FINAL REPORT

RELICT VEGETATION SURVEYS, GLEN CANYON NATIONAL RECREATION AREA, 1992

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1. INTRODUCTION

A study by The Nature Conservancy (Tuhy and MacMahon 1988) has documented the existence of relict vegetation in Glen Canyon National Recreation Area (NRA). The term relict, used in their study, is defined as natural vegetation similar to that which would have been found in the pre-Columbian period, lacking any or having only minimal disturbance resulting from the activities of European colonists or their domestic livestock. Relict or near-relict vegetation was found in 21 areas in Glen Canyon NRA during this survey, in 20 different communities.

During 1992 surveys of riparian and wetland communities around Lake Powell, several interesting communities were discovered that are considered to be relict. However, relict in this report is defined differently, as a community or patch of vegetation or species occurring in an area where it would not normally be expected, based on the prevailing regional climate, elevation, and ecological conditions, and the habitat requirements of the species. Most of the relict vegetation described in Tuhy and MacMahon is relatively extensive, often covering hundreds of hectares (such as blackbrush shrublands on Antelope Island). In most cases these relicts are examples of the dominant vegetation in the region. The different kinds of relict vegetation described in this report are much smaller, generally less than one hectare in extent, and often only a few square meters. They are best termed climatic, biogeographic, or ecological relicts, as opposed to pre-Columbian relicts. All three cases described in this report are also relicts in the Tuhy and MacMahon sense. These communities are scientifically important, as they provide valuable examples of the ability of vegetation to persist during periods of climate or ecological change. They also represents "islands", or hotspots, of high biodiversity.

This report describes the composition, and discusses the regional importance, of three small relict communities discovered during the 1992 field season. These are, 1) a small spring-fed patch of woodland in Cow Canyon, 2) an open riparian woodland on the floor of Clearwater Canyon, and 3) the Douglas Fir tree stand in upper Miller's Creek. Additional information on the rare and sensitive species discovered in these communities can be found in the reports on the flora (Spence 1992a), and rare plant species (Spence 1992b), of GLCA. The quantitative stand description technique used in this report is described in detail in the report on the riparian and wetland survey of GLCA (Spence 1992c). Table 1 provides a summary of the notation used to describe the stand vegetation.

2. COW CANYON

Welsh (1984) and Tuhy and MacMahon (1988) surveyed and discussed the vegetation in Cow Canyon (see Figure 1). All three researchers indicated the canyon to have high potential as a research natural area. The flora is rich, and includes many rare and sensitive species. Extensive and well developed hanging gardens are also found. Livestock grazing has occurred in the past, but has not had a major impact on the vegetation, other than possibly favoring the spread of western wheatgrass, Elymus elongatus, which is abundant in some stretches of the riparian zone. During the period July 28-31, the extensive riparian and wetland vegetation in the canyon was surveyed and described (Spence 1992c). Other finds in Cow Canyon are noted in the flora report (Spence 1992a).

A spring occurs in the longer northern fork of the canyon, near the end. It emerges from the base of the south wall of the canyon in a shallow alcove, apparently at the Navajo-Kayenta interface. Elevation is 1325 m. The site occupied by the spring is shaded year-round, except for a brief period in June and July. A well developed organic-rich soil exists. No sign of flooding was seen, but signs of occasional rock fall from the alcove wall were present. The cool damp microclimate has allowed the persistence of a remarkable suite of species that would otherwise not occur in Cow Canyon, or which are found only in other shaded wet sites like hanging gardens. Stand data from a 100 m^2 circular plot are listed in Table 2.

Two federal candidate C2 species (C2 species are rare and possibly endangered but more studies are needed) occur in the vegetation, *Habenaria zothecina* and *Ostrya knowltonii*. The latter was the dominant tree at the site. The most remarkable finds, however, were the montane disjuncts (disjunct means separated by significant ecological, climatic or elevational barriers where the species is incapable of surviving) blue elderberry (*Sambucus careulea*), Oregon grape (*Mahonia repens*), and sweet-scented bedstraw (*Galium triflorum*). These are all high elevation (predominantly >2000 m) species in southern Utah, generally in the Ponderosa and mixed conifer forests on the mountains. The Oregon grape has been found occasionally in hanging gardens in GLCA, but the other two species are new to the park. All these species except the *Ostrya* are new reports for Cow Canyon. Both the golden sedge (*Carex aurea*) and False Solomon's Seal (*Smilacina stellata*) are also more common at higher elevations. In GLCA these two species are generally only found in hanging gardens or shaded riparian zones. The species composition is suggestive of a kind of mid-elevation deciduous riparian woodland that was probably more widespread during the late Wisconsin. Most species are either rare, or are high elevation disjuncts that have persisted at this site only because of the favorable microclimate. This is the only example of this kind of vegetation seen in GLCA, although the woodland described from Clearwater Canyon (see below) is similar. The site and its species composition is probably unique. The area is surrounded by drier scrub dominated by Gambel's Oak (*Quercus gambelii*). *Ostrya* is known from areas to the south in New Mexico and Texas, but is most common in Utah and Arizona along the Colorado River (Figure 2). The composition and distribution of communities in which Ostrya occurs are not well known anywhere in the southwest (cf. Brown 1982).

2. CLEARWATER CANYON

Tuhy and MacMahon (1988) did not visit this canyon during their survey of GLCA. Although some climbers and backpackers may have visited the canyon, abrupt drops and impassable cliffs in the canyon bottom probably deter most visitors. The middle stretch of the canyon, from below the junction of its two forks well above both forks, in particular seems to be difficult to reach. On August 13-14, 1992, this middle stretch of the canyon was surveyed for T&E species and riparian vegetation. Access was by helicopter from Page.

Clearwater Canyon cuts through Cedar Mesa sandstone. Although a few small seeps exist on the sides along bedding planes in the Entrada, the canyon bottom is predominantly dry, with sandy patches alternating with slickrock. A well developed riparian vegetation zone does not exist, although a variety of riparian species occur (see Spence 1992c). Interesting finds include new localities for three C2 species (Erigeron kachinensis (also new to Glen Canyon NRA), Ostrya knowltonii, Rubus neomexicanus) and one C1 (enough information is available to warrant listing) species (Perityle specuicola), and several other interesting non-candidate species (documented in Spence 1992a, 1992b).

A short distance (ca. 400 m) up the left or west fork of Clearwater Canyon an interesting woodland dominated by Ostrya knowltonii was found. A plot within this woodland was surveyed (Figure 3; Table 3). Elevation was 1525 m. Rubus neomexicanus (rare) and Carex cf. rossii (common, sterile) were found in this woodland. The site is shaded by cliffs to the south, and probably only recieves sun for a short period of time in June and July. Ostrya woodlands are extremely rare on the Colorado Plateau, and the species is generally associated with two specialized habitats; seeps or hanging gardens, and the shaded bases of cliffs. The presence of a woodland composed of this species on the floor of a canyon, with species like Rubus neomexicanus and Carex cf. rossii in the understory, is significant. Based on the distribution and ecology of these species, this woodland is considered relictual.

3. UPPER MILLER'S CREEK

Although Tuhy and MacMahon (1988) were aware of the stand of Douglas fir (Pseudotsuga menziesii) at the head of Miller's Creek (they mention it briefly on p. 15), they did not visit the site. This stand is one of three known from Glen Canyon NRA (the other two are in Millard Canyon and the French Spring fork of Happy Canyon). This site was visited twice, once on foot (June 17), and once by helicopter (September 23-25). Scattered groups of trees, as well as numerous individuals, occur on NW, N, and NE aspects at the base of cliffs in the Navajo Sandstone. Overall, ca. 250 trees are found along the base of these cliffs (Figure 4). The largest stand consists of 92 trees, and is found at 1760 m in a northeast facing alcove. A perennial spring emerges near the head of the alcove, and forms a small stream. Four plots were placed within this stand (Tables 4-7). A list of all species found under the canopy of the Douglas firs in this stand can be found in Table 8.

The most important finds were the C2 species Habenaria zothecina, growing along the stream, and Ostrya knowltonii, which was one of the most important species in the understory. Acer glabrum dominated the understory, particularly along the stream. Other species included Carex rossii, Mahonia repens, and Smilacina stellata. A serviceberry tentatively identified as the high elevation Amelanchier alnifolia was also common. Most of these species are either rare relicts (the Habenaria, Ostrya) or well below their normal lower elevational limits (the Pseudotsuga, Acer, Mahonia, Carex).

All the trees in the main stand and two smaller stands (see Figure 4) were measured for diameter at ground level (DGL). Size classes established were S = seedling (DGL << 2.5 cm; height < 10 cm), S+ = older seedling (DGL < 2.5 cm; taller), saplings (DGL = 2.5-10.0 cm), and adults (DGL > 10.0 cm (see Spence 1992d). The data for these stands are listed in Table 9.

Figure 5 shows the size frequency distribution of 162 trees, based on all individuals in the main stand (no. 2) and two smaller stands (3,4). Figure 6 breaks down the size frequency data for the two largest stands (main and 3rd; 92 and 49 individuals respectively). For the combined data, trees in the sapling category (2.5-10.0 cm DGL) predominate. Most seedlings were older ones, and very few young seedlings (current year-2 yrs) were found. The most interesting aspect of the data is the spike at 71-80 cm DGL. This may represent an older period of high recruitment into the population. The age of these trees is unknown, although they are probably 300 years or more, based on an age of 156 years for a 39.0 cm DGL tree. The shape of the size frequency distribution suggests that recruitment has declined recently in the population, at least compared to an earlier period of high recruitment. Figure 6 shows that stand 3 has many more young individuals compared to the main stand.

The 92 trees in the main stand were stratified into streamside (31 individuals) and slope-talus (61 individuals) groups. Tree size was not significantly different between these two groups ($t\text{-test}_{student's}=1.04$, df=30, p=0.307). All the trees may benefit by the probable presence of seeps in the area of the spring which do not emerge at the surface. The probable presence of these seeps is shown by the presence of several small seeps found at the same level west of the main stand. The presence of the well-developed organic rich forest soil probably also acts as a "sponge", by retaining seep and melt water and releasing it slowly throughout the year.

Despite the presence of water, and lack of positional effects in the size structure, many of the trees appear to be stressed, as indicated by the presence of small growth rings. Thirteen short cores were taken during the June visit. A preliminary analysis done by Esther Schwartz, an SCA volunteer visiting from CANY, indicated that some cores showed considerable variation in ring widths. Three clearly defined periods of poor growth were noted in these cores, ca. 1890-1910, ca. 1940-1960, and 1977. The last of these occurred during the strong, short drought in the winter of 1976-77. Another feature that emerged in many cores was a narrowing of rings in the last few years, probably related to the current drought pattern.

The main stand is very dynamic, based on the presence of numerous fallen logs (ca. 35) and snags (eight large ones). Between the June and September visits, two trees had fallen in this stand. Other trees, and the understory vegetation, were also damaged or destroyed by these events, creating gaps in the canopy. No sign of fire was seen in the stand, although a fire had occurred in Quercus gambelii at the head of the alcove above the spring. Apparently, this fire did not spread beyond the oak scrub.

Other data collected but not yet analysed include pack rat middens, a water sample, and collections of cryptogamic species. Water was collected from the main spring on June 17, and stored in a sealed vial. Dr. J. Ehleringer of the University of Utah has agreed to age the water using the hydrogen isotope (deuterium/hydrogen ratio) method (see Ehleringer et al. 1991). This will provide an estimate of the age of the water, and how vulnerable the spring is to drought events. If the water is young (<1 yr), there is a possibility of the spring drying out during a drought phase. The potential effects of this event on the vegetation is not known.

Cryptogams (principally mosses) were collected from the main stand. Some species of mosses are relictual in southern Utah (see Spence 1991). A preliminary examination of the collections showed the presence of several mountain species, generally found only at higher elevations in southern Utah. However, coniferous forest old growth indicator species (cf. Romme et al. 1992) were not seen in the collections.

A pack rat midden collected from the head of the alcove had large numbers of Pinus flexilis (limber pine) needles. Elsewhere on the plateau the presence of this species generally indicates an age of 10,000 radiocarbon yrs or more. Hence the sample is probably late Wisconsin in age. Saxon E. Sharpe of the Desert Research Institue, Reno, Nevada, is currently studying this sample, which will be returned to Glen Canyon NRA for curation when dated and described.

Isolated stands of Douglas fir are currently known from several areas on the Colorado Plateau. These include the Waterpocket Fold (Glen Canyon NRA, Capitol Reef NP), the upper ends of canyons in the vicinity of Han's Flat (Glen Canyon NRA; Millard Canyon, Happy Canyon), the Needles district (Canyonlands NP), the Island in the Sky district (Canyonlands NP), White Canyon (Natural Bridges NM), and Navajo National Monument. The importance of this stand in relation to these other isolated stands of Douglas fir is high, primarily because the undestory vegetation differs substantially from other sites investigated. This may be due to the presence of the spring, which probably explains the persistence of species like Acer glabrum and Habenaria zothecina. Most investigated tree islands are drier. All these stands are of great scientific value, and should be protected and managed to minimize disturbance.

4. DISCUSSION

It is not known whether the vegetation at these three sites represent coherant relict communities. It is possible that they represent remnants of originally more widespread communities that have experienced high species extinction, invasion by new species, and persistence in favorable sites. An alternative hypothesis is that they may represent loose aggregates of species which occurred in a variety of past communities, and that currently coexist because of broadly similar ecological requirements. Paleoecological studies from the plateau and elsehwere (Betancourt et al. 1990) suggest that the composition and occurence of many communities throughout the last 15,000 yrs has been highly variable and unpredictable. Hence the vegetation described in this study may not provide good analogs of late Pleistocene vegetation. However, the coexistence of relicts in more than one stratum (eg., tree, shrub, forb, liana) provides some support for the first hypothesis. This hypothesis is also supported by the presence of fossil material of Pseudotsuga menziesii and Acer glabrum, reported from the same deposits in the Fortymile-Willow drainage and dated to ca. 12,000 BP (Agenbroad et al. 1990), suggesting vegetation similar to that in upper Miller's Creek. Clearly the floristic composition of these sites does provide clues to past vegetation and climates. Especially significant are the presence of high elevation (mountain) species occurring in a desert mesoclimate. These are traditionally assumed to be relictual from the late Wisconsin, when colder and/or wetter conditions prevailed, and vegetation zones were as much as 1000 m lower in elevation compared with present zonation on the plateau. As climates warmed, Wisconsin vegetation would have retreated upslope, leaving stranded relicts in favorable microclimates that simulate cool and wet mountain environments.

The history and biogeographic implications of the presence of Ostrya knowltonii in the area are especially problematic. The species may have been more widespread during the Pleistocene, where it might have been an important component of riparian and valley bottom deciduous woodlands. However, this is speculative as no fossil remains of the species have been reported from the area (eg., Agenbroad 1990; the related Betula (birch) is often reported, however, and as the two genera are difficult to distinguish without fruits, some of the birch reports from the region may be referable to Ostrya). An alternative hypothesis that needs to be examined is that Ostrya may have preferred the warmer and wetter conditions that prevailed during the middle Holocene (ca. 4000-8000 radiocarobon BP), when the monsoon shifted north, bringing more summer precipitation to the region (analysis in Betancourt 1984; Spence 1992d). Ecological predictions derived from these two hypotheses are different. Monitoring of stands of Ostrya and correlating growth changes with climate variations could be performed as a preliminary test of these two hypotheses.

5. FUTURE CONSIDERATIONS

All three sites are in remote parts of Glen Canyon NRA, and difficult to reach on foot. They are probably unlikely to be much affected by backcountry activities. There are two exceptions to this, however. First, the spring at the Cow Canyon site may be attractive as a camp for backpackers, and this activity could damage the vegetation around the spring. Sambucus careulea would be especially vulnerable, as only a few individuals are present. A second potential problem is backcountry activity at the Miller's Creek tree island. The site is vulnerable to fire, which could result from camping at the site. Management to prevent or reduce the likehood of these events happening is desirable.

Future work on these stands should include monitoring of the vegetation.

As the potential for climate change resulting from global warming is high, monitoring programs, such as the one developed for Bryce Canyon National Park (Spence 1992d) would provide valuable benchmark information to assess the effects of change on the vegetation. Additionally, more survey work to detect the presence of other relict sites in Glen Canyon NRA would be useful. The potential of discovering additional relict patches of vegetation in Glen Canyon NRA is high.

6. LITERATURE CITED

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Table 1. Notation and definitions used in recording of stand vegetation data.

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1. GROWTH FORM: Tr=tree; Sh=shrub/subshrub; Fo=forb; Gr=graminoid; Li=liana; Fr=fern/fern ally; Cr=cryptogam; a=annual; b=biennial.

2. ABUNDANCE: D=dominant (95-100% canopy cover); A=abundant (50-95% canopy cover); C=common (10-50% canopy cover); U=uncommon (1-10% canopy cover); O=occasional (<1% canopy cover but easily found); R=rare (<<1% canopy cover, difficult to find).

3. HEIGHT: x-y=lowest and highest average height of species in meters; 0<1=less than 1 m in height; if x=0, indicates species is regenerating at site (seedlings or vegetative growth present); if x only then a single individual present. A 0 indicates ground-hugging species less than 10 cm tall. All values rounded to nearest whole number.

4. REPRODUCTION: s=sexual reproduction occurring in current year or seen for previous year (sporangia, flowers and/or fruits present); v=extensive vegetative suckering; x=no sign of reproduction.

5. SOCIABILITY: 1=individuals evenly and uniformly distributed in plot; 2=individuals distribution not discernable from random; 3=individuals tend towards clumping or patchy distribution in plot; 4=individuals exhibit extreme clumping or patchy distribution in plot; X=too rare to determine.

Table 2. Vegetation data from a 100 m^2 stand located at the spring in the north fork of Cow Canyon.

Species	GrowthForm	Abundance	Height	Reproduction	Sociability
Litter		U			
Rock		C			
Soil		U			
Acer negundo	Tr	U	0-6	x	3
Ostrya knowltonii	Tr	C	0-9	s	3
Rhamnus betulifolia	Sh	O	0-1	s	3
Sambucus caerulea	Sh	U	0-1	s	3
Mahonia repens	Sh	U	0<1	s	4
Carex aurea	Gr	O	0<1	s	3
Galium triflorum	Fo	O	0<1	s	3
Habenaria zothecina	Fo	O	0<1	s	3
Smilacina stellata	Fo	O	0<1	x	2
Parthenocissus vitacea	Li	U	0-5	s	2
Adiantum capillus-veneris	Fr	C	0<1	s	2
Equisetum hyemale	Fr	U	0-1	s	2
mosses (not identified)	Cr	C	0	x	3

Table 3. Vegetation data from a 100 m^2 stand located in the bottom of Clearwater Canyon, western fork, ca. 500 m up from the junction of the two branches.

Species	GrowthForm	Abundance	Height	Reproduction	Sociability
Litter		A			
Rock		O			
Soil		U			
Acer negundo	Sh	O	0-1	x	3
Ostrya knowltonii	Tr	C	0-7	s	2
Rhamnus betulifolia	Sh	R	2	x	X
Brickellia longifolia	Sh	O	0<1	x	2
Mahonia fremontii	Sh	O	0-1	x	2
Rhus aromatica	Sh	O	0-1	x	3
Symphoricarpos longiflorus	Sh	U	0-1	x	2
Apocynum cannabinum	Fo	O	0<1	x	2
Aquilegia micrantha	Fo	R	0-1	s	X
Penstemon rostriflorus	Fo	U	0<1	x	2
Solidago sparsiflora	Fo	O	0<1	x	2
Carex cf. rossii	Gr	O	0<1	x	3
Elymus salinus	Gr	R	0-1	s	X
Poa sp.	Gr	C	0<1	s	1
mosses (not identified)	Cr	O	0	x	3

Table 4. Vegetation data from plot 1 (100 m^2) located in the Douglas Fir tree stand in upper Miller's Creek.

Species	GrowthForm	Abundance	Height	Reproduction	Sociability
Litter		C			
Soil		U			
Rock		U			
Pseudotsuga menziesii[1]	Tr	C	20-25	s	2
Acer glabrum	Tr	C	0-7	x	2
Erigeron cf. utahensis	Fo	R	0<1	x	X
Habenaria zothecina	Fo	R	0<1	s	X
Smilacina stellata	Fo	U	0<1	x	2
mosses[2]	Cr	0	0	x	3

[1]three individuals in plot

[2]predominantly <u>Hypnum revolutum</u>

Table 5. Vegetation data from plot 2 (100 m^2) located in the Douglas Fir tree stand in upper Miller's Creek.

Species	GrowthForm	Abundance	Height	Reproduction	Sociability
Litter		U			
Soil		O			
Rock		C			
Pseudotsuga menziesii[1]	Tr	C	20-25	s	X
Acer glabrum	Tr	C	0-5	x	2
Ostrya knowltonii	Sh	O	<1	x	X
Quercus gambelii	Sh	O	0-1	x	3
Mahonia repens	Sh	U	0<1	s	3
Habenaria zothecina	Fo	O	0<1	s	3
Smilacina stellata	Fo	O	0<1	x	3
mosses[2]	Cr	O	0	x	3

[1]two individuals in plot.

[2]mostly Hypnum revolutum on soil and Pseudoleskeella tectorum on rock

Table 6. Vegetation data from plot 3 (100 m^2) located in the Douglas Fir tree stand in upper Miller's Creek.

Species	GrowthForm	Abundance	Height	Reproduction	Sociability
Litter		C			
Soil		-			
Rock		0			
Pseudotsuga menziesii[1]	Tr	U	20-25	s	2
Acer glabrum	Tr	U	0-7	x	2
Ostrya knowltonii	Tr	U	0-6	s	2
Carex rossii	Gr	U	0<1	s	2
mosses[2]	Cr	0	0	x	3

[1]three individuals in plot

[2]predominantly Hypnum revolutum

Table 7. Vegetation data from plot 4 (100 m^2) located in the Douglas Fir tree stand in upper Miller's Creek.

Species	GrowthForm	Abundance	Height	Reproduction	Sociability
Litter		C			
Soil		C			
Rock		C			
Pseudotsuga menziesii[1]	Tr	C	25	s	X
Acer glabrum	Sh	U	0-4	x	2
Ostrya knowltonii	Sh	O	0-3	s	3
Mahonia repens	Sh	R	0<1	s	X
Rosa woodsii	Sh	O	0-2	s	3
Toxicodendron rydbergii	Sh	C	0-2	x	3

[1]one individual in plot

Table 8. Vascular plant species list from the main Douglas fir stand in upper Miller's Creek. Only species growing under the canopy of Douglas fir are listed. Rare or high elevation species are indicated with an asterisk.

Trees-Shrubs	Forbs-Ferns	Graminoids
*Pseudotsuga menziesii	*Cystopteris fragilis	Poa fendleriana
Pinus edulis	Erigeron cf. utahensis	*Carex rossii
Juniperus osteosperma	*Habenaria zothecina	Elymus elymoides
*Acer glabrum	Smilacina stellata	
*Amelanchier cf. alnifolia	Artemisia ludoviciana	
Ephedra viridis		
*Ostrya knowltonii		
Shepherdia rotundifolia		
[*Prunus virginiana (tentative id-very rare and sterile)]		
Cercocarpus intricatus		
Quercus gambelii		
*Rosa woodsii		
*Mahonia repens		
[*Physcocarpus sp. (tentative id-very rare and sterile)]		
Toxicodendron rydbergii		
Chrysothamnus linifolius		

Table 9. Diameter at ground level data for the three stands of Douglas fir in Miller's Creek. All measurements are in centimeters.

	Main Stand (2)			Stand 3		Stand 4
No. Seedlings (S)	6			2		1
No. Seedlings (S+)	4			6		5
Saplings and Adults	63.5	42.7	53.3	7.6	4.8	45.4
	42.7	31.0	101.6	13.7	7.6	74.2
	11.9	113.5	50.3	6.9	9.1	12.2
	65.3	23.1	32.8	15.7	8.6	26.7
	31.8	69.6	48.3	2.8	45.7	7.1
	56.6	90.2	38.6	4.3	30.5	82.6
	48.3	14.7	32.8	10.2	27.4	72.4
	4.1	39.1	74.4	63.0	49.5	76.2
	90.2	88.6	70.6	23.1	2.8	15.0
	6.1	10.7	57.1	17.8	79.0	18.5
	3.6	23.4	18.8	2.5	30.2	80.3
	17.1	6.1	42.9	4.6	26.7	27.9
	50.3	100.3	76.2	7.4	2.5	2.5
	35.8	88.9	11.7	2.8		10.9
	63.5	7.6	46.5	4.1		3.3
	5.1	70.6	15.0	4.1		
	19.8	35.1	27.7	26.7		
	74.2	59.2	26.9	4.1		
	2.5	33.0	39.6	30.5		
	42.4	101.1	38.6	2.5		
	8.9	26.4	8.6	77.2		
	15.5	6.1	9.4	2.8		
	43.9	6.4	4.3	2.5		
	3.0	22.9	60.7	3.8		
	8.9	27.7	75.4	5.8		
	71.9	32.3	20.1	6.4		
	2.5	18.8	75.2	4.8		
	25.7	70.0		5.1		

Figure 1. Cow Canyon (USGS 7.5 min topographic map Steven's Canyon South) showing the location of the spring and associated vegetation.

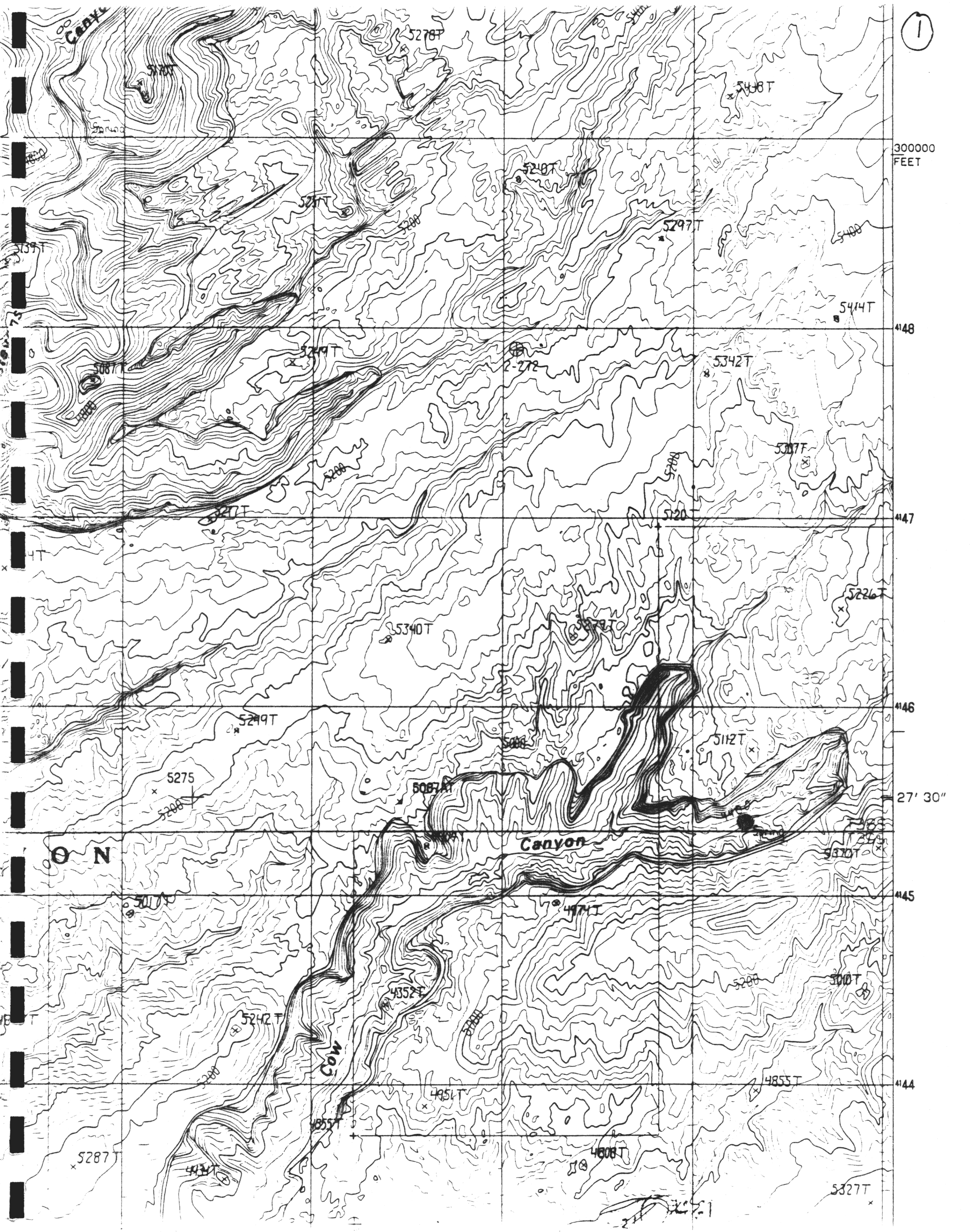
Figure 2. The distribution of Ostrya knowltonii (from Little, E.L. Jr. 1976. Atlas of United States trees. Vol. 3. Minor western hardwoods. U.S.D.A. Misc. Publ. 1314). The Miller's Canyon site is marked by an X.

Figure 3. Clearwater Canyon (USGS 7.5 min topographic map) with the Ostrya woodland marked.

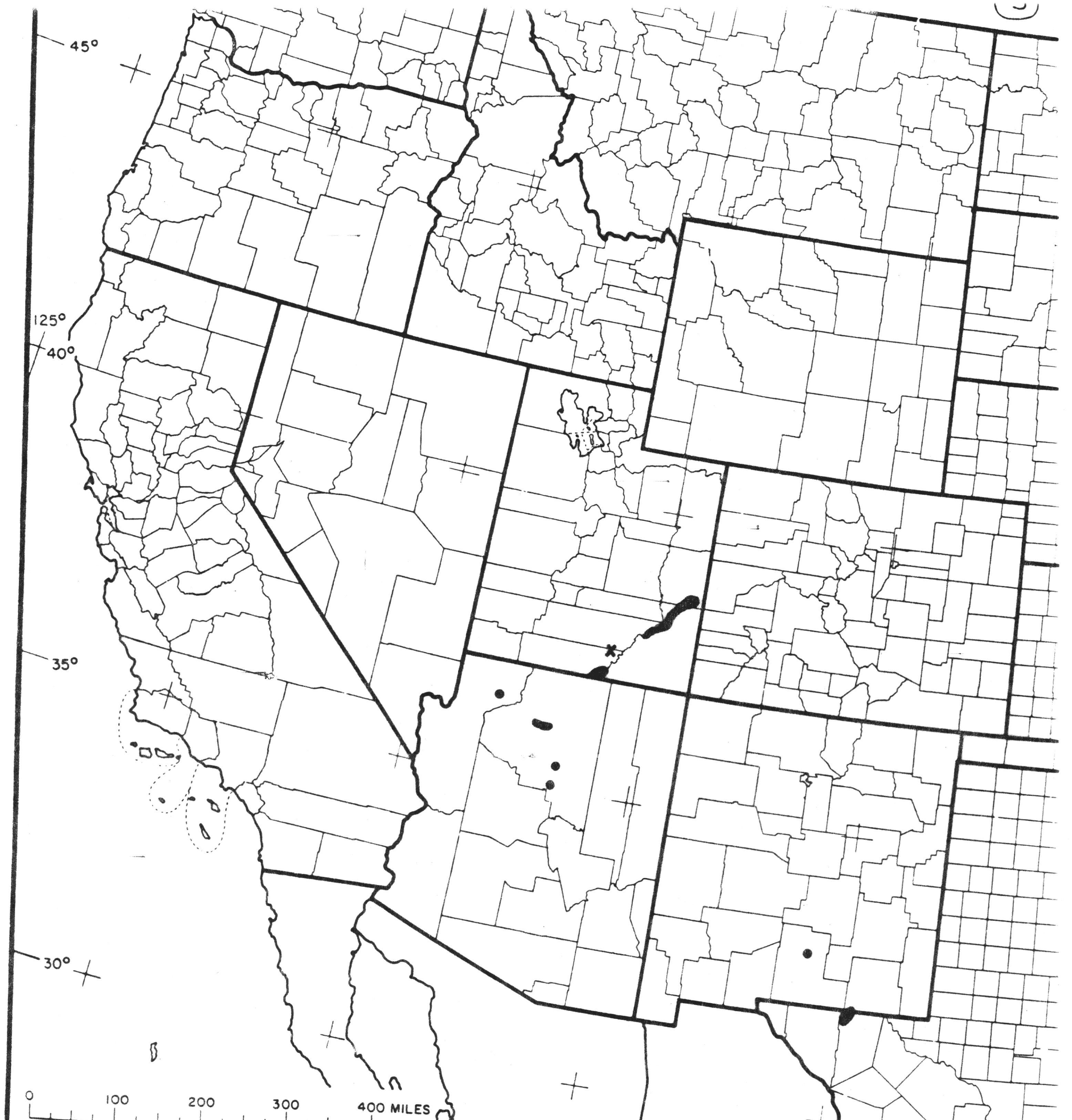
Figure 4. Miller's Creek (USGS 7.5 min topographic map Steven's Canyon North) with the location of the main Douglas fir groups (numbered 1-4) marked.

Figure 5. The size-frequency distribution of all measured trees in upper Miller's Creek, with number of trees in each class on the Y axis. N = 162.

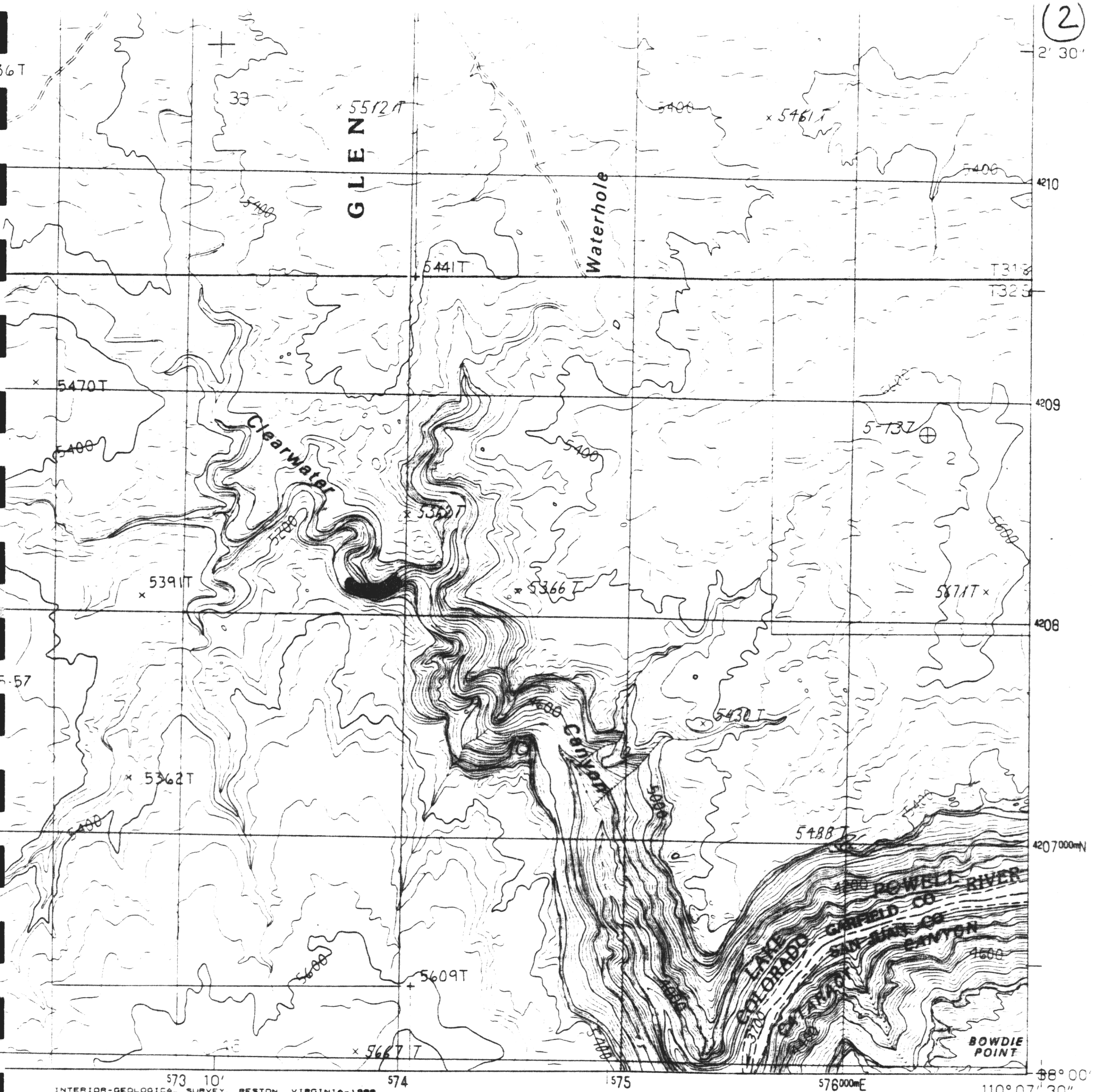
Figure 6. The size-frequency distribution of all measured trees in stands 2 and 3 in upper Miller's Creek.



1
300000
FEET
4148
4147
4146
27′ 30″
4145
4144
Canyon
Canyon
O N
COW
5278T
5418T
5210T
5297T
5414T
5249T
2-272
5342T
5340T
5226T
5249T
5275
5112T
5087T
5370T
4974T
4352T
5242T
5010T
4855T
4951T
4855T
5287T
4608T
5327T

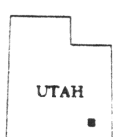


Map 106. *Ostrya knowltonii* Cov., Knowlton hophornbeam.



8000 9000 10000

2000



QUADRANGLE LOCATION

1	2	3	1 The Pinnacle 2 Gordon Flats 3 Elaterite Basin
4		5	4 Fiddler Butte 5 Teapot Rock 6 Sewing Machine
6	7	8	7 Bowdie Canyon West 8 Bowdie Canyon East

ADJOINING 7.5' QUADRANGLE NAMES

ARDS
ADO 80225

ROAD LEGEND

Improved Road . . . .
Unimproved Road . . . .
Trail . . . .

Interstate Route   U.S. Route   State Route

CLEARWATER CANYON, UTAH

PROVISIONAL EDITION 1988

38110-A2-TF-024

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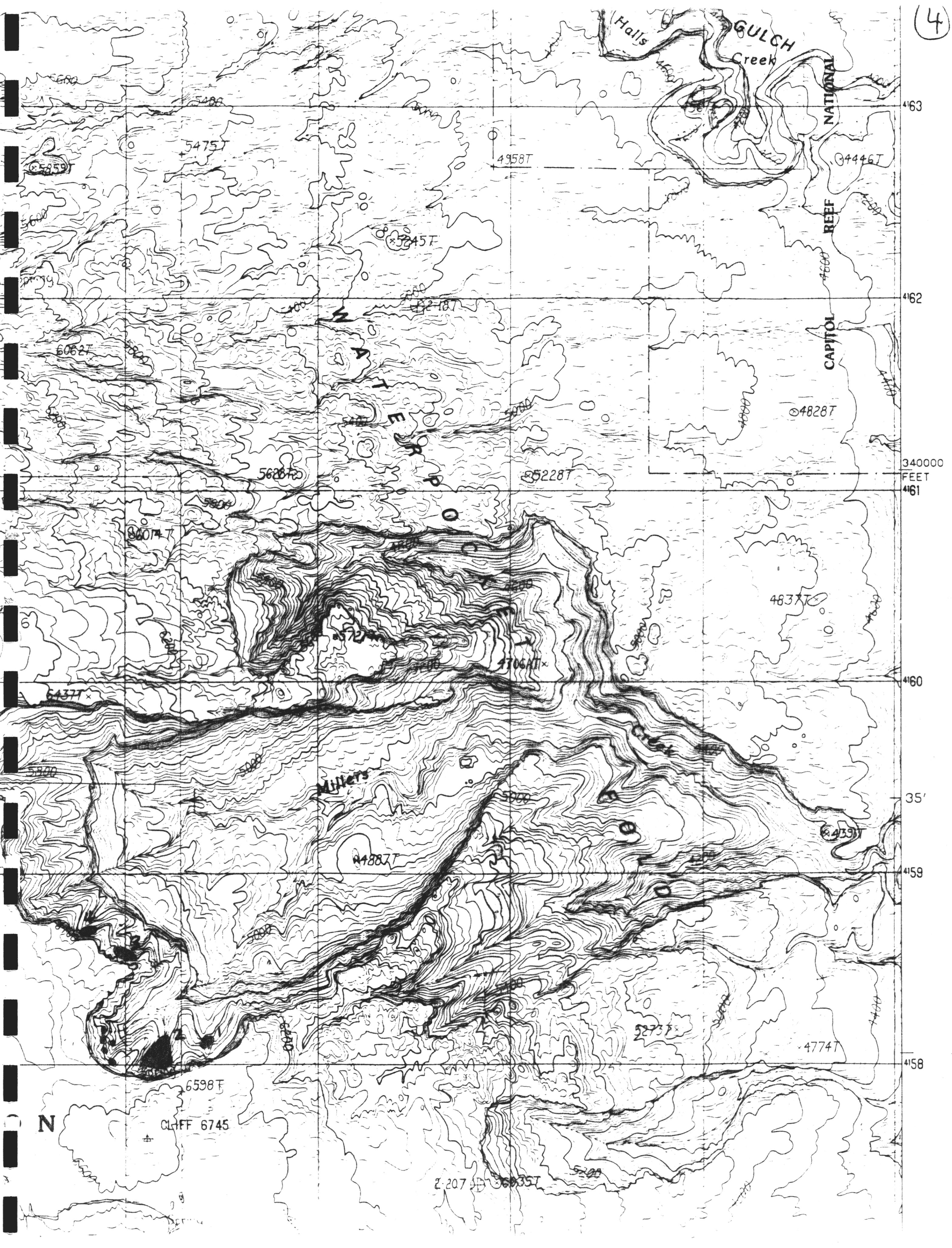
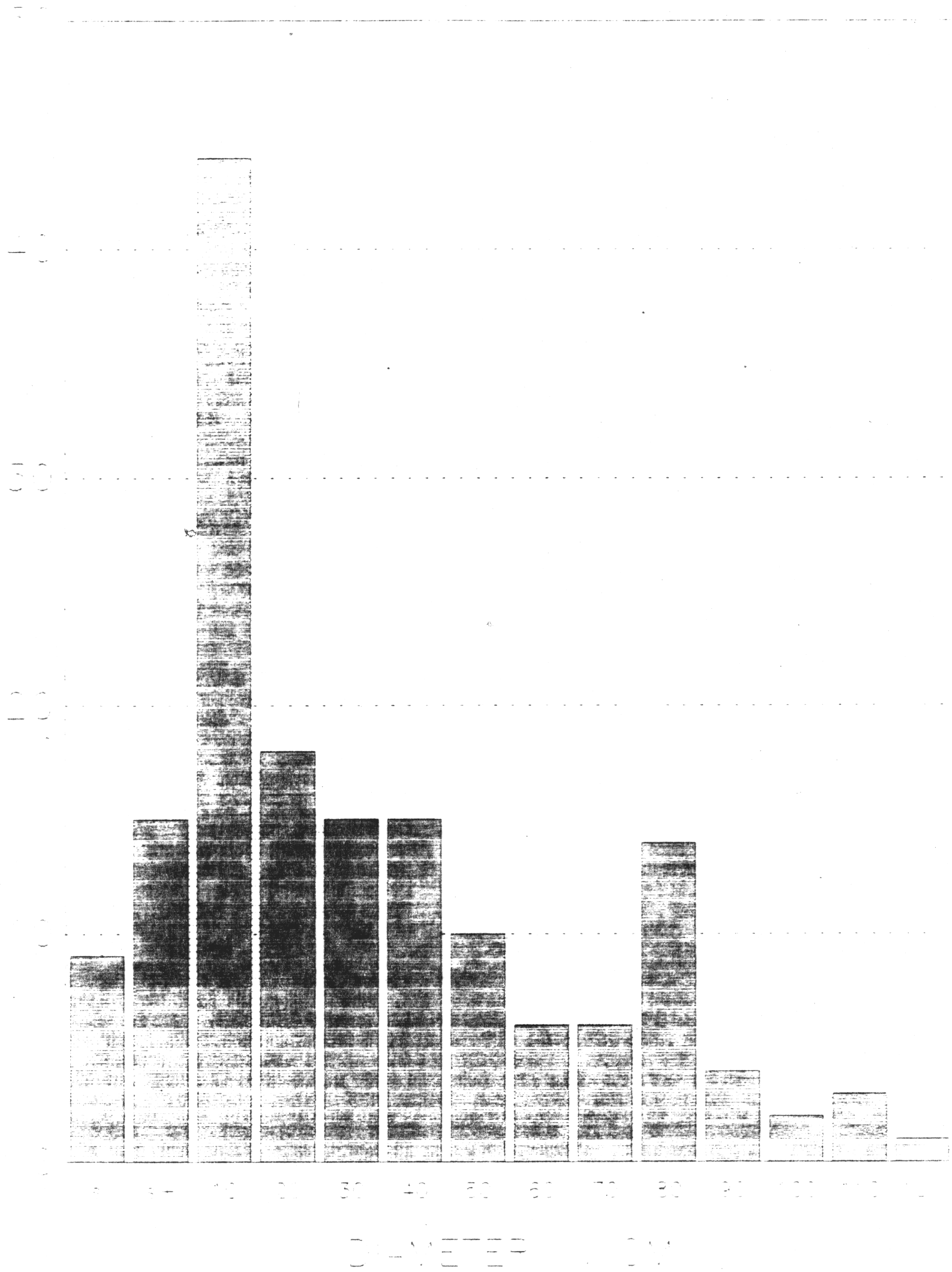
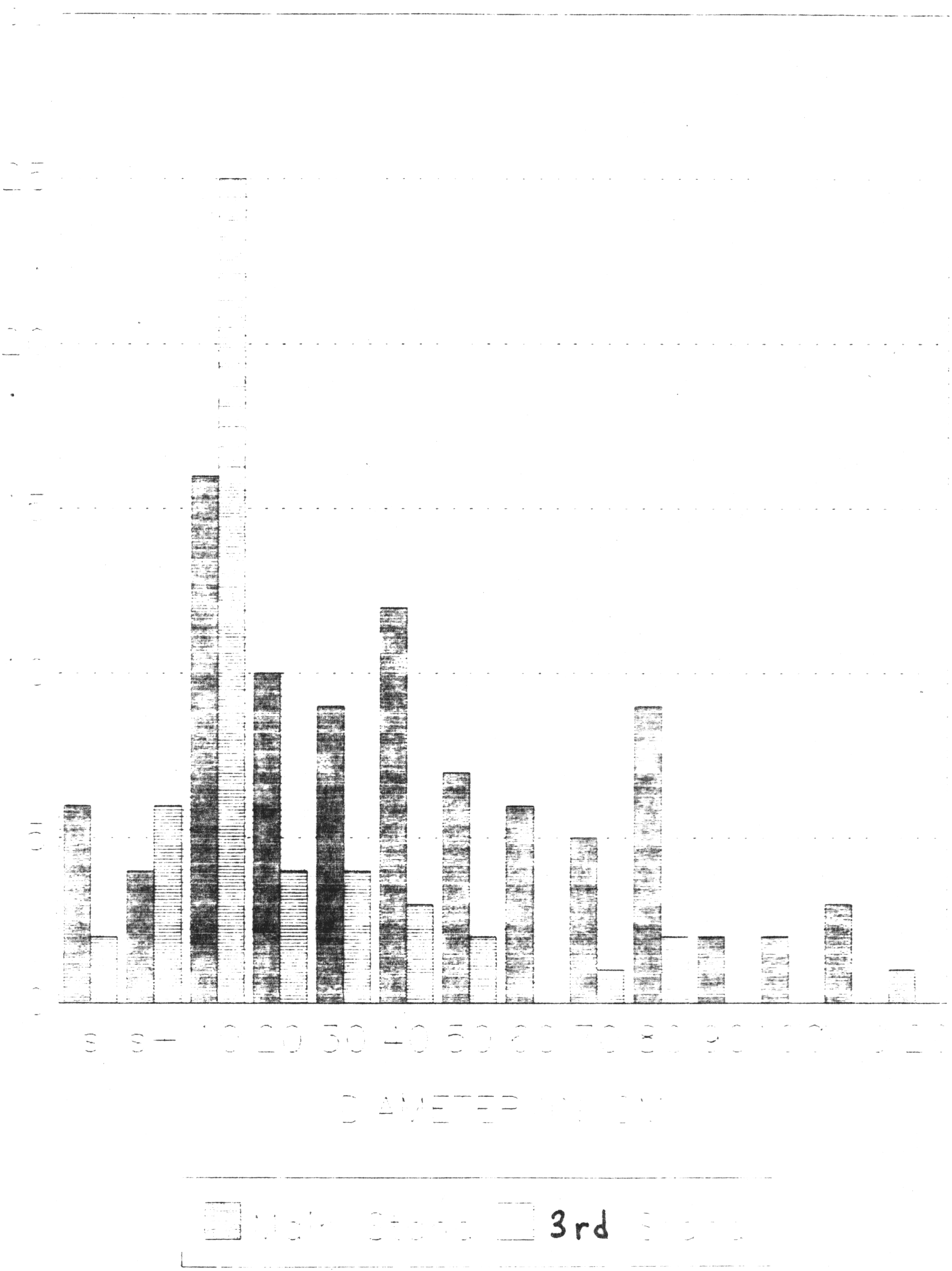

Halls
GULCH
Creek
NATIONAL
REEF
CAPITOL
WATERPOCKET FOLD
Millers
Creek
340000 FEET
4163
4162
4161
4160
35'
4159
4158
5475T
5245T
4958T
4446T
4828T
5228T
4837T
4706AT
6437T
4888T
4139T
5273T
4774T
6598T
CLIFF 6745
N
5800
5000
4800
4400
5200




3rd