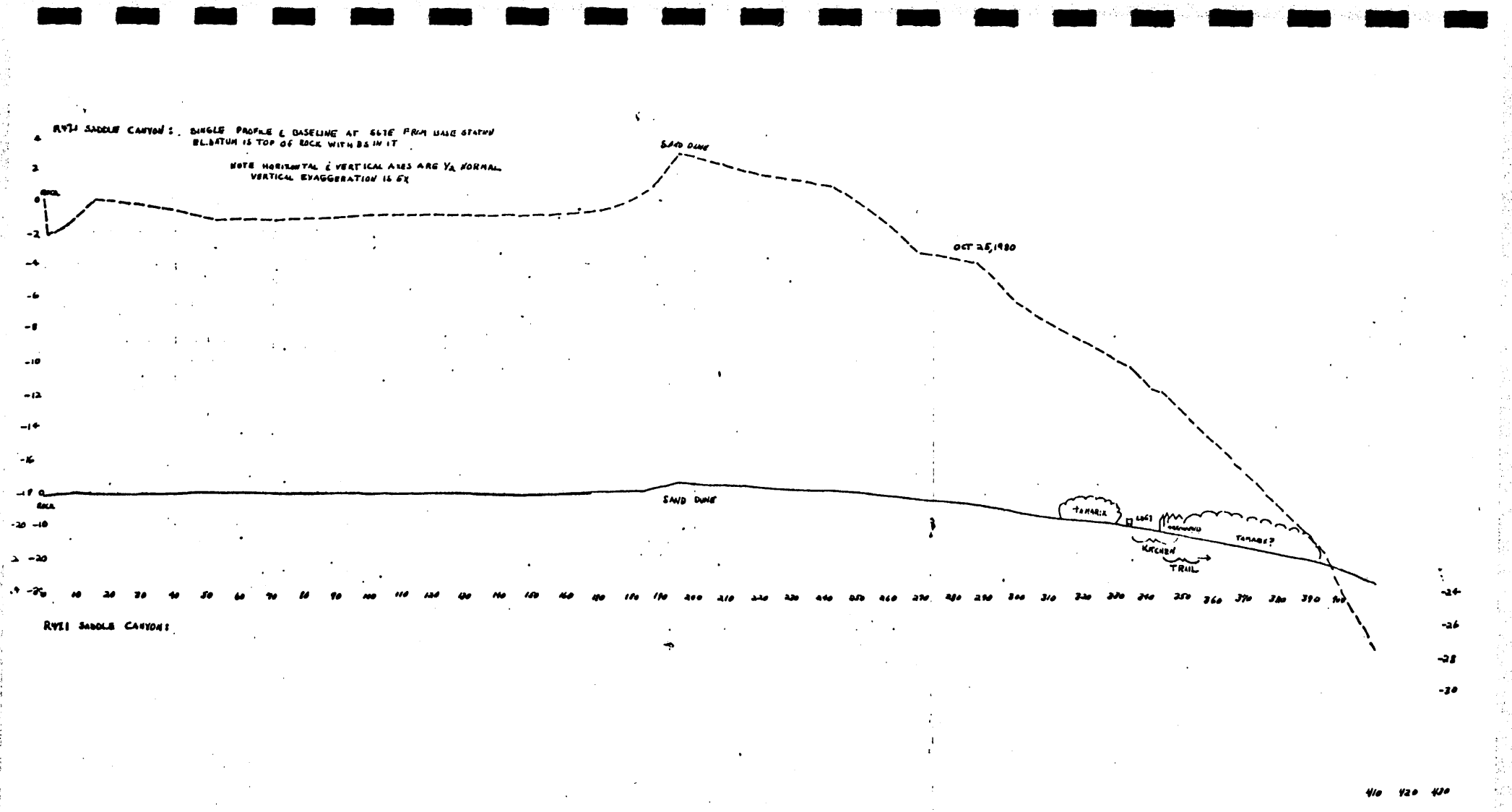

SHADOW AREA
DEEP SHADOWS IN 1980 PHOTO
SHADOW AREA
SHALLOW WATER
OVER HANG CANNOT See SHORE LINE
S
SILVER GROTTO
#3 - 295
1973 - 075
1980 -
1973 -

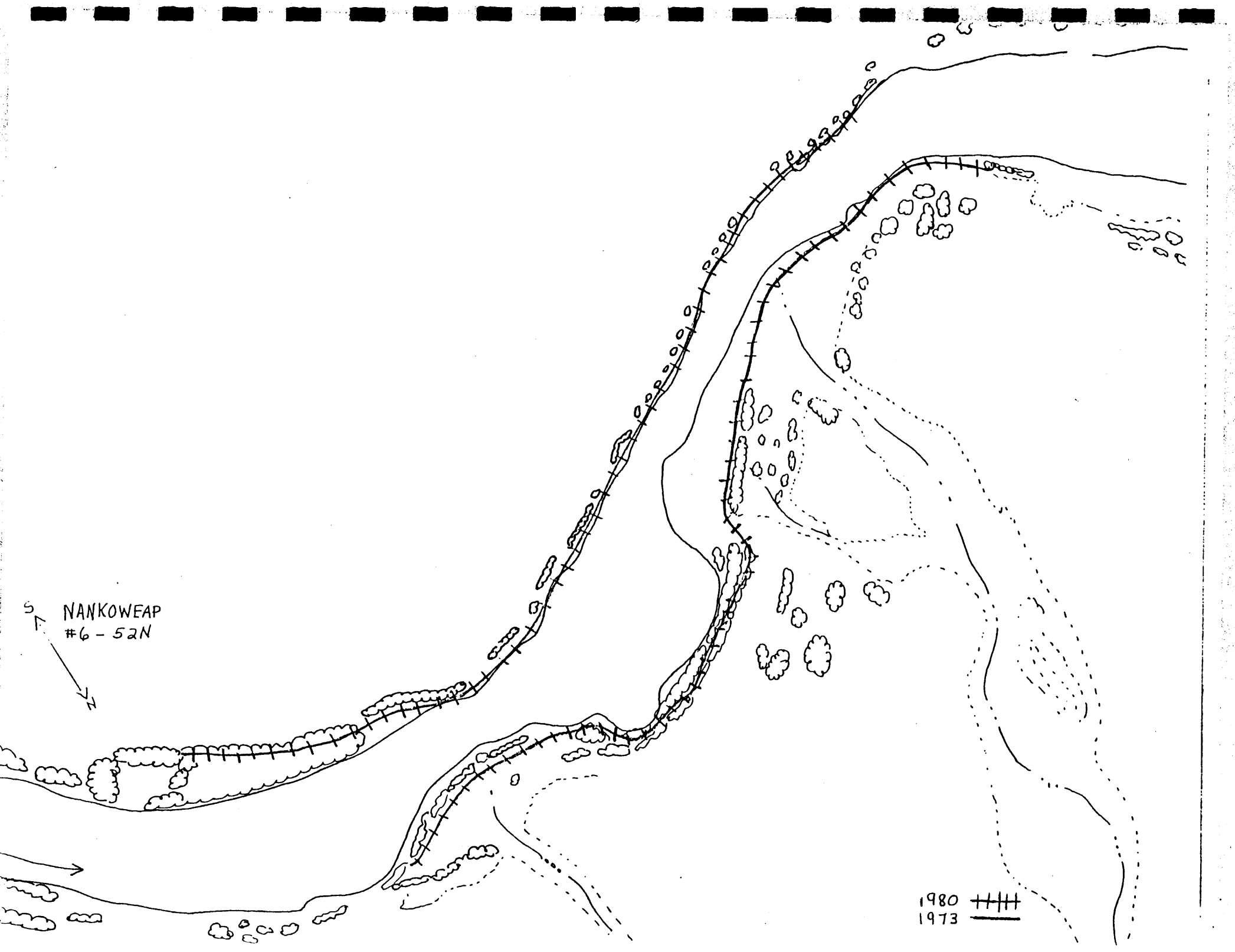

1980-
1973-
1965-
1963-
1952-
S
PRES. HARDING
#4- 445

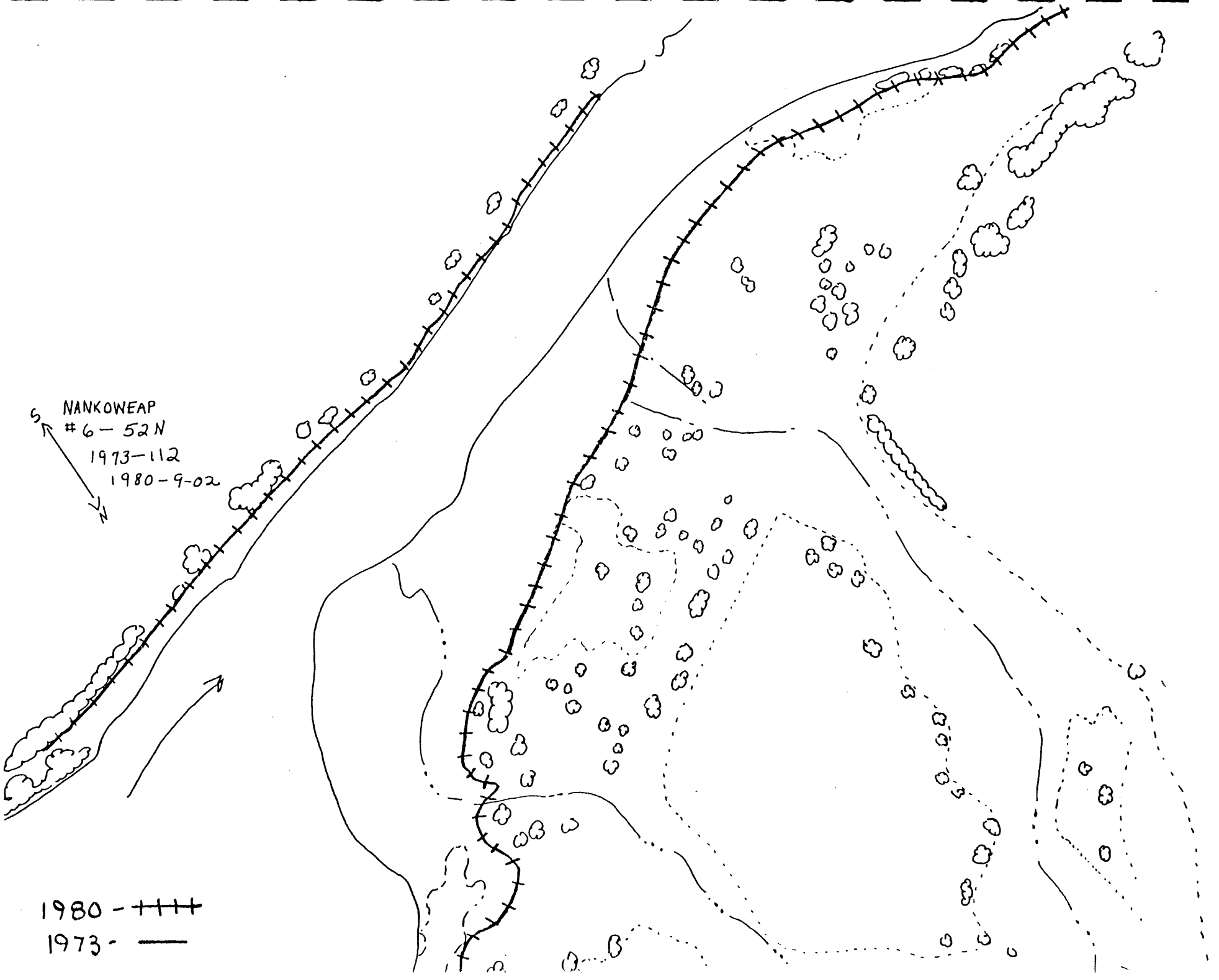

1980 -
1973 -
1965 -
1963 -
1952 -
SUBMERGED 1980
44.0
PRES. HARDING
#4 - 4115

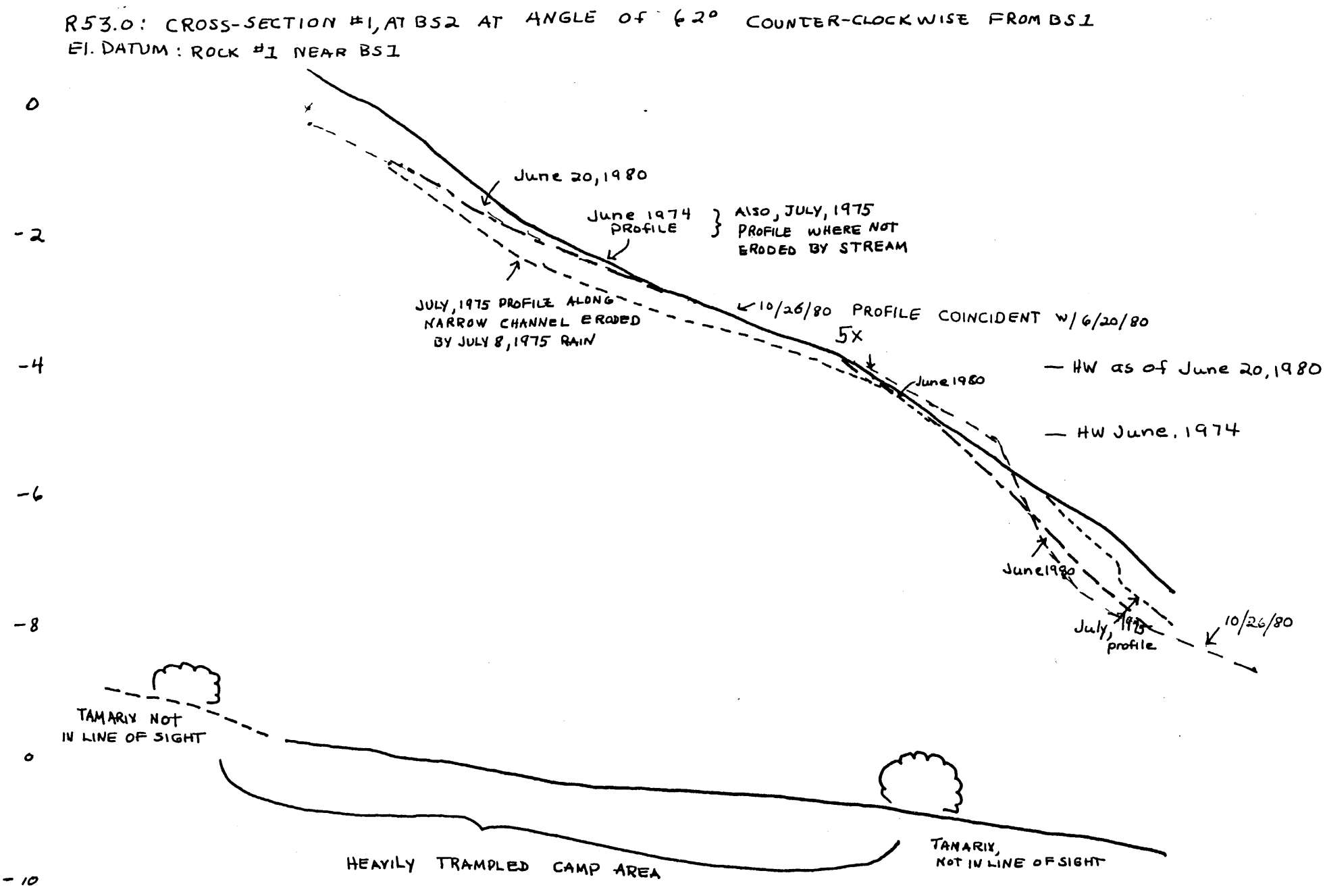

SADDLE CANYON
#5 - 47N
S
N
1980 -
1973 -
1965 -
1963 -
1952 -


NEW PROFILE
S
SADDLE CANYON
#5 - 47N
1973 - 133
1980 - 8-02
1980 -
1973 -
1965 -
1963 -
1952 -


RV1 SADDLE CANYON: SINGLE PROFILE & BASELINE AT 66'E FROM BASE STATION
BEDROCK IS TOP OF ROCK WITH BS IN IT
NOTE HORIZONTAL & VERTICAL AXES ARE ½ NORMAL
VERTICAL EXAGGERATION IS 6X
SAND DUNE
OCT 25, 1980
SAND DUNE
TAMARIX
LOG
TAMARISK?
KITCHEN
TRAIL
RV11 SADDLE CANYON:

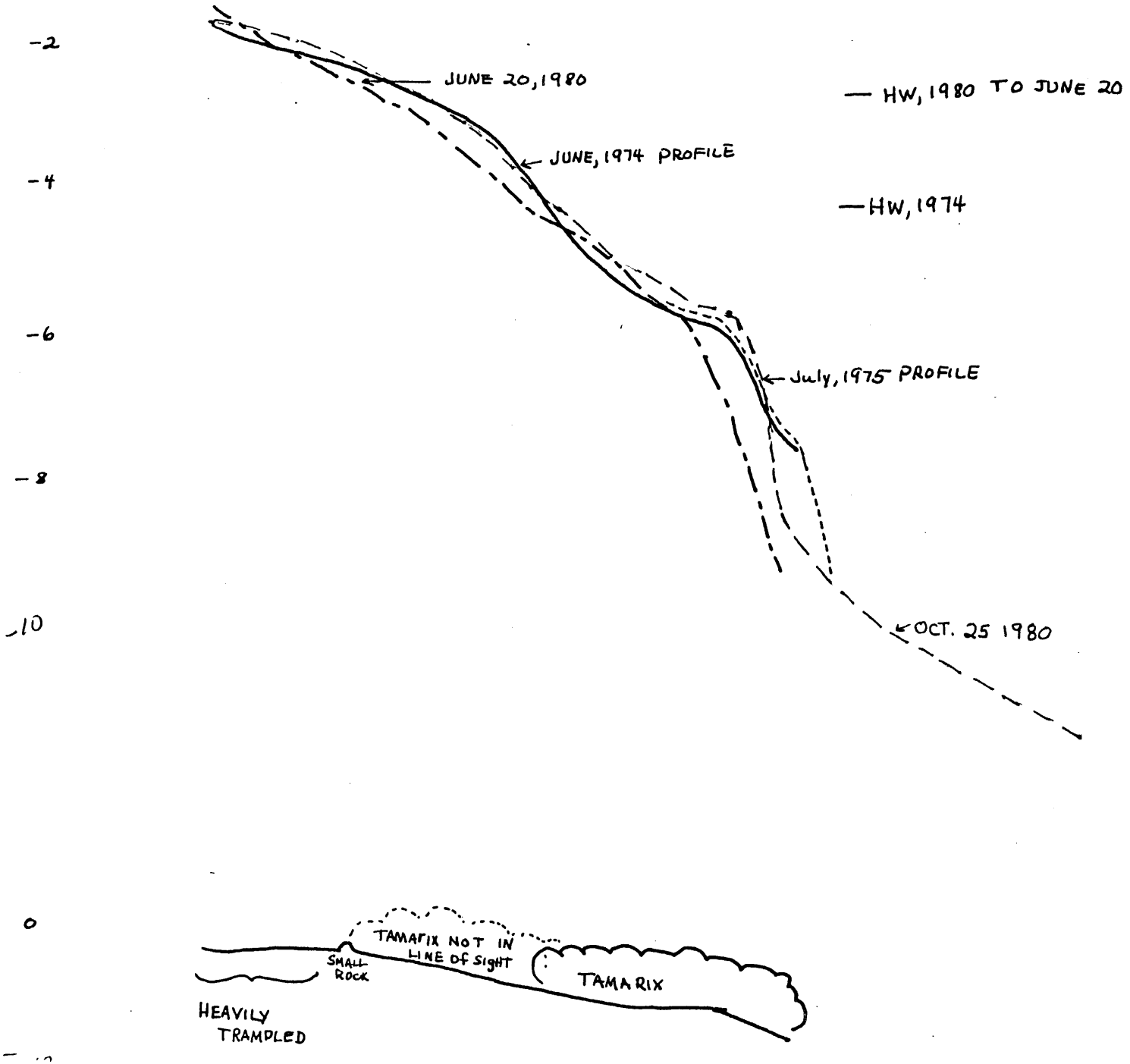

NANKOWEAP
#6 - 52N
1980
1973


NANKOWEAP
#6 – 52N
1973–112
1980-9-02
S
N
1980 - ++++
1973 - ——


R53.0: CROSS-SECTION #1, AT BS2 AT ANGLE OF 62° COUNTER-CLOCKWISE FROM BS1
El. DATUM: ROCK #1 NEAR BS1
0
-2
-4
-6
-8
0
-10
June 20, 1980
June 1974 PROFILE
ALSO, JULY, 1975 PROFILE WHERE NOT ERODED BY STREAM
JULY, 1975 PROFILE ALONG NARROW CHANNEL ERODED BY JULY 8, 1975 RAIN
10/26/80 PROFILE COINCIDENT W/ 6/20/80
5X
June 1980
— HW as of June 20, 1980
— HW June, 1974
June 1980
July, 1975 profile
10/26/80
TAMARIX NOT IN LINE OF SIGHT
HEAVILY TRAMPLED CAMP AREA
TAMARIX, NOT IN LINE OF SIGHT

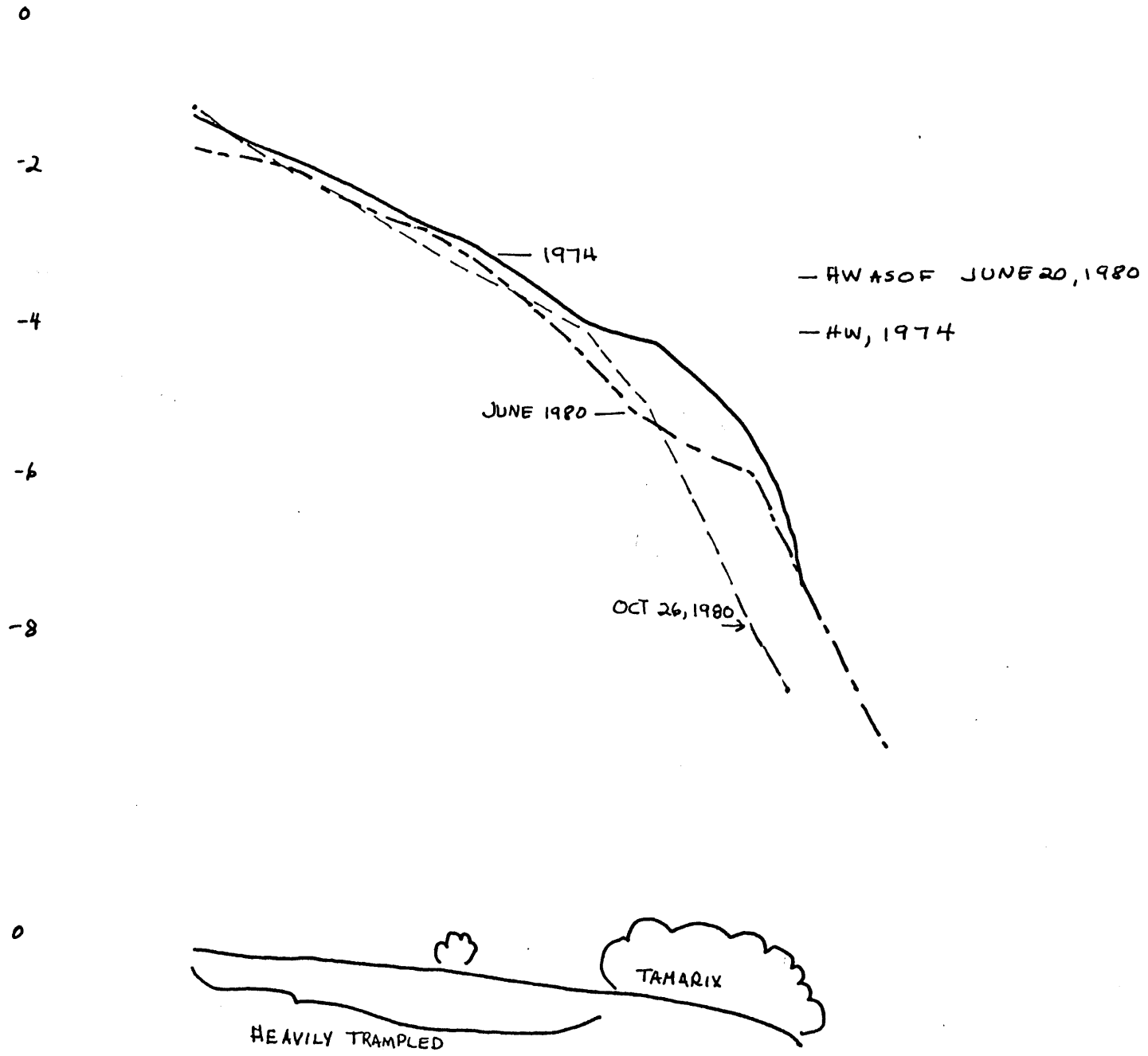
R53.0: CROSS-SECTION #2, FROM BS1 AT AN ANGLE OF 77° clockwise FROM BS2

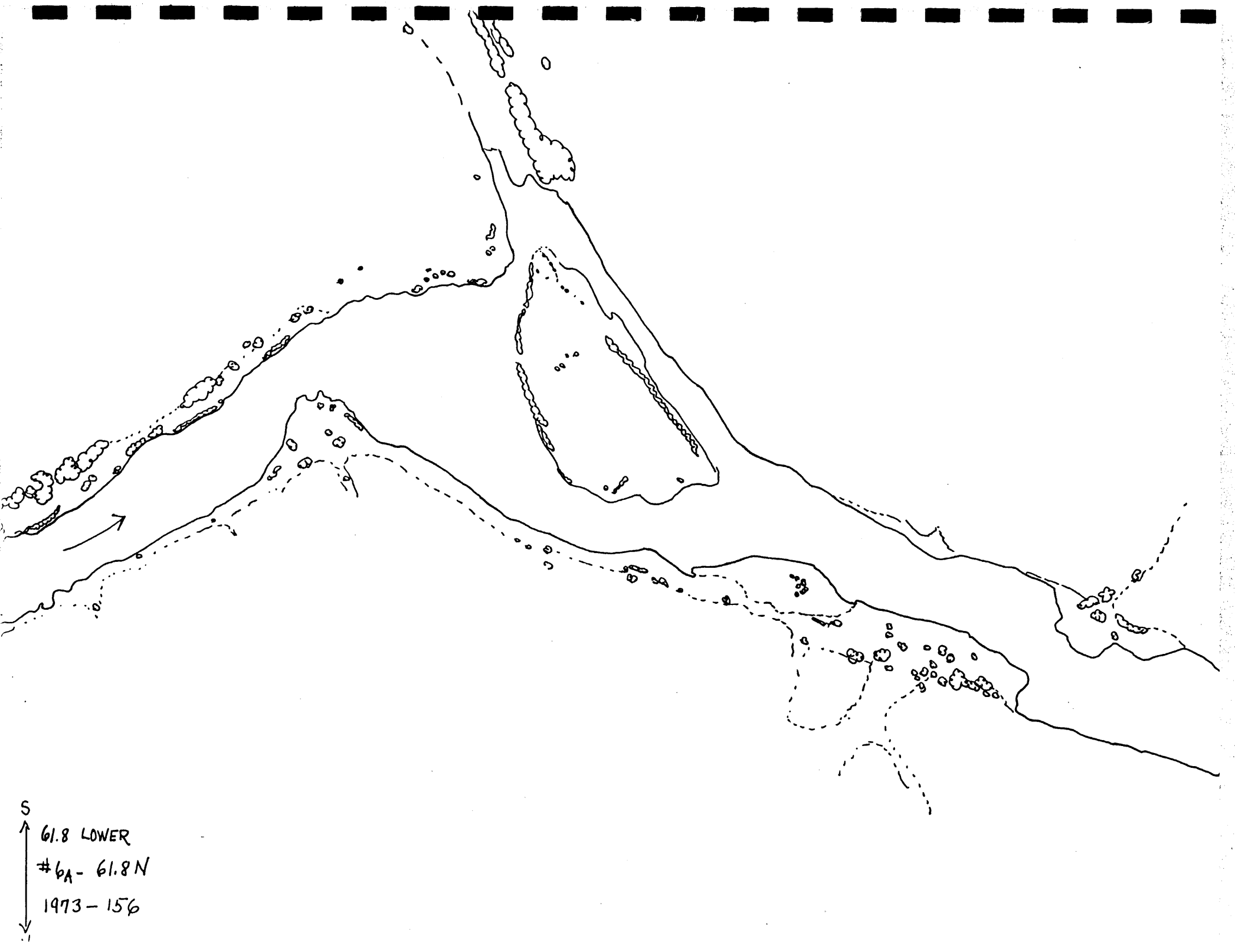
EL. DATUM: TOP OF ROCK # 1.

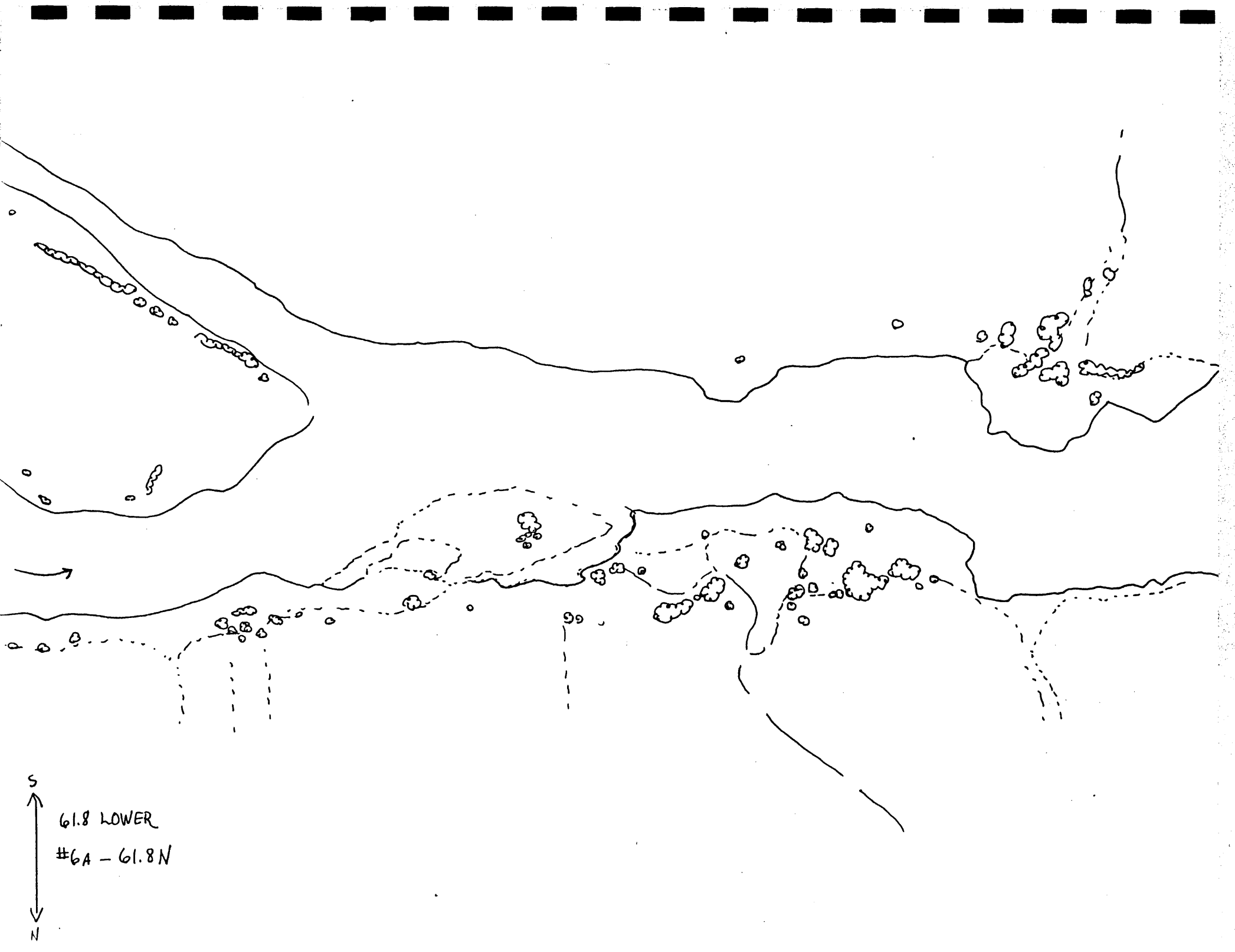


R530 CROSS SECTION #3, AT 100'0" FROM BS1 TOWARDS BS2 AT ANGLE OF 90° TO

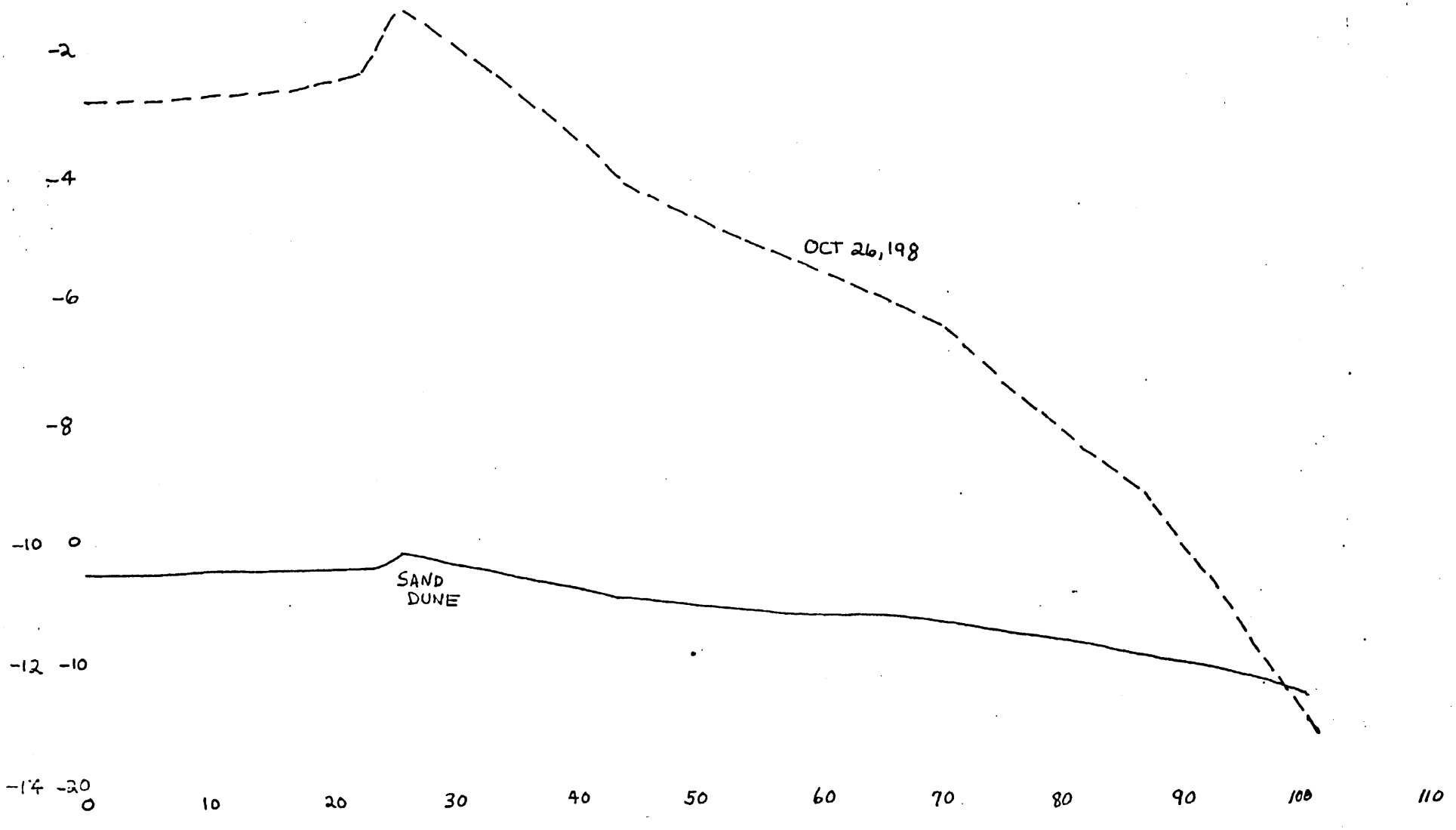
EL. DATUM: TOP OF ROCK # 1

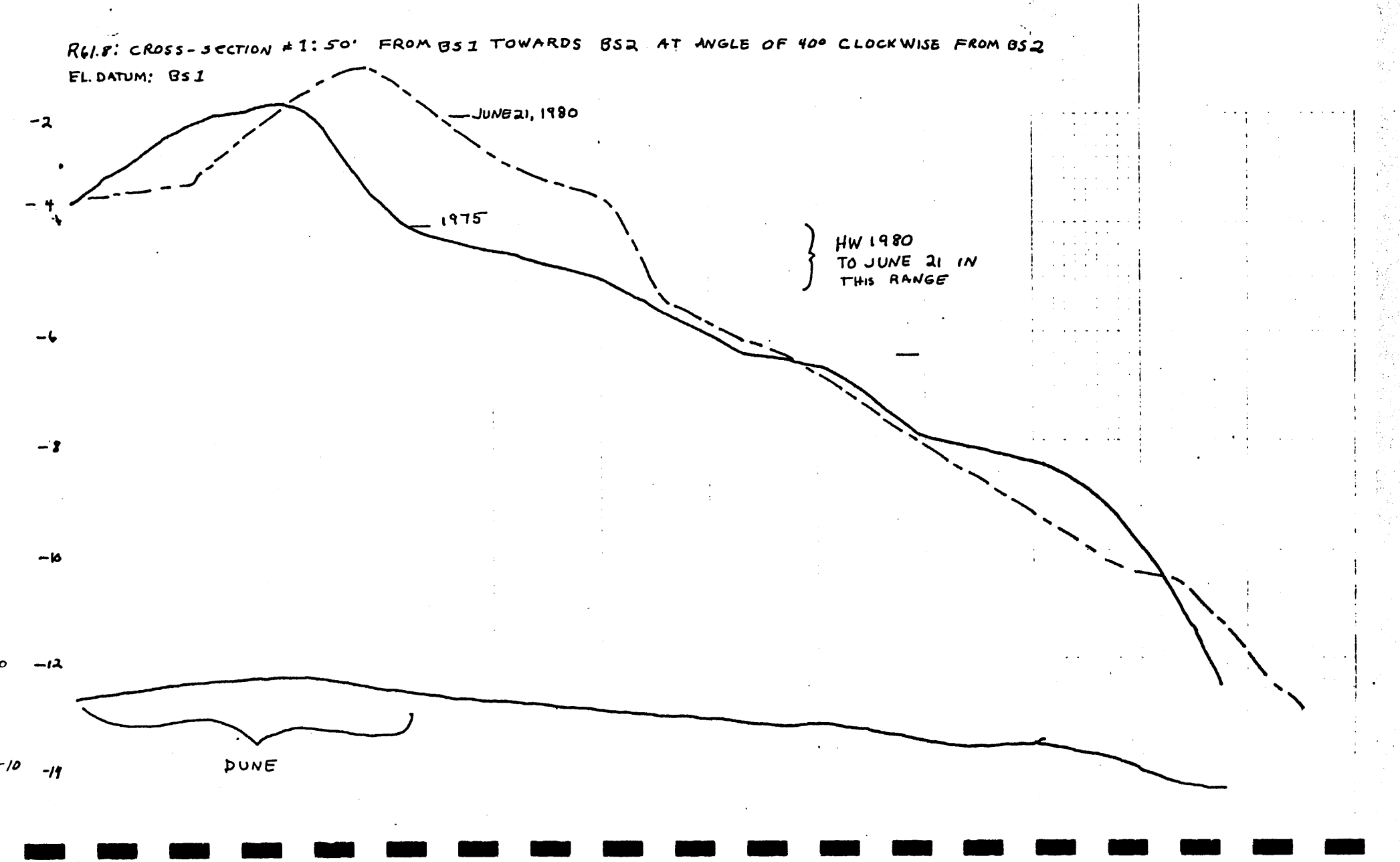



S
61.8 LOWER
#6A - 61.8N
1973 - 156

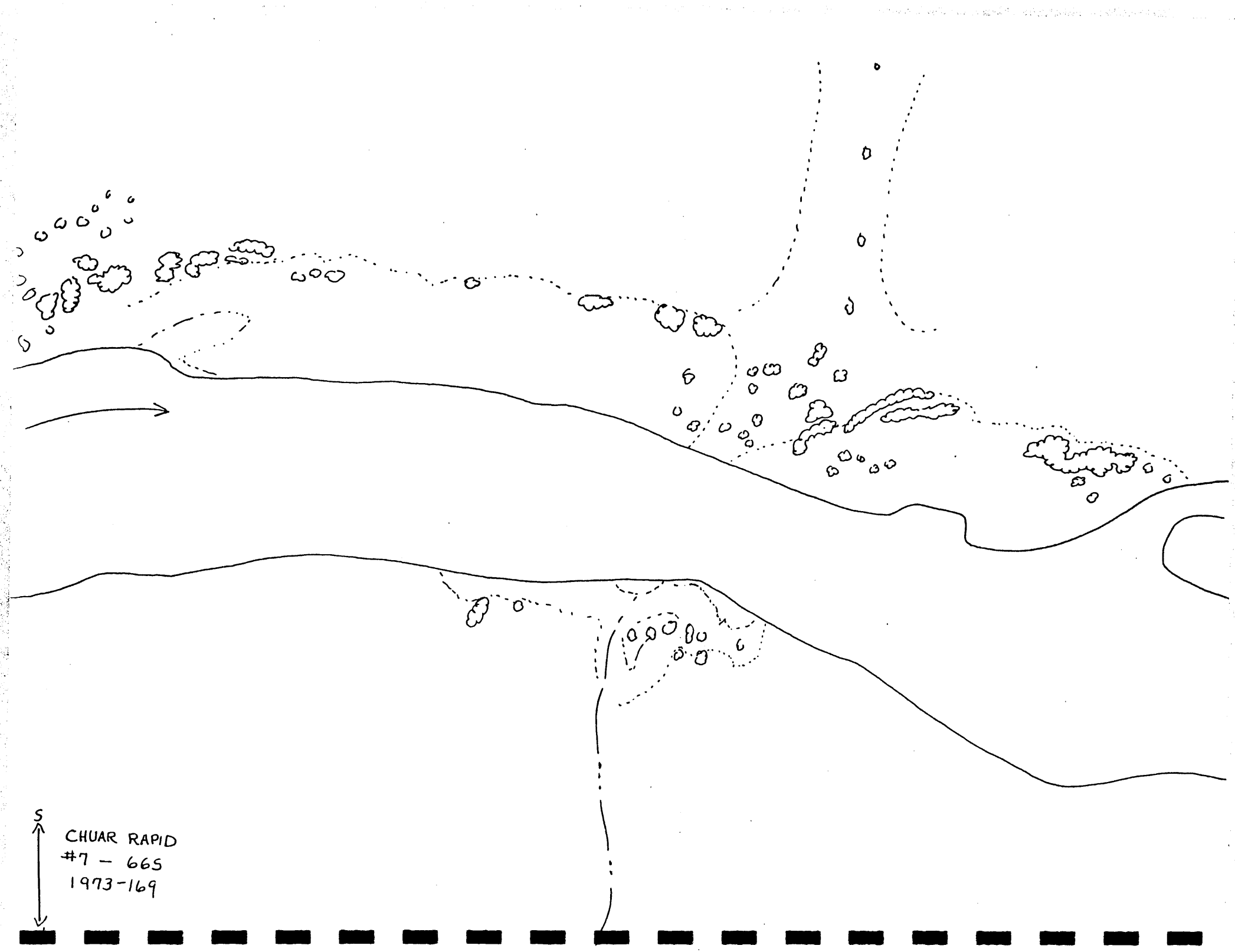

S
61.8 LOWER
#6A – 61.8N
N

o R61.8 LITTLE COLORADO RIVER: CROSS-SECTION AT 40° AT SAME BL TIE POINT AS CS1, WHICH IS AT 50° FROM BS#2



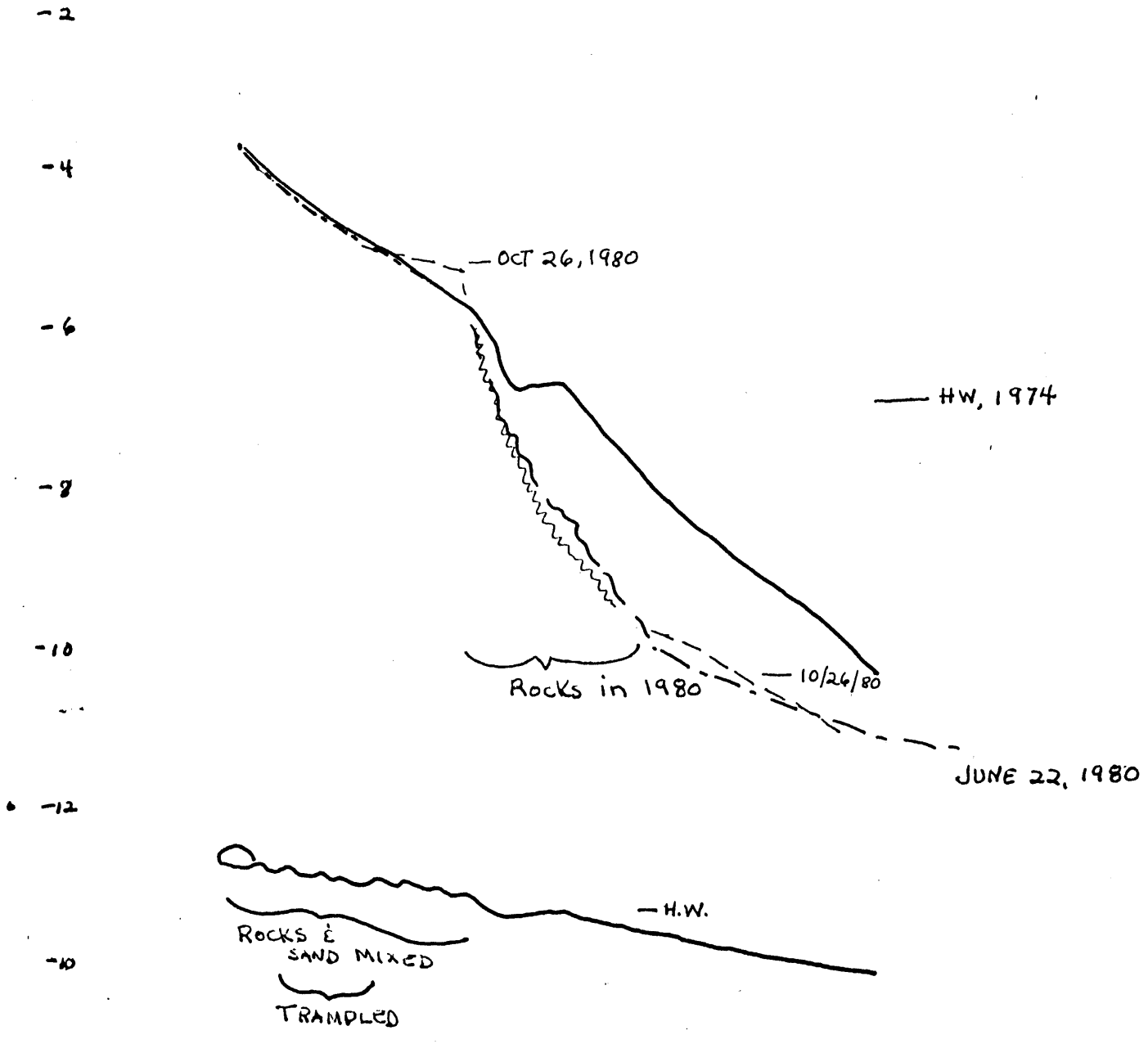

R61.8: CROSS-SECTION #1: 50' FROM BS1 TOWARDS BS2 AT ANGLE OF 40° CLOCKWISE FROM BS2
EL. DATUM: BS1
JUNE 21, 1980
1975
HW 1980
TO JUNE 21 IN
THIS RANGE
-2
-4
-6
-8
-10
-12
-14
DUNE


S
CHUAR RAPID
#7 - 665

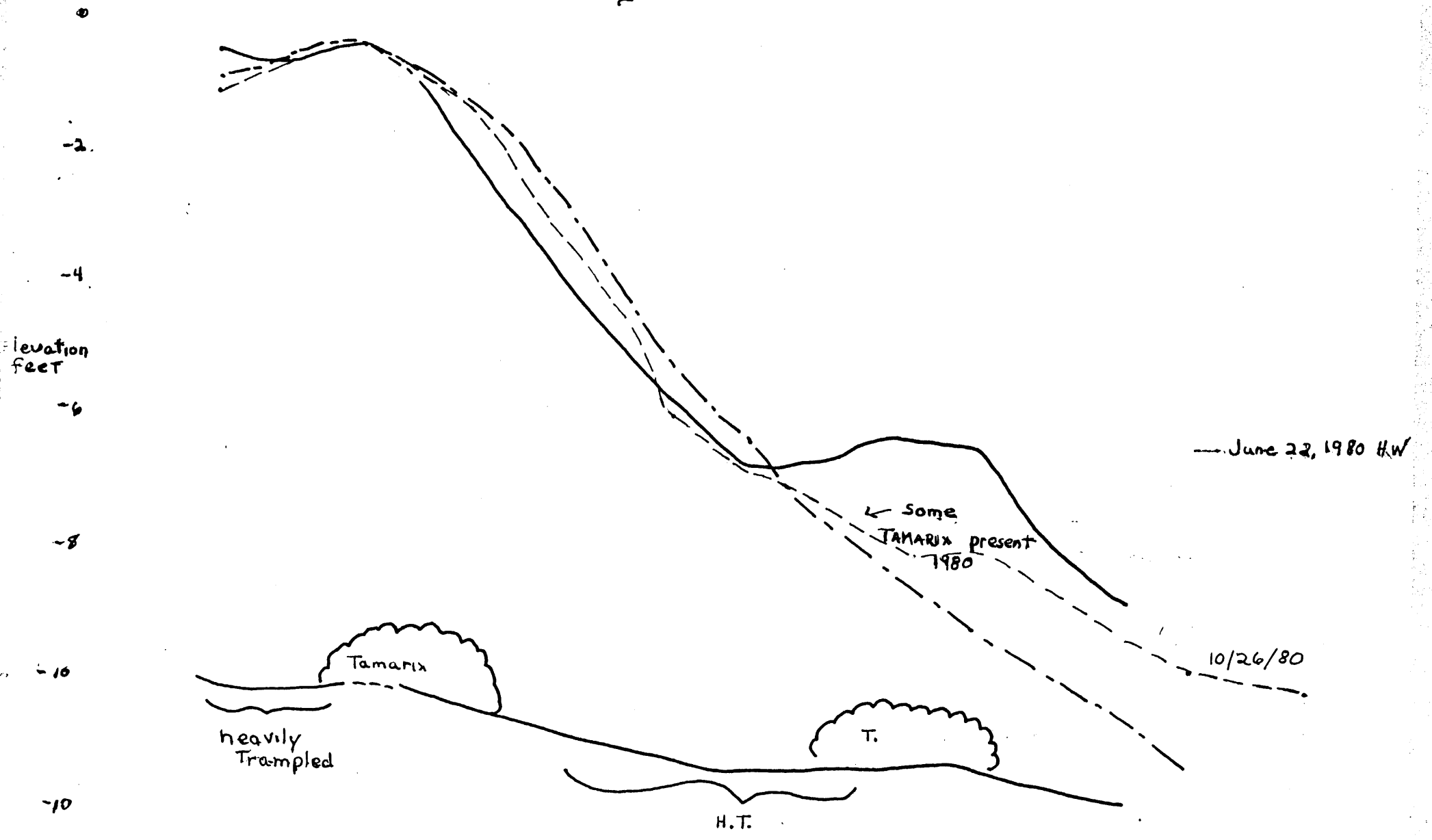

S
CHUAR RAPID
#7 – 665
1973-169

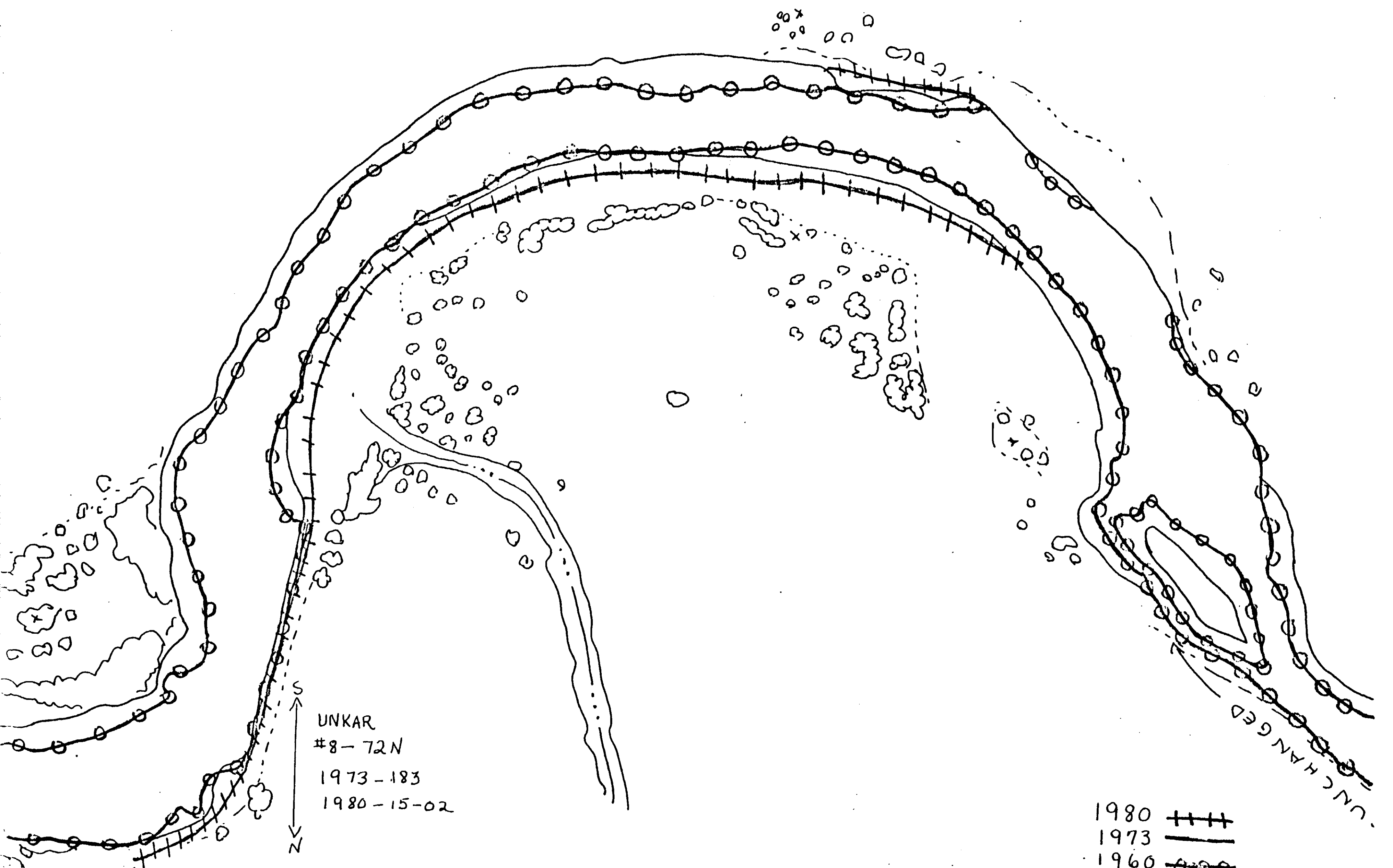
L65.5: CROSS-SECTION #1, at 34'5" FROM BS1 Towards BS2 at an ANGLE of 75° CLOCKWISE from BS1

ELEVATION DATUM: TOP OF ROCK CONTAINING BS2

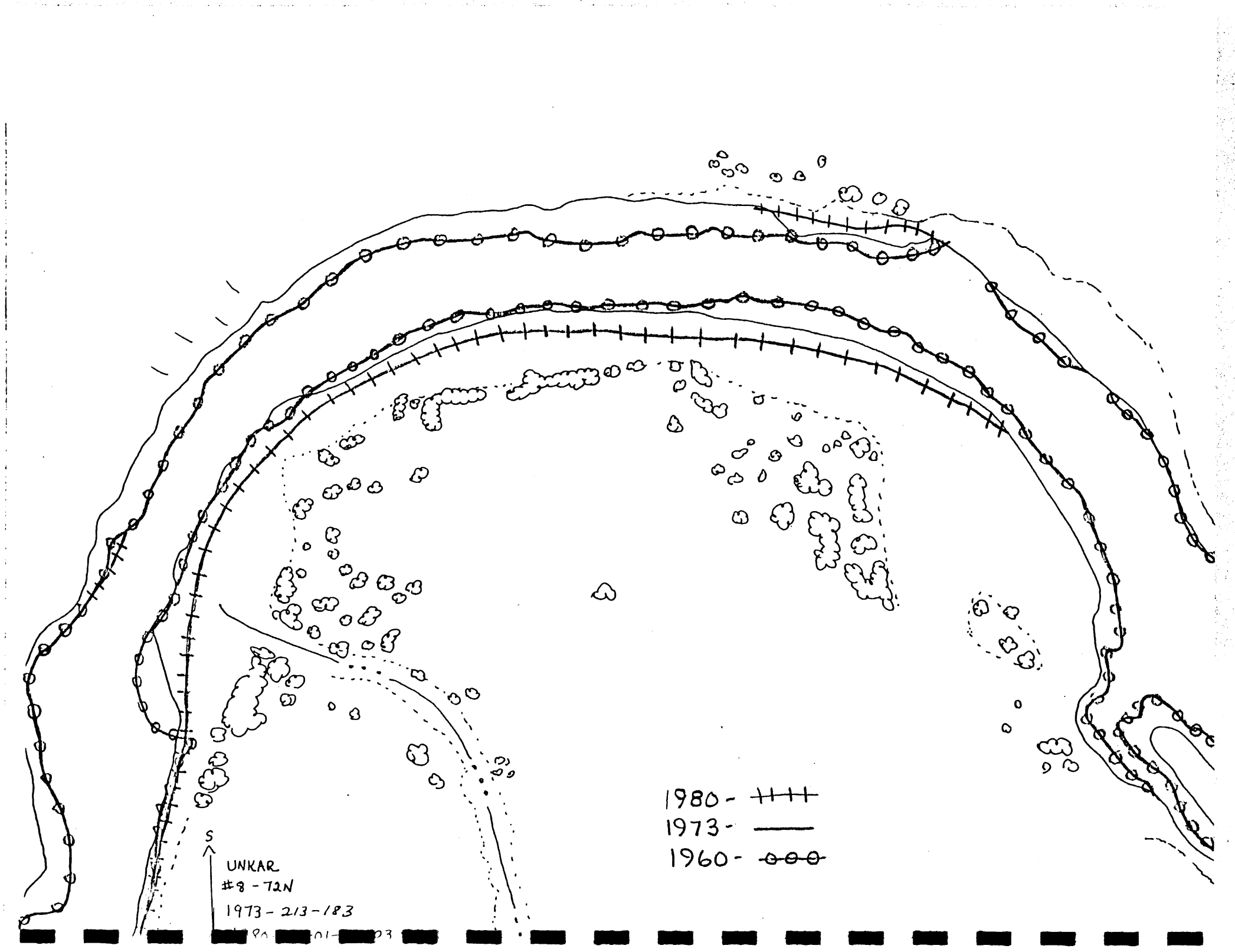


L.65.5: CROSS-SECTION #2, at 75'6 From BS2 Toward BS3 and at angle of 70° clockwise from BS2.
Elevation DATUM: TOP OF ROCK containing BS2.

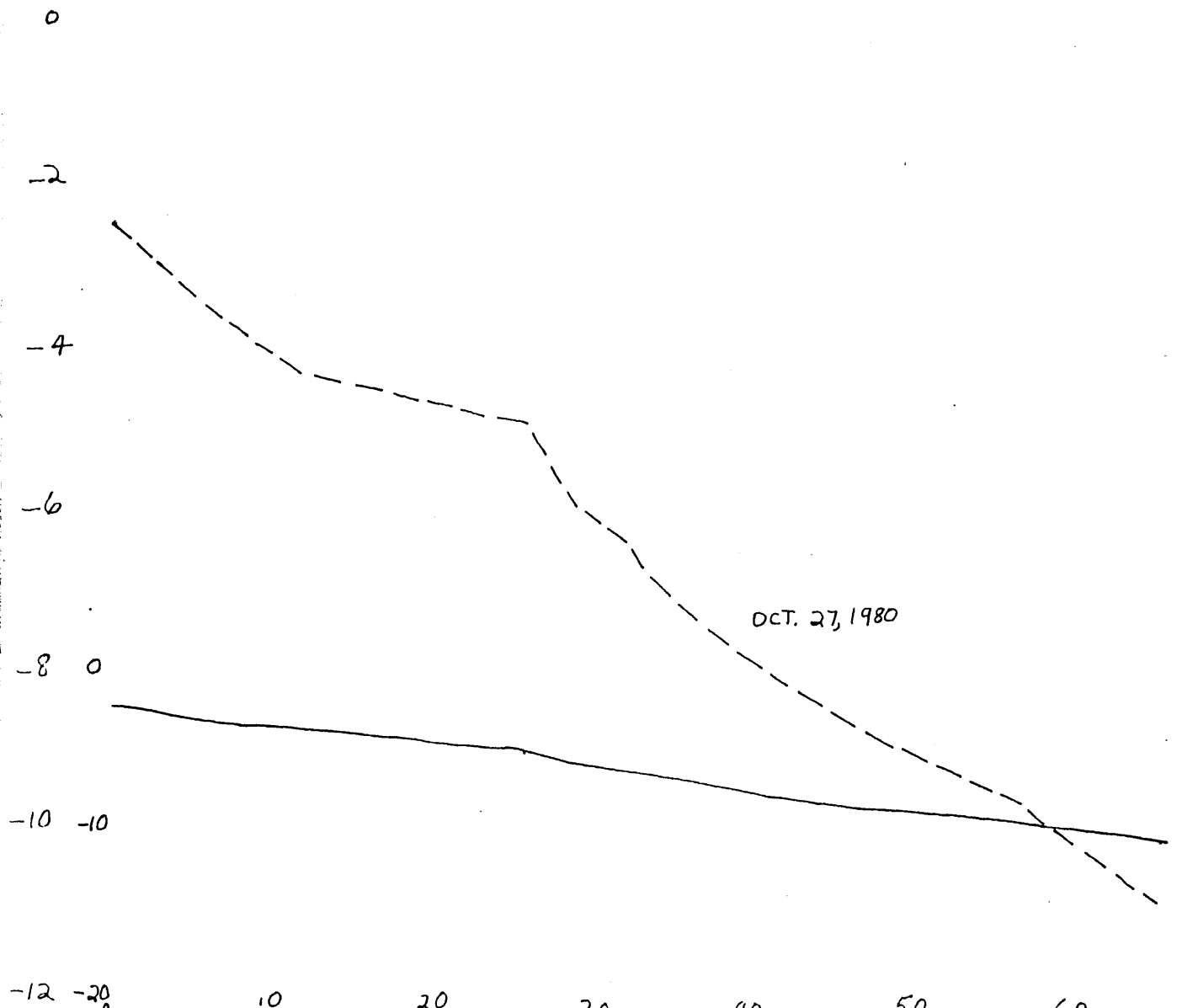


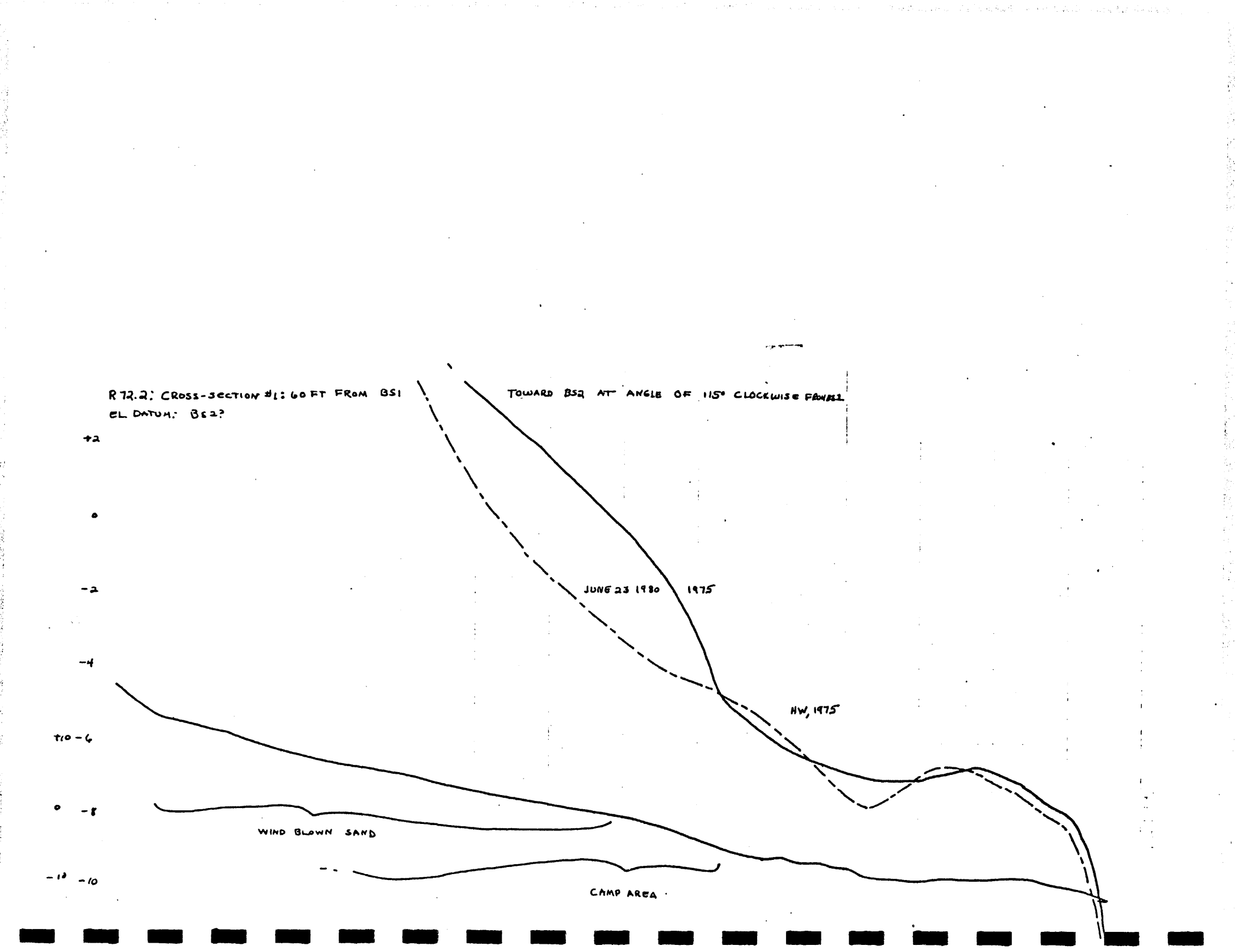


S
N
UNKAR
#8-72N
1973-183
1980-15-02
UNCHANGED
1980
1973
1960


1980-
1973-
1960-
S
UNKAR
#8 - 72N
1973 - 213 - 183

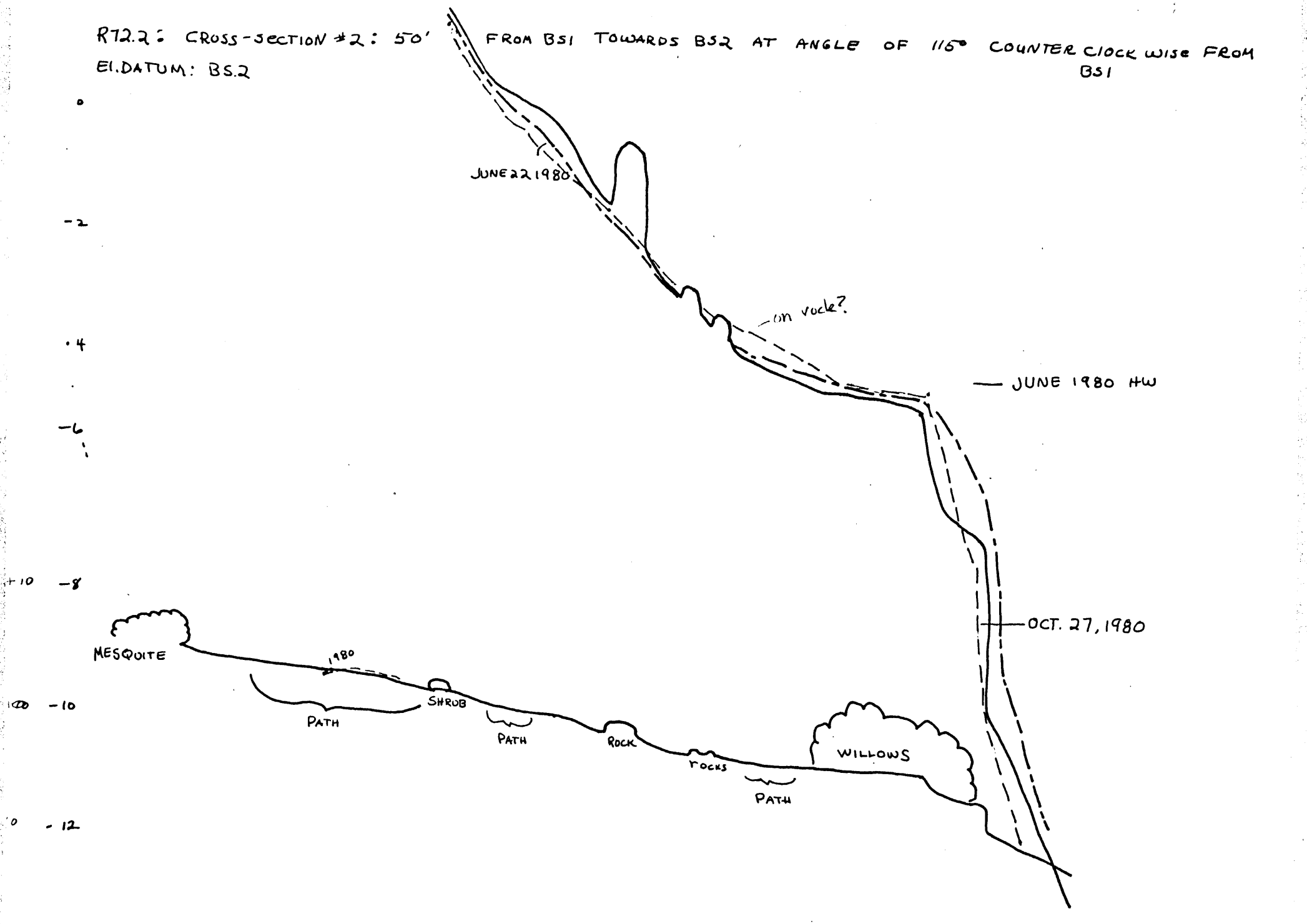
2 R 72.2 : UNKAR INDIAN VILLAGE: CSI a : AT 115° CW FROM BSI AT SOME POINT AS CSI
BUT CSI IS AT 105° EI DATUM IS BS3 ? TOP OF ROCK

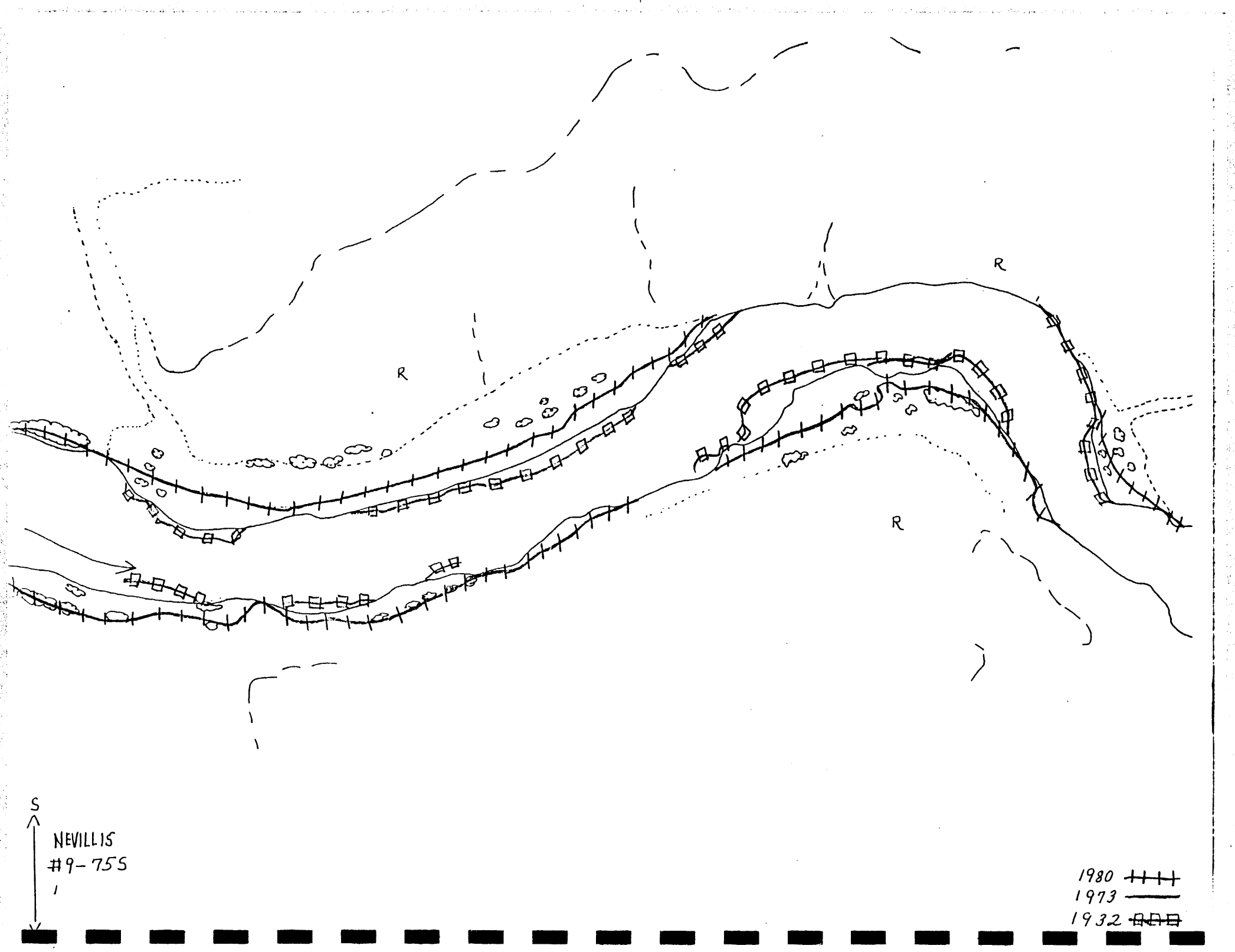


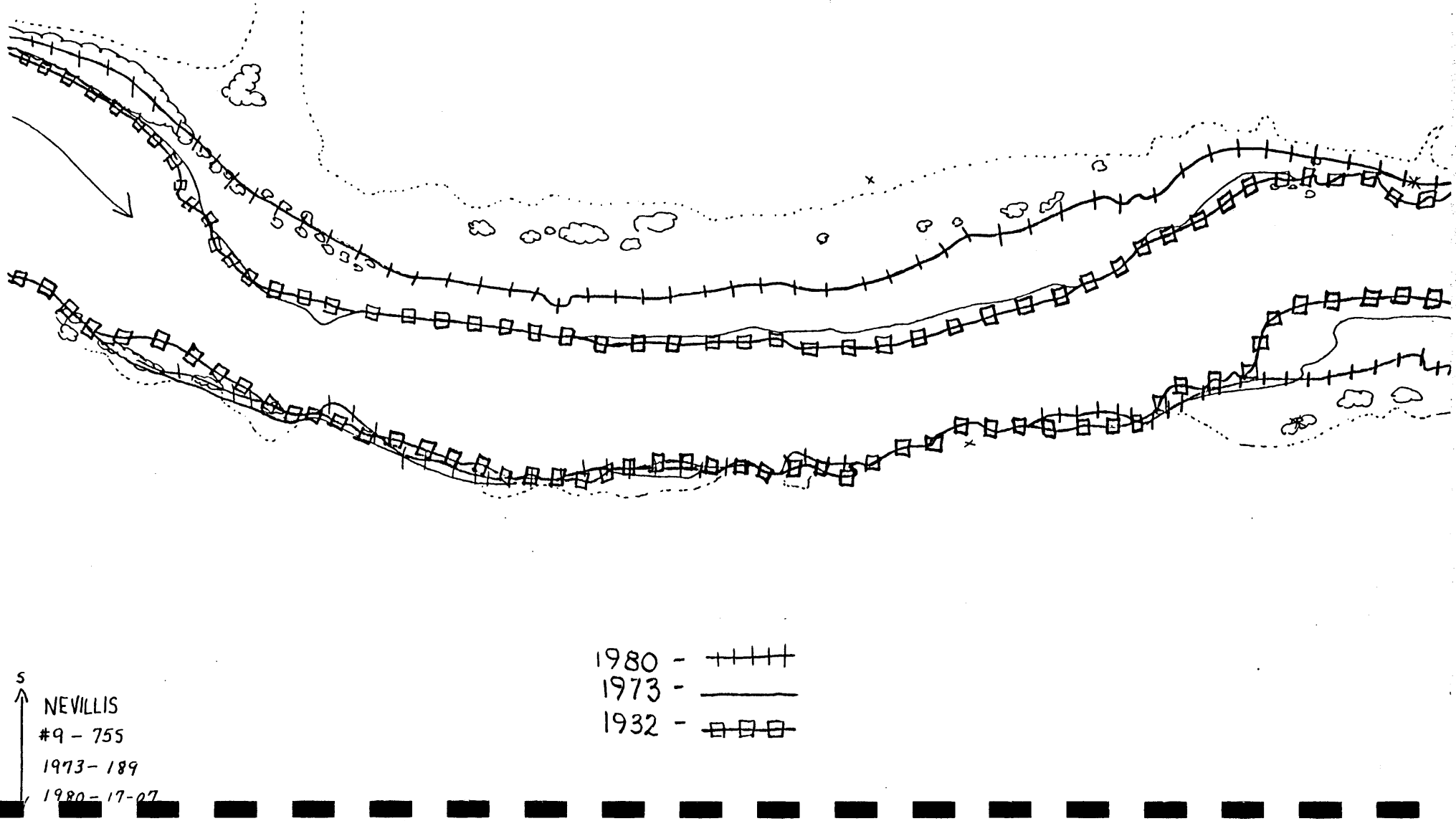

R 72.2: CROSS-SECTION #1: 60 FT FROM BS1
EL DATUM: BS2?
TOWARD BS2 AT ANGLE OF 115° CLOCKWISE FROM B1
+2
0
-2
-4
-6
-8
-10
JUNE 23 1980
1975
HW, 1975
WIND BLOWN SAND
CAMP AREA

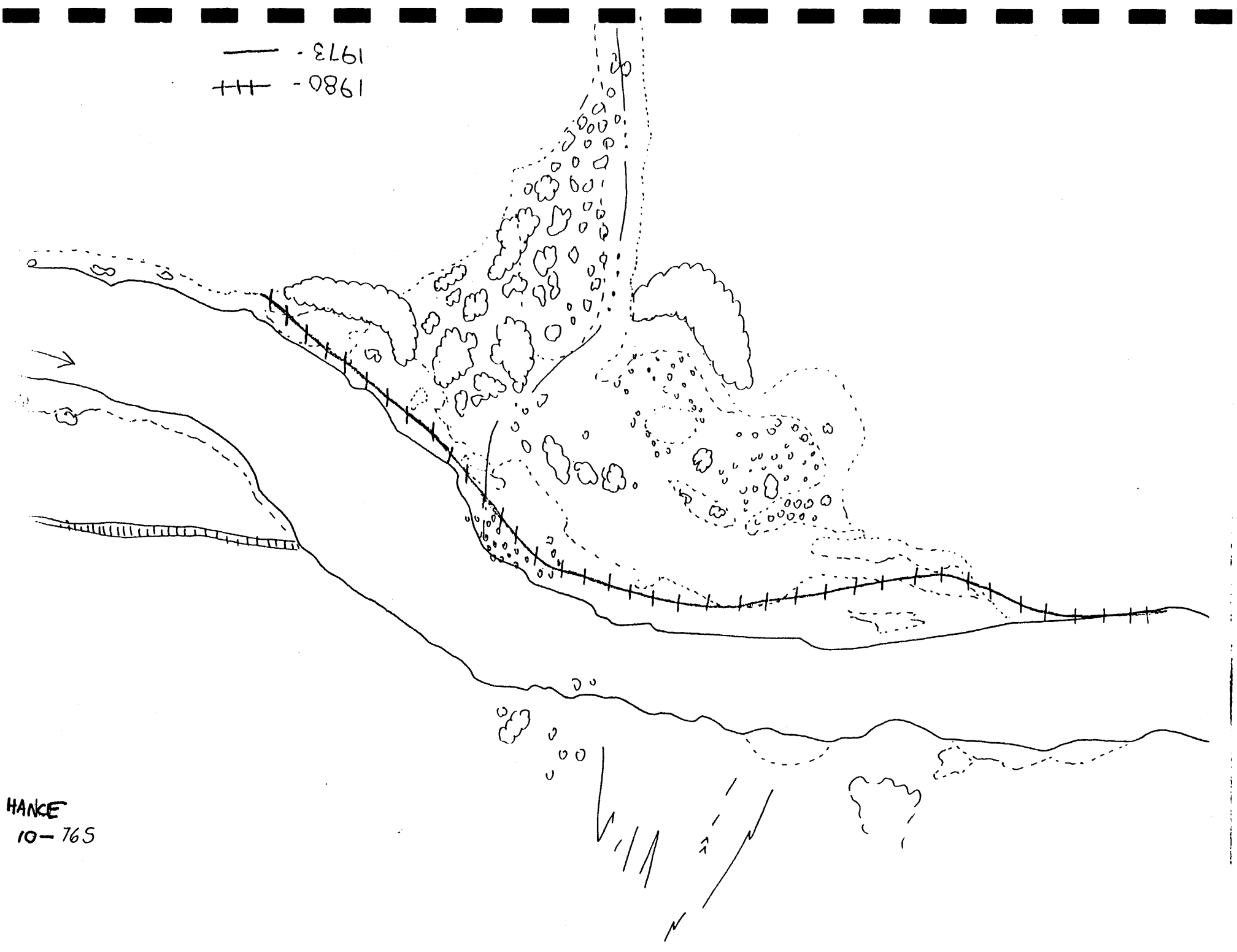
R72.2: CROSS-SECTION #2: 50' FROM BS1 TOWARDS BS2 AT ANGLE OF 116° COUNTER CLOCK WISE FROM BS1

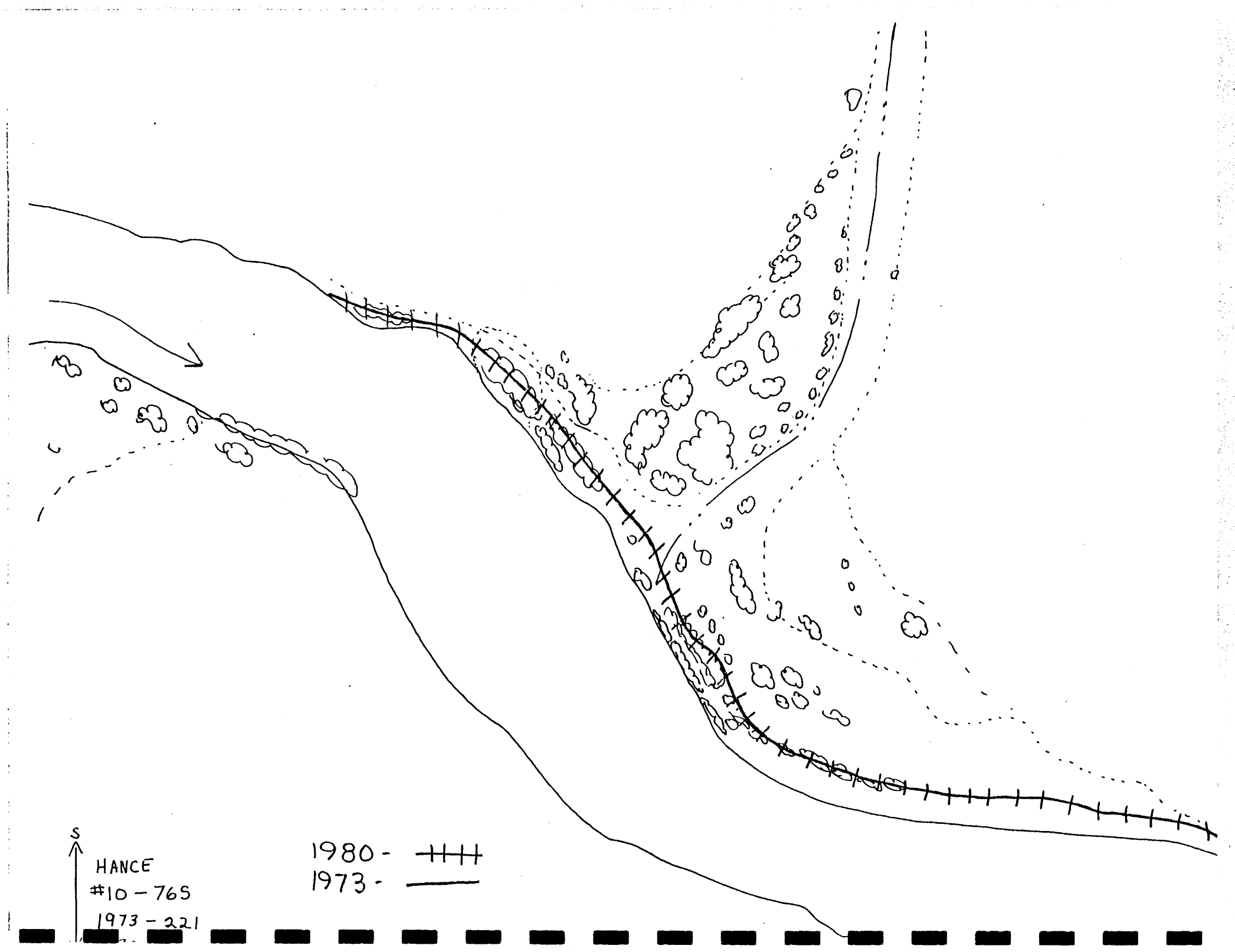
El. DATUM: BS.2

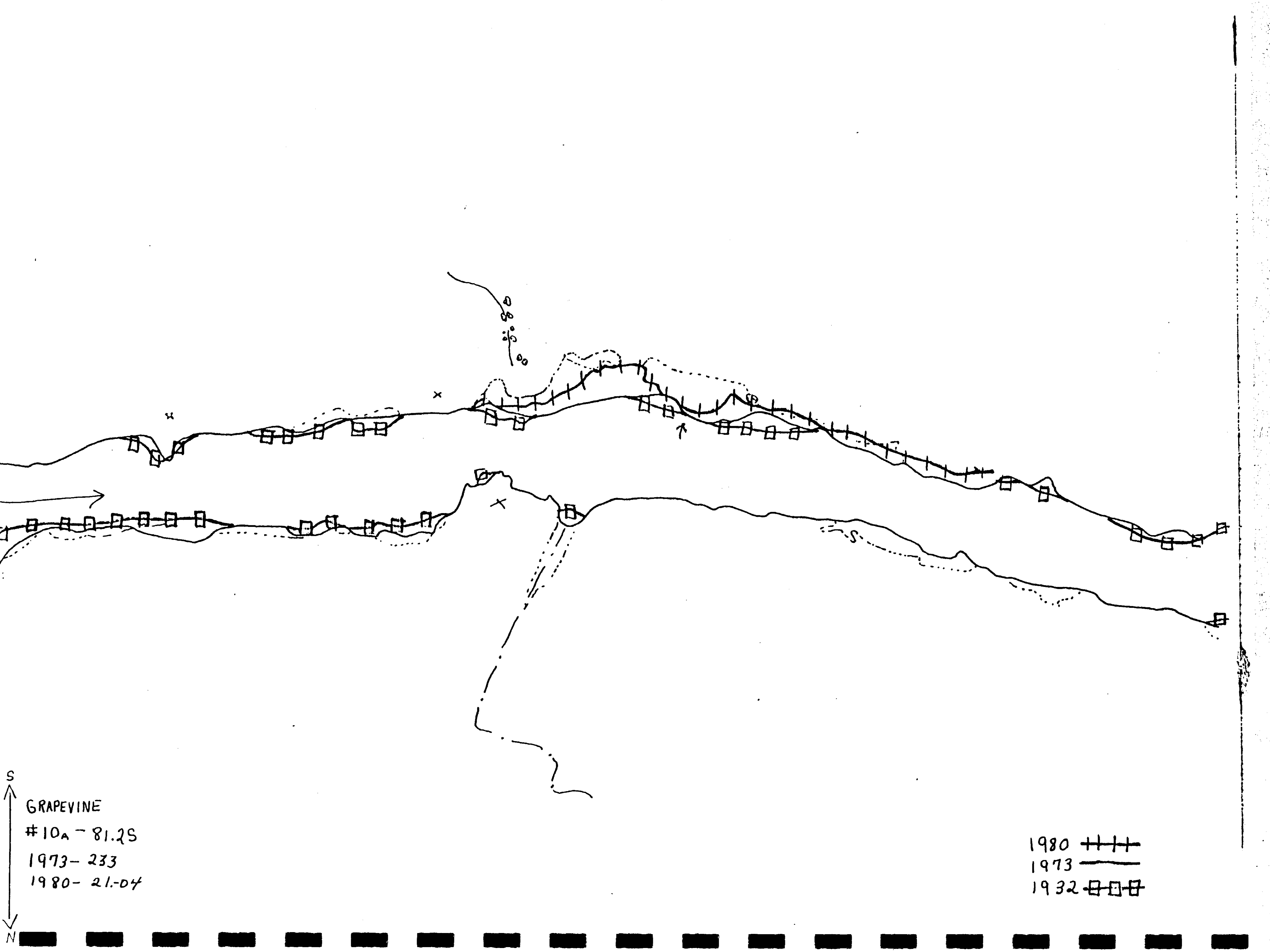


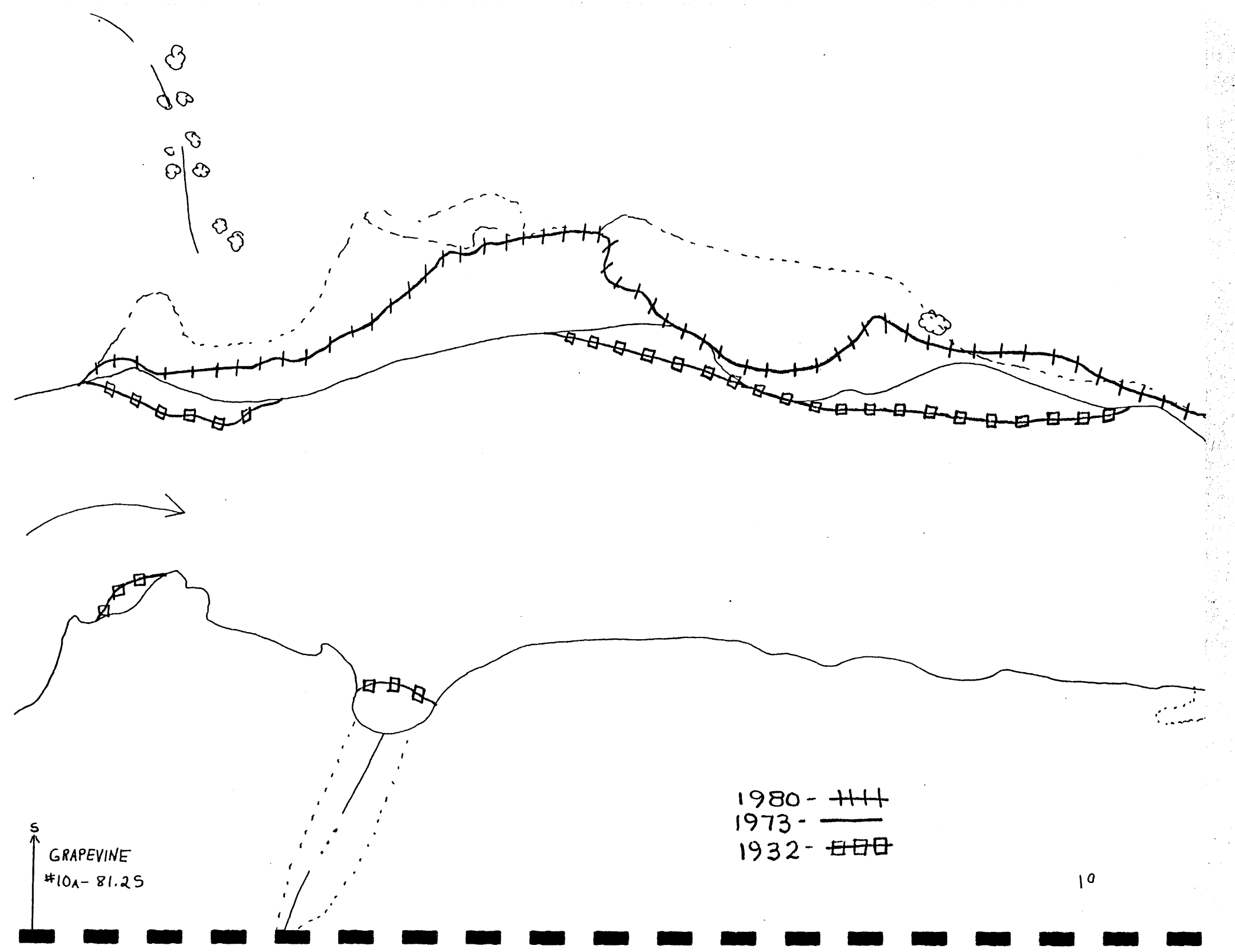

R
R
R
S
NEVILLIS
#9-755
1
1980
1973
1932


1980 -
1973 -
1932 -
S
NEVILLIS
#9 - 755
1973 - 189
1980 - 17-07


1973 -
1980 -
HANKE
10-76S

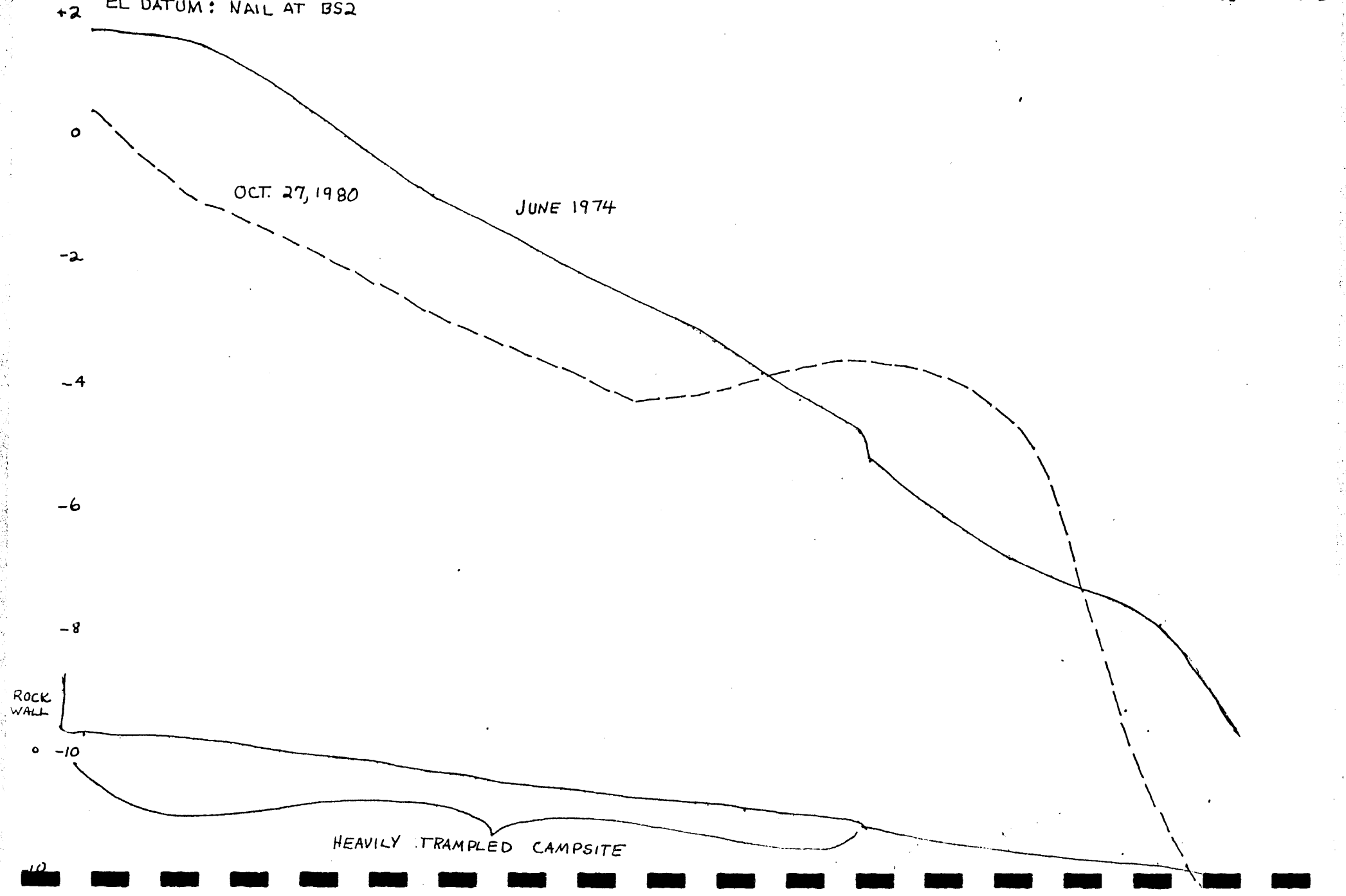

S
HANCE
#10 – 765
1973 – 221
1980 -
1973 -


S
N
GRAPEVINE
#10A - 81.2S
1973- 233
1980- 21.04
1980
1973
1932

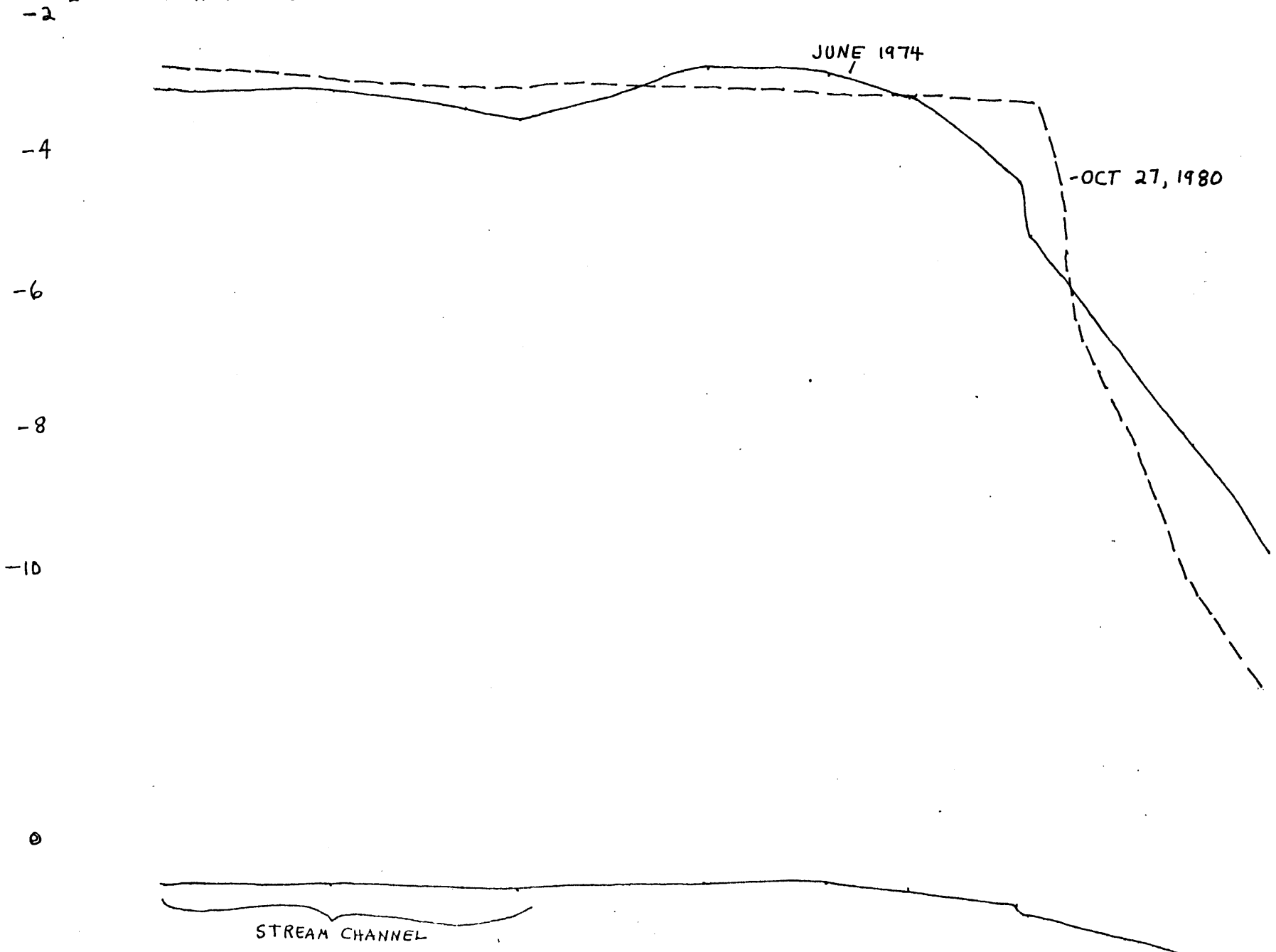

1980 -
1973 -
1932 -
S
GRAPEVINE
#10A - 81.25

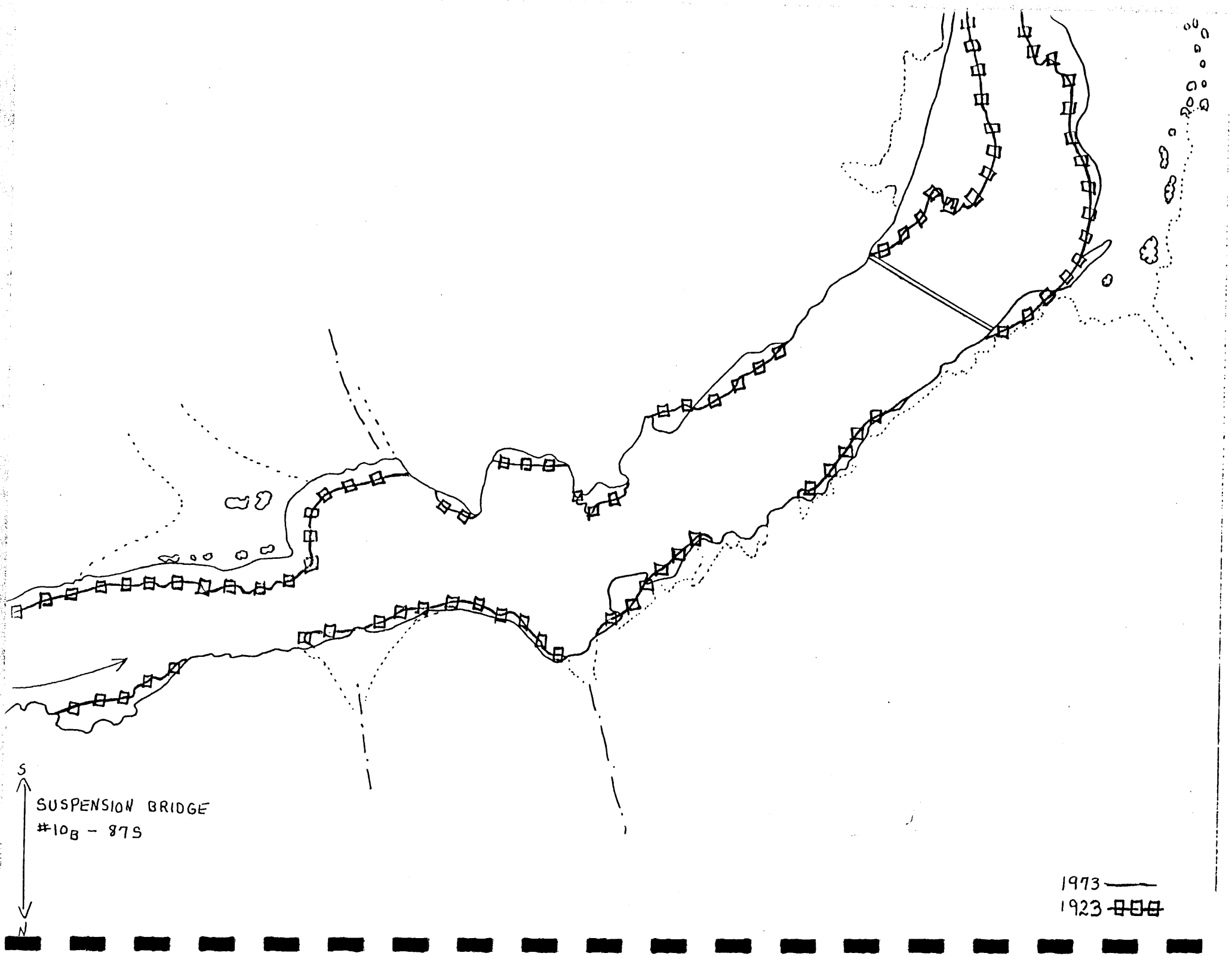
L81.1 : CROSS-SECTION #1 AT 87' 11" FROM BS2 TOWARDS BS1, AT AN ANGLE OF 105° COUNTER CLOCKWISE FROM BS1

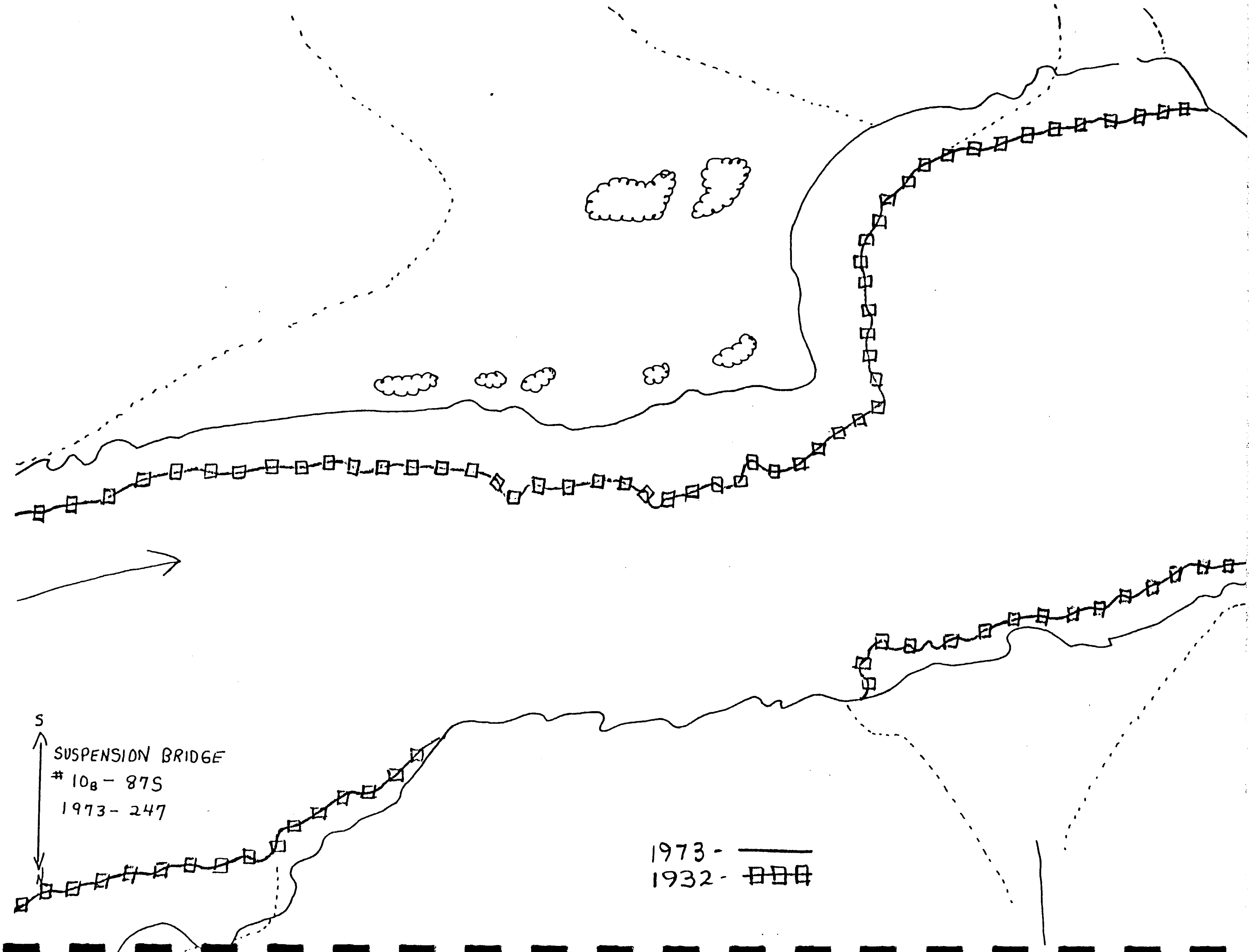
EL DATUM : NAIL AT BS2



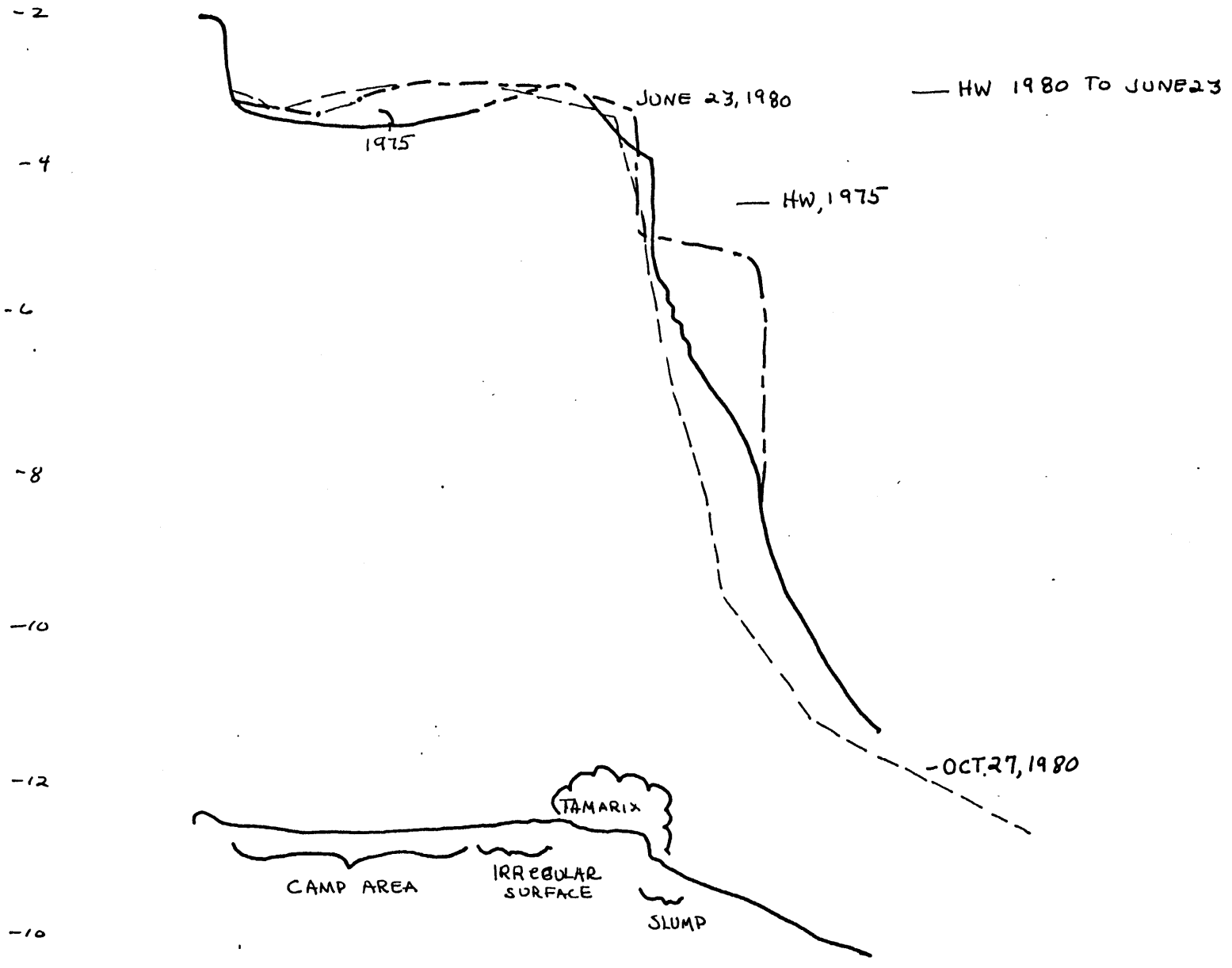
L81.1 : CROSS-SECTION #2, AT 31' 10" FROM BS2 TOWARDS BS3, AT AN ANGLE OF 100° CLOCKWISE FROM BS3
EL DATUM : NAIL AT BS2




S
SUSPENSION BRIDGE
#10B - 875
N
1973
1923


S
N
SUSPENSION BRIDGE
10_B - 87S
1973 - 247
1973 -
1932 -

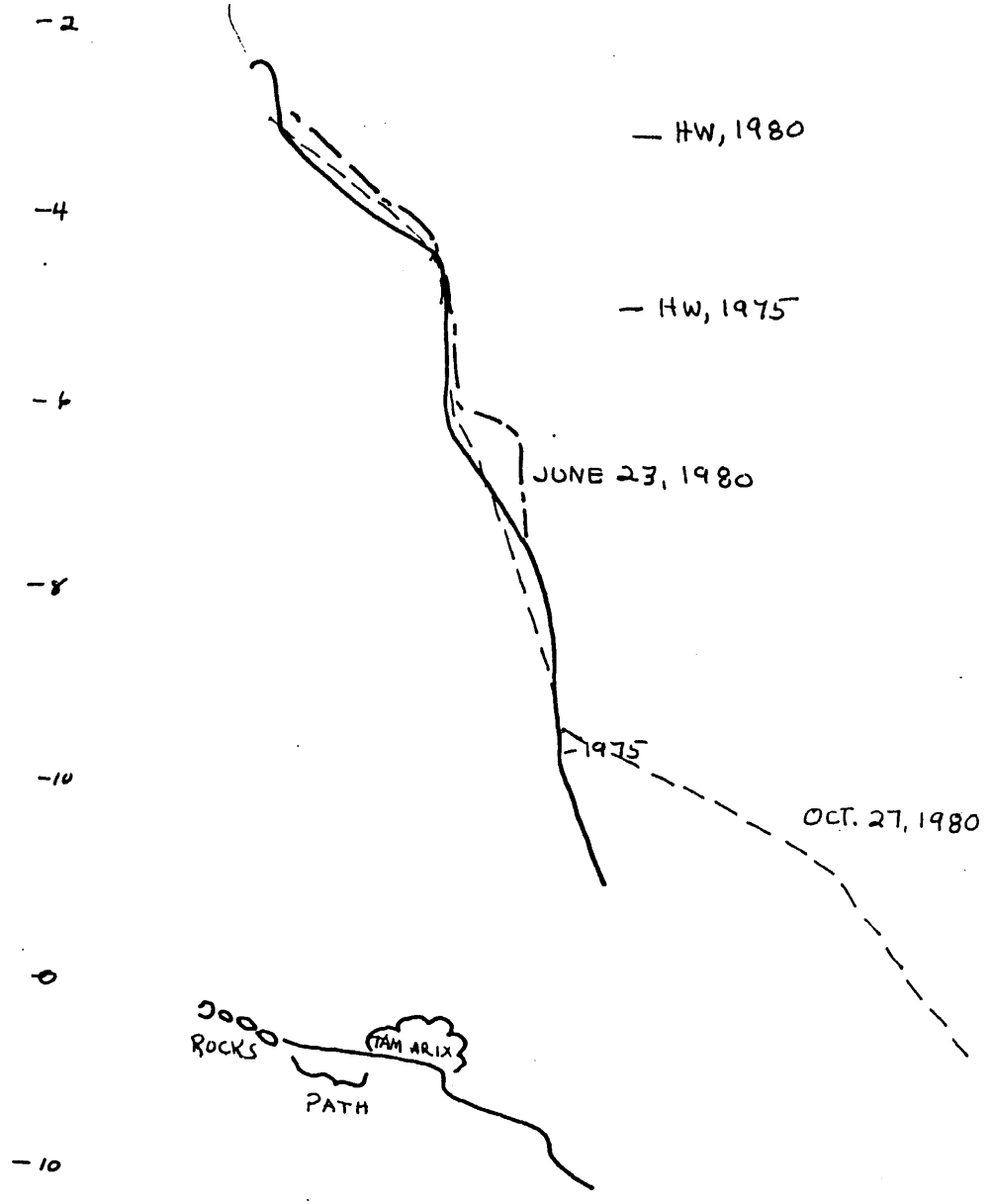
L87.1 : CROSS-SECTION #1 AT BS1, 173° 55' COUNTERCLOCKWISE FROM BS2
EL. DATUM: BS2.?

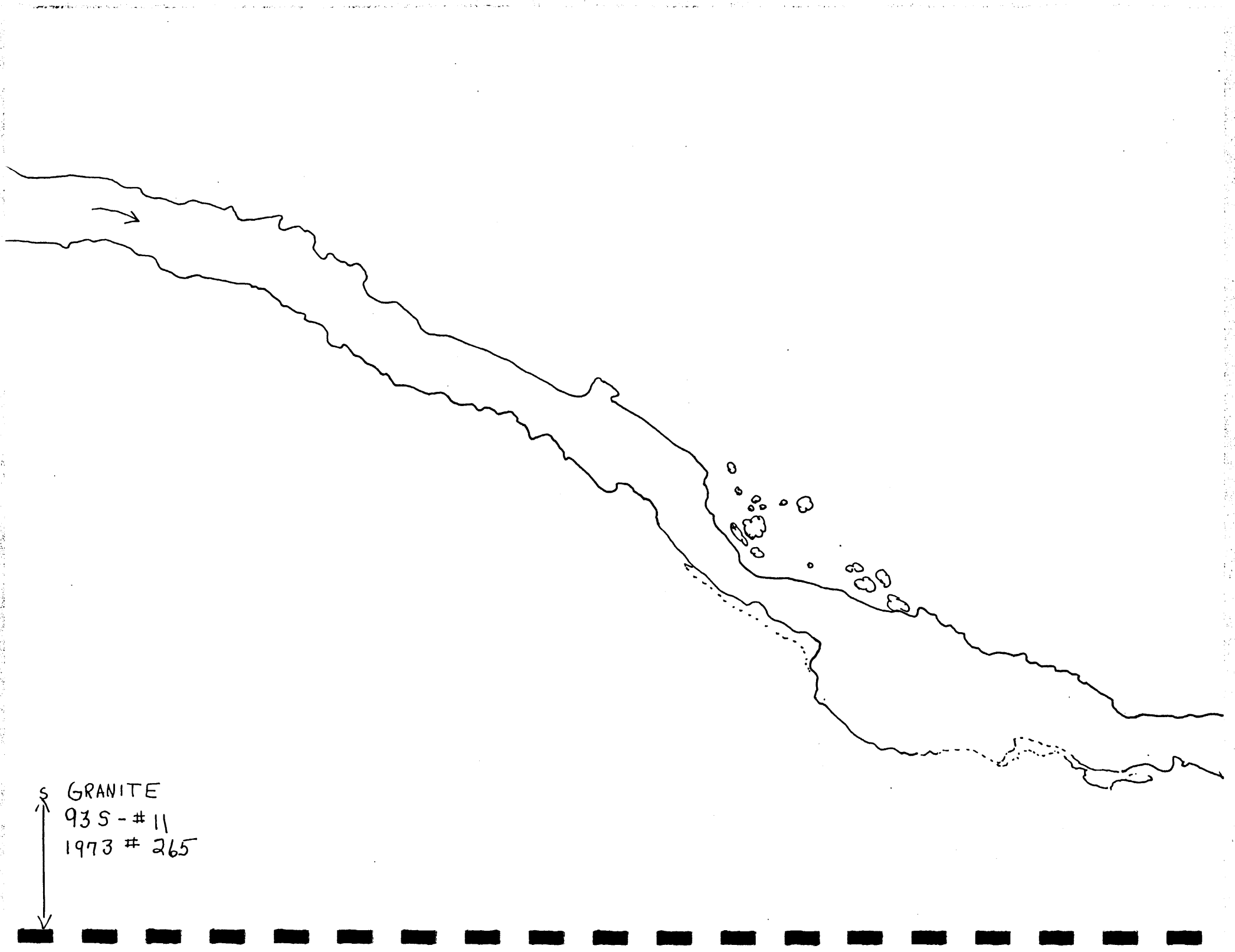


L87.1

L.87-1: CROSS-SECTION #2: 41'10" FROM BS1 TOWARDS BS2 - 90° CLOCKWISE FROM BS2

EL. DATUM: BS2

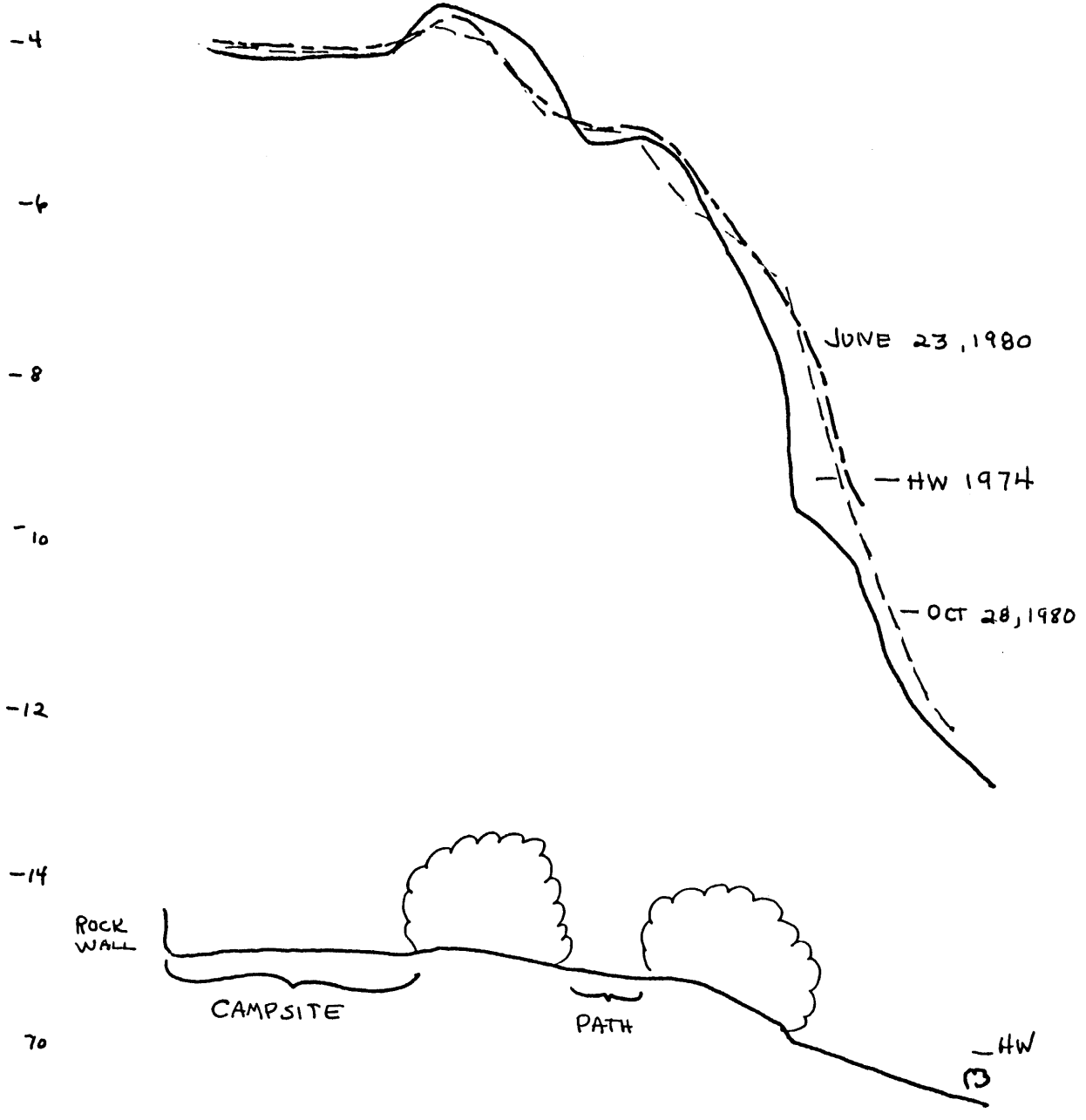



S
GRANITE
93 S - # 11
1973 # 265


S
GRANITE
93s - #11
1973 - 265

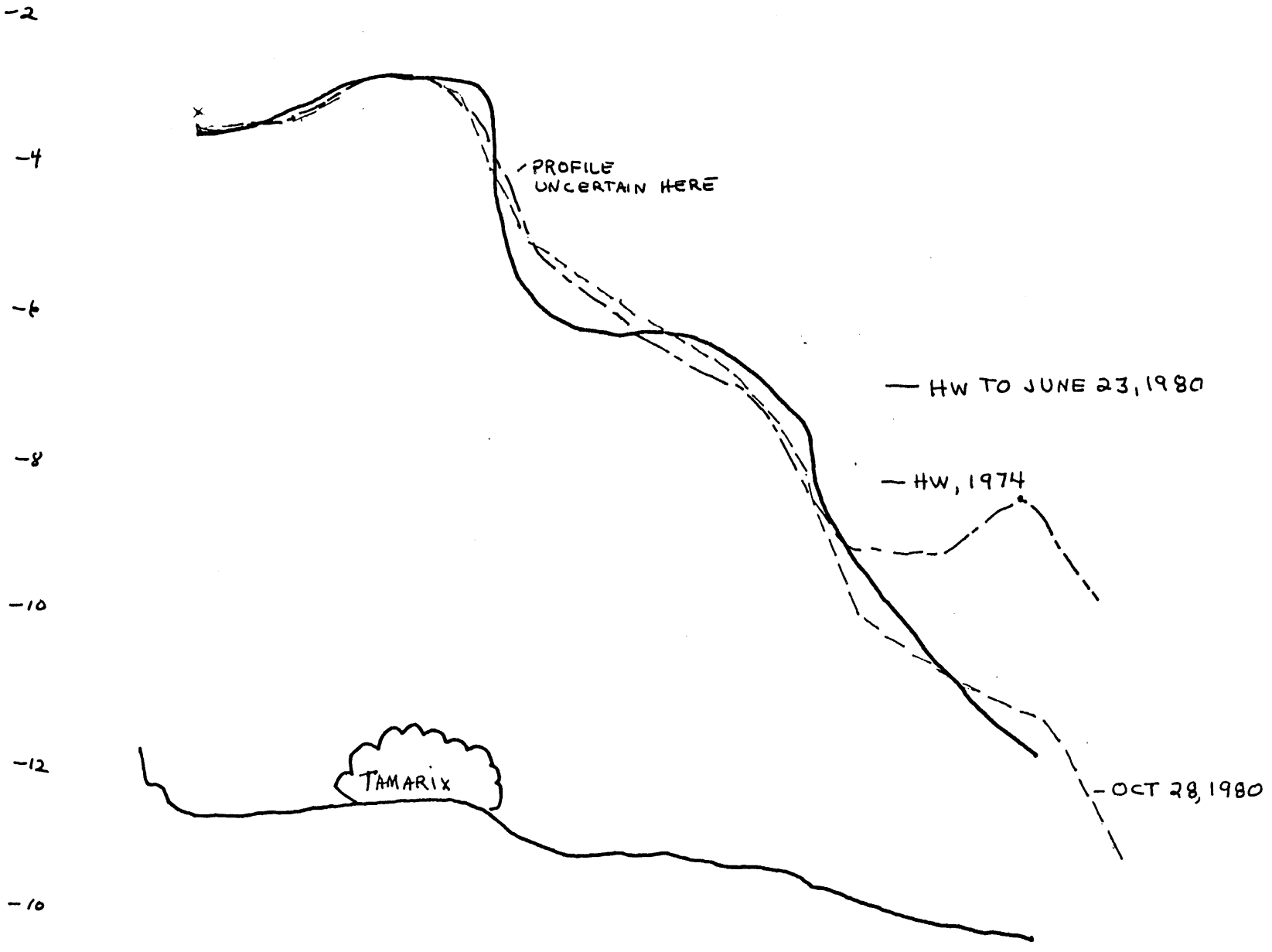
L93.2: CROSS SECTION #1, AT 5'2" FROM BS1 TOWARDS BS2 AT AN ANGLE OF 105° COUNTER CLOCKWISE FROM BS2

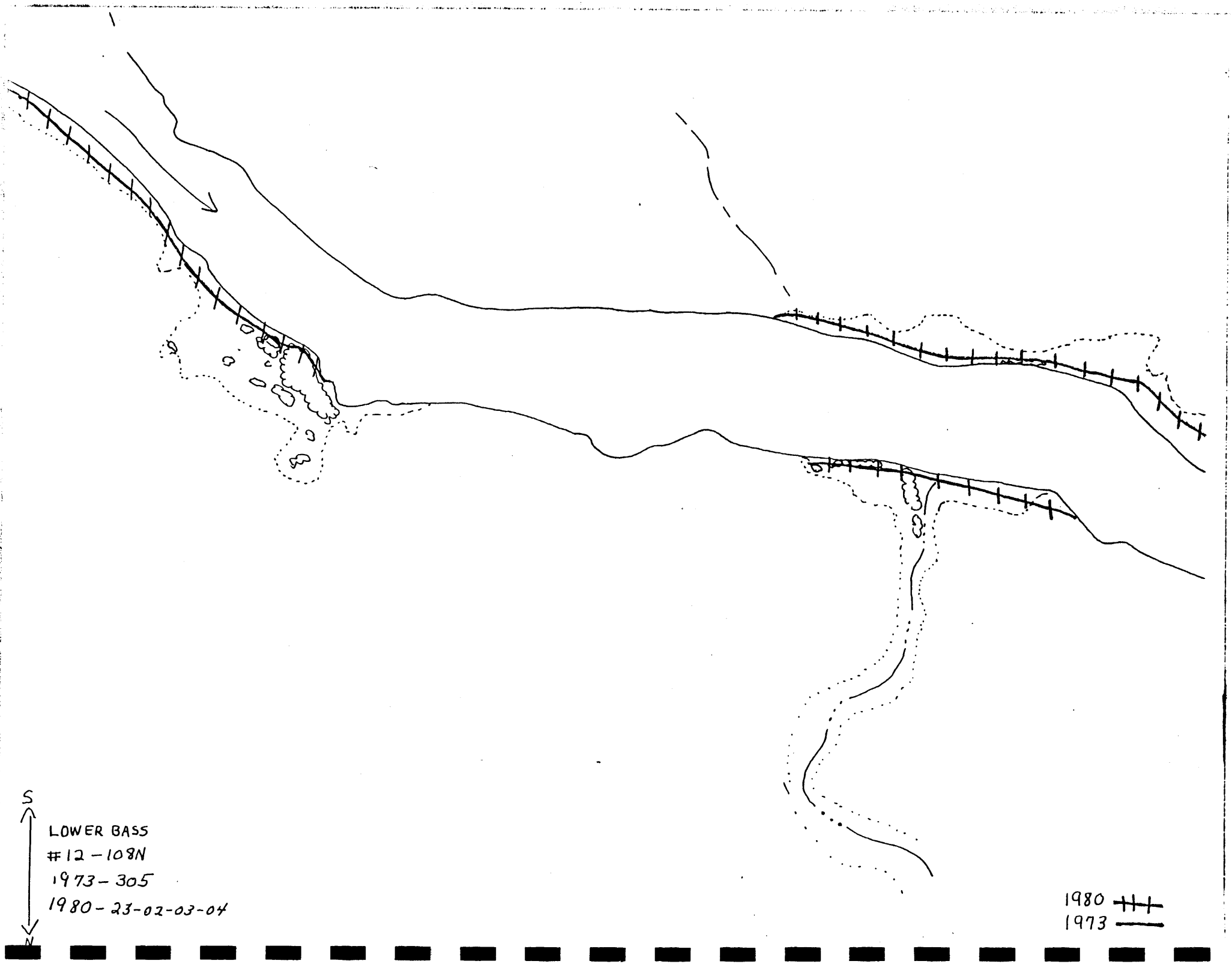
EL. DATUM: NAIL AT BS1

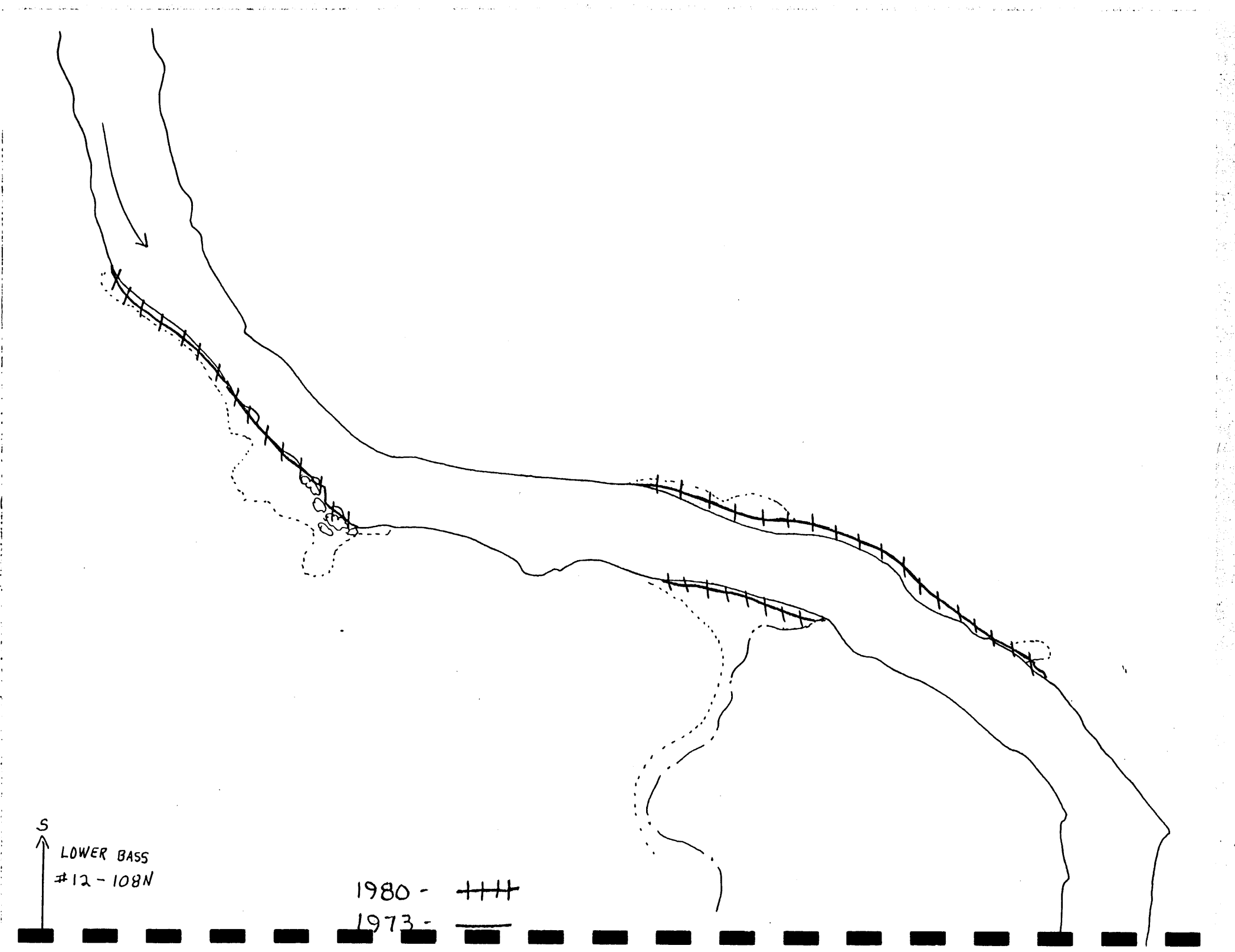


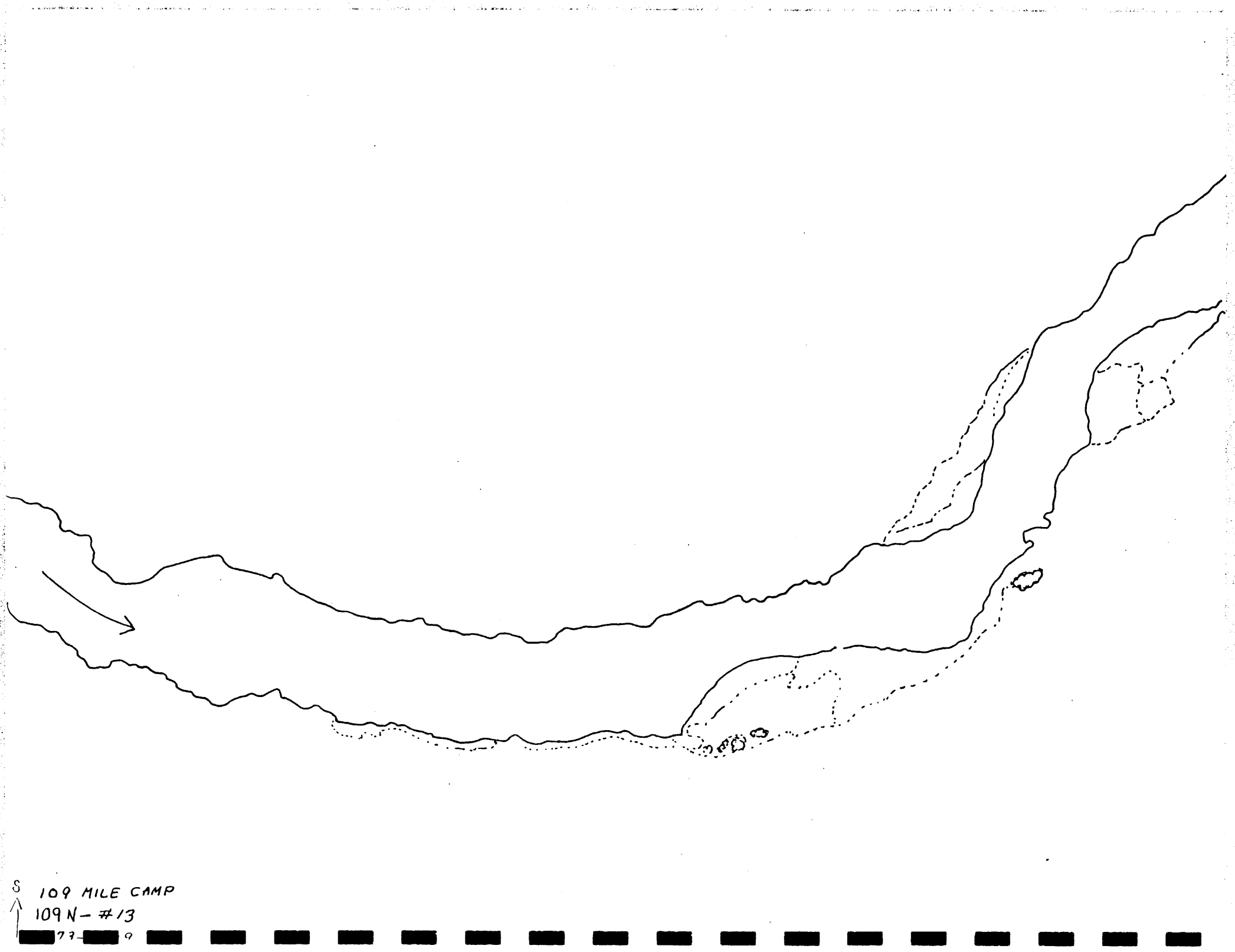
L93.2 CROSS-SECTION #2, AT 46'1" FROM BS1 TOWARDS BS2 AT AN ANGLE 104° COUNTERCLOCKWISE FROM BS2

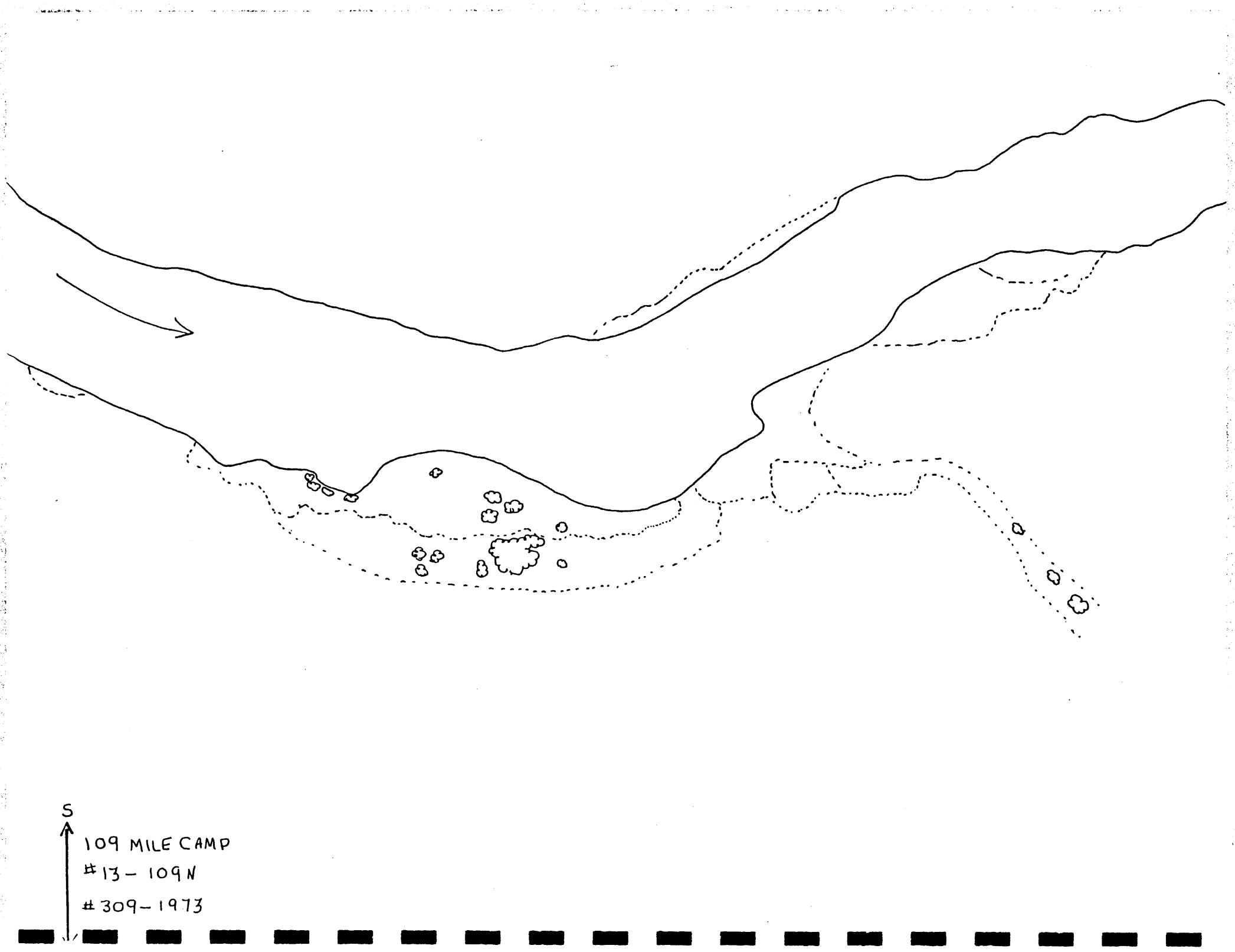
El. DATUM: NAIL at BS2



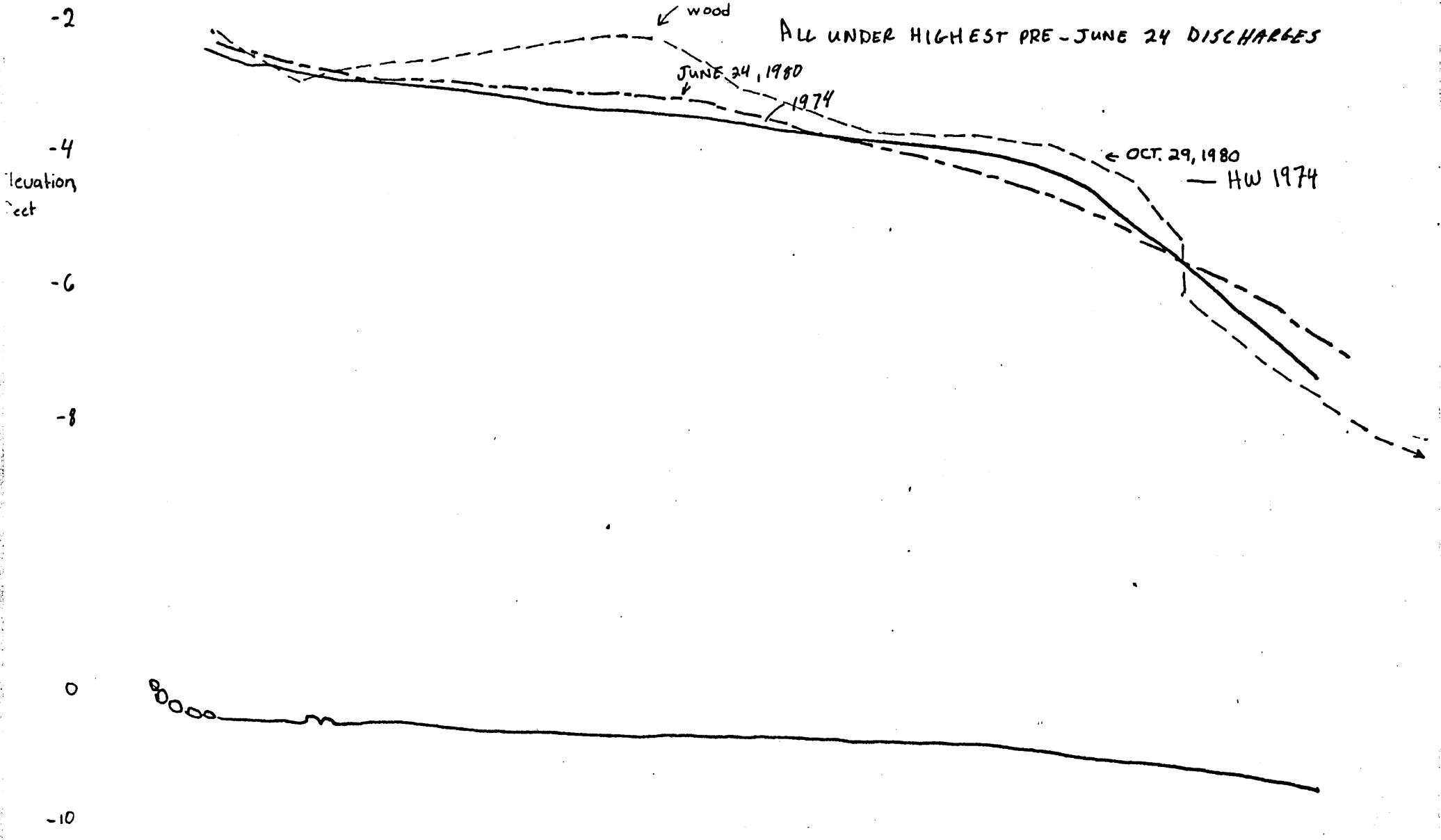

S
N
LOWER BASS
#12 – 108N
1973 – 305
1980 – 23-02-03-04
1980
1973


S
LOWER BASS
#12 - 108N
1980 -
1973 -

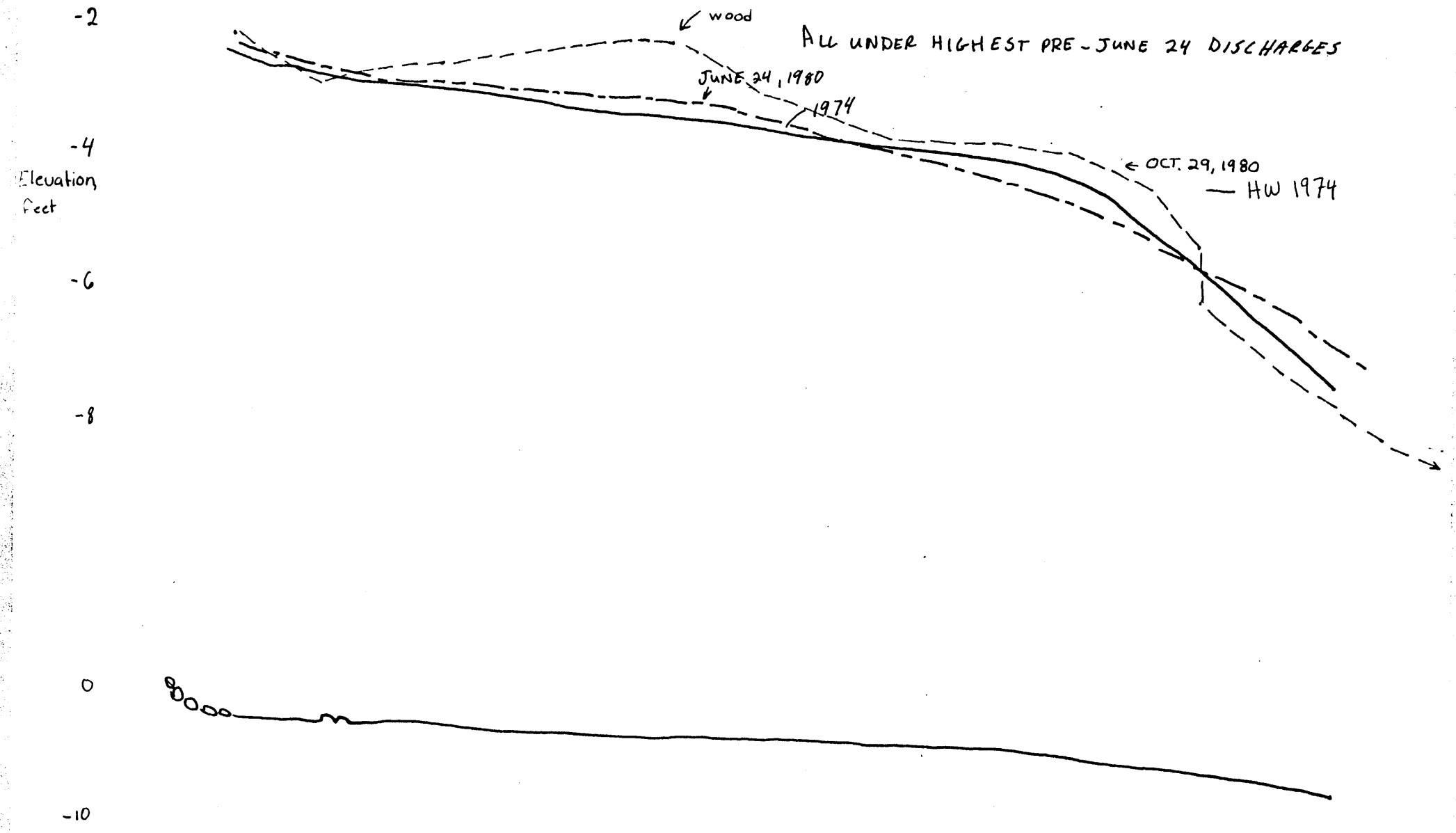

S
109 MILE CAMP
109 N – #13

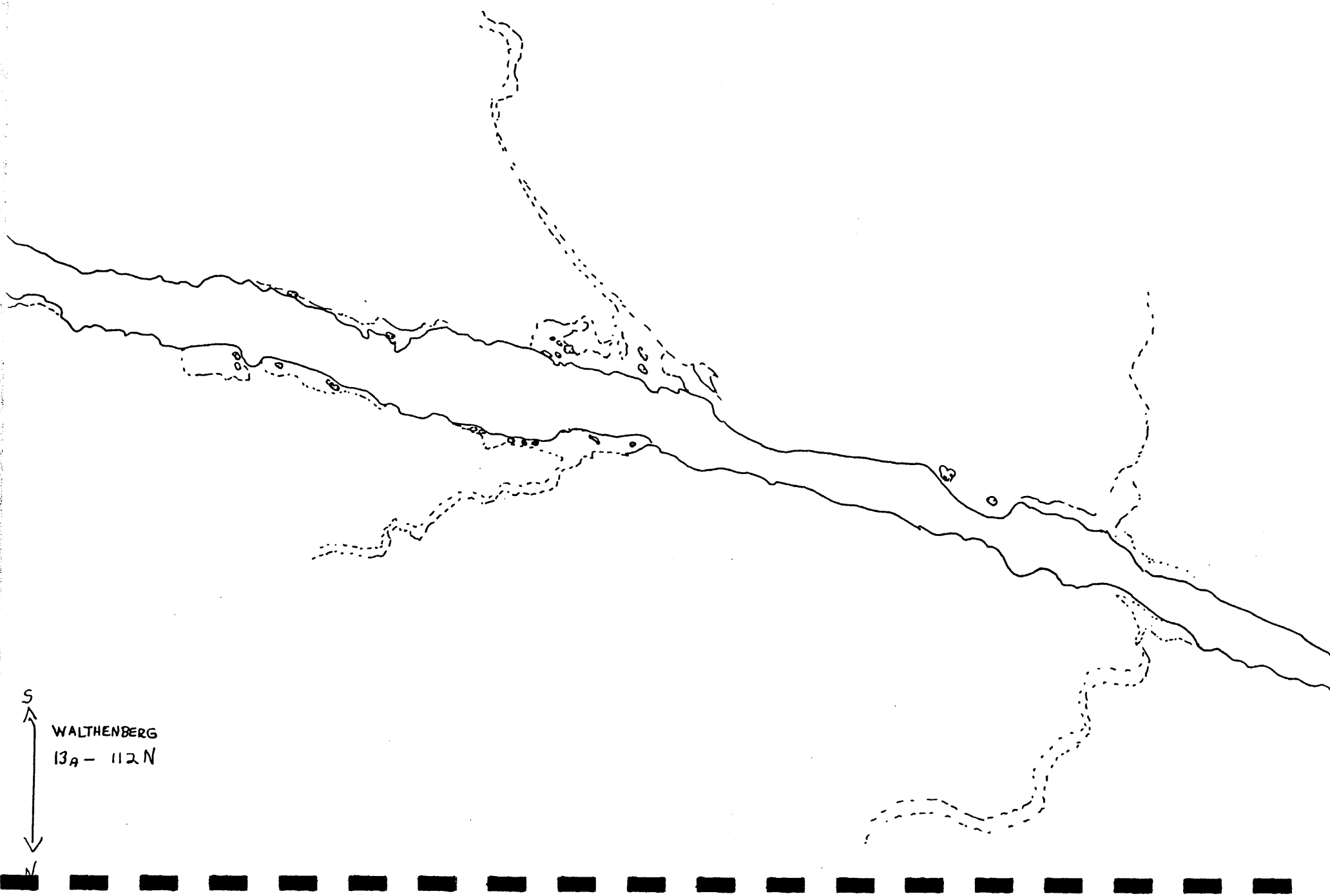

S
109 MILE CAMP
#13 - 109N
#309 - 1973

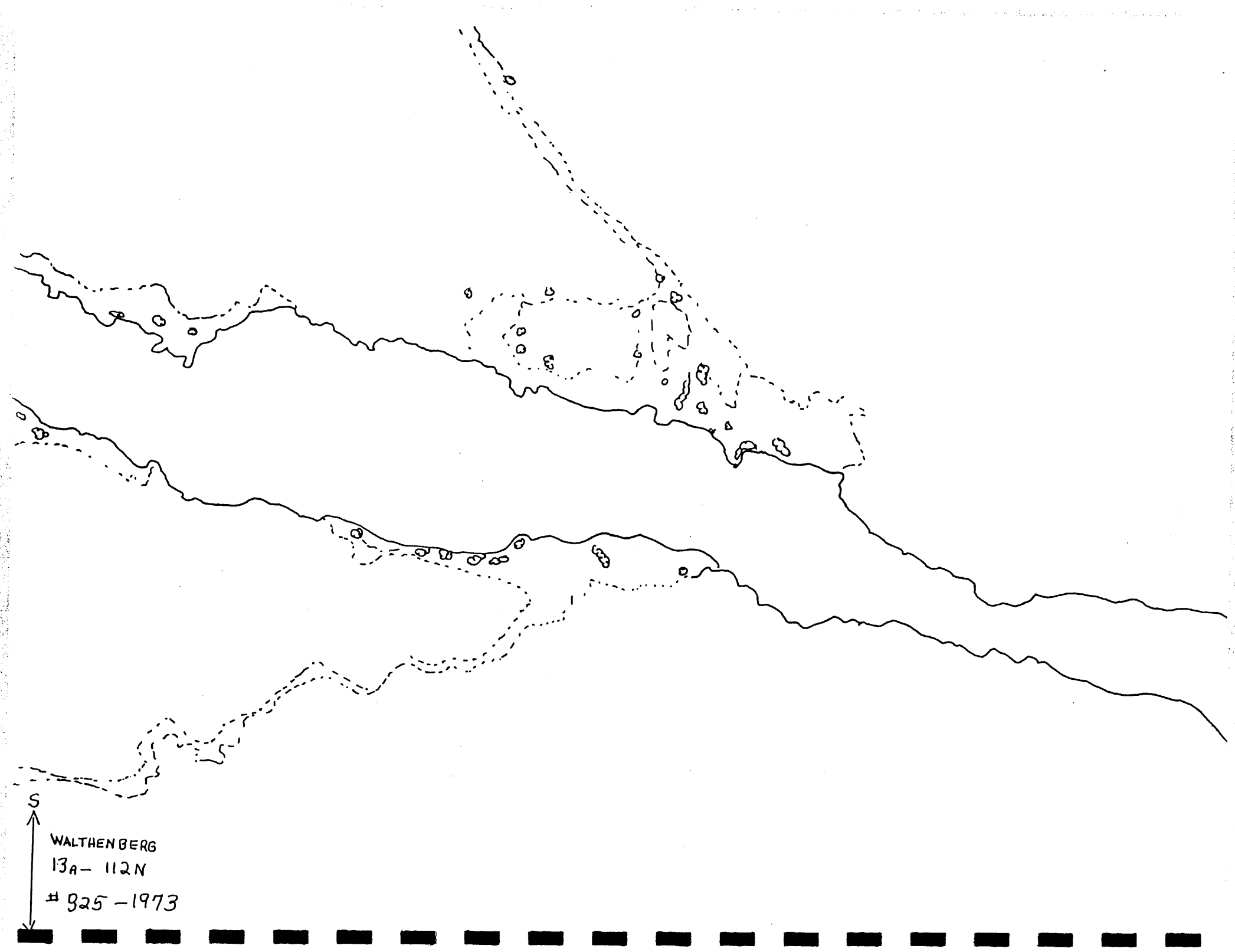
R109.4 : CROSS-SECTION #2, AT 93'6" FROM BS1 TOWARDS BS2 AT AN ANGLE OF 123° CLOCKWISE FROM BS1
ELEVATION DATUM: TOP OF ROCK IN WHICH BS2 IS LOCATED



R109.4 : CROSS-SECTION #2, AT 93'6" FROM BS1 TOWARDS BS2 AT AN ANGLE OF 123° CLOCKWISE FROM BS1
ELEVATION DATUM: TOP OF ROCK IN WHICH BS2 IS LOCATED

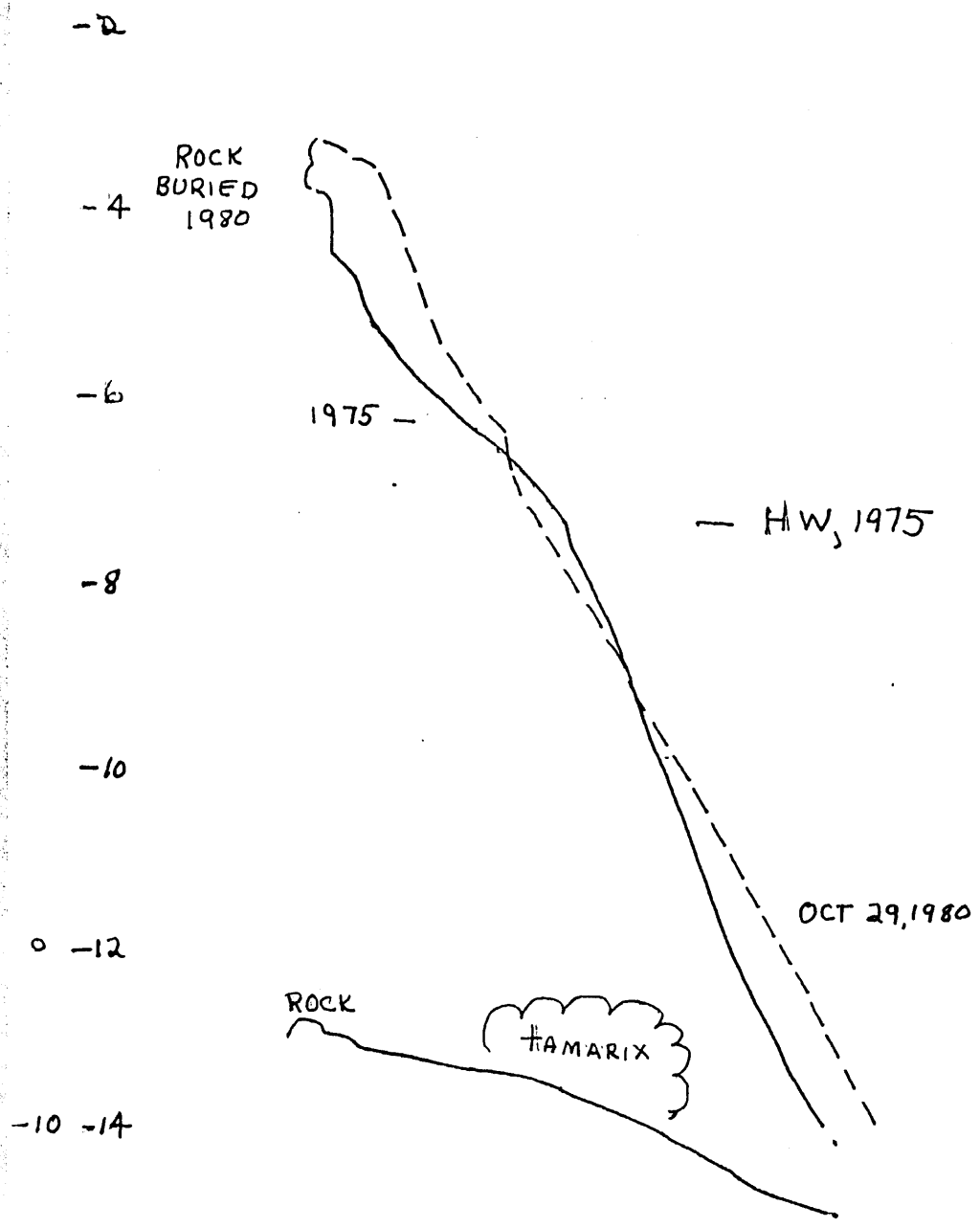



S
WALTHENBERG
13A – 112N
N

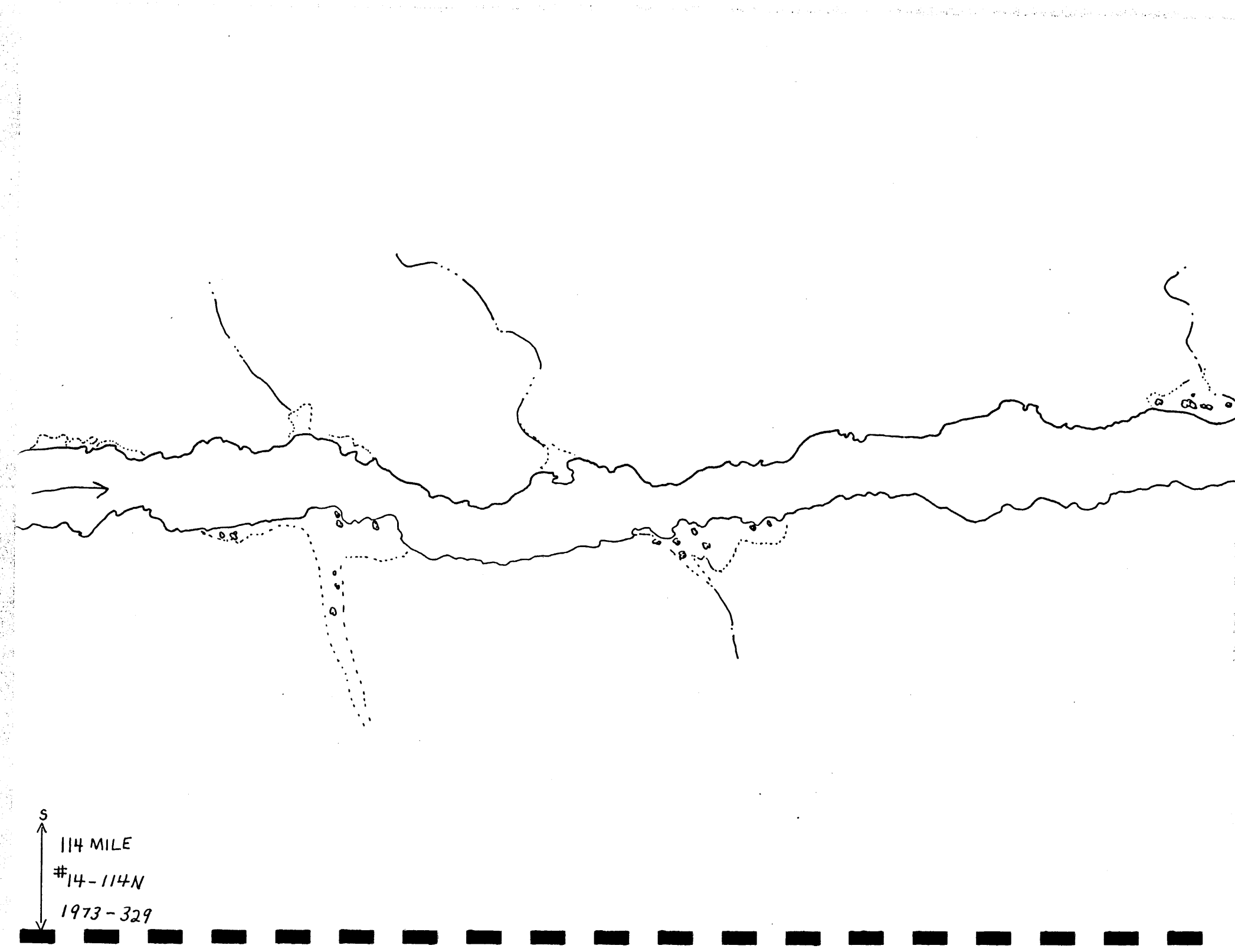

S
WALTHENBERG
13A- 112N
#925-1973

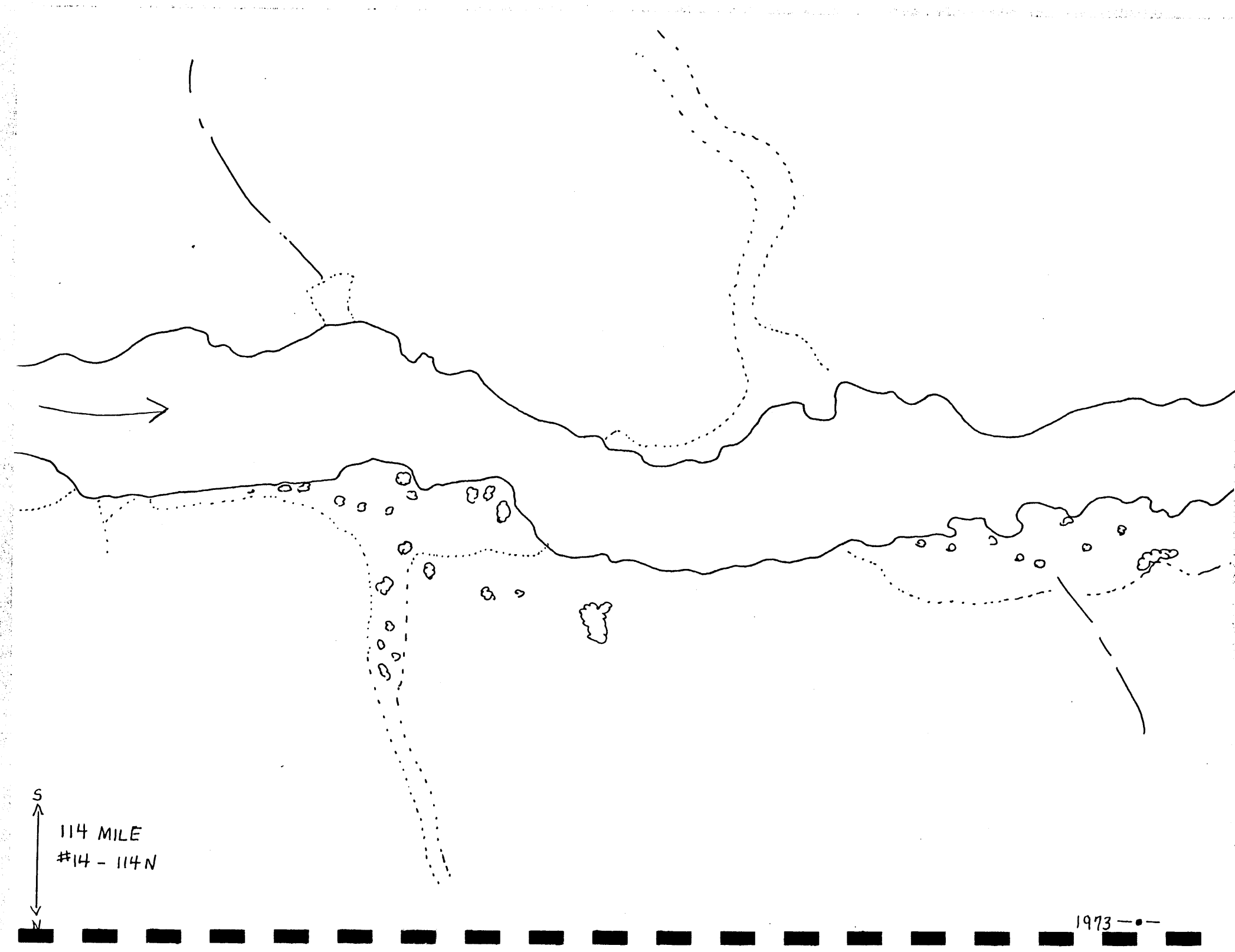
R1

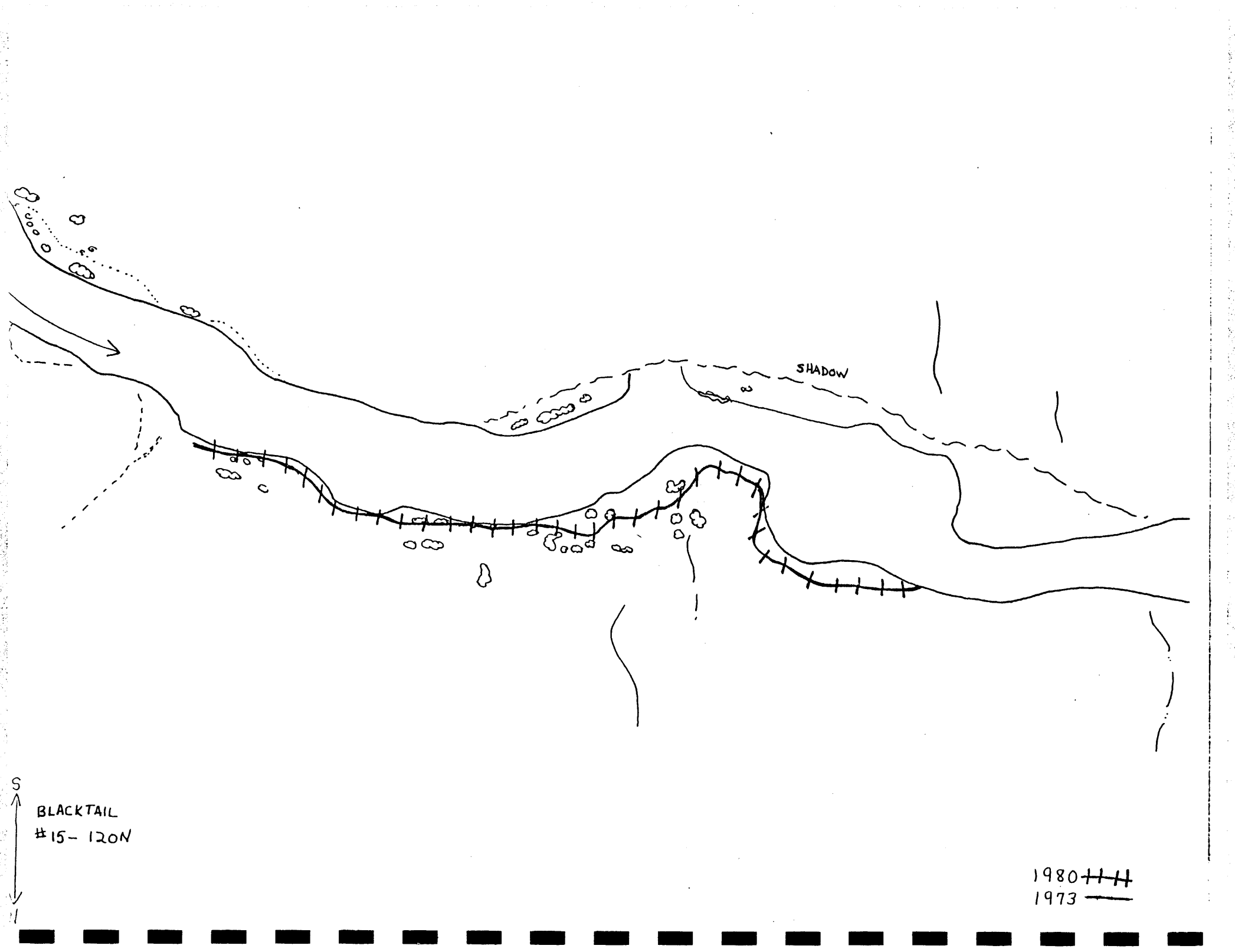
R112.2: CROSS-SECTION #1:

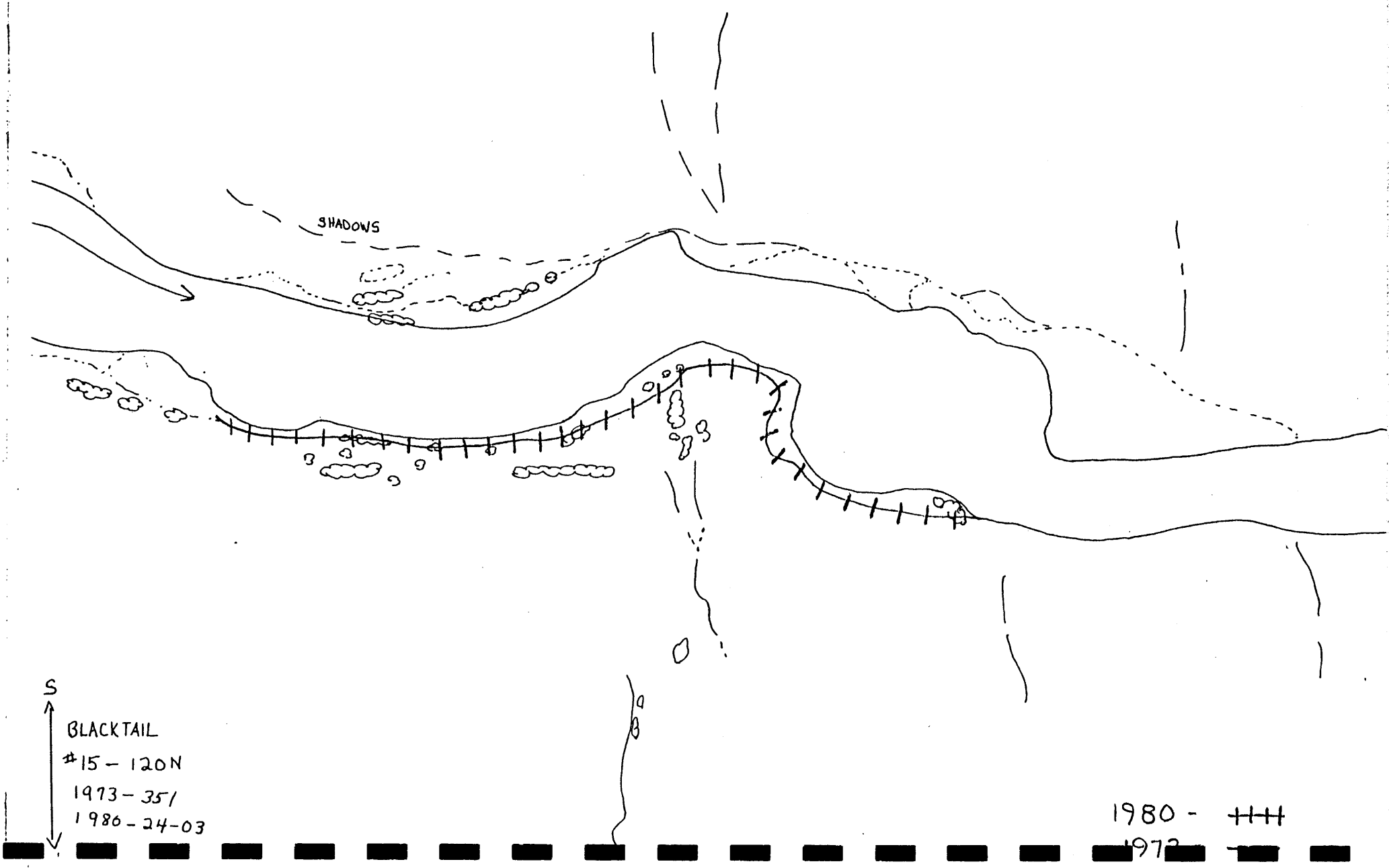


R 112.2

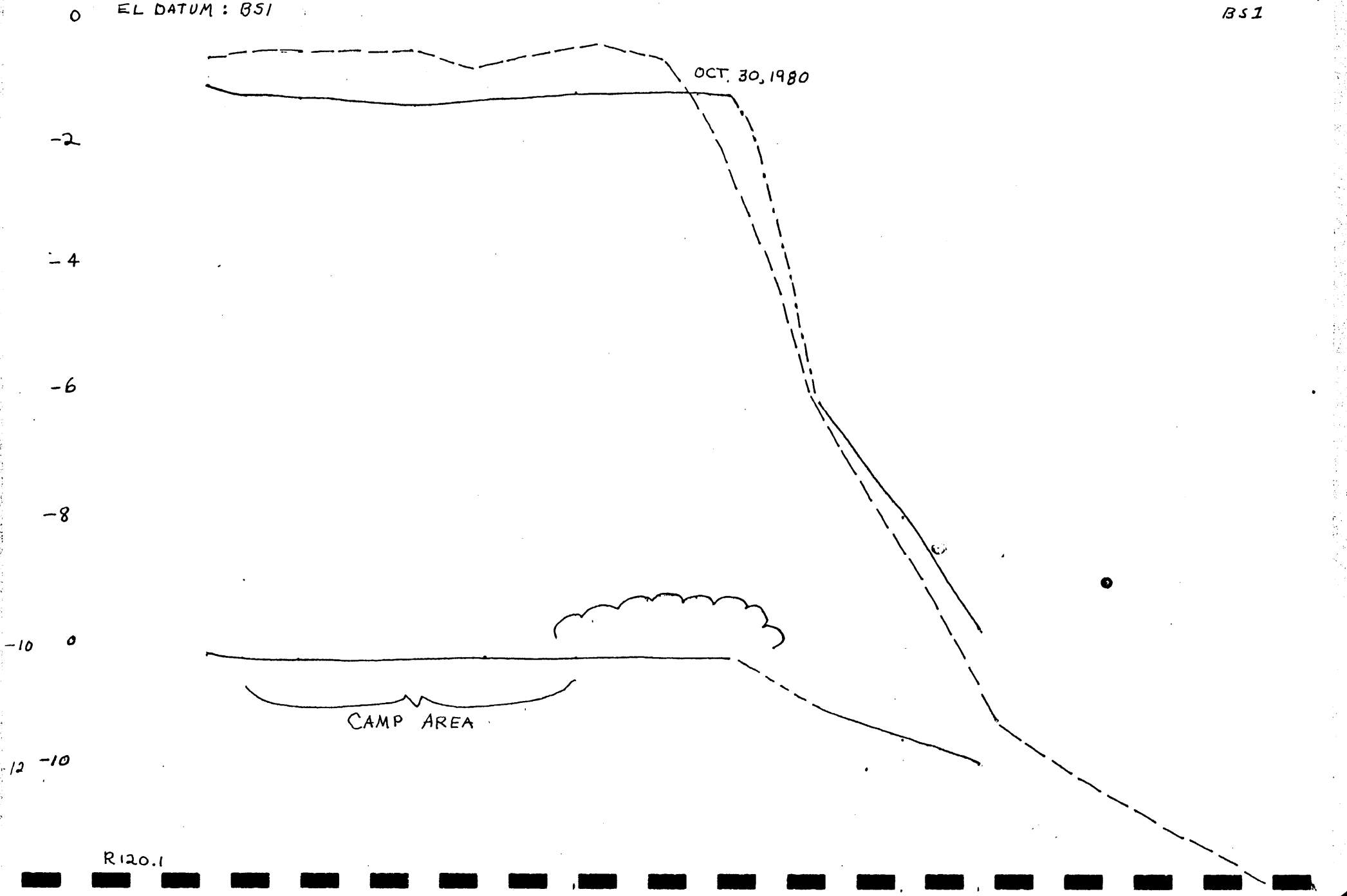

S
114 MILE
#14-114N
1973-329


S
N
114 MILE
#14 - 114N
1973


SHADOW
S
BLACKTAIL
#15- 120N
1980
1973


SHADOWS
S
BLACKTAIL
#15 - 120N
1973 - 351
1986 - 24-03
1980 - +++
1972

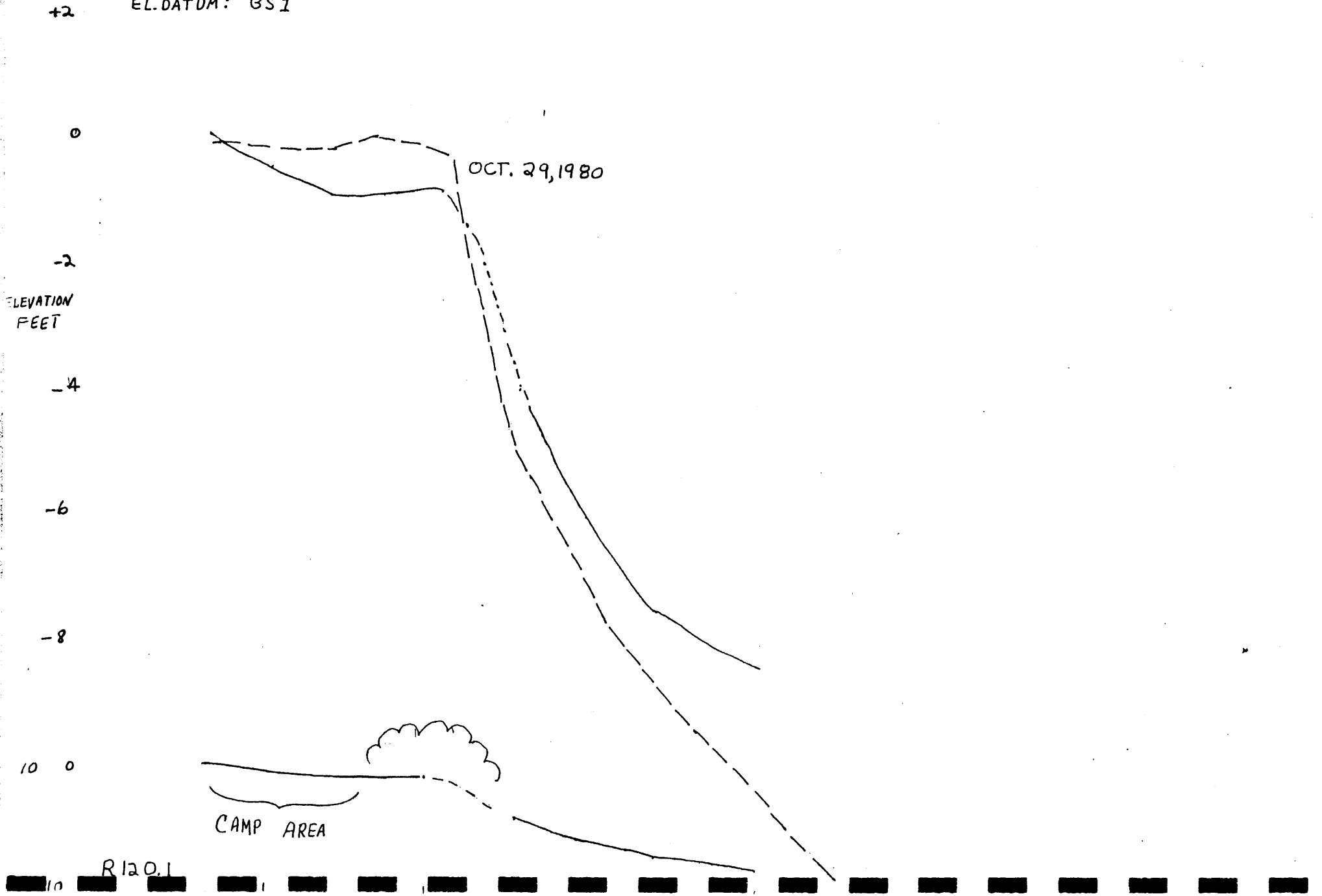
R120.1: CROSS-SECTION #1, AT 10'8" FROM BS1 TOWARDS BS2 AT AN ANGLE AT 120° COUNTERCLOCKWISE FROM BS1

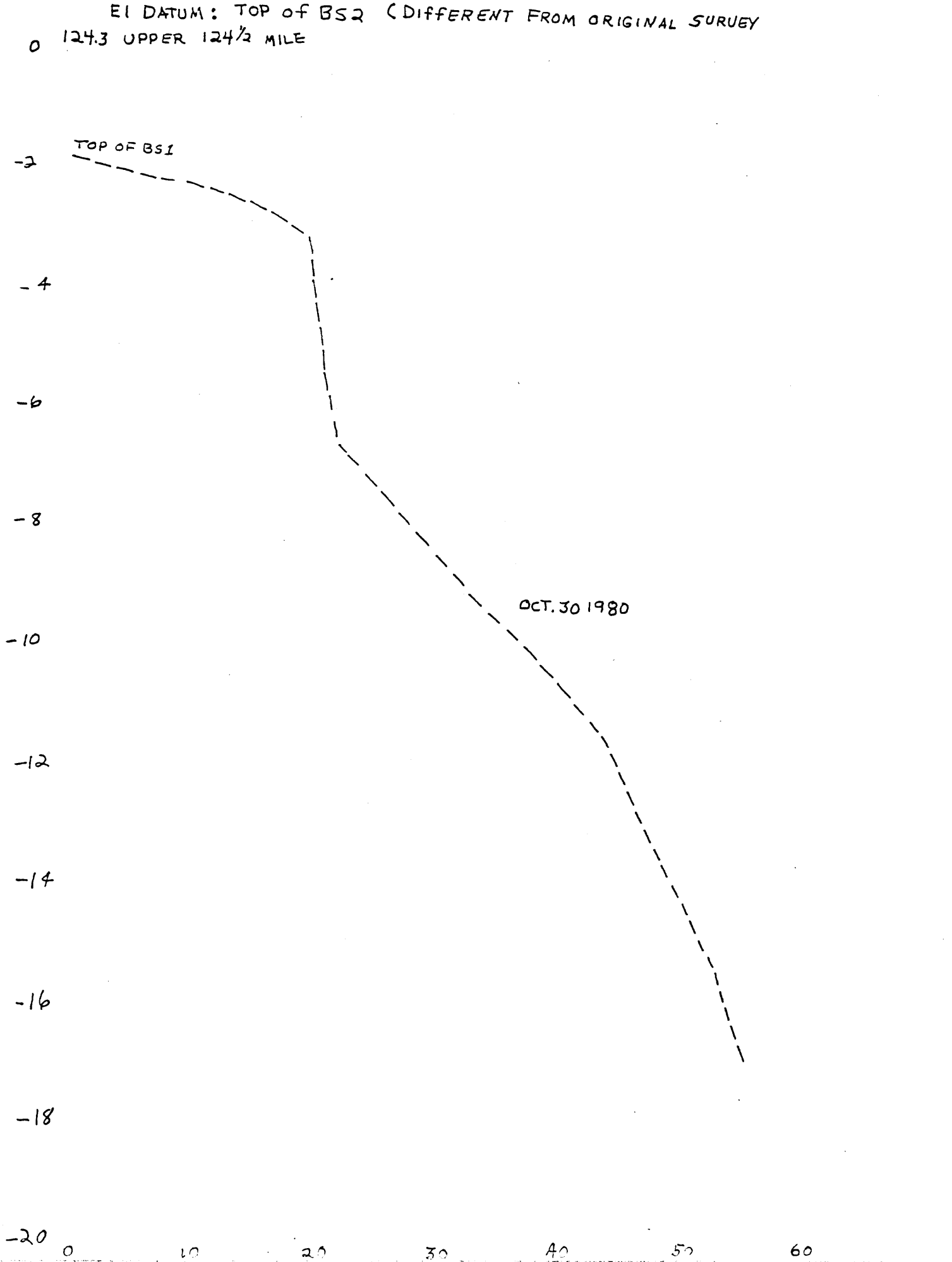


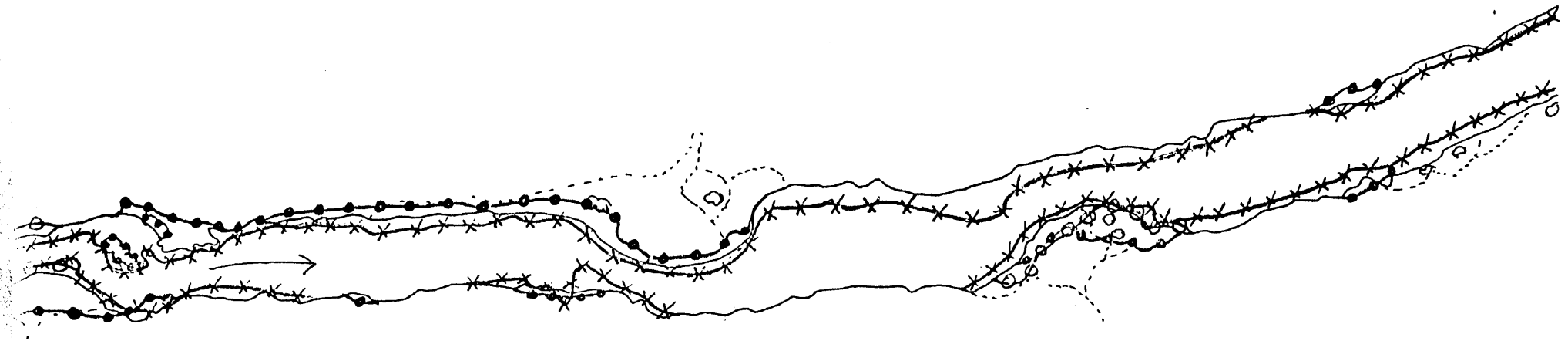
R120.1

R120.1 : CROSS-SECTION #2: AT 79' 11" FROM BS1 TOWARDS BS2 AT ANGLE OF 100° CLOCKWISE FROM BS2

EL. DATUM: BS1




EI DATUM: TOP of BS2 (DIFFERENT FROM ORIGINAL SURUEY
0 124.3 UPPER 124½ MILE
TOP OF BS1
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
OCT. 30 1980
0
10
20
30
40
50
60



S

BEDROCK

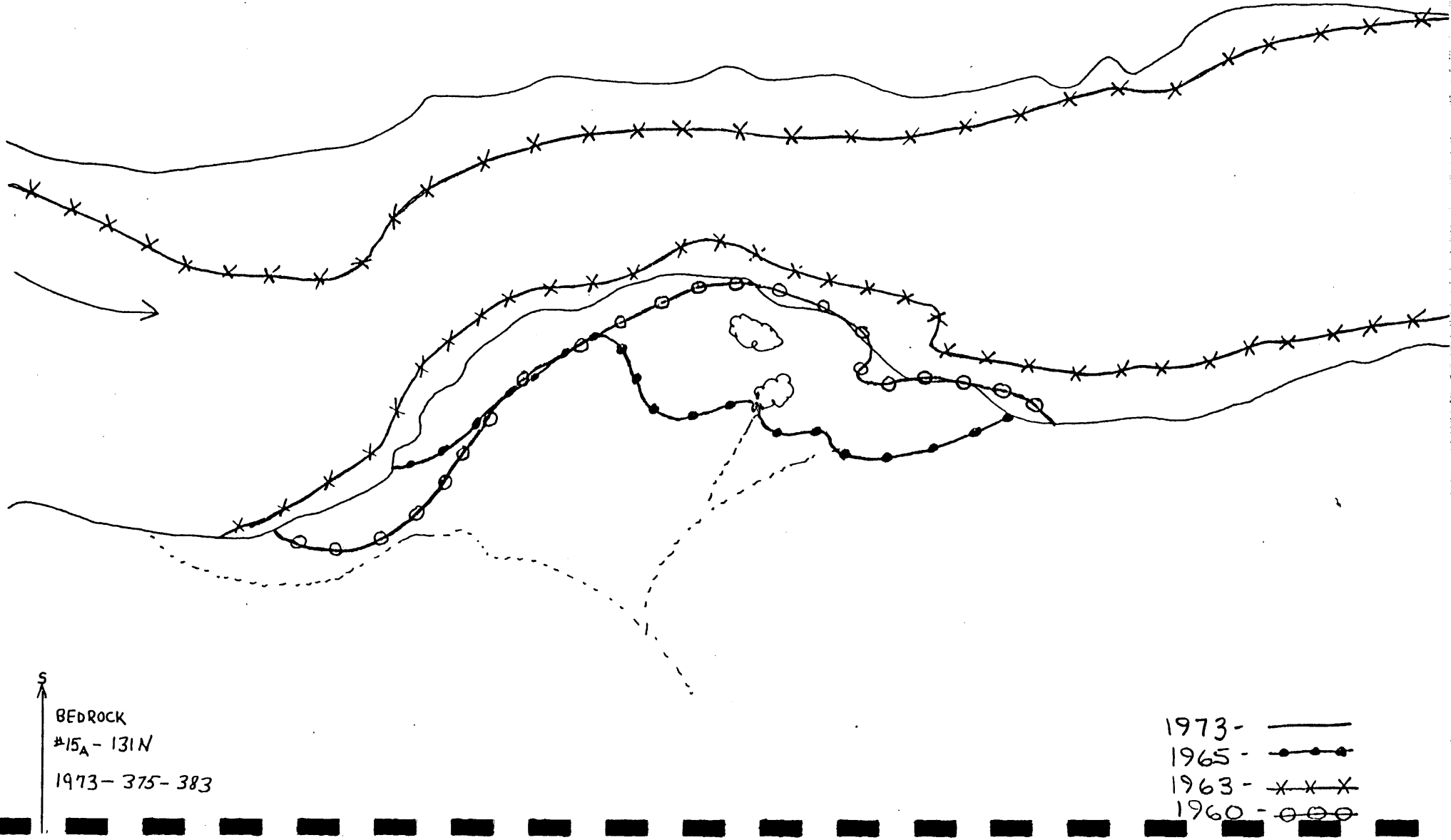
#15A – 131N

1973

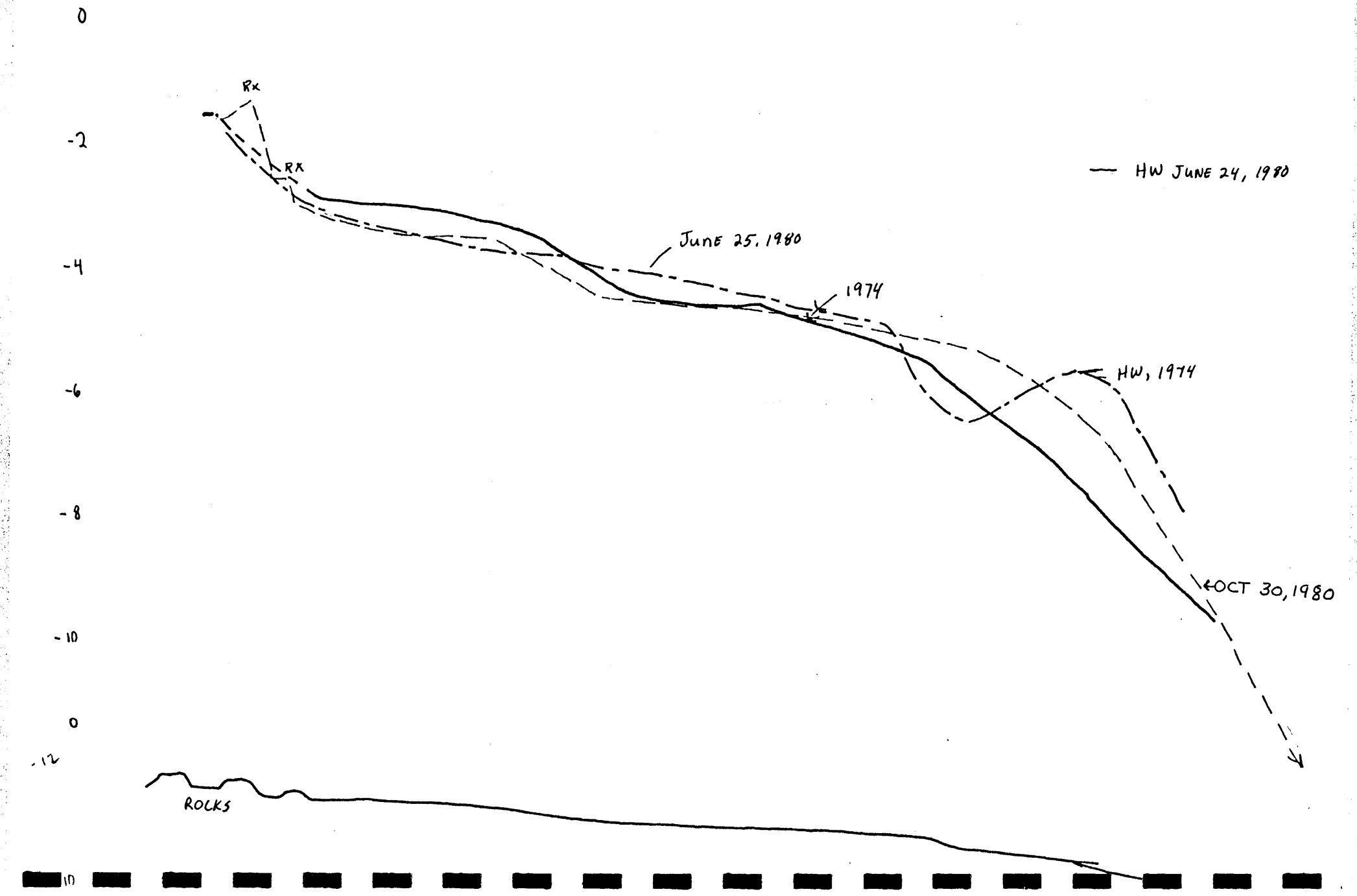
1965

1963

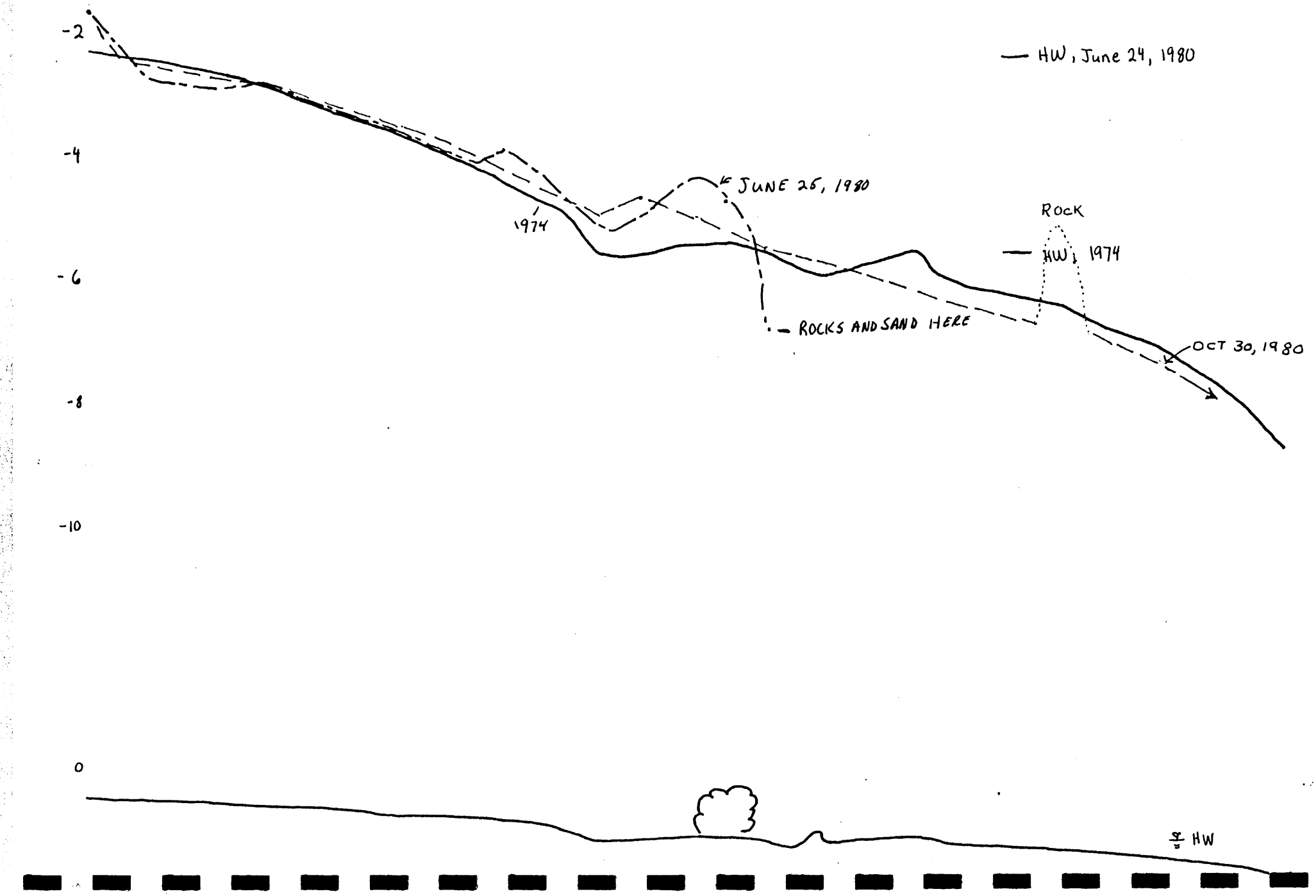
1960

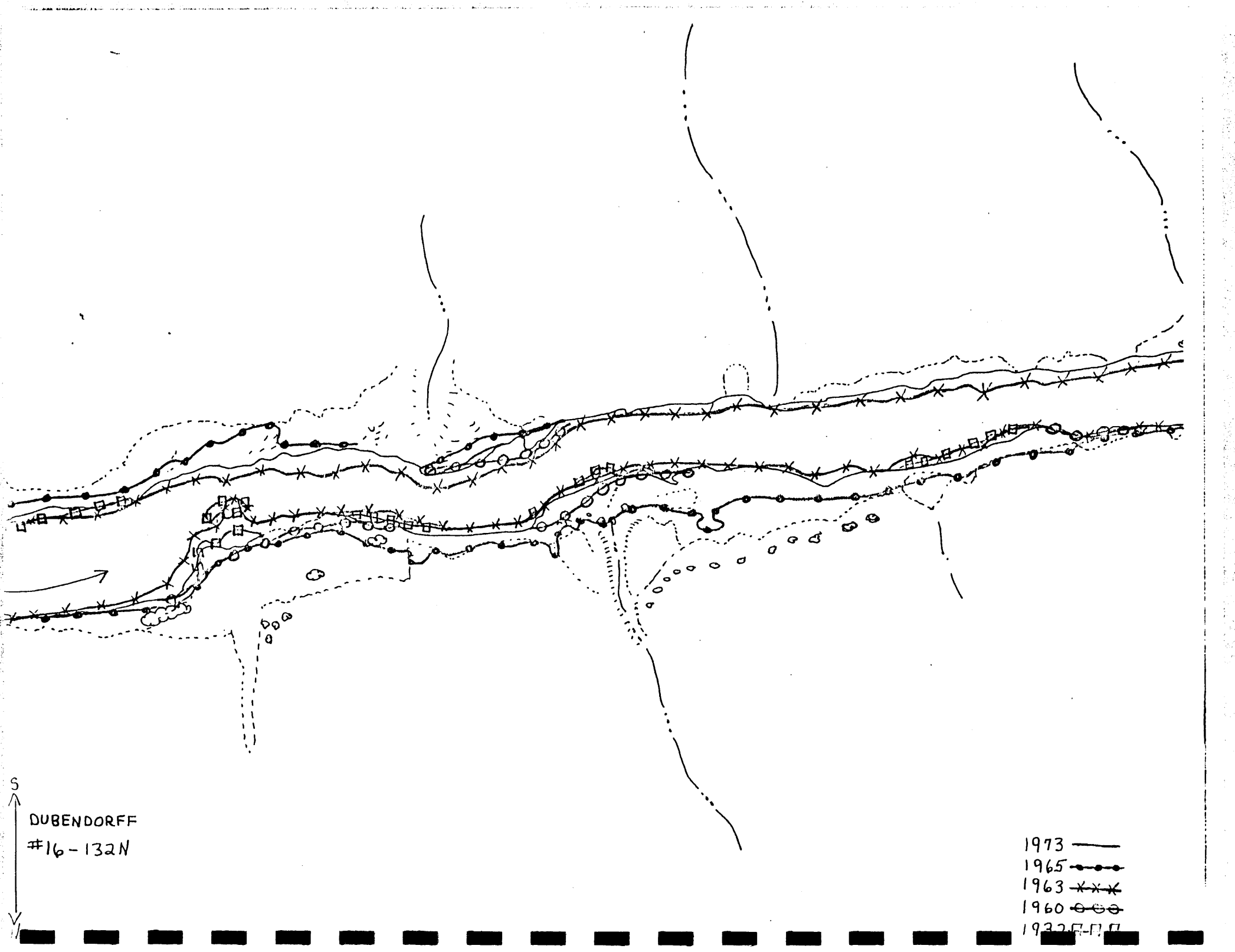

S
BEDROCK
#15A - 131N
1973 - 375 - 383
1973 -
1965 -
1963 -
1960 -

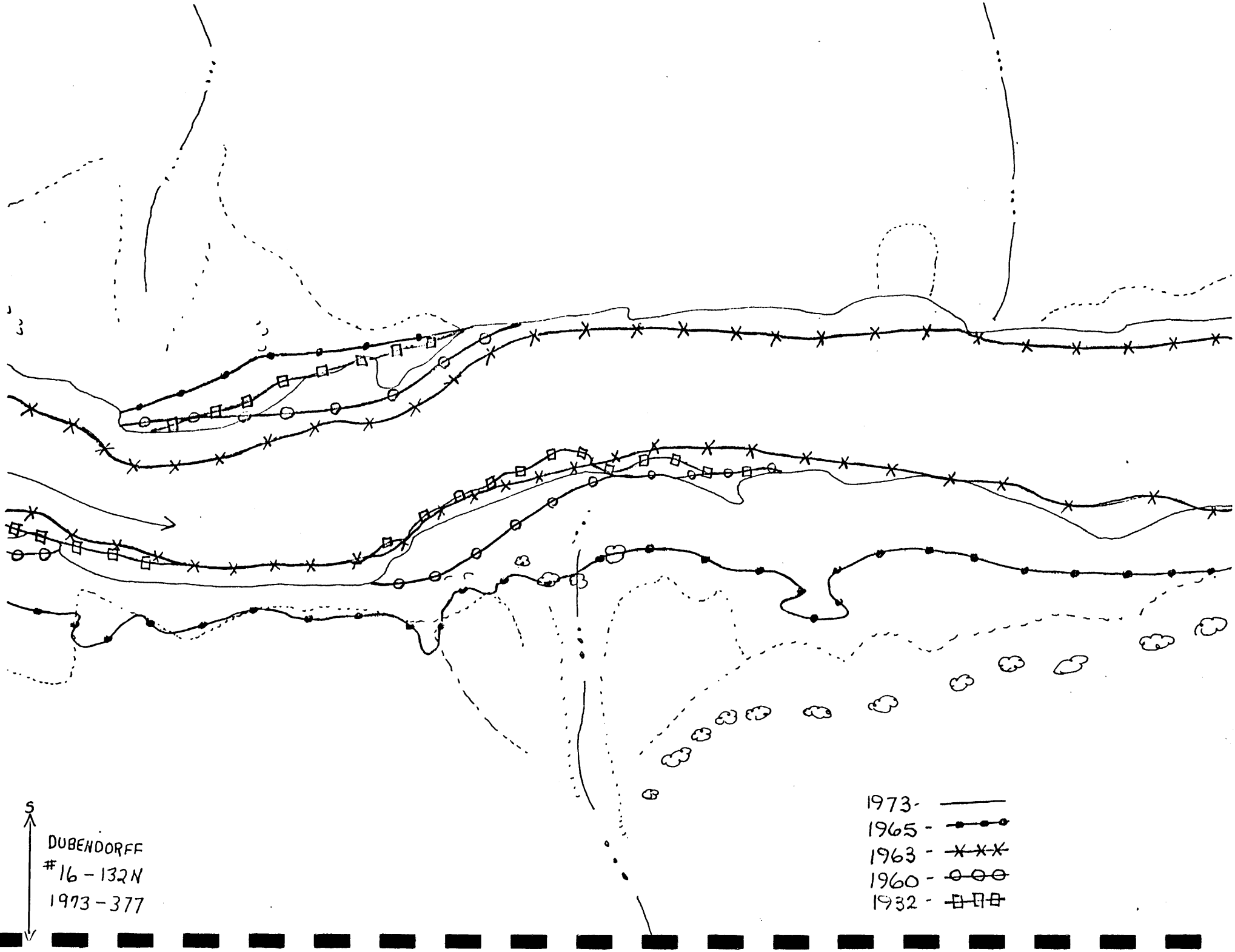
R131-0: CROSS-SECTION #1, AT 6'4" FROM BS1 TOWARDS BS2 AT ANGLE OF 103° CLOCKWISE FROM BS1
ELEVATION DATUM: NAIL AT BS1

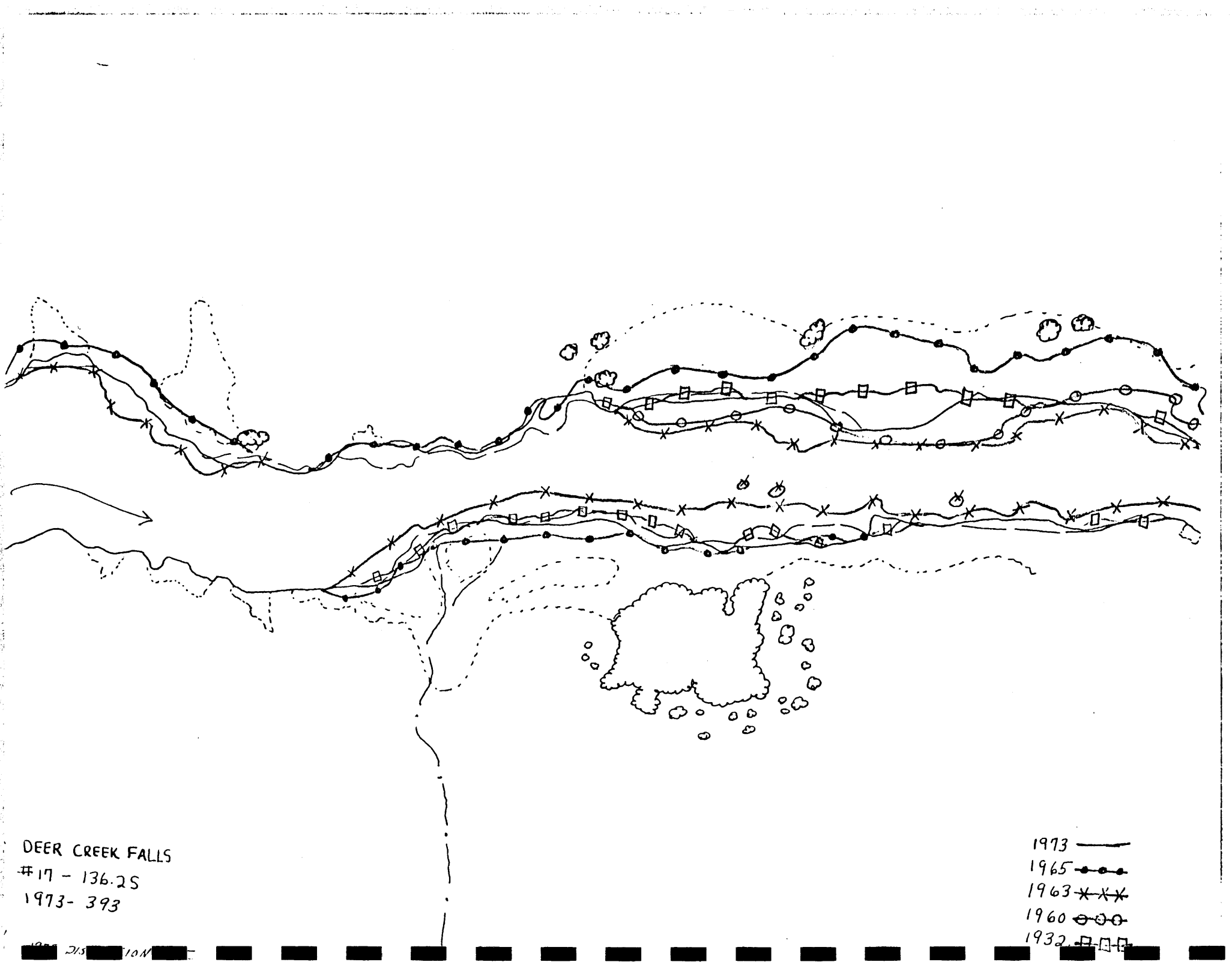


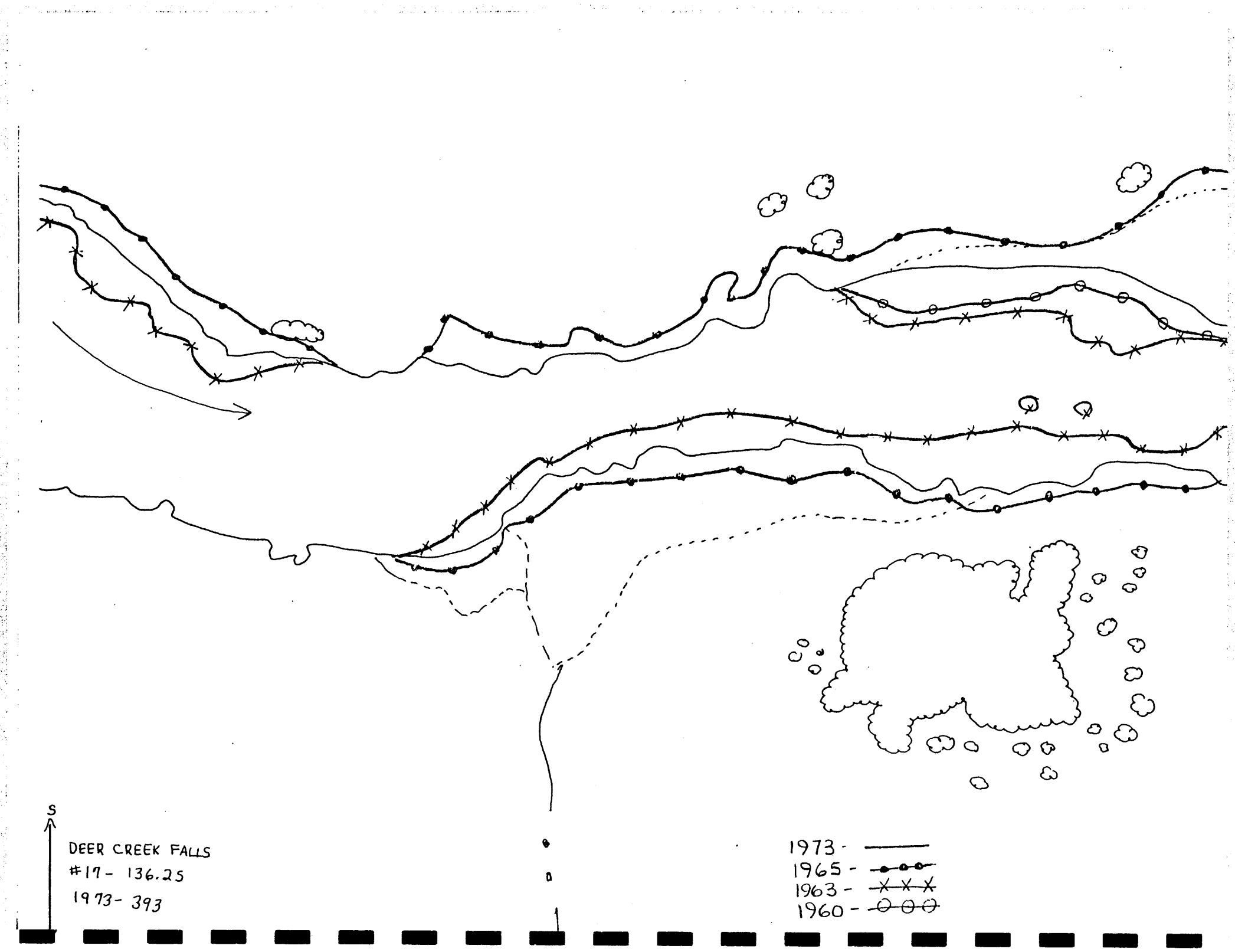
R131.0 : CROSS-SECTION #2, AT 35'0" FROM BS1 TOWARDS BS2 AT AN ANGLE OF 105° COUNTERCLOCKWISE FROM BS1
ELEVATION DATUM: NAIL AT BS1

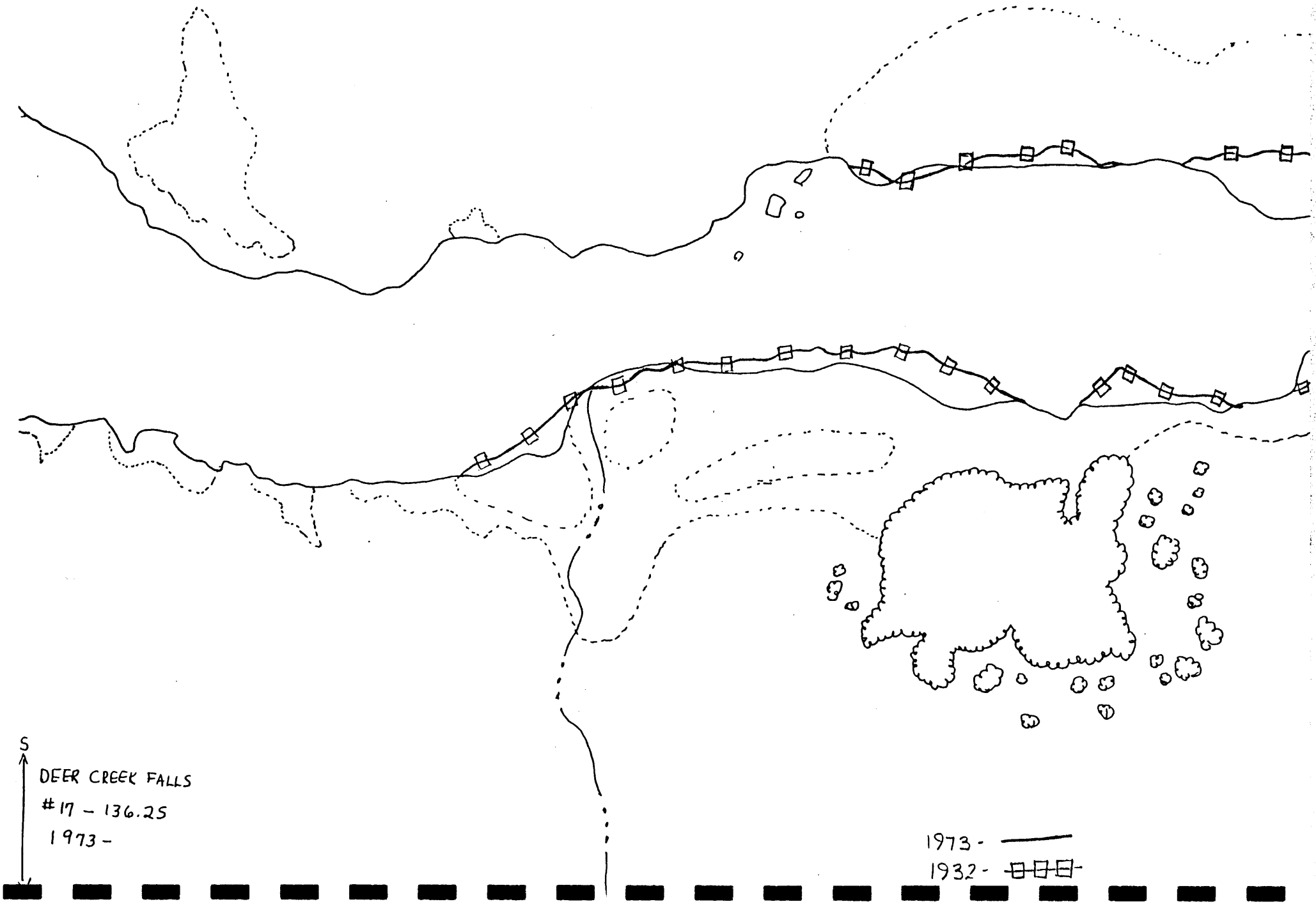



S
DUBENDORFF
#16-132N
1973
1965
1963
1960
1932

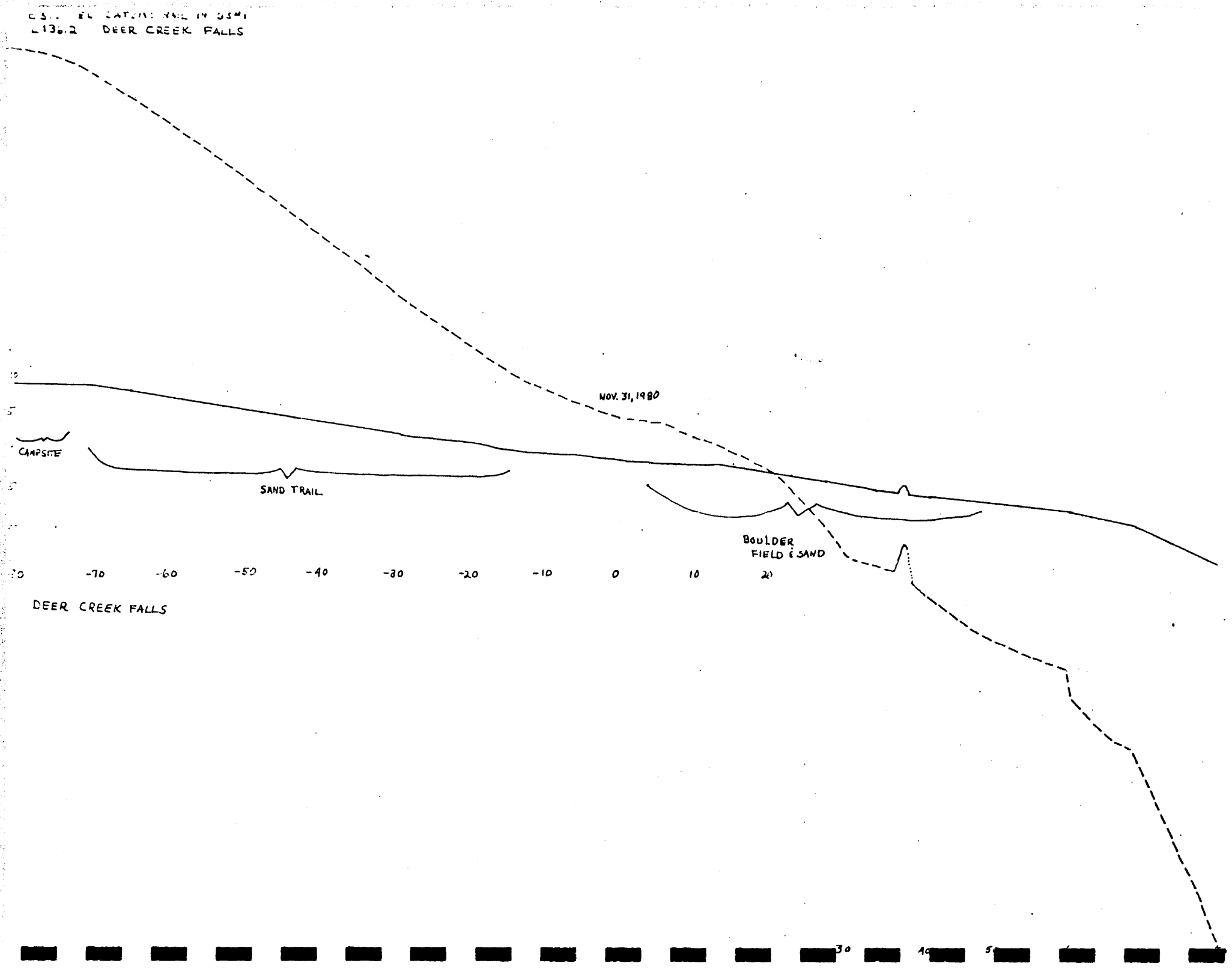

S
DUBENDORFF
#16 - 132N
1973 - 377
1973 -
1965 -
1963 -
1960 -
1932 -

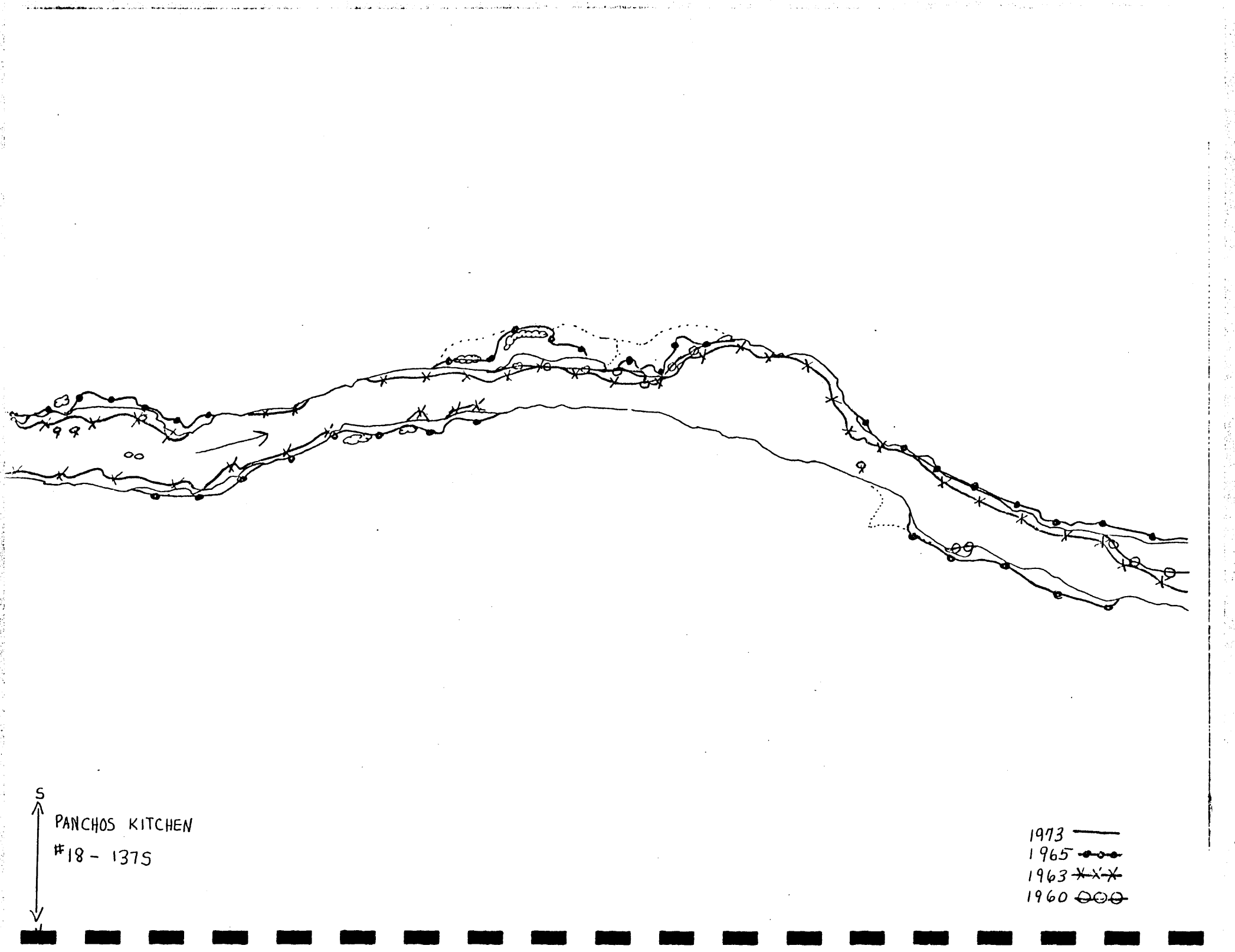

DEER CREEK FALLS
#17 - 136.2S
1973- 393
1973
1965
1963
1960
1932

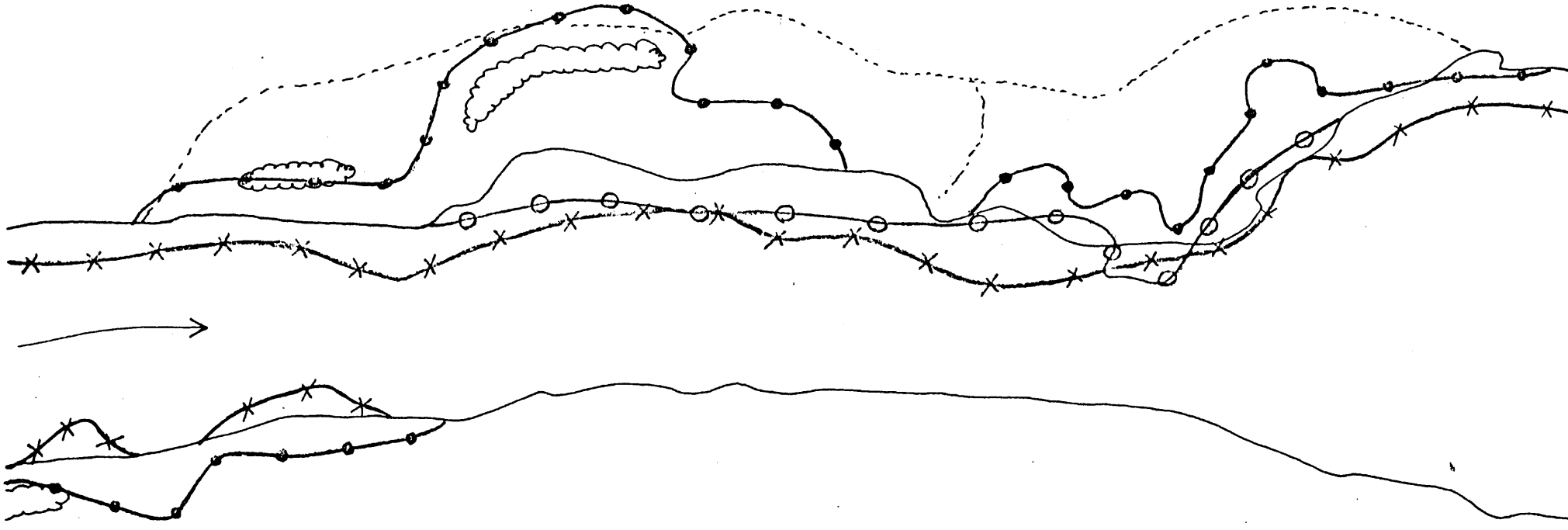

S
DEER CREEK FALLS
#17 - 136.25
1973 - 393
1973 -
1965 -
1963 -
1960 -


S
DEER CREEK FALLS
#17 – 136.25
1973 -
1973 -
1932 -

C.S. EL. DATUM: NAIL IN USM
L136.2 DEER CREEK FALLS




S
PANCHOS KITCHEN
#18 - 1375
1973
1965
1963
1960



S

PANCHOS KITCHEN

#18 - 137 S

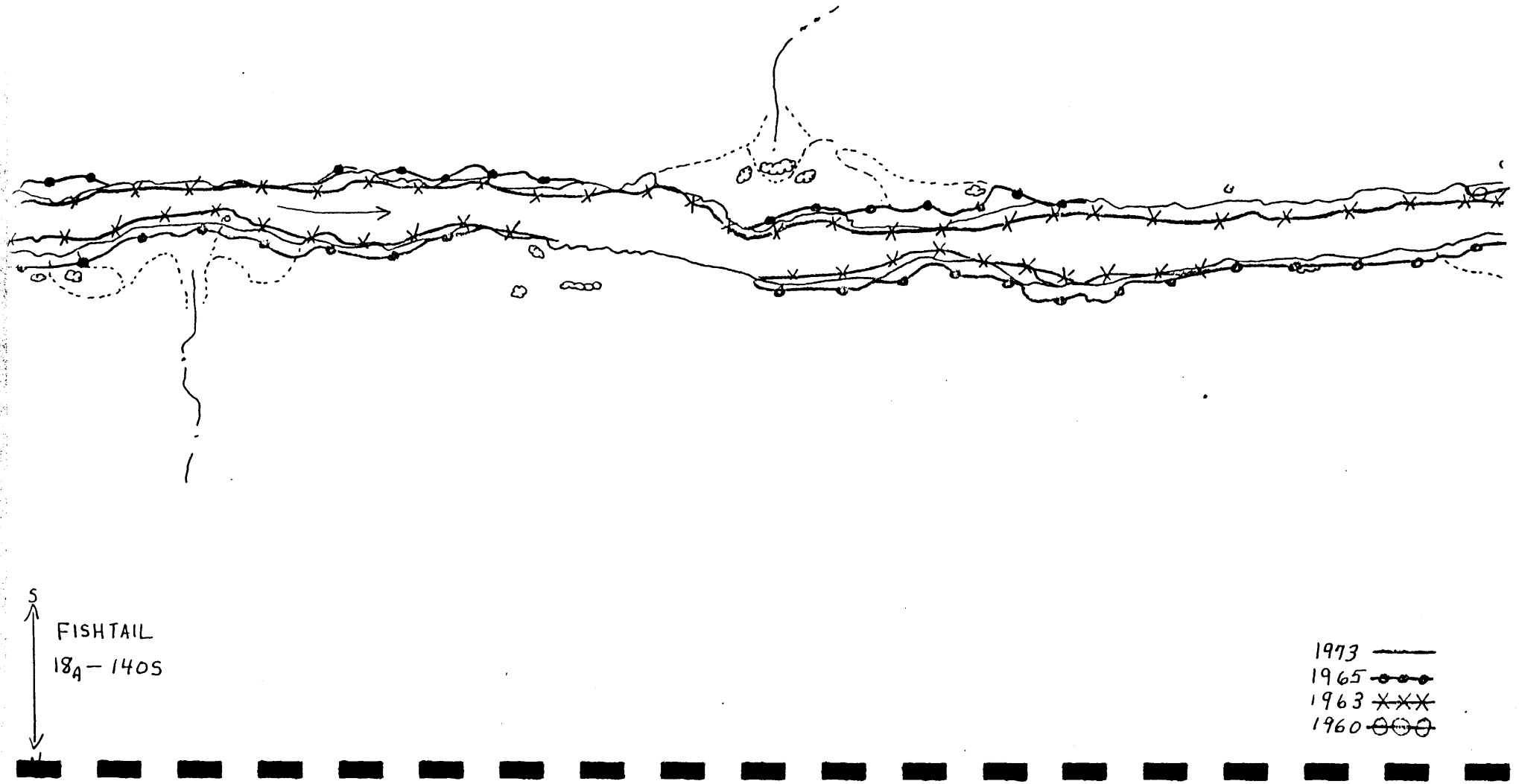
1973 - 395

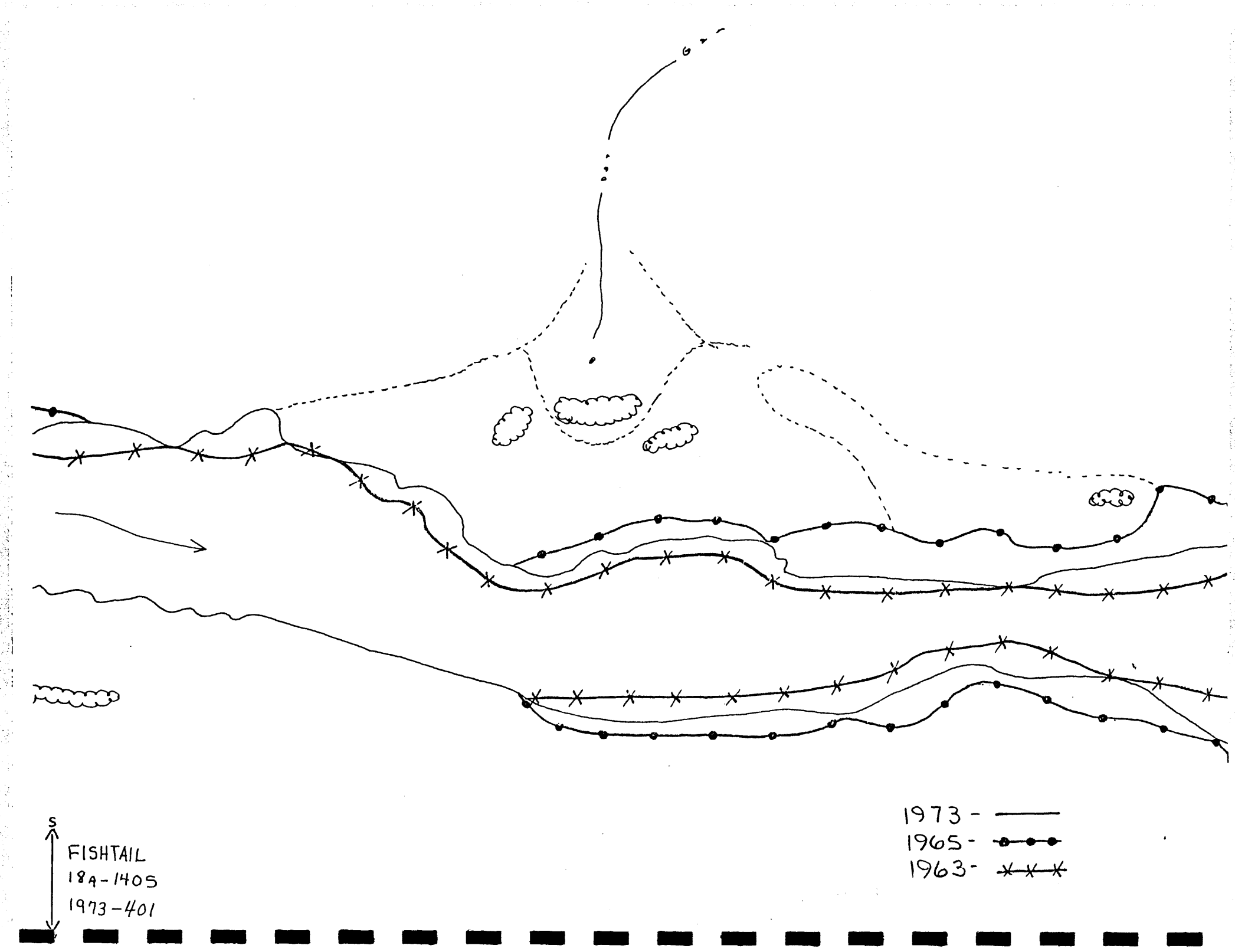
1973 -

1965 -

1963 -

1960 -

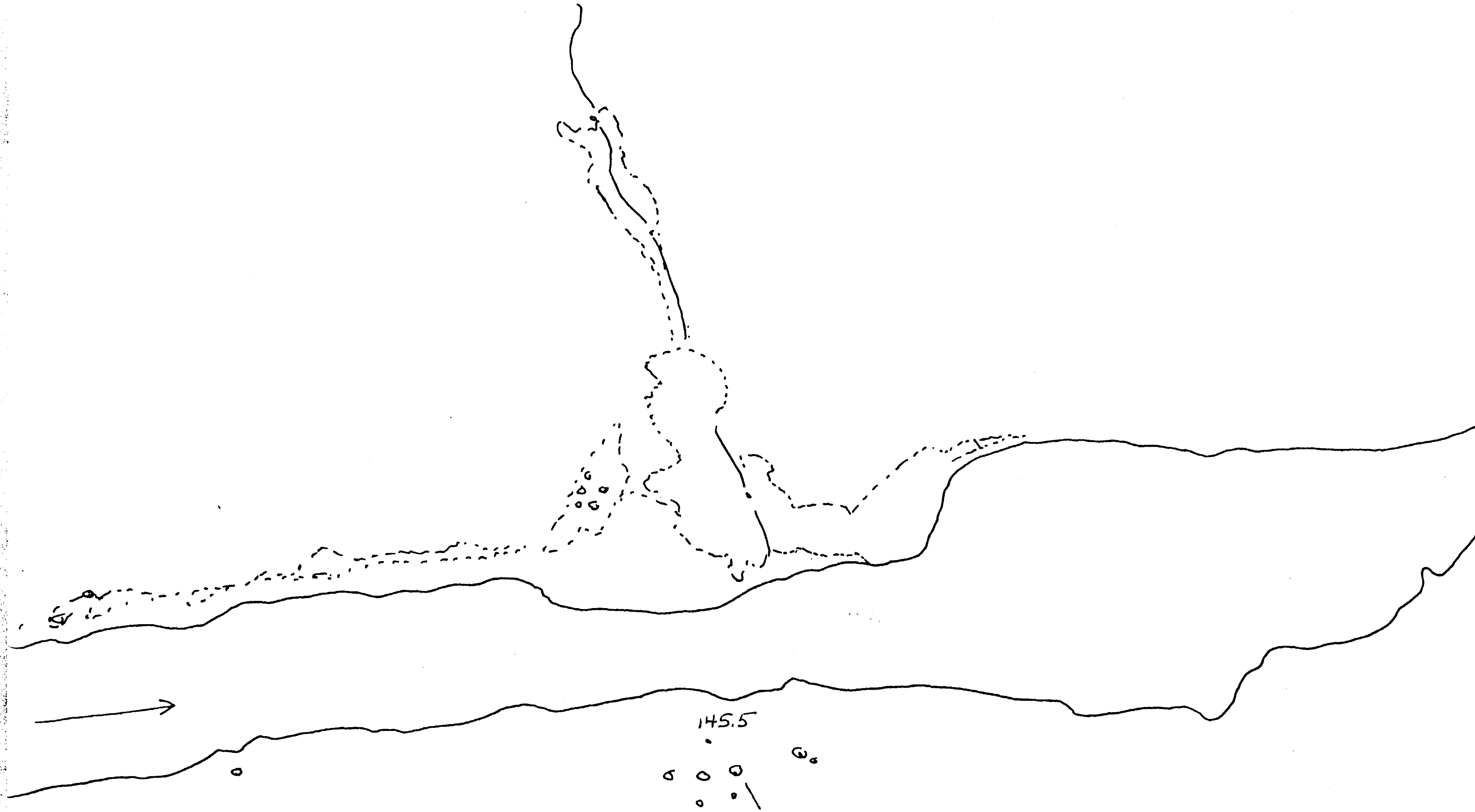

S
FISHTAIL
18A – 140S
1973
1965
1963
1960


S
FISHTAIL
184-1405
1973-401
1973 -
1965 -
1963 -

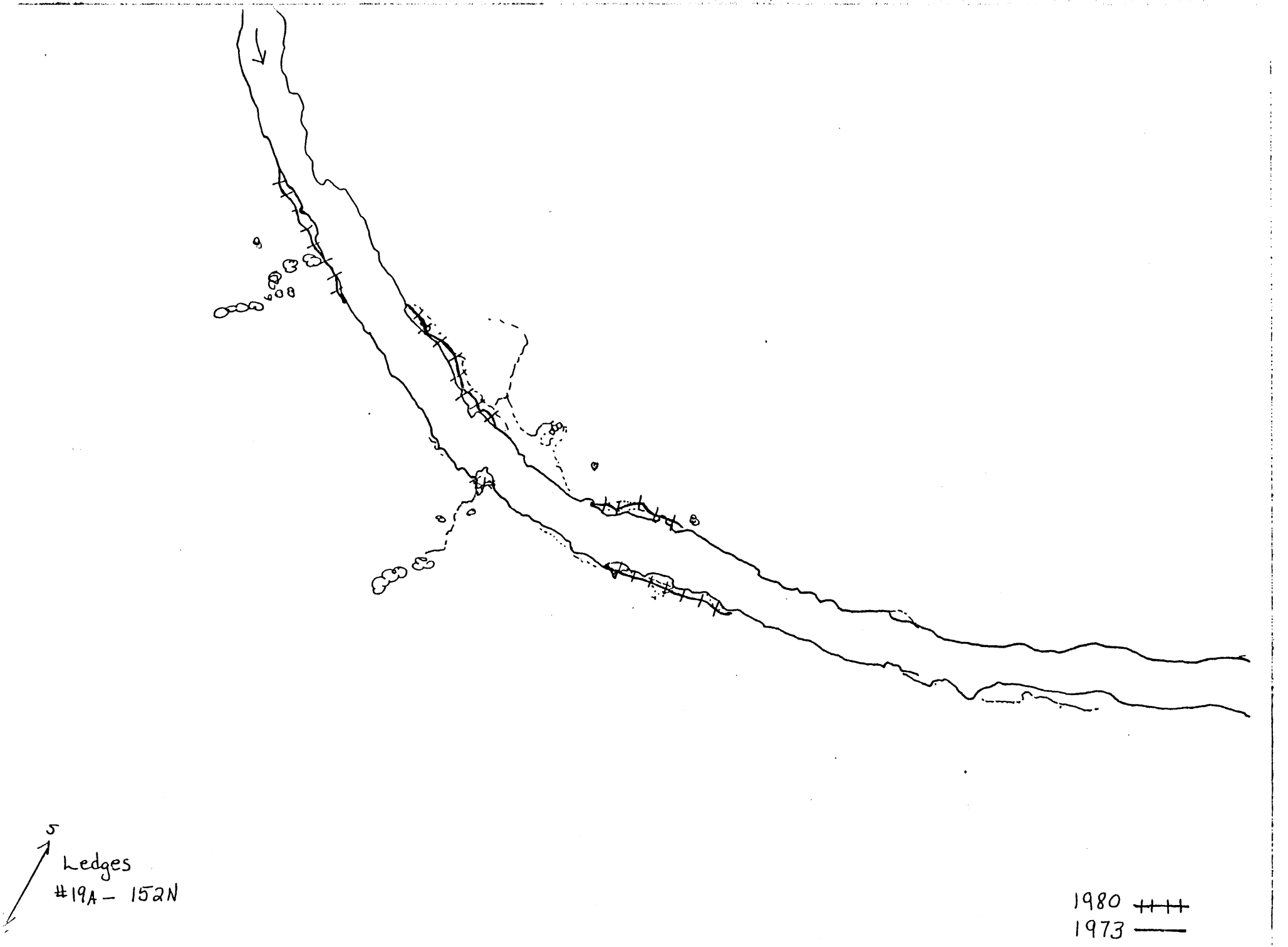
S

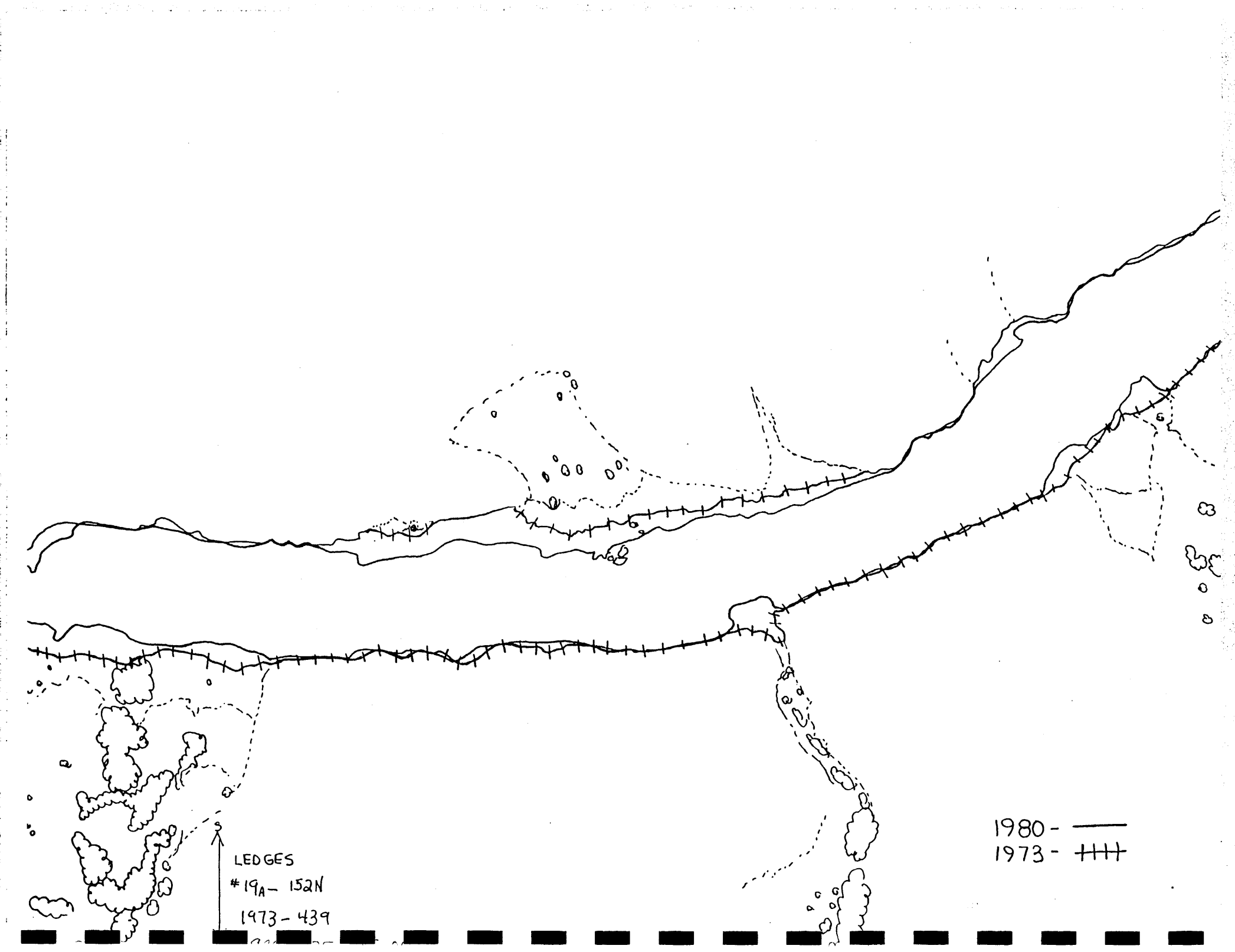
OLO CANYON

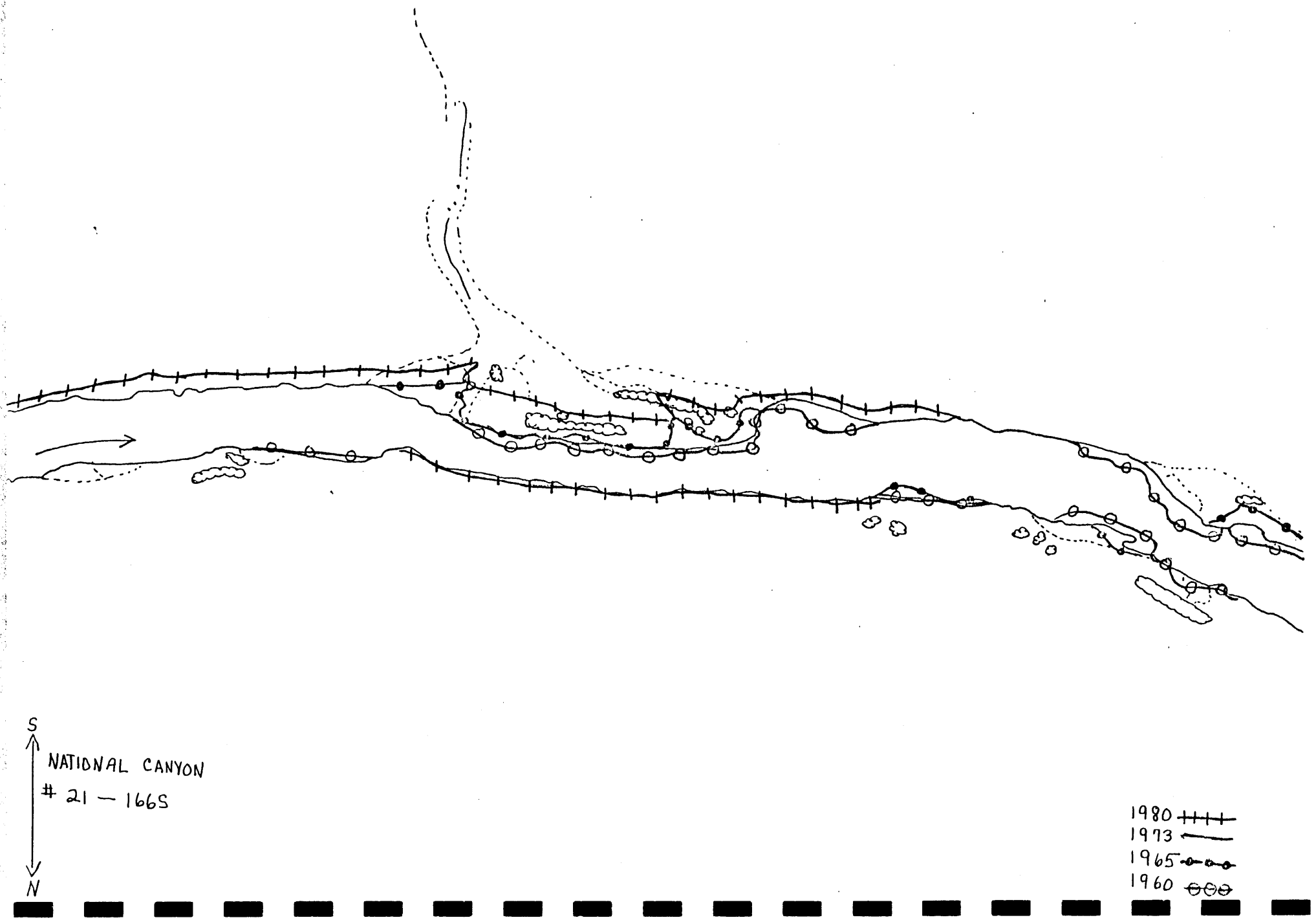
#19-1465

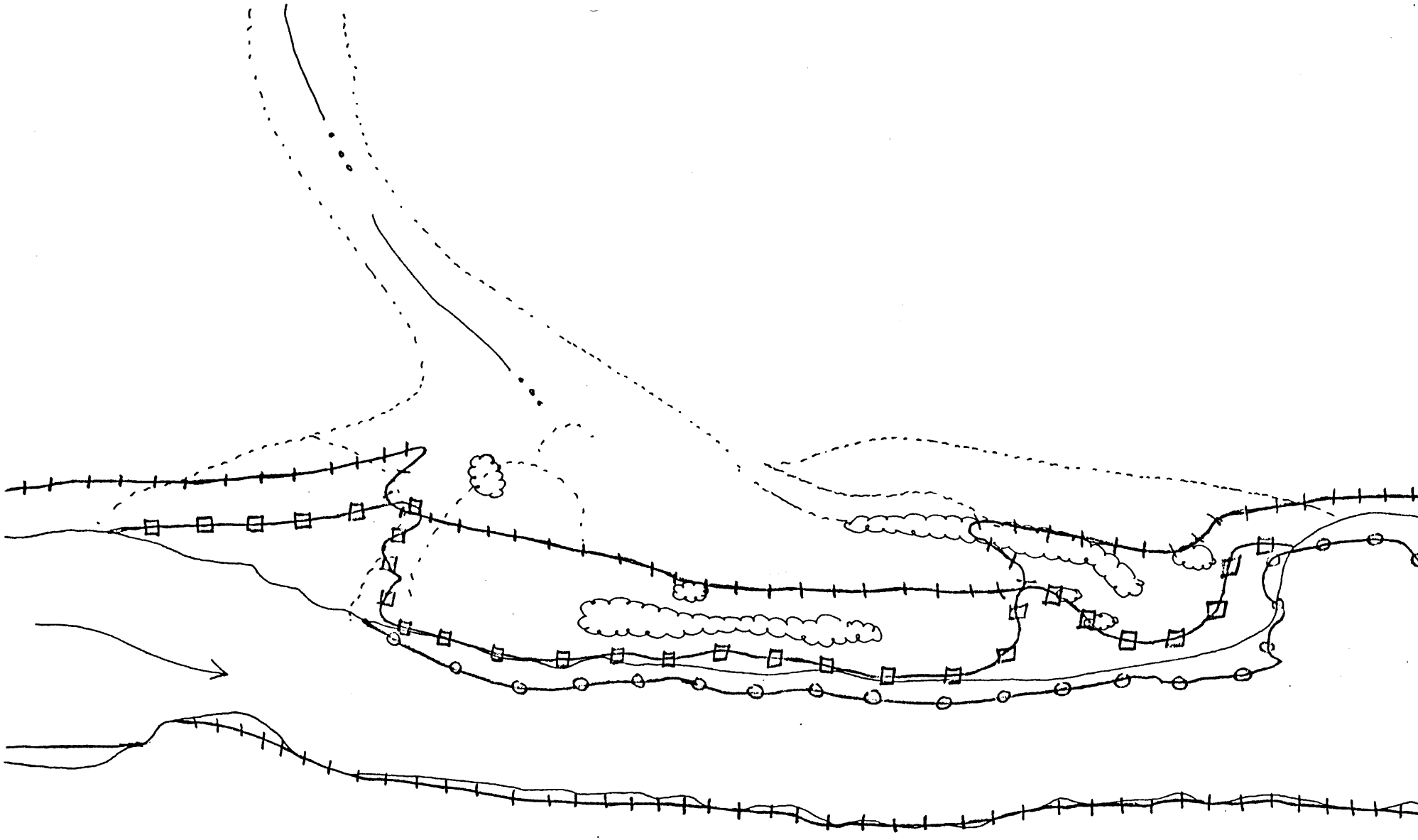


OLO CANYON
#19 - 146.5
1973 - 4/17

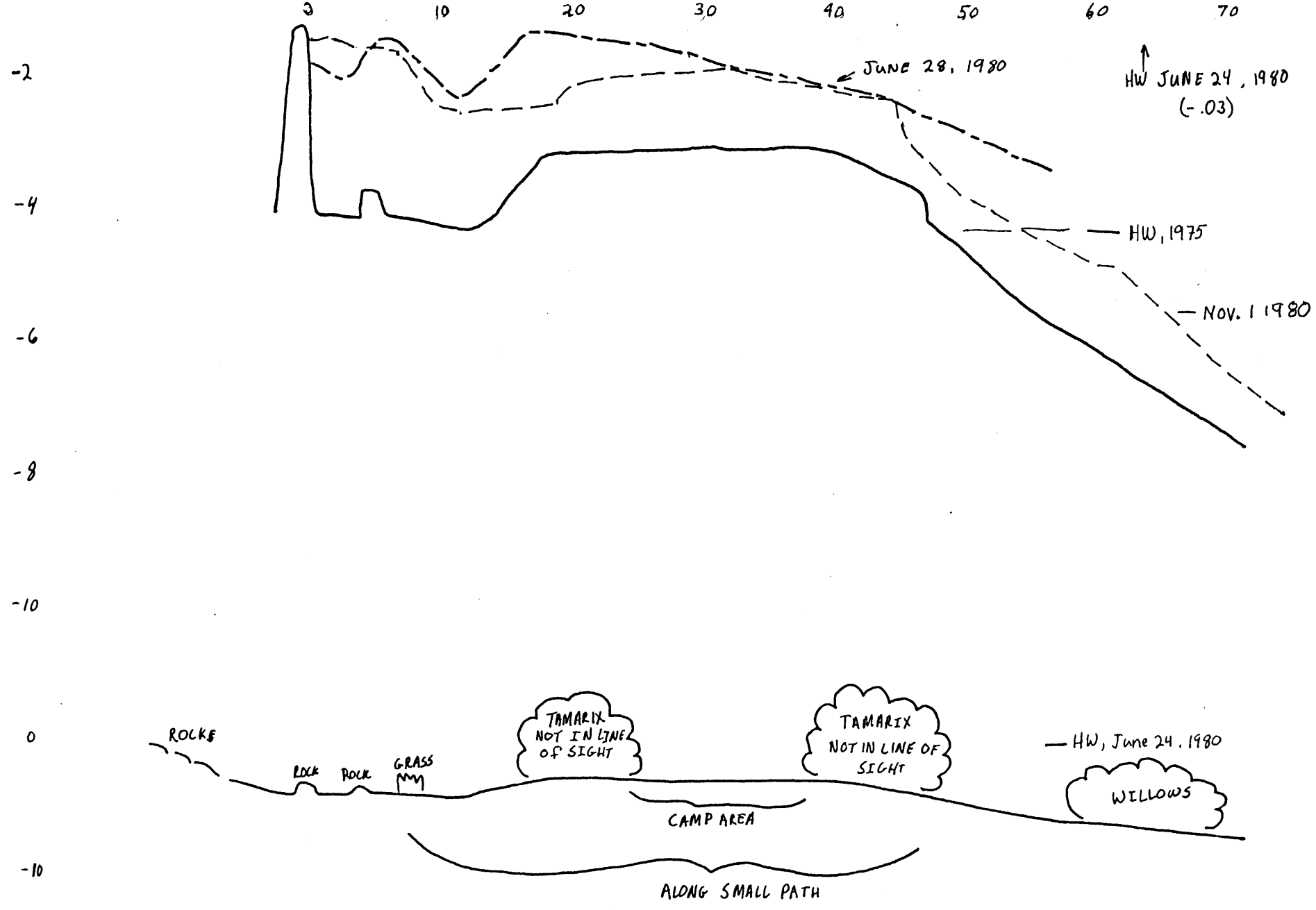

S
Ledges
#19A – 152N
1980
1973

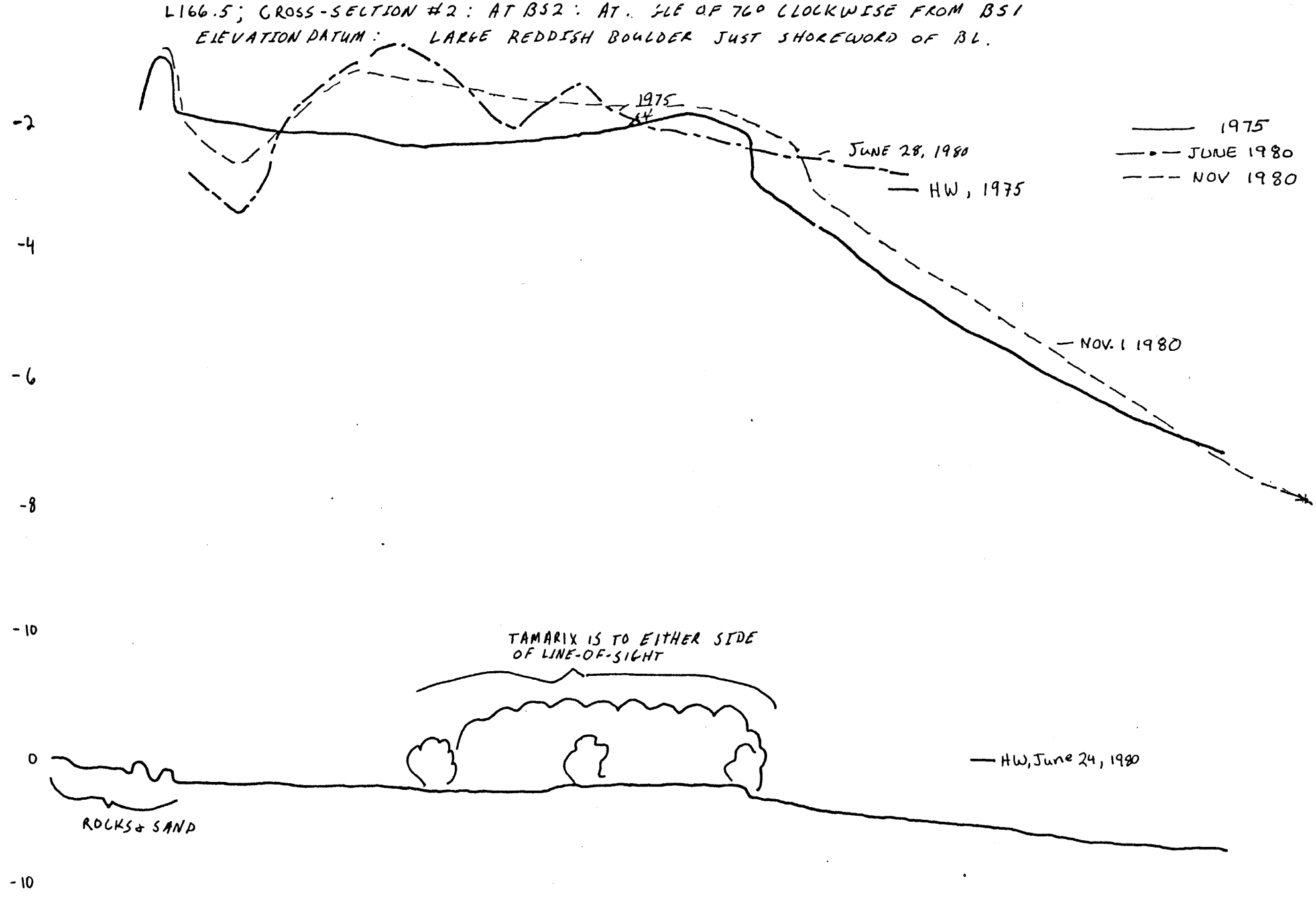

LEDGES
#19A- 152N
1973- 439
1980- ——
1973- +++

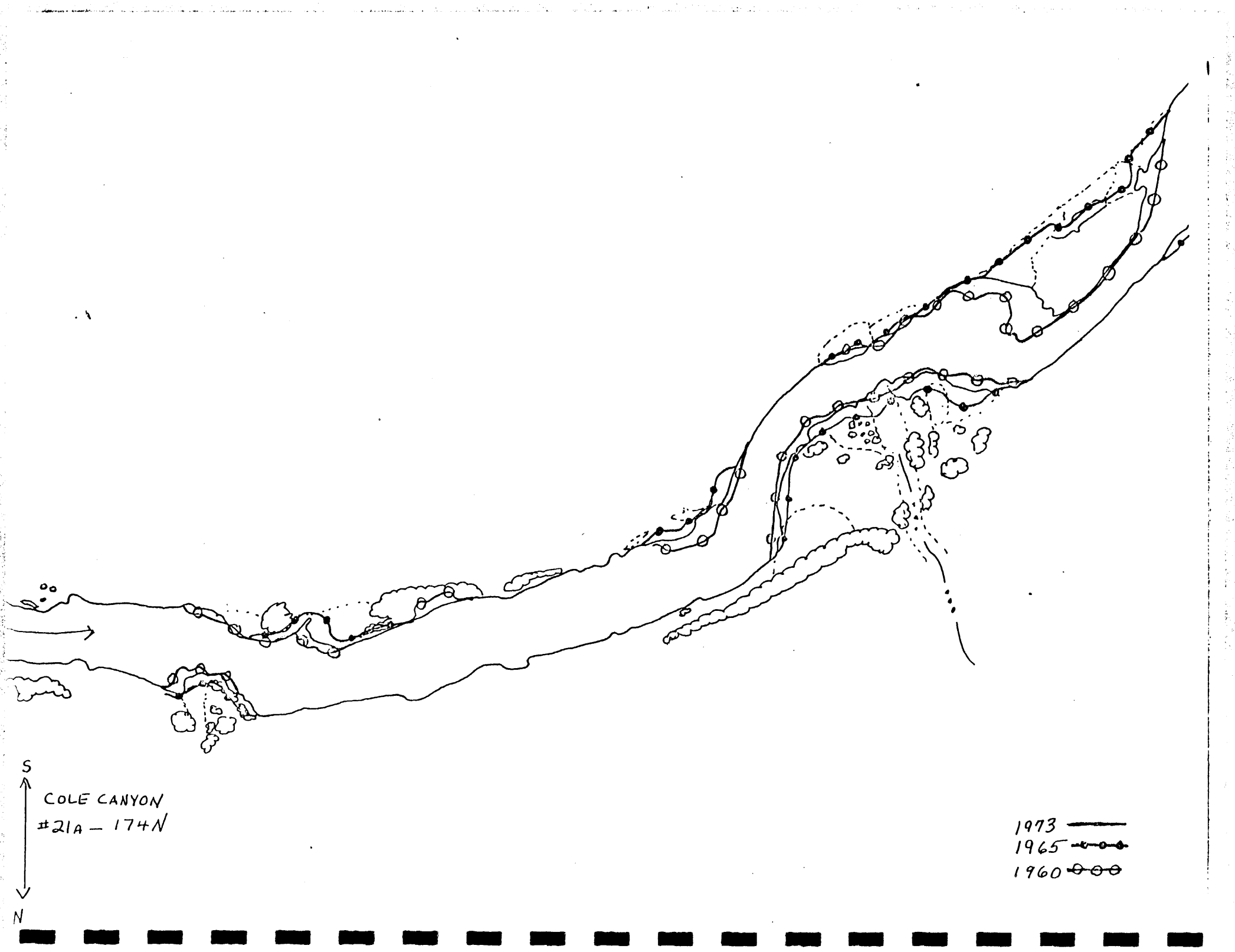

S
N
NATIONAL CANYON
21 — 1665
1980
1973
1965
1960


1980 -
1973 -
1960 -
1932 -
S
NATIONAL CANYON
#21 – 1665
1973 – 487
1980 – 27-01

L 166.5: CROSS-SECTION #1: AT BS1; 106°30 COUNTERCLOCKWISE FROM BS2
ELEVATION DATUM: LARGE REDDISH, ROUNDED BOULDER SHOREWORD OF BL



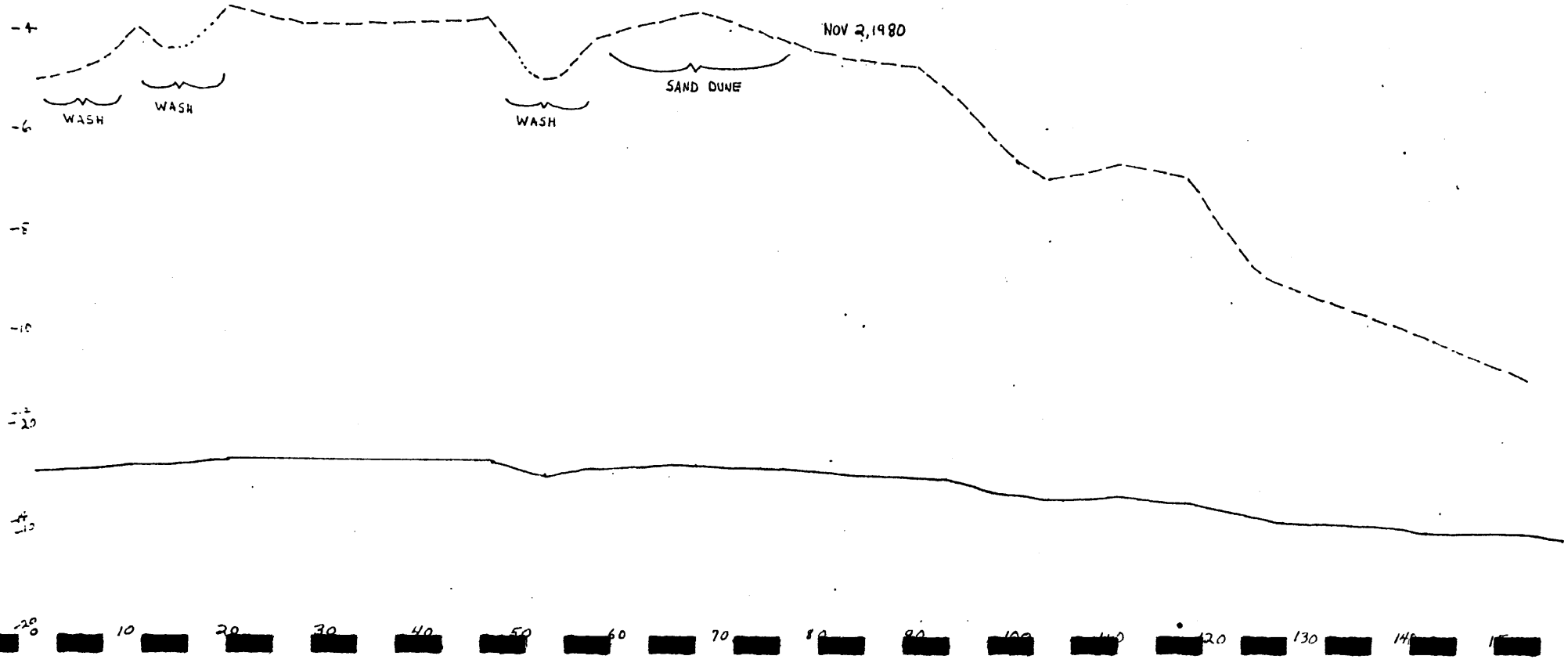

L166.5; CROSS-SECTION #2 : AT BS2 : AT. ⅄LE OF 76° CLOCKWISE FROM BS1
ELEVATION DATUM : LARGE REDDISH BOULDER JUST SHOREWORD OF BL.
1975
JUNE 28, 1980
HW, 1975
NOV. 1 1980
1975
JUNE 1980
NOV 1980
-2
-4
-6
-8
-10
0
-10
TAMARIX IS TO EITHER SIDE OF LINE-OF-SIGHT
HW, June 24, 1980
ROCKS & SAND


S
N
COLE CANYON
#21A – 174N
1973
1965
1960


S
N
COLE CANYON
21A - 174N
1973 - 507
1973 -
1965 -
1960 -

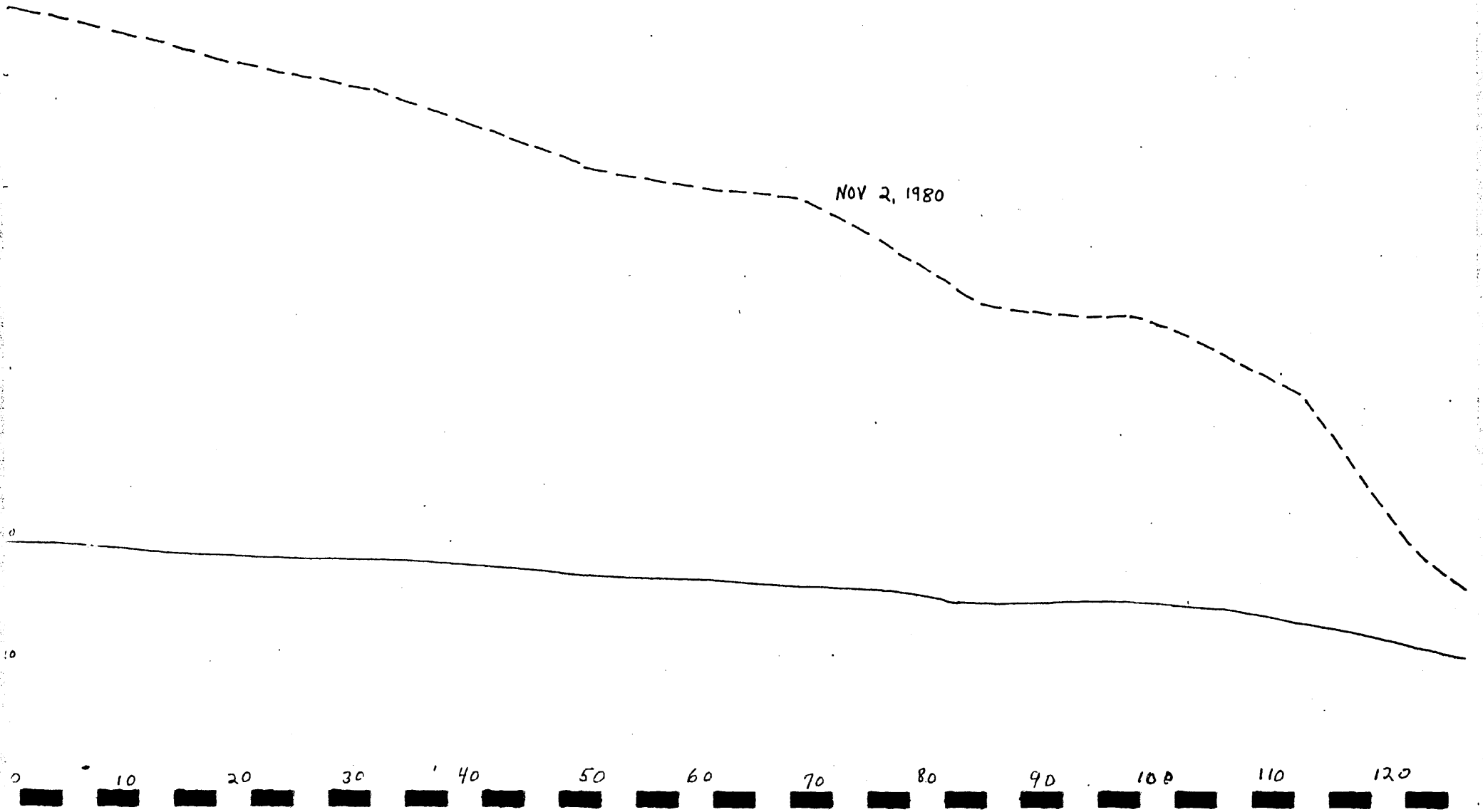
R174.3: COVE CANYON)

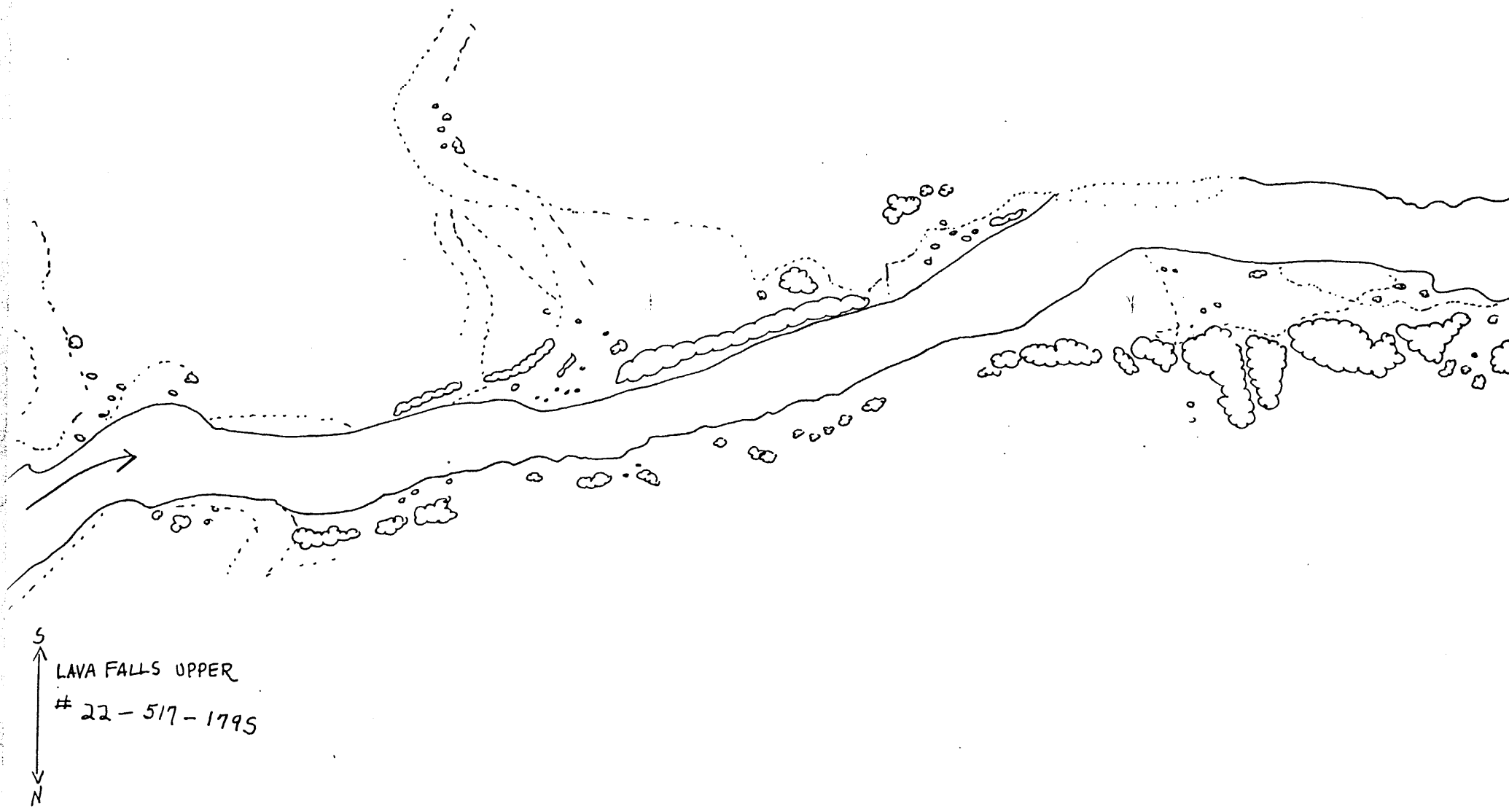
CS=2 EI DATUM: Top of Rock CONTAINING BS2



R174.3: COVE CANYON

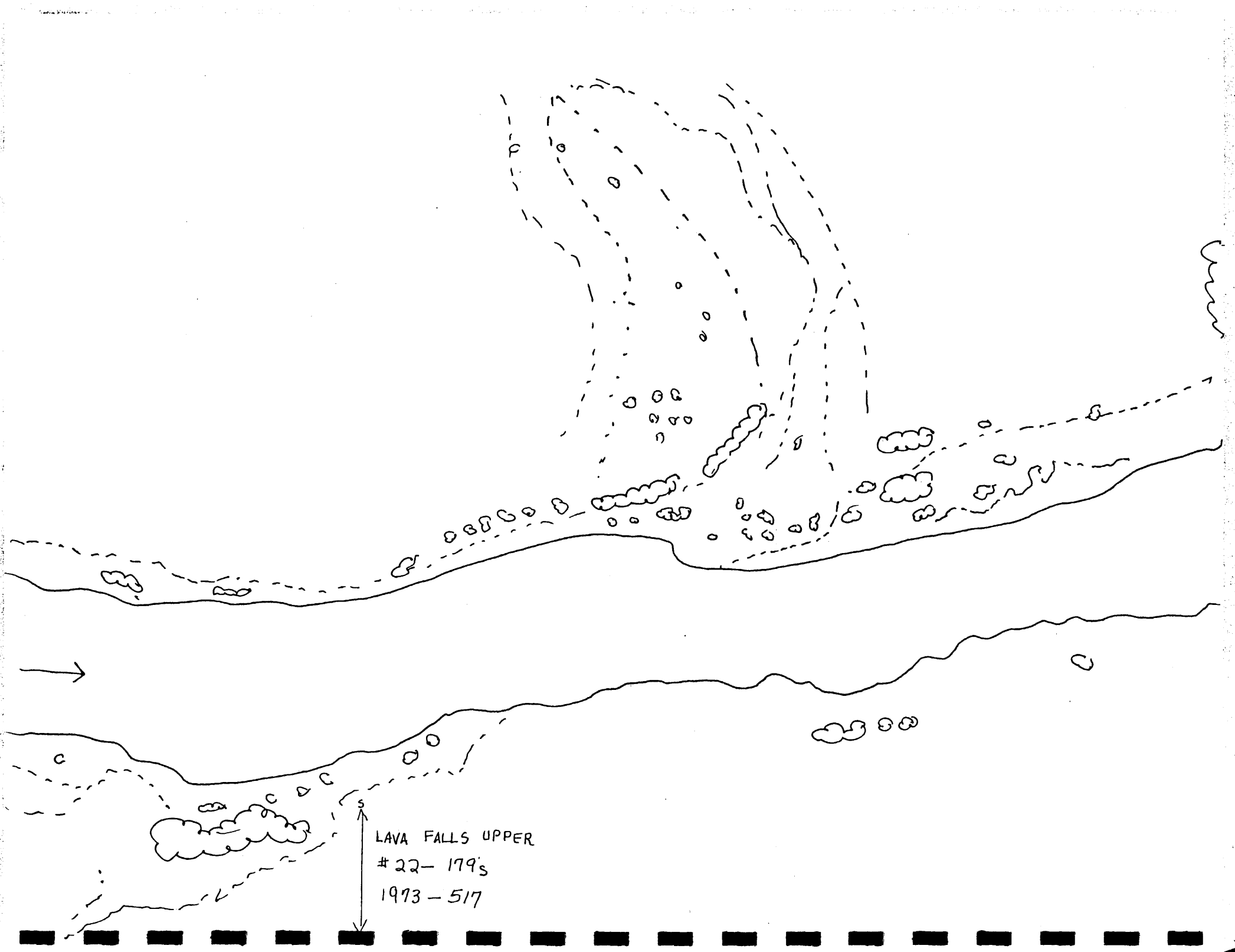
CS#1 EL. DATUM: Top of ROCK with BS#2





LAVA FALLS UPPER

22 – 517 – 1795

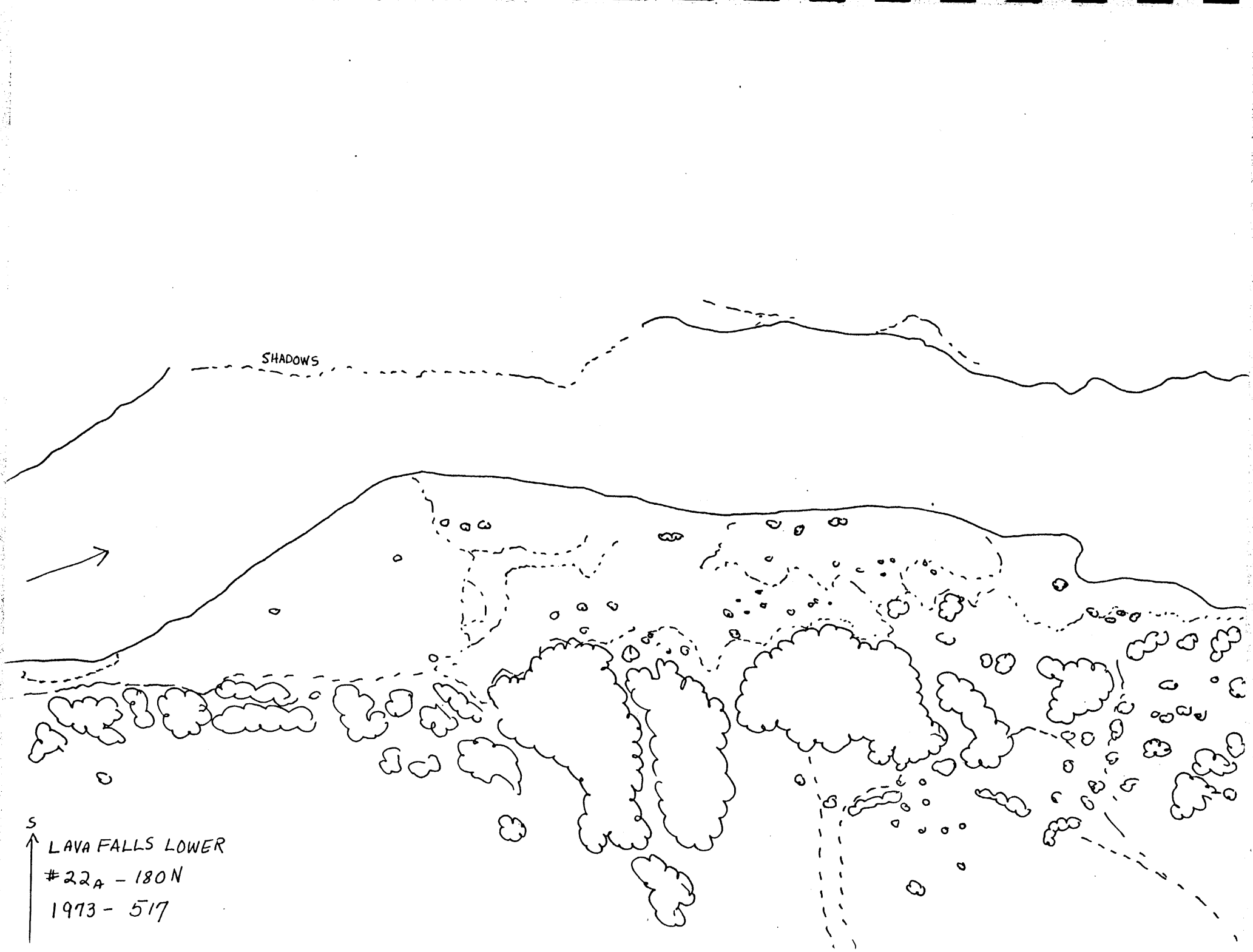

LAVA FALLS UPPER
#22– 179's
1973 – 517

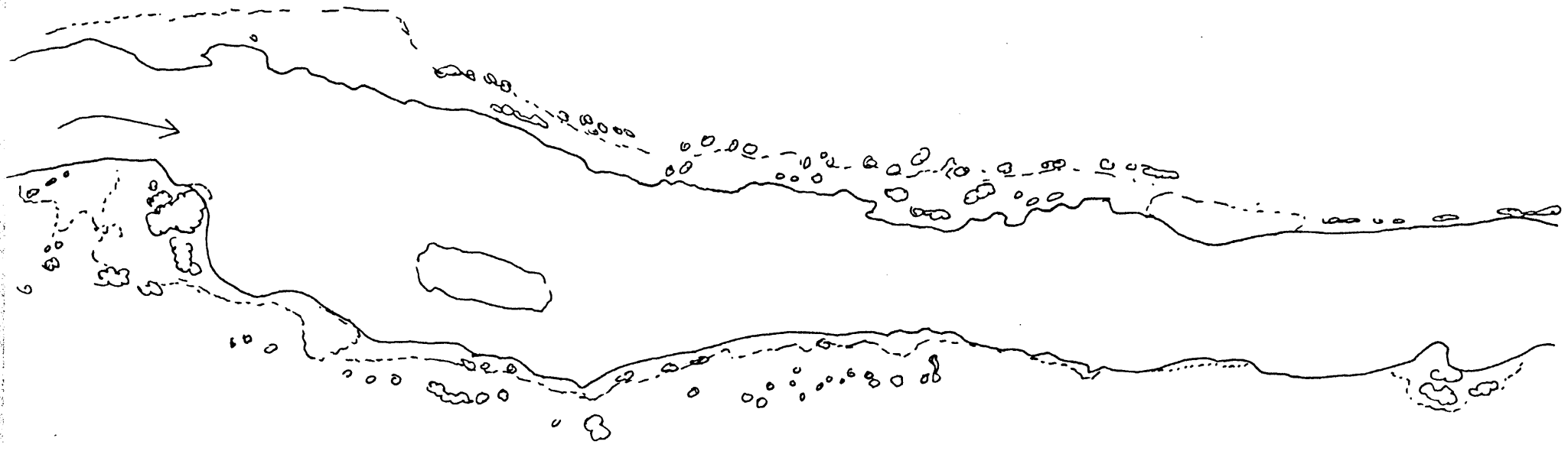
S

N

LAVA FALLS LOWER

$22_4 - 180\,N$


SHADOWS
S
LAVA FALLS LOWER
#22A - 180N
1973 - 517



S

181 MILE CAMP

#22B – 181 N

S

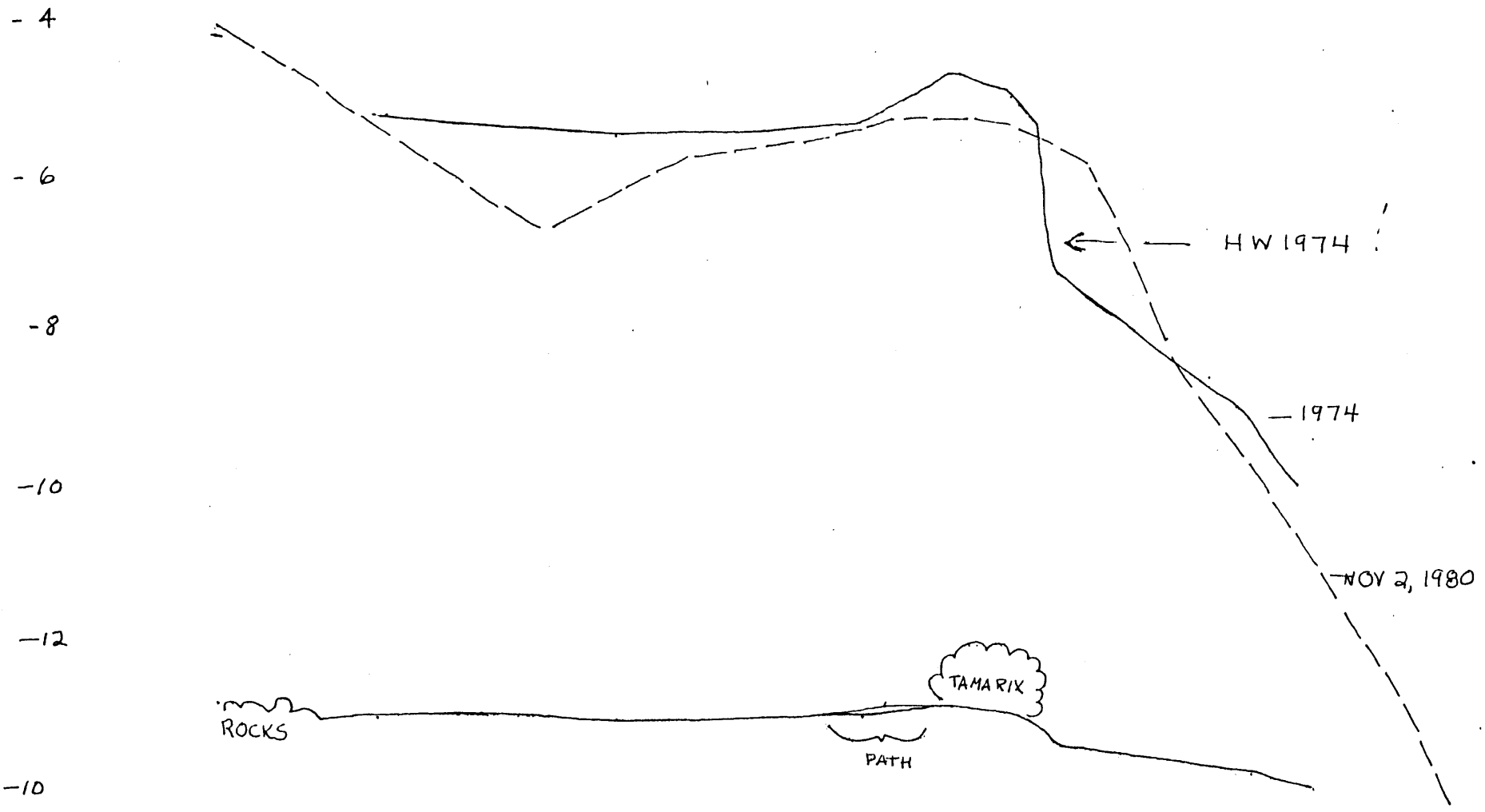
181 MILE CAMP

#22B - 181N

1973 - 5 21

R180.9 : CROSS-SECTION #2, AT 49'4" FROM BS1 TOWARDS BS2 AT ANGLE OF 109° CLOCKWISE FROM BS1

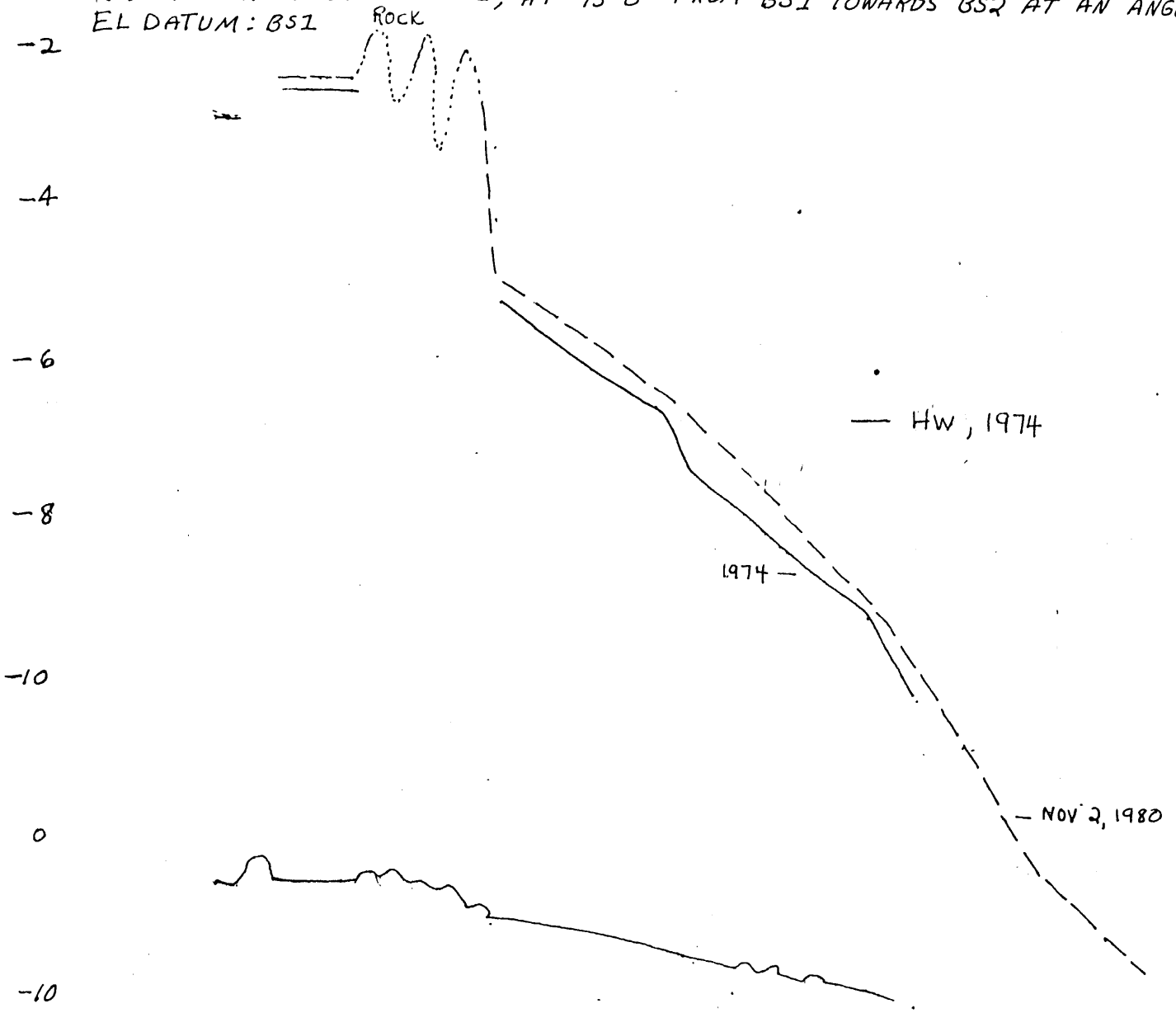
EL DATUM: BS 1



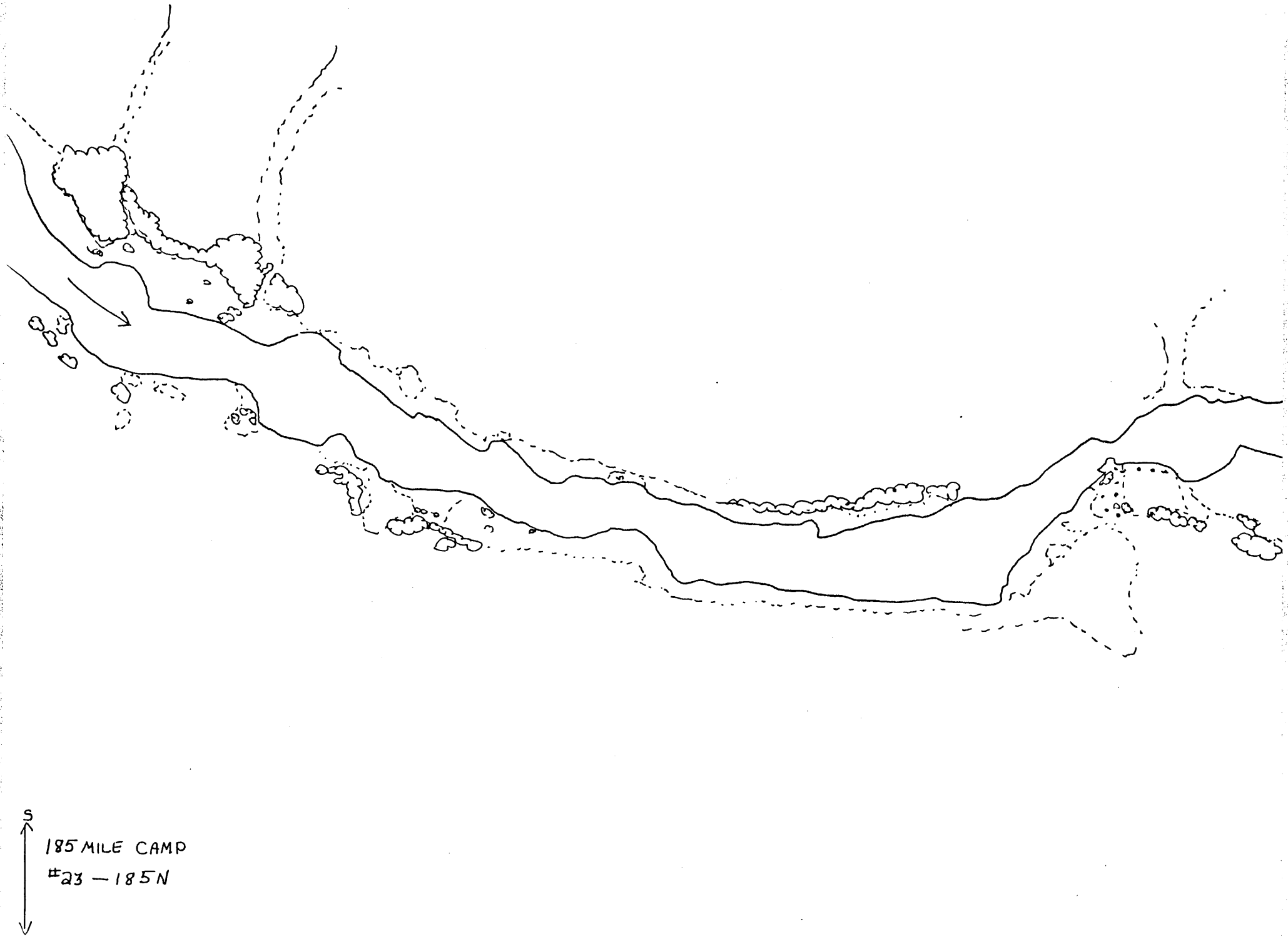
R180.9

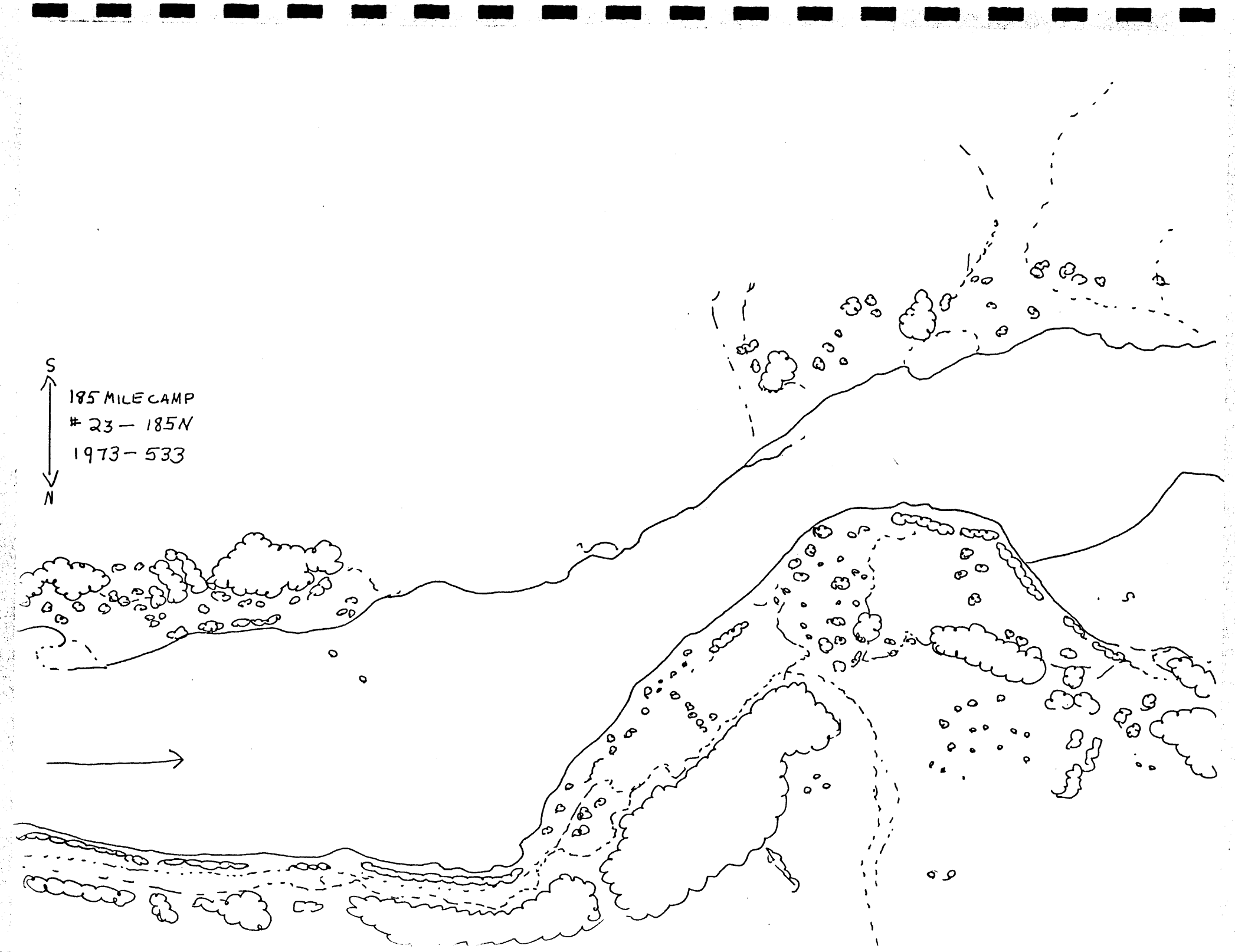
R180.9: CROSS-SECTION #1, AT 13' 0" FROM BS1 TOWARDS BS2 AT AN ANGLE OF 122° COUNTERCLOCKWISE FROM BS2

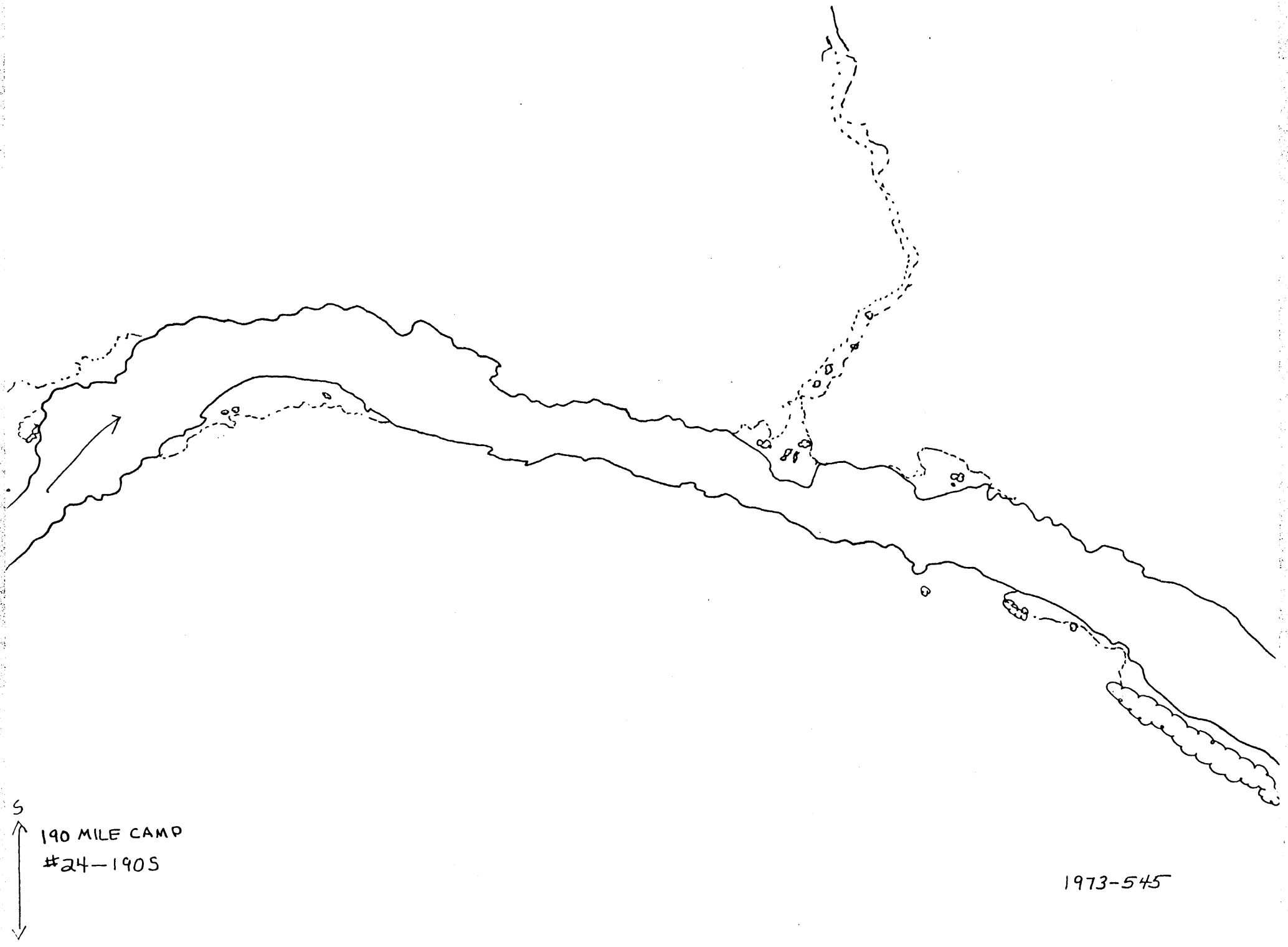
EL DATUM: BS1



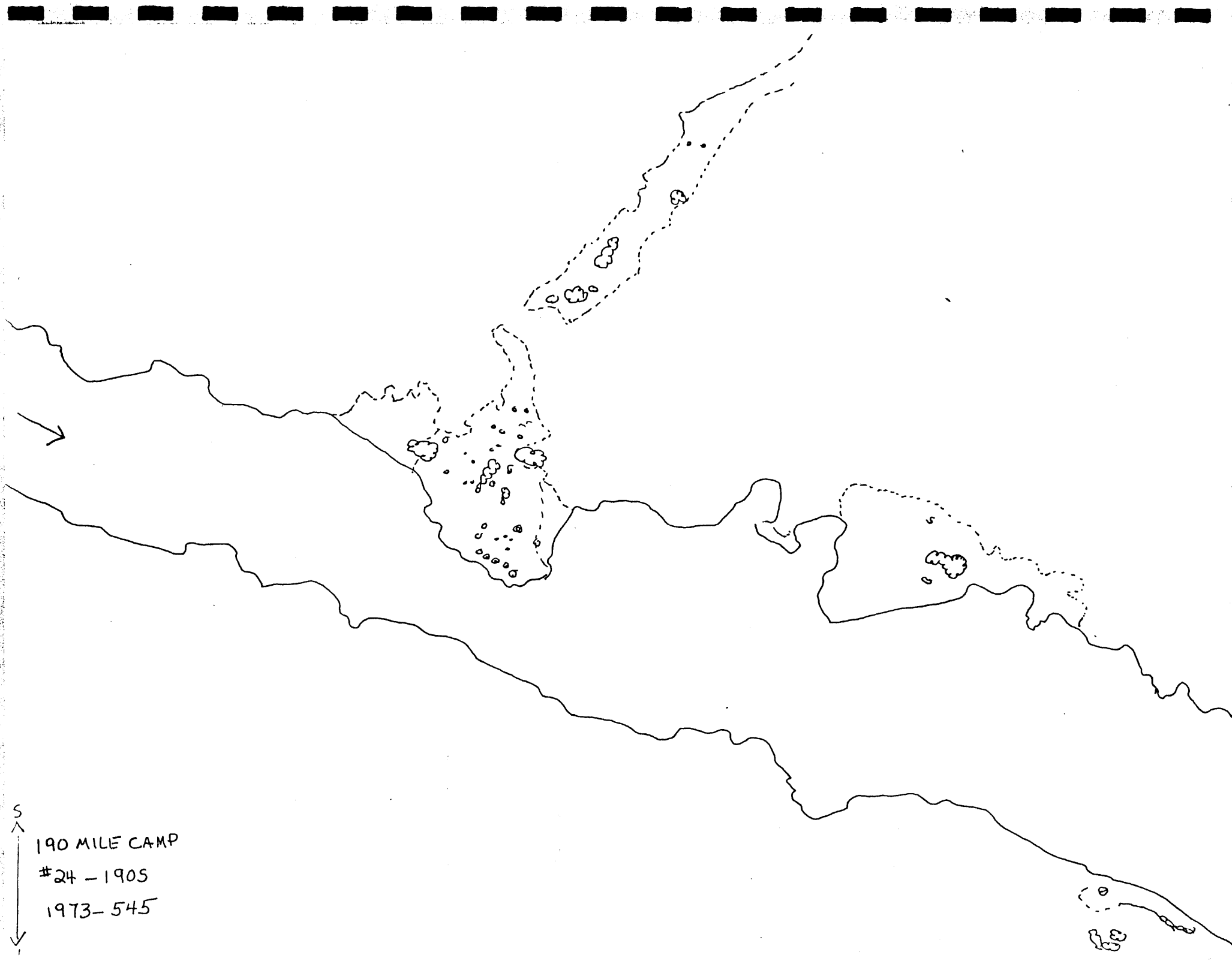
R180.9


S
185 MILE CAMP
#23 — 185N


S
N
185 MILE CAMP
23 — 185N
1973 — 533

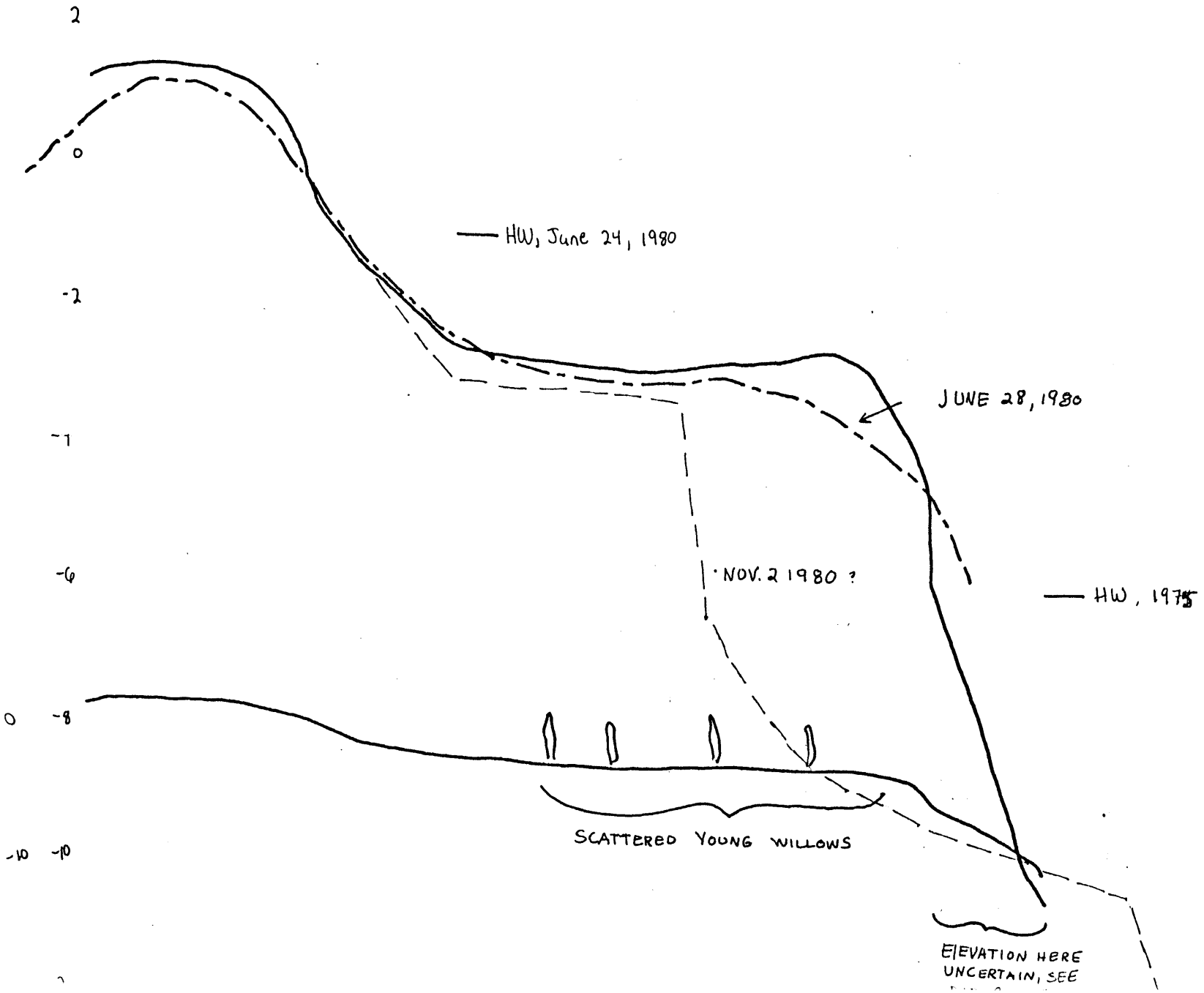


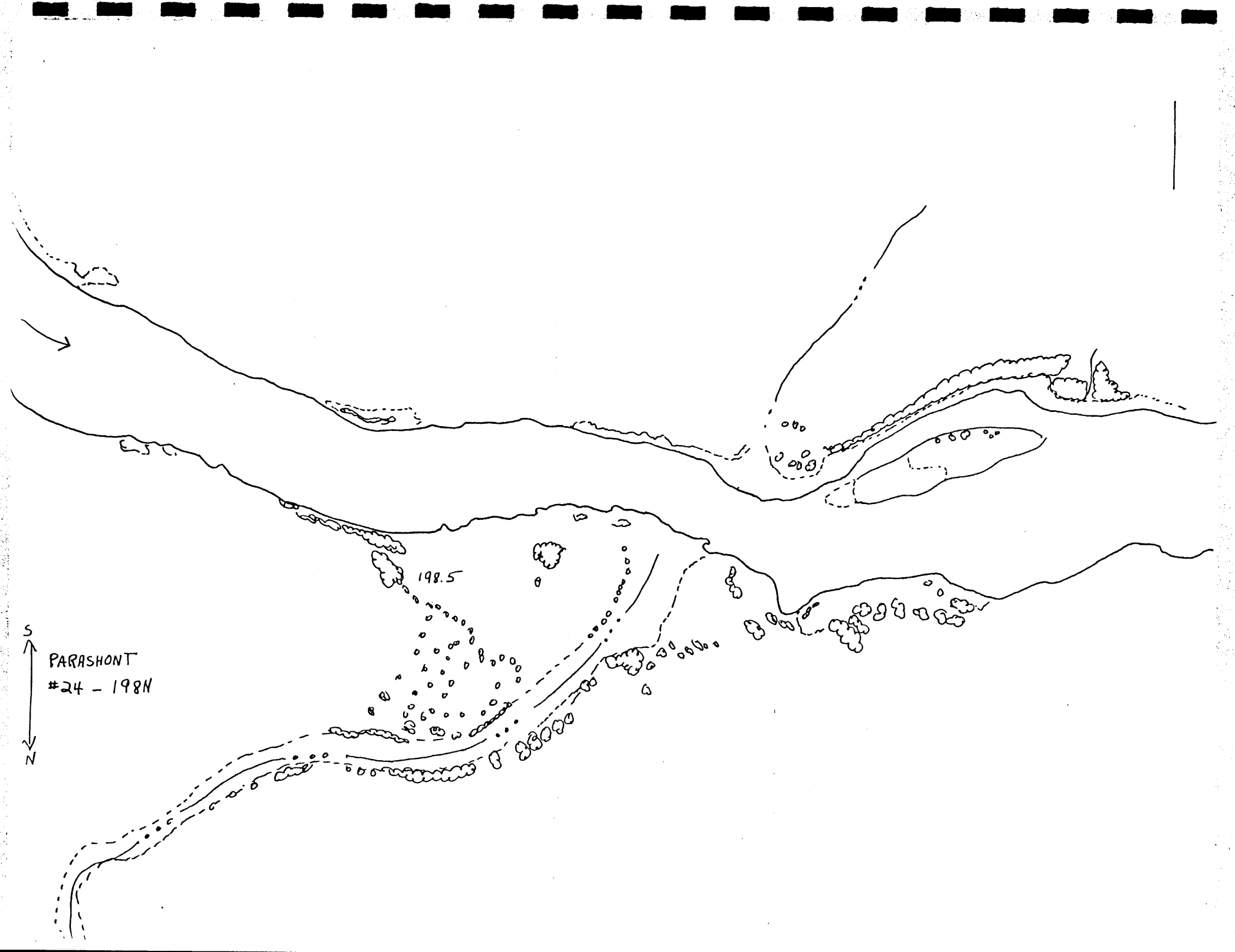
1973-545


S
190 MILE CAMP
#24 – 1905
1973 – 545

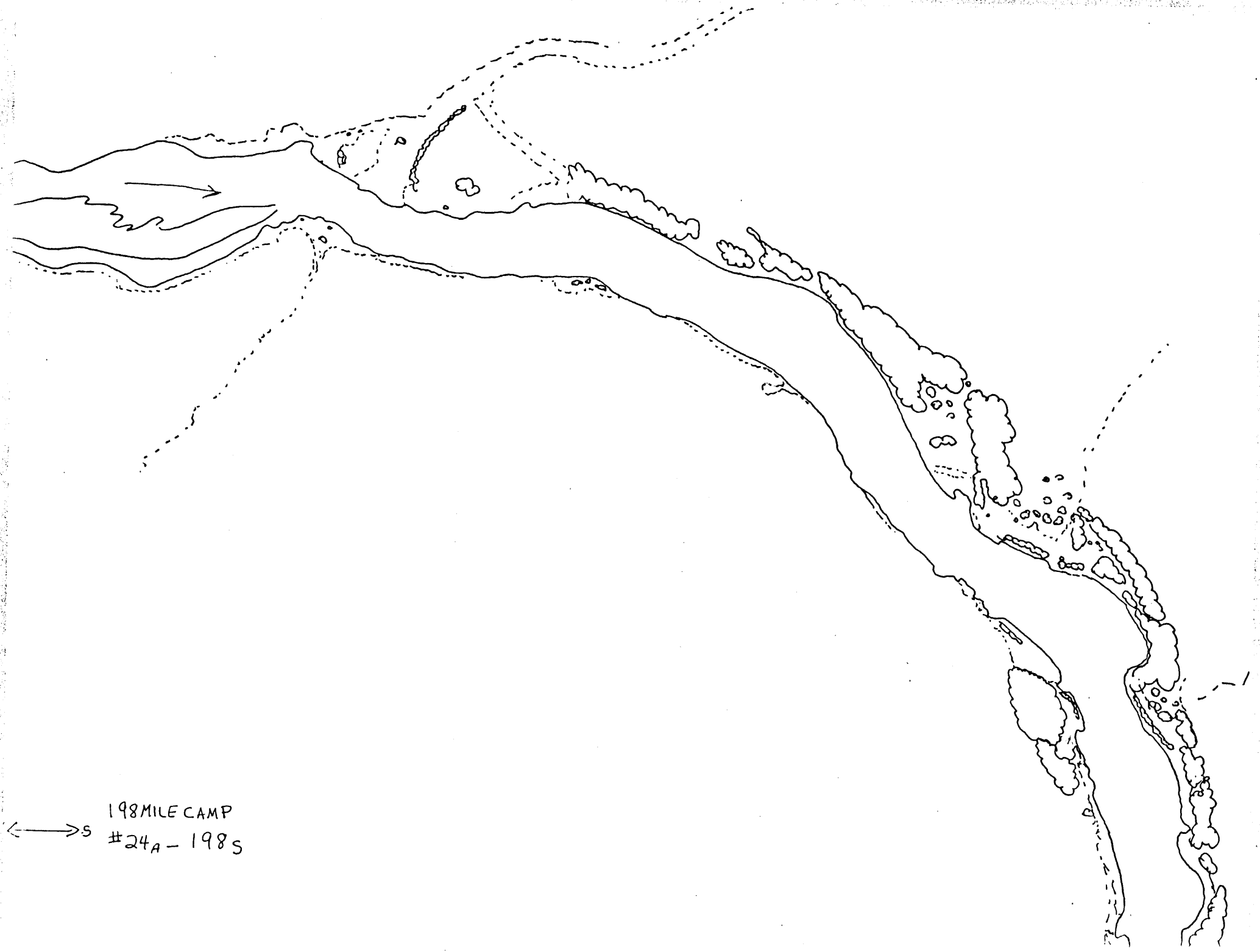
L190.2: CROSS-SECTION #1: 40' 3" FROM BS1 TOWARDS BS2. ANGLE OF 105° CLOCKWISE FROM BS2

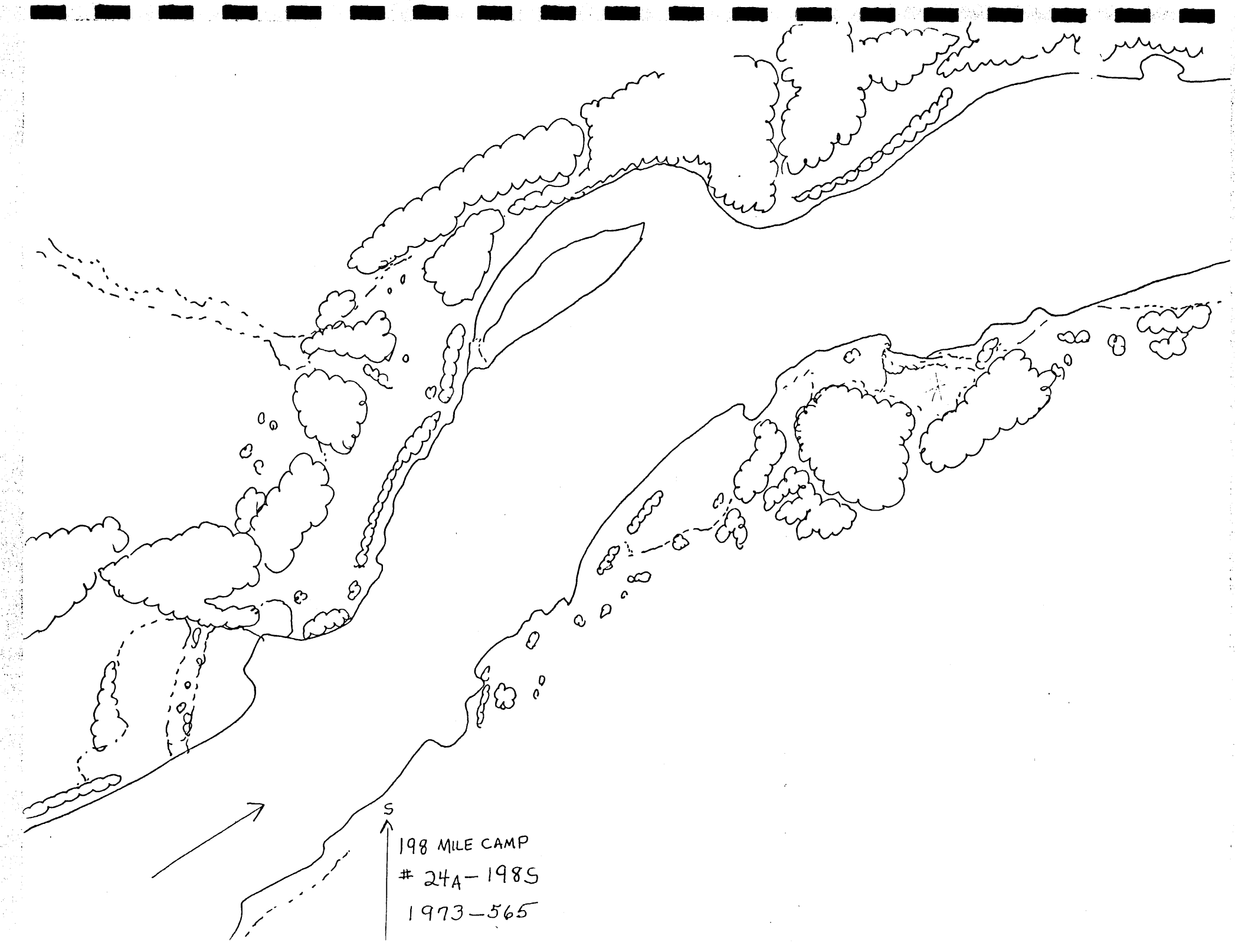
El. DATUM: BS2

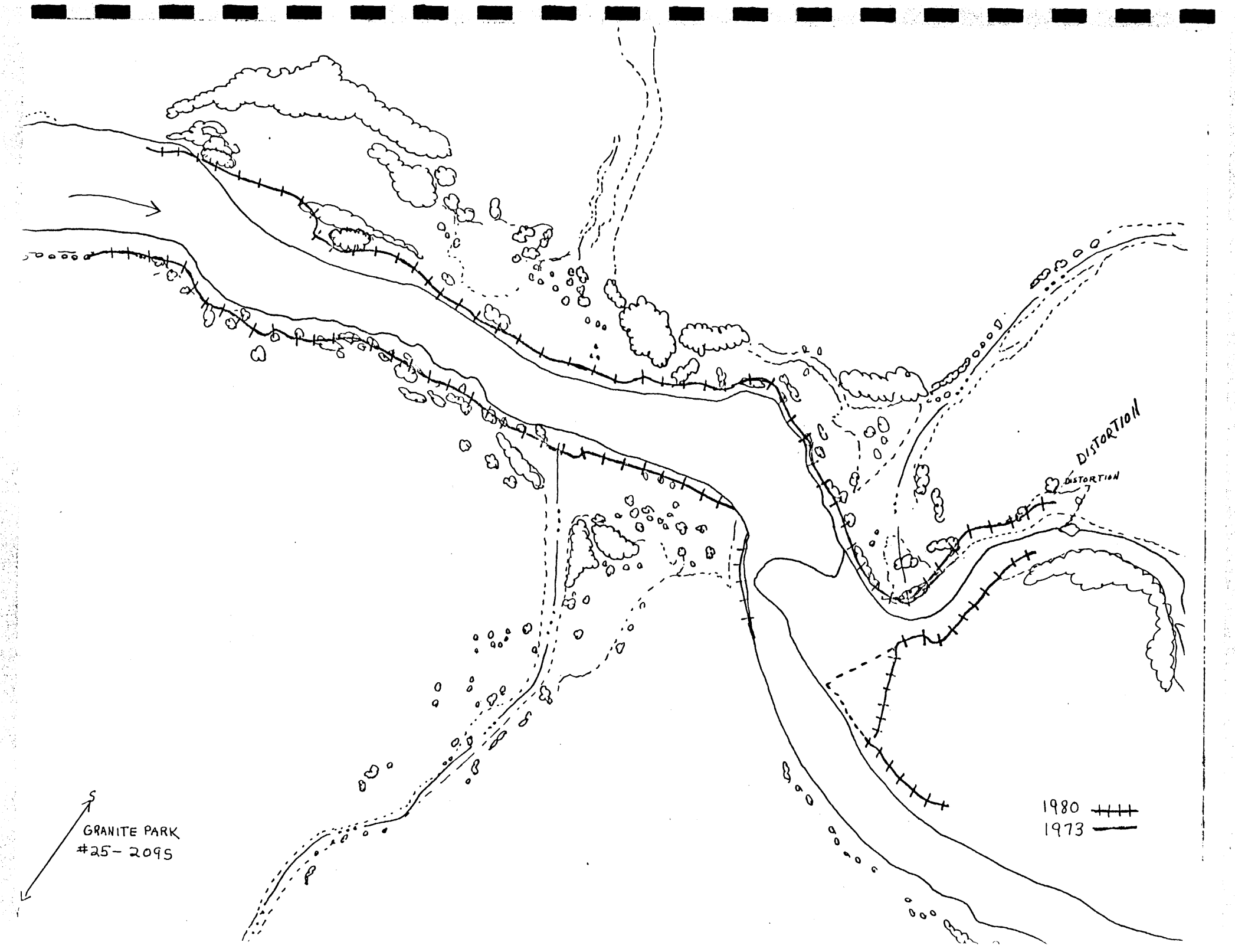


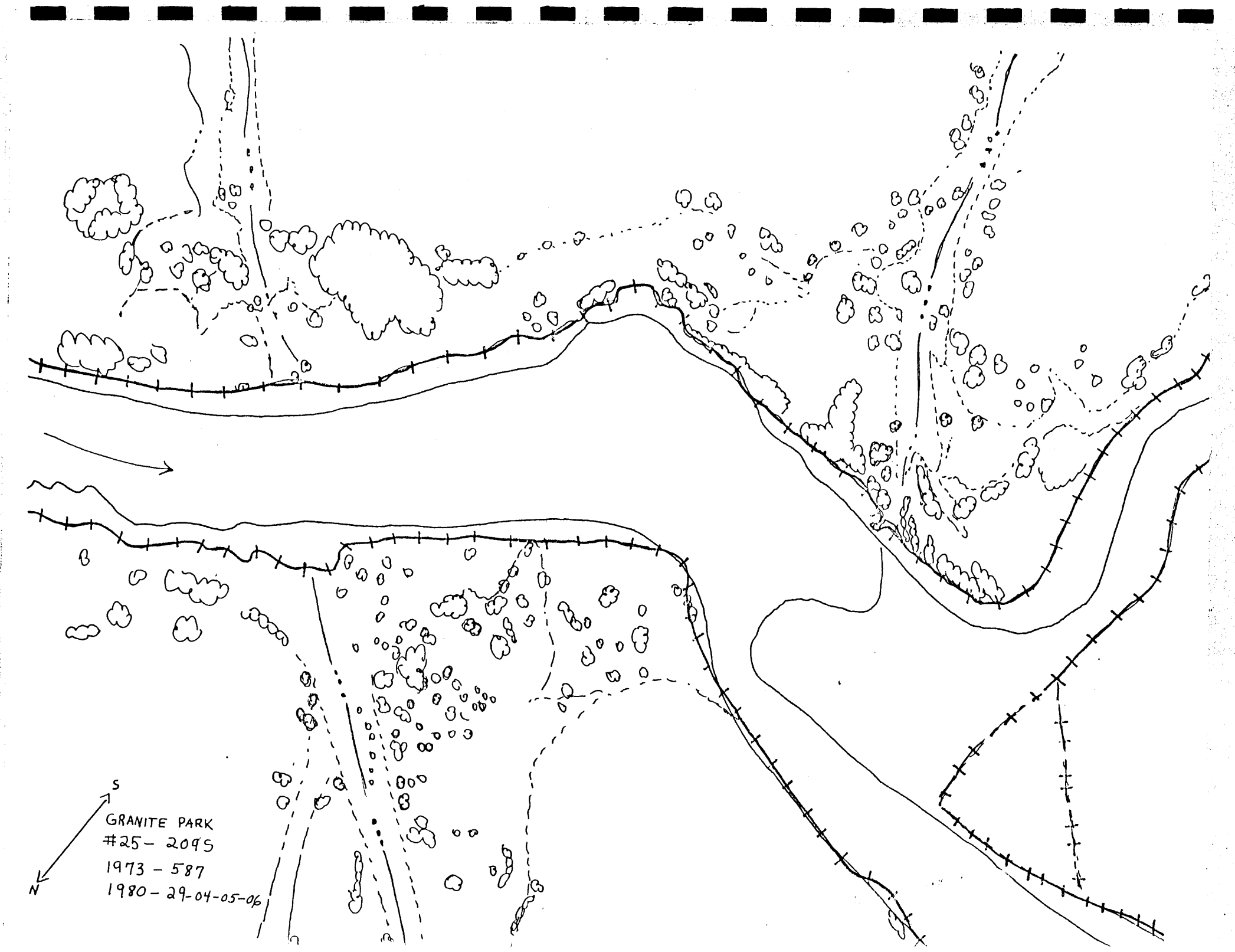

198.5
S
N
PARASHONT
#24 - 198N

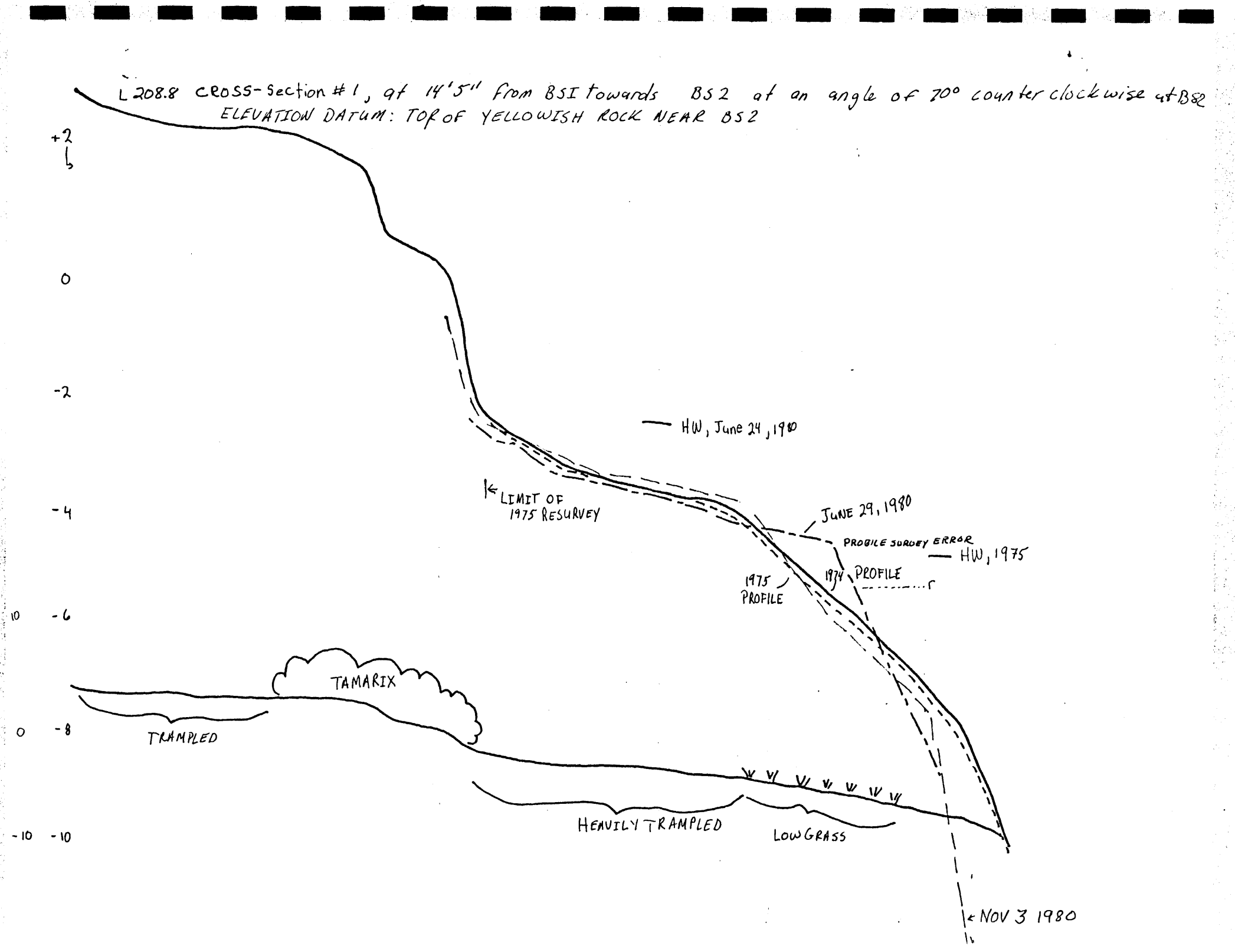

198.5
PARASHONT
#24-198N
1973-565


198 MILE CAMP
#24A – 198S


S
198 MILE CAMP
24A – 1985
1973 – 565

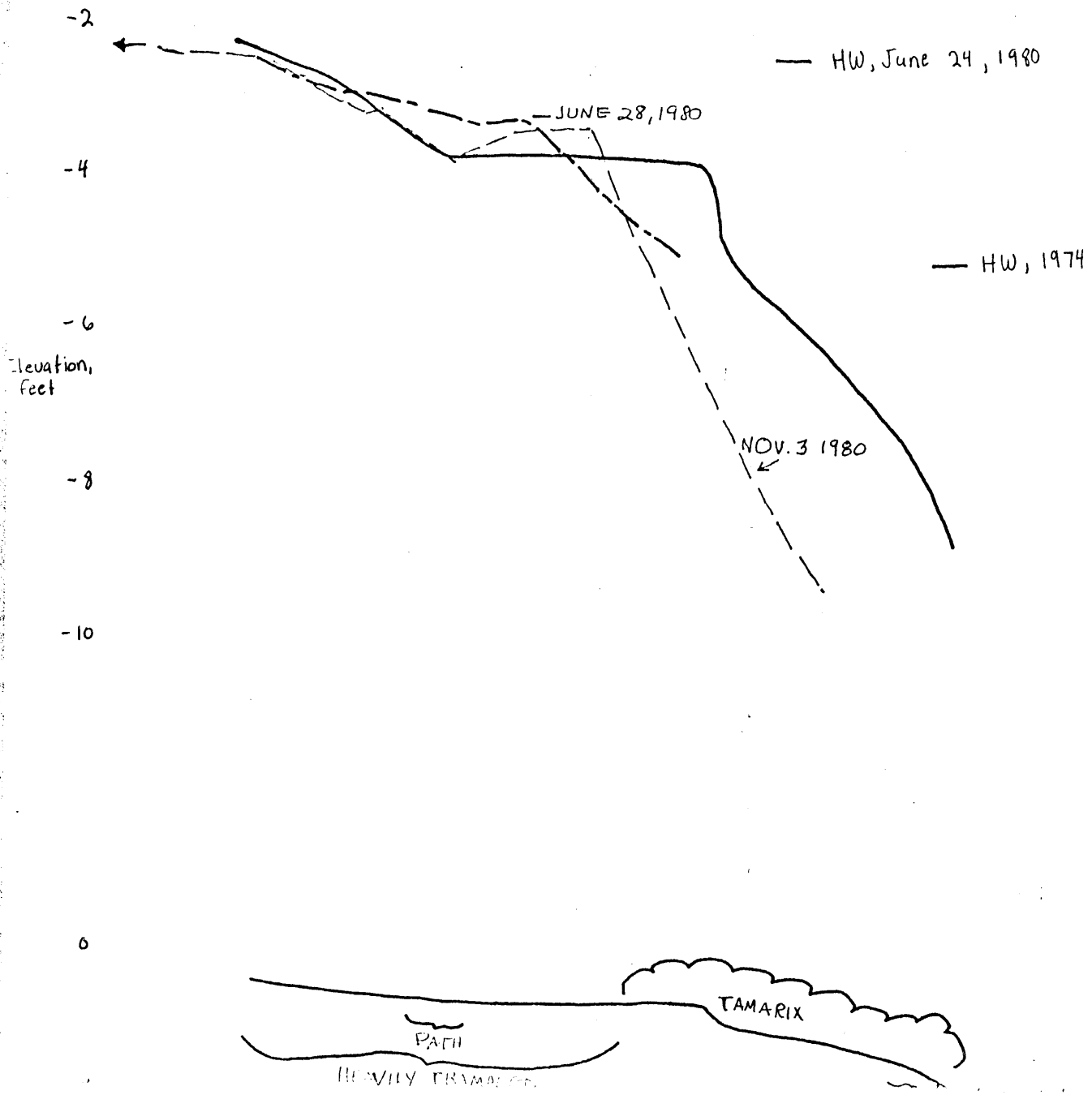

DISTORTION
DISTORTION
1980
1973
GRANITE PARK
#25-2095

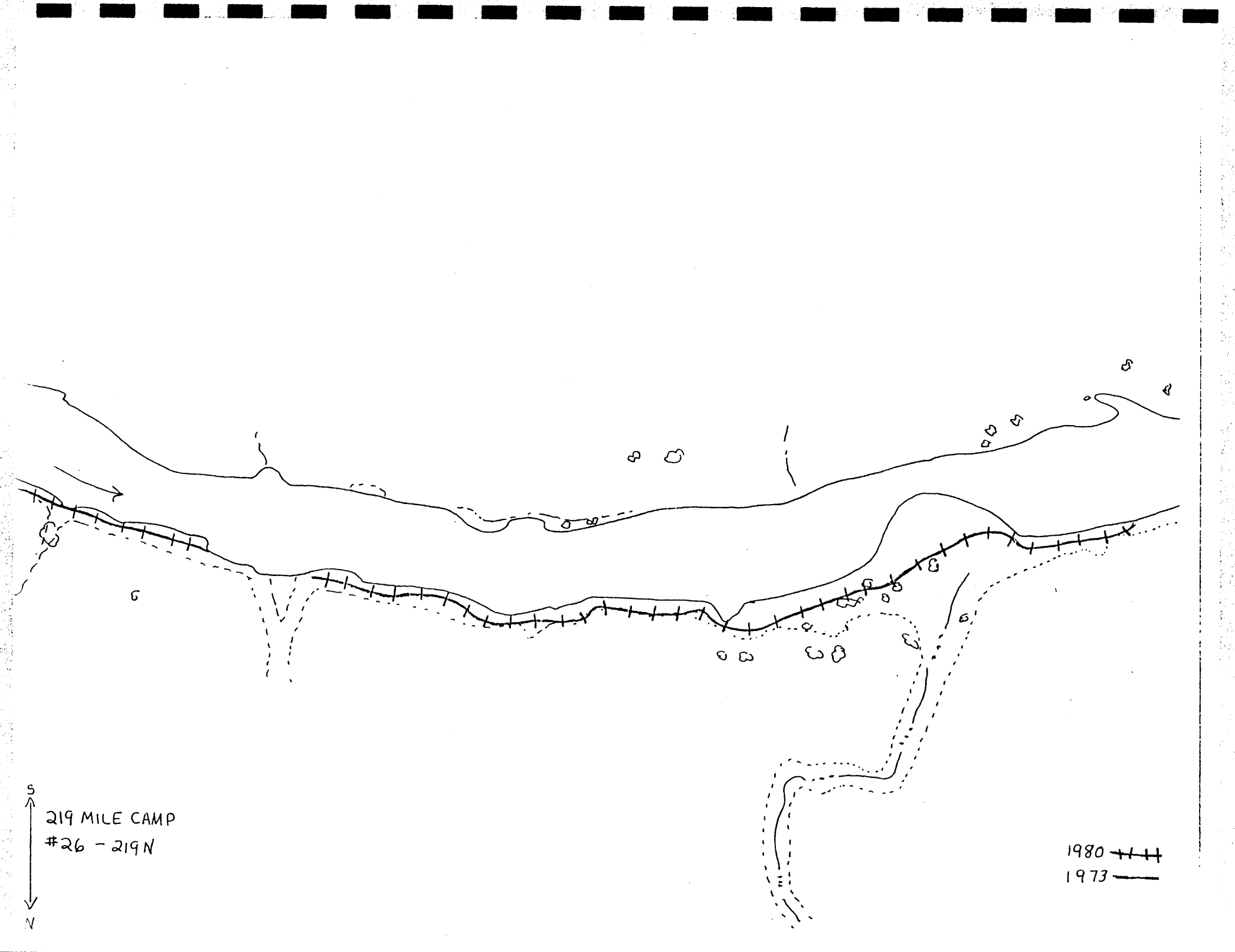

S
N
GRANITE PARK
#25- 2095
1973 - 587
1980 - 29-04-05-06

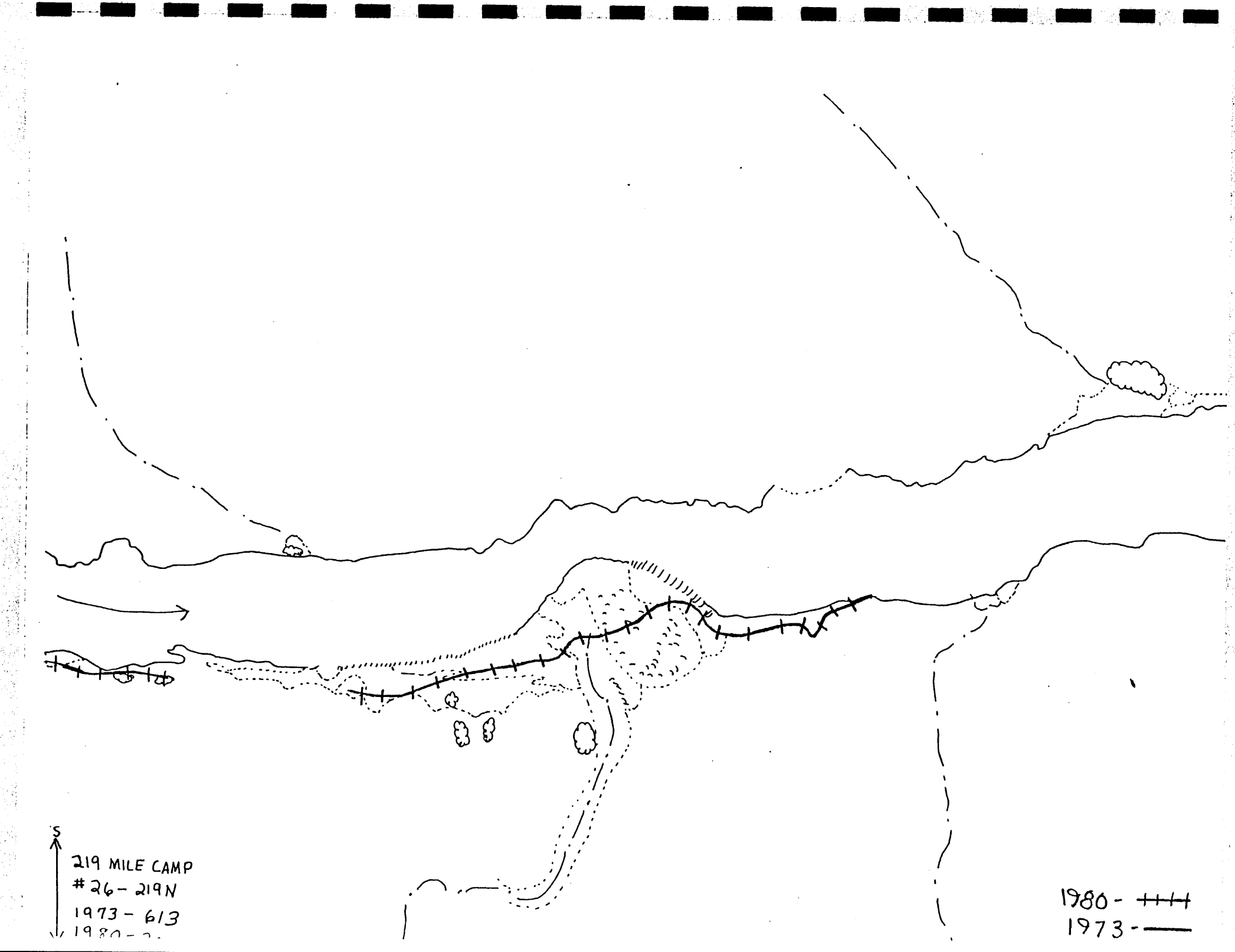

L 208.8 cross-section #1, at 14'5" from BS1 towards BS2 at an angle of 70° counter clockwise at BS2
ELEVATION DATUM: TOP OF YELLOWISH ROCK NEAR BS2
+2
0
-2
-4
-6
-8
-10
10
0
HW, June 24, 1980
LIMIT OF 1975 RESURVEY
JUNE 29, 1980
PROBILE SURVEY ERROR
HW, 1975
1974 PROFILE
1975 PROFILE
TAMARIX
TRAMPLED
HEAVILY TRAMPLED
LOW GRASS
NOV 3 1980

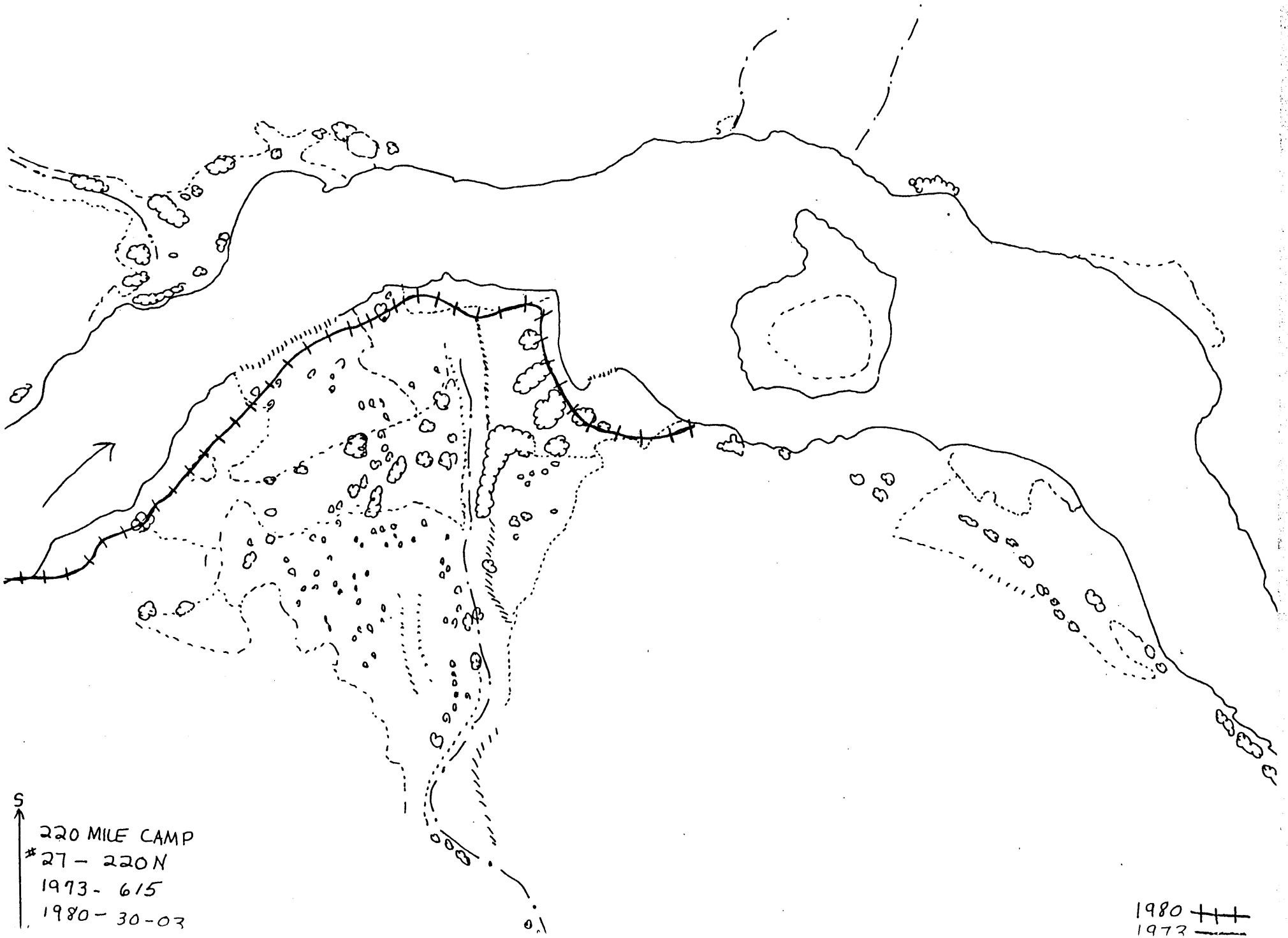
L208.8: CROSS-SECTION #2, at 12'7" FROM BS2 TOWARDS BS1 AT AN ANGLE OF 60° CLOCKWISE OF N2

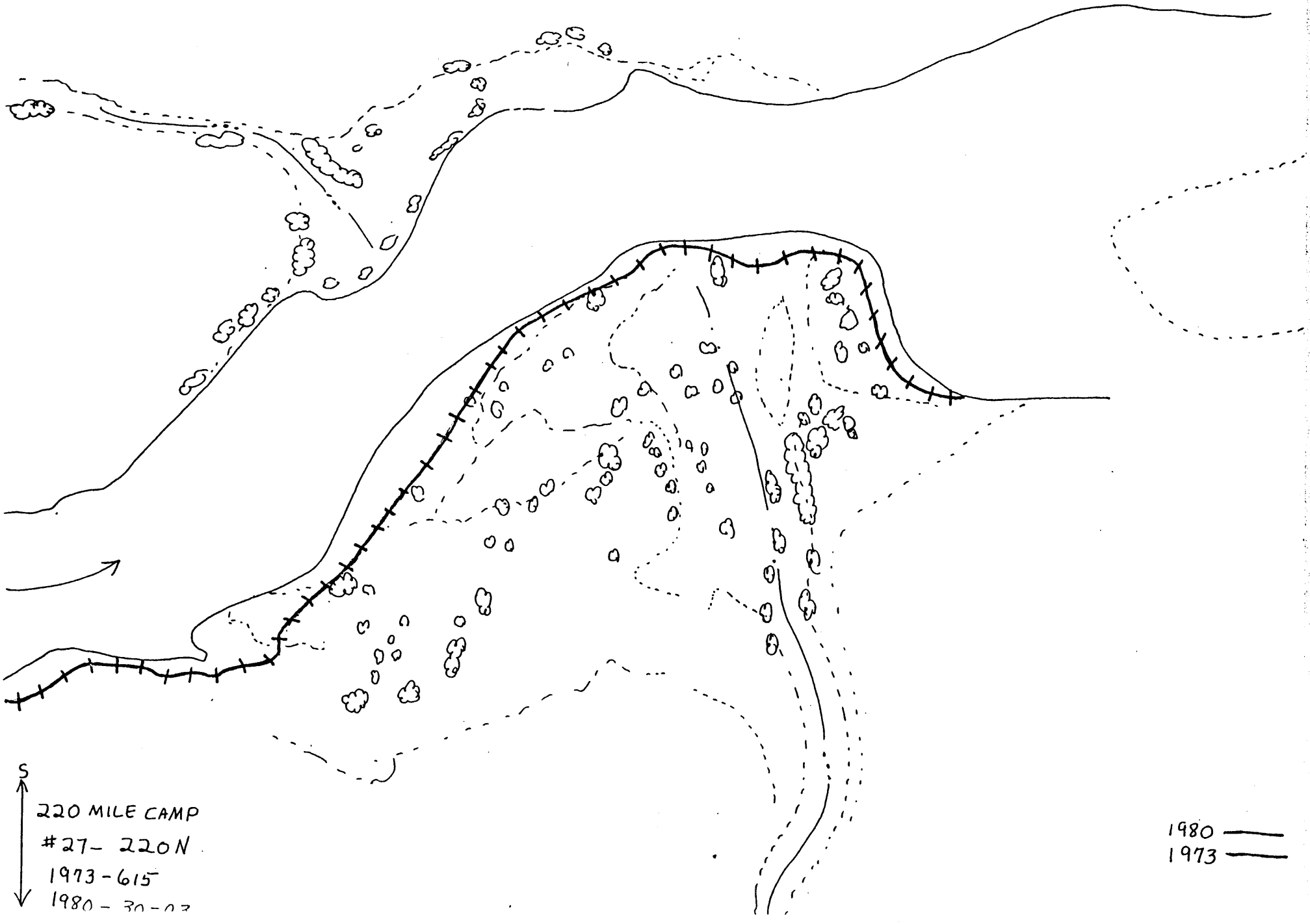
EI DATUM: TOP OF YELLOWISH ROCK NEAR BS2




S
N
219 MILE CAMP
#26 - 219N
1980
1973


S
219 MILE CAMP
#26 - 219N
1973 - 613
1980 - +++
1973 - ——


S
220 MILE CAMP
#27 - 220N
1973 - 615
1980 - 30-03
1980
1973


S
220 MILE CAMP
#27- 220N
1973 - 615
1980 - 30 - 03
1980
1973

R2W.0 TWO ROCK CAMP"

-2 CS#1: EL DATUM: Top of Rock CONTAINING BS#1