

Final Report

on

RIPARIAN ENVIRONMENTAL-VEGETATION INTERRELATIONSHIPS
ALONG THE LOWER ESCALANTE RIVER, GLEN CANYON NATIONAL
RECREATION AREA, UTAH

by

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Studies of environmental and riparian vegetation interrelationships along the lower Escalante River were conducted during 1974 and 1975. The study area included the Escalante River flood terraces between Harris Wash and Coyote Gulch.

Methods were developed compatible for wilderness use. Sixty-nine 1 by 10 meter macro-plots were taken at 23 locations. Measurements were taken of those environmental parameters thought to influence riparian vegetation: stratigraphy, soil texture and moisture, river bank angle and aspect, and height and width of flood terraces.

Canyon profile was found to be strongly influenced by geologic strata. Resistance to erosion by these strata determines canyon width, number of meanders, and river bank profile. River bank profile is further modified by flooding which creates flood terraces.

Vegetation was found to be roughly correlated with stratigraphy and flood terraces. Scirpus americanus and Equisetum laevigatum were found near the edge of the river on the lowest flood terrace. Salix exigua, Populus fremontii, and Tamarix pentandra occurred on the low, medium, and high flood terraces but showed increasing proportion of older individuals there.

Population age structure differences were attributed to flooding which dynamically maintains each population. Regeneration by root suckers for Salix and Populus have a greater survival rate than Tamarix whose seedling source is washed away by periodic fluctuations in river level. Implications of this research are that reduction in river flow or regulation of floods would remove population equilibrium controls. Tamarix, without the effect of its seed source being washed away, would have a successional advantage over the other two native tree species.

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INTRODUCTION

With a burgeoning human population, demands on natural ecosystems are increasing rapidly. Every ecosystem in the biosphere has received some direct or indirect impact of man's technology (Houston, 1971). This impact spans from air pollution at the biospheric level, to introduced species at the community level, to genetic mutation at the population and individual level. Environmental impacts can only be expected to increase as man's consumptive technology moves onward.

Besides our intrinsic ecological interests, studies of natural ecosystems can aid in land management. Land managers are required to make decisions on the allocation of resources while often lacking the data base to facilitate these judgements. Frequently, such decisions are critical to the alternation or maintenance of these systems in a natural condition. Introductions or perturbations to an ecosystem effect the ecosystem as a whole, reacting unit. Thus, benefits gained from manipulating one part of an ecosystem may lead to reduced or negative gains in other areas (Bormann and Likens, 1970).

The riparian vegetation of the lower Escalante River was chosen for study for two reasons. First, it is part of a near-natural ecosystem of which, the river is uncontrolled and the vegetation is in a near pristine state. Secondly, future energy resource developments may significantly alter this ecosystem. This study was undertaken to provide reference data to enable measures of subsequent change in the ecosystems involved and develop management strategies based on desired land use.

Purpose of study

The objectives of this study were to obtain quantitative environmental data and riparian vegetation data along the Escalante River and to relate these environmental gradients to the patterns of vegetation. To achieve these goals, studies were undertaken to accomplish the following:

1. Collect quantitative environmental data on geologic strata, river bank type, and river flow within the lower Escalante River.
2. Collect quantitative riparian vegetation data and classify vegetation types at the first level of approximation (Poore, 1962).
3. Correlate distributional patterns of riparian vegetation to the above environmental gradients.
4. Make inferences regarding the successional dynamics of vegetation within the flood terraces of the lower Escalante River.
5. Estimate effects of regulated river flow on these plant communities.

LITERATURE REVIEW

Lowe (1964) defines "riparian association" as "one which occurs in or adjacent to drainageways and/or their flood plains and which are further characterized by species and/or life forms different from that of the immediately surrounding vegetation." This definition will be used throughout this text, except that vegetation will be substituted for association so as not to presuppose species associations. This will also clarify confusion in the literature between riparian vegetation and phreatophytic vegetation; the latter has roots confined to any water table whereas the former has rooting structure confined to a drainageway watertables. Further, Campbell and Green (1968) define riparian species as one whose life cycle is obligate to the watertable of the drainageway and a pseudo-riparian species as species whose life cycle is not obligate to the drainageway watertables.

Studies concerning riparian vegetation in arid and semi-arid environments have mostly dealt with water consumption and water losses due to vegetation. Tamarix and Prosopis have been the most common species studied due to their recent invasion and/or wide scale dominance (Harris, 1966). Robinson (1958, 1961, 1970) and van Hylckama (1968, 1970, 1974) have done a considerable amount of work in this field. Horton (1959, 1966, 1972), Campbell, (1970), and Horton and Campbell (1974) have also made contributions, especially towards development of management strategies to reduce water consumption and loss.

Studies on the Colorado Plateau relating to riparian plants have been primarily taxonomic. Woodbury (1959, 1960) investigated the flora and fauna of Glen Canyon and Flaming Gorge on the Colorado River prior

to the impoundment of these areas. This work included sampling of both the riparian and upland desert shrub plant communities. These studies consist largely of floristic lists. Although quantitative analysis of vegetation was not undertaken. These studies include some discussion of habitat preferences by the various species. Woodbury (1933) also conducted an ecological study of Zion National Park. Taxonomic listings of both flora and fauna were made for each plant community type. He concluded that the riparian plant community type along the Virgin River was near the end stages of succession due to the basal leveling of the area. He made no mention of Tamarix, a now frequent species along the Virgin River.

Of more ecological interest are studies oriented toward gradient and/or ordination analyses. Such studies have been mostly conducted in central Arizona. For instance, Gary (1965) has shown a correlation between certain riparian species and soil salinity, texture and moisture. Horton et al. (1960) have shown the importance of some environmental parameters to seed germination of certain phreatophytes. They conclude that light, moisture (drought or submergence), and temperature most affected seed germination. van Hylckama (1968) has shown that salinity and moisture have significant effects on Tamarix germination and growth. Other studies by Freeman and Dick-Peddie (1970), Turner, (1974), and van Hylckama (1969) compared similar environmental parameters with the occurrence and growth of riparian vegetation in Arizona and New Mexico.

Only one study was found concerning succession of riparian vegetation in semiarid regions. Campbell and Green (1968) have shown that pseudo-riparian vegetation invades inward toward the edge of streams, but does not migrate along the stream channel. Riparian vegetation

migrates along the stream channel often bisecting sharply demarked vegetation zones. They concluded that channel vegetation never reached a climax state because of continual disturbance by the stream, although empirical proof of this point was lacking.

West (1973) observed riparian vegetation differences between the Green and Yampa Rivers. The absence of Tamarisk and abundance of Cottonwood was attributed to the scouring action of floods on the wild Yampa River. The opposite is the case on the controlled Green River. In a later paper, West (1976, p. 9) directly attributes the spread of Tamarix chinensis at the expense of Salix exigua and Populus fremontii throughout the upper Colorado River System to "the arrestment of occasional perturbations by high water".

A recent study by Johnson, Burgess, and Keammerer (1976), has lent valuable information toward understanding succession in riparian forest communities. Their research was conducted on the forested floodplain of the Missouri River in North Dakota. Dendrochronological techniques were combined with diameter measurements to yield relative age estimates. From this information, stands were aged, and survivorship curves compared between stands. This yielded a continuum of stands from young to senescent ages under similar and different environmental regimes. From this, inferences about succession were made. They attributed the decline in seedling establishment of seral stage species to be correlated with control of flooding.

DESCRIPTION OF STUDY AREA

Location and extent

The Escalante River is located within western Kane and Garfield Counties, Utah, latitudes $37^{\circ}15''$ - $37^{\circ}45''$, longitudes $111^{\circ}30''$ - $111^{\circ}45''$. The town of Escalante is the major population center near the river. Figure 1 depicts the study area (detailed in Appendix 1) and surrounding features.

The headwaters of the Escalante River are in the Table Cliffs and Aquarius Plateaus. Major tributaries feed in from the Escalante and Boulder mountains. Lower, more ephemeral tributaries feed the river from the Straight Cliffs and Circle Cliff Anticline.

The study area includes the Escalante River within the confines of the Glen Canyon National Recreation Area. It is included in three USGS topographic quadrangle: Moody Creeks, King's Mesa and The Rincon. Sampling of environmental factors and riparian vegetation started at the mouth of Harris Wash and continued to where the Escalante River enters Lake Powell.

Administration

Following passage of the Taylor Grazing Act, the study area came under Bureau of Land Management (Kanab District) jurisdiction. Beginning in December, 1970 it was administered as the Escalante Canyon Outstanding Natural Area under policy guidelines F.R. 9795, subpart 6225.0-5(b) and 6225.0-6(a). This provided for "preservation of scenic values, natural wonders and examples of significant natural ecosystems." In 1972, Congress established the Glen Canyon National Recreational Area (Public Law 92-593) acquiring, among other lands, the Escalante Canyon Outstanding Natural Area and putting it under

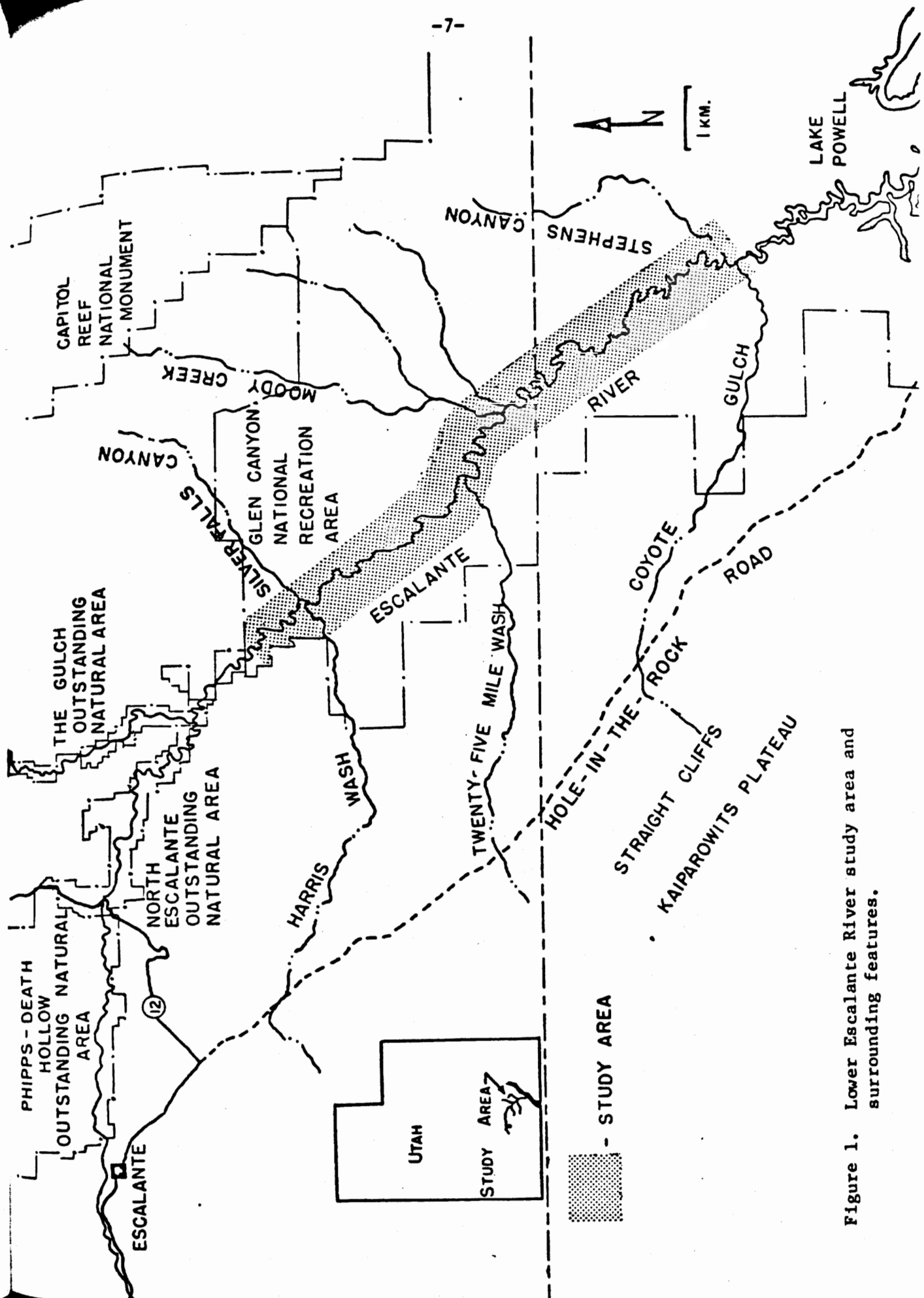


Figure 1. Lower Escalante River study area and surrounding features.

National Park Service Administration; except for grazing leases, which remained under Bureau of Land Management jurisdiction.

Current management policy is to maintain the area as a Natural Area (Carter, 1975), although official status is pending under Section 9, Public Law 92-593. In the Preliminary Environmental Assessment Master Plan and Wilderness Study Alternatives (National Park Service, 1975), proposals were put forth for public comment on an Escalante River Wilderness unit containing from a minimum of zero acres of Wilderness to a maximum of 26,750 acres of Wilderness and 43,600 acres of Potential Wilderness additions. Hence, none to all of the Escalante area may receive wilderness status. Management would have to be compatible with the Wilderness Act, if wilderness status is received.

Within the Escalante River portion of the National Recreation Area, 32 sections are owned by the State of Utah as school sections. The rest of the Recreation Area is surrounded by national resource lands administered by the Bureau of Land Management and Capitol Reef National Monument, which touches on the northeast side. The Bureau of Land Management has given special land status for most of the upper Escalante River. These include: Phipps-Death Hollow Outstanding Natural Area, The Gulch Outstanding Natural Area, and North Escalante River Canyon Outstanding Natural Area.

Use history

Grazing of domestic livestock exists on the benchlands above the Escalante River. Grazing of cattle occurs on the river bottom to about kilometer 15 (Appendix 1) where terrain inhibits further cattle passage. Grazing allotment records appear to be missing or cannot be located

(Durfey, 1975). The Bureau of Land Management claims the river is currently used by 30 to 50 head of cattle in late winter-early spring (Durfey, 1975).

Human use has been relatively light until recently. The area had been formerly frequented only by cattlemen and a few rugged tourists. With outdoor recreation becoming much more popular on wildlands, human use has increased. Recreational use is limited to horse travel and back packing, the latter being the more popular. Human recreational use is concentrated mostly in the side canyons, especially Harris Wash and Coyote Gulch. Carter (1975) has reported upwards of 200 people in Coyote Wash over Memorial Day weekend, 1975. Recreational use along the river is lighter than in side canyons, trips being concentrated near the side canyons where people enter the river. River running is negligible because the river is normally about ankle deep.

Geology

Relatively little geological work has been done in the Escalante River area. Davidson (1967) completed a detailed survey of the Circle Cliffs area to the east. Hackman and Wyant (1973) compiled a geological map from a composite of works surrounding the Escalante River. It is from these two sources and field observations that the geologic structure and stratigraphy sections are written.

The Escalante River and its tributaries are part of the Canyonlands Section of the Colorado Plateau as described by Fenneman (1931), Thornbury (1966), and Hunt (1974). The Plateau is an area of gentle uplifting, the Circle Cliffs anticline being the main geologic feature near the Escalante River. The uplifting, production of geologic structures, and

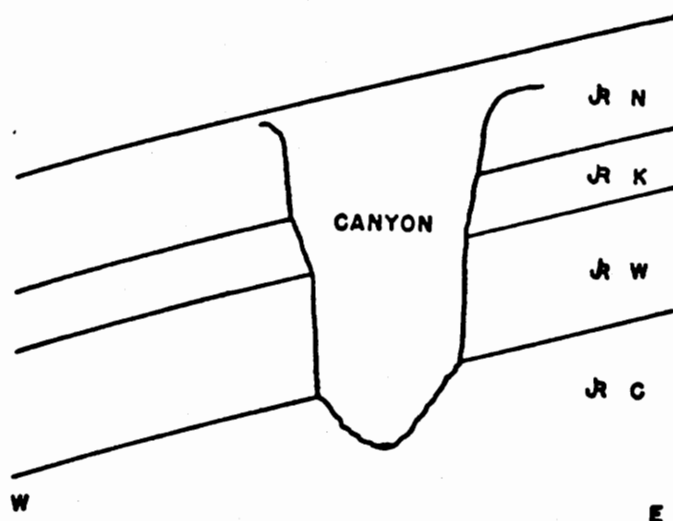
stratigraphy of the Plateau are important in determining the geomorphology of the river which in turn influences the riparian vegetation.

According to Eardley (1966) and Baars (1972) deposition of the Colorado Plateau began in Cambrian seas at the eastern shelf of the Cordilleran geosyncline. Slight rising and erosion occurred during Ordovician and Silurian times, as evidenced by the lack of rock units of this age. Lacustrine, fluvial and eolian deposition continued throughout the Mesozoic period. Uplifting started during the late Cretaceous and has continued until present. Structural features on the Plateau are mostly of Cretaceous age or younger. The Circle Cliffs Anticline originated during the early Paleocene.

Stratigraphy

The Escalante River cuts through four stratigraphic rock formations in the study area (Figure 2): The Navajo Sandstone, Kayenta Formation, Wingate Sandstone, and the Chinle Formations. To the west of the town of Escalante rocks of Cretaceous and younger age are being cut by the river (Hackman and Wyant, 1973). Davidson (1967) is the major source of the following stratigraphic descriptions. The description proceeds from a north-northwest to south-southeast direction.

Navajo Sandstone. The Navajo Sandstone is composed of massive, white to rust colored, late Triassic and Jurassic age eolian deposits. This formation is seen as massive cliffs with pillow shaped uplands having developed from remnants of petrified dunes. It is composed of well sorted and well cemented, very fine to fine subrounded frosted quartz grains, typical of eolian deposits. The orientation of cross strata indicate wind deposition from the west and northwest. The Navajo



N NAVAJO SANDSTONE
K KAYENTA FORMATION
W WINGATE SANDSTONE
C CHINLE FORMATION

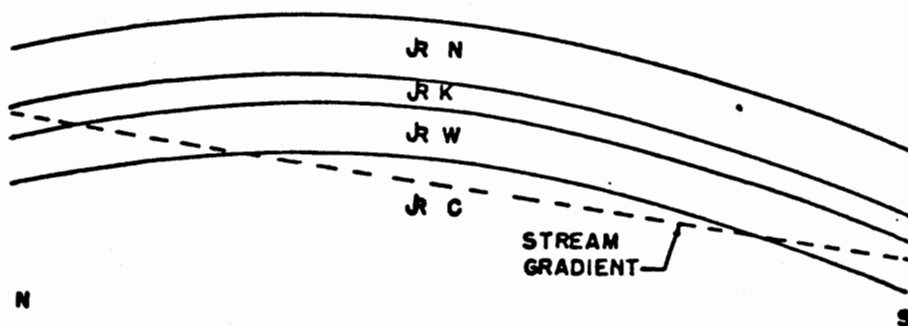


Figure 2. Geologic stratigraphy of the study area from west to east (above) and north to south (below).

Sandstone is strongly crossbedded and jointed. Jointing influences drainage patterns, mostly in the tributaries that arise on the Navajo Sandstone. A few thin carbonate lenses are present, indicative of localized shallow lakes during the period they were laid down. These beds are not present along the river but are visible on the adjacent uplands.

Kayenta Formation. The Kayenta Formation is composed of thin bedded sandstones and some siltstone laid down in Triassic-Jurassic times. It is dominantly reddish brown to dark purplish red. The beds are lenticular, weakly to strong cemented and with medium cross-stratification. The upper bed is cross-stratified sandstone of eolian origin. Lower sandstone and siltstone units are micaceous and feldspartic and many beds contain mud chips. Bedding structure indicates continental and fluvial origin, the source area being to the east in the ancestral Rocky Mountains. This formation is conformably overlain by the Navajo Sandstone. Boundary contact is difficult to discern where the upper beds of the Kayenta Formation are present.

Wingate Sandstone. The Wingate Sandstone is a massive cliff forming unit of Jurassic age. It is the basal formation in the Glen Canyon group. It is light brownish orange in color and composed of very well sorted fine grained quartzose. It is moderately well cemented with calcium carbonate. Like the Navajo Sandstone, the Wingate Sandstone is primarily eolian in origin with west and northwest winds creating the thick dunal deposits. The Wingate is conformably overlain by the Kayenta Formation and boundary contact is readily discernible.

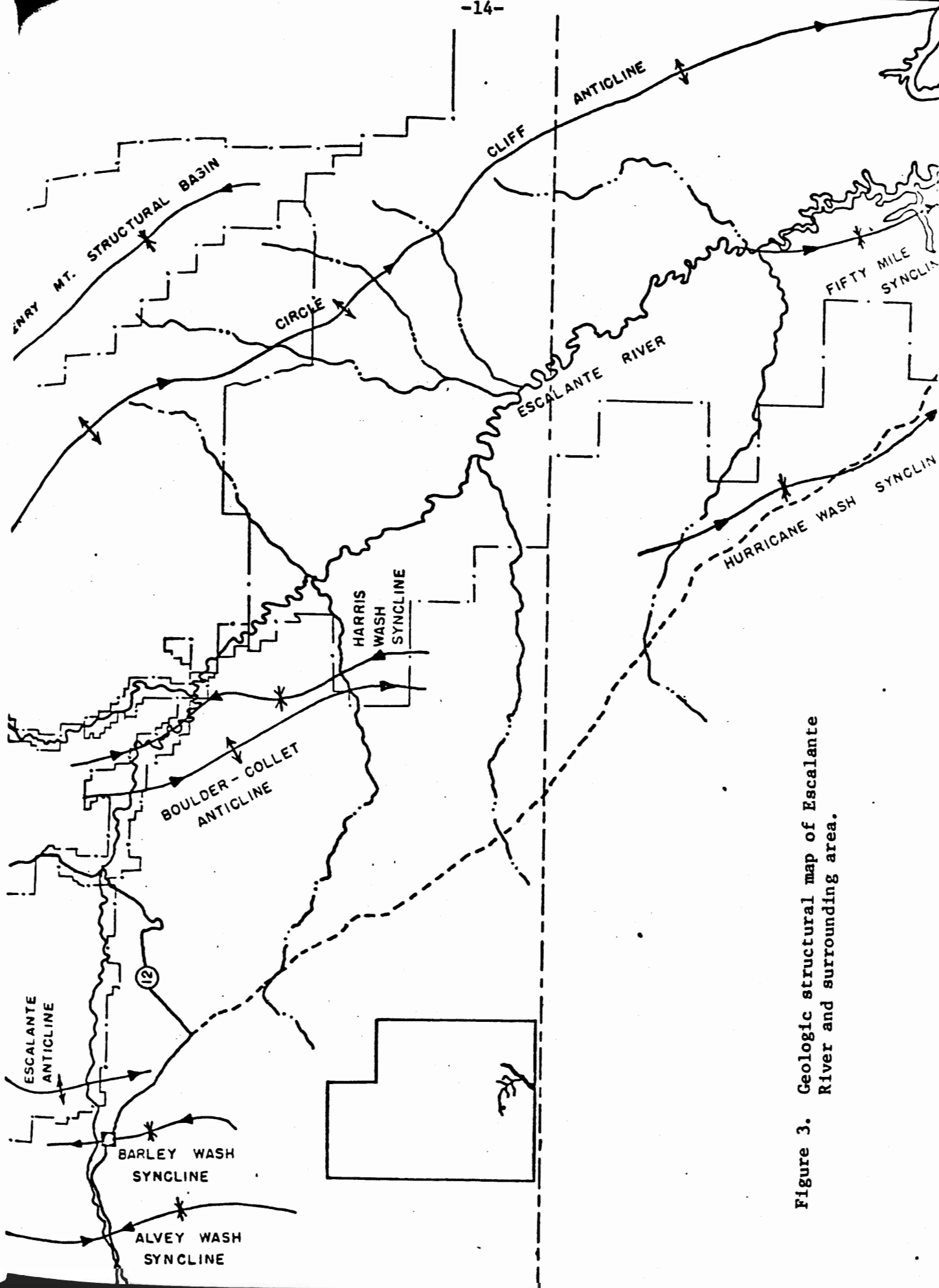
Chinle Formation. The Chinle Formation is composed of inter-tonguing fluvial mudstone, sandstone, and siltstone of Triassic age

with limestone lenses of green, red, blue and grey hues. In ascending order the Monitor Butte Member, Petrified Forest Member, Owl Rock Member, and Church Rock Member are present along the Escalante River. The basal Shinarump member is present at the head of Moody Creek Canyon but wedges out to the west. The Shinarump, Monitor Butte, and Petrified Forest Members were deposited as alluvial plains that sloped northward from a source area in near southern Arizona (Poole, 1961). The Owl Rock Member has a dominantly lacustrine origin and the Church Rock member a fluvial origin. Sediment sources for these members were the ancestral Rocky Mountains in western Colorado (Stewart et al., 1958).

Geologic structure

Most of the geological structural information is derived from work done by Hackman and Wyant (1973). Figure 3 contains a structural map of the Escalante River area synthesized from their work.

To the west of the town of Escalante, the Escalante River cuts across the Alvey Wash Syncline and the Button Anticline. The River traverses these features perpendicular to their north-south trending axes. The river then cuts across the Barley Wash Syncline which trends north-south through the town of Escalante. East of the town of Escalante the river cuts across the Escalante Monocline, Escalante Anticline, Sand Creek Syncline, and the Boulder-Collete Anticline. The Escalante River then contours the Harris Wash Syncline, meeting the western flank of the Circle Cliffs Anticline. Here, the river parallels the structural contours of the Circle Cliffs Anticline. The study area is within this Circle Cliffs Anticlinal area. The river (now Lake Powell) then turns south at the axes of the Fifty



the river cutting across structural axes. The river then turned southeastward following the base of the now retreated Straight Cliffs. The two major southwestern tributaries, Coyote Wash and Harris Wash turned northward following structural contours exposed by the retreating Straight Cliffs. This would explain the position of the river on the southwestward dipping beds of the Circle Cliff Anticline. Evidence would indicate this section is not superimposed since the river often parallels jointing planes of the Navajo Sandstone and meanders often align with jointing planes typical of rectilinear drainages.

Tributaries to the Lower Escalante River (Harris Wash Syncline, south) are generally dendritic with pinnate and rectilinear drainage patterns evident. The strong influence of jointing planes is obvious for secondary tributaries arising on the Navajo Sandstone. Tributaries of the Escalante River on the northeast side tend to show a pinnate drainage pattern paralleling the bedding dip and jointing planes. Their tributaries are both pinnate and rectilinear. On the southwestern side of the river, tributaries are generally dendritic, first following the bedding dip near the river then turning southward with the associated Straight Cliff retreat. Their tributaries also show strong preference for jointing planes on the Navajo Sandstone.

River bank morphology

Floodplain and river bank morphology are influenced by hydrologic regime, geologic structure, stratigraphy, and geomorphology (Leopold, Wolman and Miller, 1964). Since the Escalante River is deeply entrenched, floodplains are small in extent. They form under a situation

of fluvial deposition where the river is occupying less than the total canyon floor. If the river occupies all the canyon floor, then rock walls or colluvium form the river bank.

Floodplains occur where the Escalante River cuts the Navajo-Kayenta formations and to some extent the Wingate formation. Throughout the Chinle formation the riverbanks are the result of fluvial deposition and colluvium from the Chinle. Terraces form on the flood plains due to different degrees of fluvial deposition and erosion from periodic flooding.

Soils

The soils of the Escalante River floodplain are alluvial deposits that lack horizonation and vary in texture. Wilson et al. (1975) have mapped Lithic Ustic Torriorthents, Typic Torrifuvents and Ustic Torripsamments in the Escalante floodplain regions. These classifications were made without field surveys.

Vegetation has had an insignificant influence on soil development. The soils are recently deposited and are continually subjected to flooding. Flooding erodes and redeposits soils, lessening the effect of vegetation on soil development and preventing soil horizonation.

Hydrology

No gauging stations are located on the lower Escalante River. A gauging station is located just west of the town of Escalante and has been consistently maintained for the past 17 years. Mean flow for this portion of the river over this period is $.52 \text{ m}^2/\text{s}$ ($18.5 \text{ ft}^3/\text{s}$) with a yearly water yield of $16.5 \text{ hm}^3/\text{s}$ (1340 acre ft/yr). Maximum

flow in recent decades was estimated at $97.7 \text{ m}^3/\text{s}$ ($3450 \text{ ft}^3/\text{s}$) on August of 1953 (USGS, 1973). Although this section of the River is dissimilar to the lower section, intensity of flow would be expected to be similar or greater due to the increase in slickrock on the lower section. Hence, this data probably underestimates normal flow slightly and greatly underestimates peak flood flows.

Flora and vegetation

Two distinct kinds of vegetation are found in the Escalante Region: the upland desert, grassland and pigmy conifer woodland communities and the riparian plant communities associated with the river floodplains.

Atwood and Welsh (1971) did a floristic survey for the area surrounding the Kaiparowits Plateau. This included both riparian and upland species, but actual field work on the Escalante River was not conducted.

Holden and Irvine (1974) surveyed the fishes and riparian flora of the Escalante River. Ninety plant species were found on floodplains or river banks. Eleven of these species are classified as true riparian plant species by Campbell and Green (1968) and are presented in Table 1 with taxonomy consistent with that used by Atwood and Welsh (1971). A voucher collection of these species is located in the Intermountain Herbarium at Utah State University.

Table 1. Riparian and pseudo-riparian plants occurring along the lower Escalante River (Holden and Irvine, 1974).

Scientific name	Authority	Common Name	Status ^a	Origin ^b
TREES				
<u>Salix exigua</u>	Nutt.	Sandbar willow	R	N
<u>Populus fremontii</u>	Wats.	Fremonts cottonwood	R	N
<u>Tamarix pentandra</u>	Pall.	Tamarisk or Saltcedar	R	I
<u>Salix amygdaloides</u>	Anderss.	Peach-leaved willow	R	N
SHRUBS				
<u>Baccharis emoryi</u>	A.Gray	Seepwillow	R	N
<u>Chrysothamnus nauseosus</u>	Pall.	Rabbitbrush	P	N
GRASSES				
<u>Distichlis stricta</u>	(L)Greene	Salt grass	P	N
AQUATIC AND SEMI-AQUATIC SPECIES				
<u>Scirpus americanus</u>	Pers.	American bulrush	R	N
<u>Equisteum laevigatum</u>	A.Br.	Smooth horsetail	R	N
<u>Typha latifolia</u>	L.	Cattail	R	N
<u>Juncus spp.</u>	L.	Rush	R	N

^aStatus: R = riparian, P = pseudo-riparian

^bOrigin: N = native, I = introduced

METHODS

Field methods

The Escalante River is a roadless area with few access points. Foot travel is the only means of traversing through the 125 kilometer long study area. Access was gained through Harris Wash, Moody Creek, and Coyote Wash. All sampling and camping equipment had to be back-packed and/or hand carried. Therefore, it was essential to keep sampling methods simple, involving a minimum amount of equipment. Objectivity had to be compromised as situations demanded, but every attempt was made to maintain scientific quality.

The first step was to mark off each kilometer of the linear, riverside study area on the U.S. Geological Survey Topographic Quadrangle (Appendix 1). Every third kilometer was chosen for intensive sampling. Rapid surveys were made for the other two intervening kilometers. This yielded a continual sample of the river at each kilometer with intensive sampling every third kilometer. Geology, soils, river bank morphology, hydrology, and riparian vegetation were sampled at each intensive site. Presence-absence data for riparian plant species, geology, and river bank morphology were recorded at other sites.

Geology. Notes were kept on the stratigraphy and profile of the canyon at each kilometer. Stretches of the canyon profile were made with canyon width estimated. Position of the river to the strata it was cutting was also recorded.

River bank morphology. At each sampled kilometer, the river bank was measured for aspect, facing towards the River. Distinct flood

terraces were recognized and their width was measured. Slope of each flood terrace was recorded with the aid of a clinometer. River bank profile sketches were related to the canyon profile.

Soils. At each intensively sampled kilometer, measurements of soil texture on each flood terrace were conducted using standard U.S. Soil survey procedures (U.S.D.A. Soil Survey Staff, 1973). Soil moisture was estimated once during vegetation sampling for each flood terrace at the soil surface, at 10 cm and at 20 cm depths. Soil moisture categories were arbitrarily defined as dry, moist, saturated, and standing water.

Hydrology. At each intensively sampled site the width and depth of the river was measured. Speed of surface river flow was measured by recording the time it took for a small stick to float 10 meters. Roughness and composition of the river bottom was estimated.

Riparian vegetation. Field sampling of the riparian plant communities occurred over two summer field seasons, 1974 and 1975. An attempt was made to maintain sampling consistency for the two seasons, however, the sampling scheme changed slightly the second season with an increased understanding of the riparian plant communities.

During the 1974 field season a tenth-hectare strip quadrat method (macro-plots) was used, as modified by Whittaker (1960) and Whittaker and Niering (1965). Macro-plots were located every three kilometers (Appendix 1) with species presence-absence data collected on the unsampled kilometers. A 50 meter tape was laid out on the ground, 10 meters in from and parallel to the river. Three randomly chosen points spaced between three equal segments were sampled by extending a 20 x 1 meter rectangle partitioned into ten 2 x 1 meter micro-plots on each

side of the tape. This created 10 micro-plots extending inward from the river edge (Figure 4). All plants at least half rooted within the micro-plot were measured for cover and density. Cover estimates were aided with a frame representing 5% of the micro-plot. Trees, shrubs, and forbs were measured in a 50 cm x 20 cm micro-section of the micro-plot.

With a better knowledge of the problems associated with riparian vegetation sampling, slight alterations were made during the 1975 field season. It was obvious that different flood terraces were associated with different riparian plant communities and that quadrats sampled during the 1974 season crossed these flood terraces. Due to the varying width of these flood terraces, a scheme had to be developed so that each terrace could be sampled separately.

The quadrat method was again employed to remain consistent with previous sampling. The width of each flood terrace was measured, and a random number chosen within each distance. A 10 x 1 meter rectangle was extended down and parallel to the river with five 2 x 1 meter micro-plots (Figure 5). Those species occurring with greater than 20 percent frequency during the 1974 field season were surveyed. This decision was arbitrary but seemed reasonable because species either occurred with greater than 20 percent frequency or were very rare (1 percent or less). Shrubs and forbs at least half rooted within the microplot were measured for cover and density. Grasses and grasslikes were measured for cover and density in a 50 cm x 20 cm micro-section within each microplot.

The three major tree species, Salix exigua, Nutt. (Sandbar willow), Populus fremontii Wats. (Freemont Cottonwood), and Tamarix pentandra Pall.

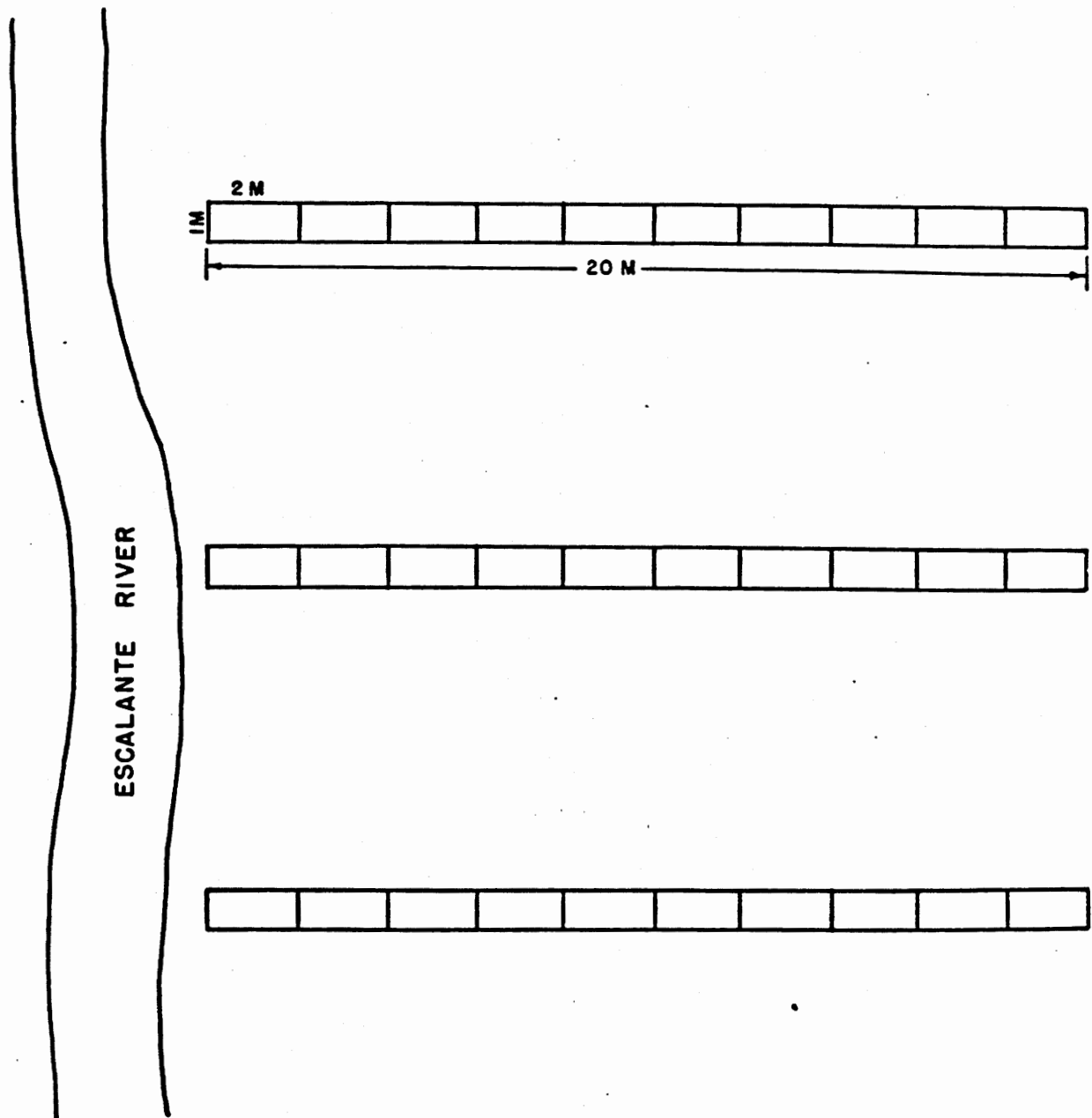


Figure 4. Macro- and micro-plot design for 1974 field season.

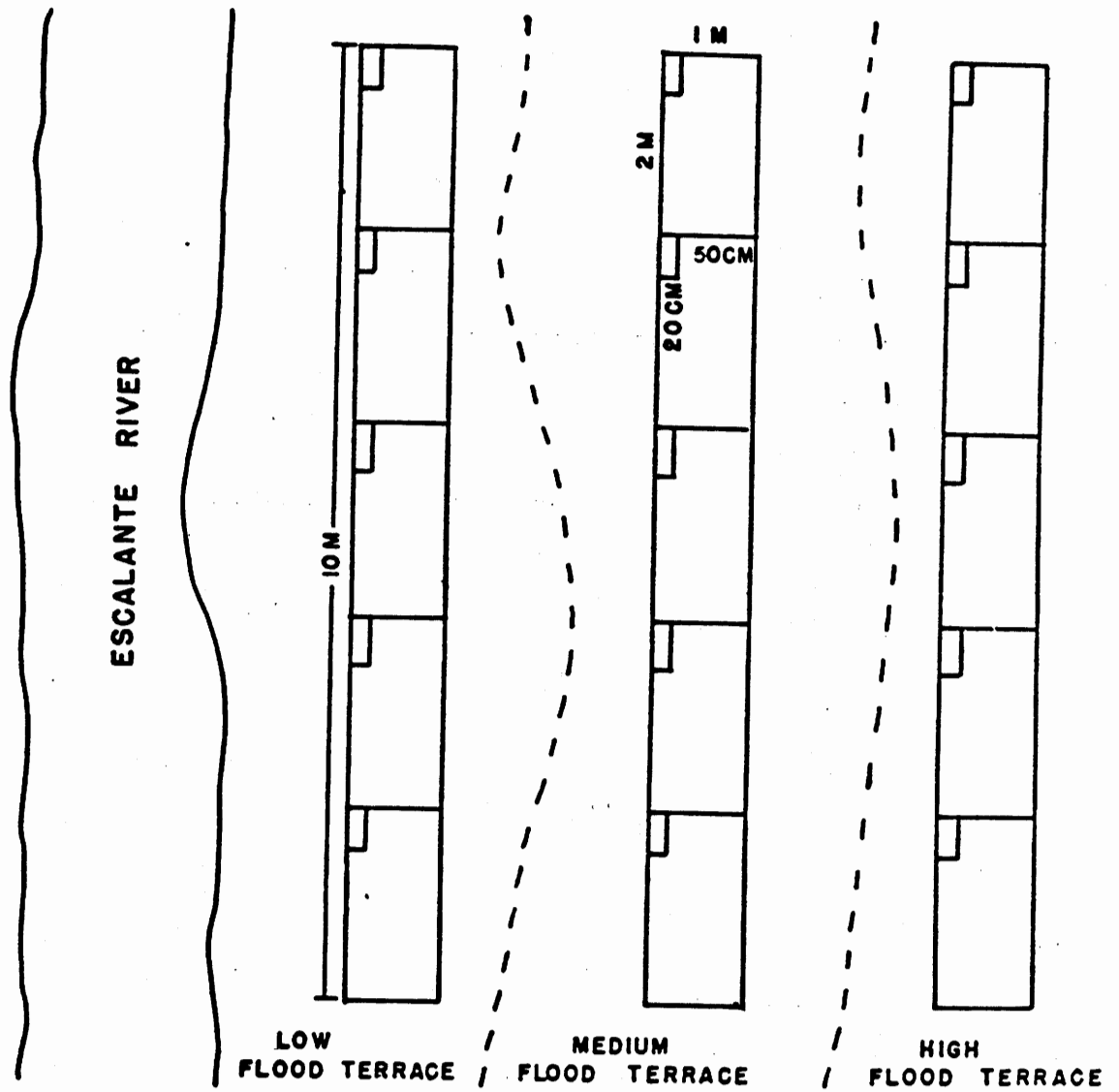


Figure 5. Macro- and micro-plot design for 1975 field season.

(Tamarisk or Salt cedar), within the 10 x 1 meter rectangle were tallied for density in 10 arbitrarily created height classes. Diameter, at base level for all trees and height, and two crown widths for ten trees in each height class were measured. Widths were taken through the widest and narrowest section of the fullest part of the crown. Cross sections at base level of two trees per species per height class per flood terrace were also collected.

Data analysis

Environmental parameters. All environmental parameters operative on each flood terrace at each macro-plot were tabularly summarized for comparison with natural vegetation groupings.

Cluster analysis. The 1974 riparian vegetation data set was reorganized to partition the macro-plots by flood terraces. Micro-plots were grouped within flood terraces and reduced to relative cover and relative density values. This was done to avoid unbalanced sample sizes. Micro-plots crossing a flood terrace boundary were not used. The reorganized 1974 data and the 1975 data were separately subjected to a cluster analysis. Clustering macro-plots by species and species by macro-plot was done by computing an index of similarity as described by Pyott (1972) where

$$\text{Index of Similarity} = \frac{2 \sum w}{\sum a + \sum b}$$

w = smallest of two values when two macro-plots have the same species in common.

a = species x in macro-plot a.

b = species x in macro-plot b.

RESULTS AND DISCUSSION

Environmental parameters

Table 2 summarizes the major environmental parameters thought to be influencing the riparian vegetation. Of particular interest are the relationships between stratigraphy, river bank morphology, and flood terracing.

In the study area the River first cuts through the Navajo Sandstone and Kayenta Formation from km 0 to km 11. Figure 6 is an idealized canyon profile of this section with detail of the canyon bottom. The Wingate Sandstone is cut by the river from km 11 to km 27. Figure 7 is a profile diagram of this section.

All three formations are relatively resistant to erosion and downcutting is slow -2.74 m/km (Figure 8). With a shallower stream gradient, kinetic stream energy is transferred to meandering. In combination with the massive nature of the Navajo Sandstone, the resultant canyon is broad (70-100 m) with respect to other sections of the canyon. Meandering lessens and the canyon narrows through the Wingate Sandstone conforming to its jointing structure.

With the slower cutting rate and shallower stream gradient, alluvial deposition is greater and creates broad flood terraces. Three terraces exist in this section. The first, a low flood terrace, 1-15 m wide, rises from the river edge 10-30 cm. It is composed of approximately equal amounts of clay, silt and sand. Soil surface moisture varies between being 100 percent saturated with water to being supersaturated, the low flood terrace succumbing to frequent inundations by rises in the river level after minor rain events. It is also completely covered in May by spring runoff.

Table 2. Major environmental parameters (organized by stratigraphic section) thought to be influencing the riparian vegetation along the lower Escalante River.

Stratigraphic section	Flood Terrace ^a	Soil Texture %						Soil Moisture ^b		River Bank Profile				
		Clay	Silt	Sand	Gravel	Cobble	Stone	Boulder	Surface	10 cm	20 cm	Mean Ter- race Width (m)	Mean Ter- race Angle (°)	Mean Elevation rise (m) of Terrace Above River Level
Navajo Sandstone- Kayenta Formation	L	22	35	30	5	8	0	0	2	1	1	13	2	0 - .3
	M	3	25	72	0	0	0	0	4	3	3	16	2	.3 - 1.0
	H	3	27	77	0	0	0	0	4	4	4	20	1	1.0 - 2.0
Wingate Sandstone	L	26	32	38	4	0	0	0	2	1	1	7	3	0 - .4
	M	5	27	68	0	0	0	0	4	4	3	10	4	.4 - 1.0
	H	0	30	70	0	0	0	0	4	4	4	10	1	1.0 - 7.2
Chinle Formation	L	14	20	40	12	10	3	1	3	2	1	8	4	0 - .3
	M	1	25	69	2	3	0	0	4	4	4	6	6	.4 - 1.4
	H	3	25	72	0	0	0	0	4	4	4	5	6	1.0 - 2.6
Wingate Sandstone	L	0	10	60	20	10	0	0	3	2	1	6	5	0 - .3
	M	0	10	65	20	5	0	0	4	4	3	5	5	.3 - 1.0
	H	0	25	75	0	0	0	0	4	4	4	5	1	1.0 - 2.1

^a L - Low flood terrace, M - Medium flood terrace H - High flood terrace.

^b 1. Standing water and/or supersaturated, 2. Saturated, 3. Moist, 4. Dry

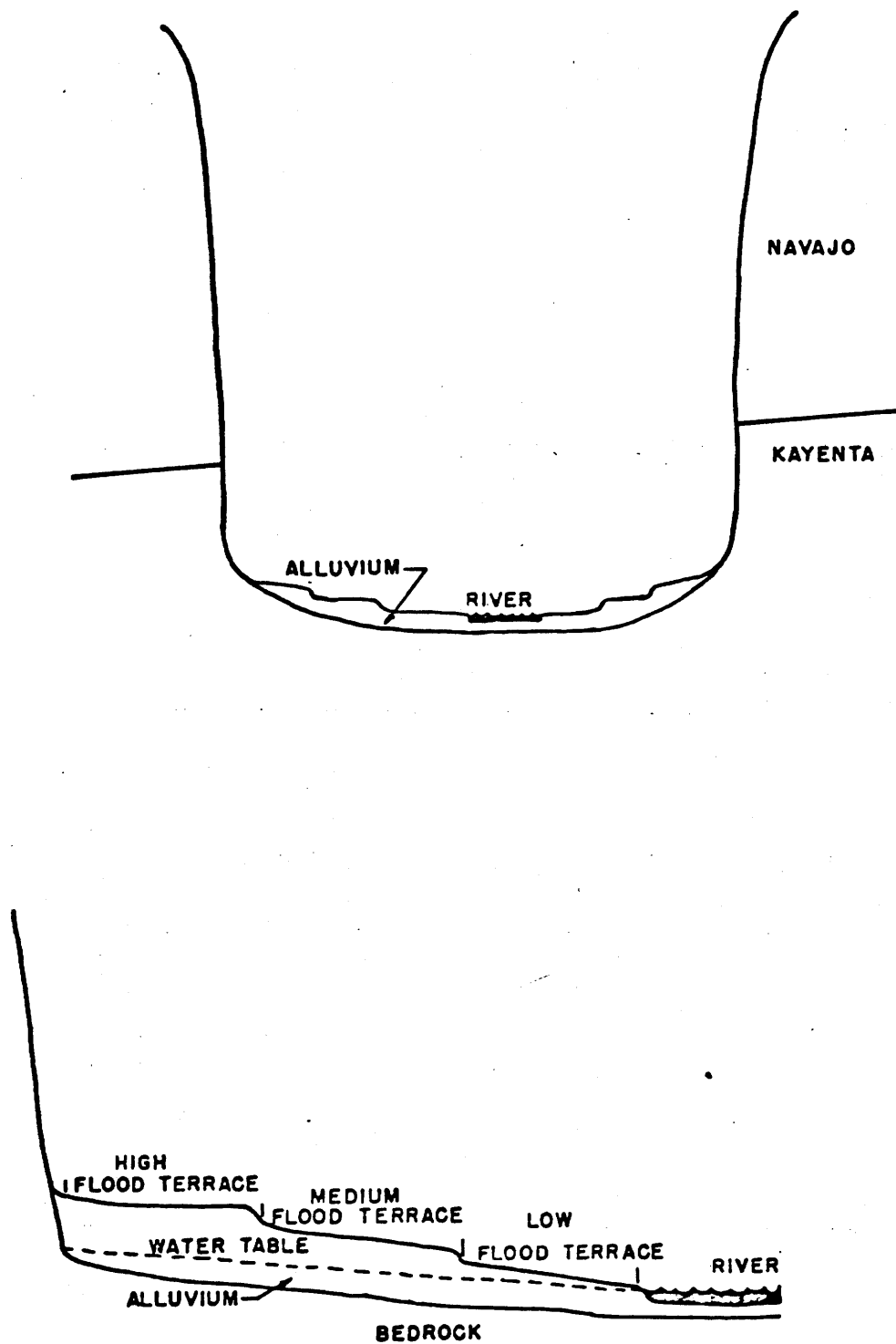


Figure 6. Canyon, river bank, and flood terrace profile of the Navajo Sandstone-Kayenta Formation section.

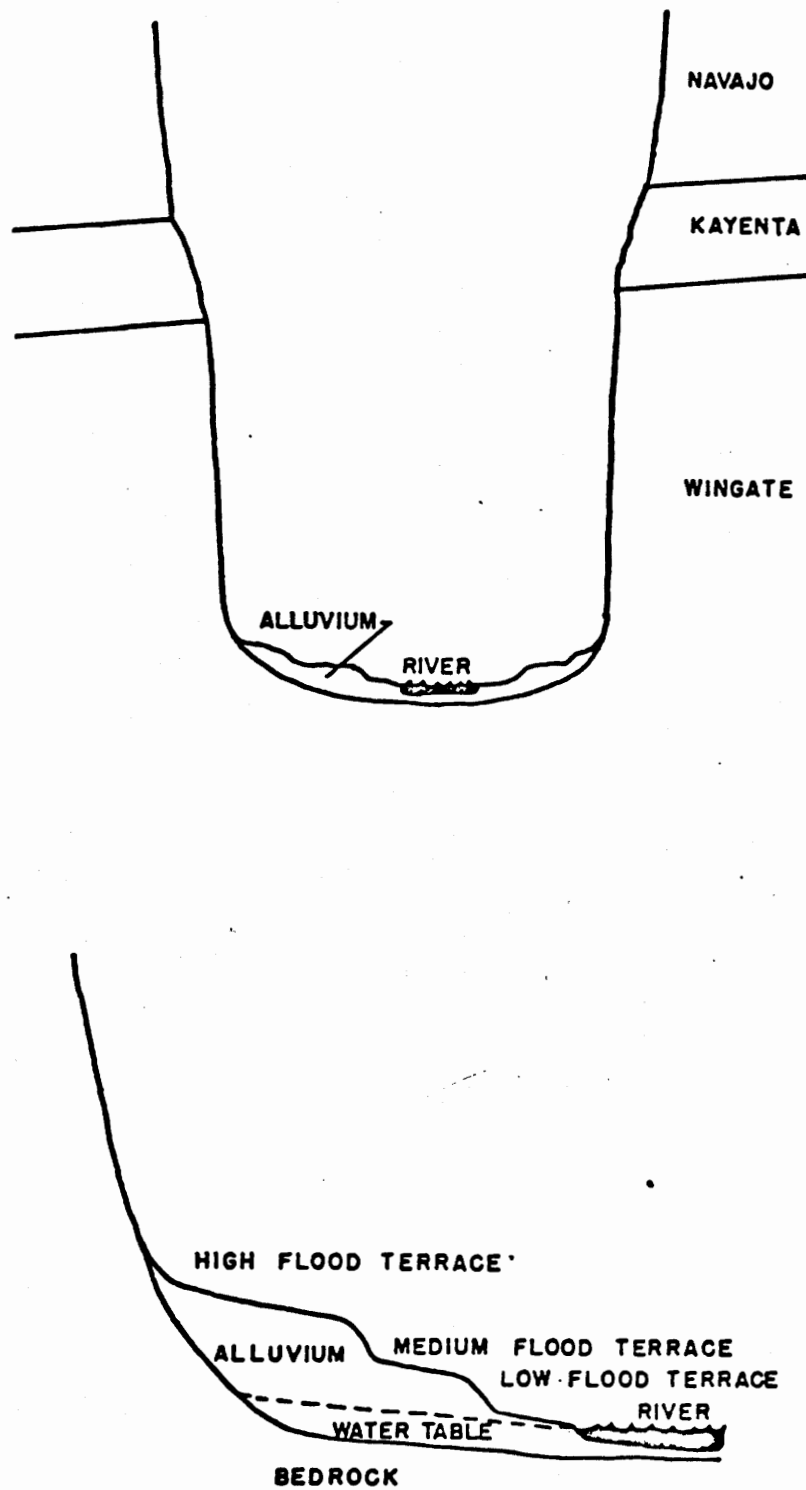


Figure 7. Canyon, river bank, and flood terrace profile of the Wingate Sandstone section.

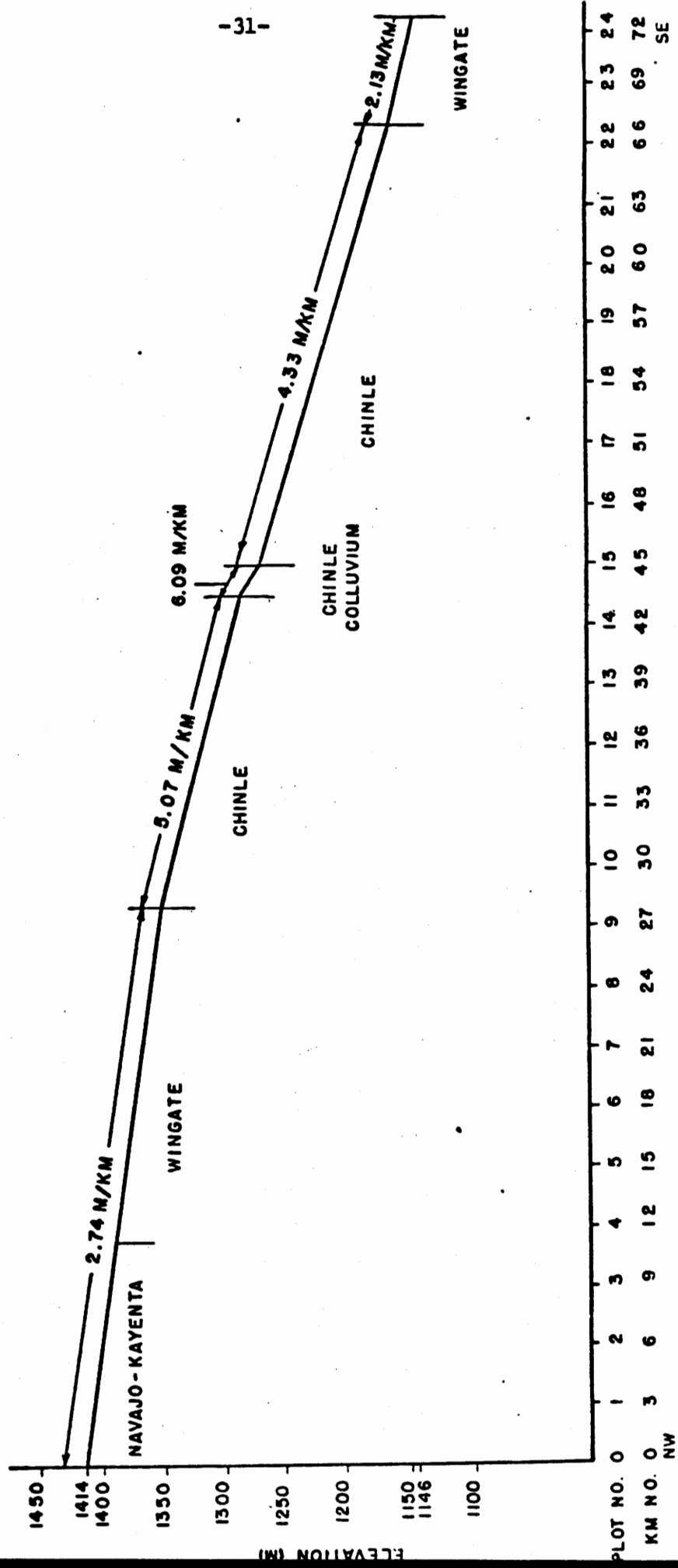


Figure 8. Stream gradient by stratigraphic section for the lower Escalante River.

The medium flood terrace is adjacent to the low flood terrace moving away from the River. It is 2-20 m wide and rises 50-100 cm above the River. The surface is usually dry but is moist below 20 cm. The terrace soil has about 30% silt and 70% sand with traces of clay. This terrace is probably inundated with water by flash floods every three to five years as evidenced by the high degree of flood debris found on this terrace (Figure 9).

The high flood terrace is 10-26 m wide, rises to 2 meters above the River, and has a soil with 70-100% sand. The end boundary of this terrace was arbitrarily defined by the lack of riparian vegetation, however, flood debris existed past this point. The high flood terrace probably rarely floods, possibly only during "100 year" floods. Flood debris with logs up to 200 cm in diameter were found indicating flooding does occasionally reach this terrace, however (Figure 10).

Through the Wingate Sandstone section, the river banks steepen as the River entrenches in the alluvium (Figure 7). Each flood terrace is foreshortened and soil moisture is noticeably different on the medium flood terrace. The high flood terrace was generally too high above the river-created water table to support riparian vegetation. It was not investigated when riparian species were absent.

The Chinle Formation is cut by the River from km 27 to km 67. The Canyon profile, river bank and flood terraces are markedly different from the previous section. The Chinle Formation is a relatively soft unit, thus downcutting by the river has been rapid, 5.07 m/km (Figure 8). Rapid downcutting and the softness of the formation have caused large colluvial deposits to form (Figure 11). Depending on the amount of

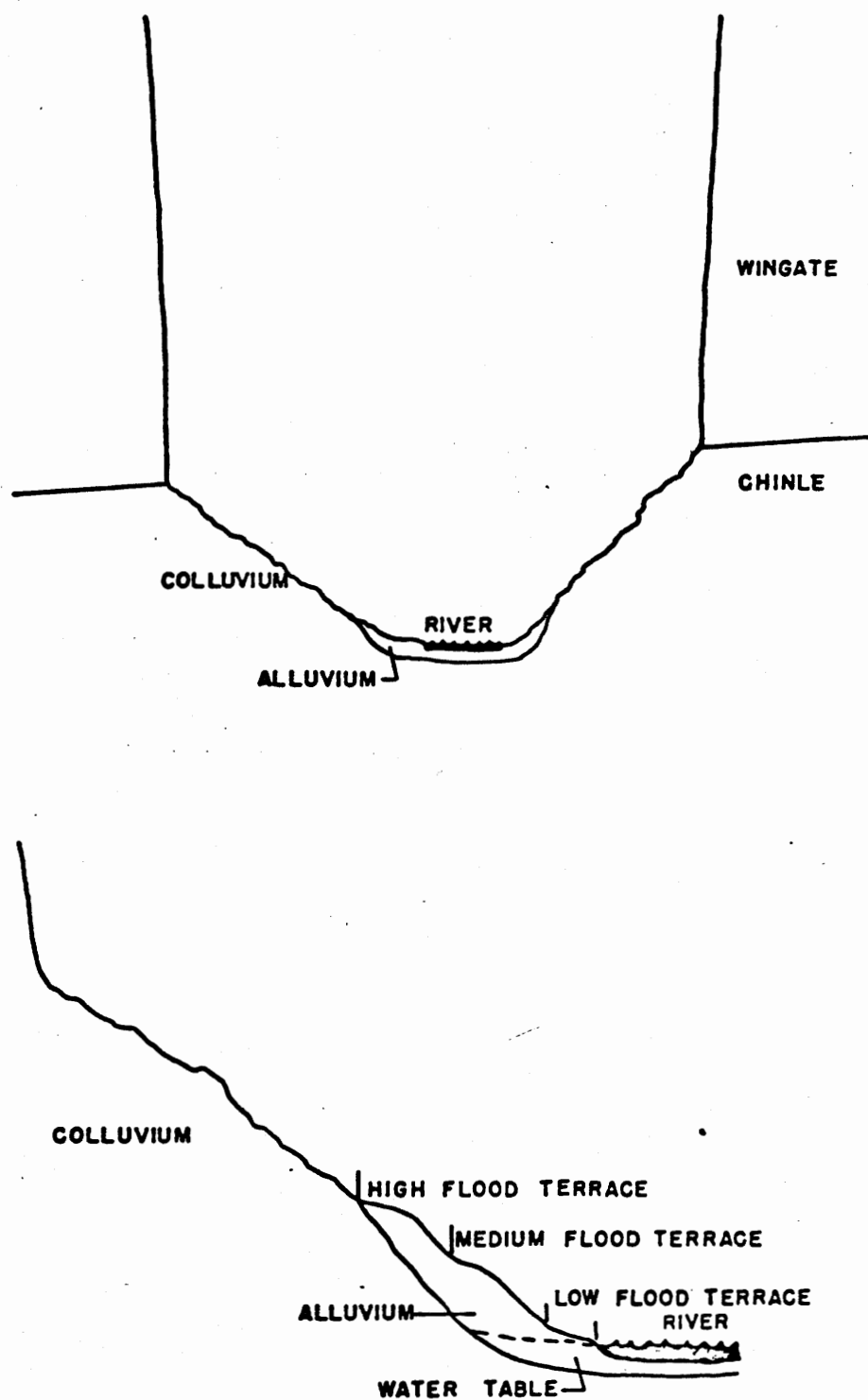


Figure 11. Canyon, river bank, and flood terrace profile of the Chinle Formation section.

colluvium, the river is either entrenched with steep river banks (Figure 12) or the low flood terraces are broad if colluvial deposits are lacking (Figure 13). In some parts, undercutting of the formation by the river has caused house-sized boulders to obstruct river flow and only a low and medium flood terrace is distinguishable.

Throughout the Chinle Formation section, percentages of gravel, cobble and stone are high on the low flood terrace soils (Table 2). This results in gravel bars forming as opposed to sand bars in the more westerly section. Soil surface moisture is usually less than the previous sections, varying between moist at the surface to saturated at 20 cm. This terrace is also inundated by periodic rises in river level.

The medium flood terraces are generally steeper but varied depending on the extent of colluvial depositions. They are generally narrower, 2-5 meters, and have a high amount of flood debris.

High flood terraces were evident in the section, but are generally 2-3 m above the river. This higher terrace level is due to the narrower profile of the canyon. Since the water table is well below this level, the terrace did not support any riparian vegetation and were not subjected to further investigation.

The last section was from km 67 to km 72 where the river entered the Wingate Sandstone. Canyon profile, river banks, and flood terraces were similar to the previous Wingate Sandstone section. However, higher amounts of gravel and cobble were present being washed downriver from the Chinle Formation and terraces were not as wide since the canyon was narrower than the previous Wingate Sandstone section.

Flora and vegetation

Twelve riparian plant species were found in the study area. Two pseudo-riparian and five non-riparian species occurring with greater than 20% frequency were also found in the study area. Table 3 is a floristic list of these species, ranked by relative cover (%) and density (plants per km²) for the whole study area.

Of the 19 species found, four of these, Tamarix pentandra, Melilotus alba, Franseria acanthacarpa and Salsola kali, are introduced species. All have established themselves as naturalized species of the riparian plant community. The most prolific of these species, Melilotus, has probably become established due to agricultural activities upriver and grazing by cattle on the upper part of the Escalante River. Tamarix, another well established species, has probably escaped cultivation or has dispersed from areas of greater abundance in the Southwest. The other two species, Franseria and Salsola, are also well established introductions.

Tables 4, 5, and 6 include relative cover and relative density values for each plant species by flood terraces throughout the study area. Species are ordinated by adding cover and density together to obtain an importance value which was ranked from high to low values. The 1974 data is presented since it represents the most comprehensive data set.

On the low flood terraces, the aquatic and semi-aquatic plant species exist. These include the dominant species Scirpus americanus and Equisetum laevigatum, Typha latifolia, and Juncus species. Melilotus alba in a vegetative form (further referred to as immature Melilotus) and Muhlenbergia asperfolia also reside here. The vegetative form of Melilotus was composed of soft tissue stems that had dense foliage cover and no flowers. As Melilotus completes its life cycle, stems increase in

Table 3. Riparian and other plant species occurring with greater than 20% frequency along the lower Escalante River.

Scientific Name	Authority	Status	Origin	Relative Density - Frequency Index
TREES				
<u>Salix exigua</u>	Nutt.	R	N	
<u>Populus freemontii</u>	Wats.	R	N	
<u>Tamarix pentandra</u>	Pall	R	I	
<u>Salix amygdaloides</u>	Anderss.	R	N	
SHRUBS				
<u>Chrysothamnus nauseosus</u>	Pall.	P	N	2.59
<u>Baccharis emoryi</u>	A. Gray	R	N	2.50
FORBS				
<u>Melilotus alba</u>	Desr.	N	I	55.43
<u>Franseria acanthacarpa</u>	Cov.	N	I	3.85
<u>Salsola kali</u>	L.	N	I	1.42
<u>Conyza canadensis</u>	(L) Cronq.	N	N	1.34
GRASSES				
<u>Muhlenbergia asperfolia</u>	Parodi	N	N	32.81
<u>Distichlis stricta</u>	(L) Greene	P	N	19.56
AQUATIC AND SEMI-AQUATIC SPECIES				
<u>Scirpus americanus</u>	Pers.	R	N	100.12
<u>Equisetum laevigatum</u>	A.Br.	R	N	42.07
<u>Juncus torreyi</u>	Cov.	R	N	
<u>Juncus bufonius</u>	L.	R	N	1.04
<u>Juncus tracyi</u>	Rydb.	R	N	
<u>Typha latifolia</u>	L.	R	N	.12

^aStatus: R = riparian, P = pseudo-riparian, N = non-riparian

^bOrigin: N = native, I = introduced.

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Species	Average				Relative density π frequency values
	22		23		
	C	D	C	D	
<i>Scirpus americanus</i>			21.25	100.00	121.25
<i>Eleocharis acicularis</i>			3.54	17.04	20.58
<i>Eleocharis laevigatum</i>			1.50	6.66	8.16
<i>Eleocharis asperfolia</i>	5.0	1	1.50	2.64	4.14
<i>Eleocharis alba</i> I		2	2.50	1.01	3.56
<i>Eleocharis alba</i> M			.96	.08	1.04
<i>Juncus</i> spp.			.09	.29	.38
<i>Scirpus canadensis</i>			.10	.27	.37
<i>Distichlis stricta</i>			.14	.19	.33
<i>Franseria acanthocarpa</i>			.17	.12	.29
<i>Chrysopsis nausaeus</i>			.22	.02	.24
<i>Salicornia kali</i>	T	0	.04	.08	.12
<i>Lythra latifolia</i>					

Table 5. Summary of the vegetation data for the medium flood terraces by cover (C, T < 0.5), density (D, number of plants per 2m²).

Species	Macro-plot number									
	0		1		2		3		4	
	C	D	C	D	C	D	C	D	C	D
<i>Melilotus alba</i> I	16.7	300	11.2	128	T	0	9.6	14		
<i>Equisetum laevigatum</i>			6.8	105			2.1	15		
<i>Diatichia stricta</i>	20.3	305					4.3	60		
<i>Muhlenbergia asperifolia</i>	10.0	45	16.7	41	T	6	5.8	35		
<i>Melilotus alba</i> M	58.3	22	33.3	5			27.9	7		
<i>Franseria acanthacarpa</i>					8.9	27	5.4	17		
<i>Baccharis emoryi</i>										
<i>Chrysanthamnus nauseosus</i>					9.9	2				
<i>Conyza canadensis</i>			T	0	T	0				
<i>Salvia lali</i>					T	0				
<i>Scirpus americanus</i>										

Species	Macro-plot number									
	11		12		13		14		15	
	C	D	C	D	C	D	C	D	C	D
<i>Melilotus alba</i> I	0.7	1					4.7	6		
<i>Equisetum laevigatum</i>	3.3	200					T	0		
<i>Diatichia stricta</i>										
<i>Muhlenbergia asperifolia</i>	16.7	80								
<i>Melilotus alba</i> M										
<i>Franseria acanthacarpa</i>										
<i>Baccharis emoryi</i>										
<i>Chrysanthamnus nauseosus</i>										
<i>Conyza canadensis</i>										
<i>Salvia lali</i>	.7	1	T	1	1.5	3	1.3	9		
<i>Scirpus americanus</i>	T	1								

Table 6. Summary of the vegetation data for the medium flood terraces by cover (C, T < 0.5), density (D, number of plants per 2m²).

Species	Average				Relative density x frequency values			
	22		23		C		D	
	C	D	C	D	C	D	C	D
<i>Melilotus alba</i> I	7.5	60	1.5	2	16.07	12.05	28.12	
<i>Equisetum laevigatum</i>	5.0	20			1.96	16.74	18.70	
<i>Diatichia stricta</i>	2.5	20			2.10	8.98	11.08	
<i>Muhlenbergia asperifolia</i>					2.61	5.88	8.49	
<i>Melilotus alba</i> M					7.59	.86	8.45	
<i>Franseria acanthacarpa</i>			1.0	1	.85	1.97	2.82	
<i>Baccharis emoryi</i>					.52	.79	1.31	
<i>Chrysanthamnus nauseosus</i>					.83	.29	1.12	
<i>Conyza canadensis</i>					.17	.24	.41	
<i>Salvia lali</i>					.21	.10	.31	
<i>Scirpus americanus</i>					.02	.10	.12	

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Species	22		23		Average		Relative density x frequency values
	C	D	C	D	C	D	
<i>Muhlenbergia asperifolia</i>	37.1	29			4.98	8	11.18
<i>Distichlis stricta</i>	T	3			1.66		6.45
<i>Mollotus alba</i> I	3.2	1			1.31	3	3.79
<i>Mollotus alba</i> M	0.9	0			5.56		5.10
<i>Equisetum laevigatum</i>	T	3			.61	2	1.18
<i>Baccharis emoryi</i>					.83	.36	1.19
<i>Chrysothamnus nauseosus</i>	T	0			.82	.31	1.18
<i>Salicola kali</i>	2.8	2			.60		.27
<i>Franseria acanthocarpa</i>	T	0			1.1	0	.27
<i>Coryza canadensis</i>	T	0			.47	.08	.55

length and stem tissue hardens to a woody appearance, further referred to as mature Melilotus. The coexistence of both forms at the same time may be related to soil moisture. Since immature Melilotus was most abundant on the low flood terraces, the seed crop from the mature Melilotus were sprouting and creating a second crop of Melilotus.

Scirpus americanus (Figure 14) exists throughout the study area adjacent to the River. Its highest densities were recorded in the Navajo Sandstone-Kayenta Formation section. It resided up to one meter from the river edge where soil was at least 100% saturated. Interspersed are Equisetum and small amounts of immature Melilotus. Scirpus is also found in the Chinle Formation where similar environmental conditions exist.

Still within the low flood terrace but past the Scirpus beds, Muhlenbergia and immature Melilotus are found (Figure 15). These species inhabit moist but not saturated soil sites. The large amount of immature Melilotus in the Kayenta Formation section may exist for two reasons. First, the moist sites may stimulate germination and secondly, cattle graze this section of the river and prefer it as a forage species. Thus, fecal deposits may increase the dispersal and moist germination sites assure success of this species. Melilotus is again found in the Chinle Formation section residing on gravel bars where soils are moist but not saturated and gravel protects root structures from being washed away during period inundations.

Muhlenbergia is mostly found in the Navajo Sandstone-Kayenta Formation section of the River. It inhabits the low flood terraces farthest from the river where the soil surface is dry or only slightly moist. The high density of Muhlenbergia may also be attributed to cattle grazing.

Canyon where this species is found. The lack of its presence on the low flood terraces may indicate an aversion to overly moist soil conditions. It may also indicate that it requires water from the river water table but is unable to maintain itself under frequent flooding conditions.

The high flood terraces contain mostly phreatophytic or non-riparian species (Table 6). Muhlenbergia asperfolia, Distichlis stricta, immature and mature Melilotus alba and Baccharis emoryi are the dominant species.

The two grasses, Muhlenbergia and Distichlis, are the dominant plants associated with the high flood terrace. Densities were highest under stands of Populus in the Navajo Sandstone-Kayenta Formation section and under Salix in the Wingate Sandstone and Chinle Formation sections of the study area. Where tree stands did not exist minor amount of Chrysothamnus, Salsola, Franeria, and Conyza were found.

Immature and mature Melilotus are scattered throughout each stratigraphic section on the high flood terrace. Their highest densities occur when trees are a minor element of the community.

Baccharis emoryi is again present on the high flood terraces of the Chinle Formation section, but in lower densities than on the medium terraces. Since the high flood terraces through this section are well above the watertable, Baccharis roots may be unable to penetrate to the depth required for watertable utilization.

In comparing the vegetation between flood terraces, Melilotus alba, Muhlenbergia asperfolia, Distichlis stricta, and Equisetum laevigatum are the dominant species in varying importance. All species were

prolific on the medium and high flood terraces of the Navajo Sandstone-Kayenta Formation section with the grasses being understory to Populus and Salix on the medium and high flood terraces of the Wingate Sandstone and Chinle Formation sections. Melilotus and Equisetum were scattered throughout the canyon but densities were highest on gravel bars and low broad flood terraces. Grazing and flood protection are related to the high densities of Melilotus but the reasons for the abundance are uncertain.

Scirpus americanus had the highest importance value and is the most dominant non-tree species in the study area. The ability of Scirpus to withstand periodic inundations by water, which seem important to its life cycle, makes it the most prolific species on the low flood terraces.

Tree distributions

Distribution of the three major tree species are plotted for each flood terrace by presence-absence in Figure 17. Both Populus and Tamarix have unique distributions while Salix occurs throughout the study area.

Populus inhabited only broad flood terraces in wide sections of the upper part of the canyons studied. It is the dominant species where the Navajo Sandstone and Kayenta Formations outcrop. The low flood terraces are dominated with aquatic species or Melilotus are inhabited by Populus root suckers (Figure 18). The medium flood terraces supported dense clones of Populus (Figure 19) and the high flood terraces had large individual trees (Figure 20). Tamarix was also sometimes found in this canyon portion, usually near the canyon walls. Populus also sparsely populated the medium and high flood terraces in the wider sections of the Chinle Formation.

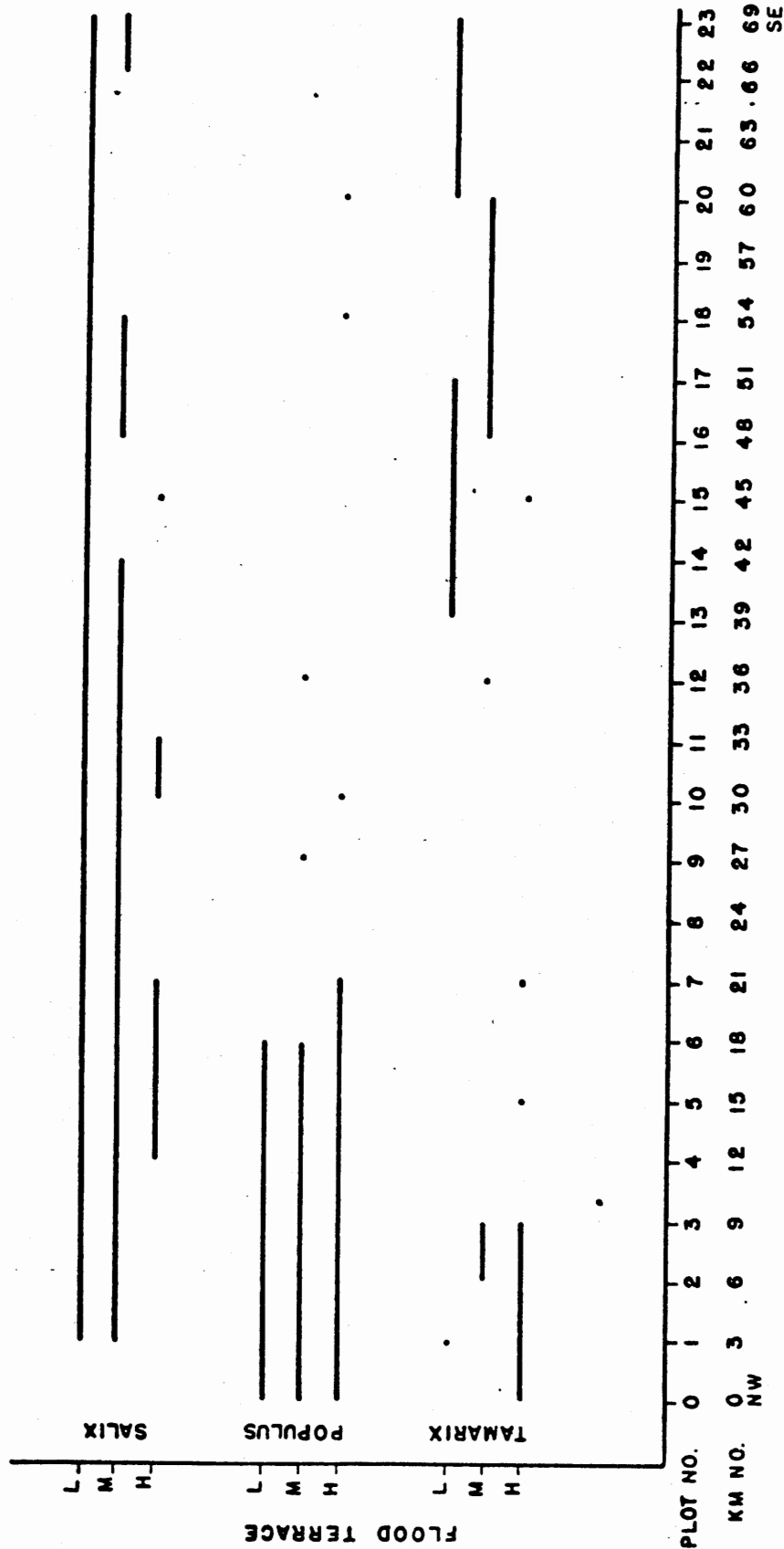


Figure 17. Tree distributions by presence-absence throughout the study area.

This site specific requirement for Populus may be related to flooding over the low broad profile of the flood terraces. The low profile allows riparian vegetation to inhabit sites situated farther from the river, since the water table remains near the surface. This is evidenced by old, large individuals inhabiting the high flood terraces where flood debris is lacking. Hence, Populus may maintain its population by rooting within the water table but past the zone of usual flooding.

Tamarix (Figure 17) is distributed primarily in two places. Minor populations of older individuals occur next to the canyon walls on the high flood terraces of the Navajo Sandstone and Kayenta Formation. Residence here, may relate to rain runoff from on the slickrock. Dried mud chip bowls and small erosion channels would tend to support this idea.

The major population of Tamarix is located along the river where large colluvial boulders from the Wingate Sandstone have fallen to the river. Tamarix exists behind large boulders (up to 10 meters in diameter) where protection from flooding is afforded. Tamarix also inhabits the medium and high flood terraces where the river bank angle is steep and susceptible to only occasional flooding.

Salix is the dominant species and occurs throughout the study area. (Figure 17). Its density is highest, however, where river bank angles are moderately steep or where the canyon is relatively narrow. Salix becomes the dominant species and Populus becomes rare as the canyon narrows through the Wingate Sandstone. It is also the dominant tree species through the Wingate Sandstone near the lower end of the study area.

Through the Chinle Formation, tree densities and herbaceous cover is low. Salix coexists with Tamarix, usually Salix being the dominant species. Salix exists in dense clonal stands (Figure 21) on the medium flood terraces and especially on the high flood terraces. It also exists on the low flood terraces in protected situations similar to Tamarix.

The lowest Salix densities were found between kilometers 39-47. The river is extremely confined here due to the steep colluvial slopes. Large boulders choke the river and flood debris is evident high on the river banks. Tamarix densities are highest however, between these kilometers. These high densities are attributed to the protection of the boulders which Salix seems unable to utilize. One reason for the low population density in this section could be due to the lack of a resident Salix population on the higher flood terraces. Since Salix reproduces mainly by root suckers, lack of a resident population would inhibit its development; Tamarix, which reproduces mainly by seed can establish wherever protection from flooding is found.

Tree population age structure

Since trees were grouped by height classes, it was logical to try to obtain a relationship between age and height. Such a relationship was weak, with a correlation coefficient for each species below .75. This approach was abandoned for the more traditional correlation of age to diameter (Johnson, Burgess, and Keemmerer, 1976). Figures 22, 23, and 24 are plots of age-diameter relationships for Salix exigua, Populus fremontii and Tamarix pentandra, respectively. The number next to each dot represents the number of stems of a specific

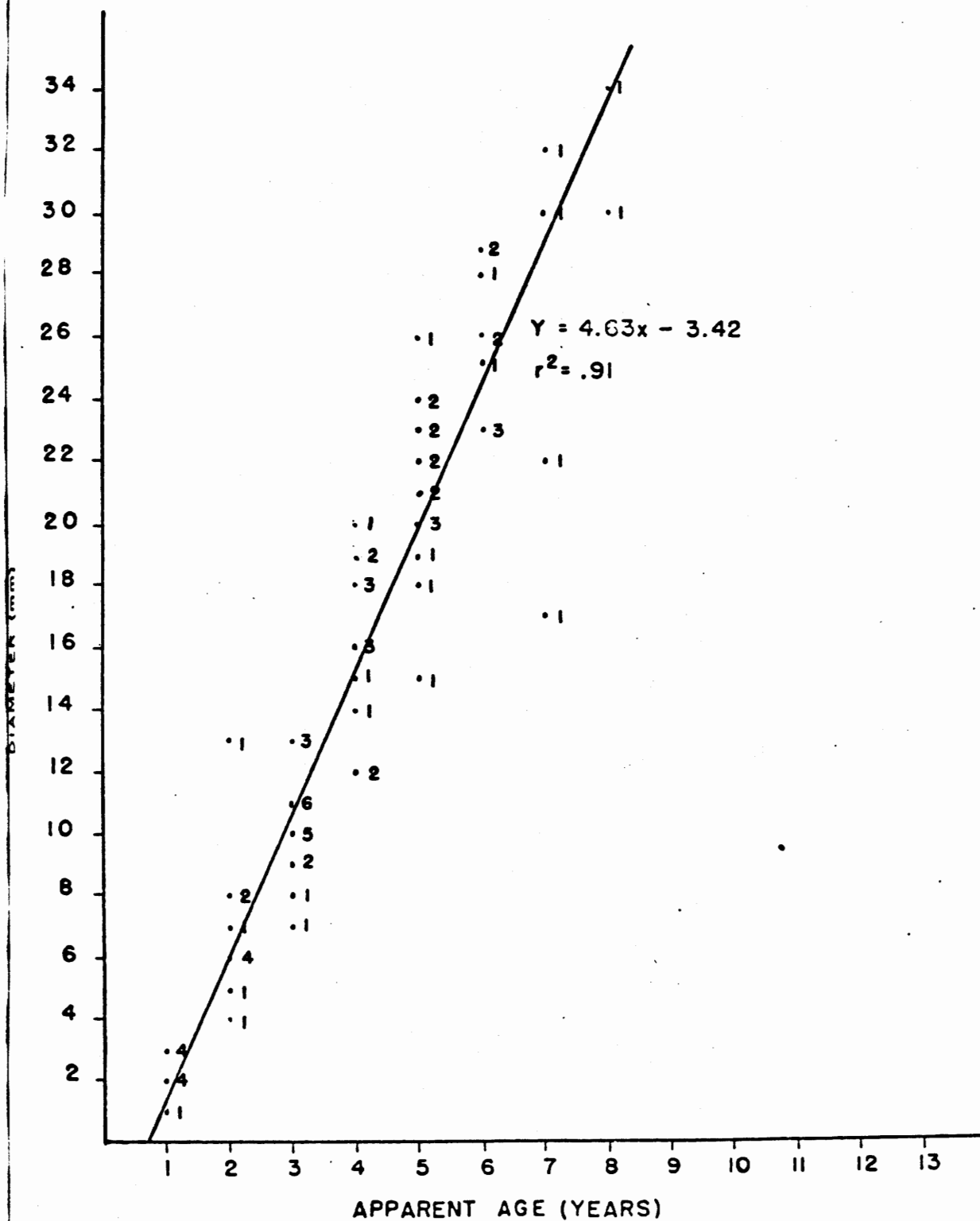




Figure 24. Correlation coefficient of age to diameter for Tamarix

age and diameter. Correlation coefficients were determined for each species with Tamarix having the highest correlation ($r^2=.95$) and Populus having the lowest ($r^2=.89$).

Ferguson (1962) conducted annual ring studies for numerous desert shrubs and trees, and found that Tamarix pendandra had annual rings that correlate well with age. He did not conduct studies of Salix exigua or any other Salix species. Furthermore, he indicated that Populus fremontii did not have usable annual rings for accurate age counts. However, the regression lines between Salix and Tamarix and a regression line for the first 8 age classes for Populus are very similar. This would indicate similar growth-age trends between species such that different tree species with the same number of annual rings were of similar age. This was further tested by comparing the mean diameters of Salix and Populus against Tamarix for each age class. This was done by a t-statistic for two means at a $\alpha = 0.1$ level. As can be seen in Table 7, no significant difference existed between mean diameters in the first eight age classes, except in age class 3 and 7. This difference may be within the comparison species, Tamarix since the diameters in age class three, Salix and Populus are similar. Furthermore, the majority of age class 3 Tamarix residents^{are} on the low flood terraces where growth conditions are more ideal. Age class 7 is significantly different and high age classes would also likely be different but sample sizes are small and confidence in the t-test breaks down. Therefore, different trees with similar diameters were assumed to be of the same age. Older trees, especially Populus, can be expected to vary in physiognomy and growth when the age to diameter relationship

Table 7. Comparison of mean diameters by age class for the three major tree species.

Apparent Age (yrs)	<u>Salix</u>		<u>Tamarix</u>		<u>Populus</u>	
	t-statistic	t-test	$\bar{x}$ diameter (mm)	$\bar{x}$ diameter (mm)	t-statistic	t-test
1	1.711	0.14	2.33	2.37	1.706	.04
2	1.697	0.18	6.22	6.79	1.708	.39
3	1.690	2.37*	11.42	13.00	1.697	1.87*
4	1.725	0.96	16.38	17.42	1.711	.58
5	1.729	1.46	21.64	23.40	1.740	1.29
6	1.833	.67	25.78	27.00	1.734	.98
7	2.132	3.99*	27.25	36.50	1.895	2.98*
8	2.920	1.61	32.00	38.50	1.895	1.37

* Significant difference at $\alpha = 0.1$

breaks down. It is expected, however, that these larger diameter trees represent increasing ages with increasing diameter.

Figures 25, 26, and 27 are population apparent age structure curves on the low, medium and high flood terraces, for Salix exigua, Populus freemontii, and Tamarix pentandra, respectively. Graphically, it is obvious that the curves differ significantly between flood terraces, and that these trends are somewhat similar between species. Densities for each species on the low flood terraces are relatively high in the first age class with densities dropping off rapidly in successive age classes. Further, for all three species, less than 95% survive into the third age class. Both phenomena are related to water inundation by periodic fluctuations in the river water level and high spring runoff. Periodic fluctuations have a duration of one to two days when the water level rises five to ten centimeters above normal flow. Fluctuations occur frequently after minor rain showers, and upon recession, expose a nearly water saturated soil surface ideal for seed germination which Horton (1960) has shown is important for these species to germinate. Density decreases in the second age class are similarly related. The frequent fluctuations make each species susceptible to being washed away or buried by fresh alluvial deposits. Severe flooding is the probable cause of each species being truncated by the fourth age class. Although periodic or flash flooding has not been observed in the canyon, varying amounts and sizes of flood debris indicates that degrees of flooding occurs. Since the population curves are truncated at the fourth age class for all species, this would indicate a major flood occurred four years prior to data collection. Hydrologic records are insufficient to support this conclusion, however.

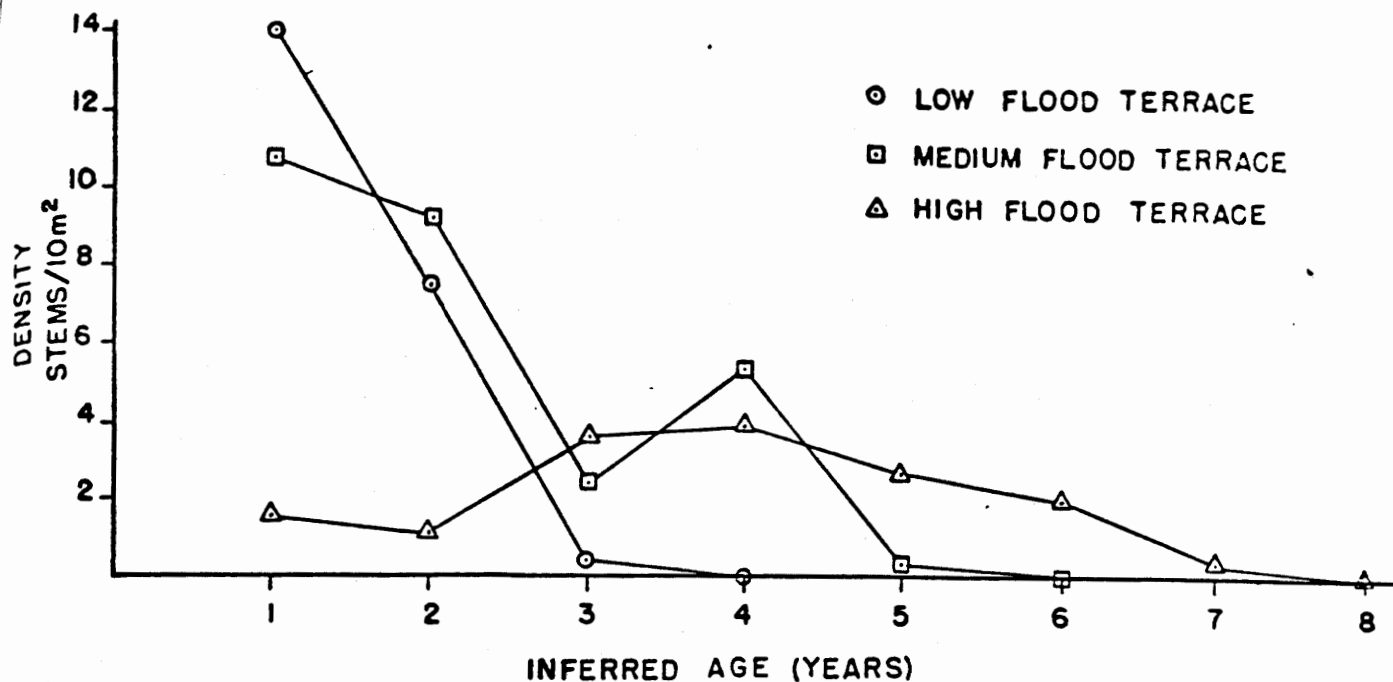


Figure 25. Population age structure by flood terrace for *Salix exigua*.

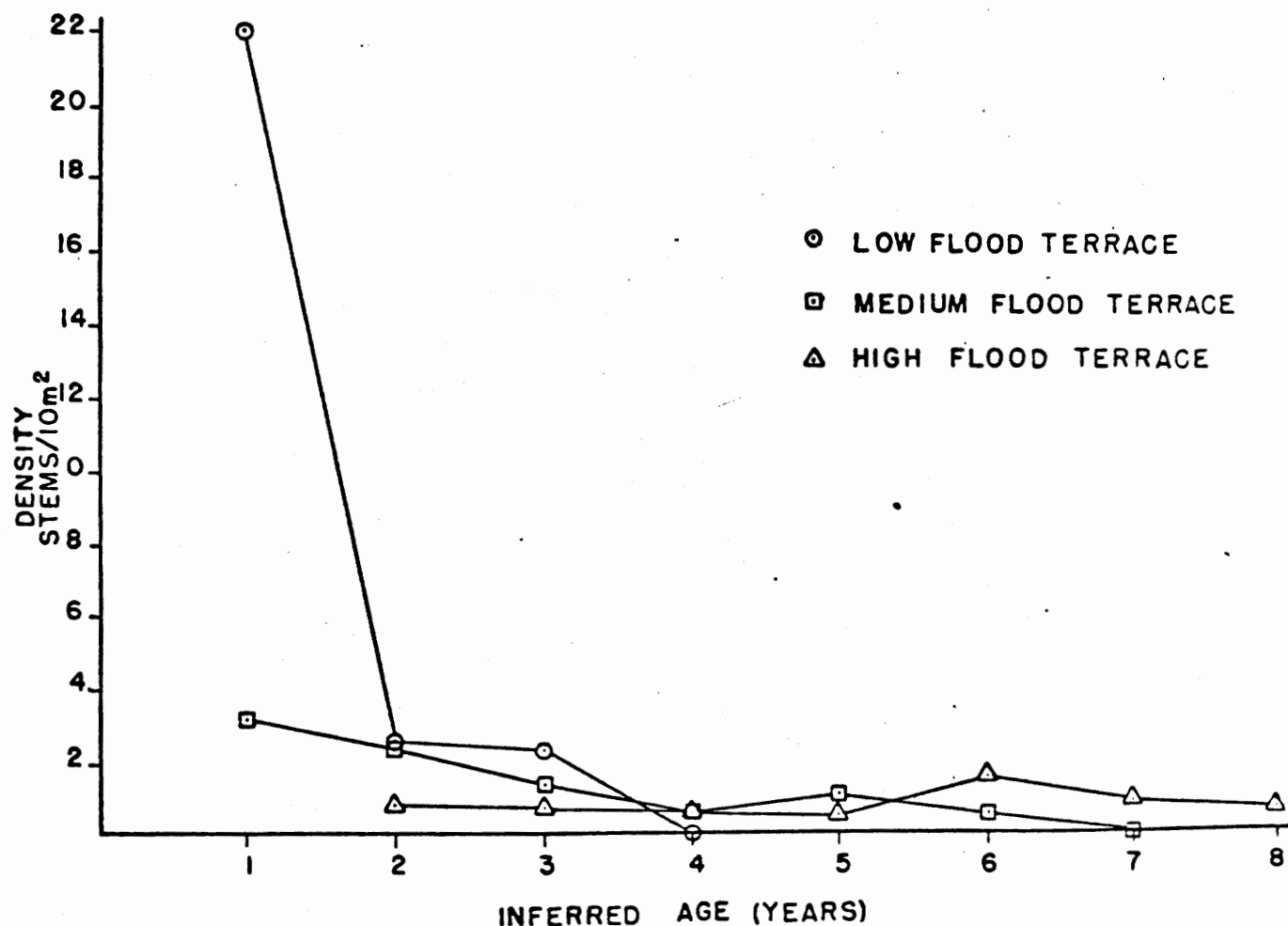


Figure 26. Population age structure by flood terrace for *Tamarix pentandra*.

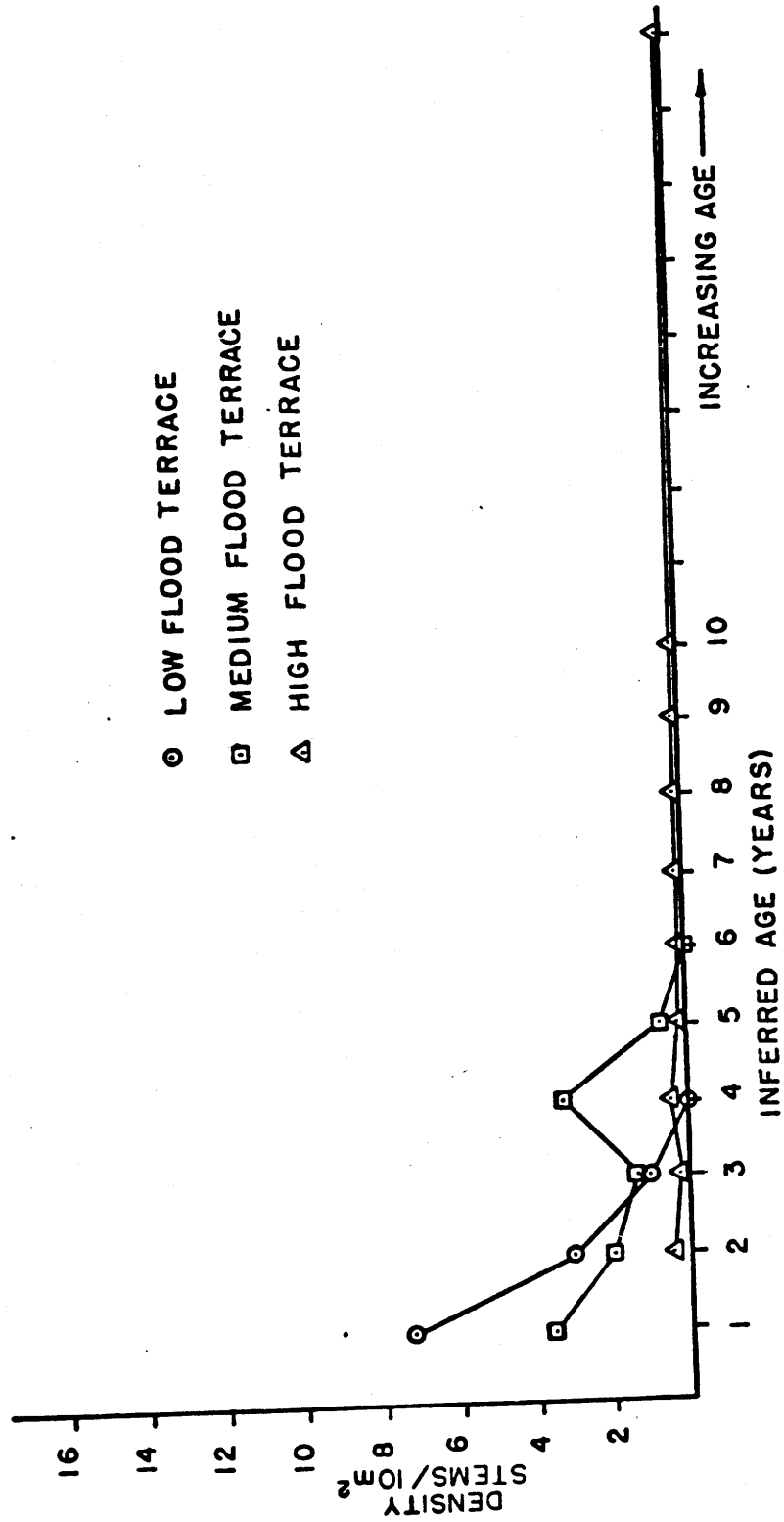


Figure 27. Population age structure by flood terrace for Populus fremontii.

Examination of each species curve on the low flood terraces show varying degrees of survival in the first age class. Tamarix has the highest density, 22.6 stems/10m², with Salix and Populus having densities of 14.0 stems/10m² and 7.2 stems/10m², respectively. In the second age class, Tamarix survival drops sharply while survival in Salix and Populus, although decreasing, have a greater survival rate than Tamarix. Lastly, Salix and Populus drop to very low densities (0.4 and 0.8 stems/10m²) while Tamarix maintains its population density in the third age class. Numerous reasons for these phenomenon may exist, but the author suggests the following explanation from field observations. First, data were collected after Tamarix had just produced its maximum seed crop. Germination occurs while seeds float on the river and establish as seedlings upon being beached by one of the frequent river fluctuations. Further, the model of reproduction seems to influence seedling numbers. From field observation, Tamarix almost exclusively reproduced by seed germination on the low flood terraces, Salix was partially regenerated by seedlings and root suckers, and Populus almost exclusively reproduced by root suckers. This difference was determined by choosing several one meter square plots where all three species existed. All stems in the first age class were pulled from the ground and roots were observed as being an entity or connected by a major rooting system. It would seem logical that seed production would far exceed root sucker production unless a major disturbance occurred to the parent population. Time of data collection and mode of reproduction would explain the relative density differences.

In the second age class, Tamarix survival is less than that of Salix or Populus. Since, minor fluctuations in the river level occur

frequently, Tamarix is susceptible to being washed away whereas Salix and Populus are held in place by a major root system. It is not uncommon to observe Tamarix seedlings floating in the river and interconnecting with roots of Salix and Populus exposed after a river fluctuation cycle.

Also, spring runoff increases from a normal flow of $.52 \text{ m}^3/\text{s}$ to $.89 \text{ m}^3/\text{s}$ (18 cfs to 32 cfs) in May and early June (USGS, 1973). This flow completely covers the low flood terraces in the early season further removing vegetation that survived the inundations of the prior year.

Lastly, Tamarix that survive through the second age class are likely to survive into the next age class barring a major flood event. Those individuals surviving are protected by natural barriers such as sand bars, stones, and/or boulders where the effect of erosion is lessened. Salix and Populus, reproducing from root suckers, are not dependent on this protection for survival. The constant river level fluctuation would have a more severe effect on these species, yielding lower densities in the third age class.

On the medium flood terraces, a noticeable shift in the age structure occurs indicating individuals have a greater longevity. Furthermore, rates of survival are greater from age class to age class, although densities are lower. A sharp decrease in age class one individuals of Tamarix occurs between flood terraces. Soil surface moisture is usually lacking on the medium flood terraces (Table 2) and seed germination is probably inhibited. Those individuals that do survive seem to survive to successive age classes.

Salix densities are relatively high in the first and second age classes. Since Salix is not dependent on seed germination, root suckers

probably do well independent of soil surface moisture. Populus also indicates similar trends.

A pulse in density occurs on the medium flood terraces for Salix and Populus individuals in the fourth age class. This increase may be related to numerous causes, one of which could have been a flood event. A major flood four years prior to data collection reducing the vegetal cover would have created an increased reproduction response to form new root suckers to replace destroyed vegetation. Tamarix, which lacks this pulse, may have had its seedling crop destroyed by such a flood event. Unfortunately no hydrological records exist to verify this assumption.

The high flood terrace supports the majority of each species population and is probably the base from which species recolonize lower flood terraces after a major flood event. Flooding that reaches the high flood terraces is most likely a rare event, but must occur since flood debris often consisting of logs up to 200 centimeters in diameter can be observed there.

On the high flood terrace Salix assumes a near normal distribution indicating an even age effect (Meyer, 1952; Johnson et al., 1976). Only a few individuals are regenerating to replace those going extinct.

Populus assumes a different life form from Salix. Although existing as a dense clonal species like Salix on the medium flood terraces, it takes the form of large individual trees with equal numbers of individuals in all age classes.

The curve for Tamarix is hard to interpret as no pure or near pure stands of Tamarix were found on the high flood terraces. Rather, Tamarix was found scattered among both Salix and Populus. Where it did

occur with Salix or Populus, no evidence of its succession over the other two species was observed. Enough available space is present such that Tamarix appears to inhabit new sites rather than compete for already established sites. As time progresses, however, this situation may change as space becomes limiting.

Figure 28 combines data for each flood terrace for each tree species. All three curves assume an inverse J-shaped or negative exponential curve hypothesized by Meyer (1952) and discussed by Johnson et al., (1976). This type of curve is characteristic of any large forest area containing a reasonable diversity of size classes or stand ages. Although Tamarix densities are higher than that of Populus, its possibility as a successor over this native species is limited by periodic flooding events which prevent Tamarix seedlings from establishing. In the older age classes, densities are approximately equivalent for each species. This would suggest an equilibrium exists between species number such that one species does not have a competitive advantage by numbers over another species under the present environmental regime.

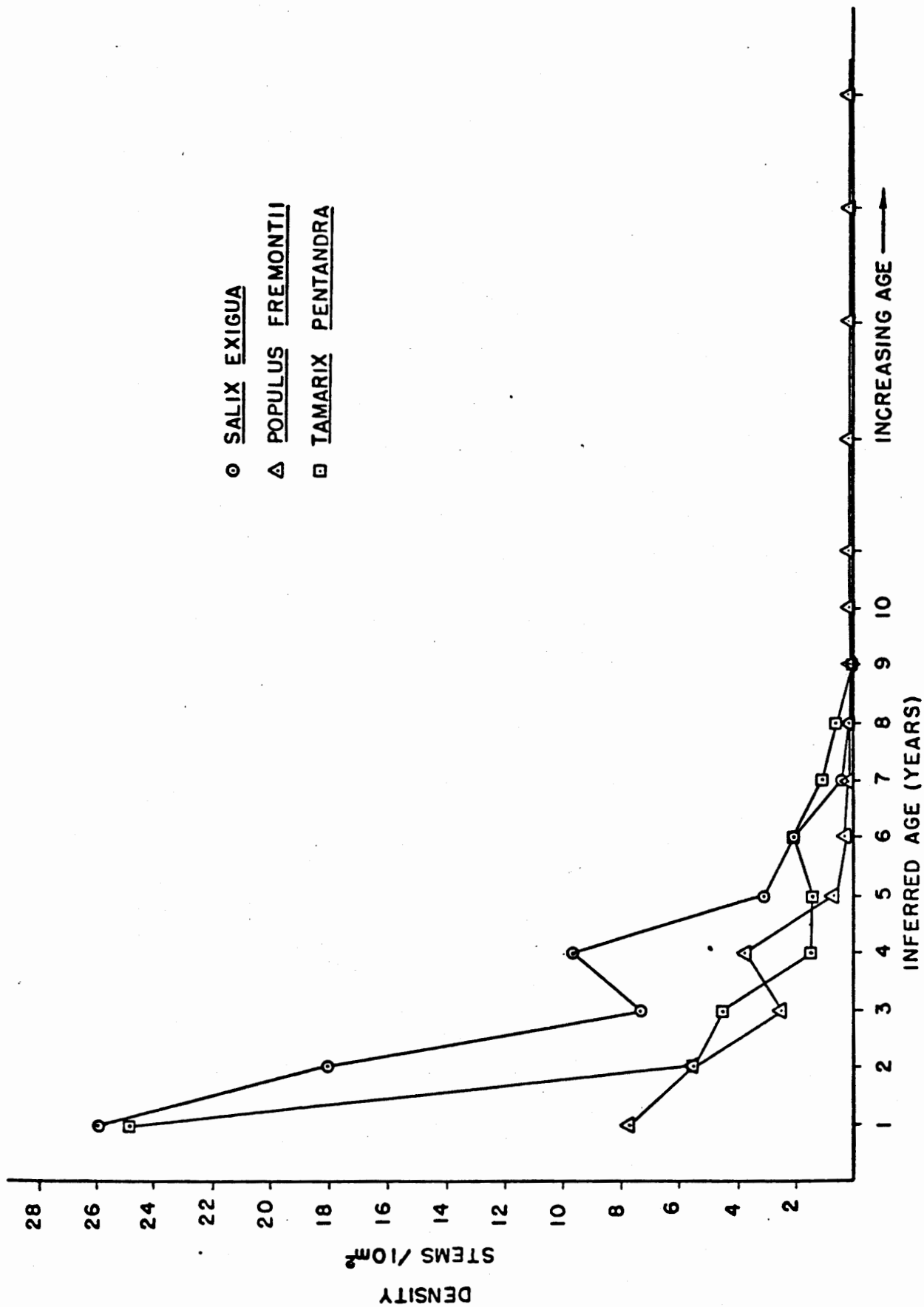


Figure 28. Population age structure with flood terraces combined for Salix exigua, Populus fremontii, and Tamarix pentandra.

IMPLICATIONS

From this study it is obvious that the environment has a strong influence on riparian vegetation. Stratigraphy controls the rate of river cutting, which in turn, controls canyon and river bank profile. River bank profile is strongly controlled by minor periodic fluctuations in the river water level and rare major floods. Of the environmental parameters influencing riparian vegetation, river water flow is the easiest and most susceptible to manipulation. Alterations of the present flow regime may significantly change the riparian plant communities. The amount of change depends on the degree of manipulation. Certain of these changes can be predicted by the information obtained from this study.

Scirpus americanus, the dominant aquatic species, is dependent on soils saturated to supersaturated with water. Reduction of river flow so as to reduce soil moisture would cause a significant density reduction in this species unless it can migrate to a new river level.

A shift in plant species population equilibria and population age structure can also be expected to occur with a reduced river flow and lessening of flash or height of major floods. Salix and Tamarix have the highest densities in the younger age classes. Without the effect of periodic rises in the river water level to wash away new seedlings, these two species would have a competitive advantage over Populus. Since Tamarix reproduces primarily by seed, it would have a competitive advantage over Salix due to its greater dispersal capabilities. This may be one reason why Tamarix is already establishing itself with Populus in sections of the river where the Navajo-Kayenta Formations are exposed. Reduced river flow would allow

a successional advantage, which the river now checks, to the introduced Tamarix over the two native tree species.

The lack of periodic fluctuations and flash floods, and reduction in species longevity, would occur if flow was regulated. Hence, all three species on all three flood terraces would increase in age and corresponding size. This would eventually create dense, impenetrable tree stands along the river. Such dense stands would have increased evapotranspiration potentials, further decreasing river flow. Another adverse effect of this likely denser vegetation would be decreased accessibility to the Escalante River for recreational use and changed aesthetic quality.

Such effects are in accordance with the views hypothesized by West (1973 and 1976) for the Green and Yampa Rivers. This author has also seen similar circumstances and effects along regulated portions of the Colorado River.

Riparian plant community changes resulting from environmental alterations can also effect wildlife habitats. Especially effected would be the resident beaver population which, from field observations, prefer Salix and Populus over Tamarix. Other animal populations would also be expected to change, although to what degree is unknown.

We suggest further monitoring of hydrologic regimes, especially river flow gauging of the lower Escalante River. This data will be necessary to make any further estimates of the effects of river regulation on biota.

SUMMARY

A study of riparian environmental-vegetation interrelationships was conducted for the National Park Service along the lower Escalante River in Glen Canyon National Recreation Area, Utah. The purpose of the study was to obtain a basic understanding of the riparian environmental factors and their influence on vegetation structure and dynamics. The effects of regulated river flow on riparian plant communities were also surmised. The most important results of this study are:

1. There is a strong relationship between stratigraphy, canyon profile, and river bank profile.

2. The river bank profile was found to have three distinct flood terraces. The low flood terrace, adjacent to the river received frequent inundations by water during spring runoff and periodic rain events. The medium flood terrace was thought to be shaped by flash flood events occurring once every 3-5 years. Although this perturbation was not observed during the study, peak flood flows, for the upper Escalante River could be expected to cover this terrace. The high flood terrace is probably flooded only rarely. The peak flow of 1953 (USGS, 1973) would have been sufficient to reach this level.

3. The most dominant semi-aquatic species, Scirpus americanus and Equisetum laevigatum were found on soils saturated to supersaturated with water on the low flood zone.

4. Numerous understory species (mostly introduced species) were found existing in the various geologic sections of the river on all three flood terraces. Baccharis emoryi showed the strongest correlation to strata exposed. It was found on the medium and high flood terraces where the Chinle Formation outcropped. Chrysothamnus nauseosus, Conyza

canadensis, Salsola kali, and Franseria acanthacarpa were found to prefer the drier, medium and high flood terraces.

5. Different time periods between river inundations and floods created significantly different population age structures for the three major tree species. Tree longevity increased from shorter to longer intervals on successively higher flood terraces.

6. Methods of reproduction significantly effect survival rates of the tree species. Tamarix pentandra regenerates from seed and is subjected to high seedling mortality as they are washed away by river fluctuations. Young Salix exigua and Populus fremontii had higher survival rates since regeneration was by root suckers, which were less likely to be washed away.

7. Tamarix and Salix both had much greater densities than Populus creating a competitive advantage for these two species. Furthermore, Tamarix has a greater dispersal capability than Salix due to its method of regeneration.

8. Speculations were made as to the effect of regulated river flow. First if river flow is lowered, thus lowering the riparian water table, Scirpus may go extinct. Regulating periodic unindations and flash floods would have two effects. First, a significant shift to older age classes of trees could be expected. Secondly, the destruction of Tamarix seedlings would not occur. Tamarix, an introduced species, would have a competitive davantage over the native Populus. Furthermore, Tamarix would have an advantage over the native Salix where Salix does not already exist. It would also have an advantage in the low flood zone since Tamarix densities are higher than Salix

densities there. In both cases, a succession of Salix and Populus to Tamarix dominated plant communities would occur.

9. If such changes in vegetation occur some deteterious effects upon stability of natural ecosystems would probably take place. Evapotranspiration potential would increase leading to further reduction in river flow. Increased density of vegetation would probably alter recreational inaccessability to the river. Wildlife habitat and aesthetic values would also be changed.

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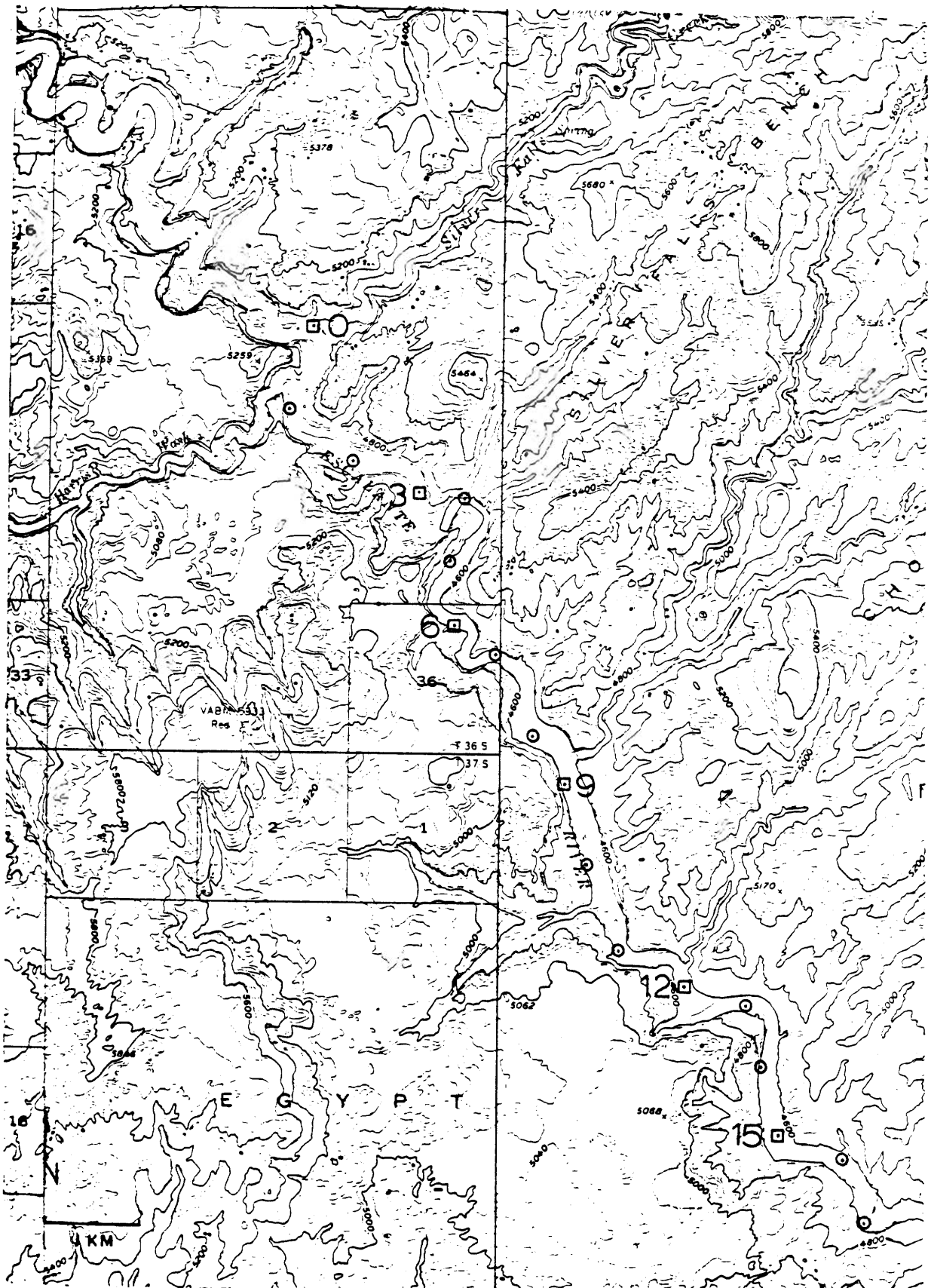
APPENDIX ONE

Detailed maps of the lower Escalante River study area.

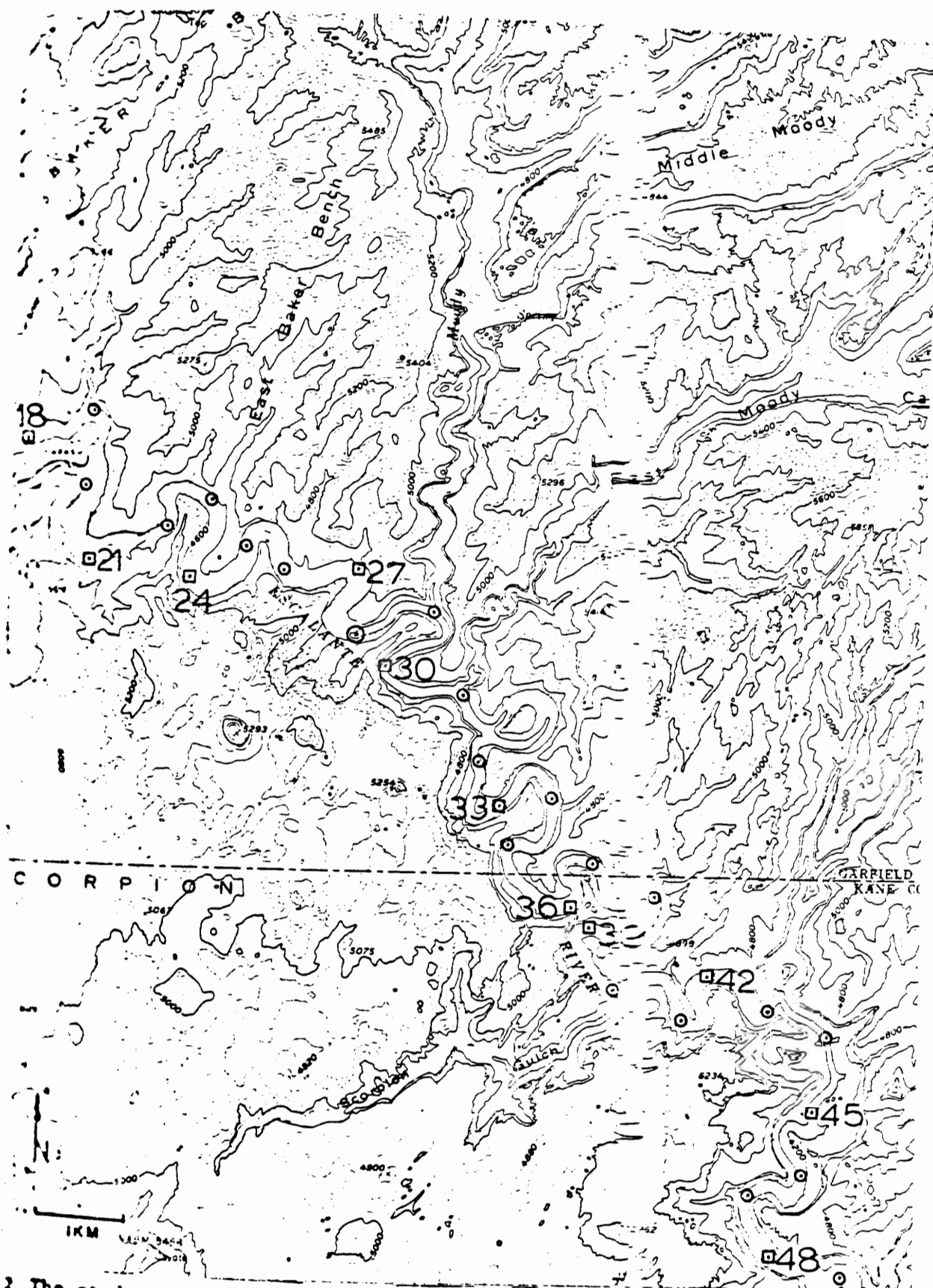
▣-Intensively sampled kilometers with kilometer number.

⊙-Unsampled kilometers.

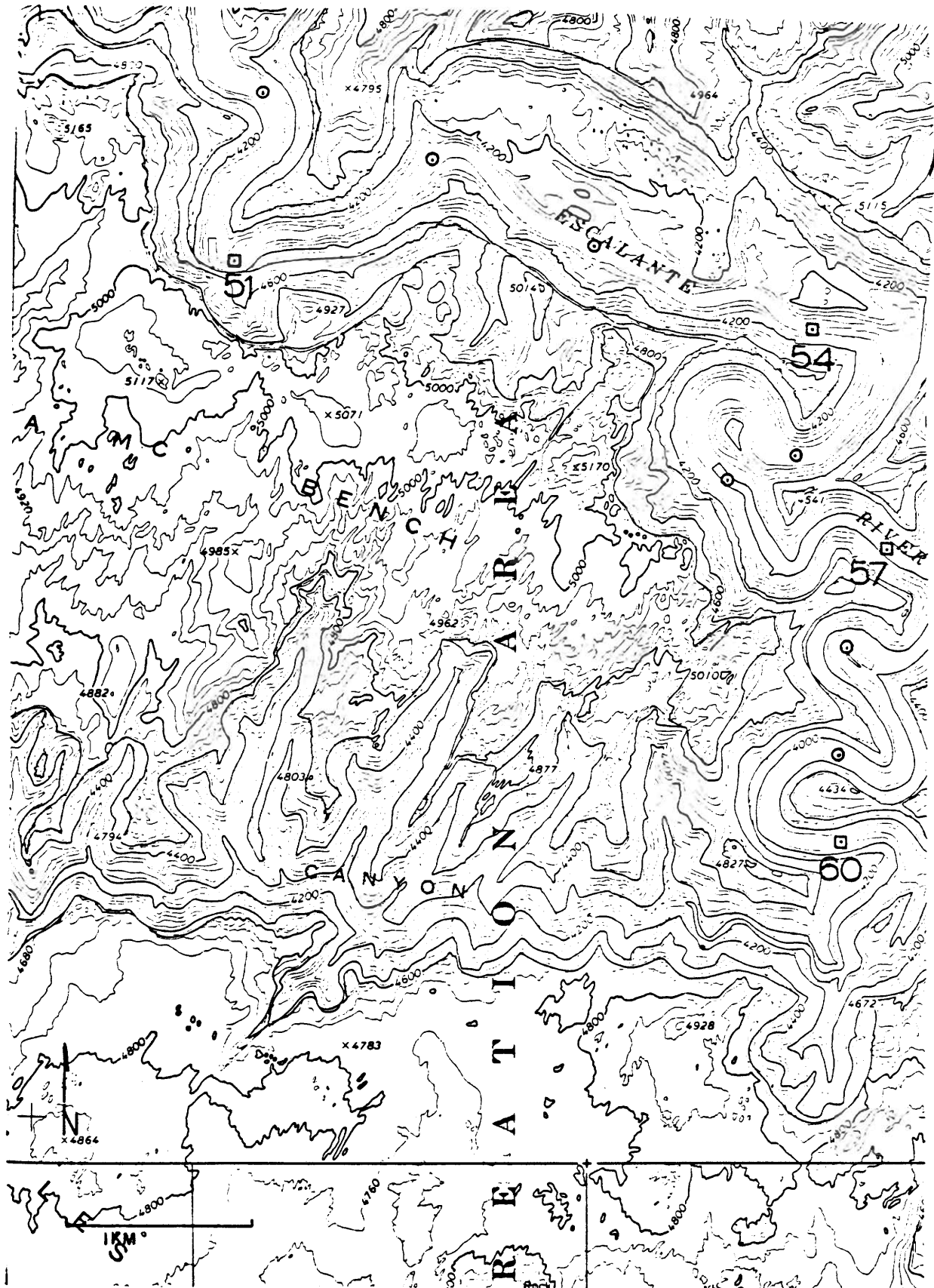
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2. The study area from km 18 - km 49.
3. The study area from km 50 - km 60.
4. The study area from km 61 - km 73.



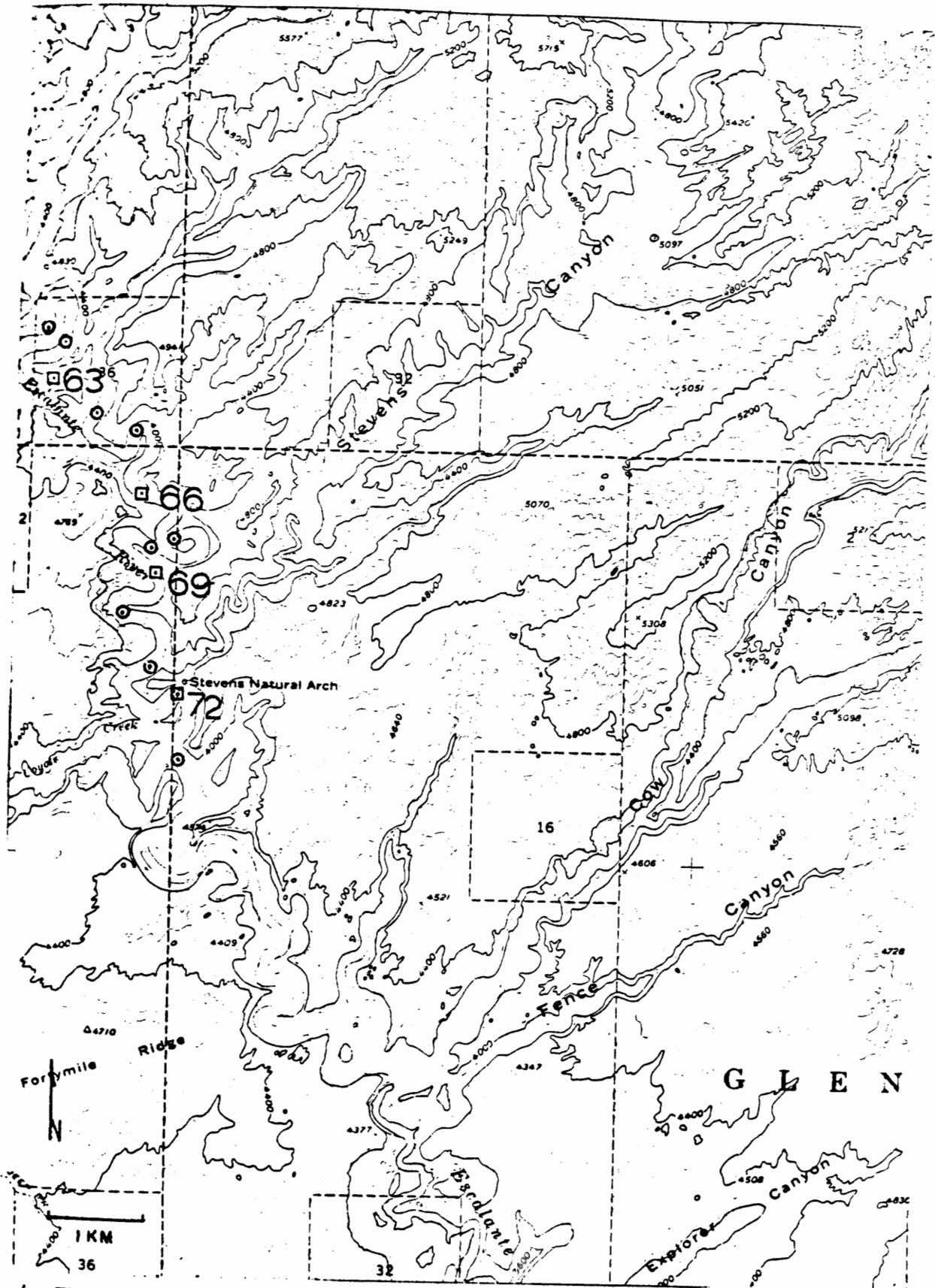
1. The study area from km. 0 - km. 17.



2. The study area from km 18 - km 49.



3. The study area from km 50 - km



4. The study area from km - km .