SRP10593

Quarterly Progress Report
(30 July 1976)

on Project Entitled

ECOLOGICAL ANALYSIS OF ARAVAIPA CREEK AND ENVIRONS RELATIVE TO PAST AND FUTURE LAND AND WATER USE

Submitted by

W. L. Minckley
Department of Zoology, Arizona State University,
Tempe, Arizona 85281

to

Bureau of Land Management
U. S. Department of the Interior

Reference: Contract No. YA-512-CT6-98

ABSTRACT

The project was commenced in late June by ordering equipment, beginning to interview for a graduate assistant, hiring of undergraduate assistance, and visiting the site of study.

Progress

Upon receipt of the signed contract in late June 1976, the following was accomplished: 1) the project account was activated by the University; 2) interviewing was commenced (under affirmative action proceedLres) toward hiring a graduate level research assistant; 3) Mr. Steve Burton was selected as an undergraduate field and laboratory assistant; 4) research supplies and equipment were ordered, including a Hydrolab "Surveyor"; and a site visit was made to initiate sampling protocol and select permanent sampling stations.

SRP10595

Cabinet
in our File

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ABSTRACT

Work included establishment of a system of designating localities and coding of information, some studies of water chemistry, sampling of algae and algal pigments, and quantitative fish and bottom fauna sampling. Miscellaneous progress and personnel participating in the progress are described.

Locality and Data Codes

Locality designations for studies of the Aravaipa Creek system have been established as a prefix of two letters derived from the place names (e.g., "AC" = Aravaipa Creek proper, "VC" = Virgus Canyon, Horse Camp Canyon, etc.; see Table 1), plus the elevation in feet above mean sea level for the center point of a given stream segment, or at the point of actual collection of data.

Codes for field recording of data on habitat parameters are similar to those used in studies of other systems in the lower Colorado River basin, examples of which are in Table 2. These deal with physical features of habitats (current types and velocities, bottom types, aquatic vegetation, and other cover), and information codes such as preserved versus non-preserved specimens, sex, stages of development of gonads, and so on. Standard field sheets have been prepared for each major type of data acquisition, with columns and spacing arranged for ease in computerization of information. All data will be stored in disc files of Arizona State University Computing Center Univac 1110/42 systems, with appropriate backup storage of original field sheets, and card output.

Taxonomic categories are being coded for storage through use of an 11-symbol scheme. Three numerals denote levels of determination, major group(s), and subgroup(s) of the organism(s). Six letters, comprising the first three letters of each of the generic and trivial names in species that can be identified, or the first six letters of any other taxonomic category, make up the body of the code, and two additional numerals are utilized to identify duplicates (Table 3).

Physical-chemical Data

Samples of water were collected at six sites on the mainstream of Aravaipa Creek, and from six points on four side canyons, for analyses of microchemicals. Data for those samples are provided by M. R. Sommerfeld (report to Bureau of Land Management, dated 30 October 1976).

Study of 24-hour cycles of dissolved oxygen, conductance, pH, and temperature was accomplished through use of the Hydrolab "Surveyor" at various localities on Aravaipa Creek. Spates from summer and autumn cyclonic storms scoured much of the main channel of the stream, and some tributaries, so that population levels of primary producers (principally algae) were reduced drastically. Changes in dissolved oxygen concentrations and pH, both indicators of primary productivity when becoming elevated in daylight hours (as a result of photosynthetic activities), were nominal. Magnitude of changes in these two factors was attributable to physical features of temperature and mixing (Figs. 1 - 2).

Limited sampling of basic plant nutrients, nitrate-nitrogen and phosphate-phosphorus, also showed few day- to nighttime differences, corroborating other indications of generally low activity by primary producers.

Temperature variations in mainstream were pronounced, as is typical of low desert streams in summer and autumn. Conductance changed little with time, reflecting high discharges and relatively moderate climatic conditions during the study period.

Biological Studies

Algae and Algal Pigments.--Qualitative samples of algae have been preserved for future taxonomic determination. Diatoms of many species dominated the aquatic flora during the study period, with some increases in larger, filamentous species such as Cladophora sp., and some encrusting kinds (travertine-forming species) in swifter waters on hard (gravel - boulder) substrates in September.

Aquatic macrophytes, such as watercress (Nasturtium officinale) that sometimes chokes the channel in Aravaipa Creek, were decimated by high flows in summer, and began re-colonization in September.

Pigment sampling is being done systematically at eight places on the channel of Aravaipa Creek. Each sampling point is first type-mapped with reference to exposiure to sunlight, depths, bottom types, and currents. Three kinds of samples are then taken in each distinct habitat. Finely-divided, surficial and interstitial materials are removed from a measured area by suction. That sample is filtered through a HA-Millipore (0.45 u) filter disc, and particulates are placed in a vial. A second sample is taken by use of #10 nylon netting; a selected area of substrate is washed into the net to a depth of about a centimeter, then small particulate materials are washed away by gentle agitation in current. A third sample is designed for coarser materials, and is taken by wire seive with 0.5 millimeter mesh, again being rinsed in current. The last two types of samples are retained in toto, placed in glass containers, and all are kept in darkness on ice until pigments are extracted with

95 per cent acetone, buffered with magnesium carbonate, and under refrigeration for a period of 20 hours.

Acetone and extracted pigments are separated from sediments by Millipore filtration, and pigment values are estimated spectrophotometrically at wave lengths reconmended by Strickland and Parsons (1968; A Practical Handbook of Seawater Analysis. Bull. Fish. Res. Bd. Canada, 167 pp).

In thick algae (e.g., Cladophora beds), a measured quadrat is cut from a mat and treated the same as samples of sediment.

Samples from various stations after flooding in August produced a range in chlorophyll A from not detected (one sample) to 19.6 milligram per square meter (Table 11.). The lowest sample was from an area of moving sand bottom, and the higher from a small, quiet area along the channel. Twenty of 38 samples ranged between 0.0 and 0.9 milligrams per square meter, 14 were between 1.0 and 9.9, and only 4 had more than 10.0 milligrams, data which correspond to a general absence of evidence for much primary productivity during the sampling period. Other pigments followed the same trend, being quite low in over-all concentrations (Tablet-O.

Bottom Fauna.--Quantitative samples of benthic invertebrates from various places in Aravaipa Creek has produced 60 per cent of the taxa previously known from the stream, with numbers of individ- ranging from 344 to 11,000 per square meter, and weights between 0.08 and 238 grams per square meter. Some sampling has been done in tributaries, and an essentially unique fauna is present when compared to that of the mainstream. Sorting of benthic samples is

extremely time-consuming, and many samples await total analysis; they will be reported upon later.

Fishes.--Collections from various points on Aravaipa Creek indicates an unusual abundance of all seven native fish species.

Tiaroga cobitis (loach minnow) is typically uncommon in the stream when compared to other species, but has spread in range to occupy 95 per cent of the channel (from the immediate source, ca. 3,225 feet elevation, to the lowermost elevation before recorded at 2,500 feet). Formerly, loach minnow was known only to about 2,600 feet at the lower end of the system.

Meda fulgida (spikedace) is presently common, ranging from 3,200 feet elevation to ca. 2,600 feet. Three year classes are present, indicating strong reproductive success in past seasons.

Rhinichthys osculus (speckled dace) occupies a range from 3,225 to 2,595 feet, and is the second-most abundant minnow in upstream reaches (and in Turkey Creek), rivaling the usually-dominant Agosia chrysogaster (longfin dace) in numbers of individuals.

Agosia remains the most abundant species of fish, as has been the case since monitoring began in 1963. The species was observed to be actively spawning in all months of the present study period.

Gila robusta grahami (roundtail chub) occupies deeper areas of Aravaipa Creek from an elevation of about 3,100 feet to about 2,550 feet, and was present at densities of I or 2 large adults per suitable "pool" habitat. Juvenile chubs were present throughout the stream segment given above, and occupied approximately the same habitat (flowing "pools") as adult spikedace.

Pantosteus clarki (Gila mountain-sucker) and Catostomus insignis (Gila coarse-scale sucker) both remain abundant throughout the system. The proclivity of the latter for deeper water tends to concentrate them in canyon sections of the stream, but the mountain-sucker is abundant from the source to 2,500 feet in elevation.

Introduced green sunfish, Chaenobryttus cyanellus, remain present from about Virgus Canyon (2,795 feet) downstream to about 2,590 feet. Flooding in August removed much pool habitat, by sanding in and through destruction of diversion dams, and seemingly reduced the population.

Quantitative sampling of the fish population in short, selected segments of creek is to be initiated in winter.

Miscellaneous Progress

Mapping of riparian vegetation and of the physical configuration of the canyon and stream channel has been started. The former includes transects from wall to wall in the canyon areas, established at 100 meter intervals, along which all vegetation is recorded. Mapping of the canyon and channel involves measurements of width, depth, and gradient, up- to downstream.

Time-of-flow studies are being computerized to allow assessment of movements of organic and inorganic materials through the channel.

A tagging program on larger fish species (Gila, Pantosteus, and Catostomus) is planned in order to assess movements relative to changes in channel configuration in flood, with season, and with time of day. Also, detailed planning is being done toward study of larval fishes

as they appear in spring. Major items to be assessed are foods, habitat relations, and interactions of species present.

Personnel

Mr. Terry Tompkins (M.S., Northern Arizona University) has begun as a graduate assistant on Aravaipa Creek studies, and hopes to use data acquired toward the Doctor of Philosophy Degree. Mr. Steve Burton remains as an undergraduate field and laboratory assistant.

Dr. Stuart Fisher, a new faculty member at Arizona State University, has obtained independent funding for specific studies on nutrients in desert streams, and is collaborating in work on the Aravaipa Creek system.

TABLE 1: Codes for place names, Aravaipa Creek ecosystem studies.

FW = Fred Wood's Ranch

AC = Aravaipa Creek proper

TC = Turkey Creek

VC = Virgus Canyon

HC = Horse Camp Canyon

JC = Javalina Canyon

PC = Paisano Canyon

BC = Booger Canyon

HH = Hell Hole Canyon

SC = Sand Canyon

CC = Cave Canyon

HA = Hell's Half Acre Canyon

TABLE 2. CODES USED FOR DEFINITION OF HABITATS AND COLLECTING TECHNIQUES, ARAVAIPA CREEK STUDIES.

CODES1 PROVIDES DEFINITIONS OF NUMERICAL DESIGNATION OF VARIOUS HABITAT PARAMETERS DETERMINED THROUGH FIELD STUDIES OF AQUATIC AND SEMI-AQUATIC SYSTEMS OF THE LOWER COLORADO RIVER BASIN. THIS ELEMENT IS INTENDED TO BE EXPANDED BY AUDITION OF NEWLY-DEFINED HABITAT PARAMETERS AS THEY ARE DETERMINED IN-FIELD. THEREFORE, INPUT SPACING IS ALLOWED FOR EACH MAJOR PARAMETER--IF ANYONE. AT AT ANY TIME' MODIFIES THIS ELEMENT THROUGH AUDITION OR DELETION' HE MUST SO INDICATE BY HIS NAME. DATE, AND HOW MODIFIED, DIRECTLY BELOW THE LAST LINE OF THIS EXPLANATORY STATEMENT. REFER TO CODES AND CODES2-CODES5 FOR MORE DATA ON CODING OF INPUT. ELEMENT CREATED 25 JUNE 1975, W. L. MINCKLEY.

CURRENTS (SUM OF VELOCITY AND TURBULENCE).

0 UNKNOWN
1 NONE
2 EDDYING LESS THAN 0.5 METERS/SECOND (M/SEC)
3 H, 0.5 - 1.0 M/SEC
4 up GREATER THAN 1.0 M/SEC
5 LAMINAR CHANNEL' LESS THAN 0.5 M/SEC

6 ", 0.5 - 1.0 M/SEC
" GREATER THAN 1.0 M/SEC
TURBULENT CHANNEL, LESS THAN 0.5 M/SEC
9 ", 0. - 1.0 M/SEC
10 " GREATER THAN 1.0 M/SEC
11 TORRENTIAL CHUTE
" TURBULENT, LINEAR
" EDDY
BOTTOMS
• UNKNOWN
1 SAPROPELIC
• MUD
0 MUD/DETRITAL
4 SILT
5 SILT/SAND, STABILIZED
• ", MOVING
7 STABLE SAND
8 MOVING "
9 SAND/GRAVEL, STABILIZED
10 ", MOVING

11 STABLL GRAVEL

12 MOVING

13 GRAVEL/BOULDER, STABILIZED

14 ", MOVING

.15 BUULDLR

16 BOULDER/BEDROCK STABILIZED

17 ", MOVING BOULDER

18 BEDROCK

19 SILT/DETRITAL

20 SANDBAR, STABLE

21 SANDBAR, SHIFTING

22 ORGANIC DETRITUS

BANKS

UNKNOv4N

1 MARSHLAND

2 BACKWATER

MUD UNCUT

4 up CUT

5 MUD/SILT, UNCUT

6 " , CUT

7 SILT, UNCUT
CUT
9 SILT/SAND, UNCUT
10 ", CUT
11 SAND, UNCUT
12 ", CUT
13 SAND/GRAVEL, UNCUT
14 ", CUT
15 GRAVEL, UNCUT
16 CUT
17 GRAVEL/BOULDER, UNCUT
18 ", Cur
19 BOULDER UNCUT
20 ", CUT
21 BOULDER/BEDROCK STABLE
22 ", UNSTABLE
23 BLDROCK (INCLUDING CONGLOMERATES)
34 - HUMAN USE AREAS SPARSE
35 ", ", MODERATE
36 ", ", INTENSE

AuUATiC VEGETATIONAL STATUS

0 UNKNOWN

1 NONE

2 SUBMERGENT ENCRUSTING ALGAE, SPARSE

¤, MODERATE

4 up DENSE

5 SUBMERGENT FILAMENTOUS ALGAE, ATTACHED,SPARSE

6 ¤ ¤, MODERATE

7 ¤, ¤, DENSE

8 ¤, UNATTACHED, SHARSE

9 ¤, ¤, mODERATE

lu ¤, ¤, DENSE

11 SUBMERGENT HIGHER VASCULAR PLANTS, PROSTRATE, SPARSE (INCLUDES CHAROPHYTA)

12 ¤, ¤, MODERATE (¤)

13 ¤, ¤, DENSE (¤)

14 ¤, ¤, ERECT' (INCLUDES CHAROPHYTA)

lb ~ MODERATE (u)

16 ¤, ¤, DENSE (~)

17 EMERGENT ROOTED VEGETATION, SPARSE

lb ¤, MODERATE

" DENSE
20 EMERGENT FLOATING VEGETATION, SPARSE
21 " MODERATE
2 " DENSE
23 FLOODED TERRESTRIAL GRASSES, SPARSE
24 " MODERATE
25 " DENSE
26 FLOODLD TERRESTRIAL GRASS/BRUSH,SPARSE
27 " " MODERATE
28 " " DENSE
29 FLOODED TERRESTRIAL BRUSH, SPARSE
3u " MODERATE
31 " DENSE
32 FLOODED TERRESTRIAL BRUSH/TREES, SPARSE
3 " MOUERATE
34 " DENSE
35 FLOODED RIPARIAN (23 - 34), SPARSE
36 " MODERATE
37 " DENSE
COVER (OTHER THAN LIVING AQUATIC, SEMI-AQUATIC, OR FLOODED TERRESTRIAL VEG-

ETATION, OR PHYSICAL FEATURES INCLUDED UNDER BANK OR BOTTOM TYPES IN THIS SAME ELEMENT)

u UNKNOWN
1 NONE
2 ALLOCHTHONOUS DEBRIS, GRASS THROUGH BRUSH, SHARSE
3 ", ", MODERATE
4 ", ", DENSE
5 ", BRUSH THRuUGH LOGS, SPARSE
", ", MODERATE
7 ", DENSE
Li INORGANIC DEBRIS, SPARSE
9 ", MOjERATE
10 ", DENSE
11 UNDERCUT BANK, CLEAR
12 ", SPARSE DEBRIS (ROOTS, LTC.)
13 ", MODERATE DEBRIS (a)
14 ", DENSE DEBRIS (a)
15 OVERHANGING RIPARIAN VEGETATION, SPARSE
16 ", MODERATE
17 ", DENSE

CODES2 PROVIDES DEFINITIONS FOR NUMERICAL DESIGNATIONS OF SAMPLING DEVICES USED IN STUDIES OF AQUATIC AND SEMI-AQUATIC HABITATS OF THE LOWER COLORADO RIVER SYSTEM. THIS ELEMENT IS INTENDED TO BE EXPANDED BY ADDITION OF NEW SAMPLING DEVICES AS ARE THEY ARE DROUGHT ON-LINE. THERERFORE, INPUT SPACING IS ALLOWED FOLLOWING THE LAST SAMPLING DEVICE LISTED--IF ANYONE, AT ANY TIME, MODIFIES THIS ELEMENT THROUGH ADDITION OR DELETION, HE MUST SO INDICATE bY HIS NAME' DATE, AND HOW MODIFIED, DIRECTLY BELOW THE LAST LINE OF THIS EXPLANATORY STATEMENT. REFER TO CODES, CODES1, AND CODES3-CODES5 FUR MORE DATA ON CODING OF INPUT. ELEMENT CREATED 2 JULY 1975, W. L. MINCKLEY

U UNKNOWN
1 CONVENTIONAL EXPERIMENTAL GILL NET
SWEDISH GILL NET
5 SALL-MESH HOOP NET
6 SMALL-MESH SEINE, 1-2 METERS LONG
7 SMALL-MESH SEINE, 3-6 METERS LONG
8 1/4 MESH SEINE, j-9 METERS LONG
9 1/2-M SH SEINE, 9-19 METERS LONG
1b HOOK AND LINE
19 ECKMAN DREDGE
20 6 X 6 GRAB

22 CLARKE-BUMPUS SAMPLER
23 STANDARD PLANKTON, #20
24 STANDARD PLANKTON, #10
25 SORBER SAMPLER
26 METRIC GRAB
27 DRIFT NET, #40
28 PLI, 1 CENTIMETER SCRAPE
29 PLI, ARTIFICIAL SUBSTRATE, 1 CENTIMETER SCRAPE
30 GIG
32 VISUAL
33 VERTICAL NET, 1/2.-INCH MESH
34 VERTICAL NET, 1.5-INCH MESH
35 VERTICAL NET, 3 INCH MESH
36 DIP NET
37 HAND CATCH

TABLE SPECIES CODE FILE' ARAVAIPA CREEK STUDIES

600ANIMAL00 ANIAL
500CHORDA00 CHORDATA
430PISCES00 PISCES
330CYPRIN00 CYPRiNIFORMES
30CYPRIN00 CYPRINIDAE
130GILA 00 GILA
030GILROB00 GILA ROBUSTA
030GILROB02 GILA ROBUSTA GRAHAMI
130MEDA 00 AEDA
030MEDFUL00 MEDA FULGIDA
130AGOSIA00 AGOSIA
030AGOCHR00 AGOSIA CHRYSOGASTER
130RHINIC00 RHINICHTHYS
030RHIOSC00 RHINICHTHYS OSCULUS
130TIAROG00 TIAROGA
030TIACOB00 TIAROGA COBITIS

230CATOST00 CATOSTOMIDAE

130CATOST00 CATOSTOMUS
030CATINS00 CATOSTOMUS INSIGNIS
130PANTOS00 PANTOSTEUS
030PANCLA00 PANTOSTEUS CLARKI
330SILURI00 SILURIFORMES
230ICTALU00 ICTALURILME
130ICTALU00 ICTALURUS
030ICTNAT00 ICTALURUS NATALIS
330CYPRIN01 CYPRINODONTIFORMES
230CYPRIN01 CYPRINODONTIDAE
130CYPRIN01 CYPRINODON
030CYPMAC00 CYPRINODON MACULARIUS
0POECIL00 POECILIIDAE
130POECIL00 POECILIOPSIS
030POEOCC00 POLCILIOPSIS OCCWENTALIS
030POEOCC01 POECILIOPSIS OCCIDENTALIS OCCIDENTALIS
0CENTRA00 CENTRARCHIDAE
130CHAENO00 CHAENOBRYTTUS
030CHACYA00 CHAENO9RYTTUS CYANELLUS
440AMPHIB00 AMPHIBIA

340 ALIEN00 SALILNTIA
40HYLIDA00 HYLIDAE
140HYLA 00 HYLA
040HYLARE00 HYLA ARENICOLOR
240RANIDA00 RANIDAE
140RANA 00 RANA
040RANPIP00 RANA PIPIENS
440REPTIL00 REPTILIA
340TESTUD00 TESTUDINATA
240CHELYD00 CHELYDRIDAE
140KINOST00 KINOSTERNON
040KINSON00 KINOSTERNON SUNORIENSL
550ARTHR000 ARTHROPODA
450INSECT00 INSECTA
350COLEOP00 COLLOPTERA
250DYTISC00 DYTISCIDAE
150LACCOP00 LACCOPHILUS
050LACHOR00 LACCOPHILUS HURNI
150BIDESS00 BIDESSUS
050BIDDEC00 BIDESSUS DECORATUS

150HYDROC00 HYDROCORUS
050HYDAR100 HYDROCORUS ARIZONICUS
150RHANTU00 RHANTUS
050RHAATR00 RHANTUS ATRICuLOR
250GYRINI00 GYRINIDAE
150DINEUT00 DINEUTES
050DINAME00 DINEUTES AMERICANUS
150GYRINU00 GYRINUS
050GYRPLI00 GYRINUS PLICIFER
250HYDROP00 HYDROPHILIDAE
150OCHTHE00 OCHTHLBIUS
050OCHLIN00 OCHTHEBIUS LINEATUS
150BEROSU00 UEROSUS
050BEREXI00 BEKOSUS EXILI
150HYDROP00 HYDROPHILUS
050HYDLIN00 HYUROPHILUS LINEATUS
150TROPOS00 TROPOTERNUS
050TROCOR00 TROPOSTERNUS LORSALIS
150PARACY00 PARACYMUS
050PARSWE00 PARACYMUS SWECUPREUS

150LACCOBUS LACCOBIUS
050LACEIL00 LACCOBIUS EILIP
150DACTYL00 DACTYLOSTERNUM
050DACCACO0 DACTYLOSTERNUM CACTI
150SPHAER00 SPHAERIDIUM
050SPHSCA00 SPHAERIDIUM SCARABAEOIDES
050SPHBIP00 SPHAERIDIUM BIPUSTULATUM
50CURCUL00 CURCULIONIDAE
250PSEPHE00 PSEPHENIDAE
50ELMIDA00 LLMIDAE
250HALIPL00 HALIPLIDAE
150PELTOD00 PELTODYTES
250DRYOPI00 DRYOPIDAE
250HYDROS00 HYPROSCAPHIDAE
150HYDROS00 HYDROSCAPHA
350DIPTER00 DIPTERA
250TIPULI00 TIPULIDAE
150NEPHRO00 NEPHROTOMA
050NEPOCC00 NEPHROTOMA OCCIDENTALIS
150RHIPID00 RHIPILJIA

050RHIBRV00 RHIPIDIA BRVANTI
150ORMOSI00 ORMOSIA
0500RMONE00 ORMOSIA ONEROSA
150MARUIN00 MARUINA LANCEOLATA
250PTYCH000 PTYCHOPTERIDAE
50CULICI00 CULICIDAE
1 0ANOPHE00 ANOPHLLES
050ANOFRE00 ANOPHELES FREEBORNI
050ANOPUN00 ANOPHELES PUNCTIPENNIS
150AEDES 00 AEDES
050AEDDOR00 AEDES DORSALIS
050AEDSOL00 AEDES SOLLICITANS
150CULEX 00 CULEX
050CULPIP00 CULEX PIPIENS PIPIENS
. 050CULTAR00 CULEX TARSALIS
150CHAOB000 CHAOBORUS
0CERAT000 CERATOPOGONIDAE
150LEPTOC00 LEPTOCONOOS
150LEPTOC01 LEPTOCONOOS KERTESZI
150CULICO00 CULICOIDES

050CULHIL00 CULICOIDEb HIEROGIVONICUS
250CHIRON00 CHIRONOMIDAE
150PARALA00 PARALAUTERBORNIELLA
050PARSUB00 PARALAUTERBORNIELLA SUBCINCTA SUBCINCTA
150POLYPE00 POLYPEDILUM
050POLHAL00 POLYPEDILUM HALTERALE
250SIMULI00 SIMULIIDAE
150PROSIM00 PROSIMULIUM
050PROLAI00 PROSIMULIUM EAIGENS
150SIMULI00 SIMULIUM
250CECIDO00 CECIDOMYIIDAE
250STRATI00 STRATIOMYIDAE
250TABANI00 TABANIDAE
150EUPARY00 EUPARYPHUS
150APATOL00 APATOLESTES
050APACOM00 APATOLESTES COMASTES
150CHRYSO00 CHRYSOPS
050CHRPAC00 CHRYSOPS PACHYCERUS
150CHLORO00 CHLOROTABANUS
050CHLCRE00 CHLOROTABANUS CREPUSCULARIS

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    150TABANU00  TABANUS
  250SYRPHI00  SYRPHIDAE
  250MUSCID00  MUSCIDAE
  250DIXIDA00  DIXIDAE
    0EMPIDI00  EMPIDIDAE
  250RHAGI000  RHAGIONIDAE
  250PYRALI00  PYRALIDAE
350ODONAT00  ODONATA
  250PETALU00  PETALURIDAE
    150CORDUL00 CORDULEGASTER
      050CORDIA00 CORDULEGASTER DIADEMA
  250GOMPHI00  GOMPHIDAE
    150PROGOM00  PROGOMPHUS
      050PROBOR00  PROGOMPHUS BOREALIS
    150OPHIOG00 OPHIOGOMPHUS
      050OPHARI00 OPHIOGOMPhUS ARIZONICUS
    150ERPET000  ERPETOGOMPHUS
      050ERPCAM00  ERPETOGOMPHUS CAMPOSITUS
    150GOMPHU00  GOMPHUS
      050GOMINT00 GOMPHUS INTRICATUS
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250ALSCHN00 ALSCHNIDAE

150ANAX Ou ANAX

050ANAJUN00 ANAX JUNIUS

150AESHNA00 AESHNA

050AESARI00 AESHNA ARIDA

050AESMUL00 AESHNA MULTICOLOR

0L1BELL00 LIBELLULIDAE

150MACROM00 MACROMIA

050MACMAG00 MACROMIA MAGNiFICA

150PSEUD000 PSEUDvLSON

050PSESUP00 PSEUDOLSON SUPEROUS

150LIBELL00 LIBELLULA

050LIBCOM00 LIUELLULA COMPOSITA

050LIBFOR00 LIUELLULA FORENSIS

050LIBPUL00 LIBELLULA PULCHELLA

050LIBSAT00 LIbELLULA SATURATA

150PLATHE00 PLATHLMIS

050PLASUB00 PLATHEMIS SUBURNATA

150ERYTHR00 ERYTHREDIPLEX

050ERYFUN00 ERYTHREDIPLEX FUNEREA

150TARNET00 TARNETRUM
050TARCOR00 TARNETRUM CORRUPTUM
150ERYTHE00 ERYTHEMIS
050ERYSIM00 ERYTHEMIS SIMPLICICOLLIS
150PALTOT00 PALTOTHEMIS
050PALLIN00 PALTOTHEMIS LINEATIPES
150PANTAL00 PANTALA
050PANFLA00 PANTALA FLAVISCENS
250AGRION00 AGRIONIDAE
150HETAER00 HETAERINA
050HETAME00 HETAERINA AMERICANA
250COENA000 COENAGRIONIDAE
050HEMIPT00 HEMIPTERA
250CORIXI00 CORIXIDAE
150SIGARA00 SIGARA
050SIGALT00 SIGARA ALTERNATA
050SIGOMA00 SIGARA OMANI
150GRAPTA00 GRAPTOCORIXA
250NOTONE00 NOTONECTIDAE

150NOTONE00 NOTONECTA
050NOTKIR00 NOTONECTA KIRDYI
150BUENOA00 BUENOA
050BUEMAR00 BUENOA MARGARITACEA
250NAUCOR00 NAUCORIDAE
150AMBRYS00 AMBRYSUS
050AMBMOR00 AMBRYSUS MORMON
50BELOST00 BELOSTOMATIDAE
150ABEDUS00 ABEDUS
050ABEDIL00 ABEDUS DILATATUS
050ABEAME00 ABEDUS AMERICANUS
050ABEINU00 ABLDUS INUENTATUS
150BELOST00 BELOSTOMA
050BELBAK00 BELOSTOMA BAKERI
150LITHOC00 LITHOCERUS
050LITAME00 LITHOCERUS AMERICANUS
250NEPIDA00 NEPIDAF
150RANATR00 RANATRA
050RANFUS00 RANATRA FUSCA
050RANQUA00 RANATRA QUADRIDENTATA

150CURICT00 CURICTA
250GELAST00 GELASTOCORIDAE
150GELAST00 GELASTOCORIS
050GELOCU00 GELASTOCORIS OCULATUS
150NERTHR00 NERTHRA
500CHTER00 OCHTERIDAE
150GERRID00 GERRIDAE
150GERRIS00 GERRIS
050GERNOT00 GERRIS NOTABILIS
050GERREM00 GERRIS REMIGIS
050GERBUE00 GERRIS BUENOI
050GERINC00 GERRIS INCOGNITUS
150HALOBA00 HALOBATES
250VELIID00 VELIIDAE
150RHAGOV00 RHAGOVELIA
050RHADIS00 RHAGOVELIA DISTINCTA
050RHAOBE00 RHAGOVELIA OBESA
150MICROV00 MICROVELIA
050MICGER00 MICROVELIA GERHARDI
050MICBEA00 MICROVELIA BEAMERI

50HYDROM00 HYDROMETRIDAE
150HYDROM00 HYDROMETRA
250MACROV00 MACROVELIIDAE
1 0MACROV00 MACROVELIA
050MACHOR00 MACROVELIA HORNII
250HEBRID00 HEBRIDAE
150HEBRUS00 HEBRUS
050HEBSOU00 HEURUS SOURINUS
150MERRAG00 MERRAGATA
250MESOVE00 MESOVELIIDAE
050MERHEB00 MERRAGATA HEBROIDES
150MESOVE00 MESOVELIA
050MESMUL00 MESOVELIA MULANTI
250SALDID00 SALDIDAE
350PLECOP00 PLECOPTERA
250PERLID00 PERLIDAE
150ALLOPE00 ALLOPERLA
050ALLPAL00 ALLOPERLA PALLIDULA
250CAPNIID00 CAPNIIDAE
150CAPNIA00 CAPNIA

350COLLEM00 COLLEMBOLA
50PODURI00 PODURIDAE
350NEUROP00 NEUROPTERA
50CORYDA00 CORYDALIDAE
150CORYDA00 CORYDALUS
SIALIDAE
250CONIOP00 CONIOPTERYGIDAE
350TRICHO00 TRICHOPTERA
50HYDROP01 HYDROPSYCHIDAE
150HYDROP01 HYDROPSYCHE
150CHEUMA00 CHEUMATOPSYCHE
250HYDROP02 HYDROPTILIDAE
150OCHROT00 OCHROTRICHIA
150LEUCOT00 LEUCOTRICHIA
250HELICO00 HLLICOPSYCHIDAE
150HELICO00 HELICOPSYCHE
250GLOSS000 GLOSSOSOMATIDAE
350EPHEME00 EPHEMEROPTERA
50LIMNEP00 LIMNEPHILIDAE
150 LIMNEPUO LIMNEPHILUS

250LEPTOP00 LEPTOPHLEBII DAE
150CHOROT00 CHORO TERPES
250BAETID00 BAET IDAE
150BAETI SU1 BAET IS
150BAETIS02 BAET IS
150NEOCLE00 NEOCLLON
150C ALL IB00 CALL I bAET IS
150CENTR000 CENTROPTILUM
50TRICOR00 TRICORYTHIDAE
150TRICOR00 TR ICORYTHODE
250EPHEMEO0 EPHEMERELL IDAE
150EPHEME00 EPHEMERELLA
250HEPTAG00 HEPTAGENI IDAE
150RHITHR00 RHITHROGENA
560MOLLUS00 MOLLUSCA
460PELECY PELECYPODA
60SPHAER00 PHAERI IDAE
4600ASIR000 GASTROPODA
360MESOGA00 MESOGASTROPODA
60PHYSID00 PHYSIDAE
160PHYSA 00 PHYSA

060PHYVIR00 PHYSA VIR(2ATA
360STYLOM00 STYLOMMATOPHORA
260SUCCIN00 SUCCINEIDAE
160SUCCIN00 SUCCINEA
570WORMS 00 RMS
470PLATYH00 PLATYHELMINTHE
370TRICLA00 Tk1CLA1)IDA
70PLANAR00 PLANARIIDAE
370NEORHA00 NEORHABDOCOELA
170NEMAT000 NEMATODA
470OLIGOC00 OLIGOCHAETA
270TUBIFI00 TUBIFICIDAE
470HIRUDI00 HIRUDINEA

6U0PLANT 00 PLAT
580TRACHE00 TRACHEOPHYTA
480DICOTY00 DICOTYLEDONEAE
.80ASTERA00 ASTERALES
280COMPOS00 COMPOSITAE
160BACCHA00 BACCHARIS

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        080BACGLU00  BACCHARIS GLUTINOSA
        080BACSAR00 BACCHARIS SAROTHROIDES
380 OLANA00 SOLANALES
    80SOLANA00  SOLANACEAE
      180NICOTI00  NICOTIANA
        080NICGLA00 NICOTIANA GLAUCA
380SALICA00  SALICALES
     0SALICA00  SALICACEAE
      180SALIX OU SALIX
        080SALEXI00 SALIX EXIGUA
        080SALGOOD0 SALIX GOODDINGII
      180POPULU00  POPULUS
        080POPFRE00  POPULUS FREMONTII
380POLYGO00  POLYGONALES
    80POLYGO00  POLYGONACEAE
      180POLYGO00 POLYGONUM
380LAMIAL00  LAMIALES
   280LABIAT00  LABIATAE
      180MENTHA00 MENTHA
        080MENSPI00 MENTHA SPICATA
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480MONOC090 MONOCOTYLEDONEAE
380CYPERA00 CYPERALES
80CYPERA00 CYPERACEAE
180ELEOCH00 ELEOCHARIS
180CYPERU00 CYPERUS
180SCIRPU00 SCIRPUS
380JUNCAL00 JUNCALES
280JUNCAC00 JUNCACEAL
380GRAMIN00 GRAMINALES
280GRAMIN00 GRAMINAE
180PASPAL00 PASPALUM
080PASDIL00 PASPALUM DILATATUM
180CYNODO00 CYNODON
080CYNDAC00 CYNODON DACTYLON
380TYPHAL00 TYPHALES
80TYPHAC00 TYPHACEAE
180TYPHA 00 TYPHA
080TYPDOM00 TYPHA DOMINGENSIS
380NAJADA00 NAJAUALES
280NAJADA00 NAJADACEAE

180NAJAS 00 NAJAS

080NAJQUA00 NAJAS QUADALUPENSIS

380POTAM000 POTAMOGETONALES

80POTAM000 POTAMOGETONACEAE

160POTAM000 POTAMOGETON

080POTPEC00 POTAMOGETON PLCTINATUS

TABLE 4. BIOLOGICAL PIGMENTS FROM VARIOUS SUBSTRATES IN ARAVAIPA CREEK.

LOCALITY AC3090. DATE 760910

	CHLOROPHYLLS (MG/M 2)			CAROTENOIDS			
SET	A	B	C	CAR-A	CAR-P	CAR-P,S+P	DIATOMS
1	0.7992	13.3658	79.7221	4.0700	0.0	2.5214	6.3036
	0.5566	0.4684	2.2317	1.2277	0.0	0.7252	1.8131
3	6.1320	0.1567	0.7967	0.0283	1.8784	1.5147	3.7868
4	6.0780	5.3793	0.1490	0.1697	4.2744	3.5530	8.8825
5	2.0305	1.7553	10.9574	4.8182	0.0	2.8405	7.1012
6	0.2548	0.3567	0.8247	0.8916	0.0	0.5307	1.3267
7	0.7556	0.6371	3.9899	1.5621	0.0	1.0510	2.6274
8	0.2767	0.0	0.0	0.0902	0.4187	0.4220	1.0551
9	0.2415	0.3174	1.0512	0.2562	0.0	0.0	0.0
10	1.8246	15.0737	10.5604	5.5533	0.0	2.7815	6.9537
11	2.2268	0.3545	0.5108	0.1180	1.1057	(1.9937	2.4843
12	2.1721	0.0585	0.1[illegible]	0.0	1.4902	1.0565	2.6413
13	0.0	0.0	0.0	0.1754	0.0510	0.2169	0.5423

LOCALITY AC3150. DATE 760910

	CHLOROPHYLLS (MG/M 2)			CAROTENOIDS			
SET		B	C	CAR-A	CAR-P	CAR-P,S+P	DIATOMS
1	0.0137	0.2874	0.0	0.0	0.7509	0.3806	0.9515
2	4.4766	1.2787	5.5593	3.0317	0.0	2.1060	5.2650
3	10.6759	1.2508	0.0	0.3577	5.6917	4.8637	12.1592
4	1.6933	1.5173	3.4804	2.8067	0.0	1.8092	4.5229
5	2.0476	0.1863	0.0	0.0	1.6745	0.8554	2.1385
6	0.7650	2.5575	0.0	0.0	0.1394	0.1043	0.2608
7	0.0	0.0	0.0	0.1245	0.1010	0.2053	0.5132
8	0.2554	0.6443	3.1496	1.1604	0.0	0.9154	2.2885
9	0.3404	0.2650	0.8142	0.3549	0.3521	0.6359	1.5896

LOCALITY AC3201. DATE 760910

	CHLOROPHYLLS (MG/M 2)				CAROTENOIDS		
SET	A	B	C	CAR-A	CAR-P	CAR-P,S+P	DIATOMS
1	0.0	0.0	0.0	0.0	0.0773	0.0	0.0
2	0.0	0.0	0.0	0.1076	0.1138	0.1984	0.4959
3	u.0	0.0	0.0	0.0	0.6217	0.2332	0.5829
4	0.9204	0.1694	3.0863	1.3047	0.0	0.6906	1.7266
5	1.6340	0.0	0.5154	0.0826	1.0657	0.9264	2.3159

LOCALITY AC3244. DATE 760910

	CHLOROPHYLL (MG/M 2)				CAROTENOIDS		
T	A	B	C	CAR-A	CAR-P	CAR-P,S+P	DIATOMS
1	u.0	0.8665	3.2436	2.0752	0.0	1.6123	4.0308
2	u.0	0.0	1.4726	0.0764	0.3099	0.3220	0.8051
3	0.1800	0.1658	0.0	0.2356	0.0534	0.2636	0.6591

LOCALITY AC3278. DATE 760910

	CHLOROPHYLLS (MG/M 2)				CAROTENOIDS		
ST	A	B	C	CAR-A	CAR-P	CAR-PrS+P	DIATOMS
1	1.4036	1.3277	16.5979	2.4364	0.0	1.6224	4.0559
2	0.0631	0.0	2.5605	0.7710	0.0	0.4998	1.2495
3	3.6873	10.6036	9.3939	4.4176	6.2151	9.3652	23.4130
4	0.2333	0.0	0.0278	0.0423	0.0560	0.0869	0.2172
5	u.0	0.4077	0.0	0.0	0.2158	0.0352	0.0879
6	0.4074	0.0283	0.1442	0.2988	0.0845	0.3677	0.9192
1	0.6886	1.5188	4.2580	0.8620	0.0	0.4324	1.0810

LOCALITY AC3303. DATE 760910

	CHLOROPHYLLS (MG/M 2)				CAROTENOIDS		
SET	A	B	C	CAR-A	CAR-P	CAR-P,S+P	DIATOMS

1	1.8052	53.9873	0.0	0.8248	0.5960	1.3019	3.2546
2	0.1552	0.0530	0.5902	0.0677	0.1355	0.1754	0.4385
3	1.5057	7.4154	5.9690	3.5861	0.0	2.3163	5.7907
4	0.6979	0.8669	4.2252	1.4242	0.0	1.1195	2.7986
5	0.0	0.0	0.0	0.1048	0.6935	0.6542	1.6356
6	0.5529	0.0	0.0	0.0	0.3308	0.1397	0.3492

LOCALITY AC2420. DATE 760918

	CHLOROPHYLLS (MG/M 2)			CAROTENOIDS			
		B	C	CAP-A	CAR-P	CAR-P,S+P	DIATOMS
1	1.1489	1.3423	5.9487	1.2434	0.7077	1.8118	4.5295
2	11.3154	0.5657	4.7107	1.0322	7.4682	6.9485	17.3712
3	19.6079	0.5780	8.0107	0.7066	12.6229	10.7013	26.7532
4	19.1248	0.0	4.9101	1.8365	10.9461	10.5101	26.2751
5	2.7032	0.0695	0.0	0.3229	1.1869	1.2642	3.1605
6	9.9765	1.1151	7.6060	2.0846	9.7547	9.6172	24.5429
7	17.4849	0.6349	6.0338	1.2139	10.5341	9.5573	23.8931
8	1.2214	0.4913	2.2012	0.8364	0.0	0.8353	2.0882

LOCALITY AC2613. DATE 760918

	CHLOROPHYLLS (MG/M 2)			CAROTENOIDS			
SLT	A	B	C	CAR-A	CAR-P	CARP,S+P	DIATOMS
1	1.1349	0.8430	3.7150	1.2150	0.0	0.7756	1.9390
2	.9603	0.1356	1.1887	0.1807	1.8684	1.6604	4.1509
3	4.4624	0.0	2.2961	0.0854	2.0818	1.7332	4.3329
4	3.4110	0.3543	2.1M	0.6169	2.5579	2.6470	6.6174
5	0.0	0.0		0.0	1.5761	0.0347	0.0867

LOCALITY AC2618. DATE 760918

	CHLOROPHYLLS (MG/M 2)			LAROTENOIDS			
SLT	A	B	C	CAR-A	CAR-P	CAR-PrS+P	DIATOMS

SLT				CAR-A	CAR-P	CAR-P,S+P	DIATOMS
1	114.1262	17.5004	85.6571	2.4408	153.8674	124.2051	310.5128
	39.0319	4.5183	20.2140	3.2945	23.3124	21.7628	54.4069
3	0.5241	0.0	0.0083	0.0	0.3508	0.2528	0.6321
4	5.3313	0.1027	6.5624	0.8943	2.6231	2.9759	7.4397
5	3.5313	0.5334	3.3365	0.7465	2.2543	2.5323	6.3307

LOCALITY AC3079. DATE 761023

	CHLOROPHYLLS (MG/M 2)			CAROTENOIDS			
SLT	A			CAR-A	CAR-P	CAR-Pr5+P	DIATOMS
1	0.4380	0.5152	1.4697	0.4853	0.0	0.2975	0.7438
	0.0	0.0	0.0	0.0	3.8114	2.0060	5.0151
3	2.2028	0.4946	1.5426	0.5361	1.3903	1.6398	4.0995

LOCALITY AC3155. DATE 761023

	CHLOROPHYLLS (MG/M 2)			CAROTENOIDS			
SLT	A			CAR-A	CAR-P	CAR-P.5+P	DIATOMS
	5.4630	0.2450	3.3591	0.8561	2.0502	2.4841	6.2102
	4.8106	0.0	2.2474	0.2227	2.1072	1.9548	4.8871
3	6.6419	0.2766	2.5677	0.4174	3.2597	2.9836	7.4591
	38.2166	1.4947	0.0028	4.1605	20.4845	20.3971	50.9926
5	63.9276	9.5505	58.3662	3.0706	81.1171	67.2753	168.1884

LOCALITY AC3200. DATE 761023

	CHLOROPHYLLS (MG/M 2)			CAROTENOIDS			
SLT	A	B	C	CAR-A	CAR-P	CAR-P,S+P	DIATOMS
1	3.8804	0.2113	2.0672	1.0921	1.0509	1.9311	4.8277
2	2.9086	0.0342	1.4273	0.0	2.0468	1.3834	3.4586
Si	2.2910	0.3094	1.7795	0.4755	1.3412	1.5399	3.8497

1	0.0558	0.1311	0.1522	0.2884	0.0	0.2134	0.5335
2	0.4018	0.0	0.0	0.0527	0.4770	0.4305	1.0764
3	0.3895	0.0	0.0	0.0315	0.6637	0.5727	1.4316
4	0.3774	0.8901	1.5247	0.9599	0.0	0.5398	1.3496
5	0.7072	0.0	0.0406	0.113	0.1997	0.2725	0.6811
6	0.4769	0.0	0.0	0.1387	0.4084	0.4628	1.1569

LOCALITY ACL680. DATE 760918

	CHLOROPHYLLS (MG/M 2)				CAROTENOIDS		
SLI	A	B	C	CAR-A	CARP	CAR-P,S+P	DIATOMS
1	0.6328	0.8015	2.2618	0.9878	0.0	0.6913	1.7283
2	0.2995	0.3397	1.1698	0.4359	0.0	0.3462	0.8654
3	0.8068	0.0	0.5464	0.3370	0.6317	0.8391	2.0978
4	1.4054	0.0	0.4762	0.1797	0.7196	0.7503	1.8757
5	0.1600	0.1607	1.2691	0.3815	0.0	0.2525	0.6313
6	1.6499	0.0	0.5625	0.1441	1.0715	0.9929	2.4822
7	1.6677	0.0	0.8089	0.2123	0.7400	0.7992	1.9981

LOCALITY AC2685. DATE 760918

	CHLOROPHYLLS (MG/M 2)				CAROTENOIDS		
SL1	A	H	C	CAR-A	CAR-P	CAR-P,S+P	DIATOMS
1	1.5333	0.9439	1.4229	0.7620	0.1789	0.9087	2.2718
2	1.4457	0.0770	0.5437	0.1891	0.7316	0.7692	1.9231
3	0.2577	0.0	0.0703	0.2317	0.0	0.0373	0.0933
4	0.2212	0.2829	3.8268	0.5498	0.0	0.3667	0.9168
5	2.6157	0.1380	1.0263	0.1559	1.5118	1.3532	3.3829
6	0.7271	0.0648	0.3997	0.2470	0.6177	0.7374	1.8435

LOCALITY AC2760. DATE 760918

	CHLOROPHYLLS (MG/M 2)				CAROTENOIDS		
SLT	A	B	C	CAR-A	CAR-P	CAR-PrS+P	DIATOMS

0.2577	0.0	0.0703	0.0789	0.3329	0.6429	0.8572
0.0812	0.0608	0.1883	0.0590	0.3435	0.3312	0.8280
0.3582	0.2656	1.2057	0.5169	0.0	0.3465	0.8663
0.0	0.0	0.0	0.1664	0.0482	0.2076	0.5191
0.3519	0.0603	0.1910	0.0800	0.3705	0.3738	0.9344
0.5077	0.2235	1.5848	0.5176	0.0	0.4577	1.1442

LOCALITY AC2320. DATE 761.023

CHLOROPHYLLS (MG/M 2) CAROTENOIDS

SET	A	B	C	CAP-A	CAR-P	CAR-P,S+P	DIATOMS
1	23.8755	0.0	7.8427	0.4760	11.8603	9.8816	24.7039
	6.4927	1.7424	18.7596	4.1965	8.8193	11.2032	28.0079
3	9.7930	1.8284	14.4017	3.1851	9.3288	10.5880	26.4701
4	1.4209	0.0	0.0	0.2996	0.2786	0.5221	1.3052
5	17.3424	0.0	7.0592	1.2572	9.3913	8.6966	21.7415
	18.3378	0.7058	9.3729	1.1294	12.2957	10.8661	27.1652
	0.9968	0.0	0.0	0.0	1.3200	0.9955	2.4888
b	3.7924	1.0911	8.6122	3.3117	4.8652	7.1995	17.9987
9	5.7040	0.046	12.2445	2.0035	6.8707	7.4535	18.6337

LOCALITY AC2480. DATE 761023

CHLOROPHYLLS (MG/M 2) CAROTENOIDS

SET				CAR-A	CAR-P	CAR-P,S+P	DIATOMS
1	1.7347	0.2129	1.0027	0.3173	0.7968	0.9499	2.3748
	5.6011	1.1802	6.1320	1.3394	6.5895	6.5625	16.4061
	6.9207	0.5822	3.5500	0.7242	4.0638	3.9446	9.8614
4	0.9526	0.2329	1.6848	0.4034	0.8341	1.0661	2.6653
	2.6968	0.6427	2.1466	0.3705	2.4135	2.2827	5.7068
	248.8394	63.2712	208.3581	15.4676	172.8660	152.3527	380.8817

LOCALITY AC2600. DATE 761023

CHLOROPHYLLS (MG/M 2) CAROTENOIDS

SLT	A			CAR-A	CAR-P	CAR-P,S+P	DIATOMS
1	1.0144	0.5142	1.9609	0.5554	0.0695	0.6299	1.5749
2	6.1396	1.3480	10.5308	3.0162	6.5486	8.2202	20.5505
	21.1240	1.7607	15.3044	2.9104	14.2731	14.2236	35.5590
4	243.0958	44.4735	164.6114	23.0727	107.8455	108.5615	271.4039
	0.6401	0.1953	1.1851	0.3877	0.0	0.3794	0.9485
	5.4447	0.1342	2.1575	0.4072	2.2906	2.2223	5.5558
7	1.8057	0.0809	1.1405	6.6321	0.0	1.2235	3.0587

LOCALiTY ACL740. DATE 761023

CHLOROPHYLLS (MG/M 2) UAROTENOIDS

SL				CAR-A	CAR-P	CAR-P,S+P	uiATUmS
1	8.6163	0.0	1.6732	0.3358	4.4121	3.8292	9.5729
	0.9407	0.5526	2.6275	0.9307	0.0	0.6710	1.6775
	1.7658	0.2865	1.7143	0.3405	2.3018	2.1641	5.4102
4	1.3127	3.3935	10.0258	0.3794	0.9552	1.1379	2.8444
	0.0798	0.1743	0.8494	0.1254	0.1842	0.2720	0.6800
	.2094	0.6402	1.7107	0.9720	1.2496	1.9673	4.9183
7	1.5369	0.0649	0.6856	0.2576	0.9556	1.0154	2.5386

LOCALITY AC2980. DATE 761023

CHLOROPHYLLS (MG/M 2) CAROTENOIDS

SLT	A	B	C	CAR-A	CAR-P	CAR-P,S+P	DIATOMS
1	10.3299	0.0	4.8005	0.5112	4.9459	4.4282	11.0704
2	22.7120	0.0414	11.1031	5.7070	0.0	3.2782	8.1954
3	5.2640	0.2294	3.2205	0.9002	1.8550	2.3740	5.9351
4	16.7692	1.3296	14.3235	2.5761	7.7157	8.6986	21.7465
5	13.5483	2.8082	9.0697	1.4030	10.7747	9.9379	24.8448

LOCALITY AC3070. DATE 761023

CHLOROPHYLLS (MG/M 2) CAROTENOIDS

4	1.6605	0.0	0.7119	0.0854	0.8501	0.7587	1.8967
	0.4953	0.3033	1.6091	0.1968	0.7957	0.6247	2.0616
	76.5187	3.9954	38.0979	10.0653	57.3327	39.6728	99.1820

LOCALITY AC3205. DATE 761023

	CHLOROPHYLLS (MUM 2)			CAROTENOIDS			
SET		B	C	CAR-A	CAR-P	CAR-P,S+P	DIATOMS
1	10.7477	0.0	1.6447	0.3461	4.7452	4.1031	10.2576
	24.1077	3.1029	18.3762	4.0475	21.6047	21.1696	52.9239
3	30.3141	2.8528	17.5225	2.5372	19.9195	18.3157	45.7894
4	90.4590	1.7792	30.4510	1.1563	52.5248	42.7214	106.8034

LOCALITY AC6603. DATE 7b1023

	CHLOROPHYLLS (MG/ð"ï 2)			CAROTENOIDS			
SET	A	B	C	CAR-A	CAR-P	CAR-P,S+P	DIATOMS
	0.0	0.0	0.0	0.0	0.5127	0.0948	0.2371
	10.5928	1.9275	4.5307	0.5662	5.3349	4.7882	11.9705
	16.1152	2.1580	5.6948	0.0590	7.9997	6.3892	15.9729
4	2.3157	0.2479	0.8102	0.0	2.6211	1.9698	4.9244
	4010	3. /17!	8.1886	0.3998	15.9309	13.0078	32.5195

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APPENDED REPORT -- "Distribution and Abundance of Benthic Invertebrates in a Sonoran Desert Stream," by Dale A. R. Bruns, August 1977 M.S. Thesis, Arizona State University, Tempe, AZ 85281

INTRODUCTION

The present document covers the period August 1776 through early June 1977 and serves as a quarterly report (Item 0001AA, July 1977), and as an annual report (Item 0001AB, April 1977) for Contract No. YA-512-CT6-98, effective date 1 April 1976, signatory date 18 June 1976, between the Bureau of Land Management and Arizona State University. Data included herein are tentative in nature, and subject to further evaluation and interpretation for the final report.

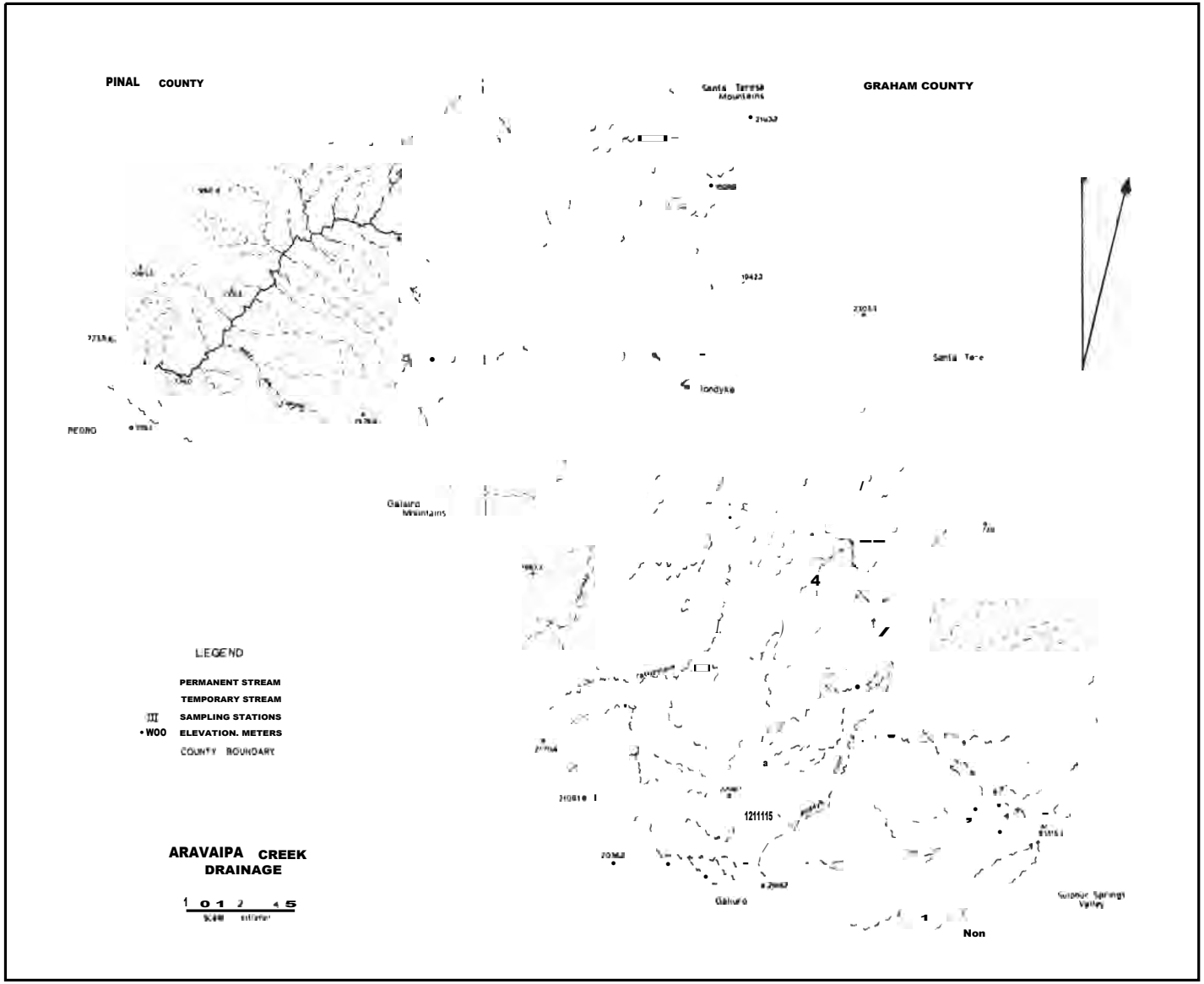
Field studies were initiated in August 1976 with receipt of equipment and supplies, and hiring of field and laboratory personnel. Data included here are those which are complete enough to allow some interpretation. Certain components of the study are fragmentary, or in the process of analysis, and will be reported later.

Each of the three segments of this report is started with a brief summary (HISTORICAL, p. 4; PHYSICO-CHEMICAL ENVIRONMENT, p. 25; and BIOLOGICAL STUDIES, p. 70), which may be consulted for a rapid overview of the project accomplishments. A report on benthos of Aravaipa Creek by Dale A. R. Bruns, is appended as part of this document.

A reduced example of a field map developed for plotting of localities and recording data on animal and plant distributions is provided as Figure 1.

The Final Report on "Microchemical Analysis of Aravaipa Creek and Adjacent Aquatic Habitats Relative to Land and Water Use Management", by Milton R. Sommerfeld (Arizona State University), stands as a sister document to the present annual presentation.

Figure 1. Sketch map of the Aravaipa Creek drainage, Graham and Pinal counties, Arizona, prepared from U. S. Geological Survey and U. S. Forest Service base maps.


PINAL COUNTY
GRAHAM COUNTY
Santa Teresa Mountains
Santa Teresa
Iondyke
Galiuro Mountains
Galiuro
Sulphur Springs Valley
LEGEND
PERMANENT STREAM
TEMPORARY STREAM
SAMPLING STATIONS
ELEVATION. METERS
COUNTY BOUNDARY
ARAVAIPA CREEK DRAINAGE
1211115
Non

HISTORICAL

Summary

Ninty-two dated photographs of Aravaipa Creek and its environs have been secured and are under study. Of special interest is a series of 8 photographs dated between 1890 and 1900, which indicate a denser riparian community than at present, substantially greater accumulation of ground litter, less incision of the stream channel, but a very similar aspect of the stream itself.

Pre-1940 Photographs

Five photographs taken between 1890 and 1900 by J. A. Munk, obtained from the Southwest Museum, Los Angeles, California (Negative Nos. 12,425-6, 12,429, 12,424, 12,427; Figs. 2-6. At that time, the extreme upper part of the floodplain (near Klondyke) was obviously cleared and under cultivation (Fig. 2), with flood irrigation already being practiced. Large cottonwoods (Populus fremonti) remained, and in an area presumably nearby, supported a dense stand of wild grape (Vitis arizonica; Fig. 3), and ground litter was dense (far more so than can be found today). The forest (or gallery) along upper Aravaipa Creek was dense, consisting of about the same species composition as now present (cottonwood, willow Dalix sppD, and sycamore [Platanus wrighti]; Figs. 4-5). Smaller riparian plants seem dominated by seep willow (Baccharis glutinosa), still present today (Fig. 6). Stream banks ranged from low to incised in bends, similar to present, but large trees of the riparian gallery obviously stand with their bases closer to water level than is the situation in 1977 (Figs. 4-6).

Wee additional photographs, dated "before 1900" and received from the Arizona Historical Society, Tucson, Arizona (Negative Nos. 8,208-9[2]), include one of the upper portion of the stream (Fig. 7), and two from within the canyon (Figs. 8-9). The upstream picture indicates a far sparser riparian vegetation, including more willow, than do Figures 4-6. Vegetation within the canyon closely resembles that observed in the 1930s (Figs. 10-11), and 1970s (Fig. 12). Those photographs with "hard rock" features (Figs. 6, 8-12) have been matched with 1976-77 photographs, and will be presented in the final report, along with more short-

term pairs (especially from the period 1963-present).

Of especial interest is a photograph donated to the Arizona Historical Society in 1939 (Negative No. 6901) depicting a log wier and two men in the stream. The specific location is obscure, but other photographs donated at the same time were from the upper segment. At first, an irrigation diversion was suspected; however, careful examination of the man to the left (Fig. 13) shows fish in each hand, and the man to the right appears to be using a dip net.

As noted in an earlier report, many photographs have been screened, but few have salient features for locality determination, and even fewer are appropriately dated. Of 432 photographs presently in hand, 92 are dated, and of those, only 24 can be located with relative certainty.

Figure 2. Aravaipa Creek floodplain near Klondyke, Graham County, Arizona, 1890 - 1900.

SRP10649

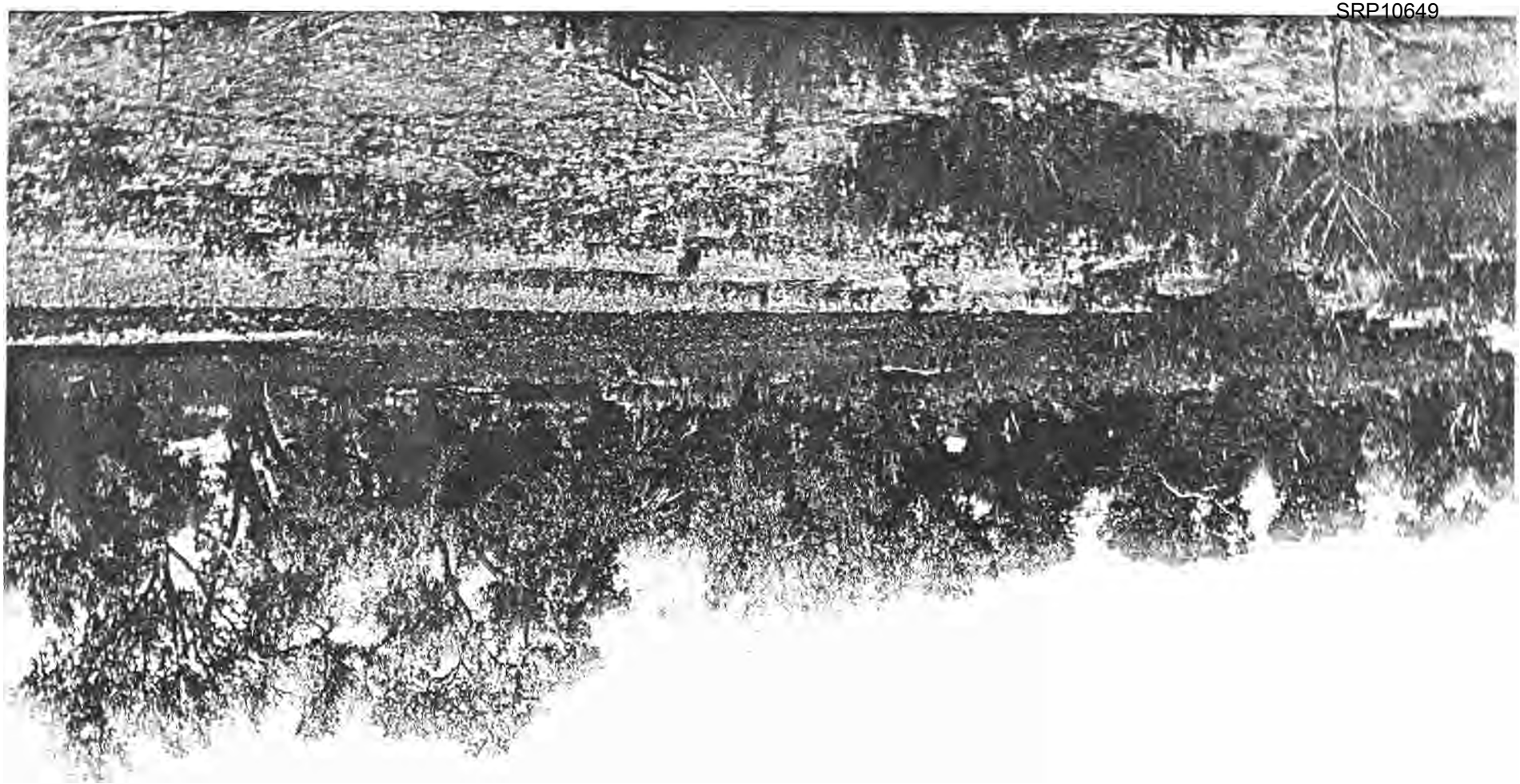


Figure 3. Aravaipa Creek riparian forest, near Klondyke, Graham County, Arizona, 1890 - 1900

SRP10651

Figure 4. Aravaipa Creek, near Klondyke, Graham County, Arizona, 1890 - 1900 (see also Fig. 5).

SRP10653

Figure 5. Aravaipa Creek, near Klondyke, Graham County, Arizona, 1890 - 1900 (see also Fig. 4).

SRP10655

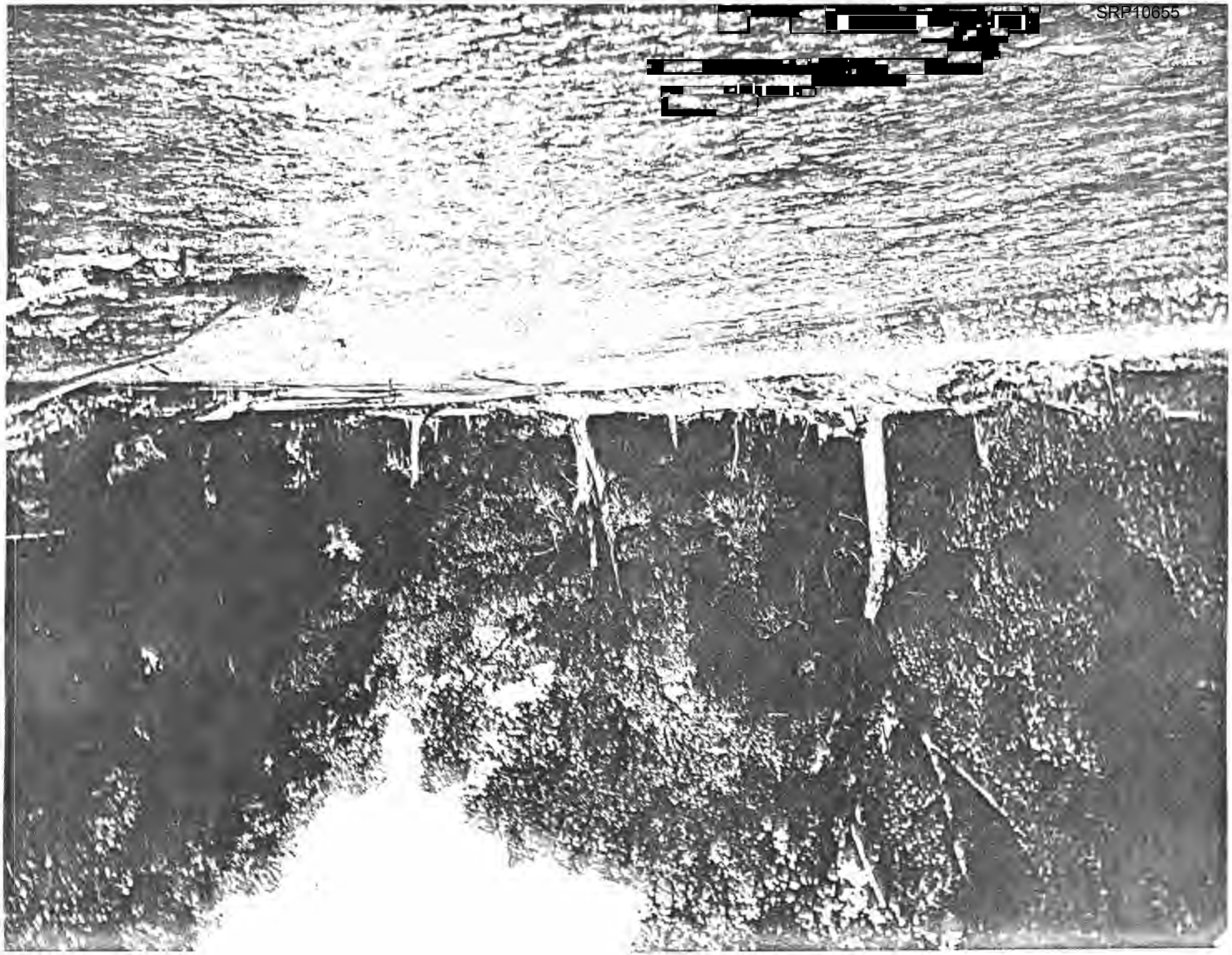


Figure 6. Aravaipa Creek, Graham County, Arizona, near "the Chimney," 1890 - 1900.

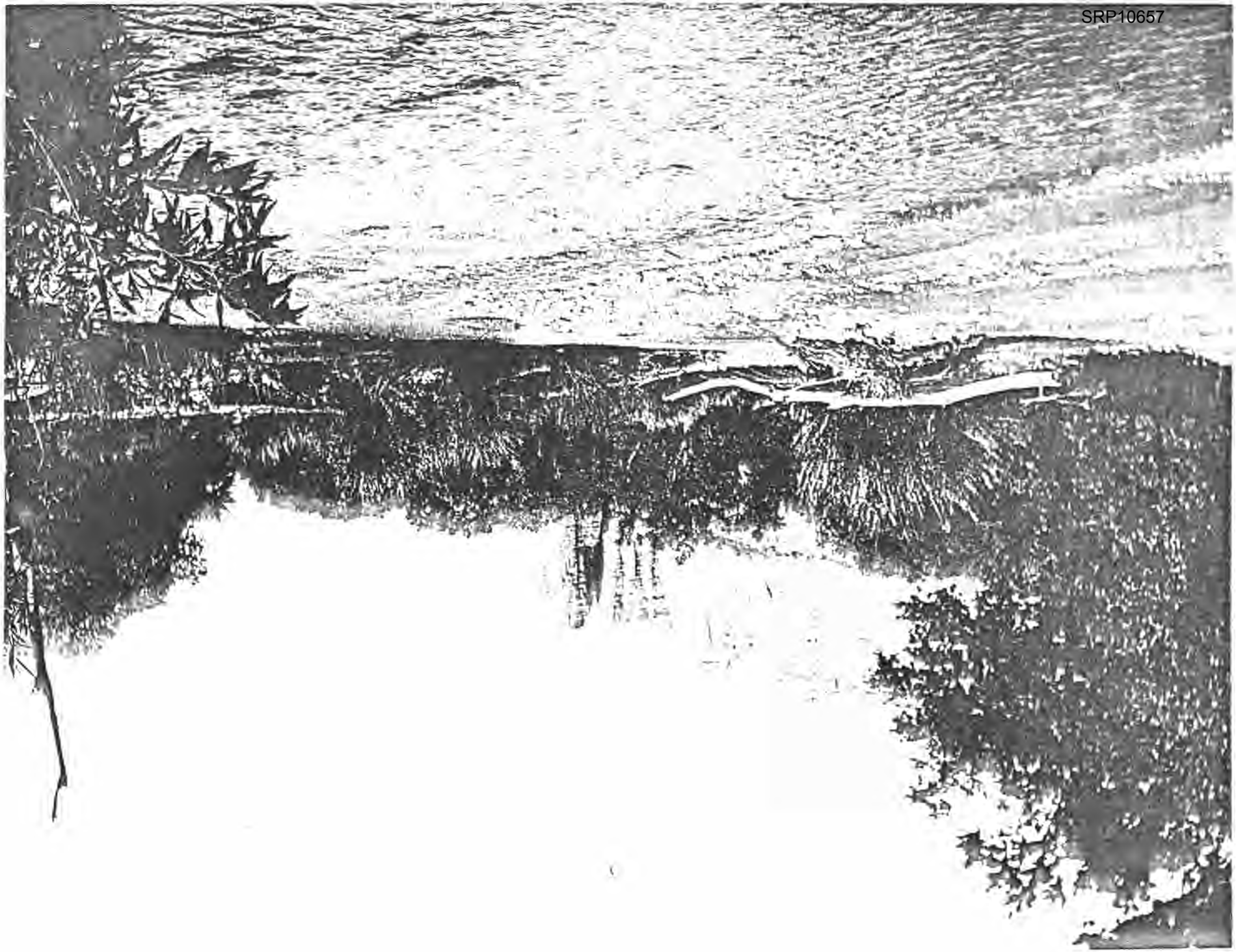

SRP10657

Figure 7. Aravaipa Creek, Graham County, Arizona, near Klondyke, "before 1900."

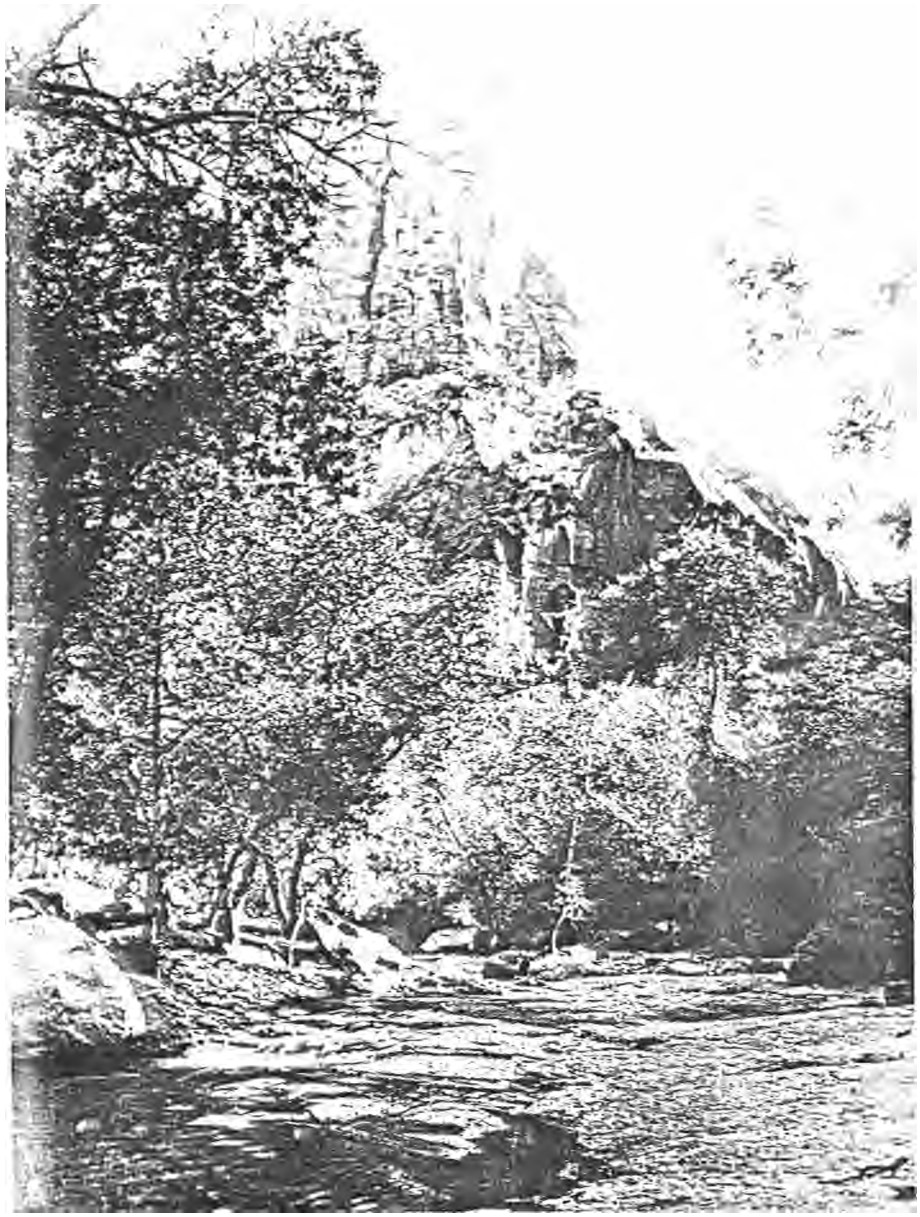


Figure 8. Aravaipa Creek, Graham or Pinal County, Arizona, in Aravaipa Canyon, "before 1900."

Figure 9. Aravaipa Creek, Graham or Pinal County, Arizona, in Aravaipa Canyon, "before 1900."

Figure 10. Aravaipa Creek, Graham County, Arizona, in Aravaipa Canyon, "Donated 1939." Arizona Historical Society Negative No. 6,903.

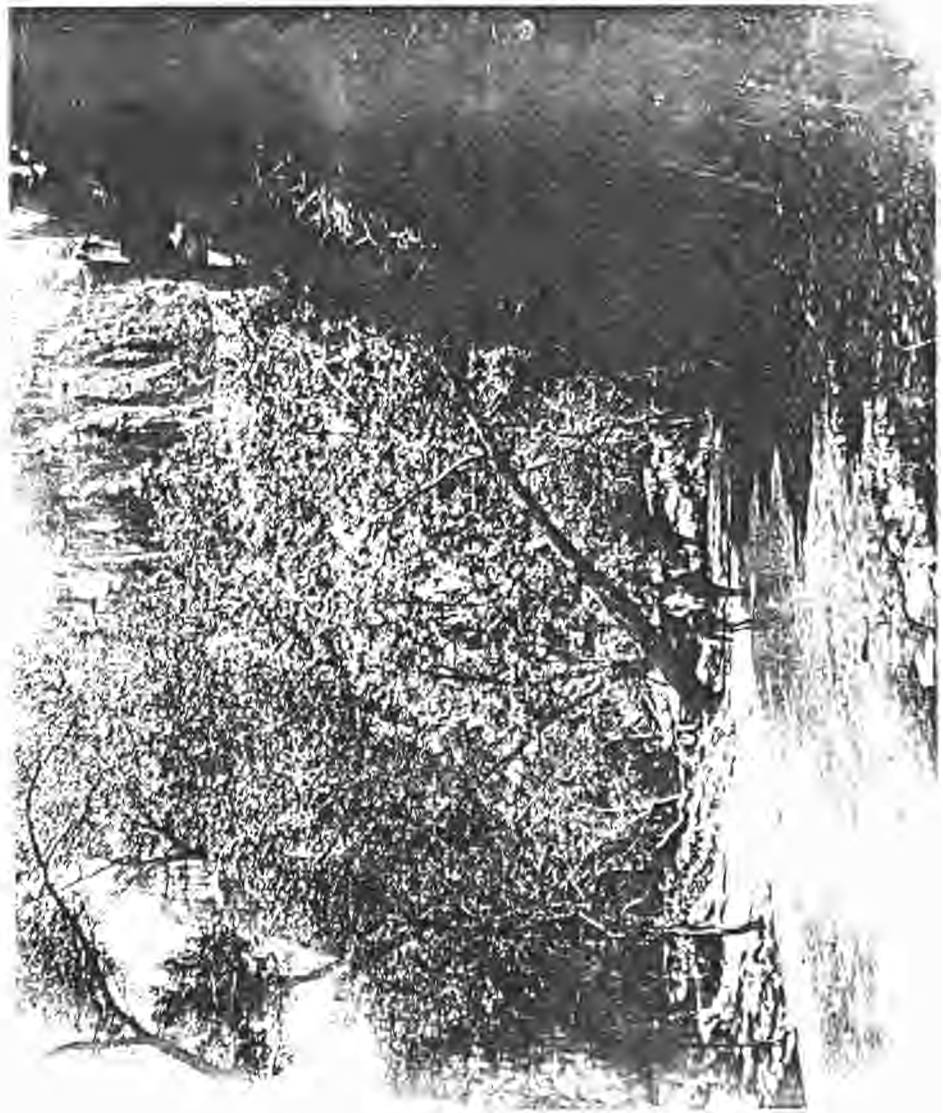


Figure 11. Aravaipa Creek, Graham County, Arizona, in Aravaipa Canyon, "Donated 1939." Arizona Historical Society Negative No. 6,902.

Figure 12. Aravaipa Creek, Pinal County, Arizona, in Aravaipa Canyon Bureau of Land Management Photograph, early 1970s.

SRP10665

Figure 13. Aravaipa Creek, Graham County, Arizona. Men fishing with log wier and dip net; Arizona Historical Society Negative No. 6,901.

PHYSICO-CHEMICAL ENVIRONMENT

Summary

Aravaipa Creek demonstrates a strongly bi-modal pattern of discharge, with greatest volumes occurring in winter (January - March) and summer (July - September). Major scour is effected at about 10 times average discharge of 30 cubic feet per second, and such an event occurred only 0.8% of 1,583 days (1966 - 1970).

Temperature changes of water are abrupt, ranging to 2.72 X 10^{-2} C/minute on heating and 1.17 X 10^{-2} C/minute on cooling. Temperature ranges are greatest in areas of open sun in summer, and least on cloudy days throughout the year. Water temperatures of 5.0° to near 30.0° have been recorded.

Values of conductance range from 405 to 478 umhos/cm in periods of average or modal flow, and dilution from spates is an obvious feature of the stream. There is a tendency for up- to downstream conductance to increase, presumably as a result of evaporation, transpiration, and input of springs.

Hydrogen ion concentration (O) varies substantially during the day, in obvious response to photosynthetic activities, and is lower upstream than downstream.

Dissolved oxygen concentrations vary with temperature, and with photosynthetic activities of algae and higher aquatic plants. There is a strong tendency for respiratory depletion of dissolved oxygen at night (to near 80% saturation), with supersaturation occurring often during daylight hours.

Macronutrient (PO_4-P and NO_3-N) concentrations are relatively high in Aravaipa Creek, with the former remaining so throughout the stream, and the latter tending to decrease at downstream stations.

The physico-chemical environment of Aravaipa Creek is strongly influenced by physical factors in cooler weather, for a short period after spates, and in areas of heavy shading. Otherwise, many features of the chemical system, at least, are under strong biological control, reflecting production and respiration within the system.

Temperature

Rates of change in water temperatures of Aravaipa Creek are great, reflecting unimpeded insolation on many reaches and general shallowness of the stream. When heating, rates of change averaged near 2.0 X 10^{-2} C/minute, ranging from 1.56 to 2.97 X 10^{-2} °C/minute on cloudless days throughout the year. Cooling rates were far more variable than those for heating, 0.28 to 1.17 X 10^{-2} °C/minute, reflecting differences in relative humidity and in ambient temperatures of air (Table 1).

Abrupt heating and slow cooling is obvious on plots of long-term temperature studies made at various stations on Aravaipa Creek, especially in mid-summer and in autumn (Figs. 15-16). Maximum temperature at an upstream station was recorded on 9 August (Fig.15A); over-all range on that date was 17.7 to 28.4 °C. Rate of heating was the greatest recorded in the period of study (2.97 X 10^{-2} °C/minute; Table 1). The reach of stream for about 1.5 kilometers above the sampling site was not shaded by canyon walls, had a sparse gallery forest, and a small spate earlier in the month had removed all emergent aquatic vegetation, so that essentially all incoming light impinged on the water surface.

Temperature variations in autumn and winter decreased in magnitude, yet greater than 17.0 °C was attained on all but 1 of 5 sampling periods between November and April, and a minimum of slightly above 10.0 °C occurred on 11 January (Figs.15B-F). Variation in June approached that of the preceding August (Fig. 15G).

Data from downstream stations are similar to those just discussed (Figs.16A-G). However, an extremely cool day occurred on 15 January, and water temperature dropped below 5.0 C at night, and achieved only

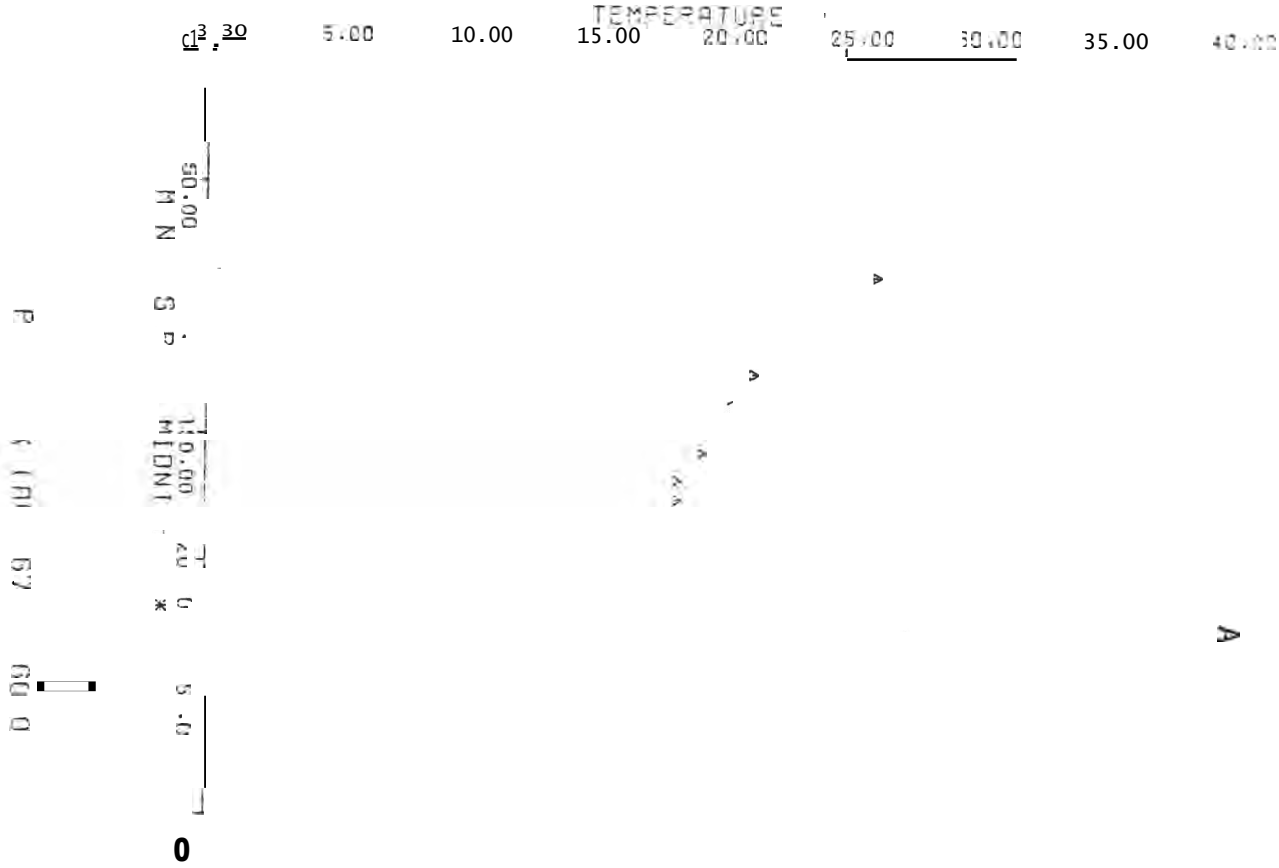
slightly more than 12.0 C in daytime (Fig.16B). Also unusual are data for 23 April (Fig.16F), recording the least variation observed in temperatures of the stream in a single day, and reflecting total cloud cover and high humidities (see also Table 1).

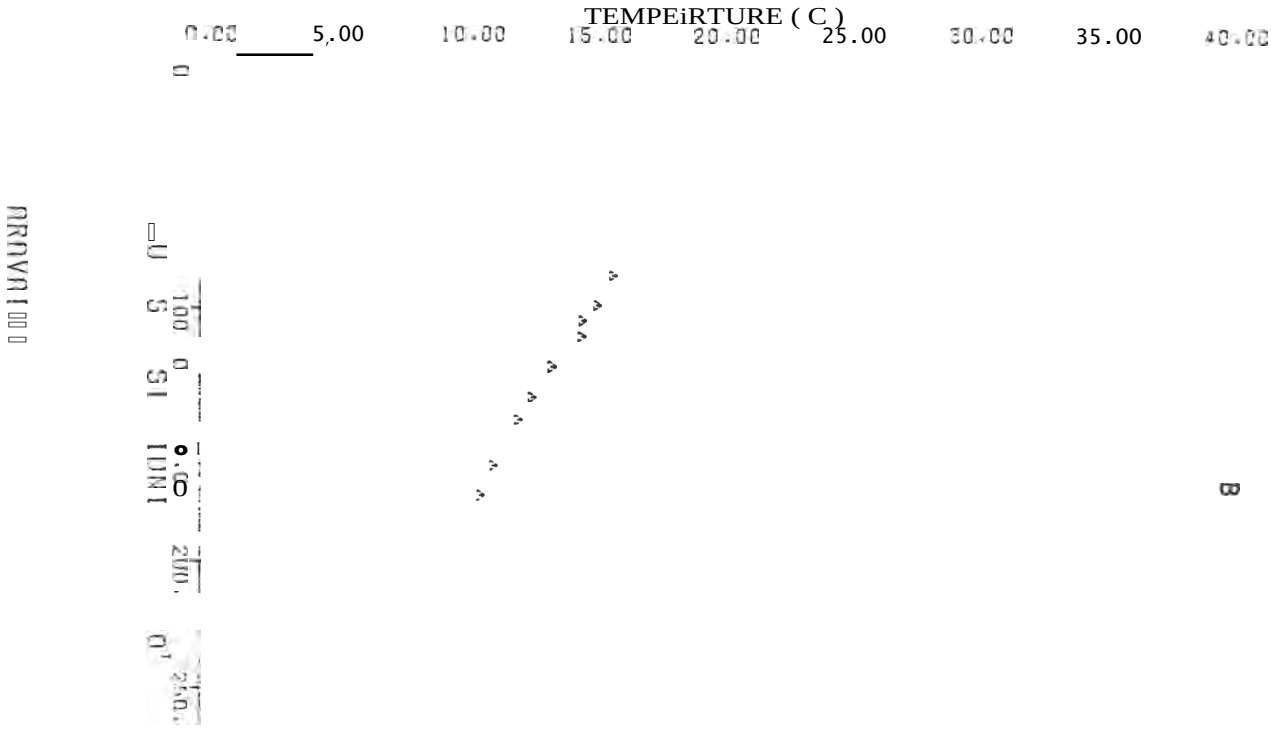
Table 1. Rates of heating and cooling of water in Aravaipa Creek, Graham and Pinal counties, Arizona; ~C/minute X 10^{-2}.

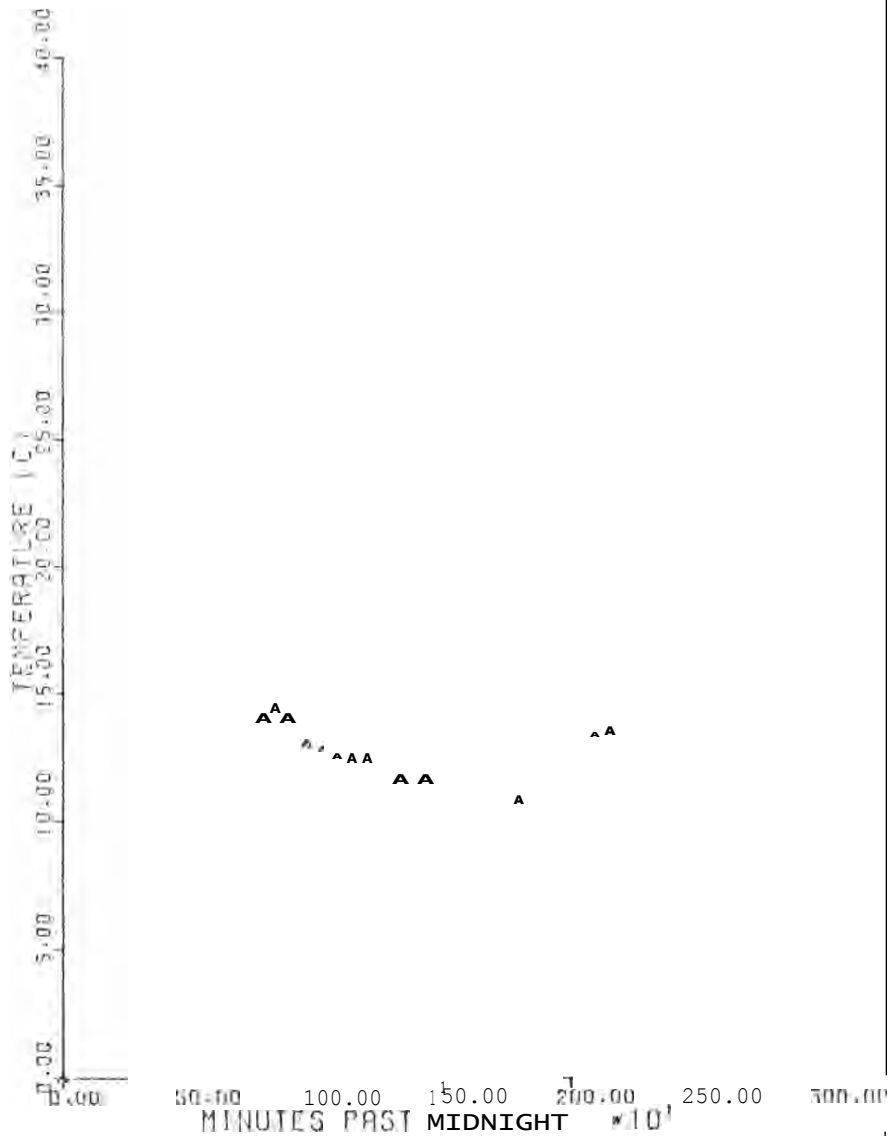
Upper Stations 1/			Lower Stations 2/		
Dates	Heating	Cooling	Dates	Heating	Cooling
760809	2.97	1.06			
			761023	1.90	0.79
761119	2.14	0.71	761120	1.95	0.84
770111	1.83	0.39	770115	1.74	0.74
			770119	2.74	1.17
770218	1.94	0.67			
770316 3/	1.23	0.55	770318	1.88	0.97
770422 3/	0.83	0.43	770423 3/	0.54	0.28
770606	1.90	0.79	770607	1.56	0.81

1/Elevations 3,090 to 3,300 feet above mean sea level (942-1,006 m).
2/Elevations 2,300 to 2,580 feet above mean sea level (701- 846 m).
/Partially overcast on 770316, and fully overcast on 770422-23.

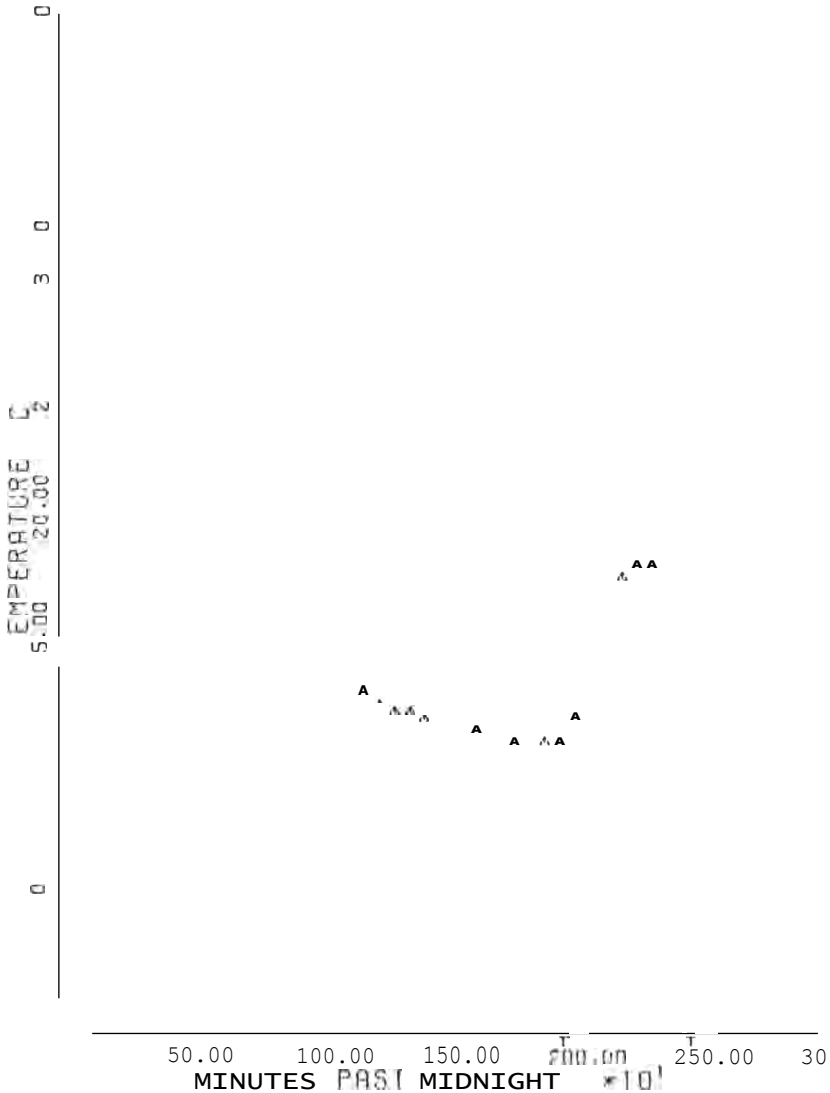
Figure 15. Long-term temperature data for upstream stations on Aravaipa Creek, Graham and Pinal counties, Arizona (pages 34 through 37).


A
TEMPERATURE
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
50.00
40.00
30.00
20.00
10.00
0.0

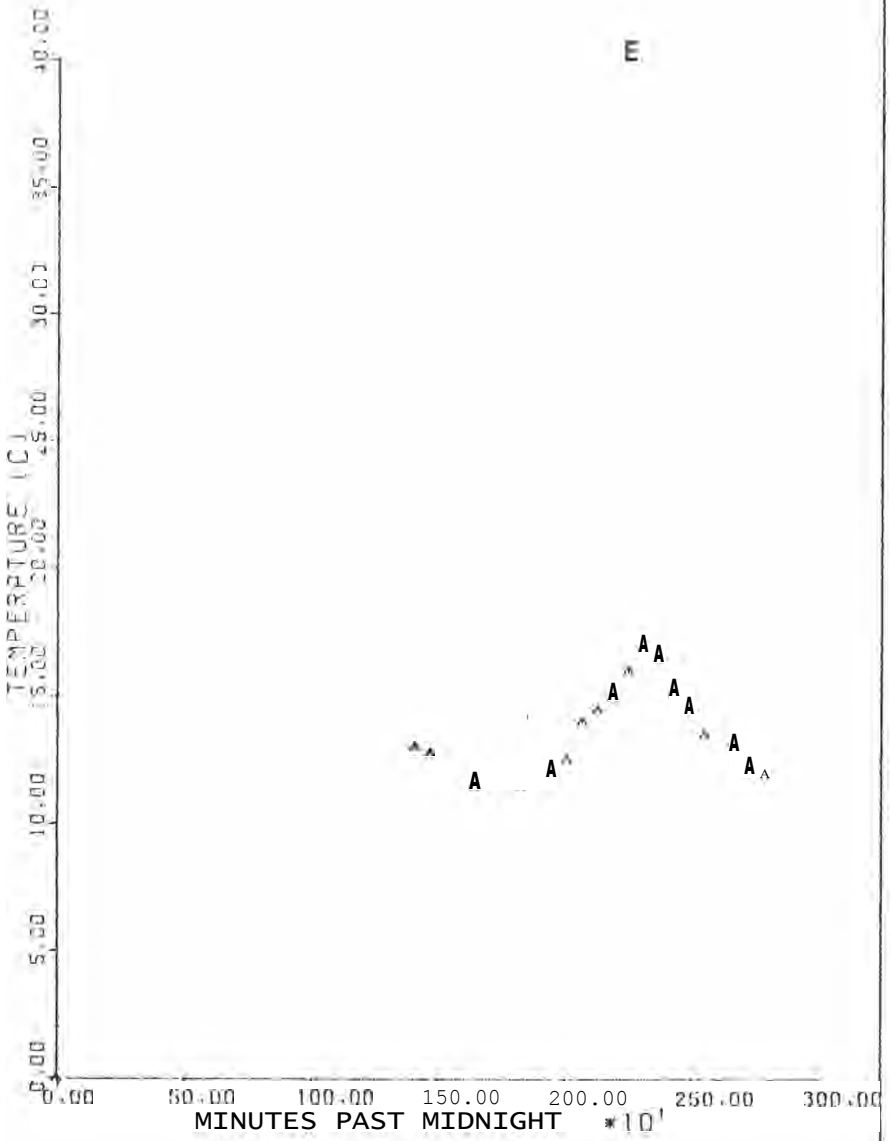

B
TEMPEiRTURE (C)
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
100.0
200.0
250.0



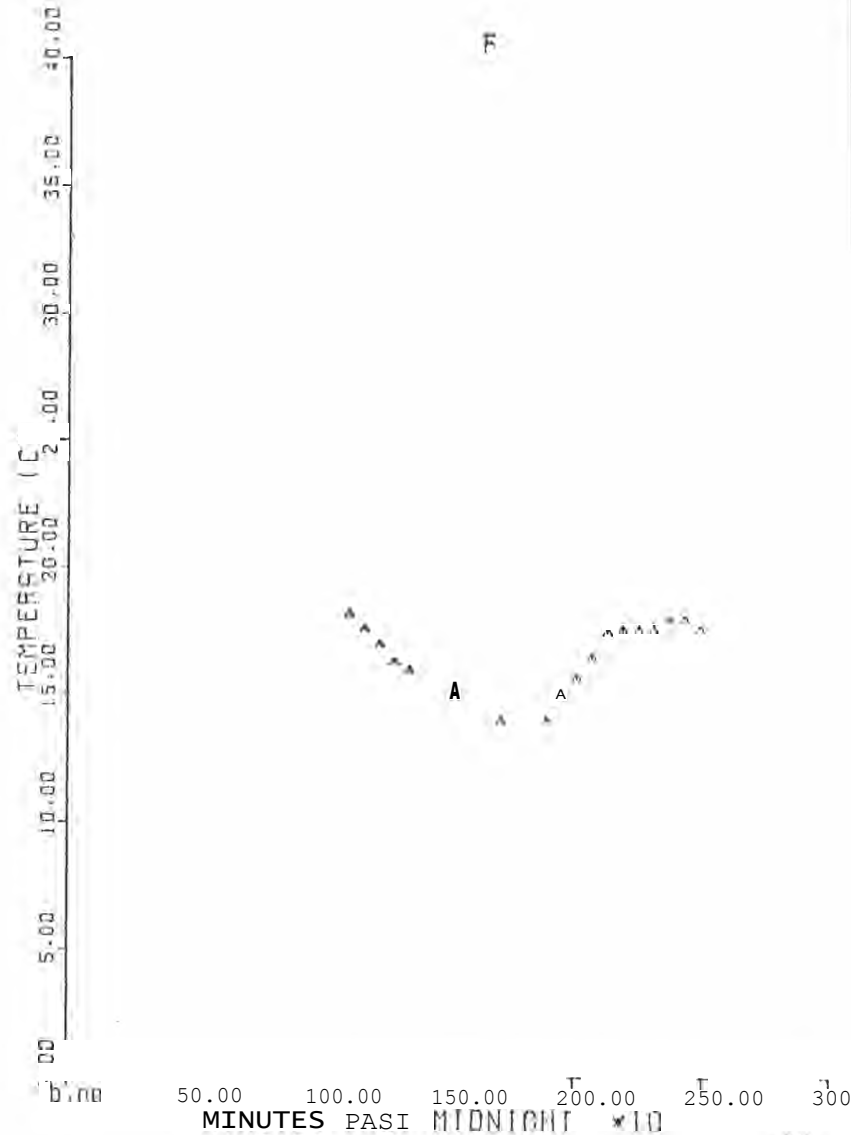
ARAVAIPA CREEK (AC3150) 770111



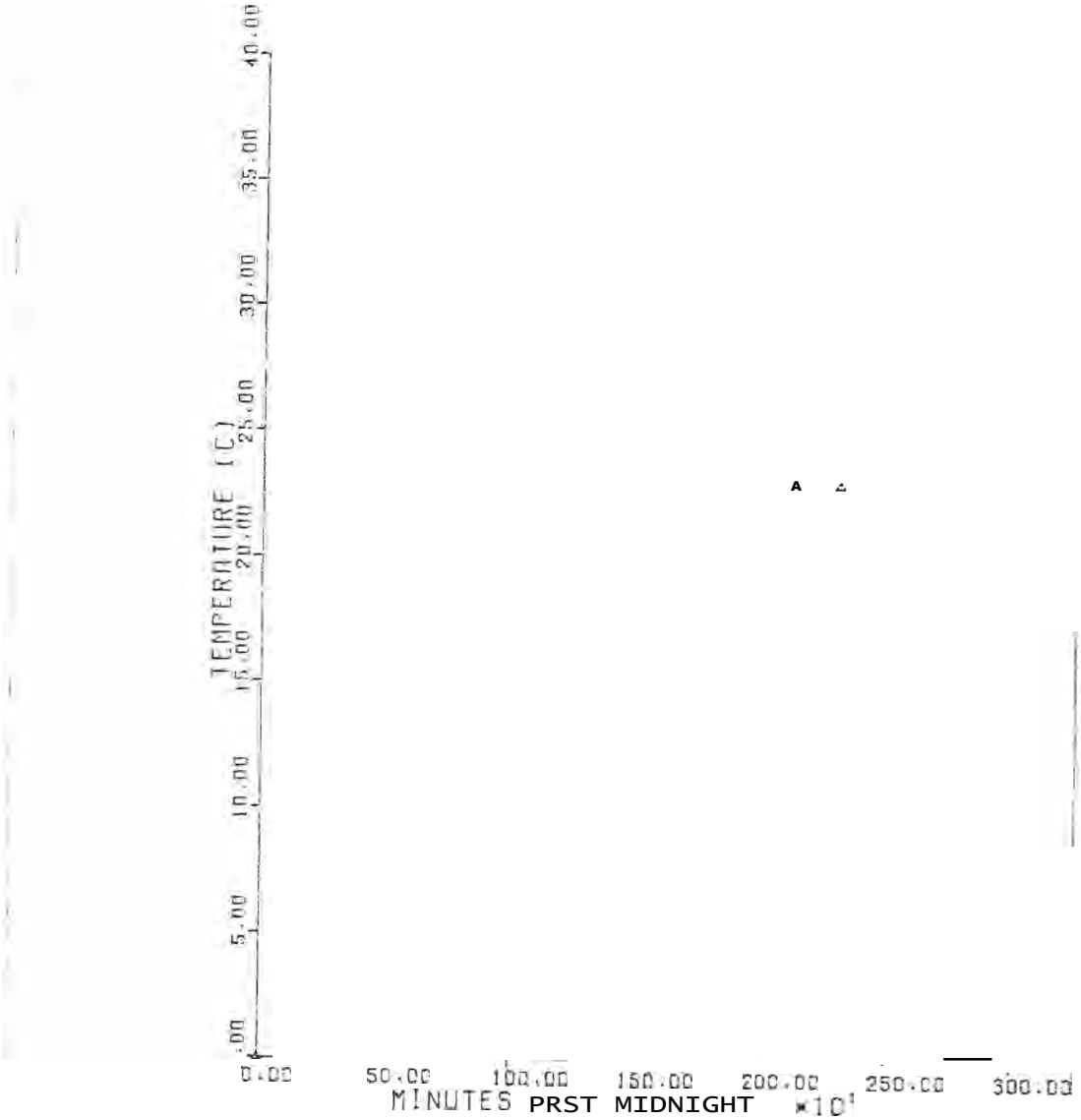
ARAVAIPA CREEK (AC3150) 770218



ARAVAIPA CRELK (AC3155) 770316

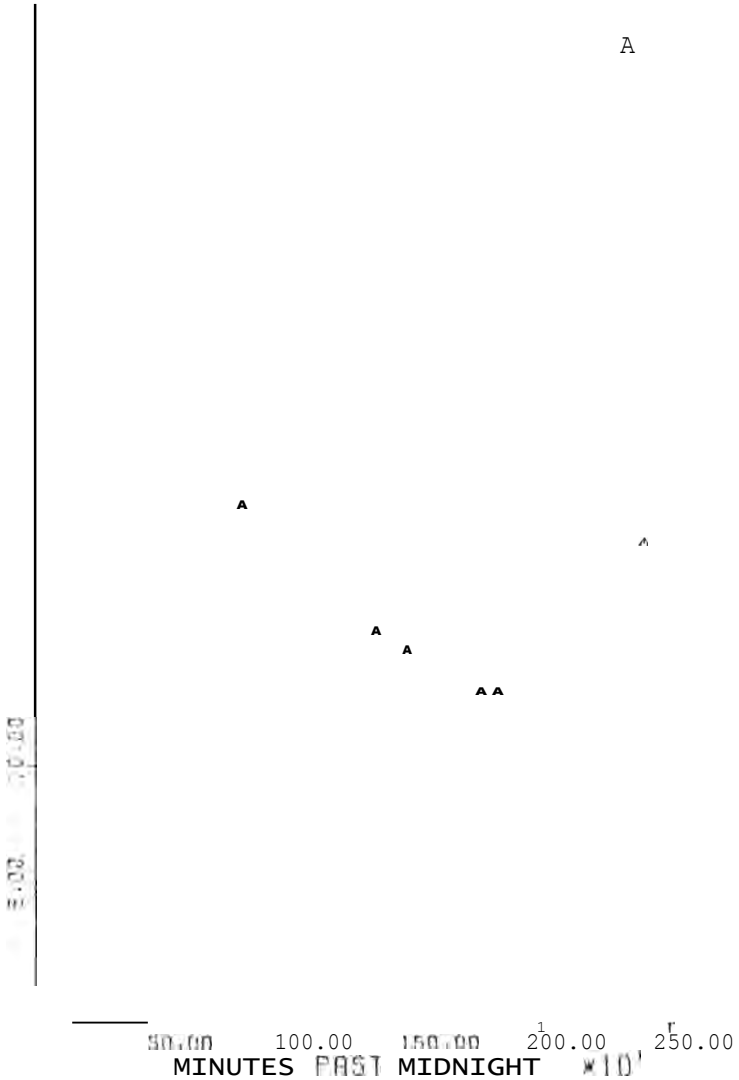


ARAVAIPA CREEK (AC3140) 770422

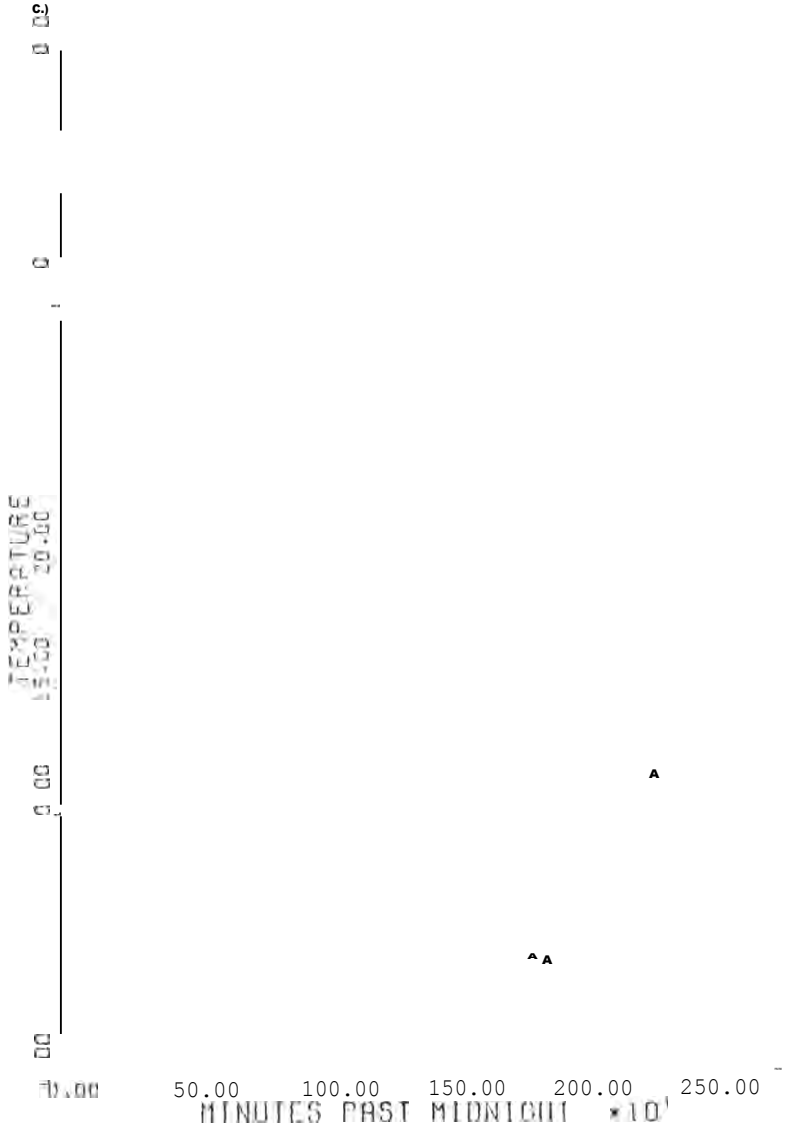


ARRAVAIPA CREEK (AC3150..) 770606

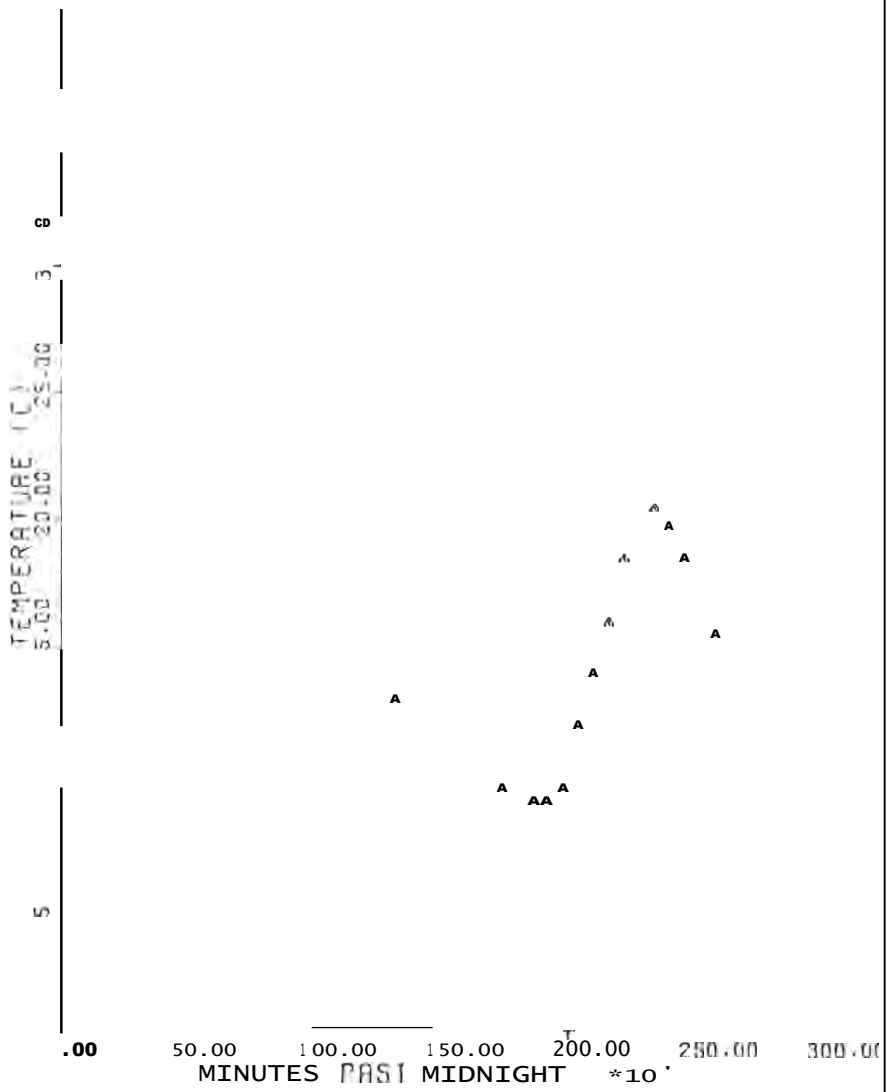
Figure 16. Long-term temperature data for downstream stations on Aravaipa Creek, Graham and Pinal counties, Arizona. (pages 39 through 42).



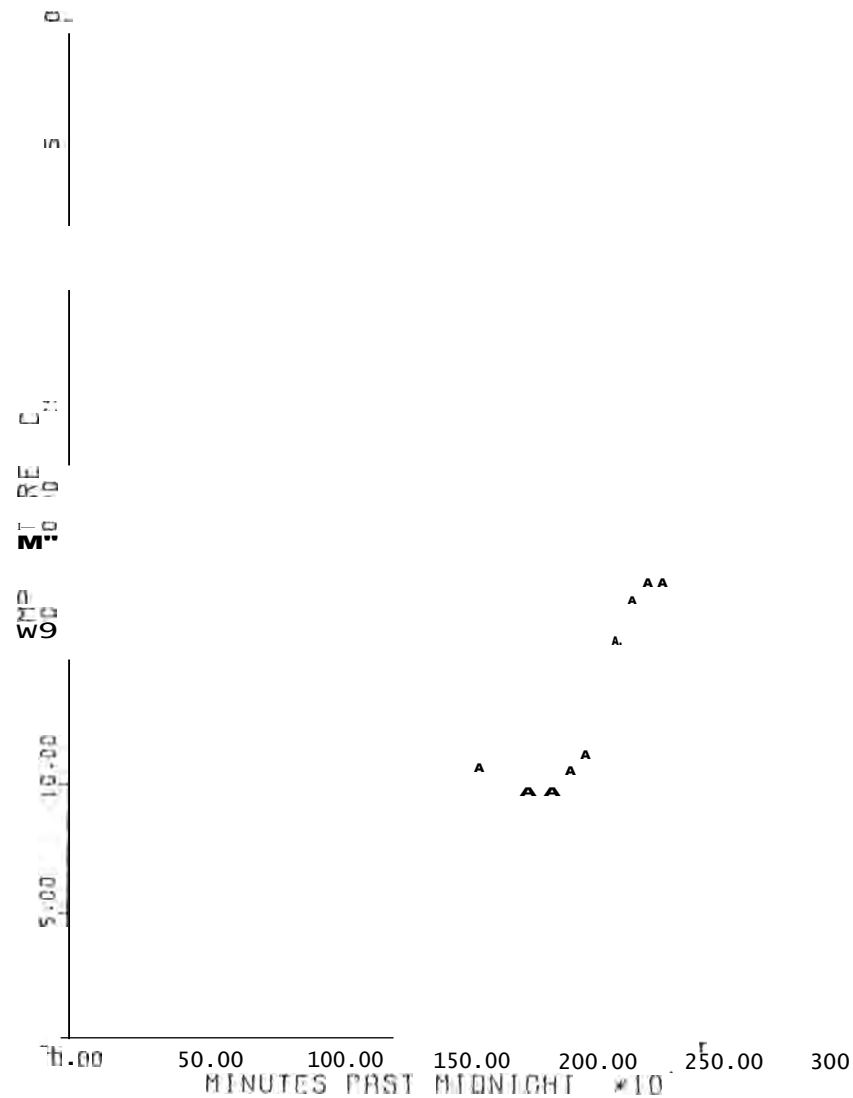
ARAVAIPA CREEK (AC2550.) 761023



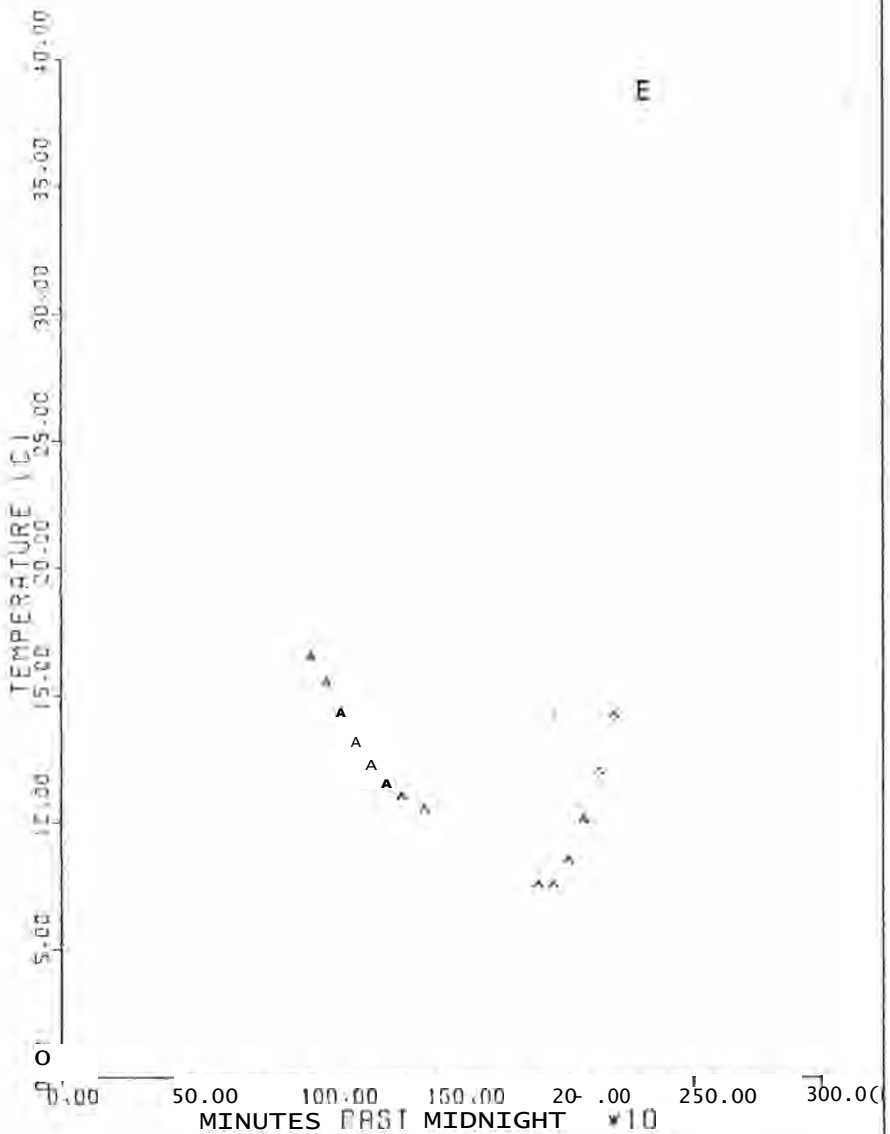
ARAVAIPA CREEK (AC2550.) 770115



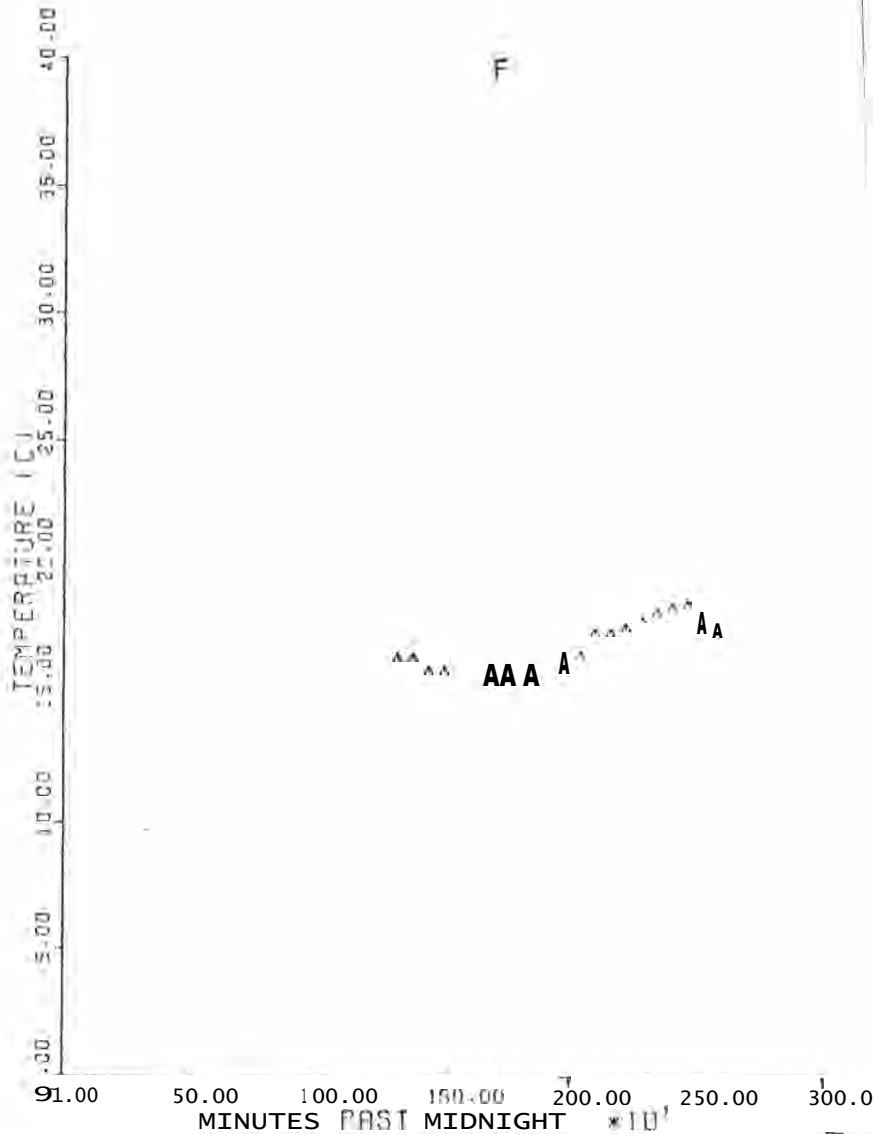
ARAVAIPA CREEK (AC2320.) 770119



ARAVAIPA CREEK (AC2320.) 761120



ARAVAIPA CREEK (AC2600.) 7703113



ARAVAIPA CREEK (AC2600.) 770423

TEMPERATURE (C)
0.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00
40.00
0.00
50.00
100.00
150.00
200.00
250.00
300.00
MINUTES PAST MIDNIGHT
GRAVBIPA CREEK (AC2550) 770607

Specific Conductance

Specific conductance, as µmhos/cm corrected to 25.0° C is a measure of total dissolved solids in water. Values in Aravaipa Creek generally ranged between 400 and 500 µmhos/cm. During spates, as in August (Table 2), dilution is effected. In periods of low discharge, and generally in summer, specific conductance increased from up- to downstream (November and June; Table 2). However, in winter when tributaries were flowing and evapotranspiration was minimal, conductance decreased up- to downstream or remained relatively uniform throughout the system.

Some variations in conductance appear diel in nature, especially at downstream stations, and presumably reflect evapotranspiration during daylight hours. Another factor may be daytime deposition of calcium salts (as travertine), which reduces ions slightly and may be detected by conductance measurements (see later). Additional work is planned on this phenomenon.

Table 2. Specific conductance (in µmhos/cm corrected to 25.0 C) of water in Aravaipa Creek, Graham and Pinal counties, Arizona; means are followed by two standard errors.

Upper Stations[1/]			Lower Stationsgi		
Dates		Values	Dates		Values
760809	21	395±5.6			— — —
761119	17	438±3.0	761120	17	475±3.8
770111	17	478+7.0	770115	19	436+4.6
— — —			770119	20	467+7.2
770218	19	459±3.4	= = =		= = =
770316	19	449±4.0	770318	14	443+9.6
770422	18	405±8.2	770423	18	406±5.8
770606	12	428±13.4	770607	18	459±5.0

1/Elevations 3,090 to 3,300 feet above mean sea level (942-1,006 m).
2/Elevations 2,300 to 2,580 feet above mean sea level (701- 846 m).

Hydrogen Ion Concentration (pH)

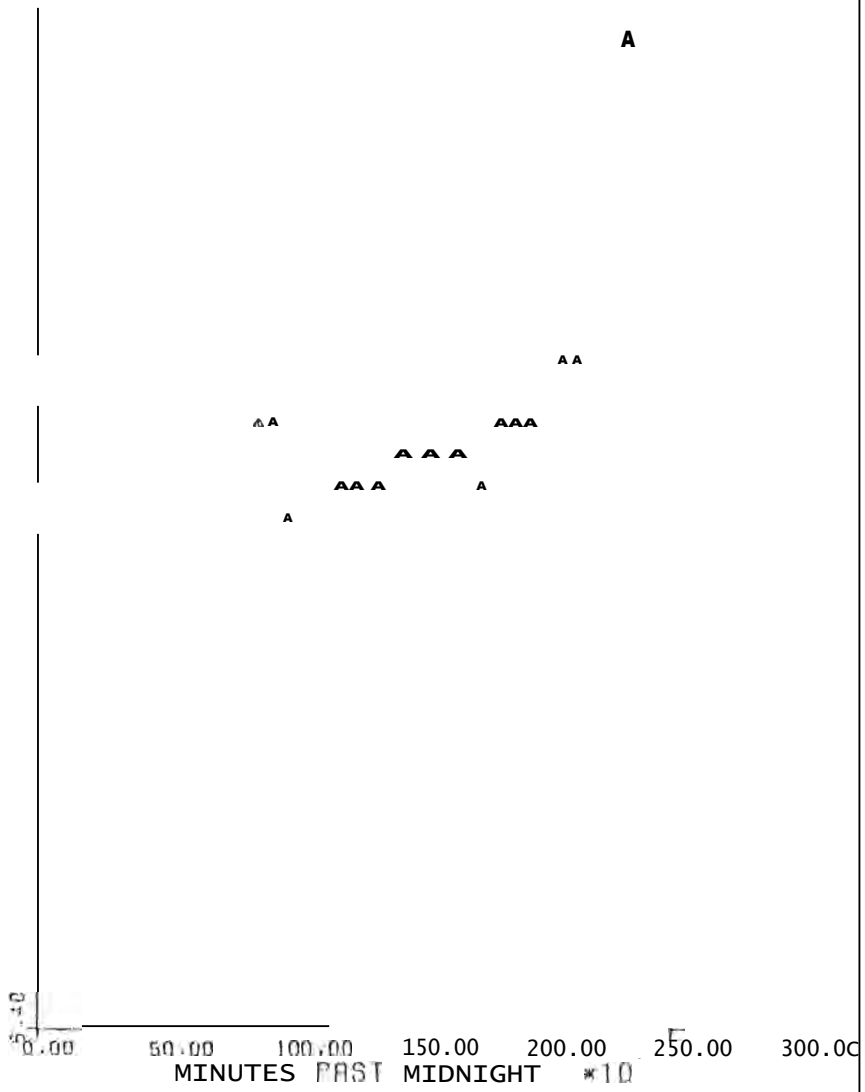
Aravaipa Creek waters are alkaline, rarely falling below O 7.6 at upstream stations, and pH 8.0 downstream (Figs.17-18). In buffered systems of high total dissolved solids, as in Aravaipa Creek waters, photosynthetic activities of algae and higher plants may utilize all free carbon dioxide (CO_2) and then depend upon "half-bound" CO_2 that is gathered from bicarbonate ions. This results in an elevation of pH and precipitation of calcium carbonate as travertine at levels higher than pH 8.3. Nighttime periods of no photosynthesis allow accumulation of respiratory CO_2 in water, or maintenance of levels carried into the system by underground flow, and pp is lowered.

The most erratic data on pH in Aravaipa Creek are from a small spate in August (Fig.17A), and the least variable was obtained in October and November, down- and upstream, respectively, during a time when algae and aquatic plants were scarce as a result of flooding (Figs. 18A and 17B, respectively). At upstream stations, pH varied 0.3 units in January, 0.5 units in February, more than 0.7 in March, and 0.4 in April and June. The pH level of 8.3 was exceeded only in March (Fig. 17E).

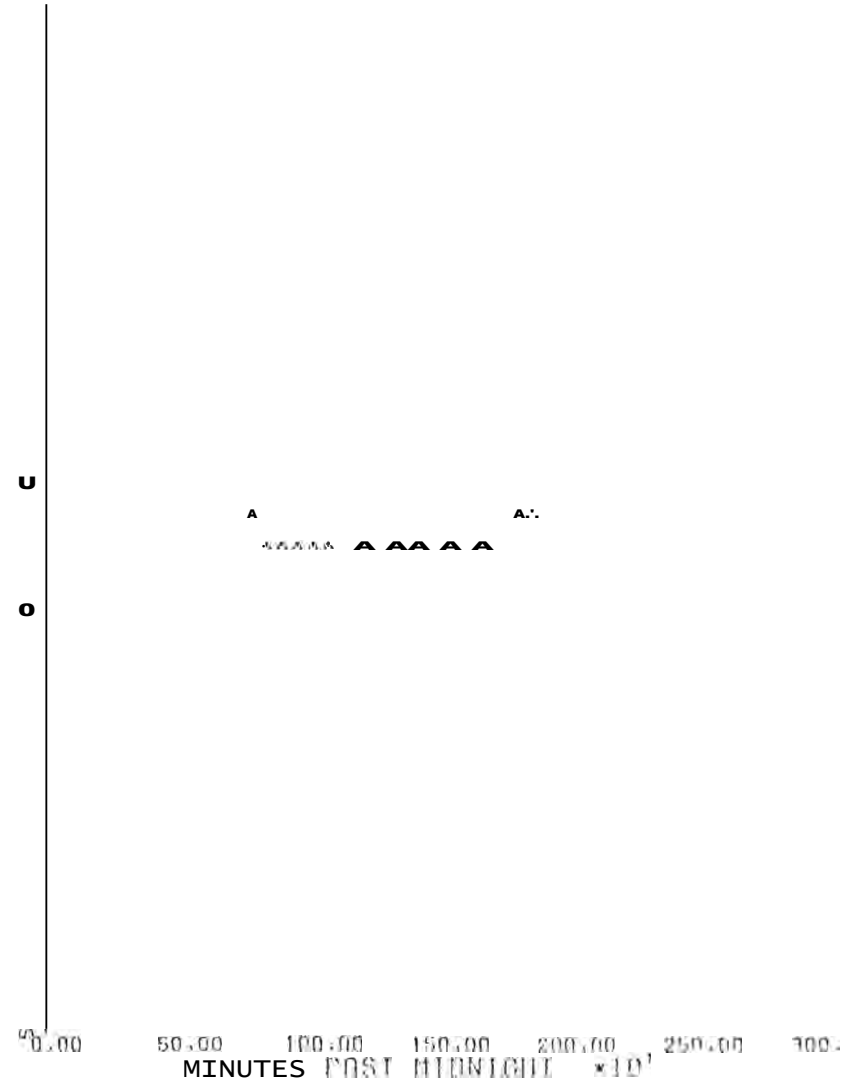
Downstream, pH dropped below 8.3 only in April and June, and ranged upward to 9.0 in most months (Figs.18B-G). Free carbon dioxide was therefore scarcely available, and it is notable that the green alga Cladophora, typical of hard water streams and capable of using half-bound CO_2 exclusively, was common. Deposition of small nodules of travertine was extensive, associated with colonies of the green alga Gongrosira, and carbonate-encrusted Chara spp. was locally common.

SRP10684

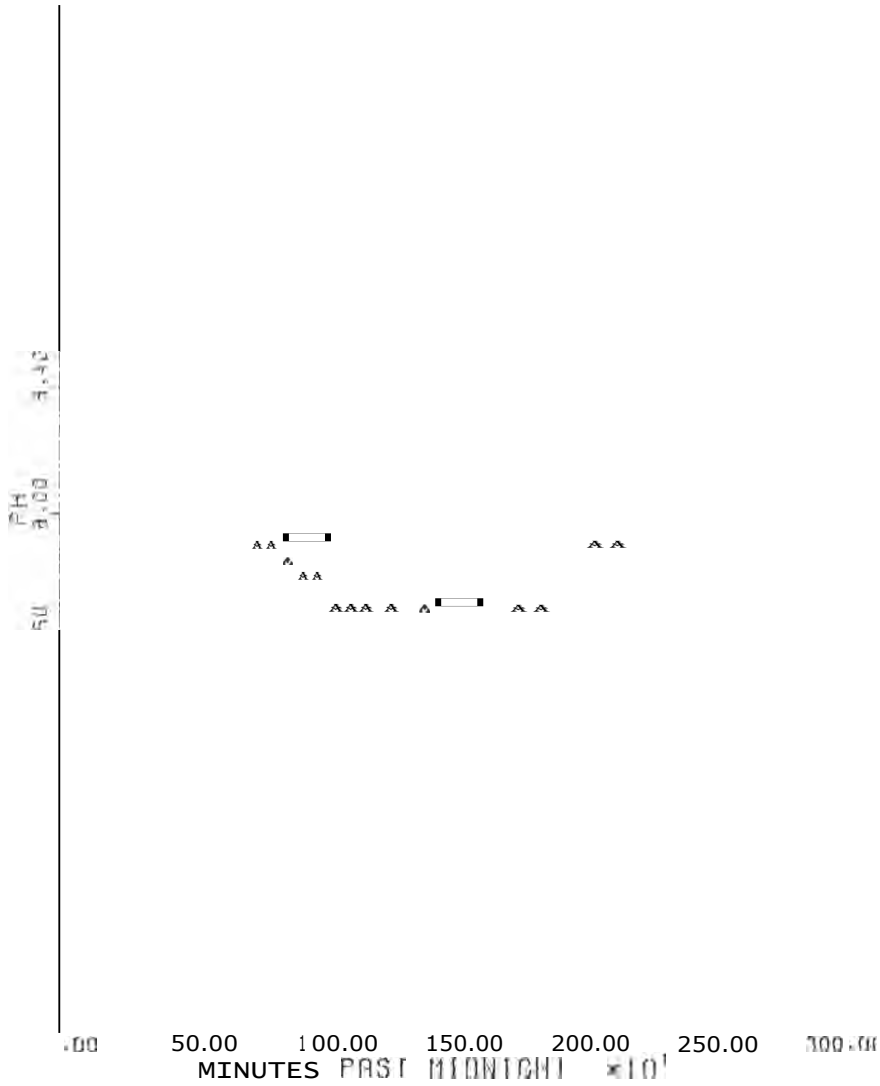
Figure 17. Long-term 2H data for upstream stations on Aravaipa Creek, Graham and Pinal counties, Arizona (pages 47 through 50).



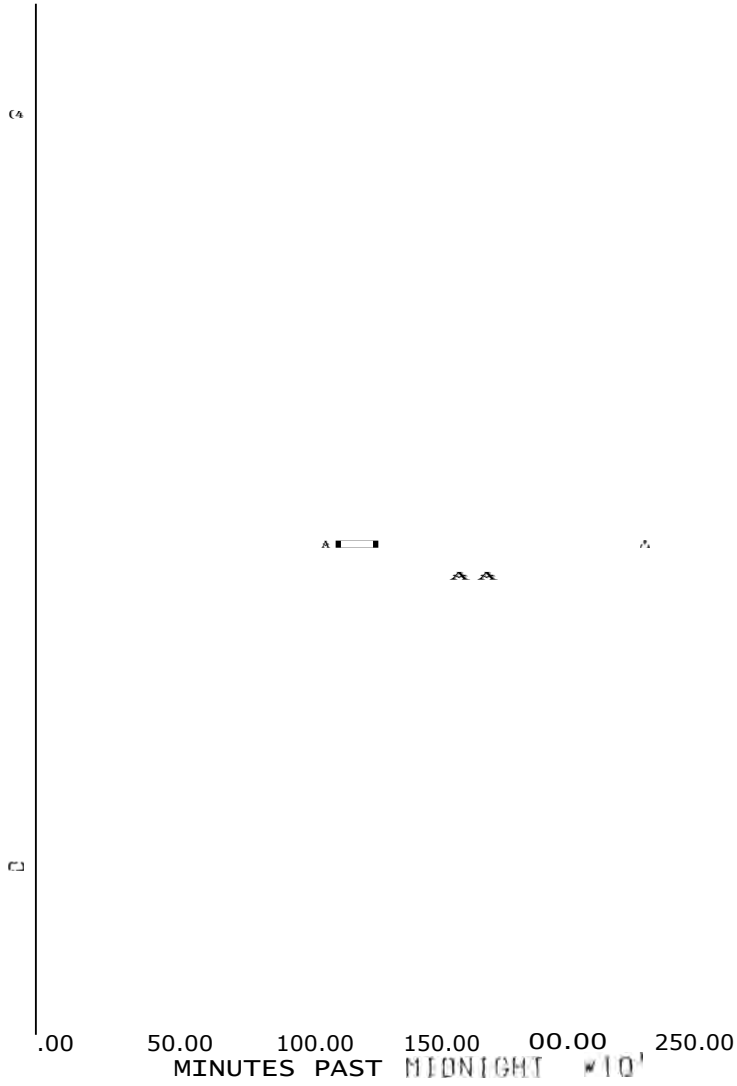
ARAVAIPA CREEK (AC3067.) 760809



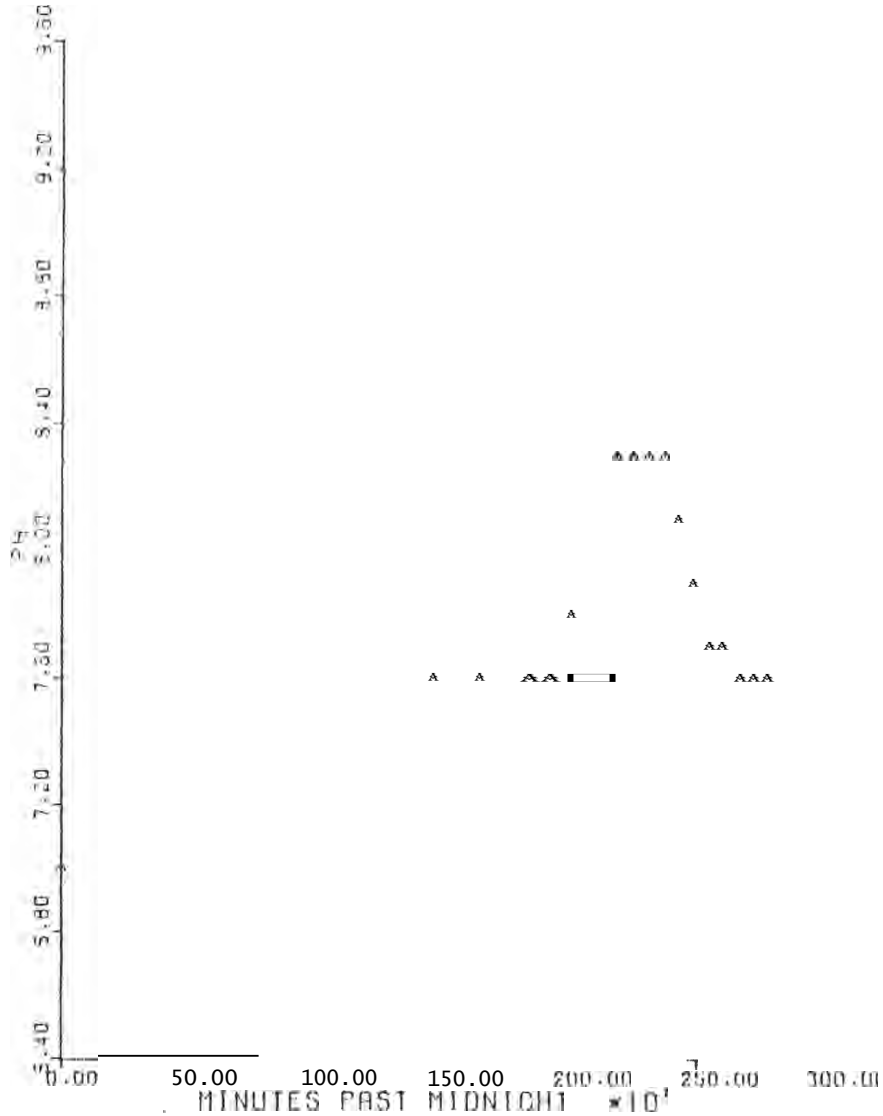
ARAVAIPA CREEK (AC3150.) 761119



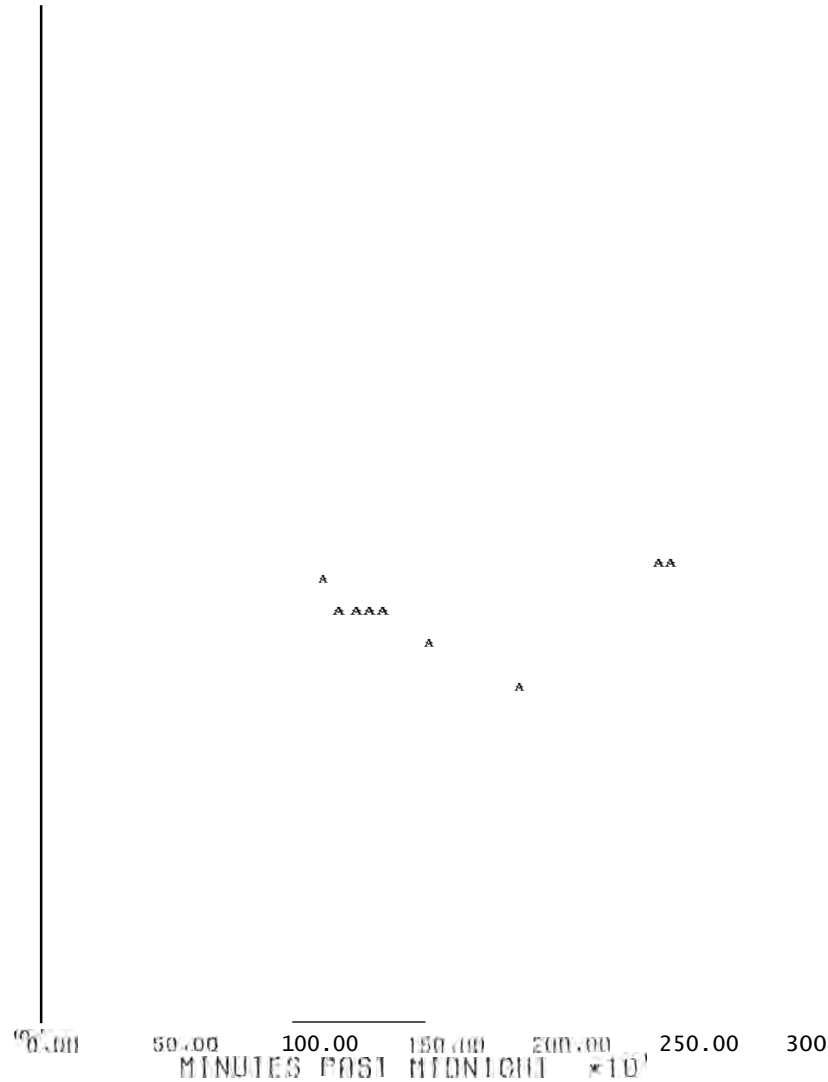
ARAVAIPA CREEK (AC3150) 770111



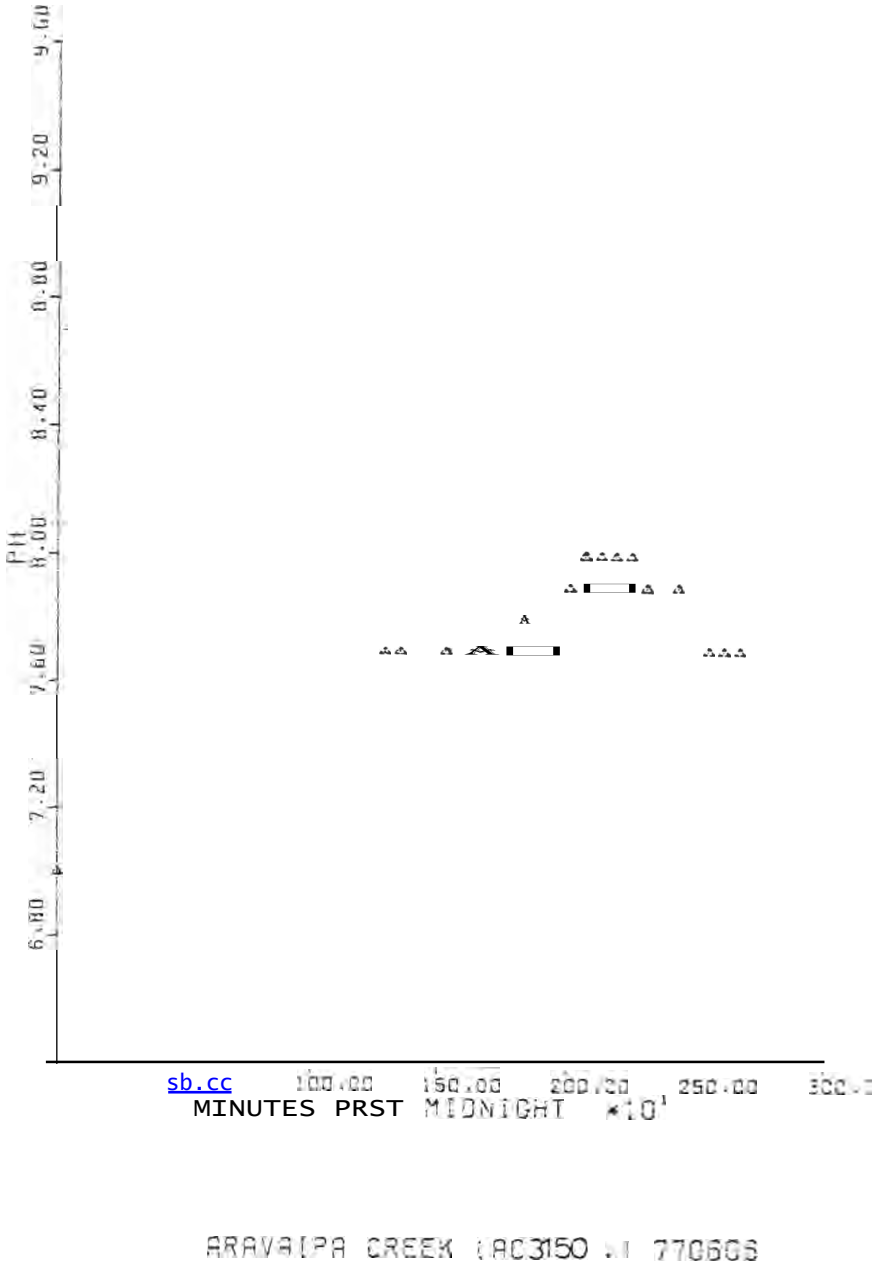
ARAVAIPA CREEK (AC3150) 770218



ARAVAIPA CREEK (AC3155) 770316

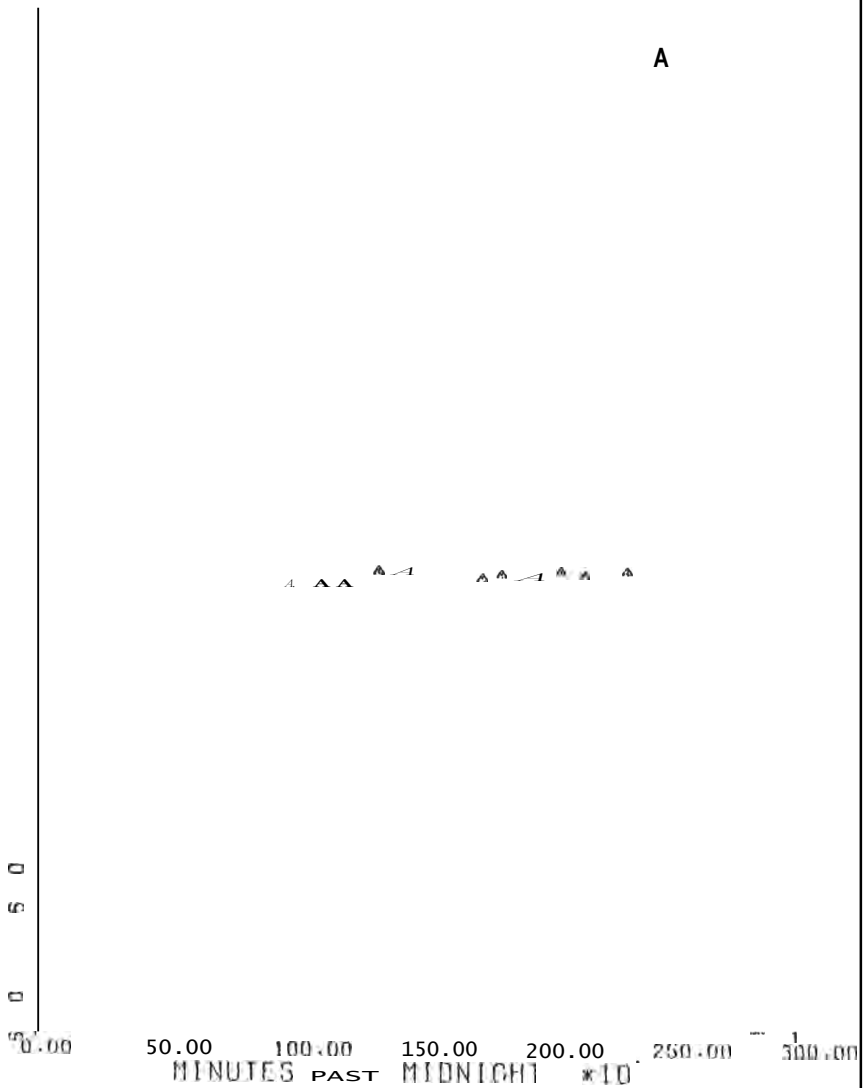


ARAVAIPA CREEK (AC3140) 770422

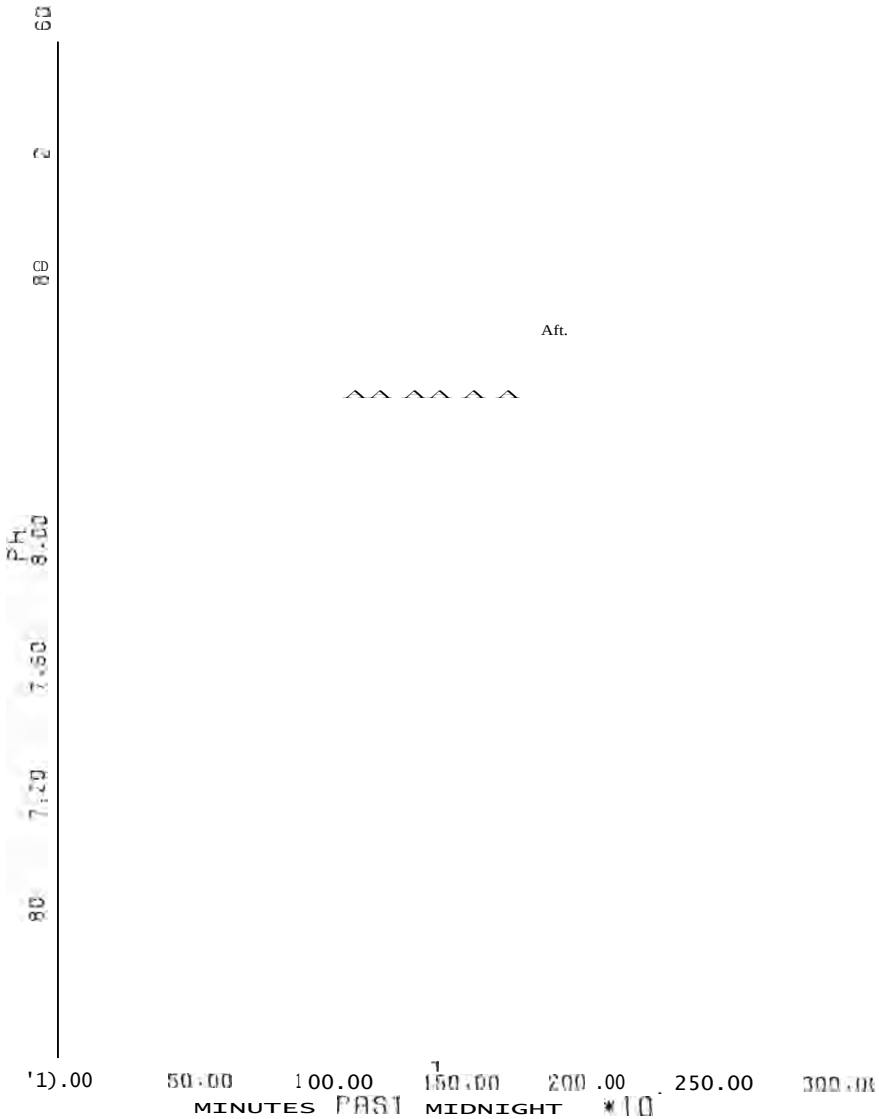

PH
6.80
7.20
7.60
8.00
8.40
8.80
9.20
9.60
100.00
150.00
200.00
250.00
MINUTES PRST MIDNIGHT *10'
ARAVAIPA CREEK (AC3150 .1 770606

sb.cc

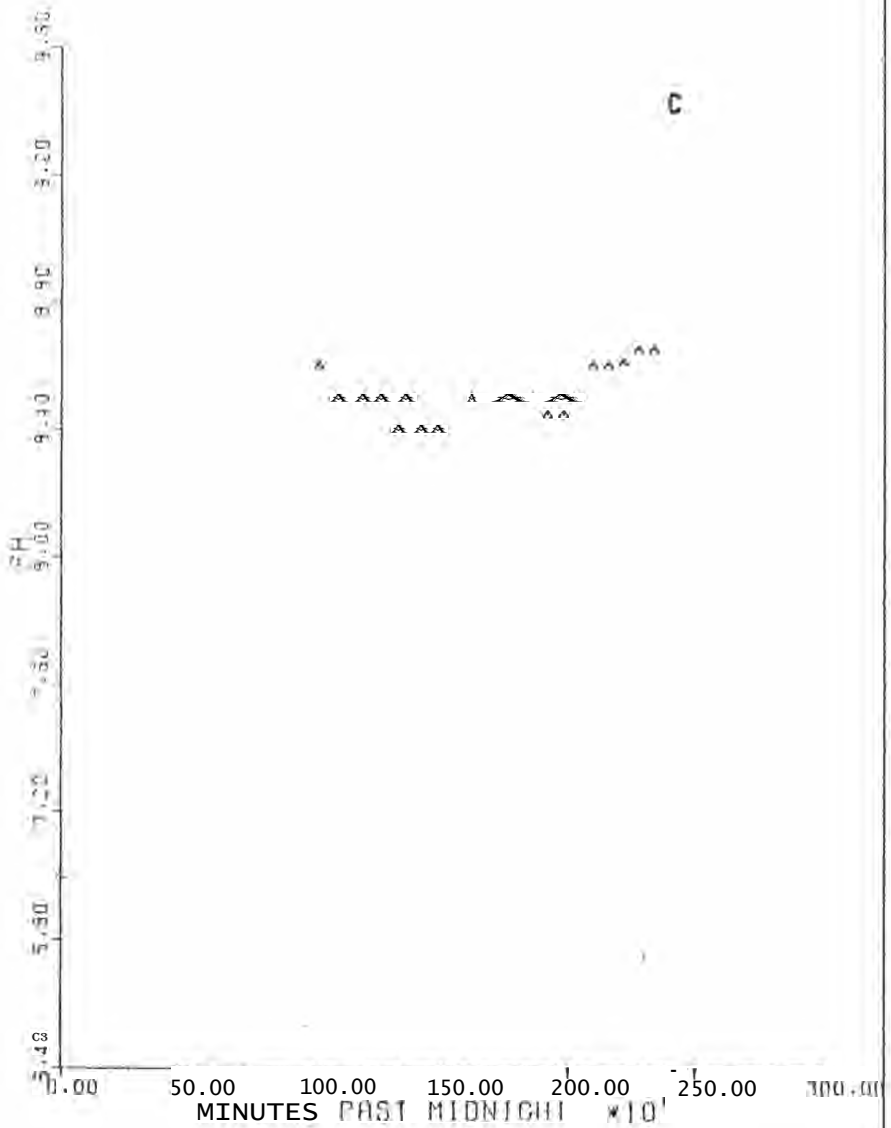
Figure 18. Long-term pH data for downstream stations on Aravaipa Creek, Graham and Pinal counties, Arizona (pages 52 through 55).



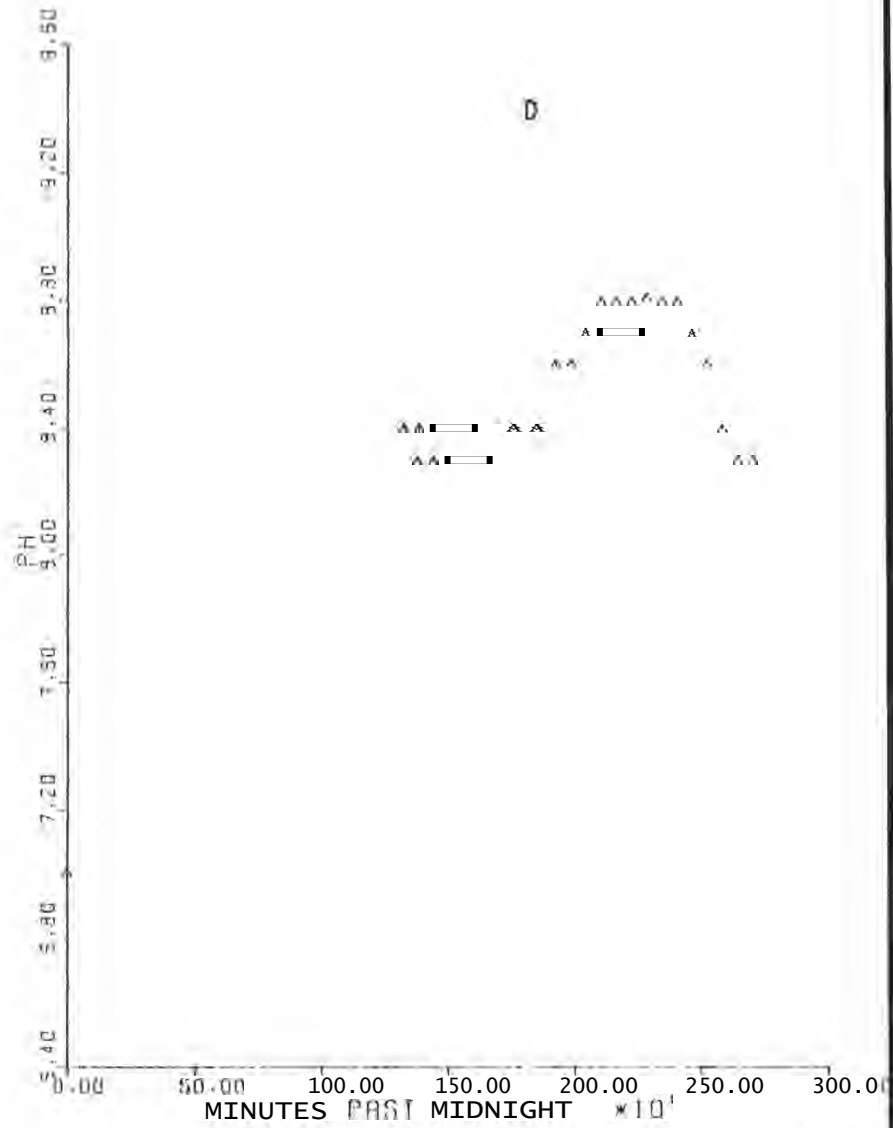
ARAVAIPA CREEK (AC2550.) 761023



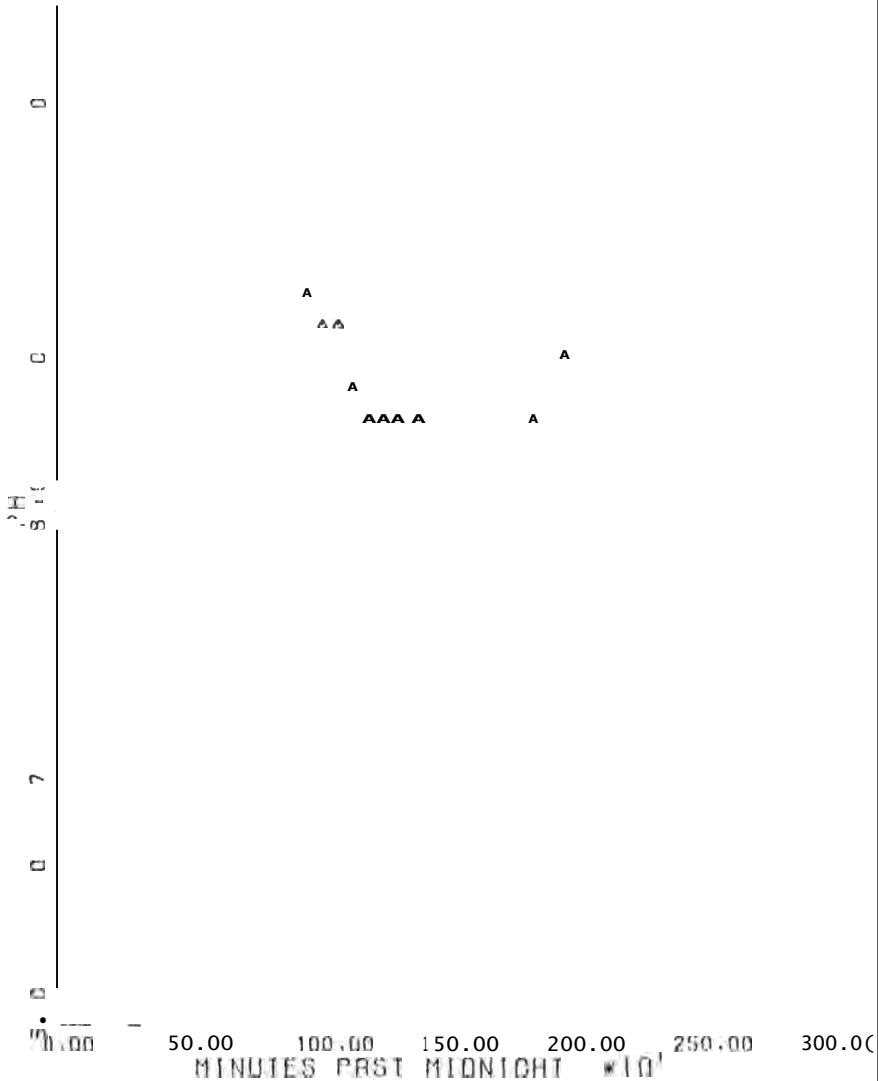
ARAVAIPA CREEK (AC2320.) 761120



ARAVAIPA CREEK (AC2550.) 770115

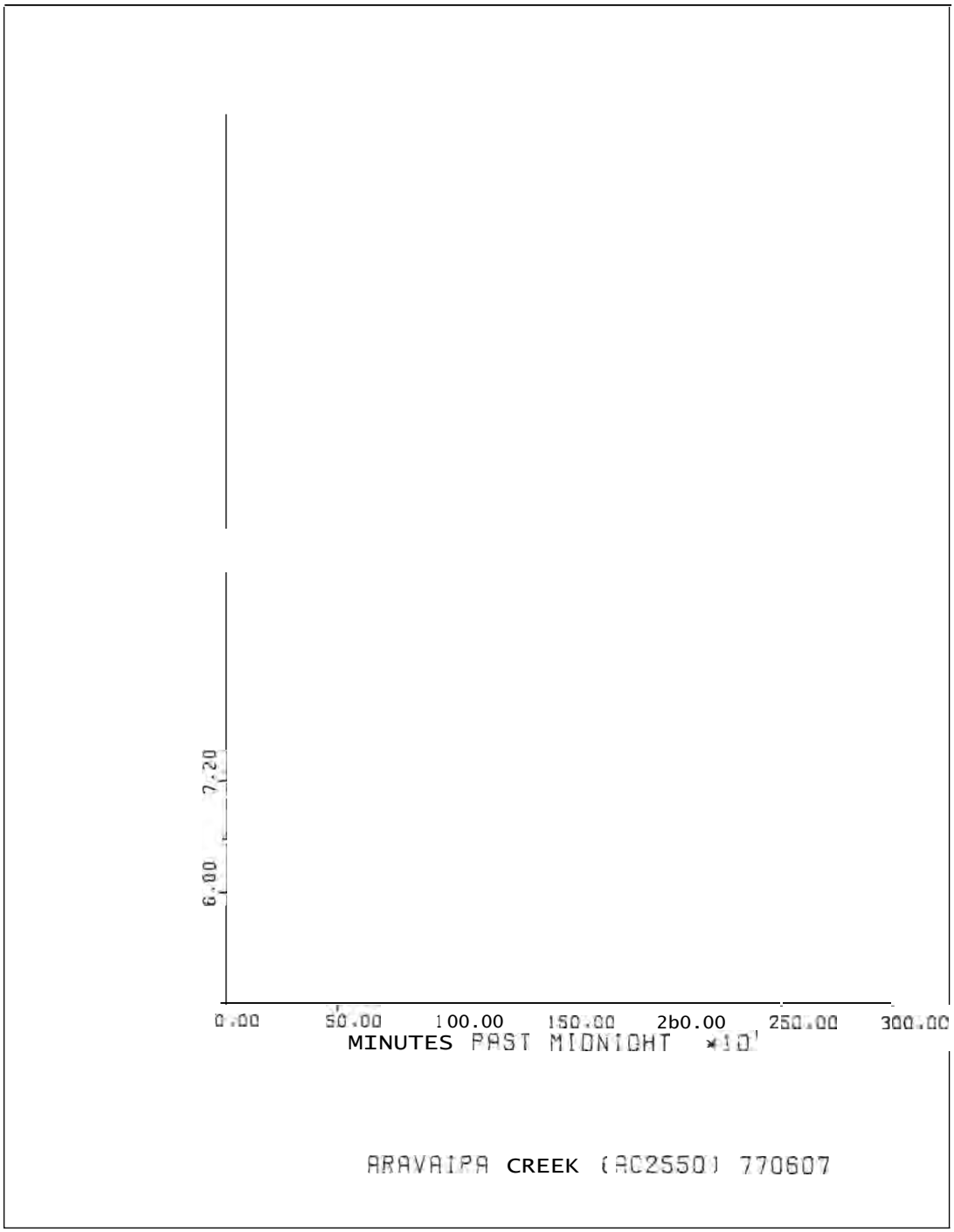


ARAVAIPA CREEK (AC2320.) 770119



ARAVAIPA CREEK (AC2600.) 770310

ARAVAIPA CREEK (AC2600.) 770423


7.20
6.00
0.00
50.00
100.00
150.00
200.00
250.00
300.00
MINUTES PAST MIDNIGHT
ARAVAIPA CREEK (AC2550) 770607

Dissolved Oxygen

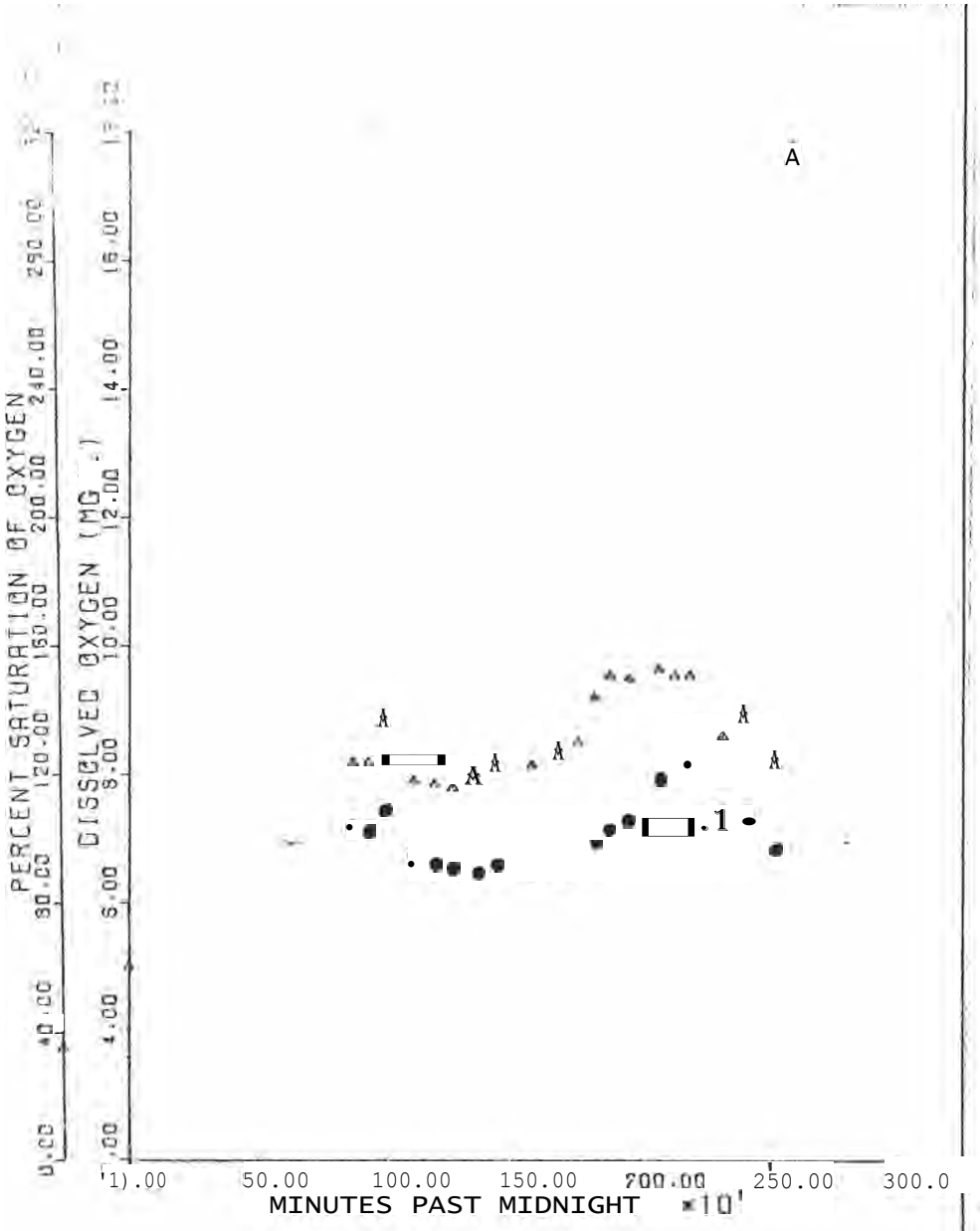
Physical features of dissolved oxygen concentrations in Aravaipa Creek are well illustrated by data for October (Fig.20A) at a downstream station and November (Fig.19B) upstream. On both those dates, oxygen concentration in mg/l varied inversely to light and positively with temperature. Percentage saturation for those data show little, if any diel variation, indicating essential balance of respiration with diffusion. Saturation in November was between 80 and 90%, which seems typical for Aravaipa Creek at most times of year. In October, however, saturation values were between 40 and 50%, unusually low and indicative of substantial respiratory loading of the system. Accumulation of fine debris, largely organic, after spates may explain the low values.

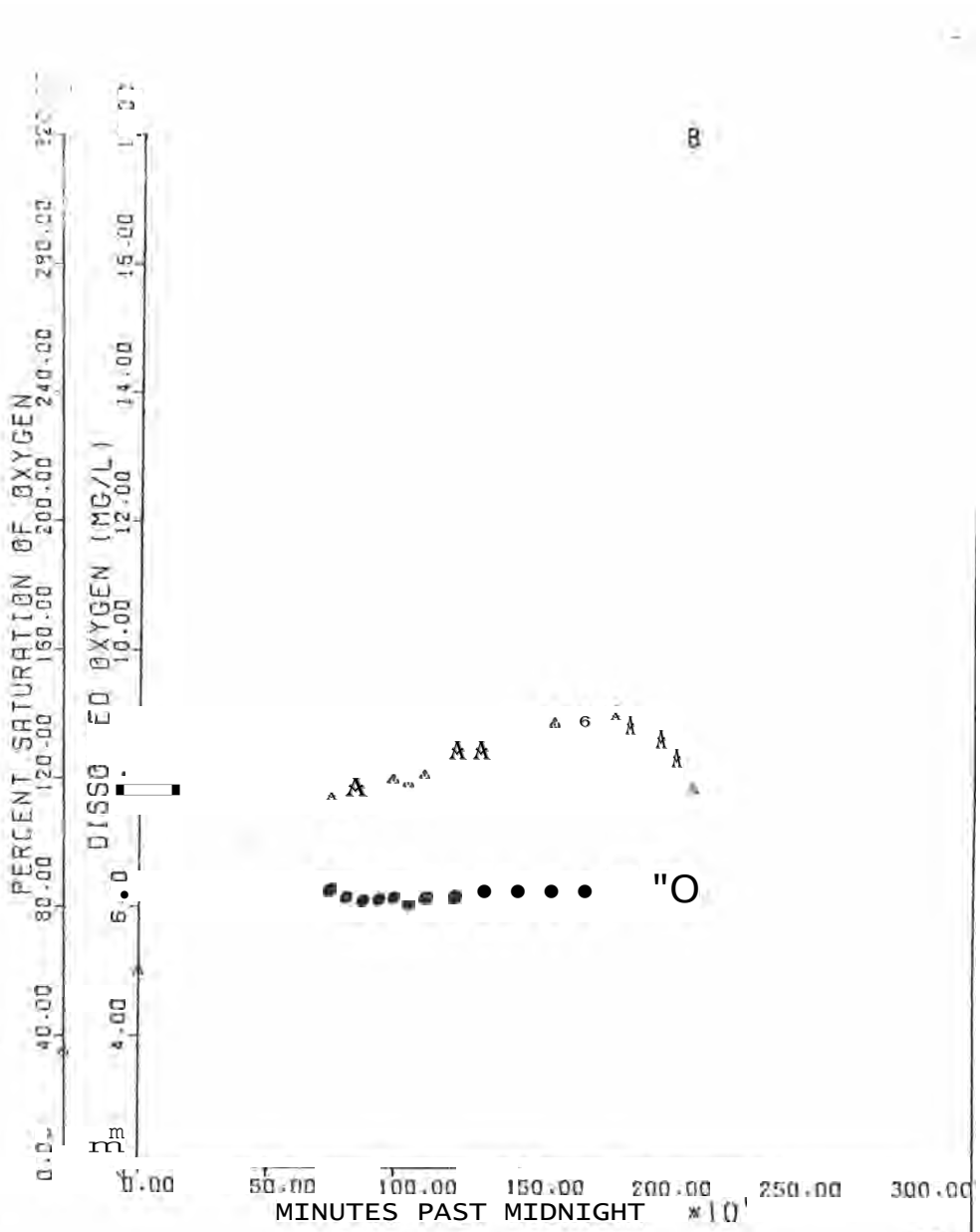
All other long-term data for dissolved oxygen indicate diurnal pulses attributable to production within the system. Even on days with total overcast (April; Figs.19F and20F), a small, but discernible, daytime pulse was in evidence.

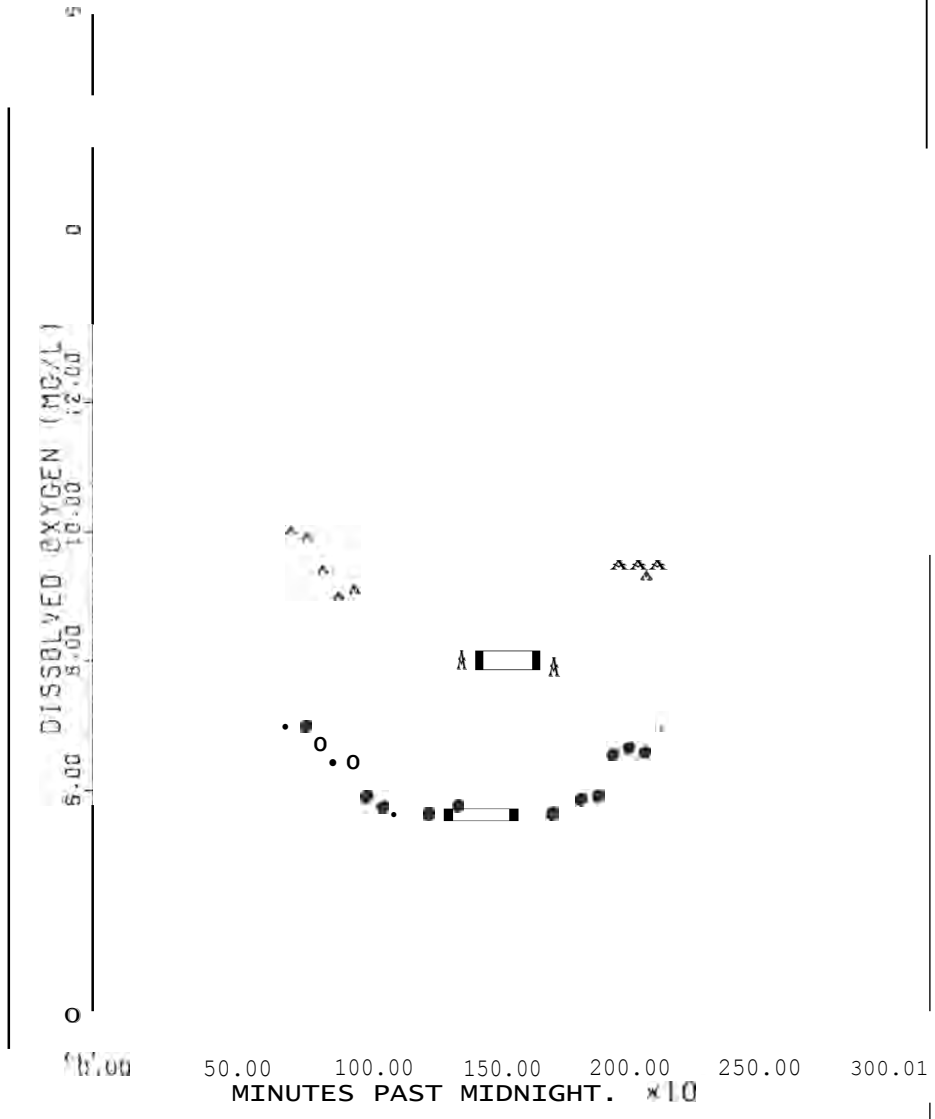
In those data demostrating more than 100% saturation of dissolved oxygen (e.a. Figs.19D-E and20B, D) , rates of change after dawn were comparable to those of temperature, with an immediate photosynthetic response to light impinging on the water surface.

The high indicated respiration in Aravaipa Creek must be attributed to organic loading of the sediments. There is no evidence for dissolved or particulate loading of the flowing water, other than accumulation of finely-divided organic detritus along the stream bed through much of the year, and accumulation of decomposing materials in beds of emergent aquatic plants. This is to be examined in the coming year.

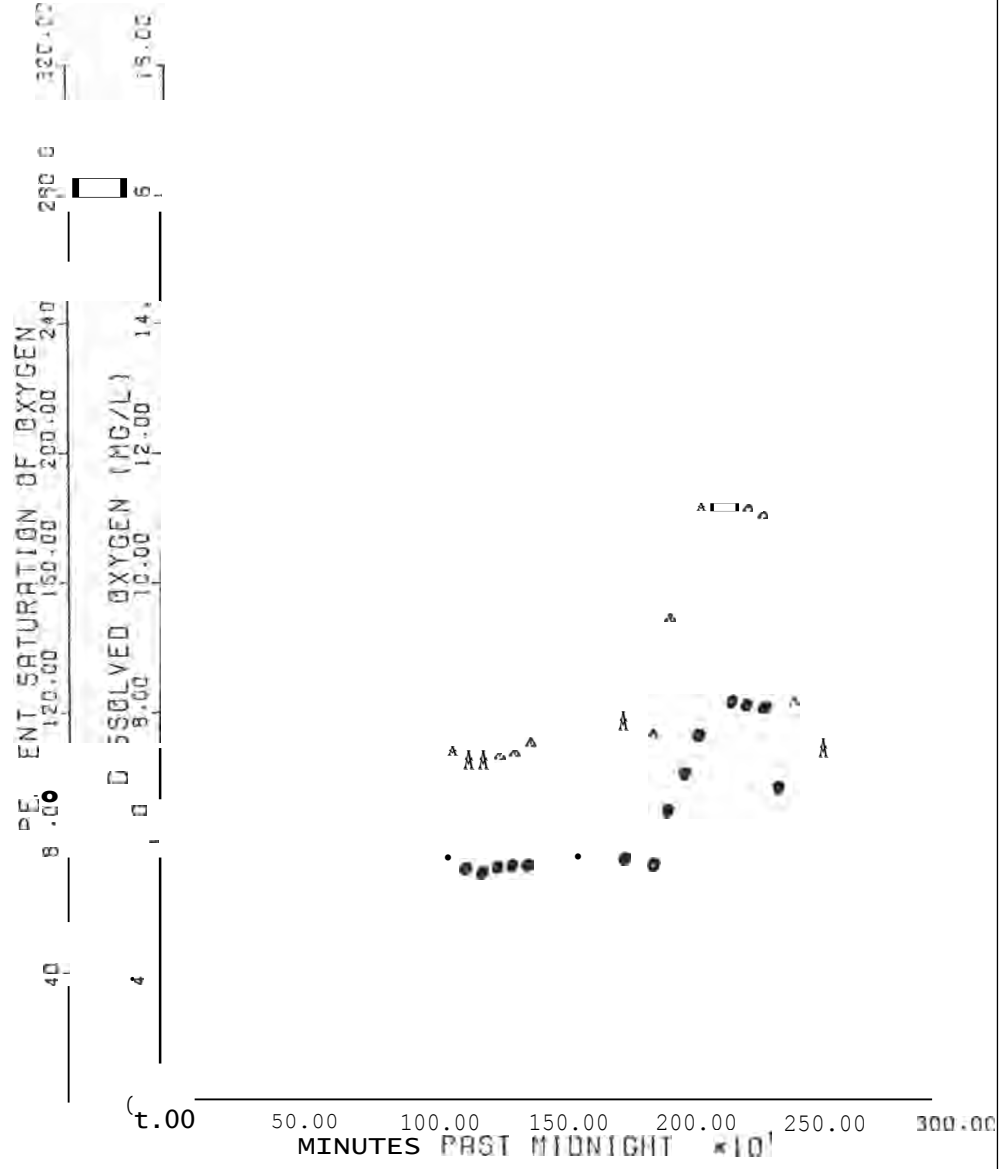
Figure 19. Concentrations of dissolved oxygen (A) in mg/I, and percentage saturation of dissolved oxygen (o) for upstream stations on Aravaipa Creek, Graham and Pinal counties, Arizona (pages 58 through 61).


A
PERCENT SATURATION OF OXYGEN
DISSOLVED OXYGEN (MG/L)
MINUTES PAST MIDNIGHT *10'
ARAVAIPA CREEK (AC3067.)760809

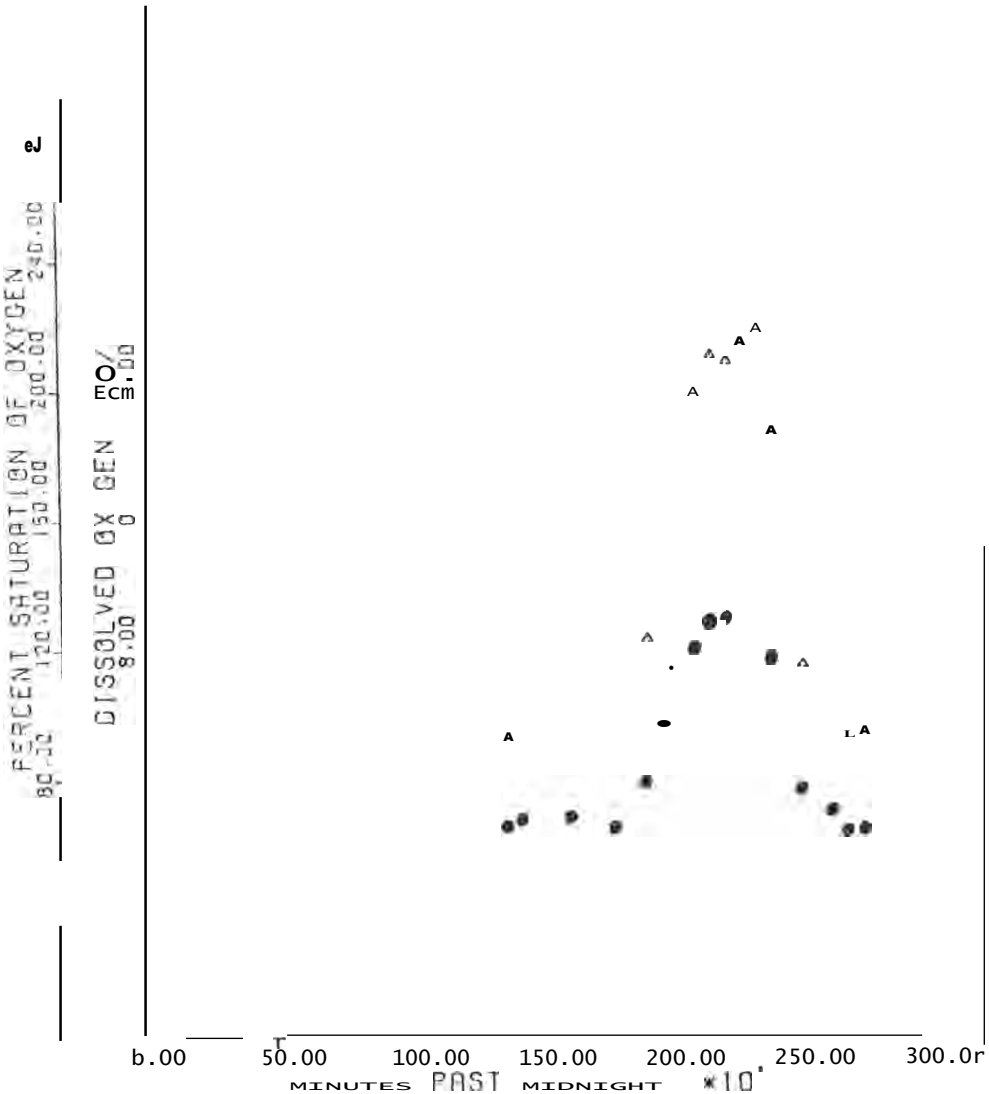

B
PERCENT SATURATION OF OXYGEN
DISSOLVED OXYGEN (MG/L)
MINUTES PAST MIDNIGHT *10'
ARAVAIPA CREEK (AC3150.)761119



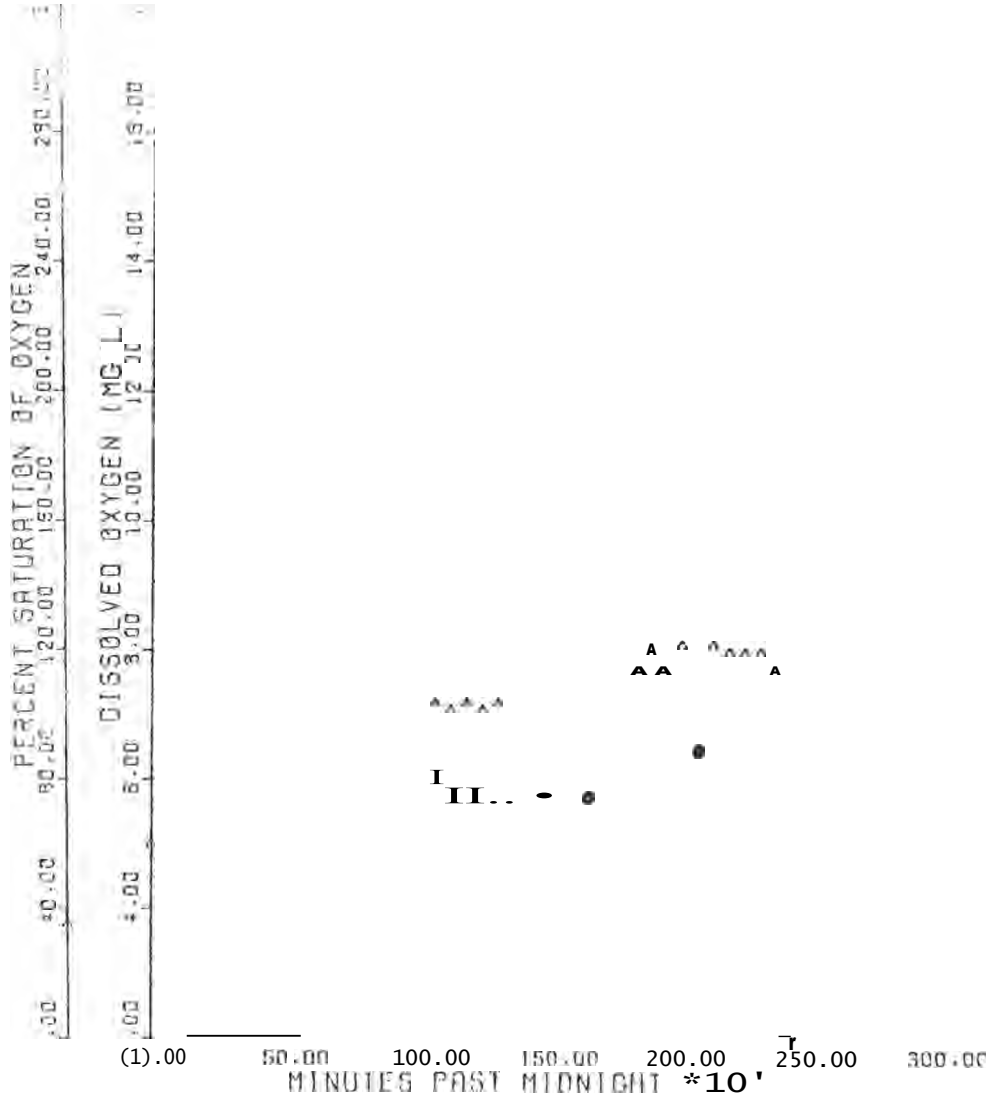
RRAVRIPR CREEK (C3150) 770111



ARAVAIPA CREEK (AC3150) 770218



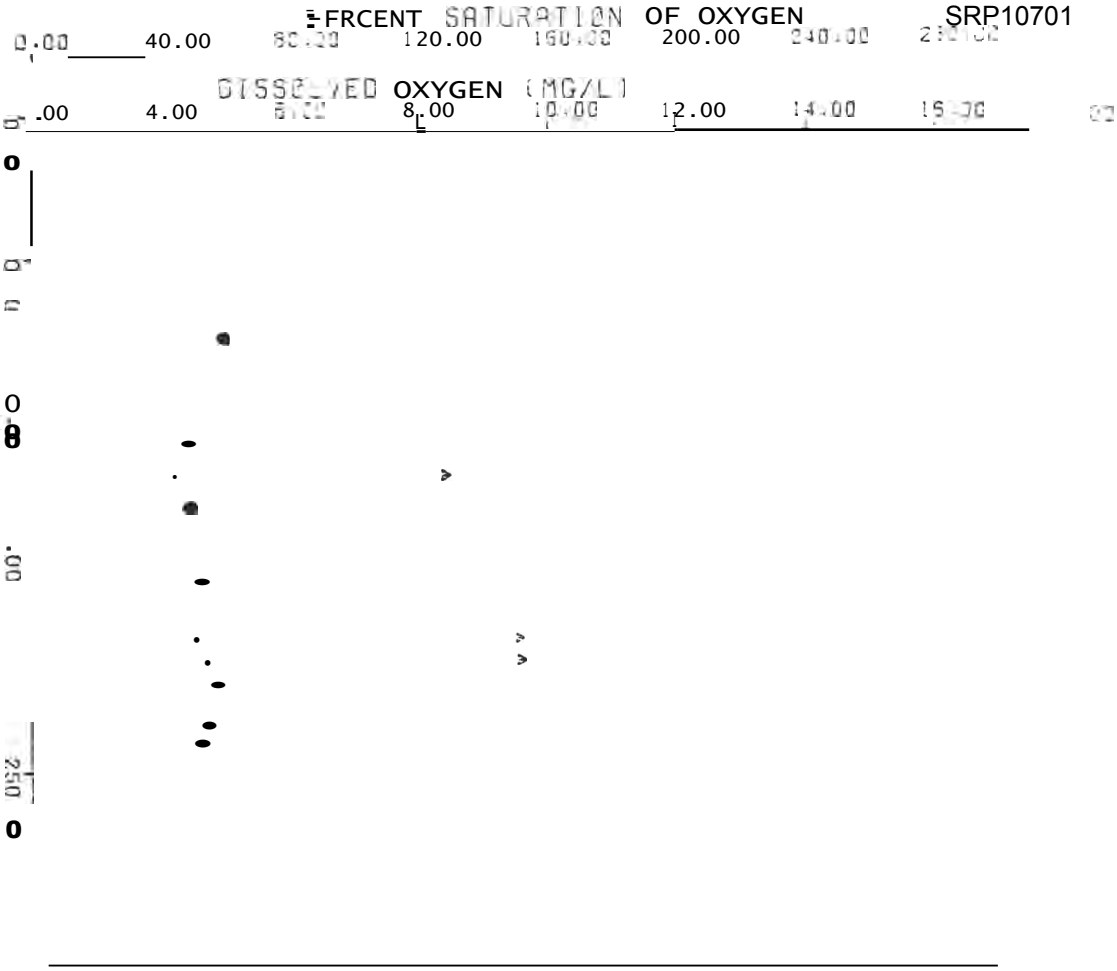
ARAVAIPA CREEK (AC3155) 770316

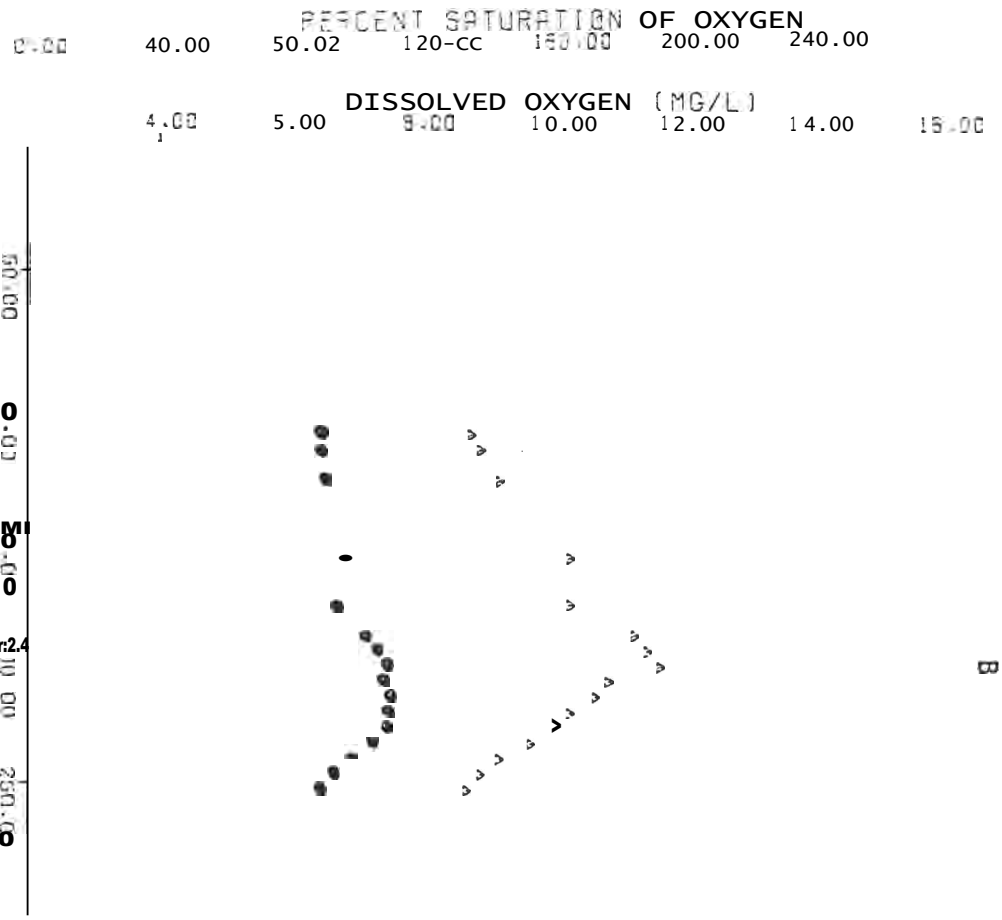


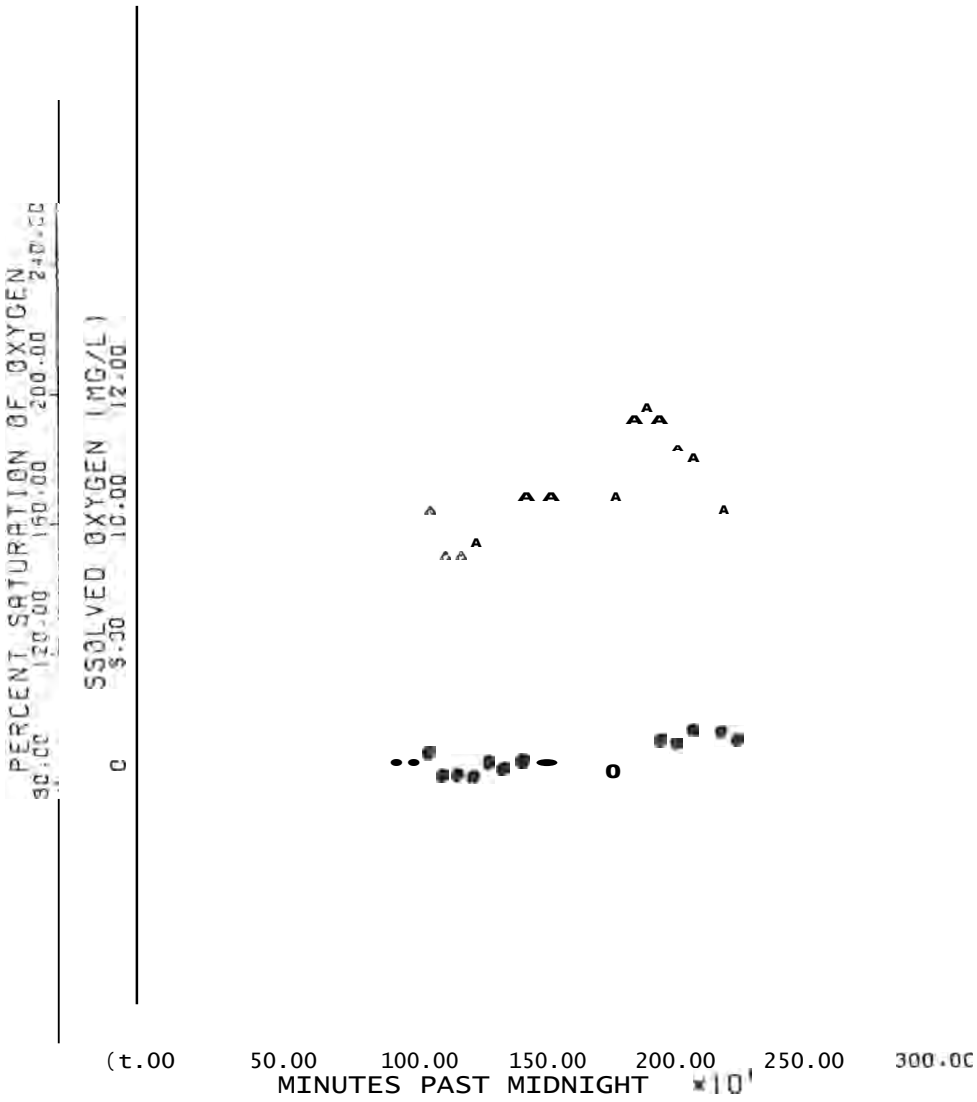
ARAVAIPA CREEK (AC3140) 770422

PERCENT SATURATION OF OXYGEN
3.00
40.00
80.00
120.00
160.00
200.00
240.00
280.00
320.00
DISSOLVED OXYGEN (MG/L)
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
18.00
ARAVAIPA
(AC3150.)
60

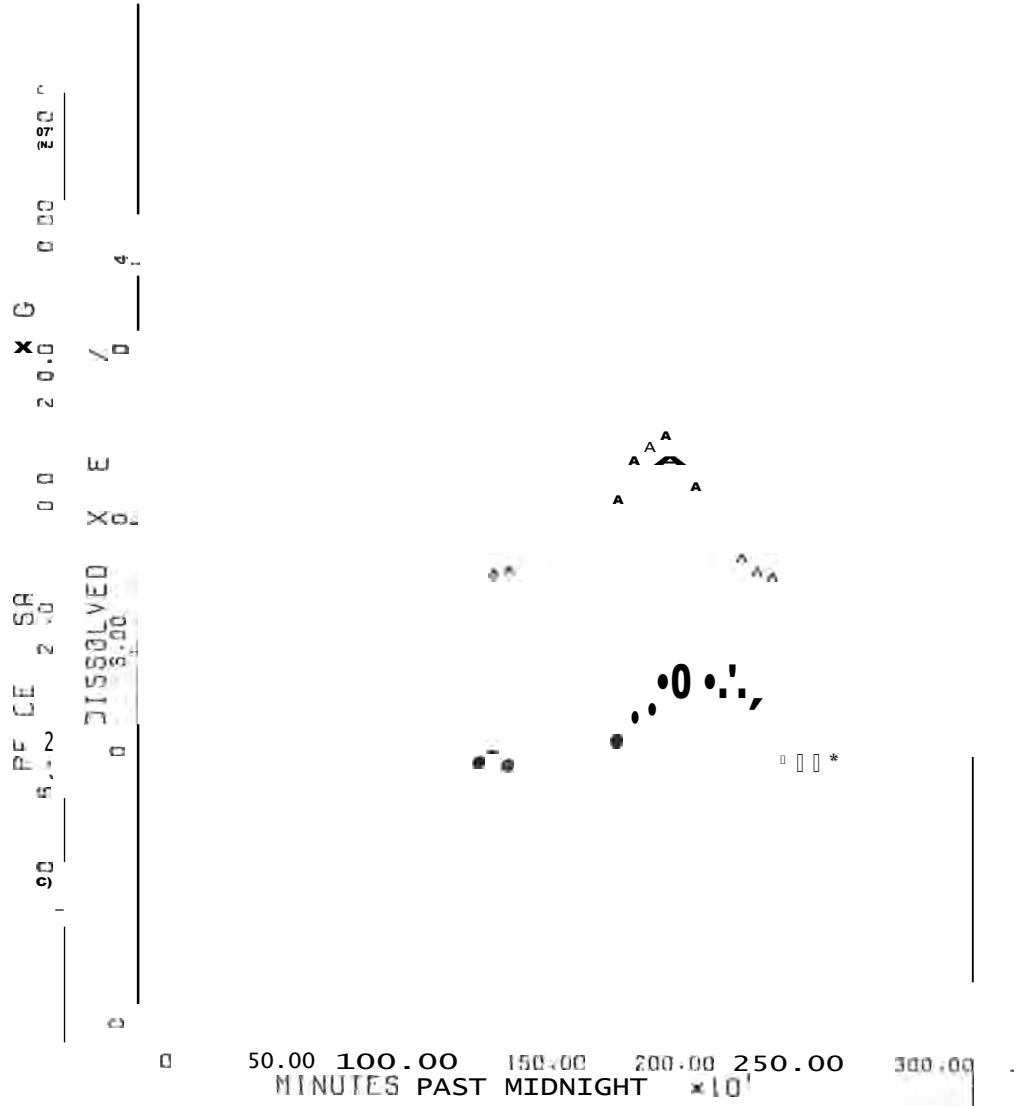
Figure 20. Concentrations of dissolved oxygen (A) in mg/l, and percentage saturation of dissolved oxygen (O) for downstream stations on Aravaipa Creek, Graham and Pinal counties, Arizona (pages 63 through 66).


PERCENT SATURATION OF OXYGEN
0.00
40.00
80.00
120.00
160.00
200.00
240.00
280.00
DISSOLVED OXYGEN (MG/L)
0.00
4.00
8.00
12.00
14.00
16.00
250.00
MONO
EAST
INTE

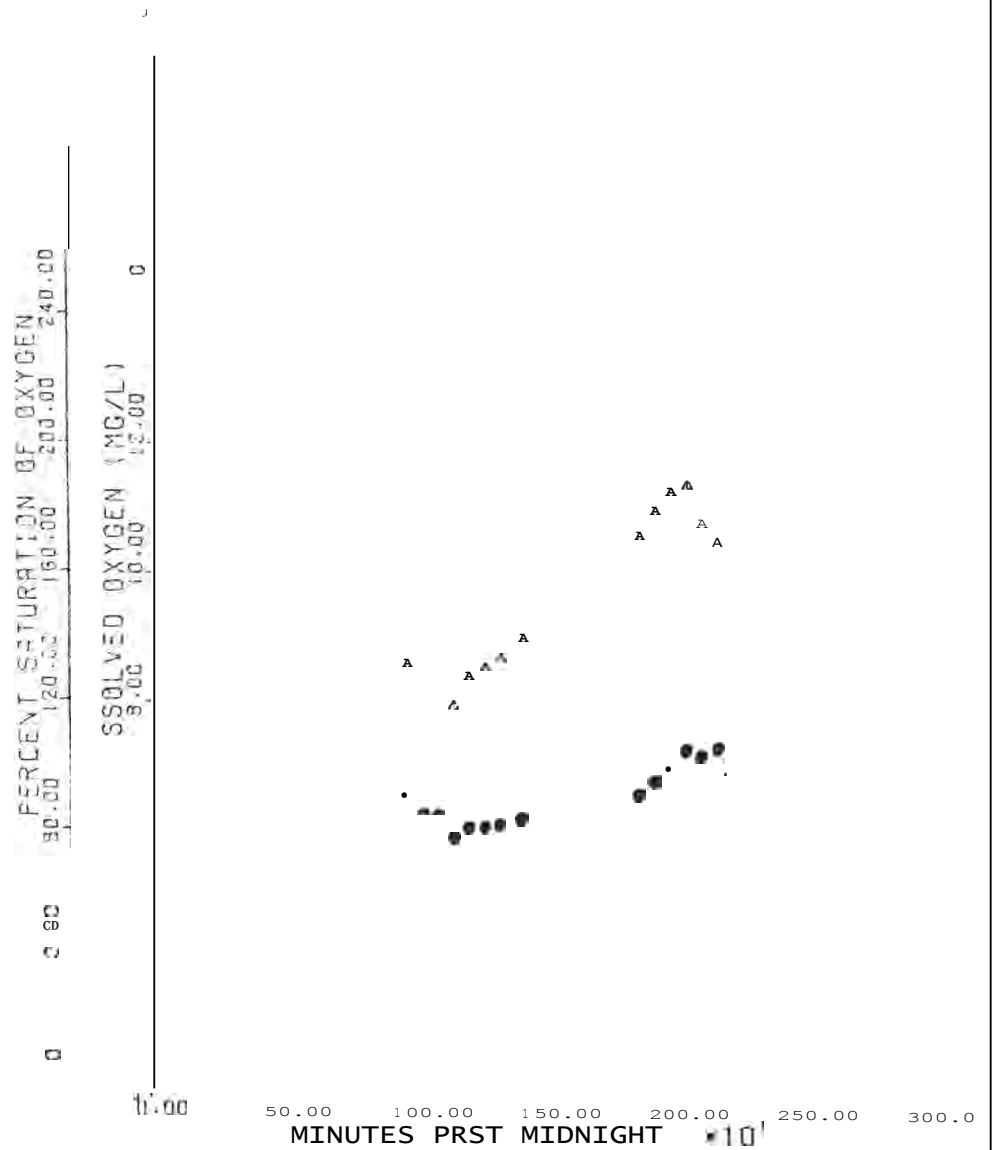

PERCENT SATURATION OF OXYGEN
40.00
50.02
120-CC
160.00
200.00
240.00
DISSOLVED OXYGEN (MG/L)
4.00
5.00
8.00
10.00
12.00
14.00
16.00
250.00
MONO
EAST
INTE



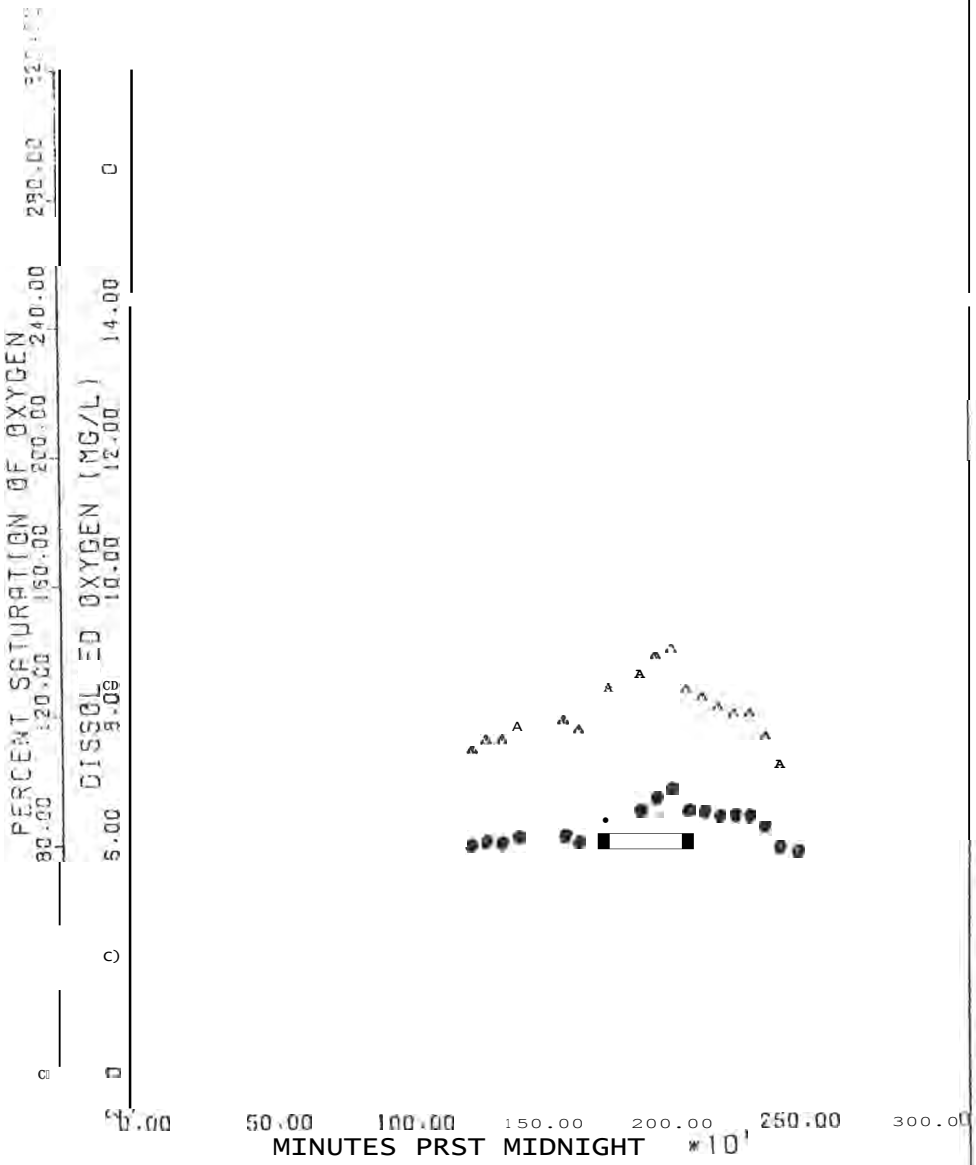
ARAVAIPA CREEK (AC2550.) 770115



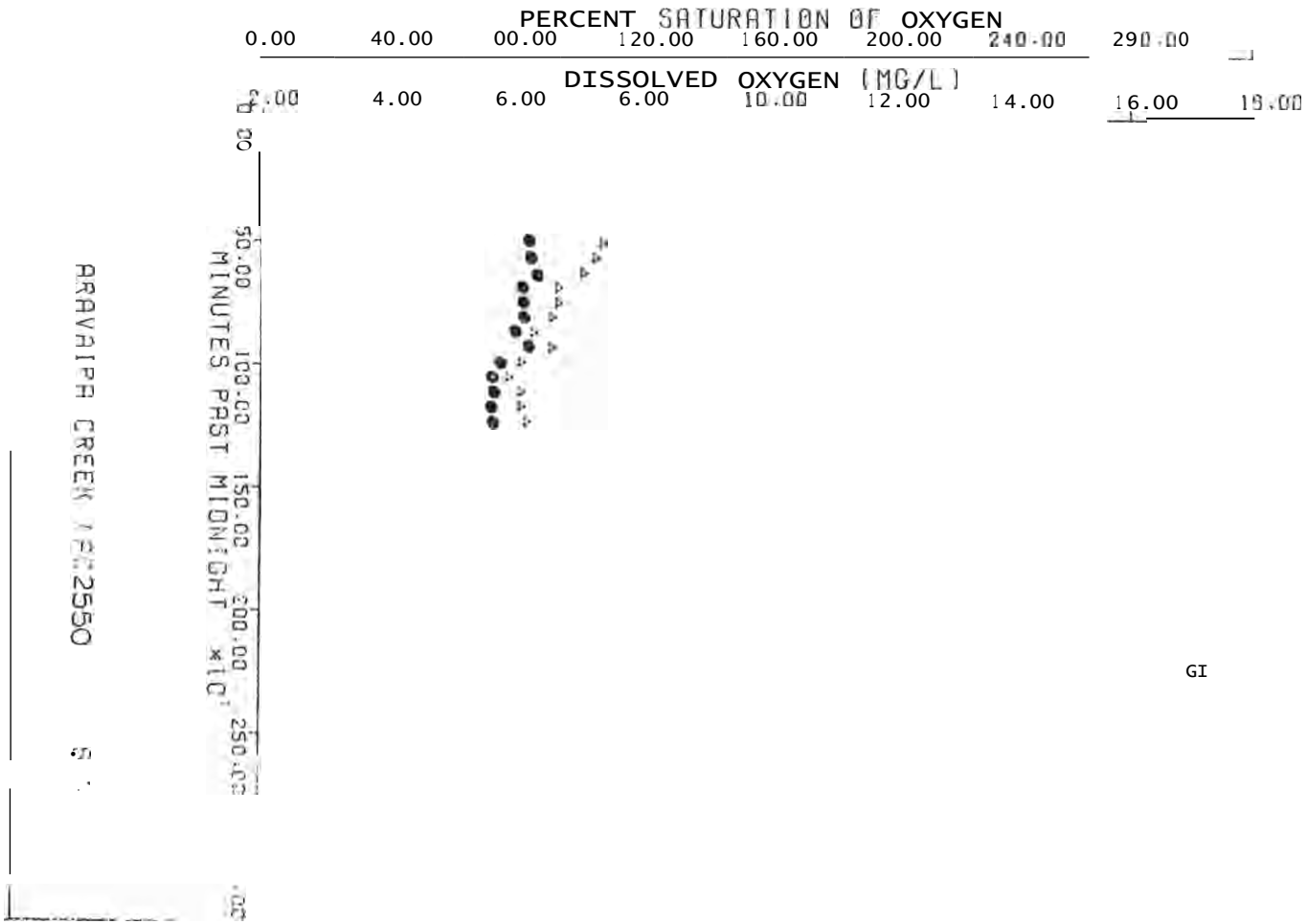
ARAVAIPA CREEK (AC2320.) 770119



ARAVAIPA CREEK (AC2600.) 770318



ARAVAIPA CREEK (AC2600.) 770423


PERCENT SATURATION OF OXYGEN
0.00
40.00
00.00
120.00
160.00
200.00
240.00
290.00
DISSOLVED OXYGEN (MG/L)
4.00
6.00
6.00
10.00
12.00
14.00
16.00
50.00
100.00
150.00
200.00
250.00
MINUTES PAST MIDNIGHT *10
ARAVAIPA CREEK AZ2550

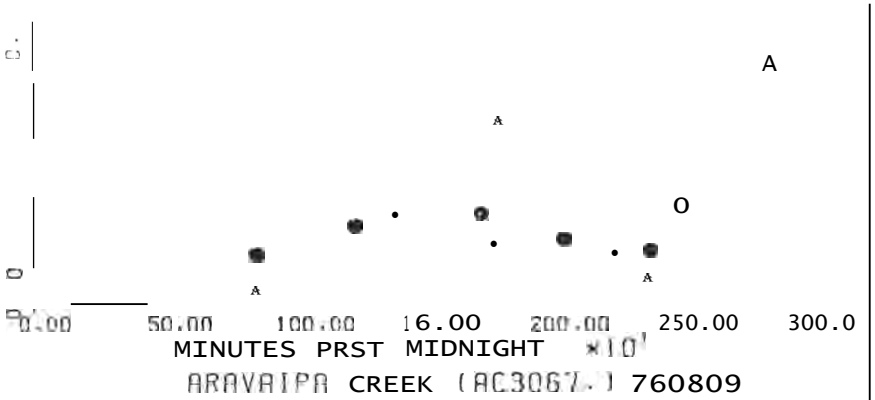
GI

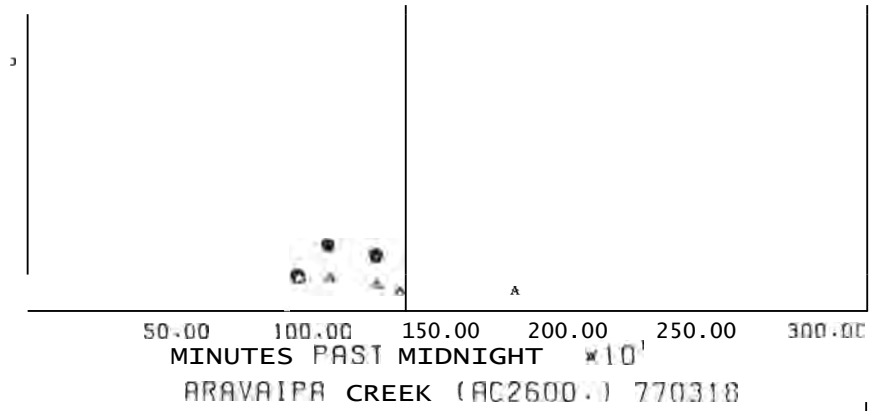
Macronutrients

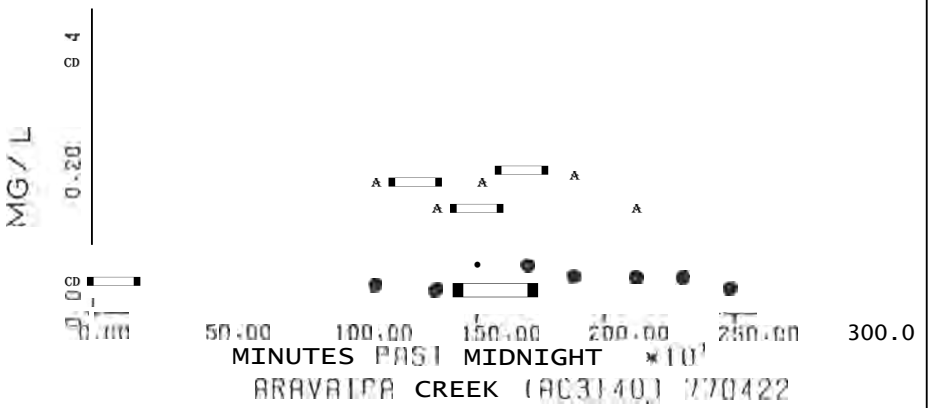
Phosphate-phosphorus (PO_4-P) and nitrate-nitrogen (NO_3-N) were analysed on each visit to Aravaipa Creek, and a consistent pattern of concentration is present. At upstream stations, NO_3-N consistently exceeds PO_4-P, while downstream, concentrations are reversed (Fig. 21). Only during a small spate (August; Fig.21A) did PO_4-P concentration exceed that of NO_3-N at an upstream station, and then only half the time. PO -P remains essentially the same throughout the stream within a given sampling period, indicating little utilization by plants or sporadic re-charge of the ion through inflow of springs or seeps. NO_3-N, on the other hand, is often reduced by an order of magnitude from up- to downstream (Fig. 21B, E and C, F), and could be deplited in a longer reach. It is tempting to speculate that riparian trees are utilizing the aquatic nutrients, but this has yet to be convincingly demonstrated. Such a land-water interaction, if occurring, would be somewhat unique to the riparian corridor concept of southwestern deserts, and should be thoroughly explored.

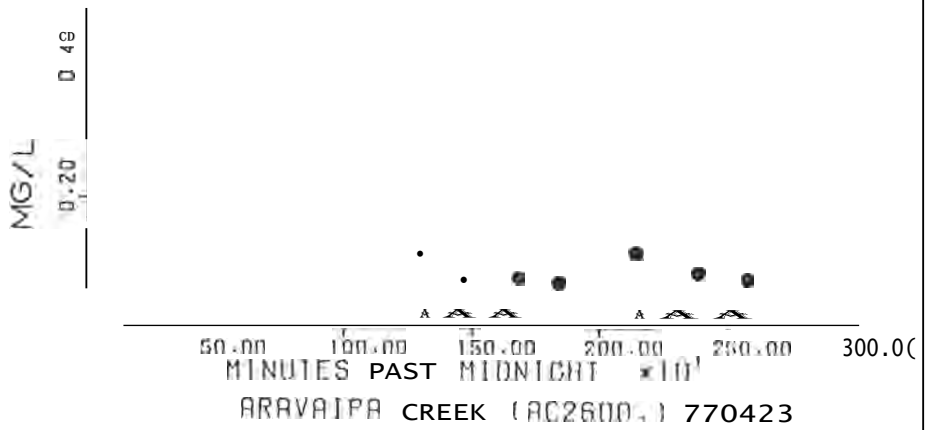
SRP10706

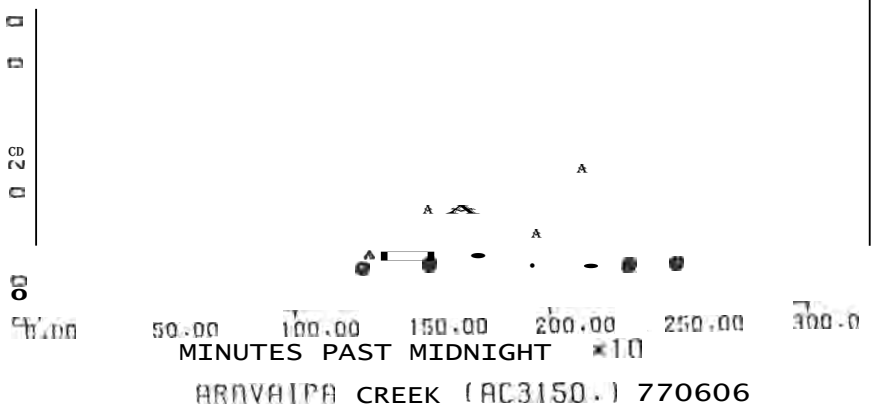
Figure 21. Concentrations of PO_4-P (●) and NO_3-N (A) in mg/l at selected stations on Aravaipa Creek, Graham and Pinal counties, Arizona.

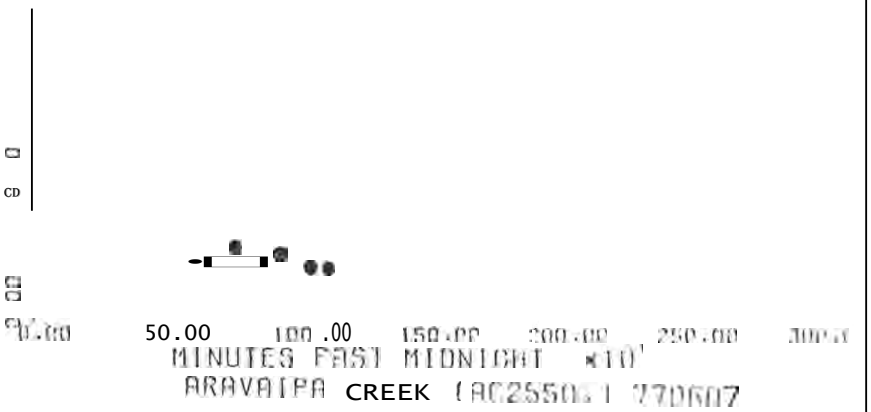

A
O
50.00
100.00
16.00
200.00
250.00
300.0
MINUTES PRST MIDNIGHT ×10'
ARAVAIPA CREEK (AC3067.) 760809


50.00
100.00
150.00
200.00
250.00
300.00
MINUTES PAST MIDNIGHT ×10'
ARAVAIPA CREEK (AC2600.) 770318


MG/L
0.20
50.00
100.00
150.00
200.00
250.00
300.0
MINUTES PAST MIDNIGHT ×10'
ARAVAIPA CREEK (AC3140.) 770422


MG/L
0.20
50.00
100.00
150.00
200.00
250.00
300.0(
MINUTES PAST MIDNIGHT ×10'
ARAVAIPA CREEK (AC2600.) 770423


50.00
100.00
150.00
200.00
250.00
300.0
MINUTES PAST MIDNIGHT ×10
ARAVAIPA CREEK (AC3150.) 770606


50.00
100.00
150.00
200.00
250.00
MINUTES PAST MIDNIGHT ×10'
ARAVAIPA CREEK (AC2550.) 770607

BIOLOGICAL STUDIES

Summary

Algal communities of Aravaipa Creek are dominated by diatoms and green algae (Bacillariophyceae and Chlorophycea4

Pigment concentrations in samples of epilithic algal conimunities range from not detectable to more than 100 mg/m^2 of substrate, with a distinct relationship to time after flooding, and a less obvious relation to time of year. Pigments accumulate rapidly after spates to a point where a preponderance of samples have more than 10 mg/m^2. In early summer, self-shading, and senescence, appear to reduce standing crops of pigments.

Eighty-three taxa of benthic invertebrates have been recorded from Aravaipa Creek, and numbers ofanimals range from 334 to 13,500/m^2; biomass estimates range from 1 to 13 gm/m^2. Data are not complete enough to discern patterns on an annual basis or relative to catostrophic events such as flooding. Diversity ranges from 6 to 20 taxa per sample, both in the mainstream and in tributaries, with the fauna of side-canyons resembling that of ponds far more than that of the channel of Aravaipa Creek.

Electrofishing has been found to catch 99% of total numbers and biomass from a measured segment of stream in three "passes", and has been selected as the principal fish sampling technique. Large fishes and those of mid-water habit are most readily obtained; bottom-dwelling, smallee fishes are difficult to sample.

Comparisons of data for comparable sampling areas in October and April indicate Agosia as most abundant and Gila as least abundant of

native fishes present. Ranking by numbers on both those dates were as follows: Agosia, Pantosteus, Rhinichthys, Catostomus, Meda, Tiaroga, and Gila. Green sunfish (Chaenobryttus cyanellus) were vary rare.

Estimates of numbers of fishes per hectare range from 11,000 to 15,000+, and biomass is near 105 kg/ha.

Gross numbers and biomasses of fishes per unit area were greatest upstream, lowest within and near the canyon, and intermediate downstream. Diversity, however, was least up- and downstream, and greatest in the heterogenous habitat of the canyon itself.

Algae and Algal Pigments

Algal communities of Aravaipa Creek appear dominated by diatoms (Bacillariophyceae) and green algae (Chlorophyceae), most of which are encrusting in growth form, and occur on relatively solid substrates in current. ChlorPhycean algae also are very common in the few quiet-water habitats and along the banks, and chrysophycean algae are locally abundant. Qualitative sampling of algae is an on-going part of the over-all study, and a listing of taxa will be provided later.

Sampling of algal pigments is being utilized to determine trends in standing crops. Three basic types of samples are taken. First, a suction device is used to obtain interstitial and fragmentary materials from a given area. Second, a scoop of substrate, approximately one cm deep, is taken and gently washed free of particles. And, third, a composite scoop of bottom material is taken. Extraction proceedures involve use of 95% acetone, in darkness and in cool surroundings, for 20 hours, and concentrations are read by spectrophotometric techniques (see earlier reports). Samples are taken at various places across the stream, in current, and at various stations on a given sampling date.

For purposes of presentation, pigment concentrations have been ranked in orders of magnitude as follows: I, no detectable pigments; II, detectable to 0.09 mg/m^2; III, 0.1 to 0.99; IV, 1.0 to 99.9 mg/m^2; and V, >100.0 mg/m^2 (Fig. 22).

Chlorophyll A is of universal occurrence in benthic microflora, and will be discussed at present. At the inception of sampling, in mid-September, more than half the samples taken contained less than order-of-magnitude III, reflecting a patchy and sparse algal flora

as a result of scouring by floods in August and early September. By mid-October, however, a preponderance of samples were order-of-magnitude IV or V, and a rich and abundant benthic algal community had developed. This persisted through November (Fig. 22). Samples from early January from the upper part of the stream still demonstrated an abundance of chlorophyll A, but those from the lower portion in late January were lower, resulting from a small spate that occurred in the intervening period. In February, a bi-modal distribution of orders of magnitude was in evidence, and this persisted through late April. Decline in the maximum amounts of chlorophyll A present appeared related to changes in the algal community. Many films of encrusting algae appeared to be senescent, and deterioration of mats was obvious in many places (especially of the larger, filamentous forms). Samples with no detectable pigments generally were those taken from interstitial habitats. The stream bed had become armored with pebbles through continuous movement and re-sorting processes, and interstitial habitats were filled and compacted with organic material and fineinorganic debris. In May, a small increase in discharge occurred, and some sediment movement was noted. By June, algal communities were quite as abundant, as indicated by pigment concentrations, as they had been in the preceding October (Fig. 22).

Chlorophylls B and C, and the composite "diatoms"* followed trends similar to those for chlorophyll A, and provide a check on the system. Similarities among the various pigments may indicate relatively great homogeneity of the community, but this is yet to be examined in detail.

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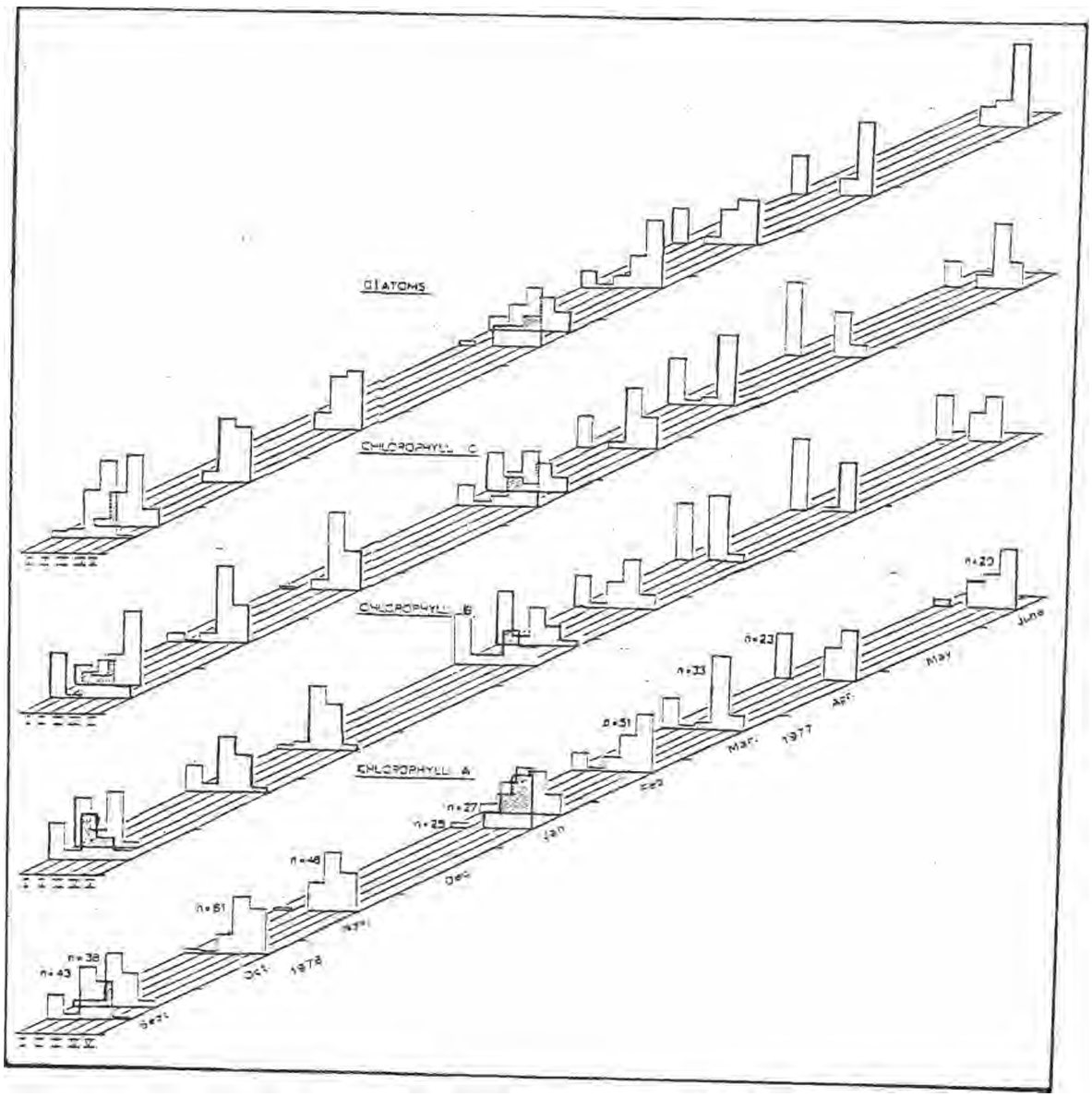
*Computed from ratios of the various chlorophylls, plus carotenoids, a technique to be detailed in Methods and Materials of the final report.

Figure 22. Percentages of total number of samples with algal pigments falling within five orders of magnitude of concentration per square meter (see text for units of concentration), all stations combined, Aravaipa Creek, Graham and Pinal counties, Arizona, 1976-77.


DIATOMS
CHLOROPHYLL C
CHLOROPHYLL B
CHLOROPHYLL A
n=43
n=38
n=61
n=48
n=27
n=25
n=51
n=33
n=23
n=20
Oct. 1978
Jan
Mar. 1977
Apr.
May
June

Benthic Invertebrates

Eighty-three taxa of benthic invertebrates have been recorded from Aravaipa Creek (Table 3). No patterns of numbers of biomass per unit area are yet in evidence (Fig. 23), since sampling has not yet been over a full year's cycle, or long enough term to assess catostrophic events such as flooding within the system.

Total numbers of animals range from about 334 to 13,500 individuals/m^2, and biomass ranges from 1.0 to 13.0 gm/m^2 (Table 4). These data are comparable to those reported by Dale Bruns, based upon a 13-month study of benthos in Aravaipa Creek, and appended as a portion of this document.

Diversity of the fauna is relatively high, ranging from 6 to 20 taxa per sample, and is similar in the mainstream and in Turkey Creek (the only side-canyon habitat from which samples have been thoroughly analysed). The fauna in side canyons, on a qualitative basis, is far more similar to that of temporary ponds than to that of the mainstream. Pool-loving insects such as corixid and notonectid hemipterans, hydrophilid and dytiscid coleopterans, and certain ephemeropterans (notably burrowing kinds) are common. Conspicuous in their absence from the side-canyon habitats are current-loving species such as simuliid dipterans, hydropsychid and helicopsychid trichopterans, and swift-water ephemeropterans such as Baetis and Choroterpes. The last groups dominate the mainstream of Aravaipa Creek.

Table 3. Taxa and codes for taxa of benthic invertebrates identified from Aravaipa Creek, Graham and Pinal counties, Arizona

CODE	TAXON
550ARTHROP00	Arthropoda
450INSECT00	Insecta
350COLEOP00	Coleoptera
250HYDROP00	Hydrophilidae
250DYTISC00	Dytiscidae
250DRYOPI00	Dryopidae
250CURCUL00	Curculionidae
250ELMIDA00	Elmidae
250HALIPI00	Halipidae
250HELODI00	Helodidae
350DIPTER00	Diptera
250CHIRON00	Chironomidae
250CULICI00	Culicidae
250SIMULI00	Simuliidae
250CERATO00	Ceratopogonidae
250PELOPI00	Pelopidae
250TABANI00	Tabanidae
250STRATI00	Stratiomyidae
250MUSCID00	Muscidae
250DIXIDA00	Dixidae
250EPHYDR00	Ephydridae
250EMPIDI00	Empididae
250DOLICH00	Dolichopidae

Table 3. Continued

350DIPTERA00 (Cont'ed)	Diptera (Cont'ed)
250PSYCH000	Psychodidae
250BLEPHA00	Blephariceridae
350LEPID000	Lepidoptera
250PYRAUL00	Pyralidae
3500DONAT00	Odonata
250GOMPHI00	Gomphidae
250LIBELL00	Libellulidae
250COENGR00	Coengrionidae
350HEMIPT00	Hemiptera
250GELAST00	Gelastocoridae
250CORIXI00	Corixidae
250NAUCOR00	Naucoridae
250BELOST00	Belostomatidae
150ABEDUS00	Abedus
250VELIID	Veliidae
250GERRID00	Gerridae
350PLECOP00	Plecoptera
250CAPNII00	Capniidae
150CAPNIA00	Capnia
350MEGAL000	Megaloptera
250CORYDA00	Corydalidae
150CORYDA00	Corydalis
350TRICH000	Trichoptera
250HYDROP01	Hydropsychidae
250HYDROP02	Hydroptilidae

Table 3 . Continued

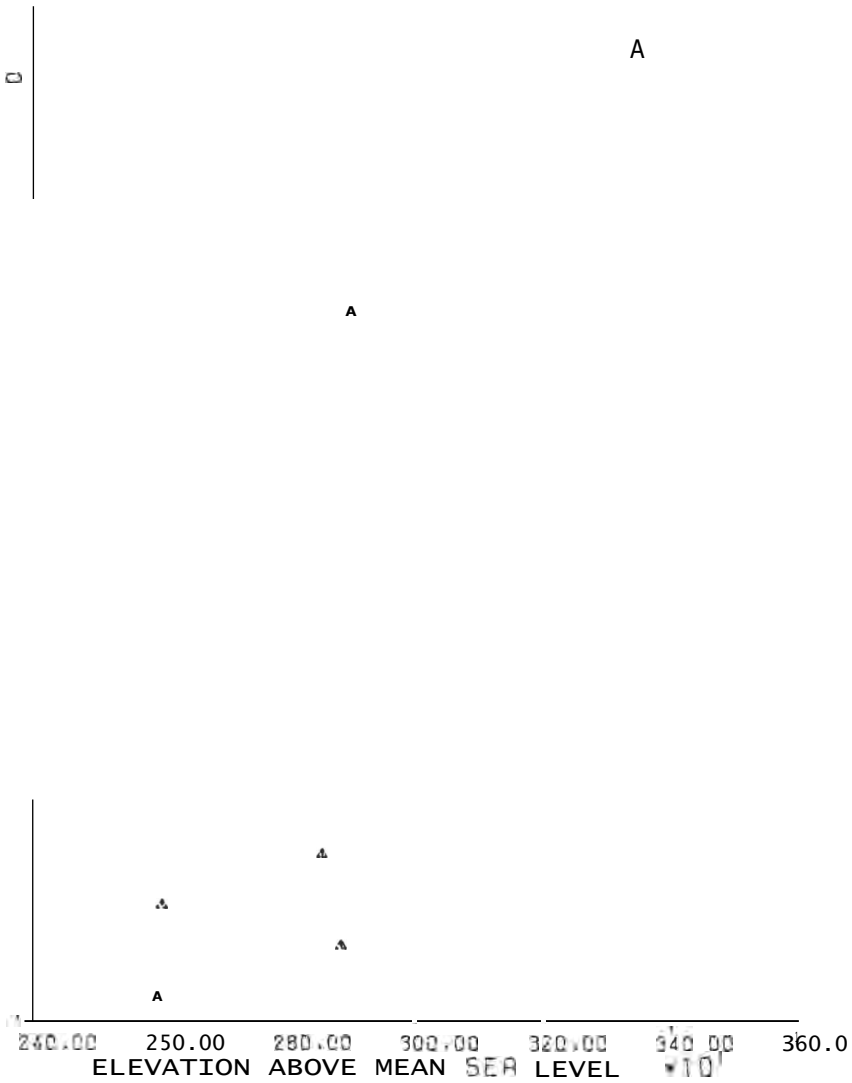
350TRICH000 (Cont'ed)	Trichoptera (Cont'ed)
250HYDROP02 (Cont'ed)	Hydroptilidae (Cont'ed)
150LEUCOT00	Leucotrichia
250HELIC000	Helicopsychidae
250LIMNEP00	Limnephilidae
250PSYCH001	Psychomyidae
250RHYACH00	Rhyachophilidae
350EPHEME00	Ephemeroptera
250EPHEME00	Ephemeridae
250HEPTAG00	Heptageniidae
150RHITHR00	Rhithrogena
250BAETID00	Baetidae[1/]
150BAETIS00	Baetis
150BAETIS01	Baetis sp. "1"
150BAETIS02	Baetis sp. "2"
150CHOROT00	Choroterpes
150TRICOR00	Tricorythodes
450ARACHN00	Arachnida
350ACARIN00	Acarina
450CRUSTA00	Crustacea
3500STRACOO	Ostracoda
350COPEP000	Copepoda
250DAPHNI00	Daphniidae
560MOLLUS00	Mollusca
460GASTR000	Gastropoda

Table 3. Concluded

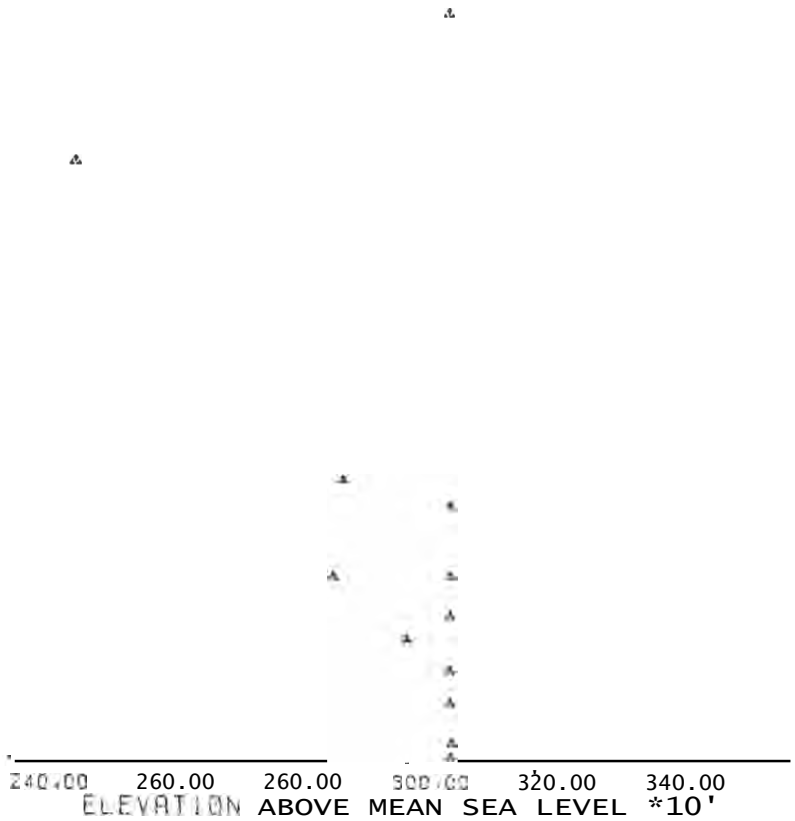
460GASTR000 (Cont'ed)	Gastropoda (Cont'ed)
360PROSOB00	Prosobrancha
260PHYSID00	Physidae
160PHYSA000	Physa
570WORMS000	"Worms"
470GORDIE00	Gordieoidea
470PLATYH00	Platyhelminthes
370TURBEL00	Turbellaria
270PLANAE00	Planariidae
470ANNELI00	Annelida
3700LIGOC00	Oligochaeta
270TUBIFI00	Tubificidae
270LUMBRI00	Lumbridulidae
370HIRUDI00	Hirudinea

1/ Includes Baetinae, Tricorythodinae, and Leptophlebinae

Figure 23. Numbers (A) and weights (B, in gm) of benthic invertebrates per meter^2 from all samples on Aravaipa Creek, Graham and Pinal counties, Arizona, 1976 -77, arranged by elevation of capture.



ARAVAIPA CREEK, ARIZONA



ARAVAIPA CREEK ARIZONA

Table 4. Data for selected samples of benthic invertebrates (Surber Sampler) from Aravaipa Creek, Graham and Pinal counties, Arizona, and Turkey Creek, Graham County, Arizona.

Period	No. Samples	No. Taxa	Gm/m^2	No./m^2
August 1976 (AC)	3	23 (12 - 16)[2/]	2.1[1/] (0.9 - 4.0)	3,006 (2,206 - 3,907)
September 1976 (AC)	3	20 (6 - 11)	4.1 (1.1 -11,8)	445 (333 - 1,527)
October 1976[3/] (AC)	5	24 (9 - 13)	3.5 (1.0 - 7.8)	2,540 (1,111 - 9,344)
October 1976[4/] (AC)	4	26 (9 - 16)	2.9 (1.9 - 4.4)	5,513 (1,194 -11,194)
January 1977 (AC)	2	26 (11 - 20)	11.0 (9.5 -12.5)	10,183 (6,846 -13,520
Septpmber 1976 (IC)	3	23 (11 - 13)	12.4 (11.9 -23.5)	1,280 (344 - 1,280)
January 1976 (TC)	1	14	14.7	2,325

i/All benthos weights are "wet weight", blotted dry on tissue.

2/Rangos for all data are In parentheses

3/Includes some samples taken after a slight rise in one segment of the creek, hence the low values given in ranges and a somewhat suppressed mean for weights and numbers.

4/Includes samples taken before the small spate mentioned in footnote #3.

Fishes

Quantitative sampling of fishes in Aravaipa Creek was attempted by seining and by electrofishing. Seines followed by electrofishing indicated an error as high as 20% in estimates of number, and far more than that in estimation of biomass, especially when seining was done in areas of heterogenous bottoms and variable depths. That technique was therefore discontinued except for qualitative purposes.

Electrofishing apparatus was used repeatedly in blocked, measured segments of stream to assess its efficiency. Ninty-nine per cent, or more, of total numbers and biomass obtained in 6 to 10 "passes" through 3 separate stream segments was taken in the first 3 passes (Table 5). Larger fishes (Catostomus, Pantosteus, and Gila) were most susceptible to the electrical field, and small, bottom-dwelling species (especially Tiaroga cobitis) were least efficiently sampled. Only in the largest pools was the electrofishing unit obviously inefficient, when deeper water and turbidity hampered recovery of stunned animals.

Numbers and weights of fishes taken from selected segments in three sampling periods were variable, especially in February when only four localities were collected (Table 6). Comparison of data for October 1976 and April 1977, however, indicated a remarkably similar order of magnitude of numbers of each of the seven native species. Ranking of numerical abundance was identical on both of those dates, with Agosia being dominant and Gila as being the least abundant species. Ranking of weights per hectare also were the same in October and April, in all but the catostomids (which exchanged dominance of biomass; Table 6). In autumn, juvenile Catostomus move readily onto riffles, where they

Table 5. Percentages of total numbers (above) and weights (below) of fishes taken in consecutive "passes" of electrofishing apparatus in Aravaipa Creek, Graham and Pinal counties, Arizona, based upon sampling of three separate stream segments.

Species	"Pass" Number					
	1	2	3	4	5	6-10
Catostomus insignis	82.7	14.0	2.6	0.7		
	93.8	2.6	3.0	0.6		
Pantosteus clarki	91.0	6.6	1.7	0.3	0.3	0.1
	92.4	5.4	0.7	0.5	0.6	0.4
Agosia chrysogaster	90.0	7.9	1.7	0.1 1/		0.3
	92.2	6.1	1.5		----	0.3
Rhinichthys osculus	86.8	11.3		0.6		1.3
	89.2	9.3		0.6		0.9
Tiaro a cobitis	53.8	30.8	7.7		7.7	
	20.0	60.0	8.0		12.0	
Meda fulgida	88.7	2.4	8.1		0.8	
	94.3	1.6	3.2		1.0	
Gila robusta	100.0					
grahami	100.0					
Total numbers and	3,224	289	69	7	4	8
weights (gm)	10,768.8	453.0	233.1	55.9	28.6	21.4
Over-all	89.5	8.0	1.9	0.2	0.1	0.2
Percentages	93.2	3.9	1.9	0.5	0.2	0.2

1/Tr. = less than 0.05 per cent.

live with adults and juveniles of Pantosteus. In spring, C. insignis tends to occupy the deepest available water during the day, where electrofishing was most inefficient.

Estimates of numbers of fishes per hectare in October (15,000+) and April (ca. 11,000) are consistent with an expected decrease through the year, and the similarity of biomass per hectare (105 kg) in each period also seems reasonable.

Table 6. Summary of fishes per hactare indicated by sampling Aravaipa Creek, Graham and Pinal counties, Arizona; numbers of individuals above, weights below (in parentheses).

Species	Sampling Methods and Periods			
	October 1976		February 1977	April 1977
	Seines		Electrofishing	
Catostomus insignis	446 (19.9)	734 (27.7)	1,382 (78.1)	701 (46.6)
Pantosteus clarki	446 (7.2)	3,284 (54.8)	4,244 (83.8)	2,009 (27.8)
Agosia chrysogaster	11,800 (17.8)	8,643 (15.7)	2,122 (6.7)	6,238 (17.4)
Rhinichthys osculus	15,659 (16.3)	2,064 (2.6)	592 (1.3)	1,413 (2.5)
Tiaroga cobitis	134 (0.2)	119 (0.2)	2,287 (5.4)	202 (0.5)
Meda fulgida	848 (1.4)	312 (0.5)	1,102 (1.9)	287 (0.8)
Gila robusta grahami	(- -)	83 (2.6)	115 (1.8)	96 (9.2)
Chaenobryttus cyanellus	(-)	9 (0.9)	(-)	(-)
Totals	29,333 (62.8)	15,249 (105.0)	11,844 (178.9)	10,946 (104.6)

Percentages of each species' number and weights in individual collections are in Tables 7 and 8, respectively, and absolute data per hectare are plotted in Figure 24.

Of fishes taken, only Agosia and Pantosteus tended to be generally distributed throughout the stream, Agosia was most abondant in the upper and lower parts. Pantosteus varied from being concentrated in the mid-section in October, upper section in February, and downstream in April. Catostomus was commonest in middle sections in October and April, and somewhat concentrated upstream in February. Rhinichthys obviously preferred upstream habitats. Tiaroga tended to be very widely distributed, but rare, and Meda and Gila were most abundant in the middle, canyon sections of the stream. Distributions of biomass resembled those for numerical abundance.

Diversity (number of species per locality) was obviously lower at extreme up- and downstream stations, and highest within and adjacent to the canyon section of the stream.

Both gross numbers and biomass of fishes per hectare, as estimate from individual electrofishing samples, was greatest upstream, lowest within and near the canyon segment, and intermediate downstream (Fig. 24).

Table 7. Summaries of relative abundance (as percentages of total numbers of fishes taken by electrofishing apparatus) at various sites on Aravaipa Creek, Graham and Pinal counties, Arizona, 1976-77; see Table for comparable data on weights of fishes taken.

Species	October 1976						
	3200	3170	3150	2595	2460	2400	Over-all
Catostomus insignis	4.8		10.7	7.0	12.3	5.4	4.8
Pantosteus clarki	19.0	4.3	28.4	29.4	67.0	19.8	21.5
Agosia chrysogaster	16.2	73.1	6.7	58.8	10.3	74,5	56.7
Rhinichthys osculus	59.0	22.6	29.4			- -	13.5
Tiaroga cobitis	1.0		4.9	1.9	1.0	0.2	0.8
Meda fulgida			11.7	2.3	8.7		2.0
Gila robusta grahami			7.9	0.5			0.5
Chaenobryttus cyanellus					0.5		0.1

Species	February 1977				
	3200	3090	2480	2300	Over-all
Catostomus insignis	20.4	11.8	11.7		11.7
Pantosteus clarki	57.4	39.2	22.8	25.0	35.8
Agosia chrysogaster	7.4	2.4	47.4	75.0	17.9
Rhinichthys osculus		7.5	1.2		5.0

Table 7. Concluded

Species	February 1977 (concluded) 3200	3090	2480	2300	Over-all
Tiaroga cobitis	1.9	26.4	11.1		19.3
Meda fulgida	9.3	12.2	4.1		9.3
Gila robusta grahami	3.7	0.4	1.8	----	1.0

Species	April 1977 3300	3200	3170	3150	2485	2400	2300	Over-all
Catostomus insignis	0.4			25.4	18.2	11.2		6.4
Pantosteus clarki	----	7.5	7.4	43.7	63.6	31.7	20.0	18.4
Agosia chrysogaster	68.9	75.0	75.3	1.4		50.9	80.0	57.0
Rhinicnthys osculus	30.7	15.0	16.7	5.6	----	----	----	12.9
Tiaroga cobitis		2.5	0.6	9.9		0.9	----	1.8
Meda fulgida	----		----	9.2	18.2	4.5	----	2.6
Gila robusta grahami	----	----	----	4.9	----	0.9	----	0.9

Table 8. Summaries of relative abundance (as percentage of total weights of fishes taken by electrofishing apparatus) at various sites on Aravaipa Creek, Graham and Pinal counties, Arizona, 1976-77; see Table for comparable data on numbers of fishes taken.

Species	October 1976						
	3200	3170	3150	2595	2460	2400	Over-all
Catostomus insignis	4.8		55.7	30.8	23.1	21.7	26.4
Pantosteus clarki	75.5	19.9	28.4	51.1	72.7	43.8	52.2
Agosia chrysogaster	6.4	68.3	0.9	13.7	1.1	34.4	14.9
Rhinichthys osculus	13.1	11.8	2.6				2.5
Tiaroga cobitis	0.2		0.4	0.5	0.1	0.1	0.2
Meda fulgida			1.0	0.5	0.5		0.4
Gila robusta grahami			11.0	3.5			2.5
Chaenobryttus cyanellus					2.4		0.9

Species	February 1977				
	3200	3090	2480	2300	Over-all
Catostomus insignis	46.7	47.0	20.6		11.7
Pantosteus clarki	50.1	46.4	46.0	38.2	38.2
Agosia chrysogaster	0.7	0.4	25.1	61.8	17.9
Rhinichthys osculus		0.8	0.8		0.7

Table 8. Concluded

Species	February 1977 (concluded) 3200		3090	2480	2300	Over-all
Tiarocia cobitis	0.2	3.	3.4	4.6		3.0
Meda fulgida	0.5		1.2	1.3	----	1.1
Gila robusta grahami	1.9			1.6		1.0

Species	April 1977 3300	3200	3170	3150	2485	2400	2300	Over-all
Catostomus insignis	3.2			57.9	43.5	51.8	----	44.5
Pantosteus clarki	----	46.5	4.2	27.8	54.3	22.7	29.5	26.5
Agosia chrysogaster	71.1	46.5	84.5	0.1	----	14.0	70.5	16.6
Rhinichthys osculus	25.7	6.6	11.0	0.4	----			2.4
Tiaroga cobitis		0.4	0.3	0.8		0.2	----	0.5
Meda fulgida	----	----		0.8	2.2	1.0	----	0.7
Gila robusta grahami	----	----	----	12.3		10.3	----	8.8

Figure 24. Numbers (A) and weights (B, in kg) of fishes per hectare from all samples taken by electrofishing on Aravaipa Creek, Graham and Pinal counties, Arizona, 1976-77, arranged by elevation of capture.

SRP10731

Quarterly Progress Report
(30 January 1977)

on Project Entitled

ECOLOGICAL ANALYSIS OF AVAVAIPA CREEK AND ENVIRONS RELATIVE TO PAST AND FUTURE LAND AND WATER USE

Submitted by

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to

Bureau of Land Management
U. S. Department of the Interior

Reference: Contract No. YA-512-CT6-98

Physico-chemical Data

Selected physical and chemical parameters are being monitored at a minimum of two stations at 4- to 6-week intervals, and at other stations as personnel and time permits. Temperature, conductance, pH, dissolved oxygen, and oxygen-reduction potential are recorded by the Hydrolab II-B, "Surveyor," and macronutrients (Phosphate-Phosphorus and Nitrate-Nitrogen) are analysed with a Bausch & Lomb, Mini-spectrometer Data are transferred from field sheets directly into the Univac 1110/42 computing system at Arizona State University, and plotted by Cal-Comp plotting techniques for study and for presentation in reports.

Within the quarter, data from the period August 1976 through early January 1977 have been examined. Temperatures in the summer - autumn period ranged between 17 and 27 °C in August and 12 and ca. 20° in November at an upper station, and 13 to 20° in October and 10 to 18+° in November at a lower station. In January temperatures up- and downstream were 10-16 ° and 5-13 °C on different dates, respectively.

Conductance varies inversely with discharge, ranging between 400 and 500 ummhos/cm (corrected to 25° C) in the period. Conductance tends to be slightly higher downstream, consistently, reflecting evapotranspiration through the system.

Hydrogen-ion concentration (pH) i alkaline in Aravaipa Creek, with pronounced diel variability related to photosynthetic activities of benthic algae (and rare macrophytes) in daytime, and respiratory behavior of the system at night. Most values approach 8.4 at mid-day, and typically fall to near 7.6 at night. In January, the range in pH was only 7.6 to 8.0 at an upstream station, reflecting cool water and low photosynthetic activity as a result of cloud cover. Values for January

at a downstream station ranged from 8.4 to 8.6. There is a strong tendency, as with conductance, for higher pH at downstream stations. This presumably reflects less interflow of water through the canyon as a result of shallower sediments, and less respiratory influence on the carbonate-bicarbonate equillibrium systems.

Night-time values for dissolved oxygen hover near 80% of satuaration at all stations on Aravaipa Creek at all times recorded thus far, and approach or exceed 100% of saturation during mid-day except in extremely cloudy or cool periods. The decline of saturation values and maintenance near 80% indicates substantial respiration within sediments of the stream bed (less downstream from the canyon, however, as mentioned above for pH). There seems a positive correlation, as might be expected, between chlorophyll standing crop (see below) and oxygen production, and this is being examined in more detail for the annual report.

Relationships of oxidation-reduction potential, as measured by the Hydrolab II-B, are as yet obscure, and will be discussed later.

Patterns of macronutrients seem well fixed in Araviapa Creek. Nitrate-nitrogen is relatively high in upstream waters, usually between 0.05 and 0.30 mg/l, and declines radically throughout the run of the stream to between 0.01 and 0.05 mg/l. Phosphate-phosphorus behaves independently of nitrate-nitrogen, ranging from 0.05 to 0.15 mg/l in samples from upstream habitats, and 0.04 to 0.13 mg/l downstream from Aravaipa Canyon. During spates, both macronutrients behave erratically through time, varying without pattern; however, in times of low water, some diel utilization of each is detectable at a given station. Variations during periods of high water are attributable to exchanges of solutes with materials in suspension.

Historical Studies

More than 130 queries about availability of dated photographs of the Aravaipa Creek drainage have been mailed, with only 37 replies in the period covered by this report. Many photographs are available, but few include physiography usable in re-location of sites, and even fewer have reliable dates. A reliable series of pictures are available from the period 1963 to present, however, from Arizona State University personnel and students who have worked on various aspects of ecology in the area.

Data from the U. S. Geological Survey on discharges of Aravaipa Creek are sporadic, and based upon differing gage sites and types. Records are available from the following periods (U.S.G.S. 1975): 1920-21; 1932-38; and 1966-present. These data are in the process of reduction and interpretation toward hydrologic interpretations for the system. Of special interest are relative frequencies and intensities of flood and drought.

Benthic Invertebrates

Mr. Dale Bruns, Arizona State University, is well along in analysis of 13 months of samples of benthic invertebrates at eight stations along Aravaipa Creek, two of which are within the Primitive Area. His data are to be submitted as part of the annual report for this project, and provide a long-term basis for interpretation of sampling now underway. A total of 64 samples of benthic invertebrates from Aravaipa Creek are at some level of processing, and data for 21 samples are in Table I. To date, numbers of individual organisms (principally insects) have

Table 1. Data for selected samples of benthic invertebrates (Surber Sampler) from Aravaipa Creek, Graham and Pinal counties, Arizona, and Turkey Creek, Graham County, Arizona.

Period	No. Samples	No. Taxa	Gm/m^2	$No./m^2$
August 1976 (AC)	3	23 (12 - 16)[2/]	2.1[1/] (0.9 - 4.0)	3,006 (2,206 - 3,907)
September 1976 (AC)	3	20 (6 - 11)	4.1 (0.1 -11.8)	445 (333 - 1,527)
October 1976[3/] (AC)	5	24 (1 - 13)	3.5 (0.01- 7.8)	2,540 (11 - 9,344)
October 1976[4/] (AC)	4	26 (9 - 16)	2.9 (1.9 - 4.4)	5,513 (1,194 -11,194)
January 1977 (AC)	2	26 (11 - 20)	11.0 (9.5 -12.5)	10,183 (6,846 -13,520)
Septqmber 1976 (TC)	3	23 (11 - 13)	12.4 (11.9 -23.5)	1,280 (344 - 1,280)
January 1976 (TC)	1	14	14.7	2,325

benthos weights are "wet weight", blotted dry on tissue.

2/ Ranges for all data are in parentheses

3/ Includes some samples taken after a slight rise in one segment of the creek, hence the low values given in ranges and a somewhat suppressed mean for weights and numbers.

4/ Includes samples taken before the small spate mentioned in footnote #3.

been relatively high except in September following flooding.

Many kinds of invertebrates, especially larvae of dipterans, some ephemeropterans, and coleopterans, cannot at present be identified to species. However, diversity is quite high, with most samples yielding at least 10 taxa despite a level of identification often as broad as family. Heterogeneity is obvious within the data, with a range of diversity in samples from 1 to 20, over-all (including those from Turkey Creek; Table 1), typically providing a total of 20 to 26 taxa when samples are combined for presentation.

Biomasses are variable, with the highest weights often reflecting presence of a single large individual of a relatively rare taxon (such as a dragonfly larva).

Fishes

Quantitative sampling of fishes has been done by electrofishing apparatus and by seine. Table 2 presents information on electrofishing success in repeated "passes" through a measured segment of stream, and indicates the basis for the fixed technique of three "passes" within an area. Less than 0.5% of the total fishes taken from the segment occurred after the third pass in three separate studies.

Seines of various lengths and meshes are used within the Primitive Area, which yield from 13 to 47% of the numbers and 32 to 58% of the biomass taken by electrofishing gear. Statistical studies are in progress to equate the two sampling methods, and will be presented in a later report

Fishes taken are identified, enumerated, and weighed, and data are espressed as Kg/hectare (Table 3). Aravaipa Creek is obviously dominated by longfin dace (Agosia chrysogaster) and speckled dace (Rhinichthys

Table 2. Numbers and weights (in gms) of fishes taken from measured and blocked segments of Aravaipa Creek, Graham and Pinal counties, Arizona, in repeated passes of electrofishing apparatus.

Species	Pass Number 1	2	3	4	5	6	7	8	9	10
Catostomus insignis	19 (935.0)	3 (19.8)	0	0	0	0				
Pantosteus clarki	238 (1,072.8)	41 (31.7)	2 (9.8)	0	1 (17.9)	0				
Agosia chrysogaster	397 (111.7)	29 (9.4)	3 (1.4)	0	0	0				
Rhinichthys osculus	67 (29.7)	9 (4.2)	0	1 (0.3)	0	1 (0.4)				
Tiaroga cobitis	0	3 (1.3)	0	0	0	0				
Catostomus insignis	204 (3,002.7)	40 (139.2)	7 (91.9)	1 (13.9)	0	0	0	0	0	0
Pantosteus clarki	439 (2,327.0)	27 (107.0)	0	3 (22.1)	0	0	0	0	1 (19.7)	0
Aciosia chryswaster	1,139 (465.7)	104 (23.6)	19 (4.9)	0	0	1 (0.4)	0	3 (0.9)	0	0
Meda fulgida	67 (19.4)	1 (0.3)	3 (0.4)	0	0	0	0	0	0	0

Table 2. Concluded

Species	Pass Number 1	2	3	4	5	6	7	8	9	10
Catostomus insignis	31 (1,744.2)	0	1 (89.7)	1 (19.4)	0	0	0	0		
Pantosteus clarki	392 (821.7)	9 (106.9)	17 (21.1)	0	2 (10.4)	0	0	0		
Agosia chrysogaster	107 (40.9)	11 (7.7)	9 (3.1)	1 (0.2)	0	0	0	1 (0.4)		
Rhinichthys oscous	71 (19.2)	9 (0.9)						(0.1)		
Meda fulgida	43 (10.4)	2 (0.2)	7 (0.6)	0	1 (0.3)					
Tiaroga cobitis	7 (0.5)	1 (0.2)	1 (0.2)	0	0	0	1 (0.3)			
Gila robusta grahami	3 (167.9)	0	0	0	0	0	0	0		
TOTALS	3,224 (10,768.8)	289 (453.0)	69 (223.1)	7 (55.9)	4 (28.6)	8 1/ (21.4)				
Percentages	89.5 93.2	8.0 3.9	1 9 1.9	0.2 0.5	0.1 0.2	0.2 0.2				

1/ Numbers of fishes taken in passes 6-10 combined

Table 3. Numbers and weights of fishes per hectare at various stations on Aravaipa Creek, Graham and Pinal counties, Arizona, October 1976; weights are in parentheses ().

Species	Localitiesi/ 3300?-1	3200	3100	2800a/	2700Z/	2500	2400	Average
Catostomus insignis	1,330 (10.2)	615 (3.9)	411 (42.5)	125 (21.1)	290 (27.2)	513 (18.2)	957 (25.7)	606 (21.3)
Pantosteus clarki	950 (6.6)	2,460 (61.6)	2,019 (30.7)	125 (3.4)	677 (16.7)	2,156 (30.2)	4,316 (73.6)	1,815 (31.8)
Gila robusta grahami	0 (0.0)	0 (0.0)	299 (8.4)	0 (0.0)	0 (0.0	34 (2.1)	0 (0.0)	48 (1.5)
Agosia chrysogaster	46,059 (67.7)	2,091 (5.2)	16,342 (31.7)	501 (0.5)	3,095 (6.9)	4,312 (8.1)	7,070 (11.4)	11,353 (18.8)
Rhinichthys o. osculus	66,381 (69.0)	7,626 (10.7)	6,095 (7.3)	125 (0.2)	0 (0.0)	0 (0.0)	0 (0.0)	11,461 (12.5)
Tiaroga cobitis	475 (0.5)	123 (0.2)	187 (0.3)	42 (0.1)	0 (0.0)	137 (0.3)	59 (0.1)	146 (0.2)
Meda fulgida	0 (0.0)	0 (0.0)	449 (0.8)	710 (1.2)	2,031 (3.0)	171 (0.3)	332 (0.4)	484 (0.8)
Chaenobryttus cyanellus	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	20 (2.0)	3 (0.3)

[1]/Localities designated in feet above mean sea level.

/Seining collection; all un-noted collections were by electrofishing apparatus.

osculus) which collectively made up more than 85% of all fishes taken. In terms of biomass, however, the two catostomids (Catostomus ins ignis and Pantosteus clarki) obviously share dominance, followed closely by longfin dace and then speckled dace. Concentration of fishes, especially the two daces, near the source of Aravaipa Creek (elevation 3300 feet) was unusual, and unexplained. Distributional relations of the various species, however, are consistent with past data. Speckled dace are commonest upstream, and absent downstream. Longfin dace tend to be mo abundant up- and downstream from the Canyon, a pattern also demonstrated by the suckers. Tiaroga, Gila, and Meda are typically rare, as compared to other forms, and generally more abundant within canyon sections of the creek.

Algae and Algal Pigments

Techniques for sampling algae and algal pigments described in the last quarterly report seem to be succeeding, with a definite relationship being established between standing crops and amounts of chlorophylls and other pigments present. Many hundreds of samples have been analysed, and patterns now are apparent. The flora is dominated by green algae and diatoms (Chlorophyceae and Bacillariophyceae) and pigment concentrations strongly reflect this composition. Pigment concentrations in excess of 10 mg/m^2 are present after periods of low flow (sometimes more than 100 mg/m^2), and after spates none or less than 0.1 mg/m^2 are present. A three-dimensional technique of presenting pigment information is being developed, to facillitate comparison of this measure of standing crop and physical-chemical parameters.

Personnel

Mr. Terrill Tompkins resigned from the project and left the University. His position was taken by Mr. Mark Foster, Master of Science student, and it is anticipated that he will use some data toward a thesis for an advanced degree.

SRP10742

Annual Progress Report
(April 1977)

and

Quarterly Progress Report
(July 1977)

on Project Entitled

ECOLOGICAL ANALYSIS OF ARAVAIPA CREEK AND ENVIRONS RELATIVE TO PAST AND FUTURE LAND AND WATER USE

Submitted by

W. L. Minckley
Dept. of Zoology, Arizona State University,
Tempe, Arizona 85281

to

Bureau of Land Management
U. S. Department of the Interior

Reference: Contract No. YA-512-CT6-98

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APPENDED REPORT -- "Distribution and Abundance of Benthic Invertebrates in a Sonoran Desert Stream," by Dale A. R. Bruns, August 1977 M.S. Thesis, Arizona State University, Tempe, AZ 85281

INTRODUCTION

The present document covers the period August 1776 through early June 1977 and serves as a quarterly report (Item 0001AA, July 1977), and as an annual report (Item 0001AB, April 1977) for Contract No. YA-512-CT6-98, effective date 1 April 1976, signatory date 18 June 1976, between the Bureau of Land Management and Arizona State University. Data included herein are tentative in nature, and subject to further evaluation and interpretation for the final report.

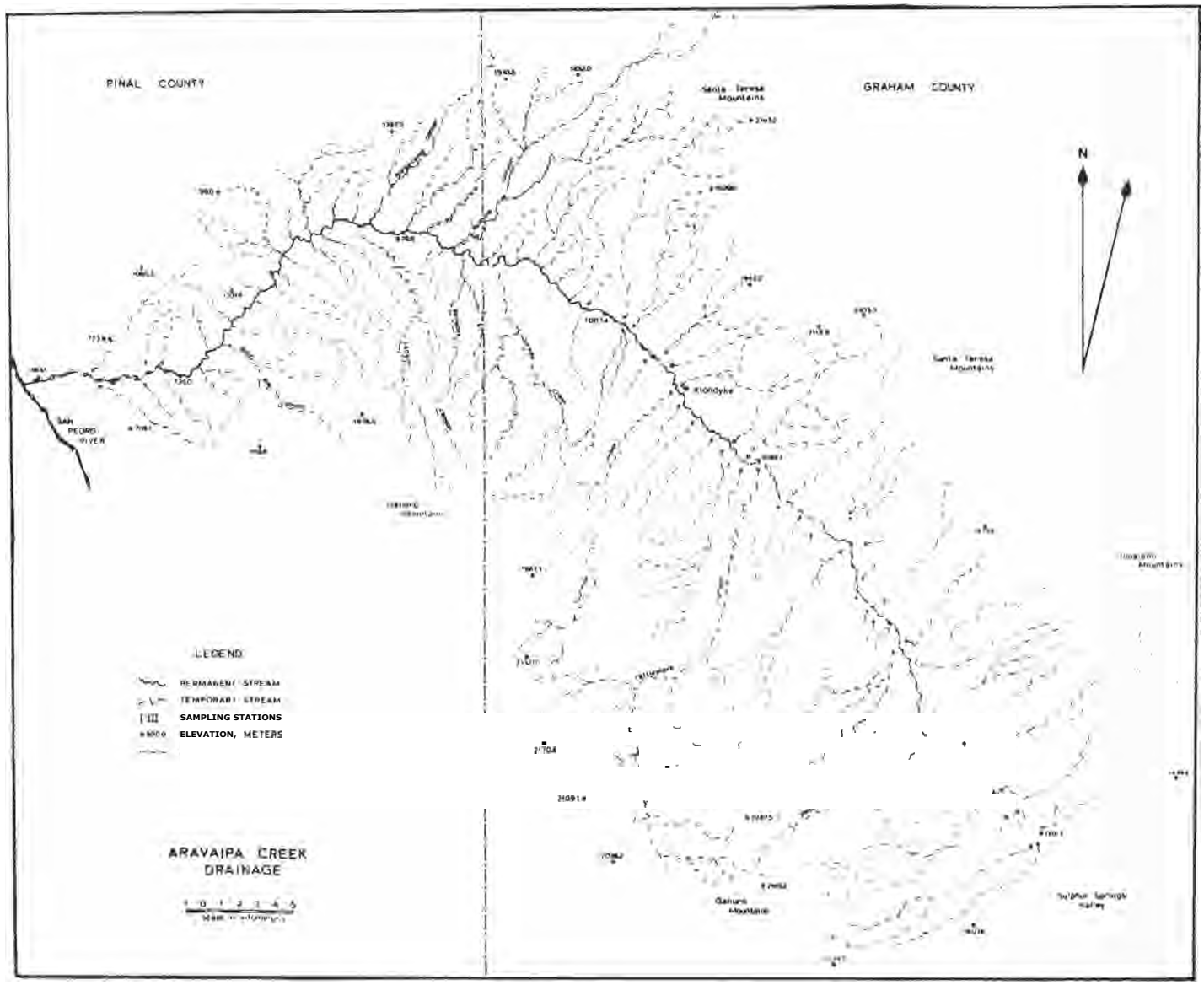
Field studies were initiated in August 1976 with receipt of equipment and supplies, and hiring of field and laboratory personnel. Data included here are those which are complete enough to allow some interpretation. Certain components of the study are fragmentary, or in the process of analysis, and will be reported later.

Each of the three segments of this report is started with a brief summary (HISTORICAL, p. 4; PHYSICO-CHEMICAL ENVIRONMENT, p. 25; and BIOLOGICAL STUDIES, p. 70), which may be consulted for a rapid overview of the project accomplishments. A report on benthos of Aravaipa Creek by Dale A. R. Bruns, is appended as part of this document.

A reduced example of a field map developed for plotting of localities and recording data on animal and plant distributions is provided as Figure 1.

The Final Report on "Microchemical Analysis of Aravaipa Creek and Adjacent Aquatic Habitats Relative to Land and Water Use Management", by Milton R. Sommerfeld (Arizona State University), stands as a sister document to the present annual presentation.

Figure 1. Sketch map of the Aravaipa Creek drainage, Graham and Pinal counties, Arizona, prepared from U. S. Geological Survey and U. S. Forest Service base maps.


PINAL COUNTY
GRAHAM COUNTY
N
SAN PEDRO RIVER
Klondyke
LEGEND
PERMANENT STREAM
TEMPORARY STREAM
SAMPLING STATIONS
ELEVATION, METERS
ARAVAIPA CREEK DRAINAGE

HISTORICAL

Summary

Ninty-two dated photographs of Aravaipa Creek and its environs have been secured and are under study. Of special interest is a series of 8 photographs dated between 1890 and 1900, which indicate a denser riparian community than at present, substantially greater accumulation of ground litter, less incision of the stream channel, but a very similar aspect of the stream itself.

Pre-1940 Photographs

Five photographs taken between 1890 and 1900 by J. A. Munk, obtained from the Southwest Museum, Los Angeles, California (Negative Nos. 12,425-6, 12,429, 12,424, 12,427; Figs. 2-6. At that time, the extreme upper part of the floodplain (near Klondyke) was obviously cleared and under cultivation (Fig. 2), with flood irrigation already being practiced. Large cottonwoods (Populus fremonti) remained, and in an area presumably nearby, supported a dense stand of wild grape (Vitis arizonica; Fig. 3), and ground litter was dense (far more so than can be found today). The forest (or gallery) along upper Aravaipa Creek was dense, consisting of about the same species composition as now present (cottonwood, willow Dalix sppj, and sycamore [Platanus wrighti]; Figs. 4-5). Smaller riparian plants seem dominated by seep willow (Baccharis glutinosa), still present today (Fig. 6). Stream banks ranged from low to incised in bends, similar to present, but large trees of the riparian gallery obviously stand with their bases closer to water level than is the situation in 1977 (Figs. 4-6).

Three additional photographs, dated "before 1900" and received from the Arizona Historical Society, Tucson, Arizona (Negative Nos. 8,208-9[2]), include one of the upper portion of the stream (Fig. 7), and two from within the canyon (Figs. 8-9). The upstream picture indicates a far sparser riparian vegetation, including more willow, than do Figures 4-6. Vegetation within the canyon closely resembles that observed in the 1930s (Figs. 10-11), and 1970s (Fig. 12). Those photographs with "hard rock" features (Figs. 6, 8-12) have been matched with 1976-77 photographs, and will be presented in the final report, along with more short-

term pairs (especially from the period 1963-present).

Of especial interest is a photograph donated to the Arizona Historical Society in 1939 (Negative No. 6901) depicting a log wier and two men in the stream. The specific location is obscure, but other photographs donated at the same time were from the upper segment. At first, an irrigation diversion was suspected; however, careful examination of the man to the left (Fig. 13) shows fish in each hand, and the man to the right appears to be using a dip net.

As noted in an earlier report, many photographs have been screened, but few have salient features for locality determination, and even fewer are appropriately dated. Of 432 photographs presently in hand, 92 are dated, and of those, only 24 can be located with relative certainty.

Figure 2. Aravaipa Creek floodplain near Klondyke, Graham County, Arizona, 1890 - 1900.

SRP10752

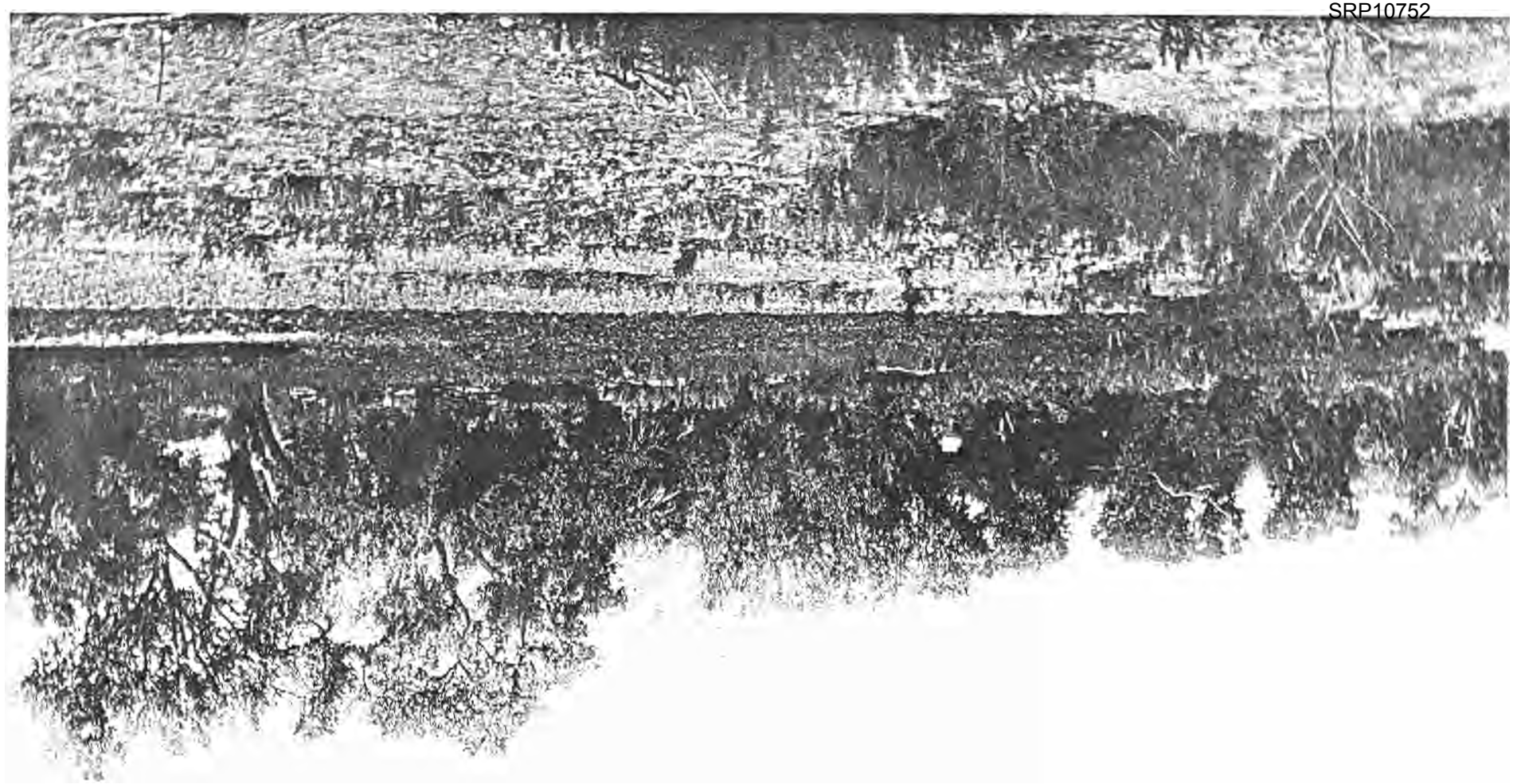
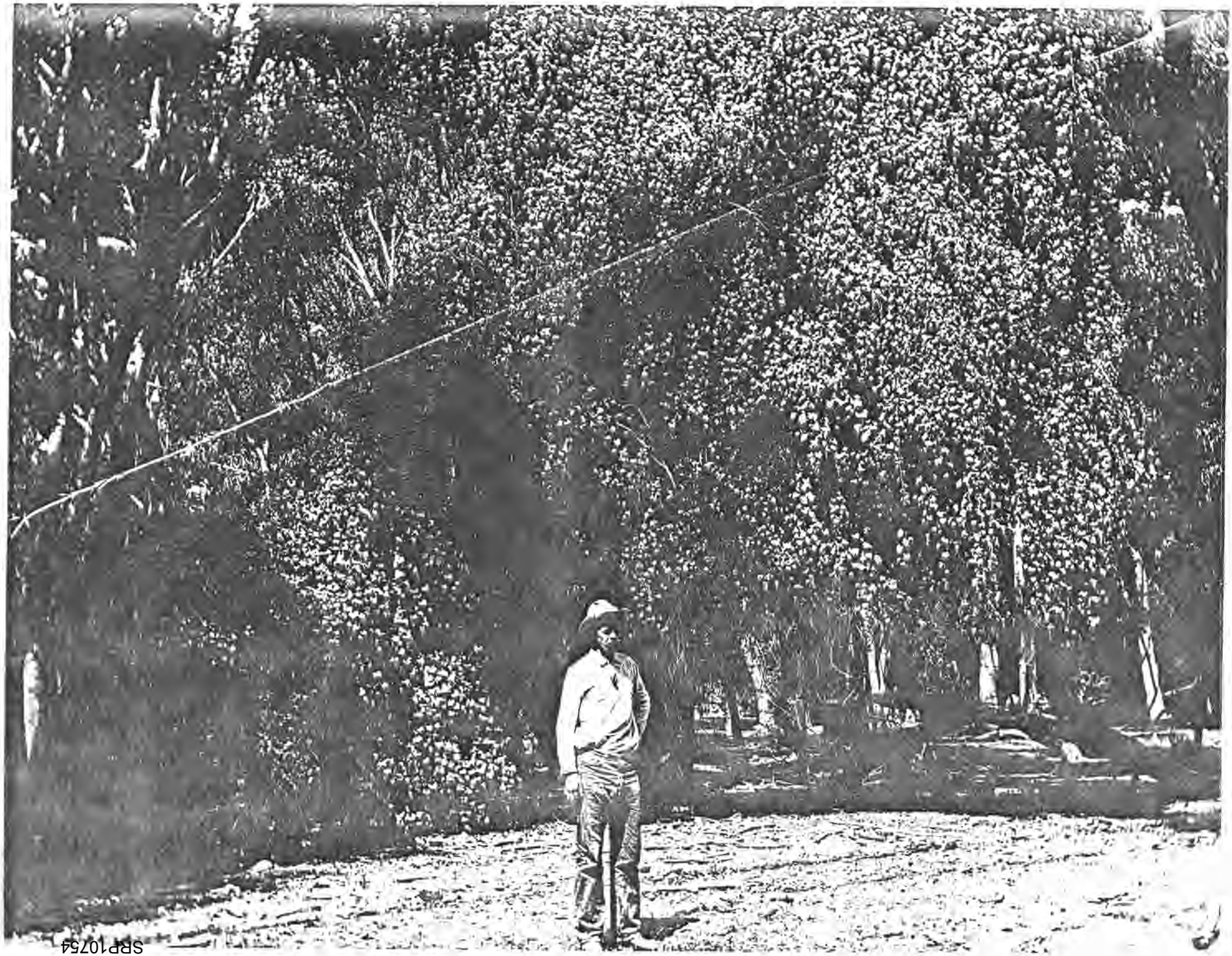


Figure 3. Aravaipa Creek riparian forest, near Klondyke, Graham County, Arizona, 1890 - 1900



SRP10754

Figure 4. Aravaipa Creek, near Klondyke, Graham County, Arizona, 1890 - 1900 (see also Fig. 5).

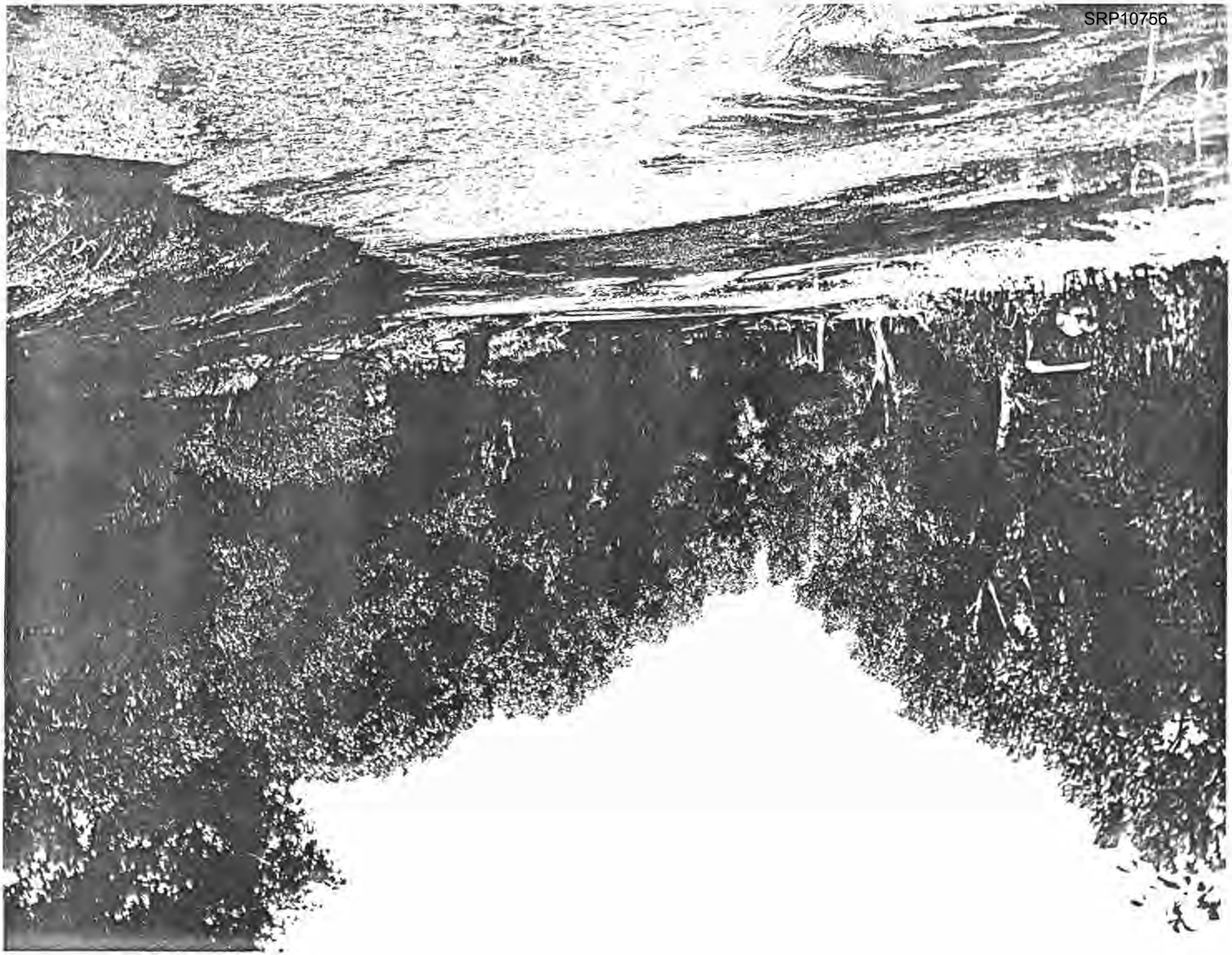

SRP10756

Figure 5. Aravaipa Creek, near Klondyke, Graham County, Arizona, 1890 - 1900 (see also Fig. 4).

SRP10758

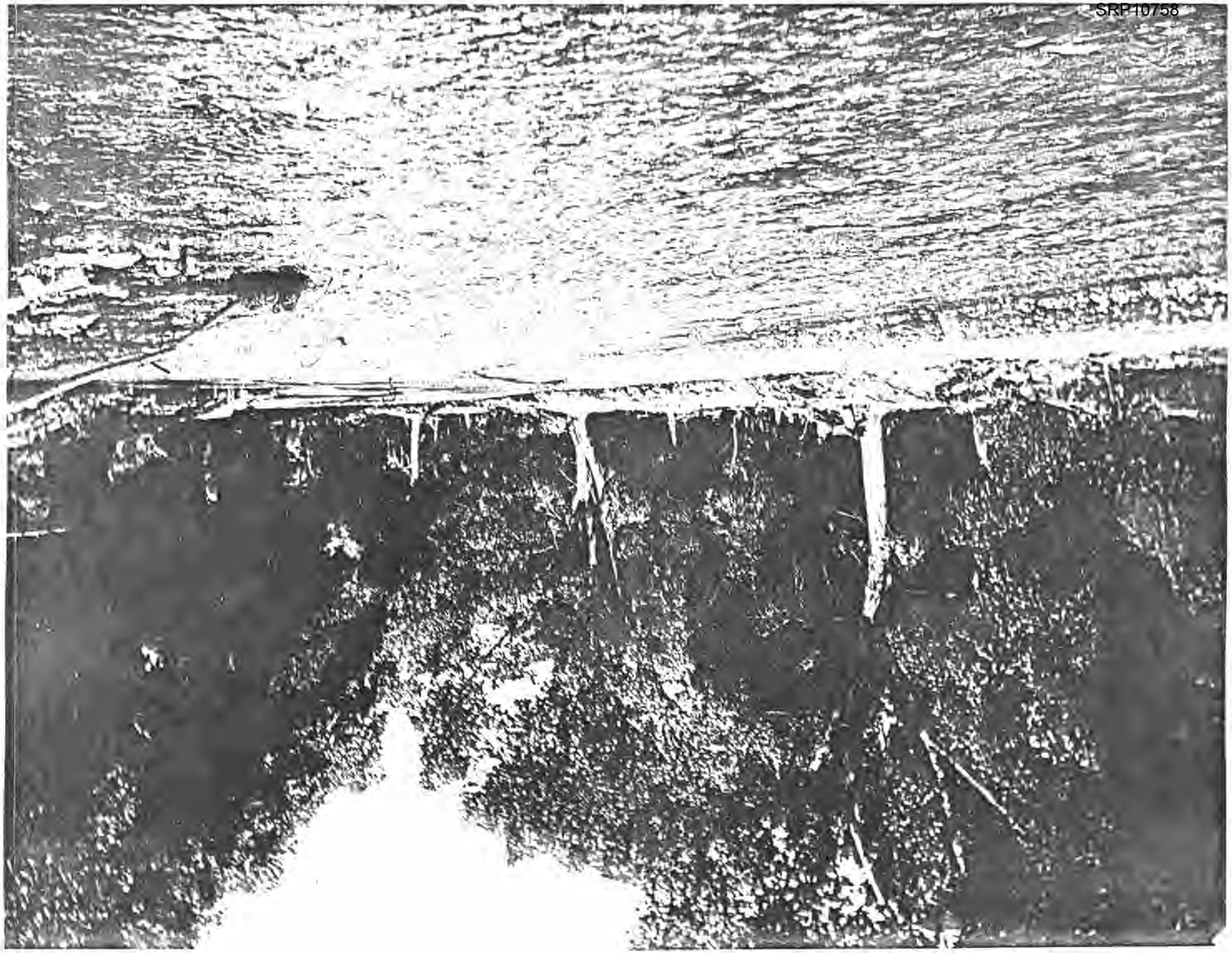


Figure 6. Aravaipa Creek, Graham County, Arizona, near "the Chimney," 1890 - 1900.

SRP10760

Figure 7. Aravaipa Creek, Graham County, Arizona, near Klondyke, "before 1900."

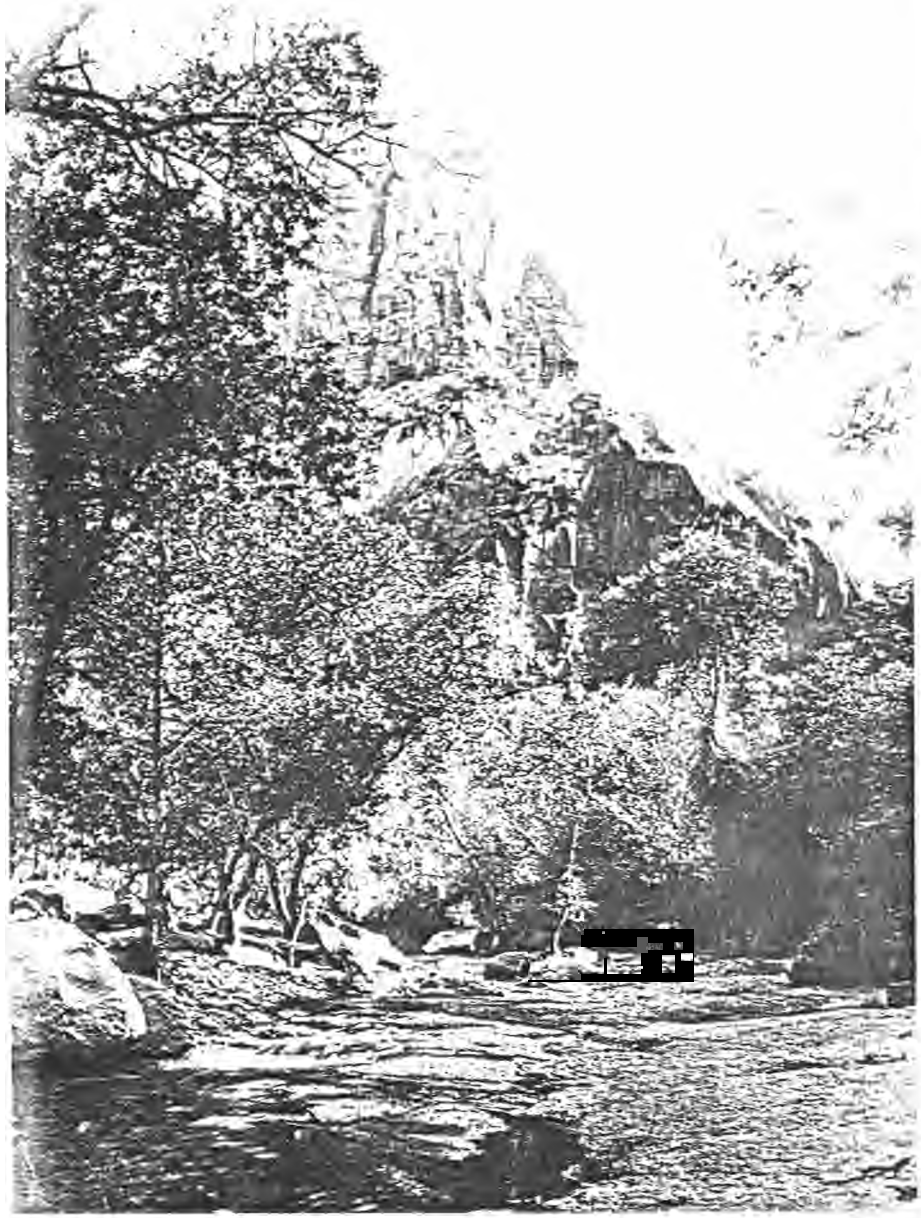


Figure 8. Aravaipa Creek, Graham or Pinal County, Arizona, in Aravaipa Canyon, "before 1900."

Figure 9. Aravaipa Creek, Graham or Pinal County, Arizona, in Aravaipa Canyon, "before 1900."

Figure 10. Aravaipa Creek, Graham County, Arizona, in Aravaipa Canyon, "Donated 1939." Arizona Historical Society Negative No. 6,903.

R

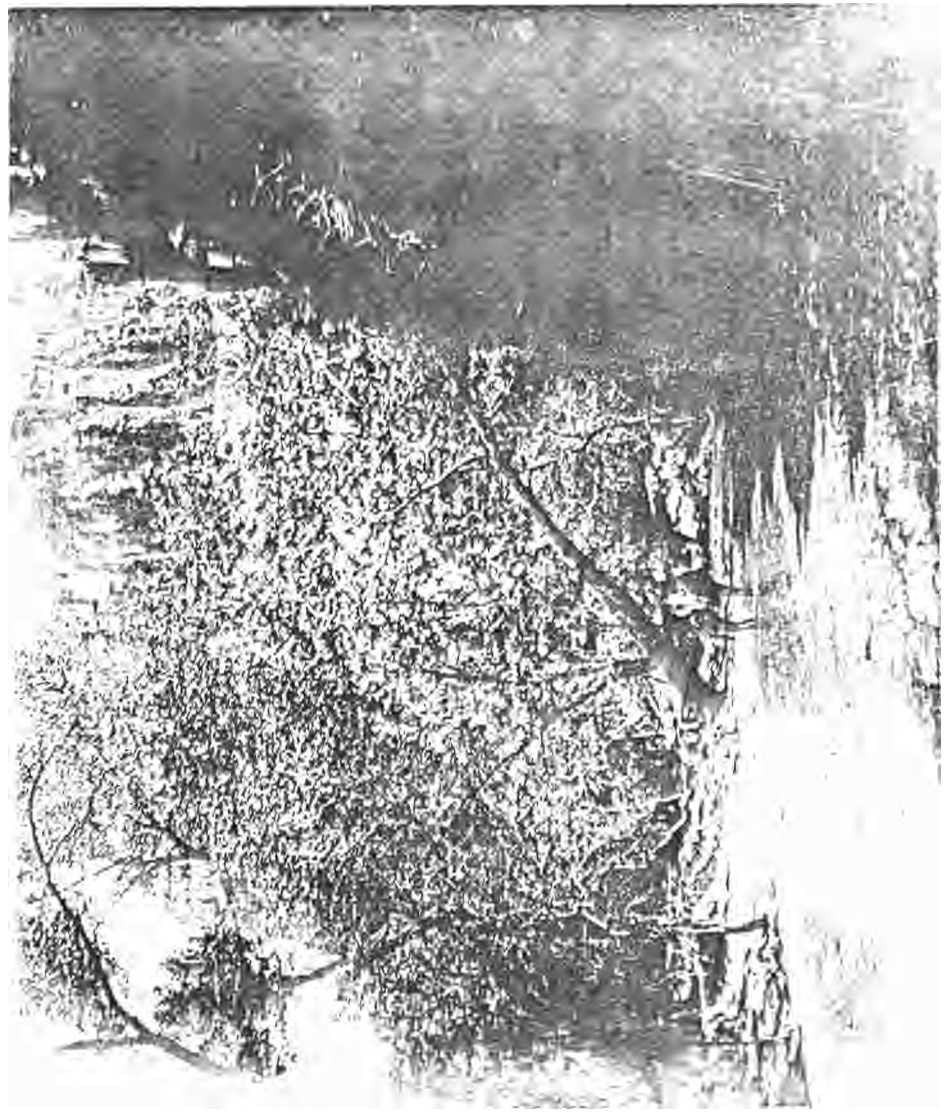


Figure 11. Aravaipa Creek, Graham County, Arizona, in Aravaipa Canyon, "Donated 1939" Arizona Historical Society Negative No. 6,902.

Figure 12. Aravaipa Creek, Pinal County, Arizona, in Aravaipa Canyon Bureau of Land Management Photograph, early 1970s.

SRP10768

Figure 13. Aravaipa Creek, Graham County, Arizona. Men fishing with log wier and dip net; Arizona Historical Society Negative No. 6,901.

PHYSICO-CHEMICAL ENVIRONMENT

Summary

Aravaipa Creek demonstrates a strongly bi-modal pattern of discharge, with greatest volumes occurring in winter (January - March) and summer (July - September). Major scour is effected at about 10 times average discharge of 30 cubic feet per second, and such an event occurred only 0.8% of 1,583 days (1966 - 1970).

Temperature changes of water are abrupt, ranging to 2.72 X 10^{-2} °C/minute on heating and 1.17 X 10^{-2} °C/minute on cooling. Temperature ranges are greatest in areas of open sun in summer, and least on cloudy days throughout the year. Water temperatures of 5.0° to near 30.0° have been recorded.

Values of conductance range from 405 to 478 umhps/cm in periods of average or modal flow, and dilution from spates is an obvious feature of the stream. There is a tendency for up- to downstream conductance to increase, presumably as a result of evaporation, transpiration, and input of springs.

Hydrogen ion concentration (O) varies substantially during the day, in obvious response to photosynthetic activities, and is lower upstream than downstream.

Dissolved oxygen concentrations vary with temperature, and with photosynthetic activities of algae and higher aquatic plants. There is a strong tendency for respiratory depletion of dissolved oxygen at night (to near 80% saturation), with supersaturation occurring often during daylight hours.

Macronutrient (PO_4-P and NO_3-N) concentrations are relatively high in Aravaipa Creek, with the former remaining so throughout the stream, and the latter tending to decrease at downstream stations.

The physico-chemical environment of Aravaipa Creek is strongly influenced by physical factors in cooler weather, for a short period after spates, and in areas of heavy shading. Otherwise, many features of the chemical system, at least, are under strong biological control, reflecting production and respiration within the system.

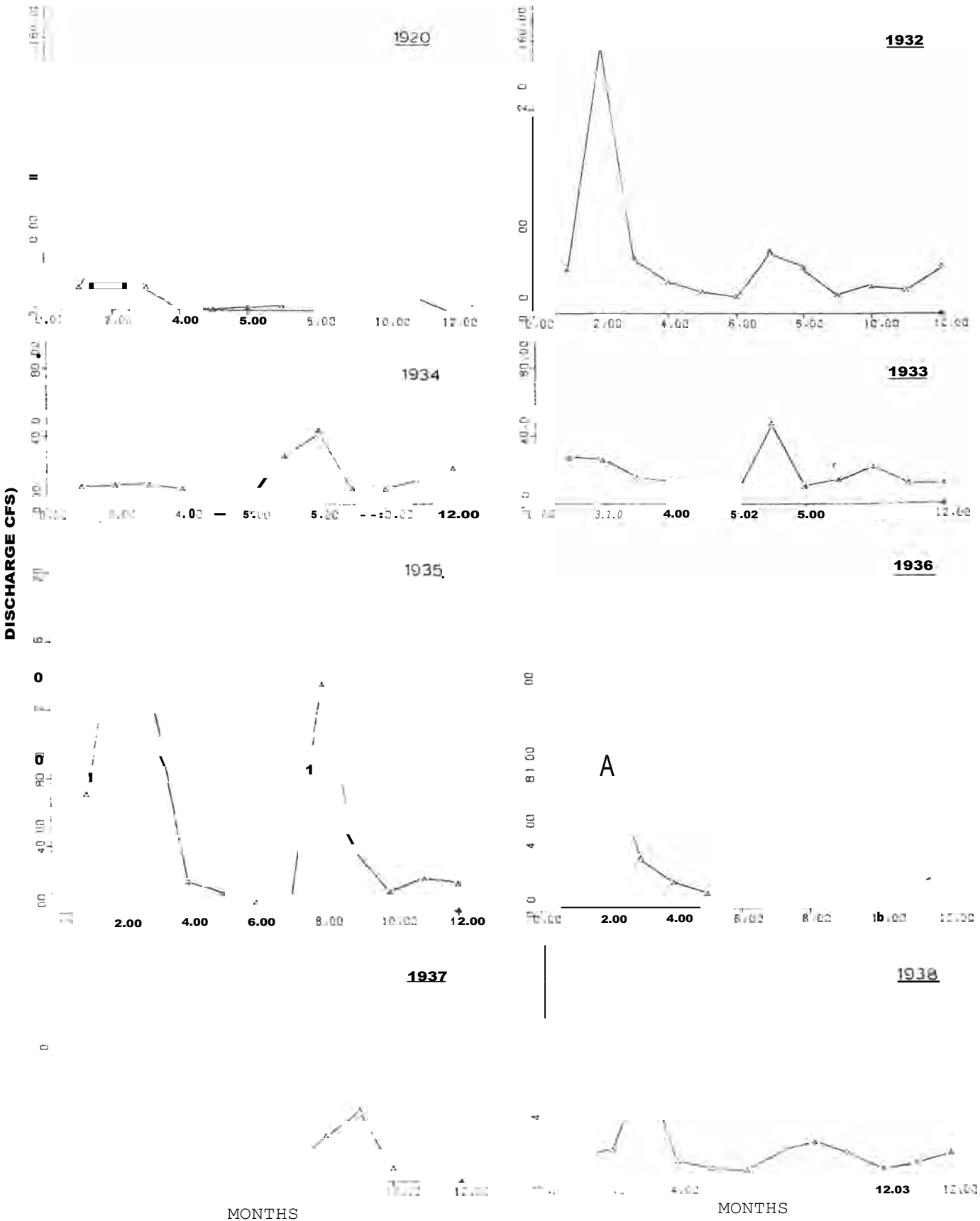
Discharges

The bi-modal nature of annual precipitation is strongly depicted by patterns of discharge in Aravaipa Creek. For 21 years (252 months) of record, mean monthly volume exceeded 35 cubic feet per second (cfs X D283 = cubic meters per second) for 17.9% of the months (45). Of these, 18 months were in the period January - March, and 14 in July - September. The typical spring drought is obvious, with only 2 discharge peaks being recorded in the period April - June, but autumn discharges in excess of 35 cfs (monthly mean) numbered 11. Average discharge over 24 years of record is about 30 cfs, with a median of 23 cfs (U. S. Geological Survey compilations).

On the basis of field data, major scour is effected in Aravaipa Creek when discharge increases 10 fold. A mean monthly discharge exceeding 100 cfs (Fig. 14) generally reflects an event of that magnitude (>-250 cfs), and such occurred in only 9 of 252 months represented (4 of which were in January - March, none in April - June, 2 in July - September, and 3 in October - December).

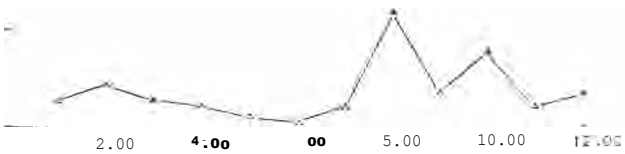
Use of monthly means greatly obscures the dynamics of discharge events in desert streams, and analysis of hydrologic features on a daily basis (and perhaps on shorter term, when data become available) is underway, but an example is provided to illustrate long-term trends. In the period 1 June 1966 through 30 September 1970 (1,583 days), discharge was greater than the mean of 30 cfs only 8.2% of the time (140 days), exceeded 100 cfs 1.8% of the time (29 days), 1,000 cfs 0.2%, and the peak discharge (daily mean) was 2,700 cfs (one day). Discharge of a magnitude to decimate the benthic flora and fauna (10 fold increase over the mean) occurred on 13 days (daily mean), or 0.8%.

Figure 14. Mean monthly discharges for Aravaipa Creek, Pinal County, Arizona, for 21 years of record (pages 28 through 30).



1939

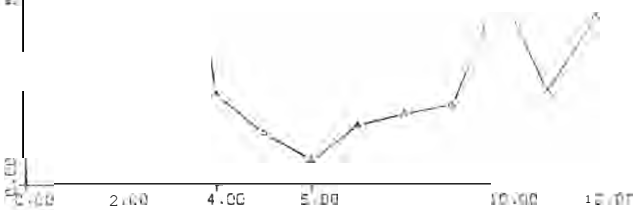
1940

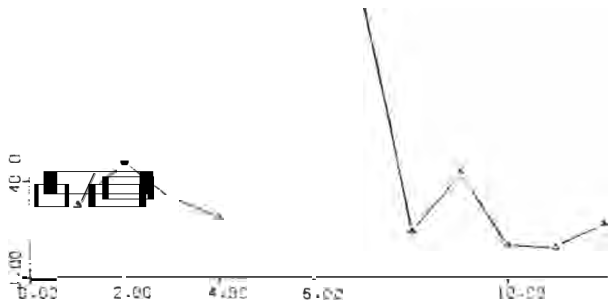


1941

1942

HARGE (CFS)





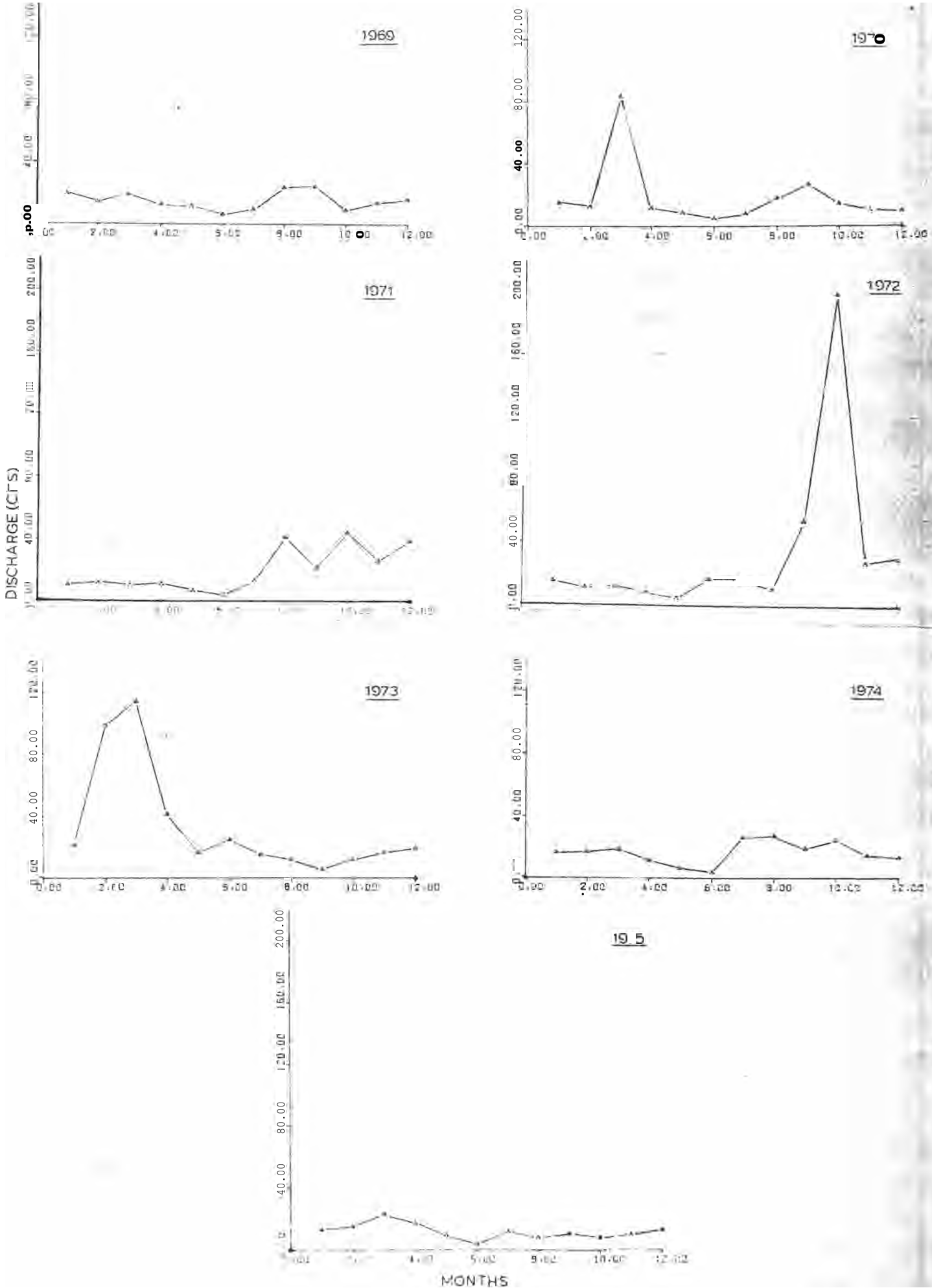
1967

1968

MONTHS

MONTHS

SRP10775



Temperature

Rates of change in water temperatures of Aravaipa Creek are great, reflecting unimpeded insolation on many reaches and general shallowness of the stream. When heating, rates of change averaged near 2.0×10^{-2} °C/minute, ranging from 1.56 to 2.97×10^{-2} °C/minute on cloudless days throughout the year. Cooling rates were far more variable than those for heating, 0.28 to 1.17×10^{-2} °C/minute, reflecting differences in relative humidity and in ambient temperatures of air (Table 1).

Abrupt heating and slow cooling is obvious on plots of long-term temperature studies made at various stations on Aravaipa Creek, especially in mid-summer and in autumn (Figs. 15 16). Maximum temperature at an upstream station was recorded on 9 August (Fig.15A); over-all range on that date was 17.7 to 28.4 °C. Rate of heating was the greatest recorded in the period of study (2.97×10^{-2} °C/minute; Table 1). The reach of stream for about 1.5 kilometers above the sampling site was not shaded by canyon walls, had a sparse gallery forest, and a small spate earlier in the month had removed all emergent aquatic vegetation, so that essentially all incoming light impinged on the water surface.

Temperature variations in autumn and winter decreased in magnitude, yet greater than 17.0 °C was attained on all but 1 of 5 sampling periods between November and April, and a minimum of slightly above 10.0 °C occurred on 11 January (Figs.15B-F). Variation in June approached that of the preceding August (Fig. 15G).

Data from downstream stations are similar to those just discussed (Figs.16A-G). However, an extremely cool day occurred on 15 January, and water temperature dropped below 5.0 C at night, and achieved only

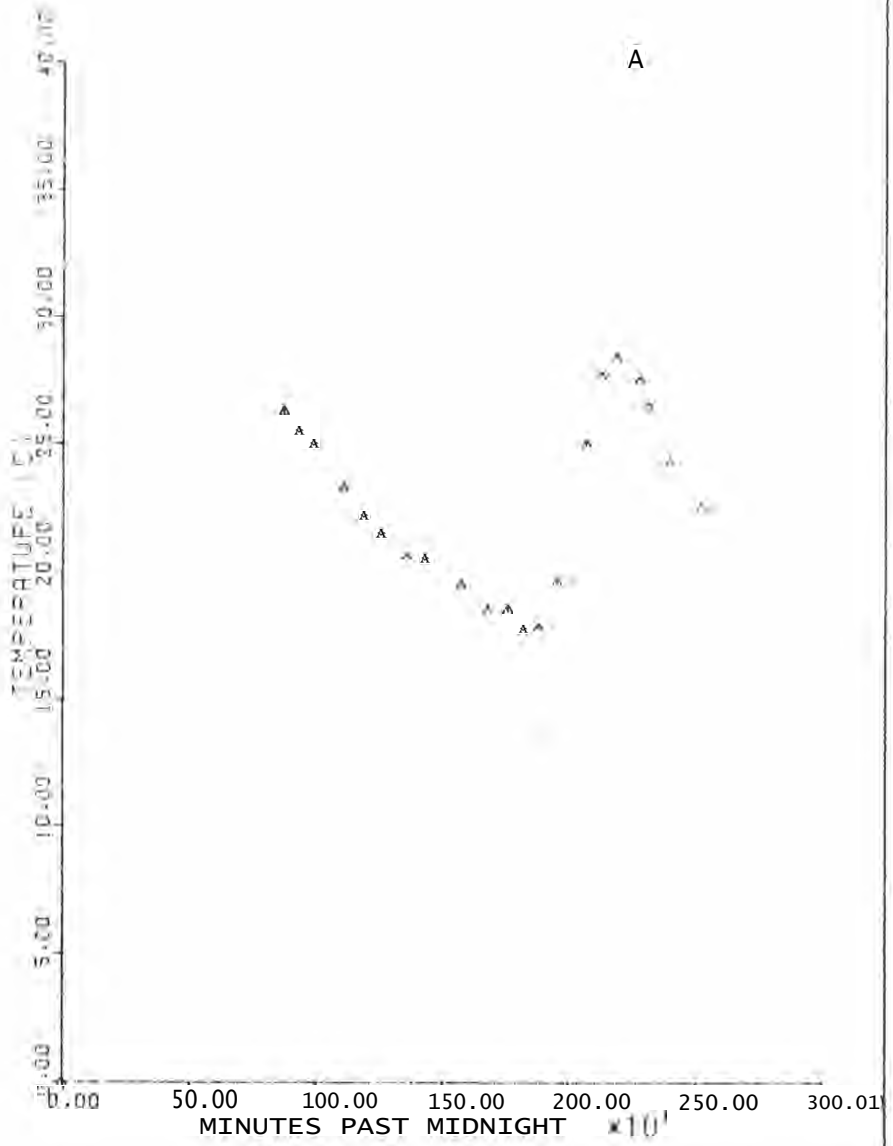
slightly more than 12.0 C in daytime (Fig.16B). Also unusual are data for 23 April (Fig.16F), recording the least variation observed in temperatures of the stream in a single day, and reflecting total cloud cover and high humidities (see also Table 1).

Table 1. Rates of heating and cooling of water in Aravaipa Creek, Graham and Pinal counties, Arizona; °C/minute X 10^{-2}.

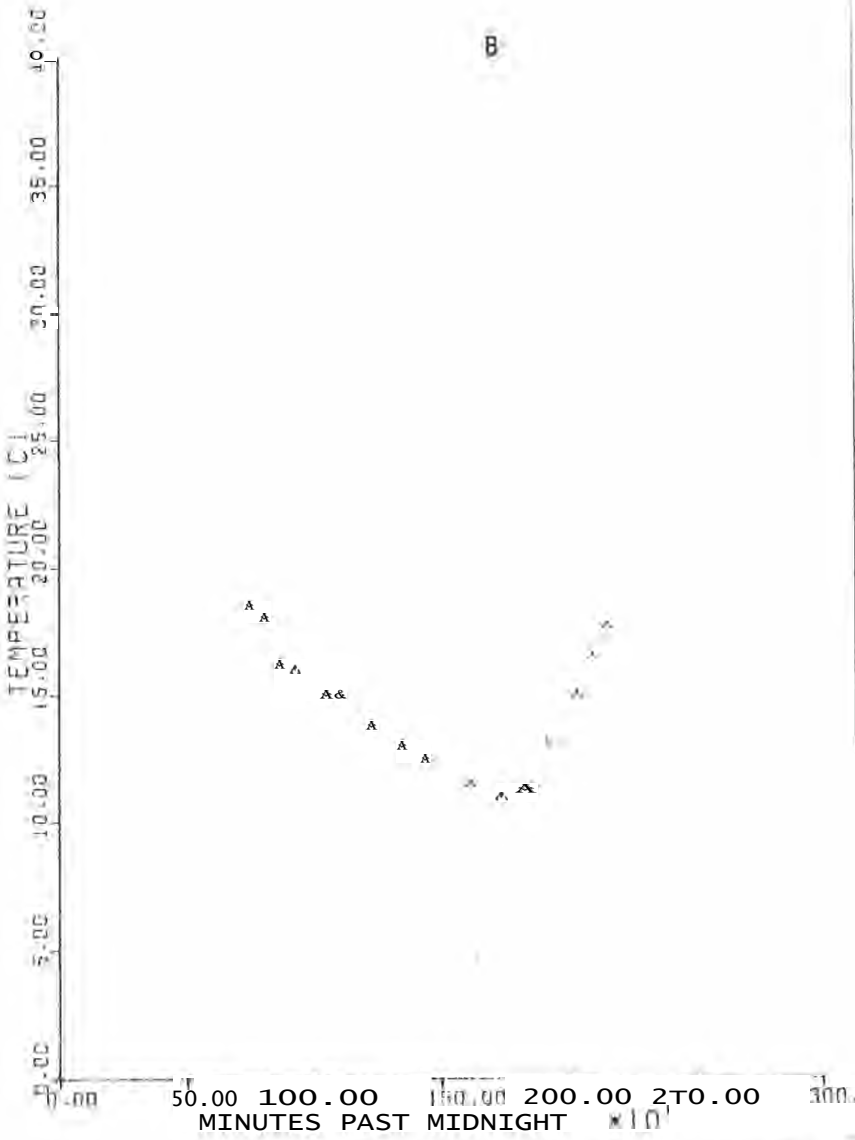
Upper Stations 1/			Lower Stations 2/		
Dates	Heating	Cooling	Dates	Heating	Cooling
760809	2.97	1.06			
			761023	1.90	0.79
761119	2.14	0.71	761120	1.95	0.84
770111	1.83	0.39	770115	1.74	0.74
			770119	2.74	1.17
770218	1.94	0.67			
770316 2/	1.23	0.55	770318	1.88	0.97
770422 2/	0.83-	0.43	770423 2/	0.54	0.28
770606	1.90	0.79	770607-	1.56	0.81

1/Elevations 3,090 to 3,300 feet above mean sea level (942-1,006 m).
2/Elevations 2,300 to 2,580 feet above mean sea level (701- 846 m).
1/Partially overcast on 770316, and fully overcast on 770422-23.

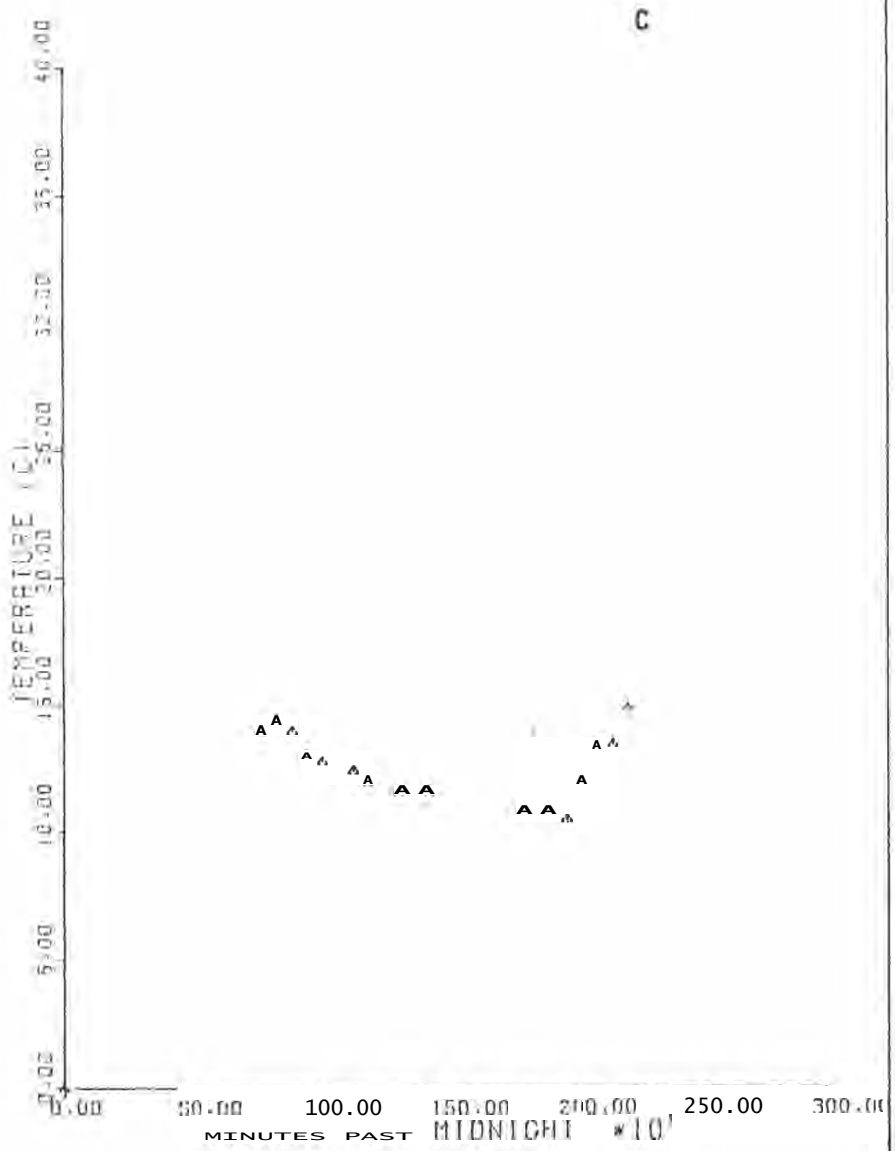
Figure 15. Long-term temperature data for upstream stations on Aravaipa Creek, Graham and Pinal counties, Arizona (pages 34 through 37).

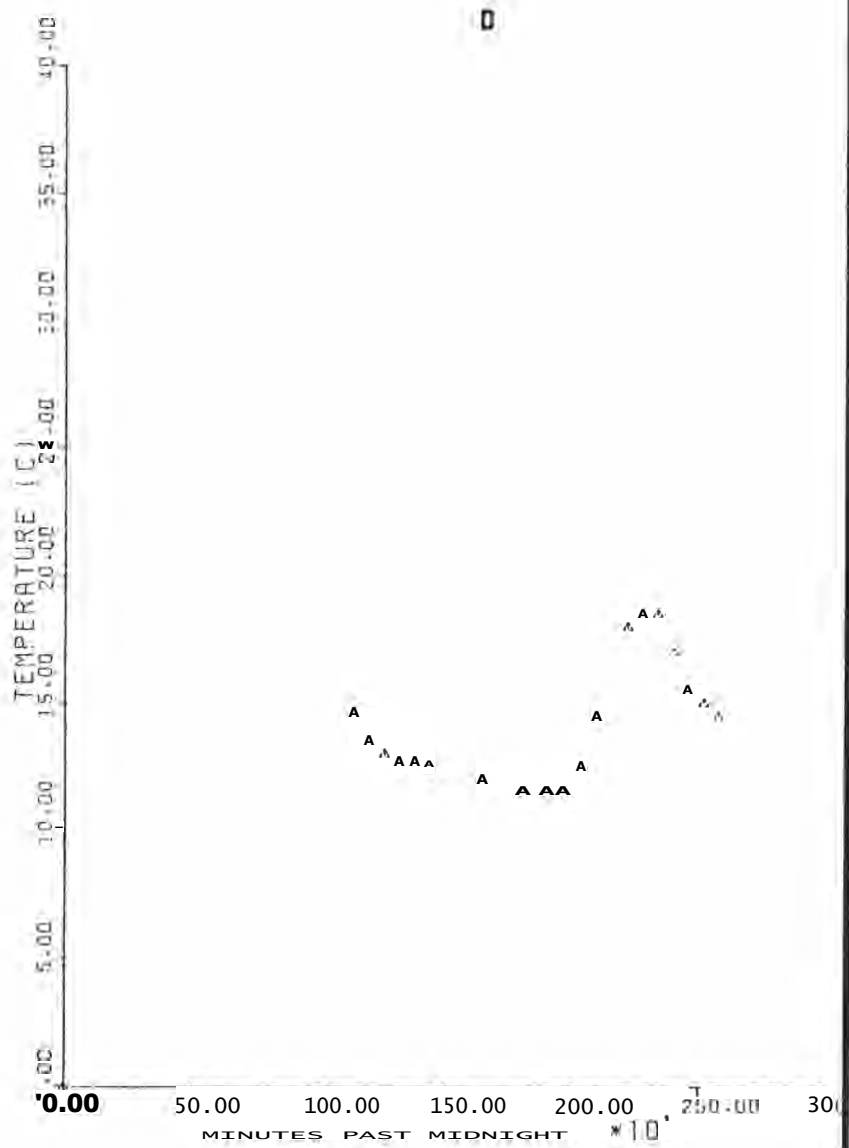


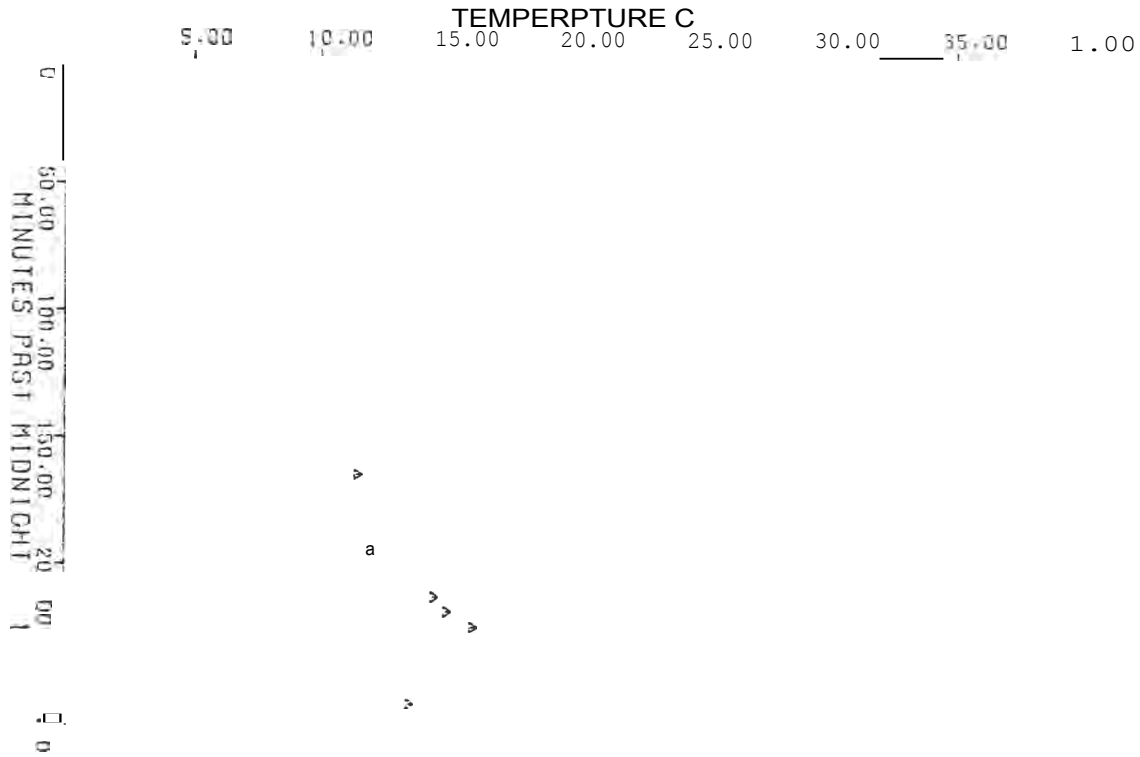
ARAVAIPA CREEK (AC3067.) 760809



ARAVAIPA CREEK (AC3150.) 761119


C
TEMPERATURE (C)
MINUTES PAST MIDNIGHT *10'
ARAVAIPA CREEK (AC3150) 770111


D
TEMPERATURE (C)
MINUTES PAST MIDNIGHT *10'
ARAVAIPA CREEK (AC3150) 770218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5.00
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MINUTES PAST MIDNIGHT
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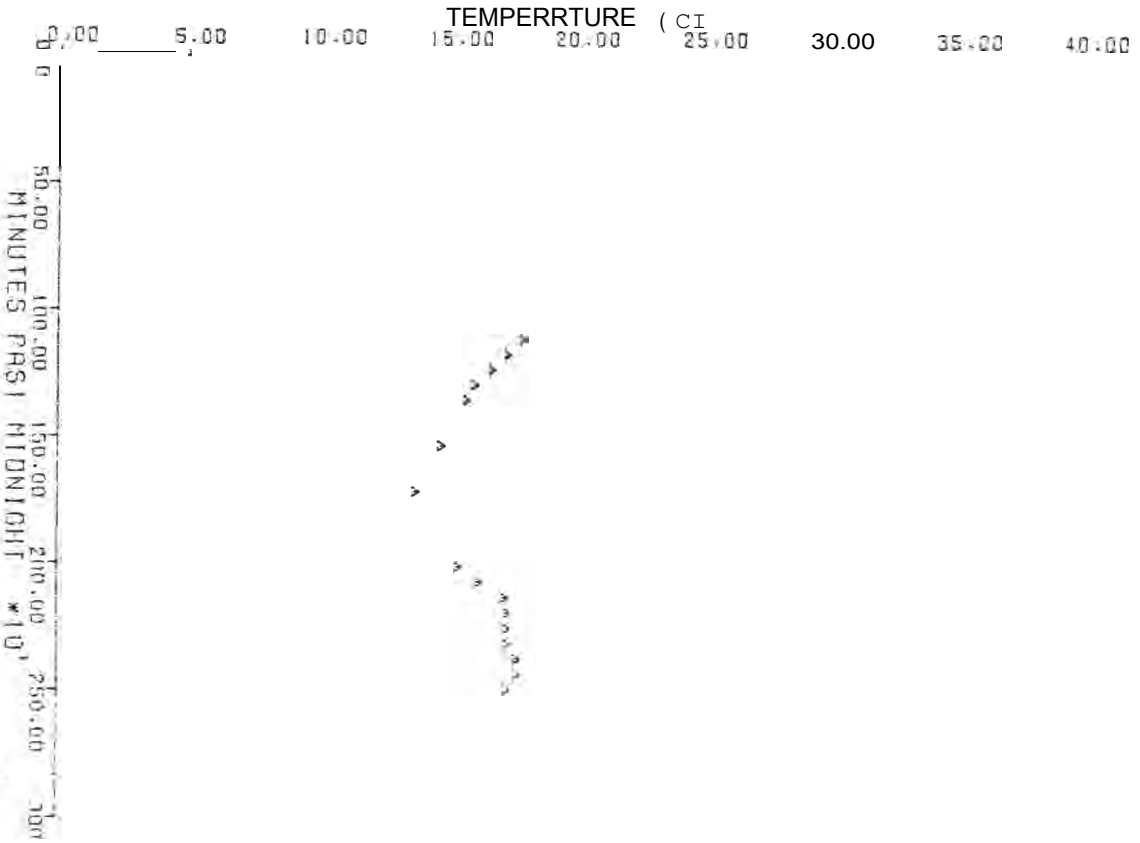
TEMPERRTURE (CI
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200.00
250.00
MINUTES PAST MIDNIGHT *10'

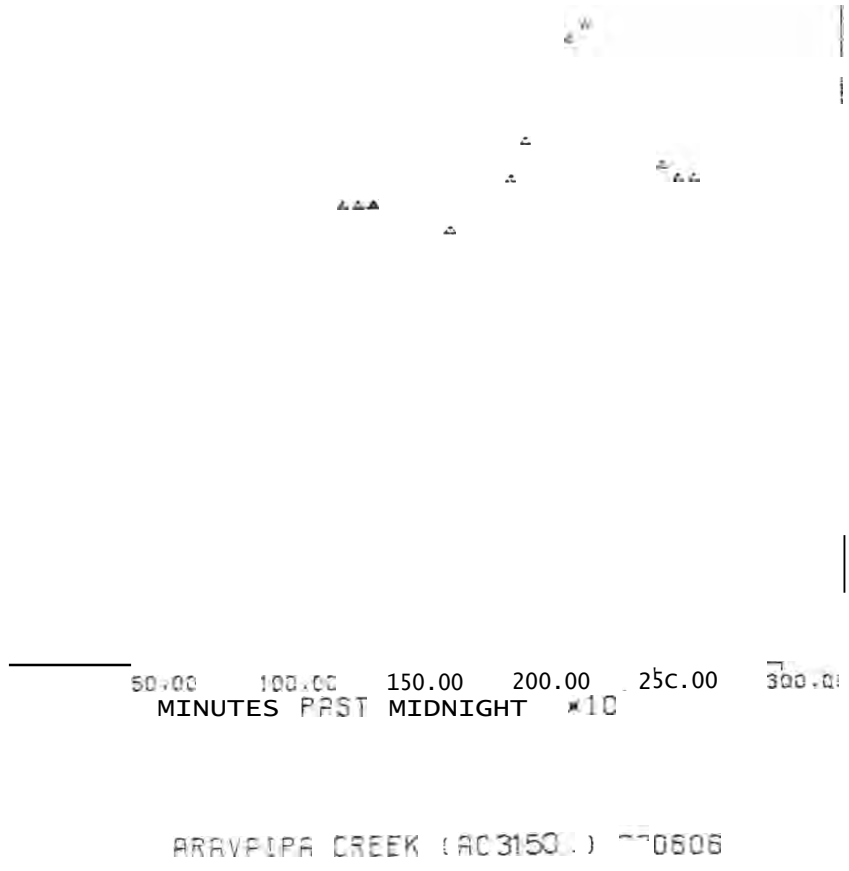
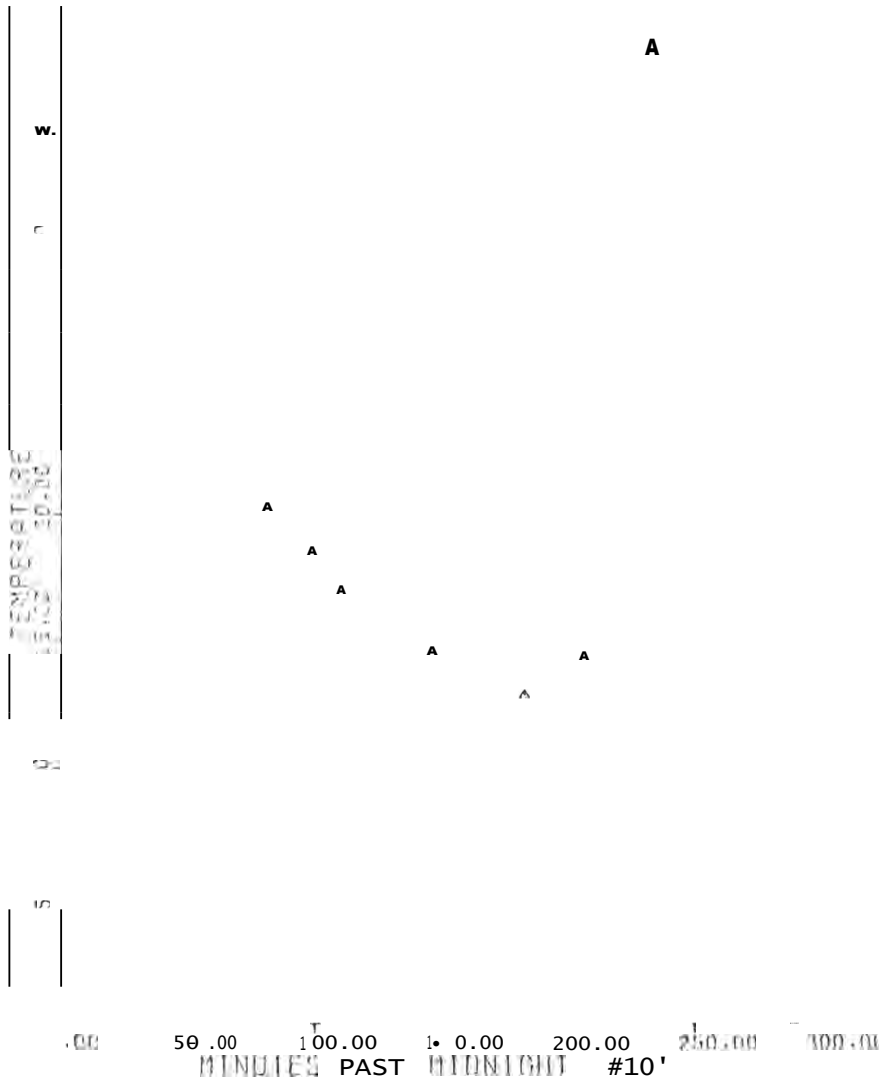
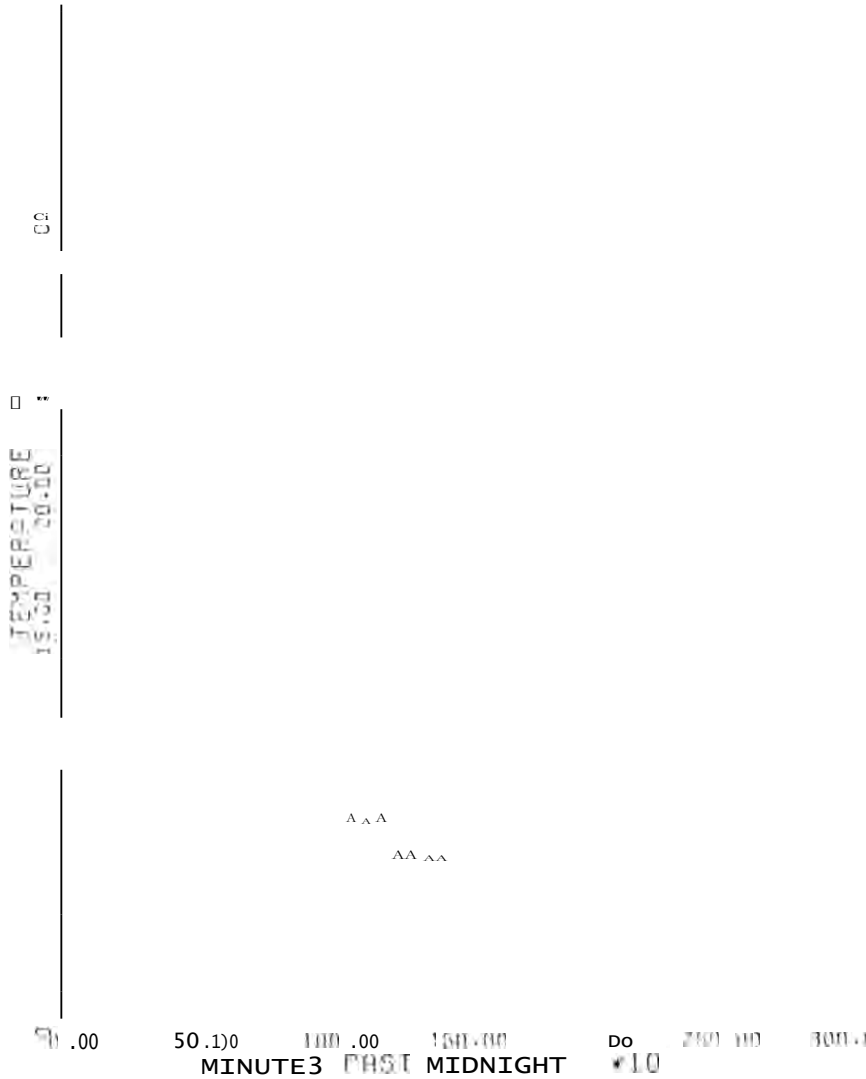
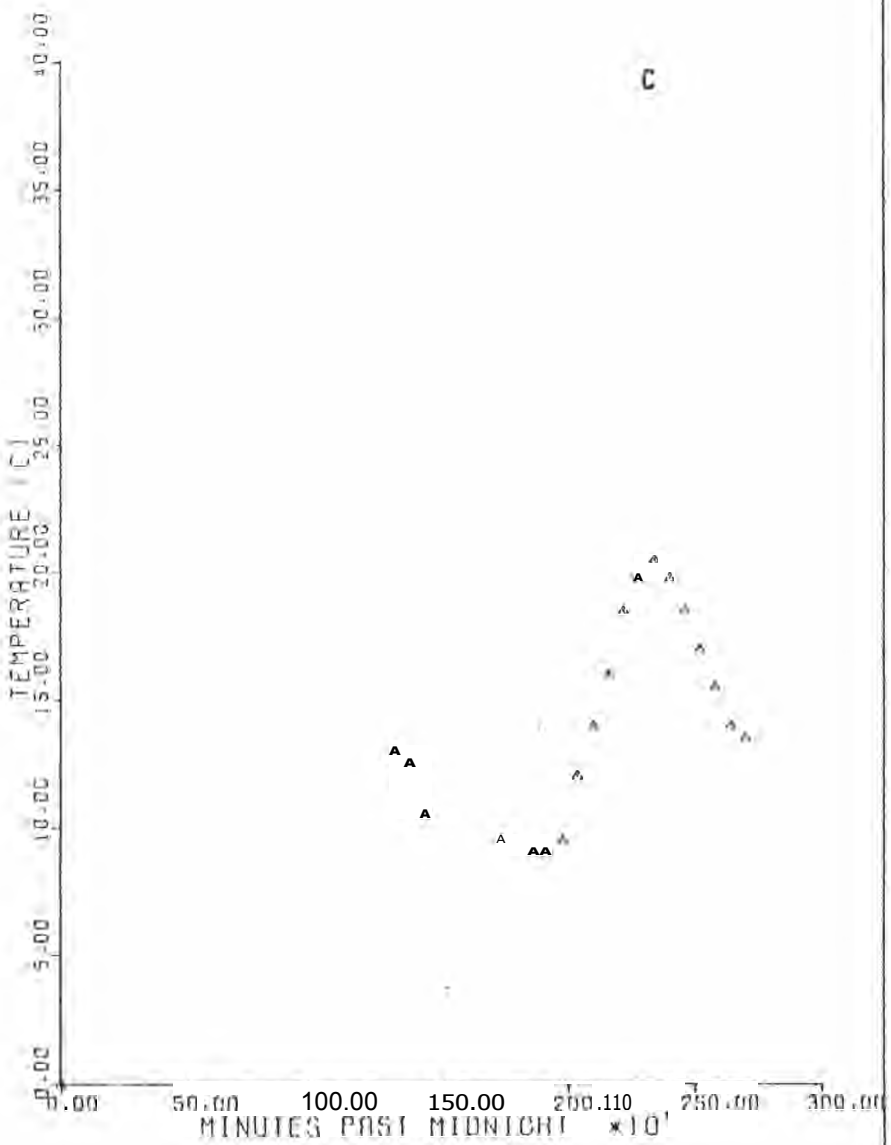

50.00
100.00
150.00
200.00
250.00
300.00
MINUTES PAST MIDNIGHT *10
ARRAYPIPA CREEK (AC3150..) 770606

Figure 16. Long-term temperature data for downstream stations on Aravaipa Creek, Graham and Pinal counties, Arizona. (pages 39 through 42).

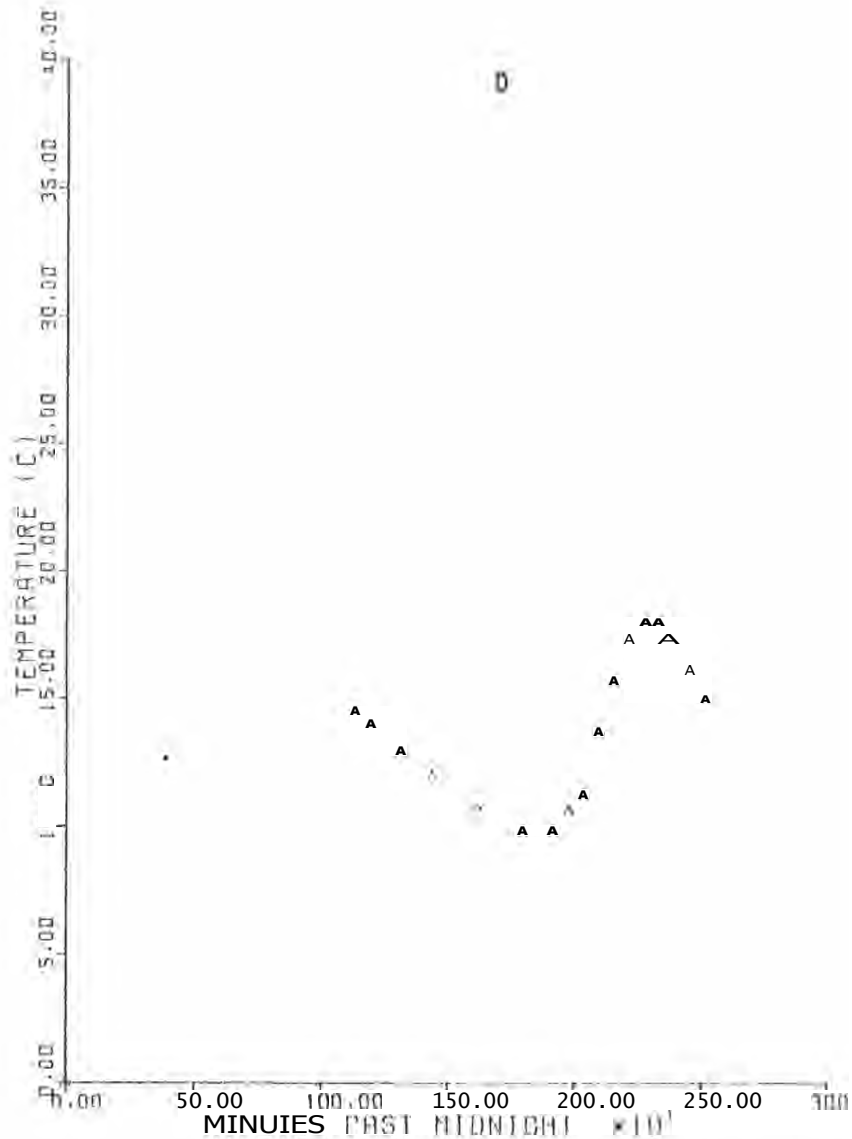
SRP10784


TEMPERATURE
MINUTES PAST MIDNIGHT #10'
ARAVAIPA [REEK (AC2550.1 761023

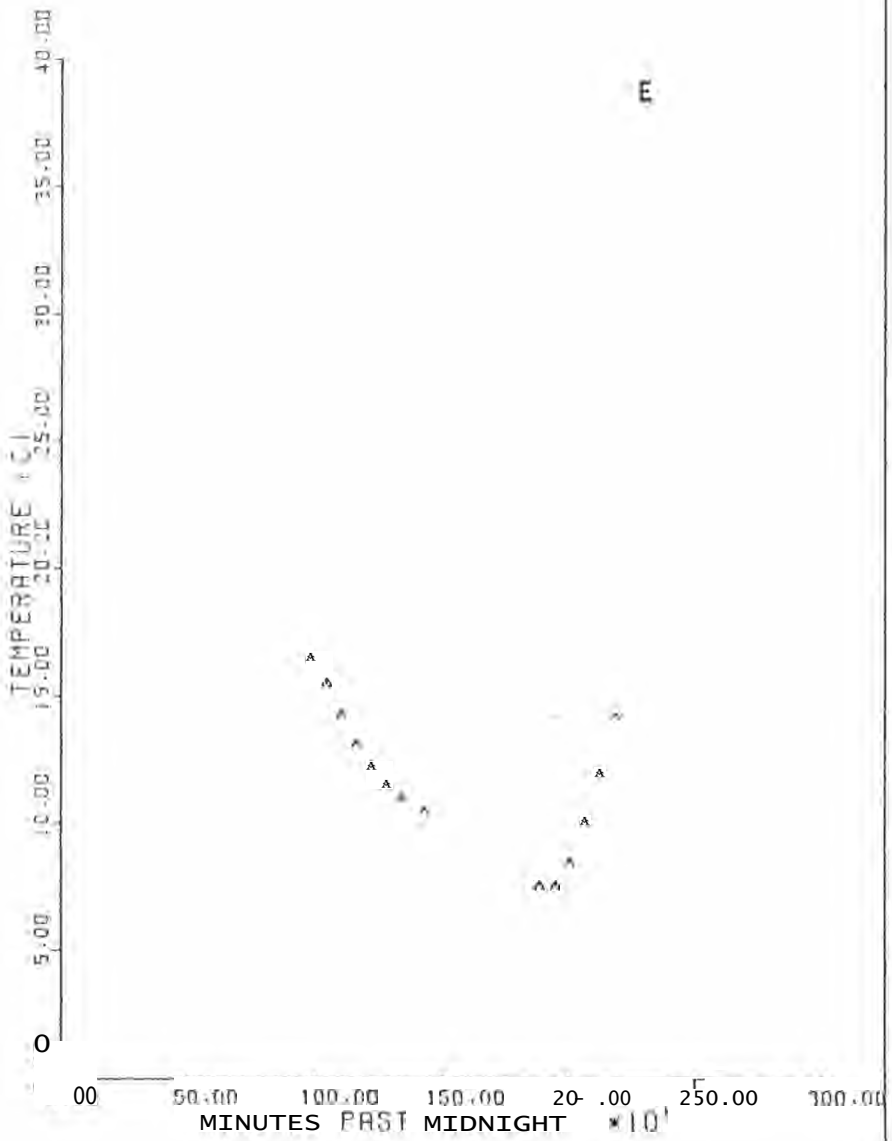

TEMPERATURE
MINUTE3 PAST MIDNIGHT
ARAVAIPA CREEK (AC2550.1 770115



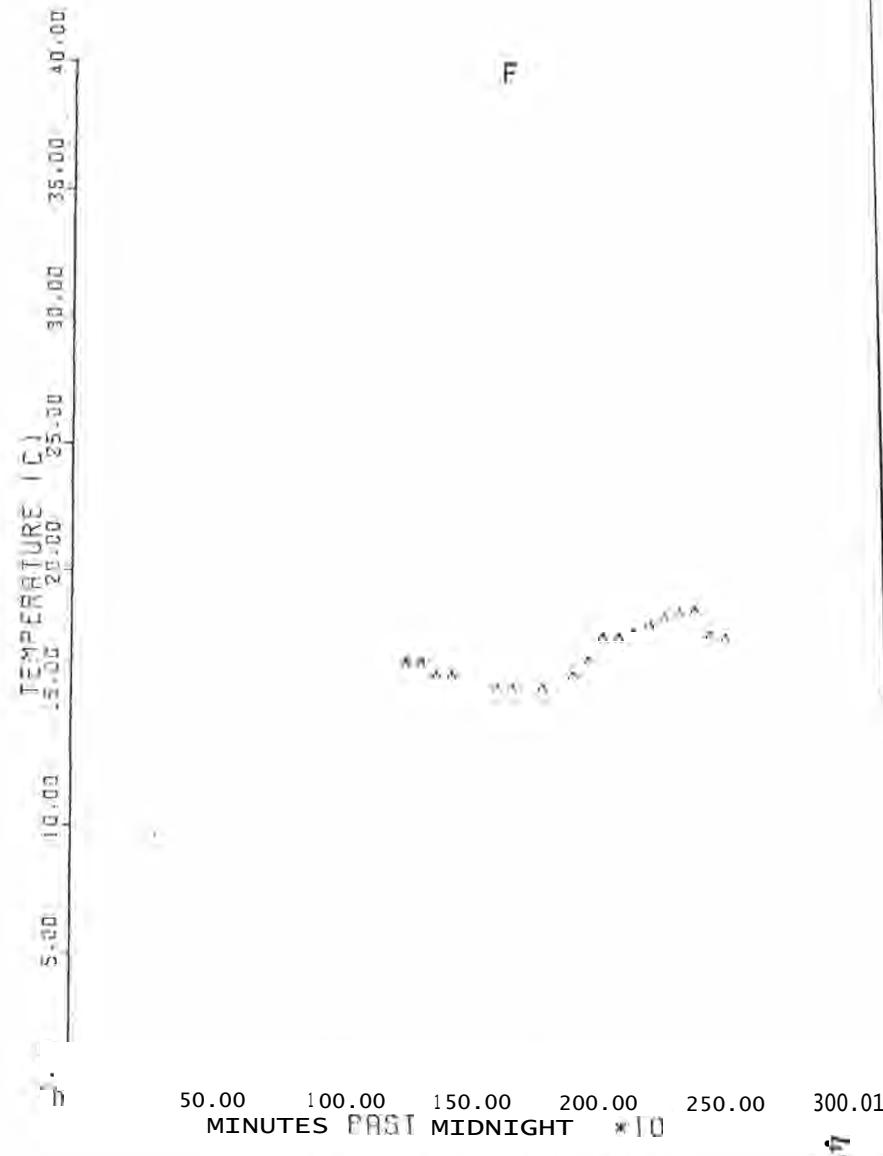
ARAVA PA CREEK (AC2320-) 770119



ARAVAIPA CREEK (AC2320-) 761120



ARAVAIPA GREEK (AC2600) 770318



ARAVAIPA CREEK (AC2600.) 770423

TEMPERATURE (C)
0.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00
40.00
50.00
MINUT
.0
S
S
MIDNIGHT
200.00
250.00
SRAVAIPA
E3
AC2550 770607

Specific Conductance

Specific conductance, as µmhos/cm corrected to 25.0° C is a measure of total dissolved solids in water. Values in Aravaipa Creek generally ranged between 400 and 500 µmhos/cm. During spates, as in August (Table 2), dilution is effected. In periods of low discharge, and generally in summer, specific conductance increased from up- to downstream (November and June; Table 2). However, in winter when tributaries were flowing and evapotranspiration was minimal, conductance decreased up- to downstream or remained relatively uniform throughout the system.

Some variations in conductance appear diel in nature, especially at downstream stations, and presumably reflect evapotranspiration during daylight hours. Another factor may be daytime deposition of calcium salts (as travertine), which reduces ions slightly and may be detected by conductance measurements (see later). Additional work is planned on this phenomenon.

Table 2. Specific conductance (in µmhos/cm corrected to 25.0° C) of water in Aravaipa Creek, Graham and Pinal counties, Arizona; means are followed by two standard errors.

Upper Stations 1/			Lower Stations 2/		
Dates		Values	Dates		Values
760809	21	395±5.6			
761119	17	43813.0	761120	17	475+3.8
770111	17	478+7.0	770115	19	436+4.6
			770119	20	467+7.2
770218	19	459±3.4	- -		
770316	19	449±4.0	770318	14	443+9.6
770422	18	405±8.2	770423	18	406±5.8
770606	12	428±13.4	770607	18	459±5.0

1/Elevations 3,090 to 3,300 feet above mean sea level (942-1,006 m).
2/Elevations 2,300. to 2,580 feet above mean sea level (701- 846 m).

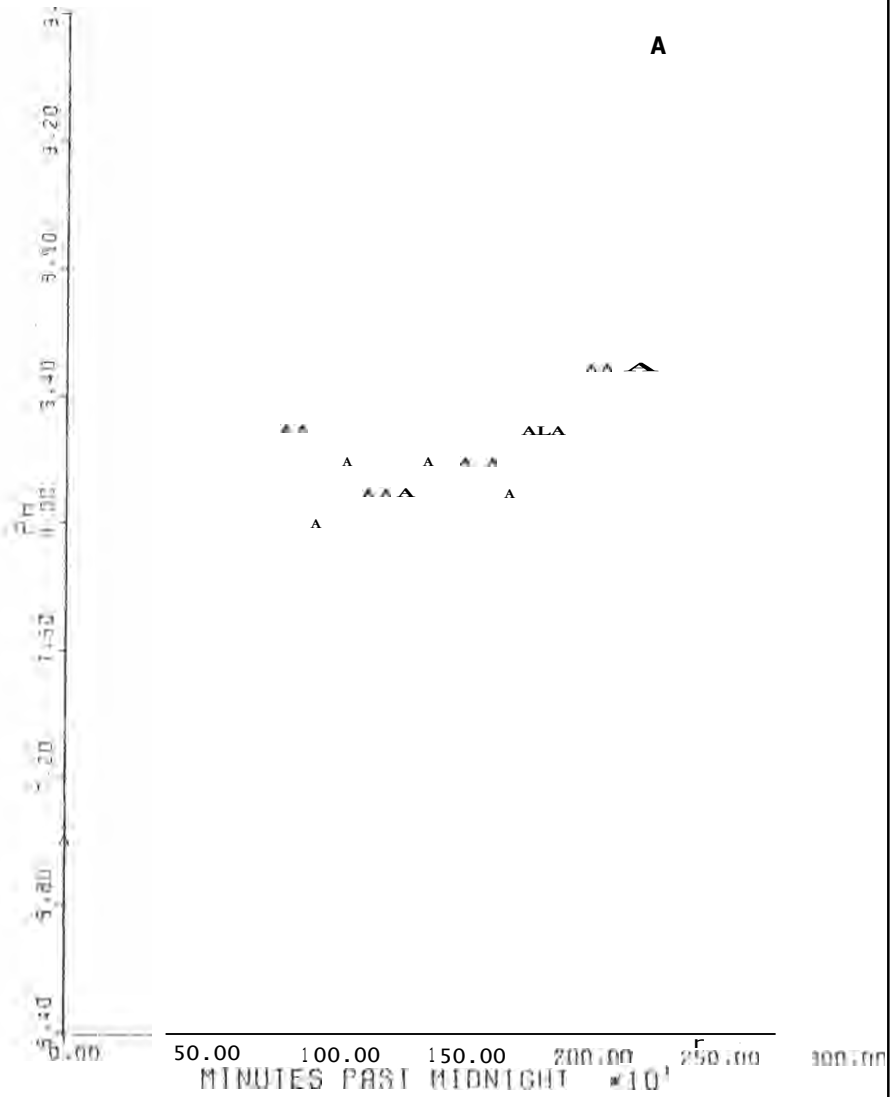
Hydrogen Ion Concentration (pH)

Aravaipa Creek waters are alkaline, rarely falling below pH 7.6 at upstream stations, and pH 8.0 downstream (Figs.17-18). In buffered systems of high total dissolved solids, as in Aravaipa Creek waters, photosynthetic activities of algae and higher plants may utilize all free carbon dioxide (CO_2) and then depend upon "half-bound" CO_2 that is gathered from bicarbonate ions. This results in an elevation of pH and precipitation of calcium carbonate as travertine at levels higher than pH 8.3. Nighttime periods of no photosynthesis allow accumulation of respiratory CO_2 in water, or maintenance of levels carried into the system by underground flow, and pH is lowered.

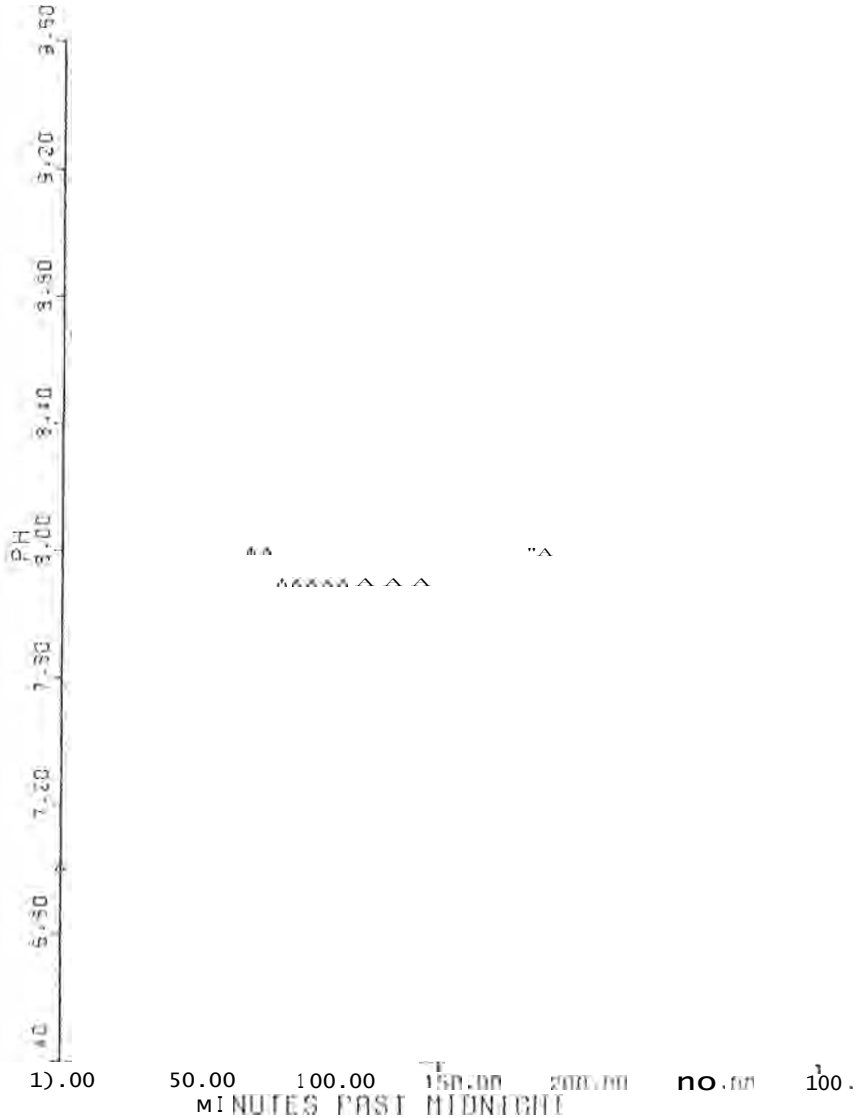
The most erratic data on pH in Aravaipa Creek are from a small spate in August (Fig.17A), and the least variable was obtained in October and November, down- and upstream, respectively, during a time when algae and aquatic plants were scarce as a result of flooding (Figs. 18A and 17B, respectively). At upstream stations, pH varied 0.3 units in January, 0.5 units in February, more than 0.7 in March, and 0.4 in April and June. The pH level of 8.3 was exceeded only in March (Fig. 17E).

Downstream, 0 dropped below 8.3 only in April and June, and ranged upward to 9.0 in most months (Figs.18B-G). Free carbon dioxide was therefore scarcely available, and it is notable that the green alga Cladophora, typical of hard water streams and capable of using half-bound CO_2 exclusively, was common. Deposition of small nodules of travertine was extensive, associated with colonies of the green alga Gongrosira, and carbonate-encrusted Chara spp. was locally common.

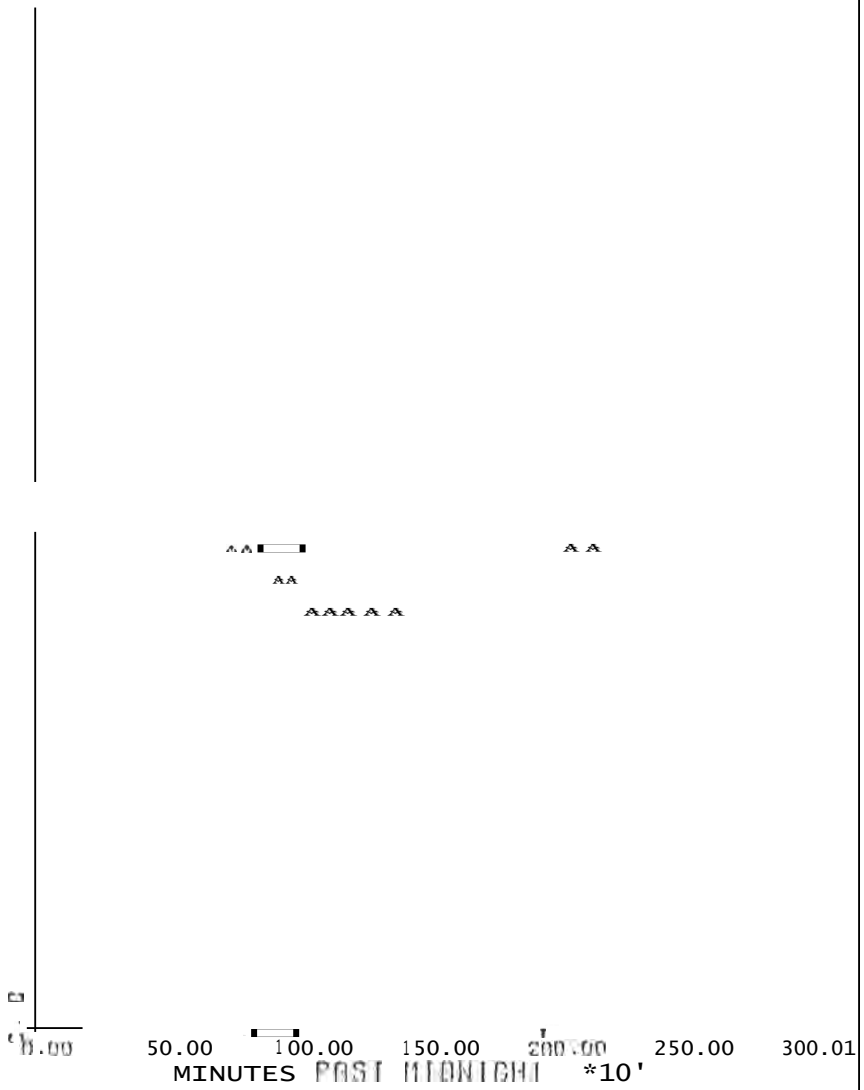
Figure 17. Long-term 2H data for upstream stations on Aravaipa Creek, Graham and Pinal counties, Arizona (pages 47 through 50).



ARAVAIPA CREEK (AC3067.1 760809



ARAVAIPA CREEK (AC3150.1 761119



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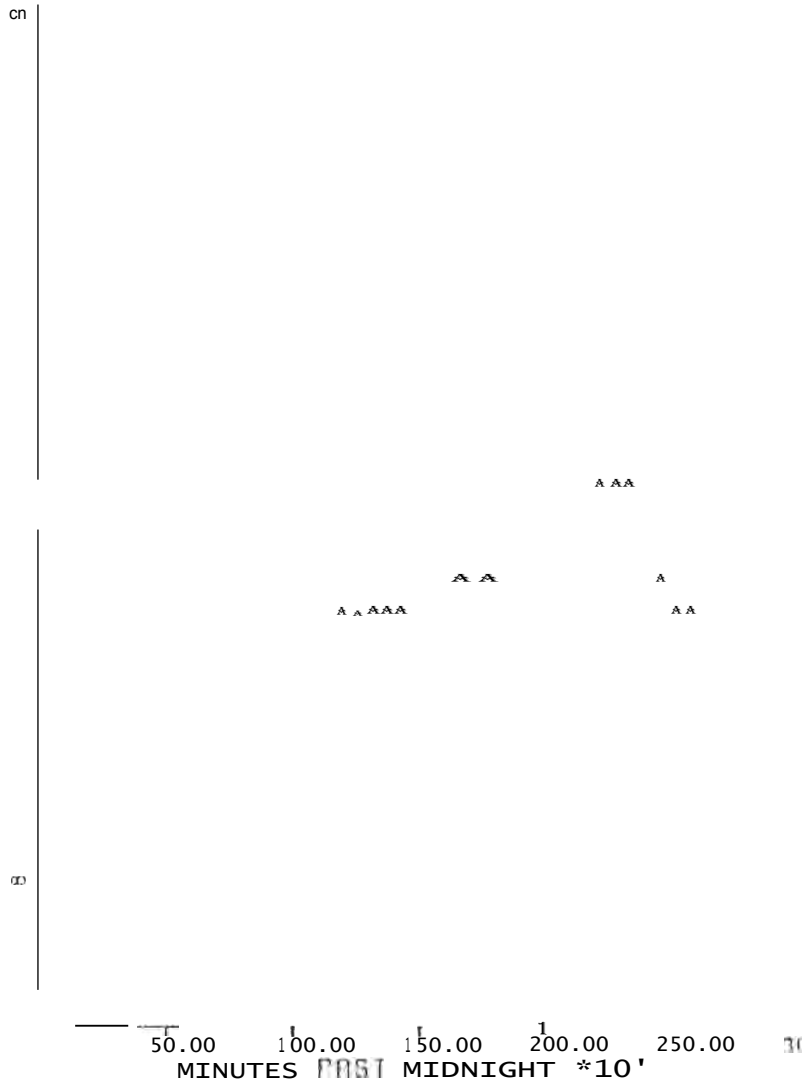

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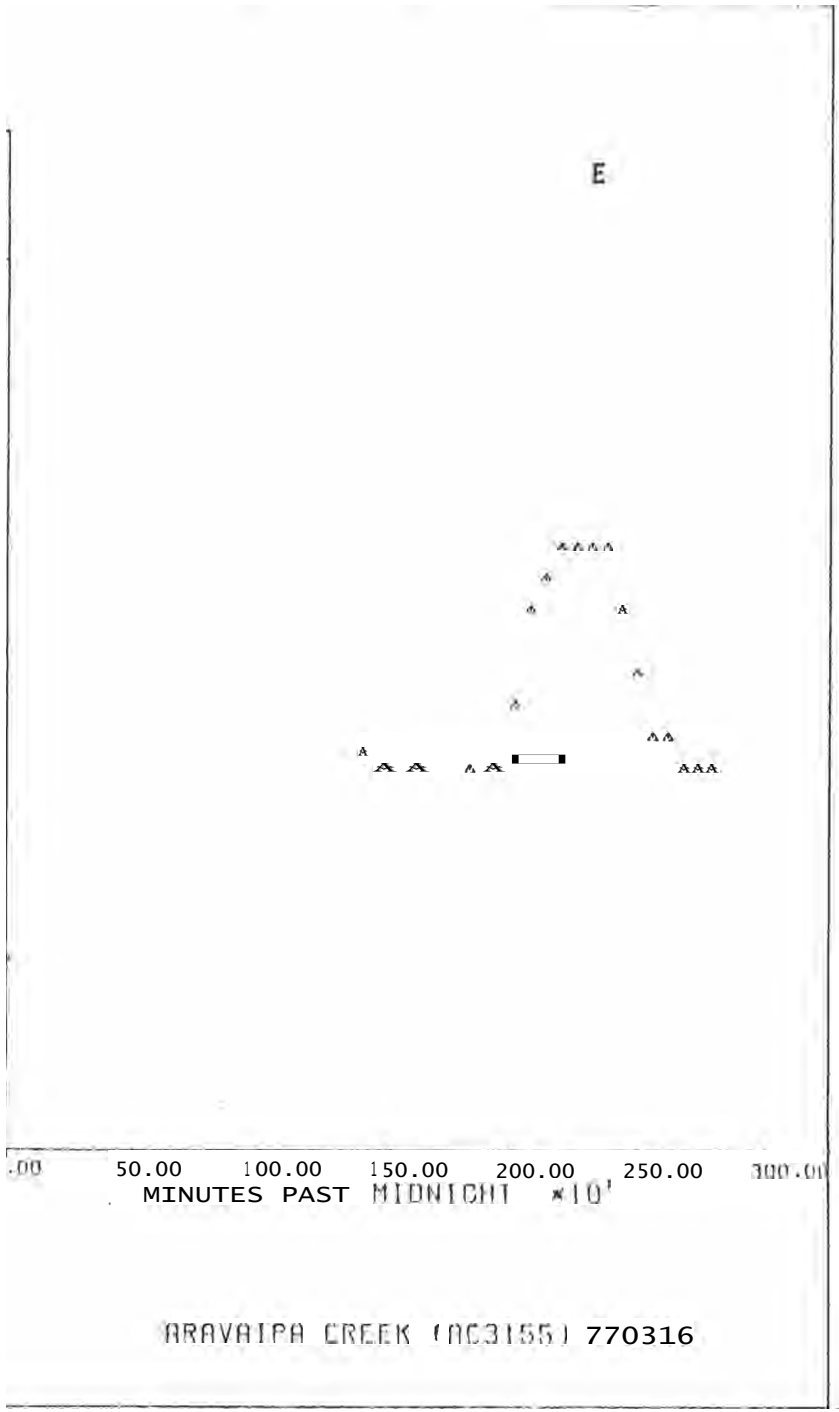
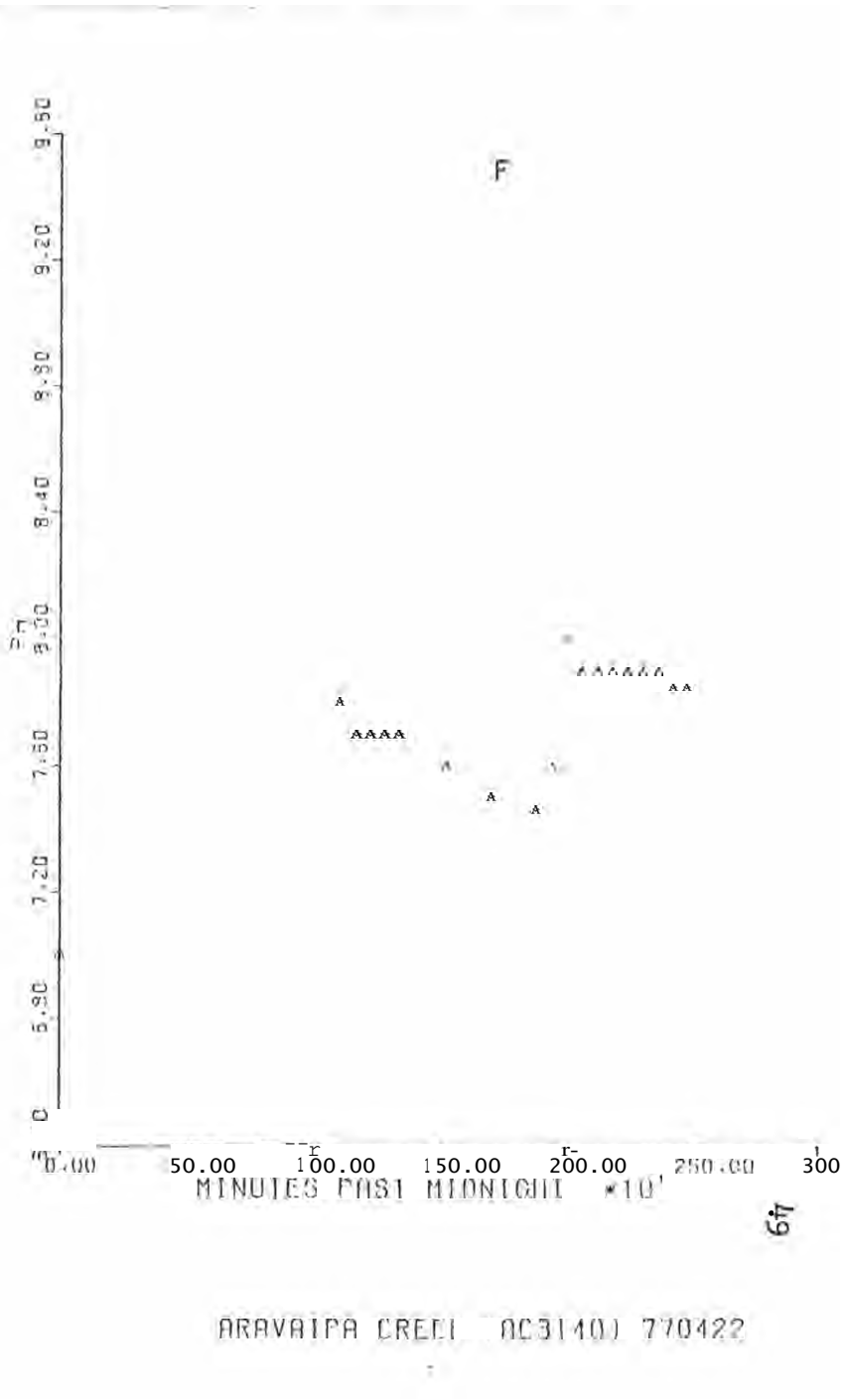
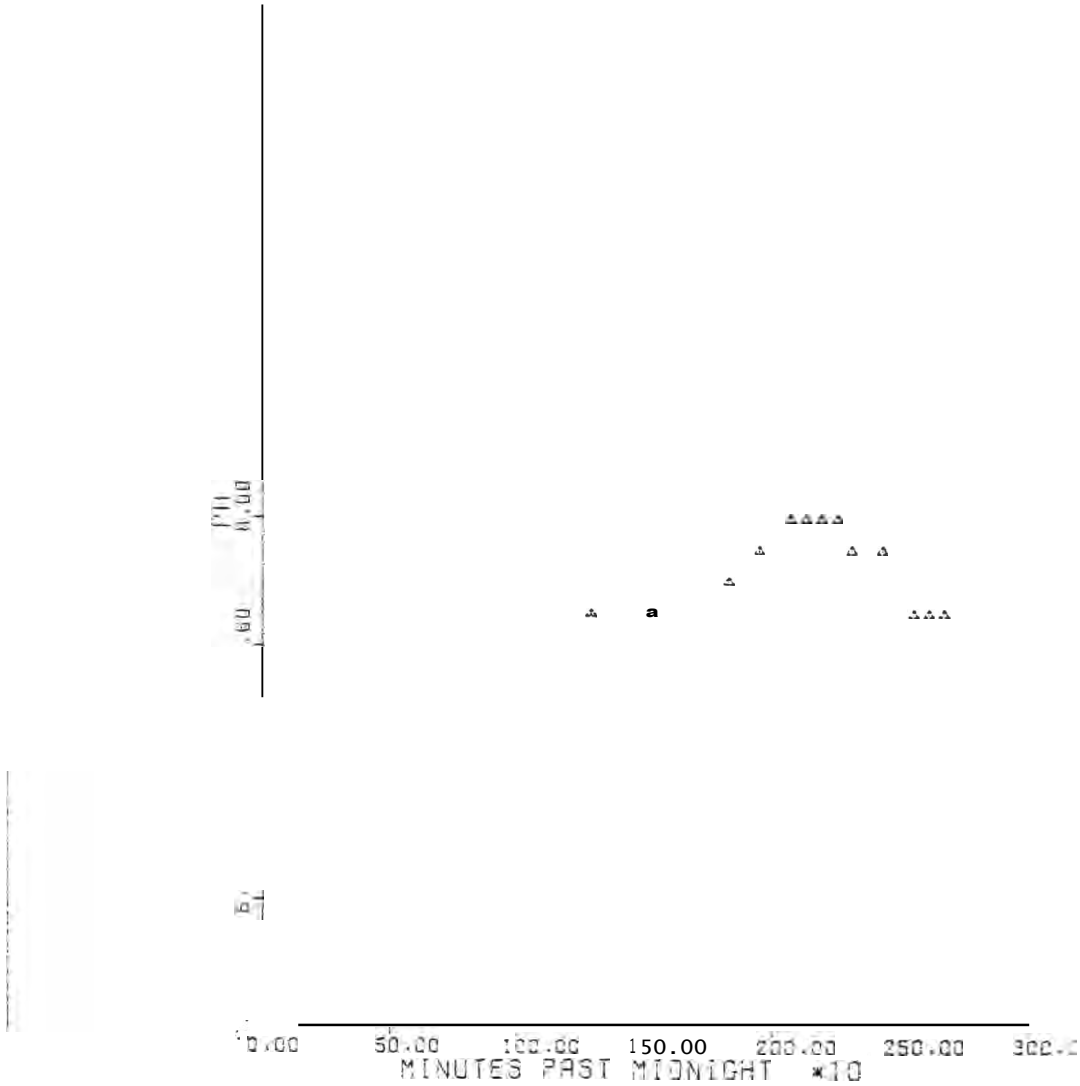
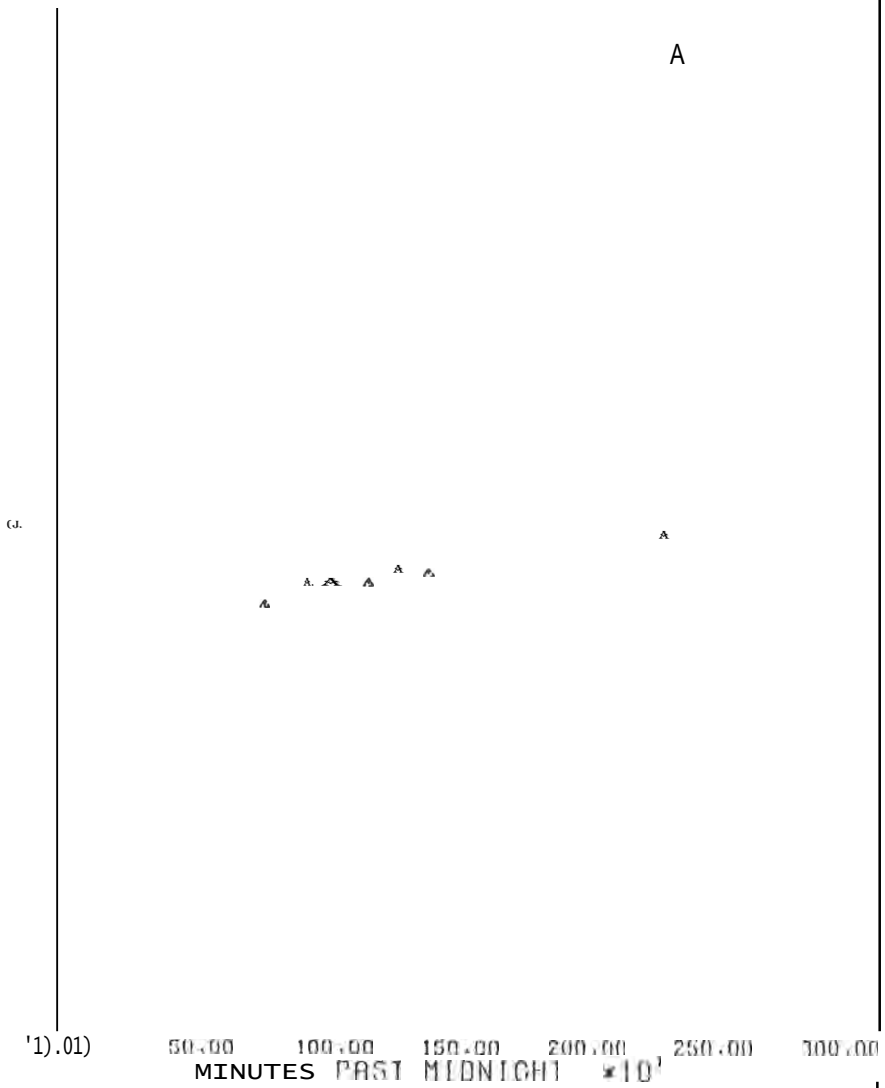

E
.00
50.00
100.00
150.00
200.00
250.00
300.00
MINUTES PAST MIDNIGHT *10'
ARAVAIPA CREEK (AC3155) 770316


F
9.60
9.20
8.80
8.40
8.00
7.60
7.20
6.80
0
50.00
100.00
150.00
200.00
250.00
300
MINUTES PAST MIDNIGHT *10'
ARAVAIPA CREEK (AC3140) 770422

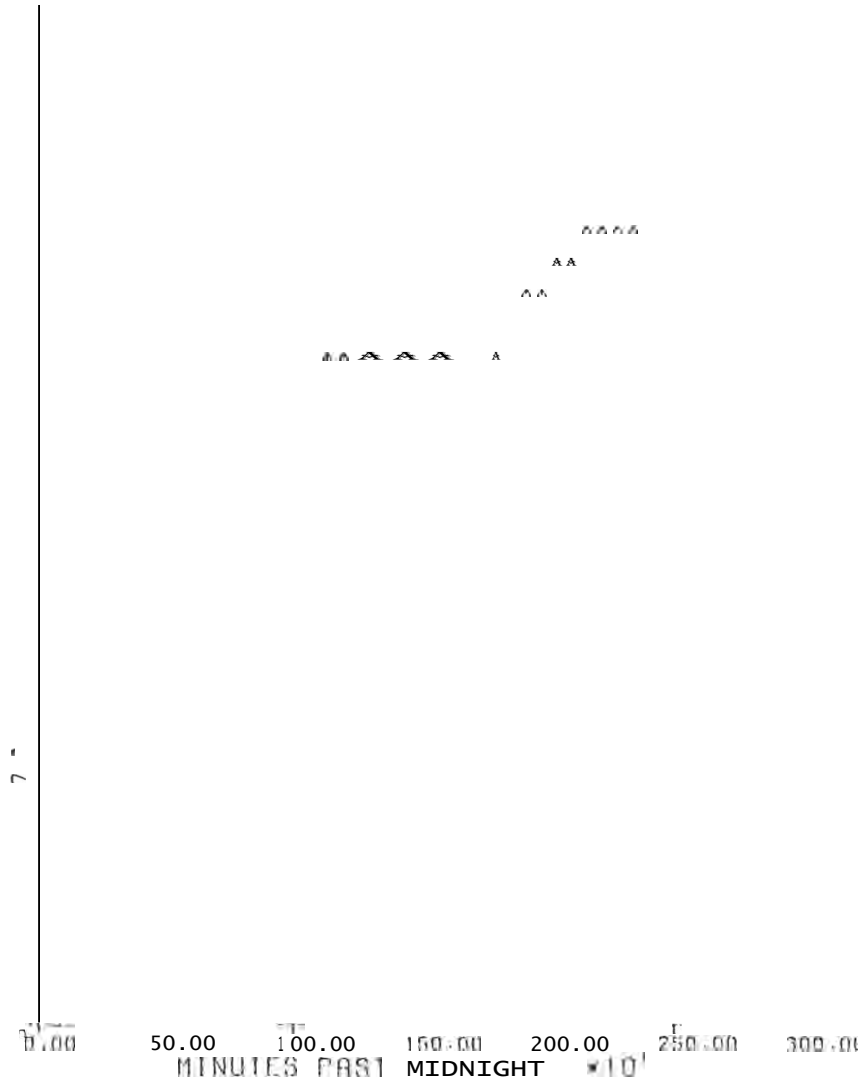


ARAVAIPA CREEK (AC3150 . 770606

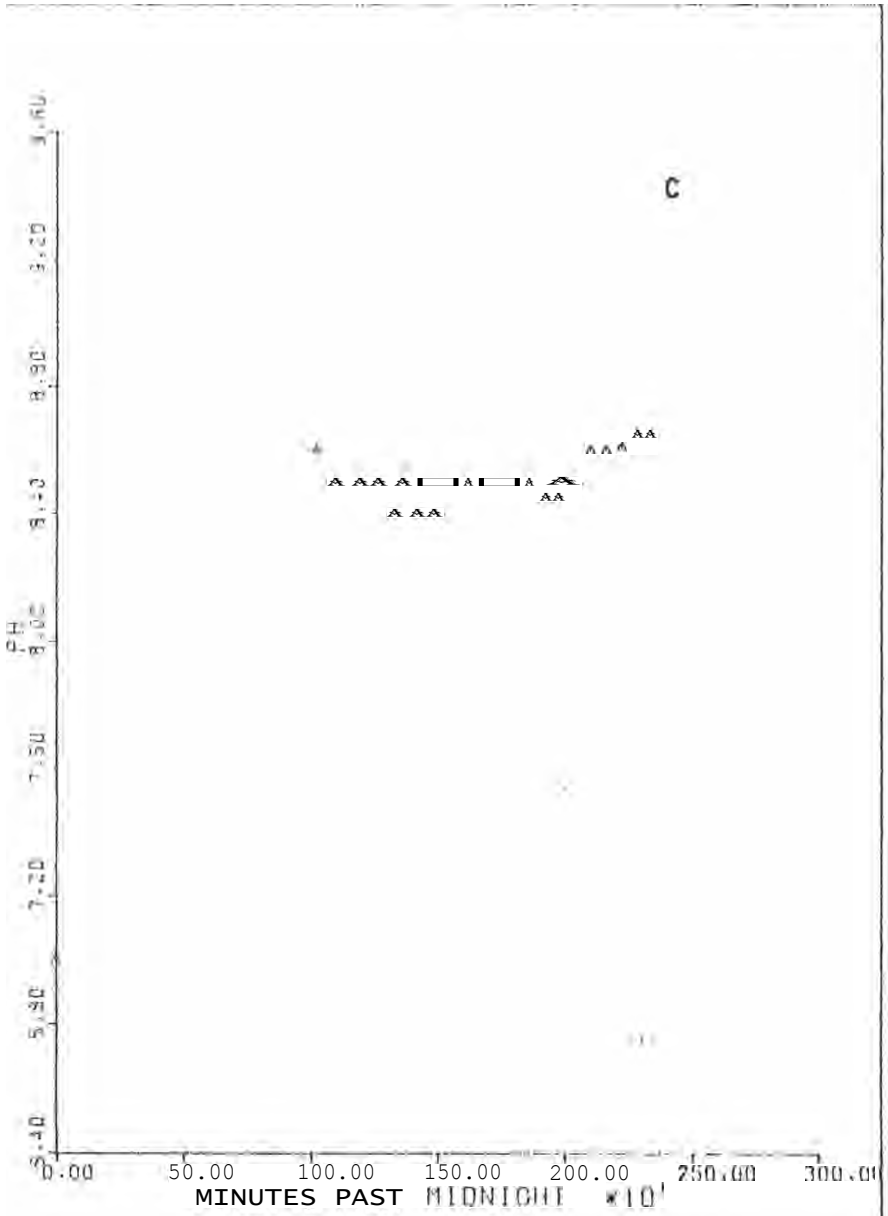
Figure 18. Long-term pH data for downstream stations on Aravaipa Creek, Graham and Pinal counties, Arizona (pages 52 through 55).



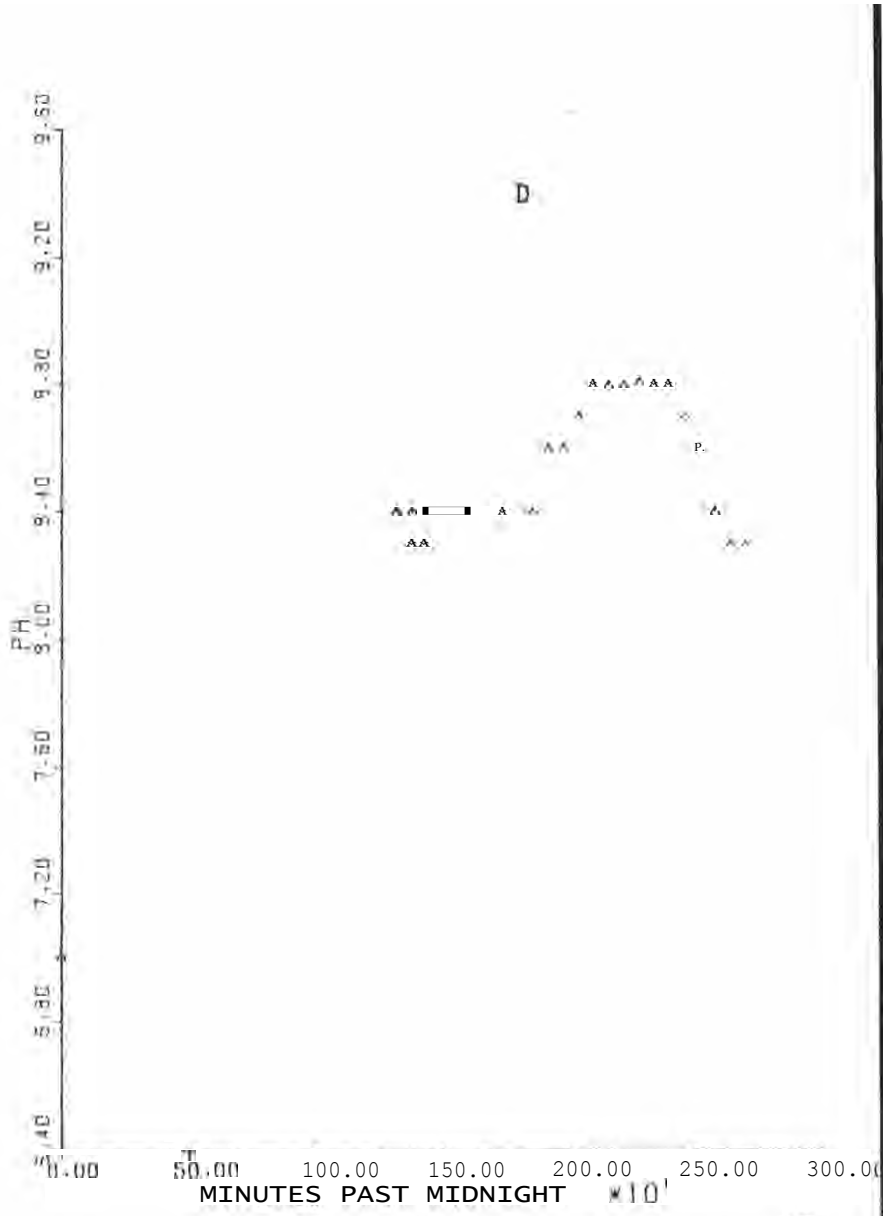
ARAVAIPA CREEK (AC2550.) 761023



ARAVAIPA CREEK (AC2320.) 761120

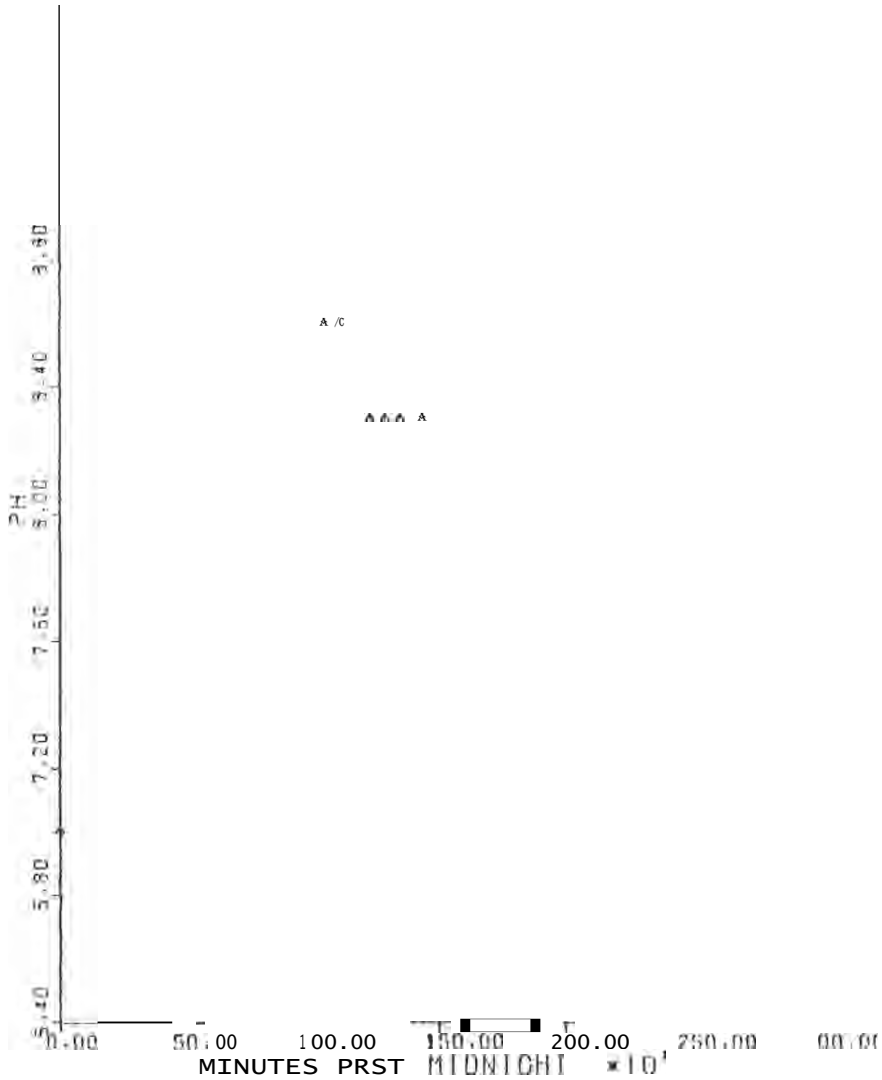


ARAVAIPA CREEK (AC2550.) 770115

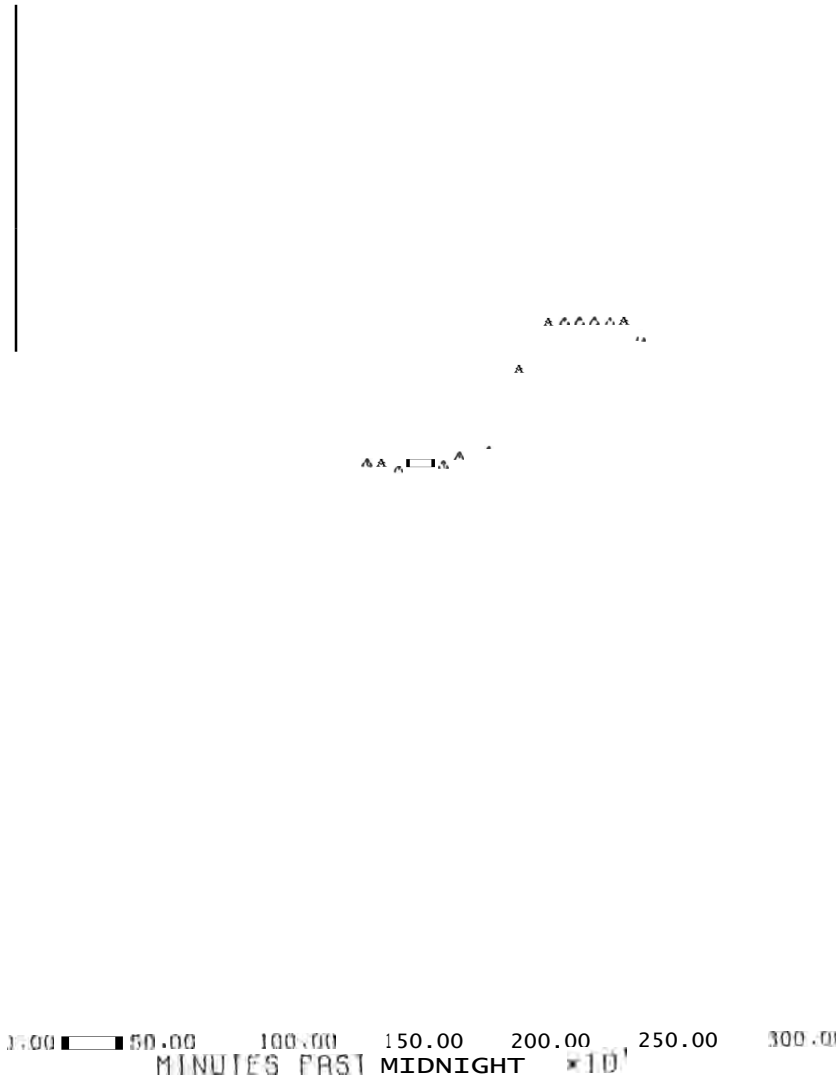


ARAVAIPA CREEK (AC2320.) 770119

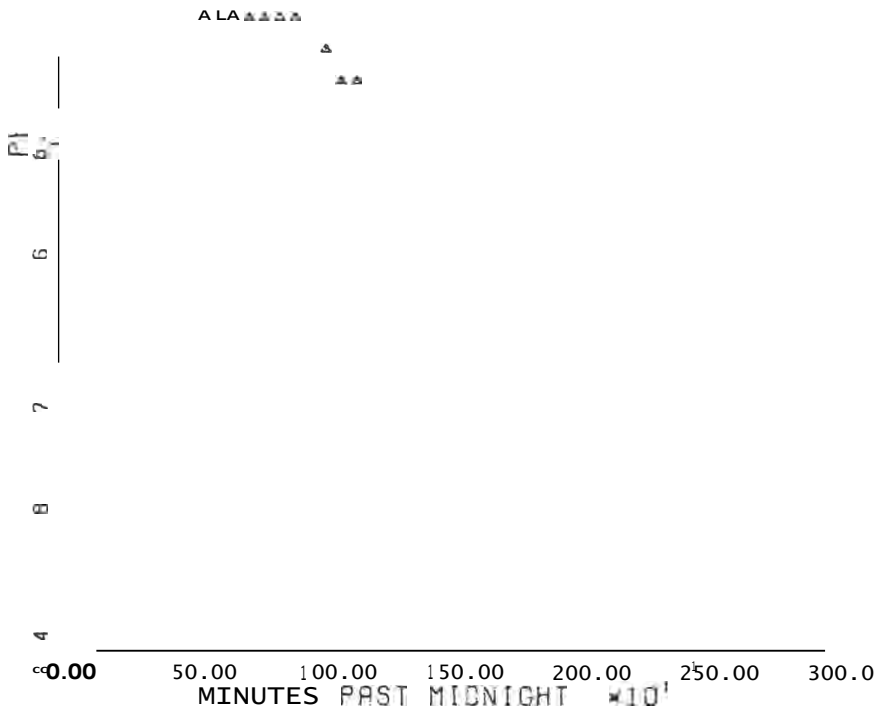
SRP10799



ARAVAIPA CREEK (AC2600.) 770318



ARAVAIPA CREEK (AC2600.) 770423



ARAVAIPA CREE RC25501 770507

Dissolved Oxygen

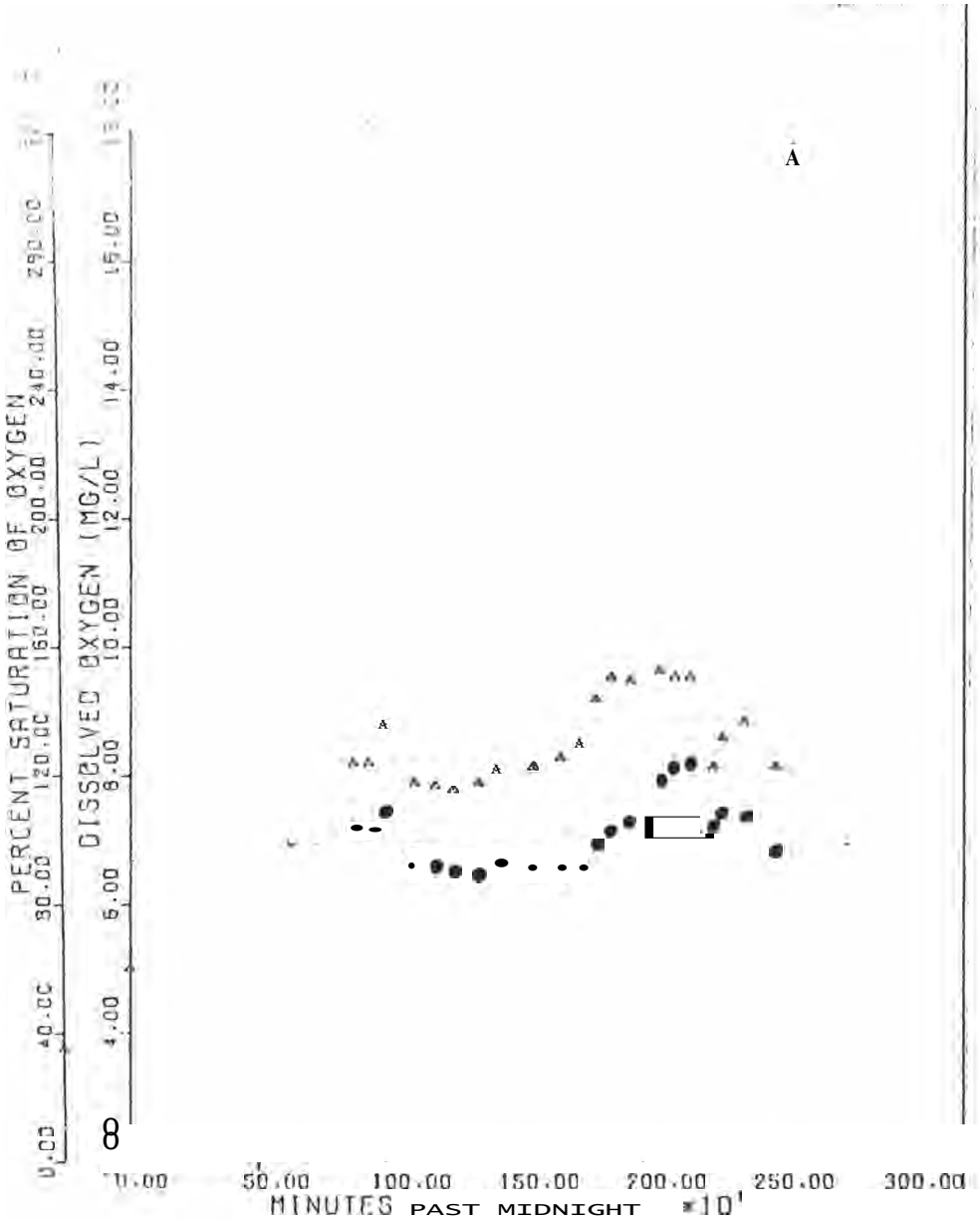
Physical features of dissolved oxygen concentrations in Aravaipa Creek are well illustrated by data for October (Fig.20A) at a downstream station and November (Fig.19B) upstream. On both those dates, oxygen concentration in mg/l varied inversely to light and positively with temperature. Percentage saturation for those data show little, if any diel variation, indicating essential balance of respiration with diffusion. Saturation in November was between 80 and 90%, which seems typical for Aravaipa Creek at most times of year. In October, however, saturation values were between 40 and 50%, unusually low and indicative of substantial respiratory loading of the system. Accumulation of fine debris, largely organic, after spates may explain the low values.

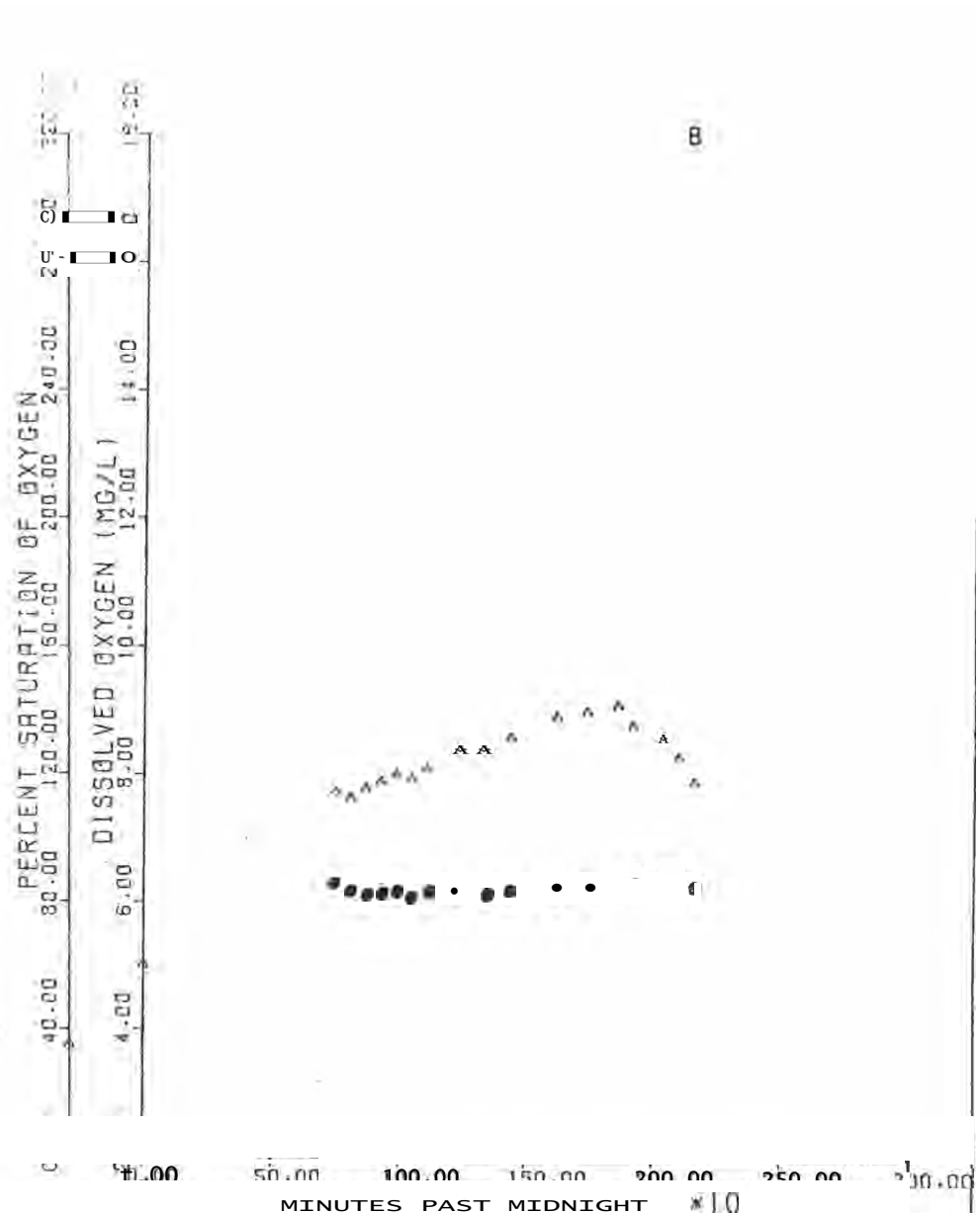
All other long-term data for dissolved oxygen indicate diurnal pulses attributable to production within the system. Even on days with total overcast (April; Figs.19F and20F), a small, but discernible, daytime pulse was in evidence.

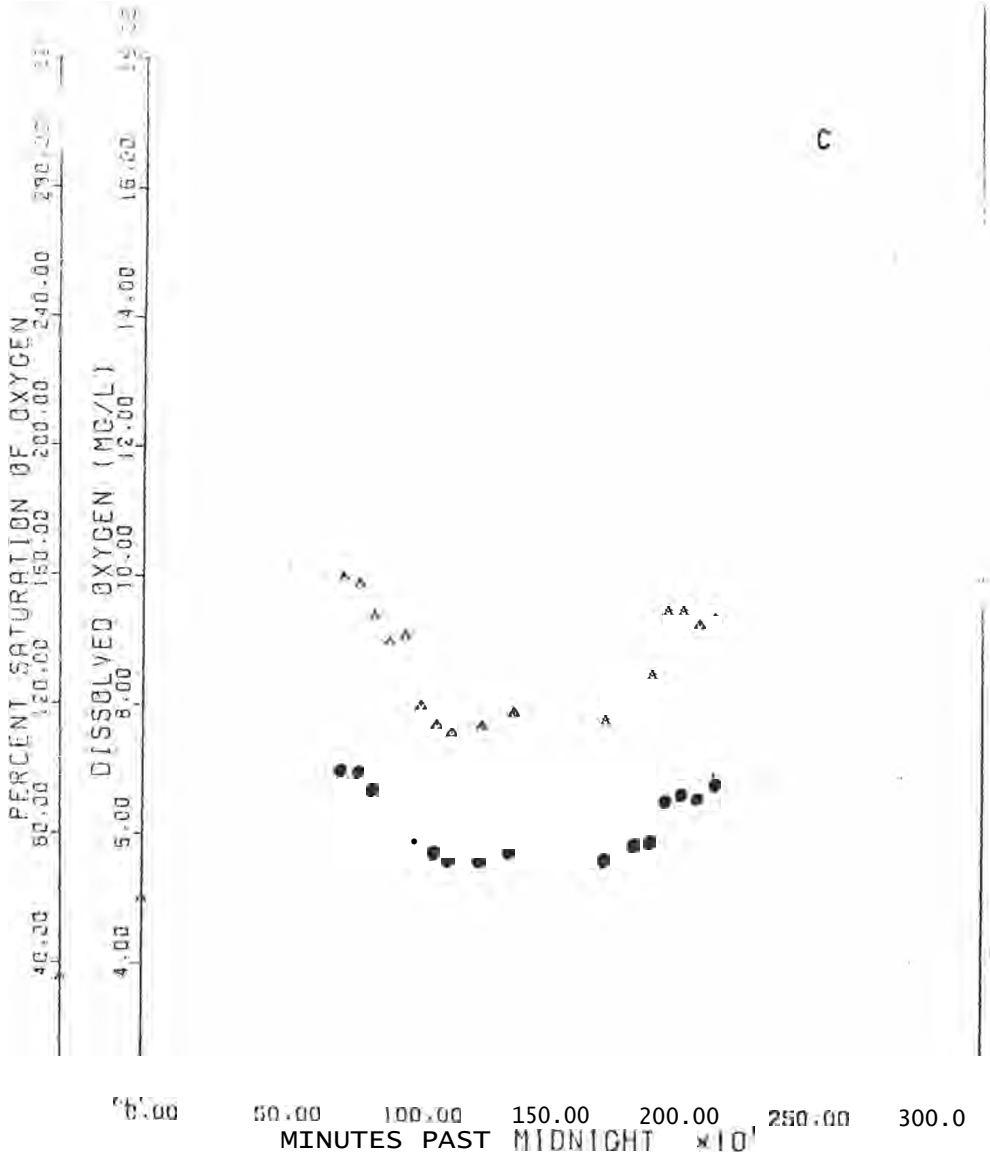
In those data demostrating more than 100% saturation of dissolved oxygen (e.g. Figs.19D-E and20B, D) , rates of change after dawn were comparable to those of temperature, with an immediate photosynthetic response to light impinging on the water surface.

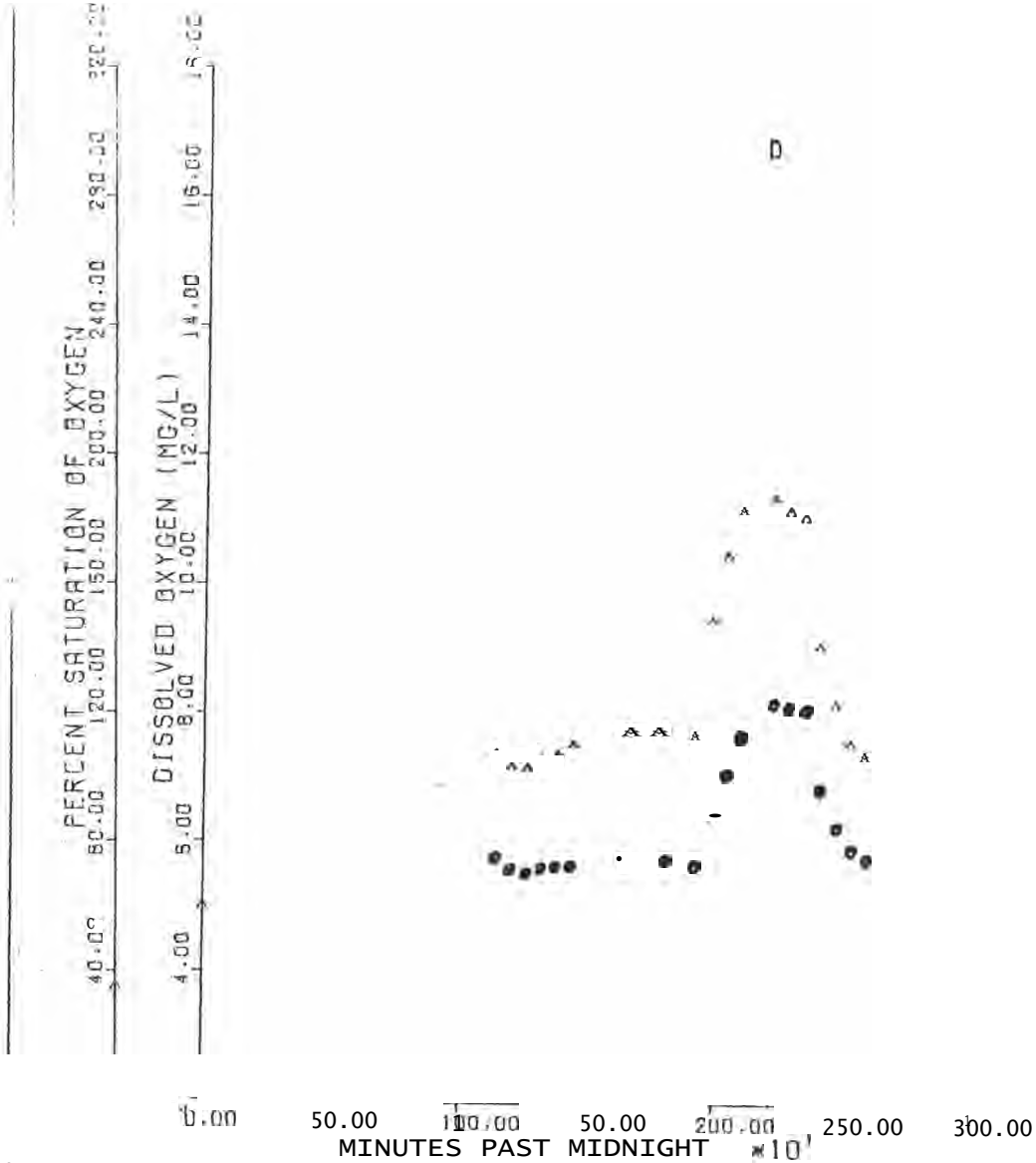
The high indicated respiration in Aravaipa Creek must be attributed to organic loading of the sediments. There is no evidence for dissolved or particulate loading of the flowing water, other than accumulation of finely-divided organic detritus along the stream bed through much of the year, and accumulation of decomposing materials in beds of emergent aquatic plants. This is to be examined in the coming year.

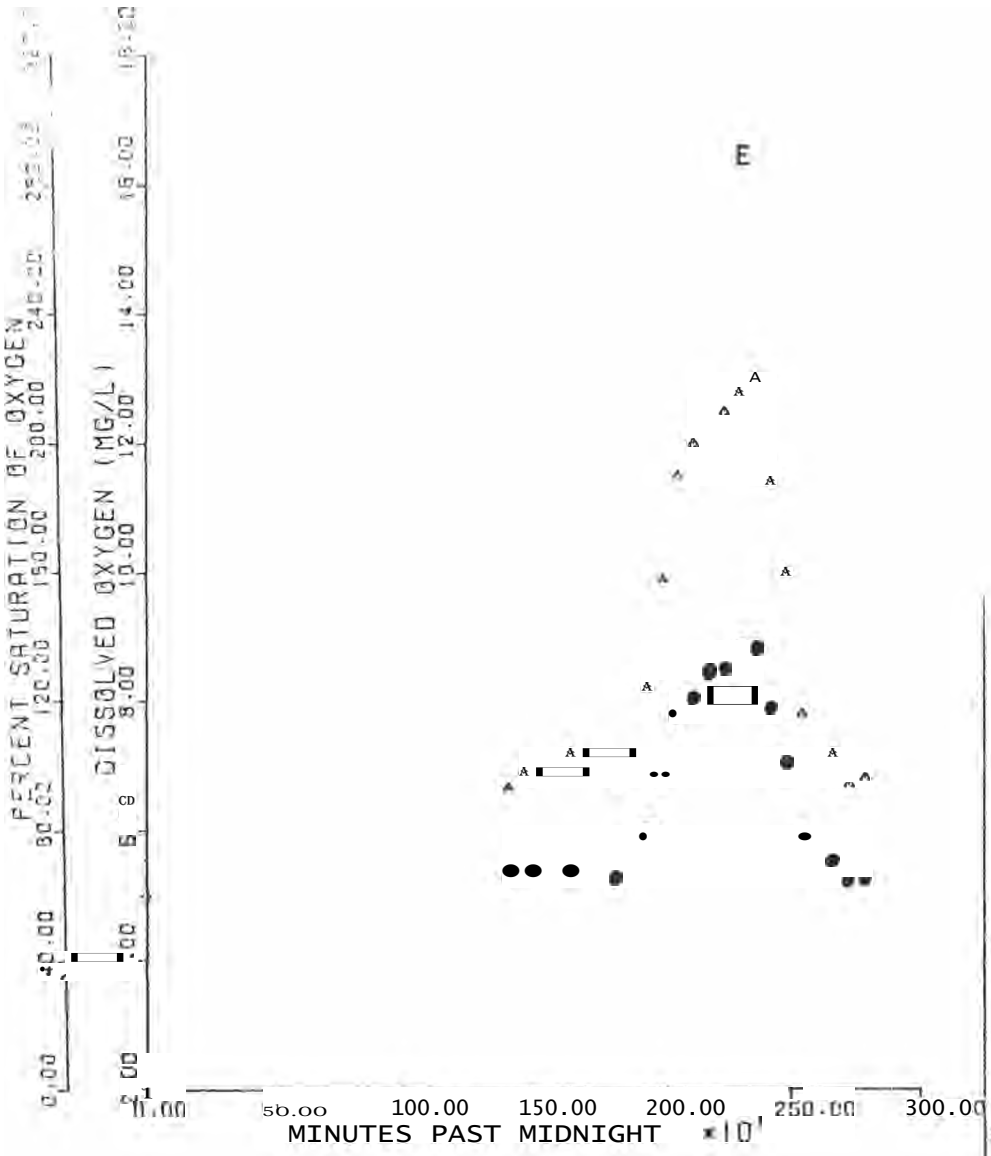
Figure 19. Concentrations of dissolved oxygen (A) in mg/I, and percentage saturation of dissolved oxygen (o) for upstream stations on Aravaipa Creek, Graham and Pinal counties, Arizona (pages 58 through 61).

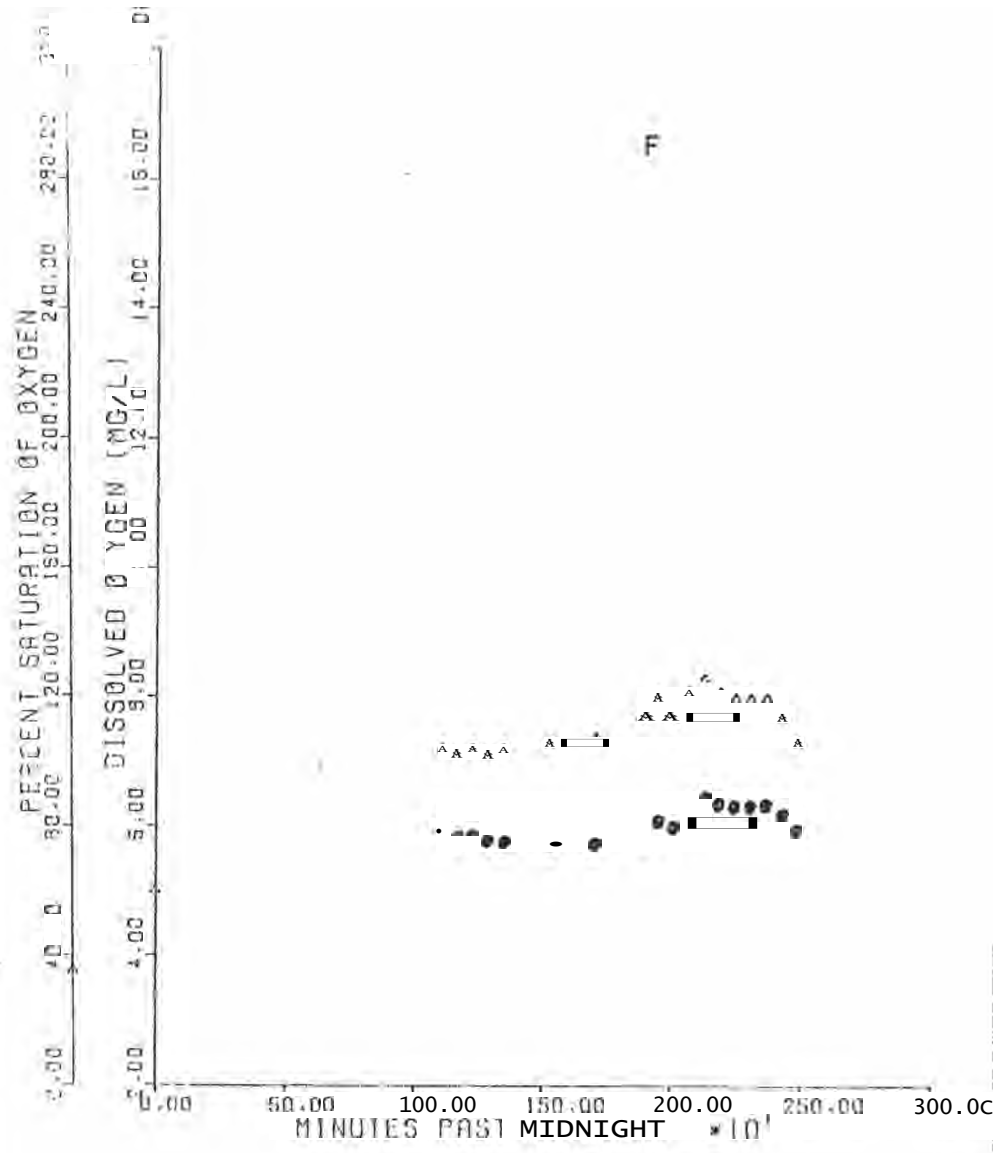

A
PERCENT SATURATION OF OXYGEN
DISSOLVED OXYGEN (MG/L)
MINUTES PAST MIDNIGHT *10'
ARAVAIPA CREEK (AC3067.) 760809


B
PERCENT SATURATION OF OXYGEN
DISSOLVED OXYGEN (MG/L)
MINUTES PAST MIDNIGHT *10
ARAVAIPA CREEK (AC3150.) 761119


C
PERCENT SATURATION OF OXYGEN
DISSOLVED OXYGEN (MG/L)
MINUTES PAST MIDNIGHT ×10'
ARAVAIPA CREEK (AC3150) 770111

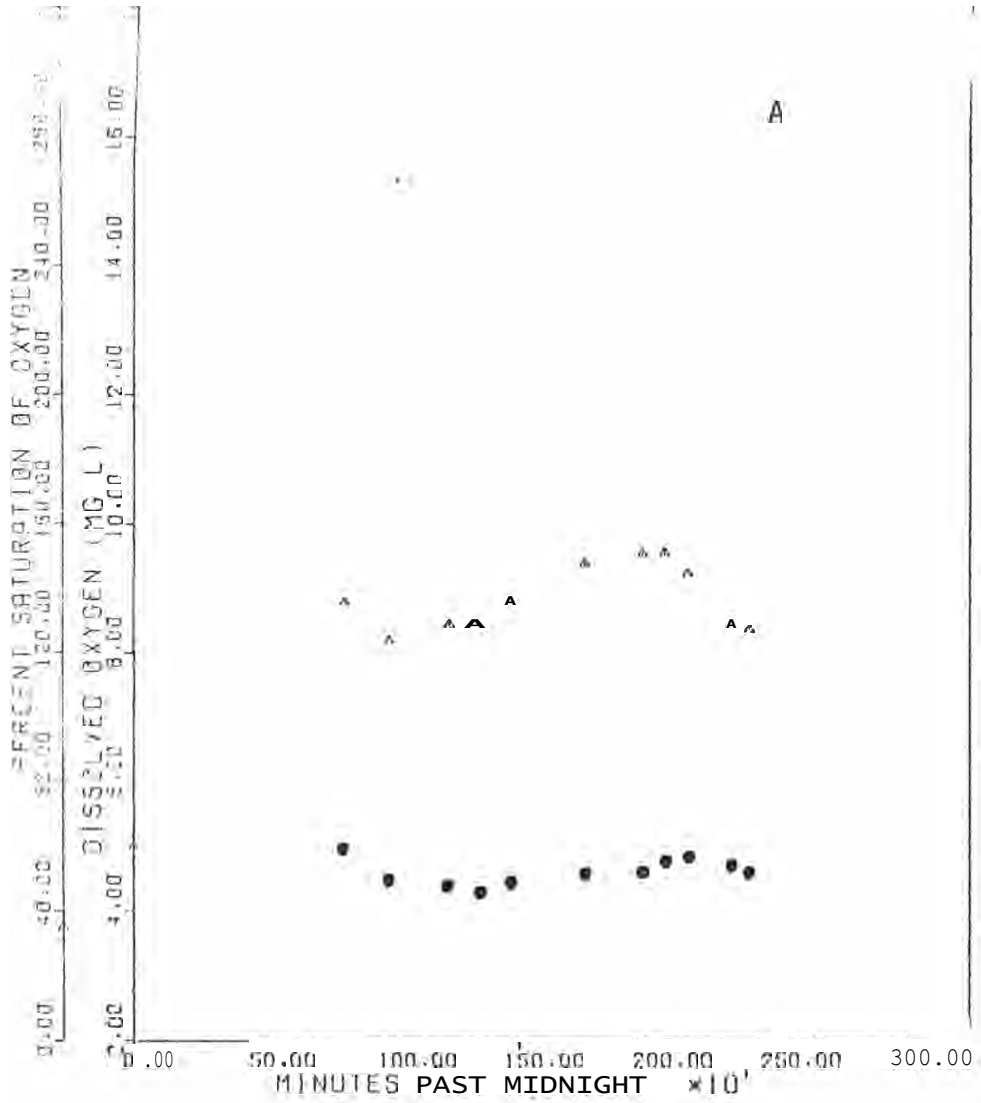

D
PERCENT SATURATION OF OXYGEN
DISSOLVED OXYGEN (MG/L)
MINUTES PAST MIDNIGHT ×10'
ARAVAIPA CREEK (AC3150) 770218


E
PERCENT SATURATION OF OXYGEN
DISSOLVED OXYGEN (MG/L)
MINUTES PAST MIDNIGHT *10'
ARAVAIPA CREEK (AC3155) 770316

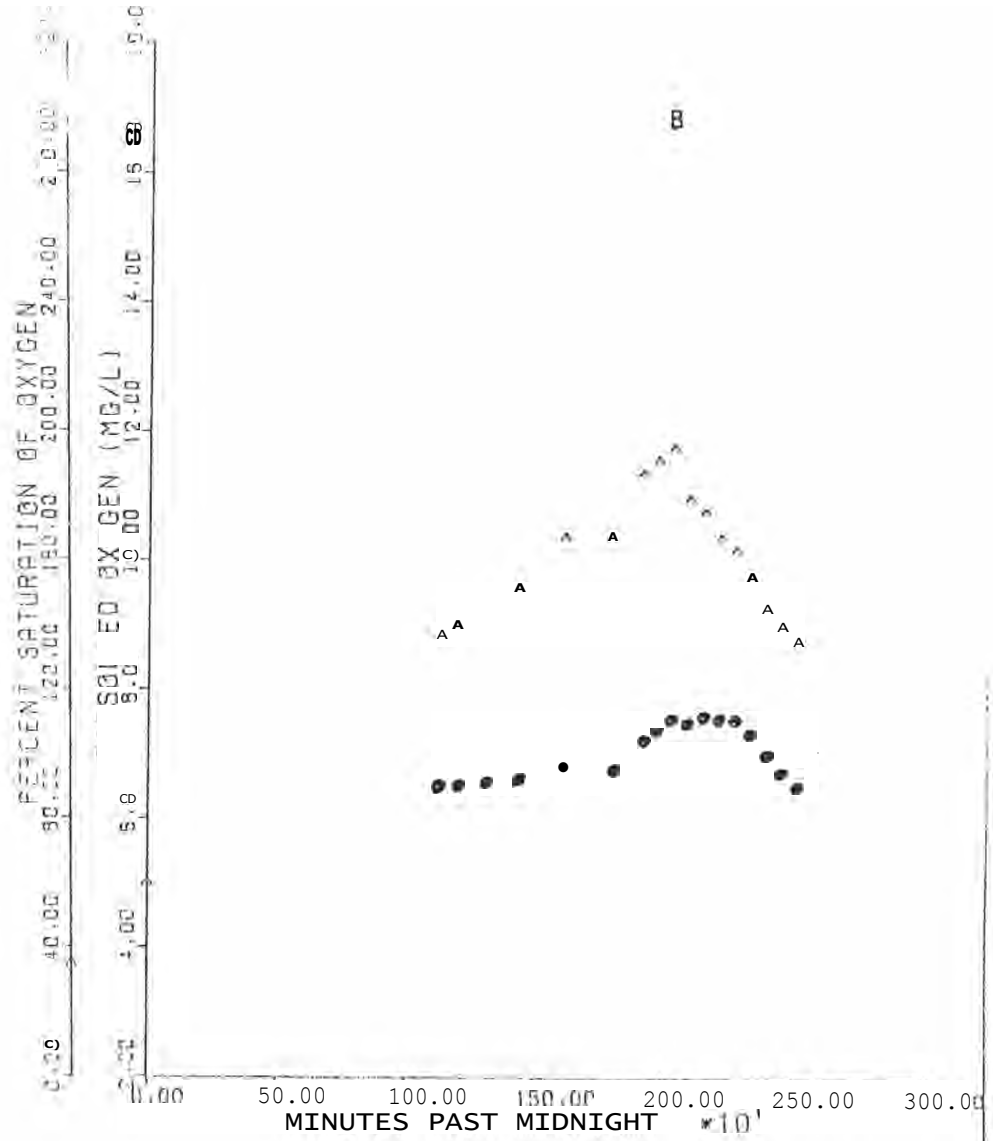

F
PERCENT SATURATION OF OXYGEN
DISSOLVED OXYGEN (MG/L)
MINUTES PAST MIDNIGHT *10'
ARAVAIPA CREEK (AC3140) 770422

PERCENT SATURATION OF OXYGEN
0.00
40.00
80.00
120.00
160.00
240.00
DISSOLVED OXYGEN (MG/L)
4.00
6.00
10.00
12.00
16.00
10.00
ARAVAIPA CREEK (AC315O 770606

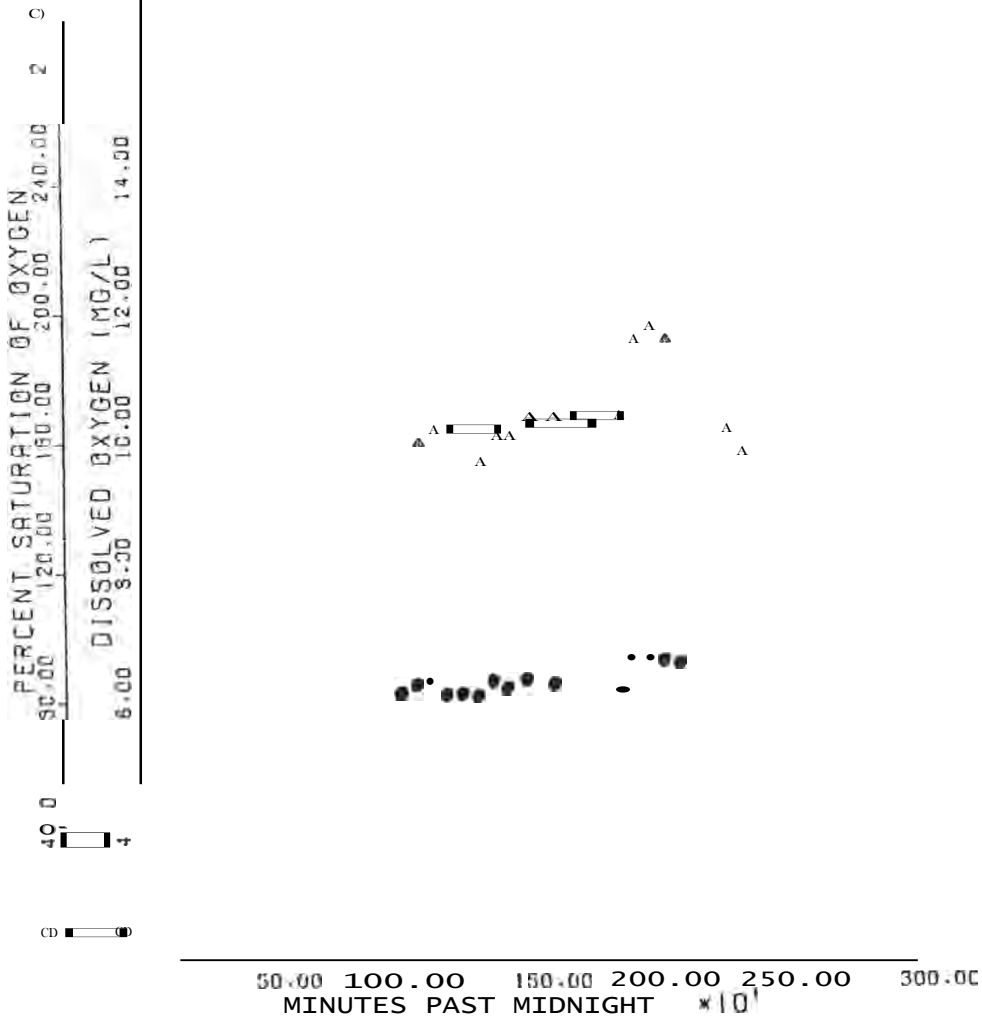
Figure 20. Concentrations of dissolved oxygen ( ) in mg/l, and percentage saturation of dissolved oxygen (●) for downstream stations on Aravaipa Creek, Graham and Pinal counties, Arizona (pages 63 through 66).



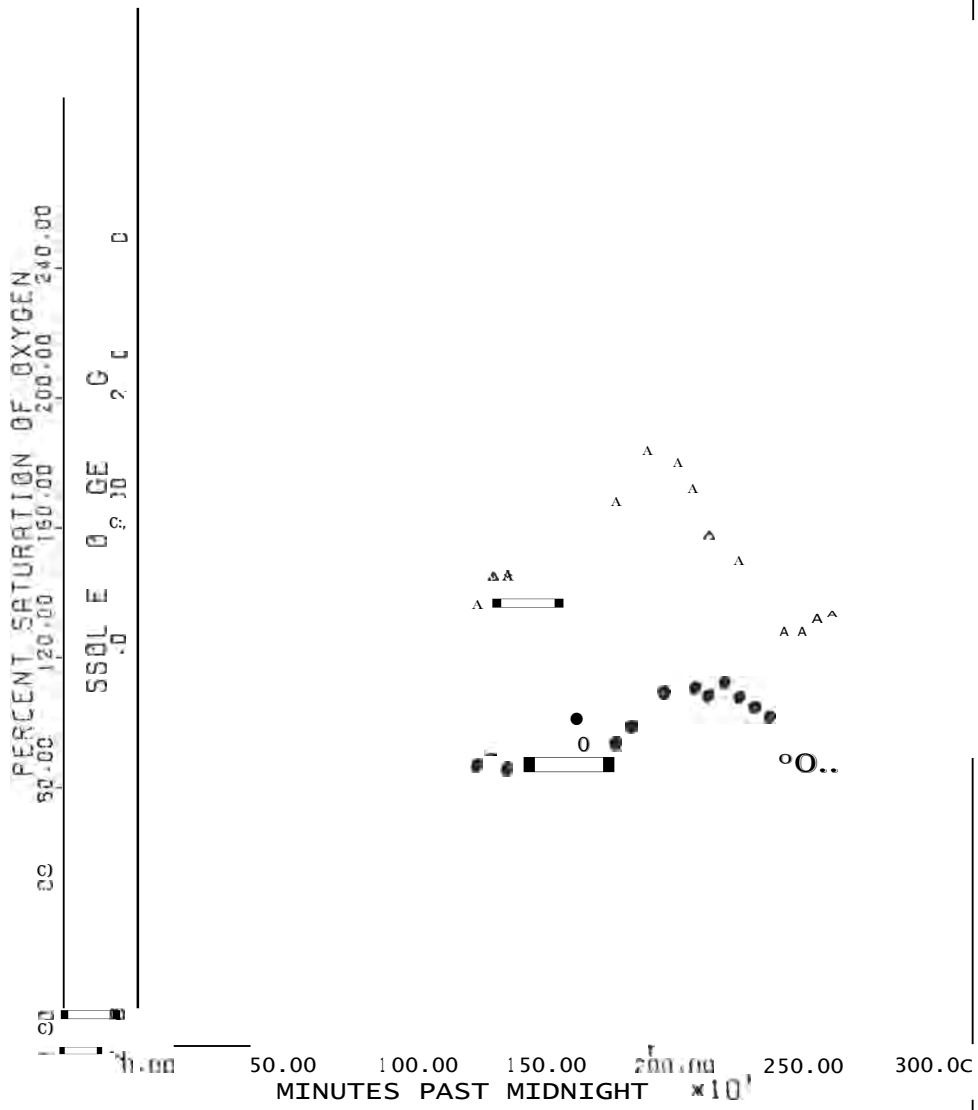
ARAVAIPA CREEK (AC2550.) 761023



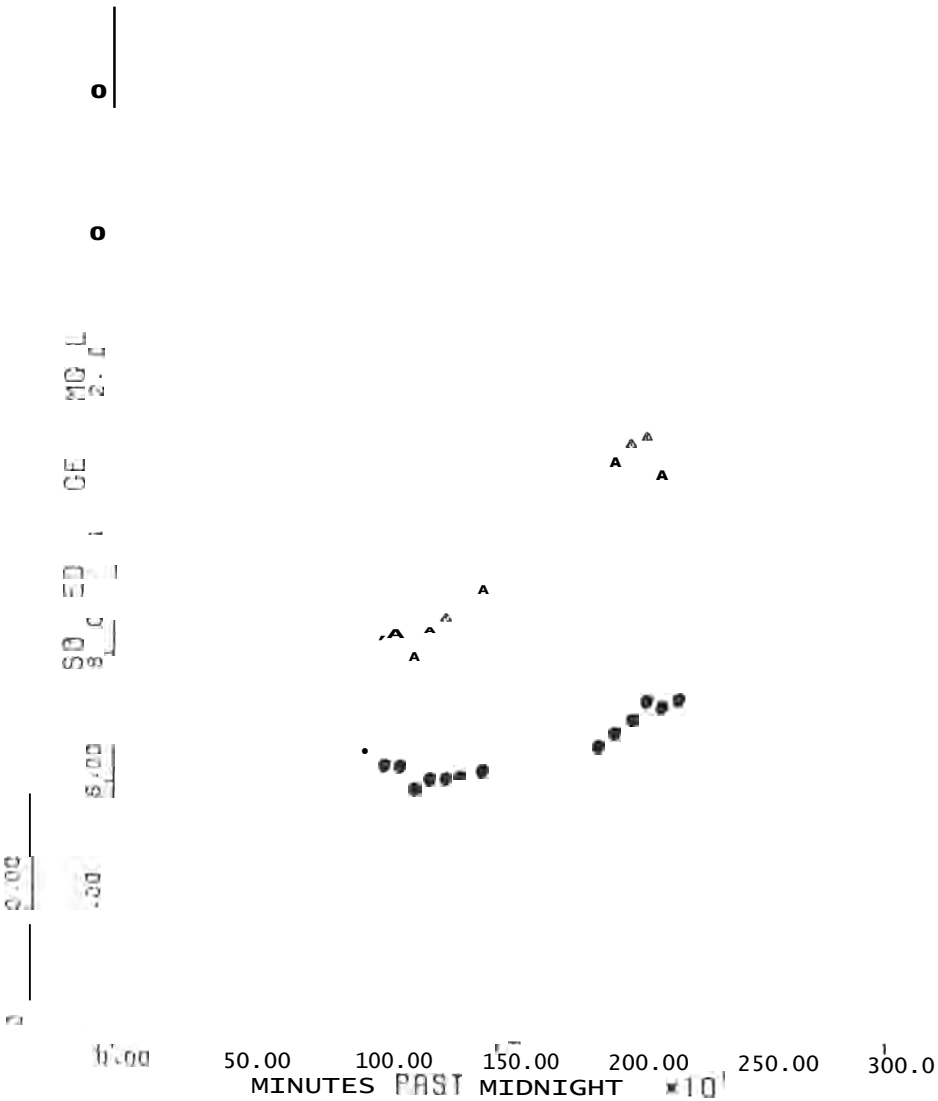
ARAVAIPA CREEK (AC2320.) 761120



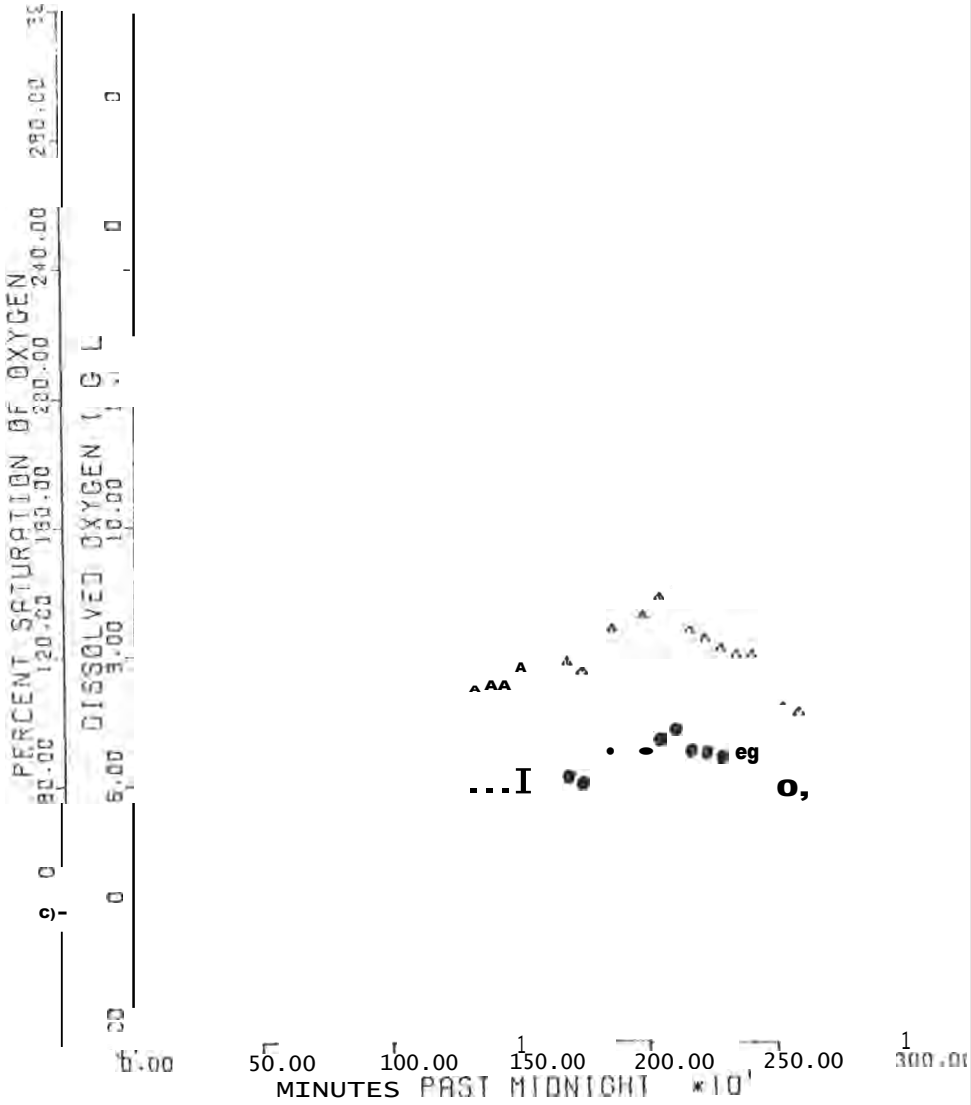
RRAVAIPA CREEK (AC2550.1 770115



ARAVAIPA CREEK AC2320.1 770119



ARAVAIPA CREEK (AC2600.) 770318



ARAVAIPA CREEg (AC2600.) 770423

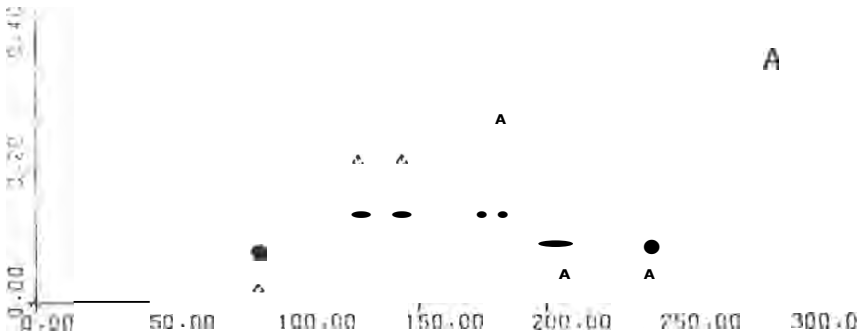
PERCENT SATURATION OF OXYGEN
0.00
40.00
80.00
120.00
160.00
200.00
240.00
280.00
320.00
DISSOLVED OXYGEN (MG/L)
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
18.00
50.00
100.00
150.00
200.00
250.00
300.00
MINUTES PAST MIDNIGHT *10
ARAVAIP CREEK

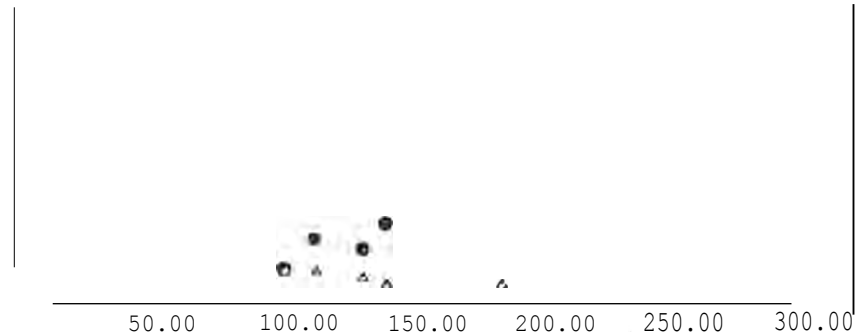
G

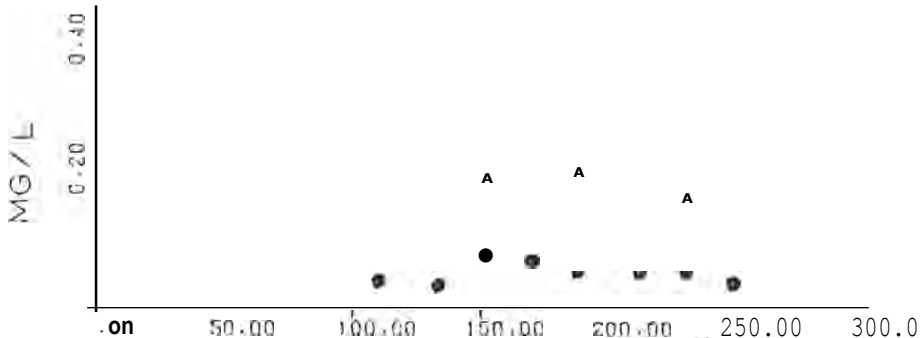
Macronutrients

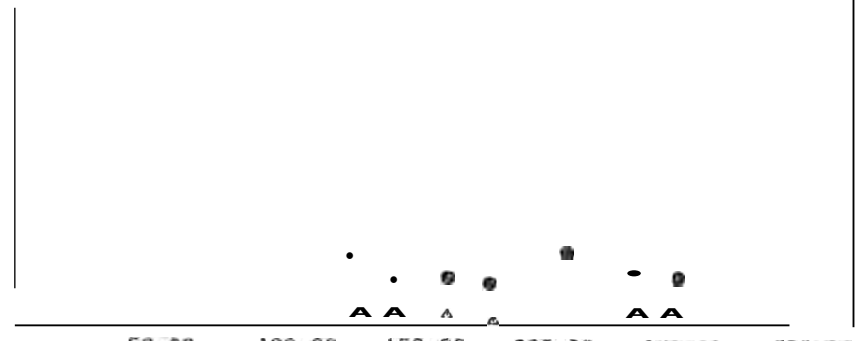
Phosphate-phosphorus (PO_4-P) and nitrate-nitrogen (NO_3-N) were analysed on each visit to Aravaipa Creek, and a consistent pattern of concentration is present. At upstream stations, NO_3-N consistently exceeds PO_4-P, while downstream, concentrations are reversed (Fig. 21). Only during a small spate (August; Fig.21A) did PO_4-P concentration exceed that of NO_3-N at an upstream station, and then only half the time. PO_4-P remains essentially the same throughout the stream within a given sampling period, indicating little utilization by plants or sporadic re-charge of the ion through inflow of springs or seeps. NO_3 N, on the other hand, is often reduced by an order of magnitude from up- to downstream (Fig. 21B, E and C, F), and could be deplited in a longer reach. It is tempting to speculate that riparian trees are utilizing the aquatic nutrients, but this has yet to be convincingly demonstrated. Such a land-water interaction, if occurring, would be somewhat unique to the riparian corridor concept of southwestern deserts, and should be thoroughly explored.

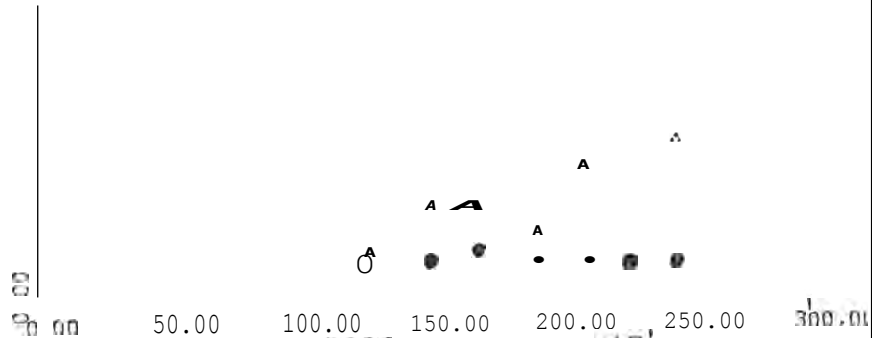
Figure 21. Concentrations of PO_4-P (o) and NO_3-N (A) in mg/l at selected stations on Aravaipa Creek, Graham and Pinal counties, Arizona.

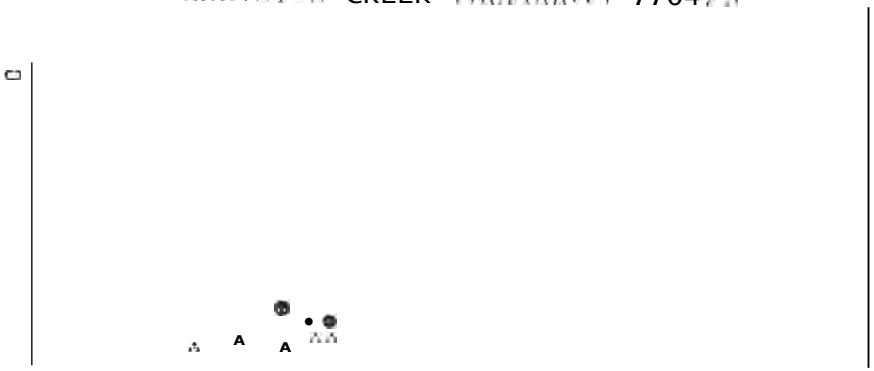

A
0.00
0.20
0.40
0.00
50.00
100.00
150.00
200.00
250.00
300.0
MINUTES PAST MIDNIGHT *10
ARAVAIPA CREAK (AC3067.) 760809


50.00
100.00
150.00
200.00
250.00
300.00
MINUTES PAST MIDNIGHT *10
ARAVAIPA CREAK (AC2600.) 770318


MG/L
0.20
0.40
.00
50.00
100.00
150.00
200.00
250.00
300.0
MINUTES PAST MIDNIGHT *10'
ARAVAIPA CREAK (AC3140.) 770422


50.00
100.00
150.00
200.00
250.00
300.00
MINUTES PAST MIDNIGHT *10'
ARAVAIPA CREAK (AC2600.) 770423


0.00
50.00
100.00
150.00
200.00
250.00
MINUTES PAST MIDNIGHT *10'
ARAVAIPA CREAK (AC3150.) 770606


MINUTES PAST MIDNIGHT *10'
ARAVAIPA CREAK (AC2550.) 770607

BIOLOGICAL STUDIES

Summary

Algal communities of Aravaipa Creek are dominated by diatoms and green algae (Bacillariophyceae and Chlorophyceae).

Pigment concentrations in samples of epilithic algal communities range from not detectable to more than 100 mg/m^2 of substrate, with a distinct relationship to time after flooding, and a less obvious relation to time of year. Pigments accumulate rapidly after spates to a point where a preponderance of samples have more than 10 mg/m^2. In early summer, self-shading, and senescence, appear to reduce standing crops of pigments.

Eighty-three taxa of benthic invertebrates have been recorded from Aravaipa Creek, and numbers ofanimals range from 334 to 13,500/m^2; biomass estimates range from 1 to 13 gm/m^2. Data are not complete enough to discern patterns on an annual basis or relative to catostrophic events such as flooding. Diversity ranges from 6 to 20 taxa per sample, both in the mainstream and in tributaries, with the fauna of side-canyons resembling that of ponds far more than that of the channel of Aravaipa Creek.

Electrofishing has been found to catch 99% of total numbers and biomass from a measured segment of stream in three "passes", and has been selected as the principal fish sampling technique. Large fishes and those of mid-water habit are most readily obtained; bottom-dwelling, smaller fishes are difficult to sample.

Comparisons of data for comparable sampling areas in October and April indicate *Agosia* as most abundant and *Gila* as least abundant of

native fishes present. Ranking by numbers on both those dates were as follows: Agosia, Pantosteus, Rhinichthys, Catostomus, Meda, Tiaroga, and Gila. Green sunfish (Chaenobryttus cyanellus) were vary rare.

Estimates of numbers of fishes per hectare range from 11,000 to 15,000+, and biomass is near 105 kg/ha.

Gross numbers and biomasses of fishes per unit area were greatest upstream, lowest within and near the canyon, and intermediate downstream. Diversity, however, was least up- and downstream, and greatest in the heterogenous habitat of the canyon itself.

Algae and Algal Pigments

Algal communities of Aravaipa Creek appear dominated by diatoms (Bacillariophyceae) and green algae (Chlorophyceae), most of which are encrusting in growth form, and occur on relatively solid substrates in current. Chlorophycean algae also are very common in the few quiet-water habitats and along the banks, and chrysophycean algae are locally abundant. Qualitative sampling of algae is an on-going part of the over-all study, and a listing of taxa will be provided later.

Sampling of algal pigments is being utilized to determine trends in standing crops. Three basic types of samples are taken. First, a suction device is used to obtain interstitial and fragmentary materials from a given area. Second, a scoop of substrate, approximately one cm deep, is taken and gently washed free of particles. And, third, a composite scoop of bottom material is taken. Extraction proceedures involve use of 95% acetone, in darkness and in cool surroundings, for 20 hours, and concentrations are read by spectrophotometric techniques (see earlier reports). Samples are taken at various places across the stream, in current, and at various stations on a given sampling date.

For purposes of presentation, pigment concentrations have been ranked in orders of magnitude as follows: I, no detectable pigments; II, detectable to 0.09 mg/m^2; III, 0.1 to 0.99; IV, 1.0 to 99.9 mg/m^2; and V, $>$ 100.0 mg/m^2 (Fig. 22).

Chlorophyll A is of universal occurrence in benthic microflora, and will be discussed at present. At the inception of sampling, in mid-September, more than half the samples taken contained less than order-of-magnitude III, reflecting a patchy and sparse algal flora

as a result of scouring by floods in August and early September. By mid-October, however, a preponderance of samples were order-of-magnitude IV or V, and a rich and abundant benthic algal community had developed. This persisted through November (Fig. 21). Samples from early January from the upper part of the stream still demonstrated an abundance of chlorophyll A, but those from the lower portion in late January were lower, resulting from a small spate that occurred in the intervening period. In February, a bi-modal distribution of orders of magnitude was in evidence, and this persisted through late April. Decline in the maximum amounts of chlorophyll A present appeared related to changes in the algal community. Many films of encrusting algae appeared to be senescent, and deterioration of mats was obvious in many places (especially of the larger, filamentous forms). Samples with no detectable pigments generally were those taken from interstitial habitats. The stream bed had become armored with pebbles through continuous movement and re-sorting processes, and interstitial habitats were filled and compacted with organic material and fineinorganic debris. In May, a small increase in discharge occurred, and some sediment movement was noted. By June, algal communities were quite as abundant, as indicated by pigment concentrations, as they had been in the preceding October (Fig. 22).

Chlorophylls B and C, and the composite "diatoms" followed trends similar to those for chlorophyll A, and provide a check on the system. Similarities among the various pigments may indicate relatively great homogeneity of the community, but this is yet to be examined in detail.

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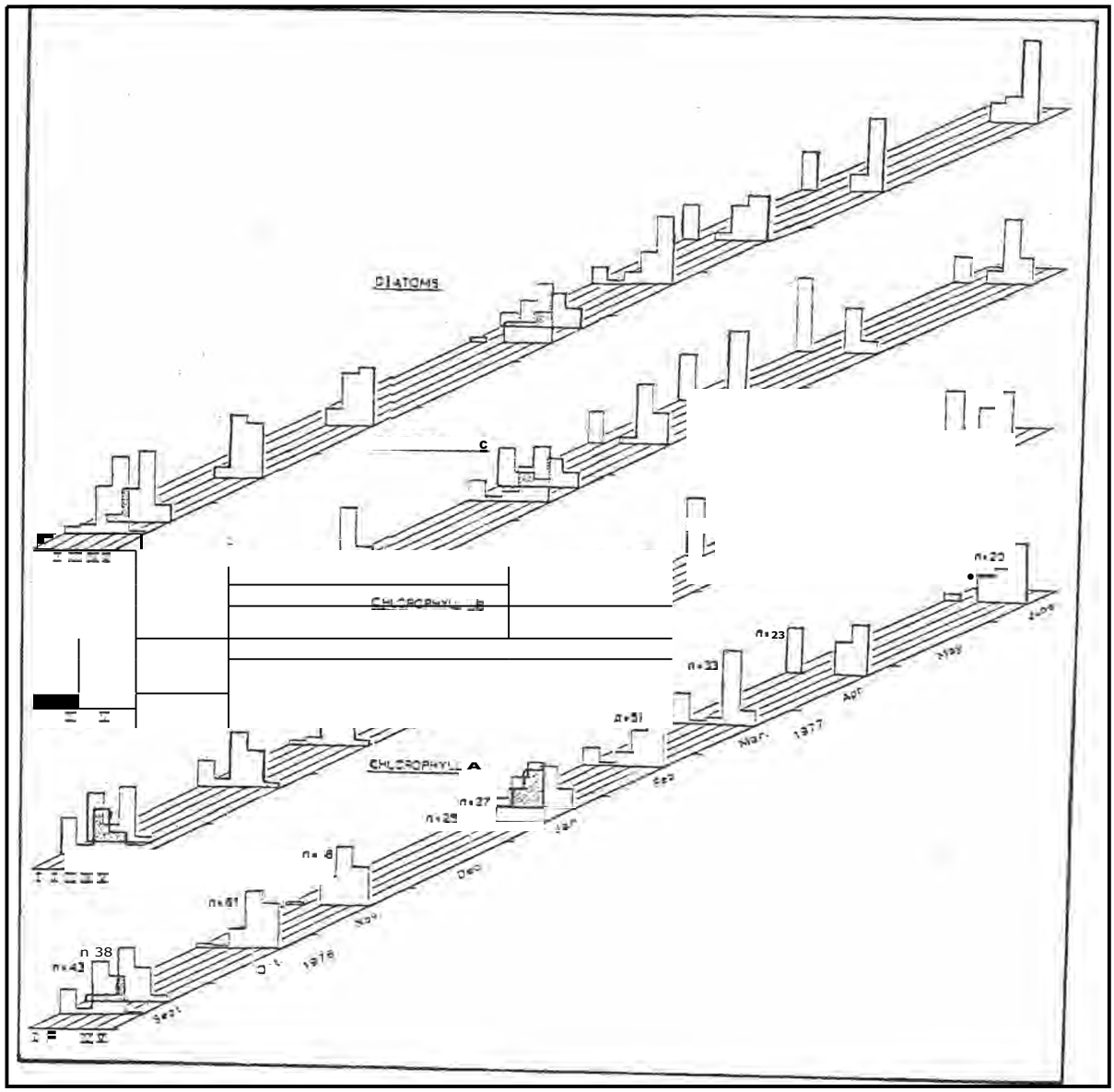
*Computed from ratios of the various chlorophylls, plus carotenoids, a technique to be detailed in Methods and Materials of the final report.

Figure 22. Percentages of total number of samples with algal pigments falling within five orders of magnitude of concentration per square meter (see text for units of concentration), all stations combined, Aravaipa Creek, Graham and Pinal counties, Arizona, 1976-77.


DIATOMS
CHLOROPHYLL B
CHLOROPHYLL A
n=23
n=33
n=51
n=27
n=29
n=8
n=61
n 38
n=43
Mar. 1977
Apr.
Oct. 1976

Benthic Invertebrates

Eighty-three taxa of benthic invertebrates have been recorded from Aravaipa Creek (Table 3). No patterns of numbers of biomass per unit area are yet in evidence (Fig. 23), since sampling has not yet been over a full year's cycle, or long enough term to assess catostrophic events such as flooding within the system.

Total numbers of animals range from about 334 to 13,500 individuals/m^2, and biomass ranges from 1.0 to 13.0 gm/m^2 (Table 2f). These data are comparable to those reported by Dale Bruns, based upon a 13-month study of benthos in Aravaipa Creek, and appended as a portion of this document.

Diversity of the fauna is relatively high, ranging from 6 to 20 taxa per sample, and is similar in the mainstream and in Turkey Creek (the only side-canyon habitat from which samples have been thoroughly analysed). The fauna in side canyons, on a qualitative basis, is far more similar to that of temporary ponds than to that of the mainstream. Pool-loving insects such as corixid and notonectid hemipterans, hydrophilid and dytiscid coleopterans, and certain ephemeropterans (notably burrowing kinds) are common. Conspicuous in their absence from the side-canyon habitats are current-loving species such as simuliid dipterans, hydropsychid and helicopsychid trichopterans, and swift-water ephemeropterans such as Baetis and Choroterpes. The last groups dominate the mainstream of Aravaipa Creek.

Table 3. Taxa and codes for taxa of benthic invertebrates identified from Aravaipa Creek, Graham and Pinal counties, Arizona

CODE	TAXON
550ARTHROPOO	Arthropoda
450INSECTOO	Insecta
350COLEOPOO	Coleoptera
250HYDROPOO	Hydrophilidae
250DYTISCOO	Dytiscidae
250DRYOPIOO	Dryopidae
250CURCULOO	Curculionidae
250ELMIDAOO	Elmidae
250HALIPIOO	Halipidae
250HELODIOO	Helodidae
350DIPTEROO	Diptera
250CHIRONOO	Chironomidae
250CULICIOO	Culicidae
250SIMULIOO	Simuliidae
250CERATOOO	Ceratopogonidae
250PELOPIOO	Pelopidae
250TABANIOO	Tabanidae
250STRATIOO	Stratiomyidae
250MUSCIDOO	Muscidae
250DIXIDAOO	Dixidae
250EPHYDROO	Ephydridae
250EMPIDIOO	Empididae
250DOLICHOO	Dolichopidae

Table 3. Continued

350DIPTERA00 (Cont'ed)	Diptera (Cont'ed)
250PSYCH000	Psychodidae
250BLEPHA00	Blephariceridae
350LEPID000	Lepidoptera
250PYRAUL00	Pyralidae
3500DONATOO	Odonata
250GOMPHI00	Gomphidae
250LIBELL00	Libellulidae
250COENGR00	Coengrionidae
350HEMIPT00	Hemiptera
250GELAST00	Gelastocoridae
250CORIXI00	Corixidae
250NAUCOR00	Naucoridae
250BELOST00	Belostomatidae
150ABEDUS00	Abedus
250VELIID	Veliidae
250GERRID00	Gerridae
350PLECOP00	Plecoptera
250CAPNII00	Capniidae
150CAPNIA00	Capnia
350MEGAL000	Megaloptera
250CORYDA00	Corydalidae
150CORYDA00	Corydalis
350TRICH000	Trichoptera
250HYDROP01	Hydropsychidae
250HYDROP02	Hydroptilidae

Table 3 . Continued

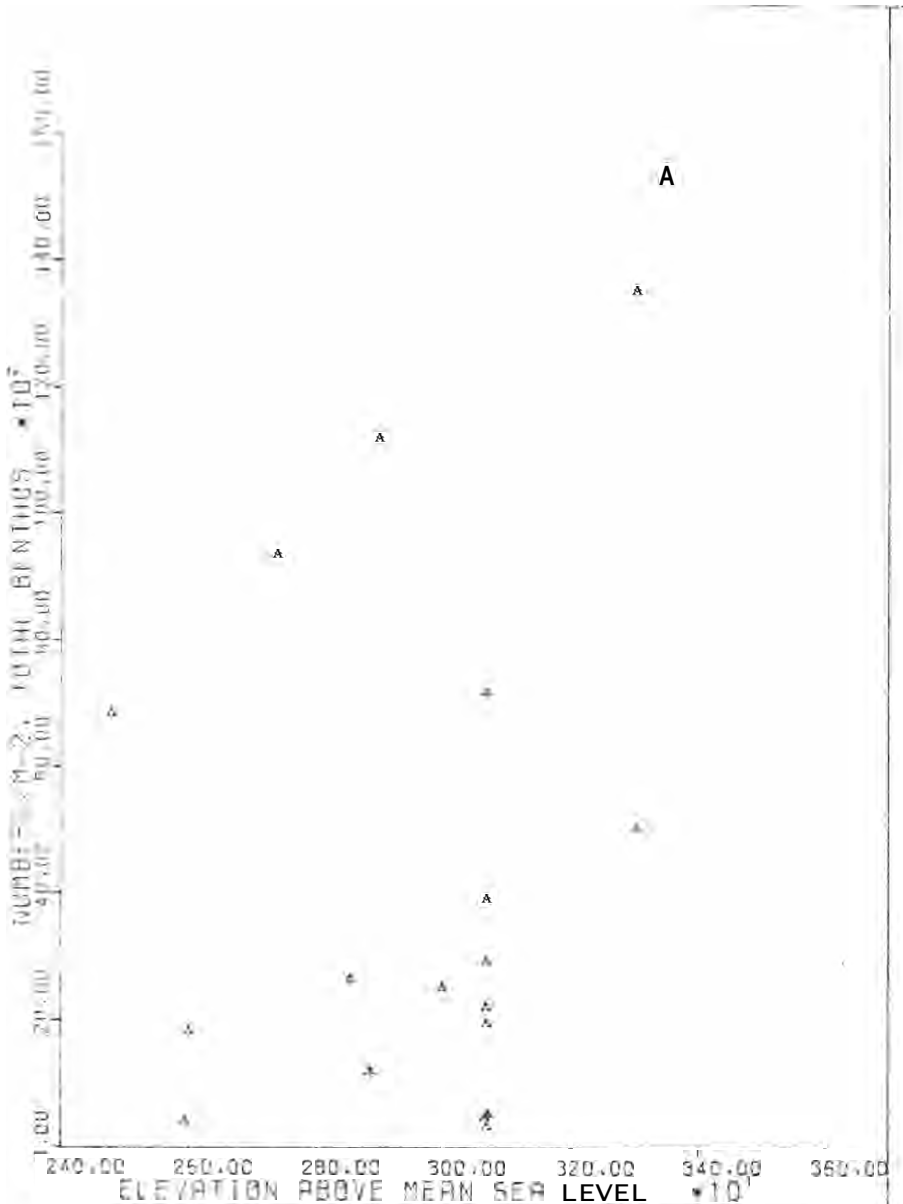
350TRICH000 (Cont'ed)	Trichoptera (Cont'ed)
250HYDROP02 (Cont'ed)	Hydroptilidae (Cont'ed)
150LEUCOT00	Leucotrichia
250HELIC000	Helicopsychidae
250LIMNEP00	Limnephilidae
250PSYCH001	Psychomyidae
250RHYACH00	Rhyachophilidae
350EPHEME00	Ephemeroptera
250EPHEME00	Ephemeridae
250HEPTAG00	Heptageniidae
150RHITHR00	Rhithrogena
250BAETID00	Baetidae[1/]
150BAETIS00	Baetis
150BAETIS01	Baetis sp. "1"
150BAETIS02	Baetis sp. "2"
150CHOROT00	Choroterpes
150TRICOR00	Tricorythodes
450ARACHN00	Arachnida
350ACARIN00	Acarina
450CRUSTA00	Crustacea
3500STRACOO	Ostracoda
350COPEP000	Copepoda
250DAPHNI00	Daphniidae
560MOLLUS00	Mollusca
460GASTR000	Gastropoda

Table 3. Concluded

460GASTR000 (Cont'ed)	Gastropoda (Cont'ed)
360PROSOB00	Prosobrancha
260PHYSID00	Physidae
160PHYSA000	Physa
570WORMS000	"Worms"
470GORDIE00	Gordieoidea
470PLATYH00	Platyhelminthes
370TURBEL00	Turbellaria
270PLANAE00	Planariidae
470ANNELI00	Annelida
3700LIGOC00	Oligochaeta
270TUBIFI00	Tubificidae
270LUMBRI00	Lumbridulidae
370HIRUDI00	Hirudinea

1/ Includes Baetinae, Tricorythodinae, and Leptophlebinae

Figure 23. Numbers (A) and weights (B, in gm) of benthic invertebrates per meter^2 from all samples on Aravaipa Creek, Graham and Pinal counties, Arizona, 1976 -77, arranged by elevation of capture.


A
NUMBER/M-2, TOTAL BENTHOS *10
1.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
240.00
260.00
280.00
300.00
320.00
340.00
360.00
ELEVATION ABOVE MEAN SEA LEVEL *10
ARAVAIPA CREEK, ARIZONA

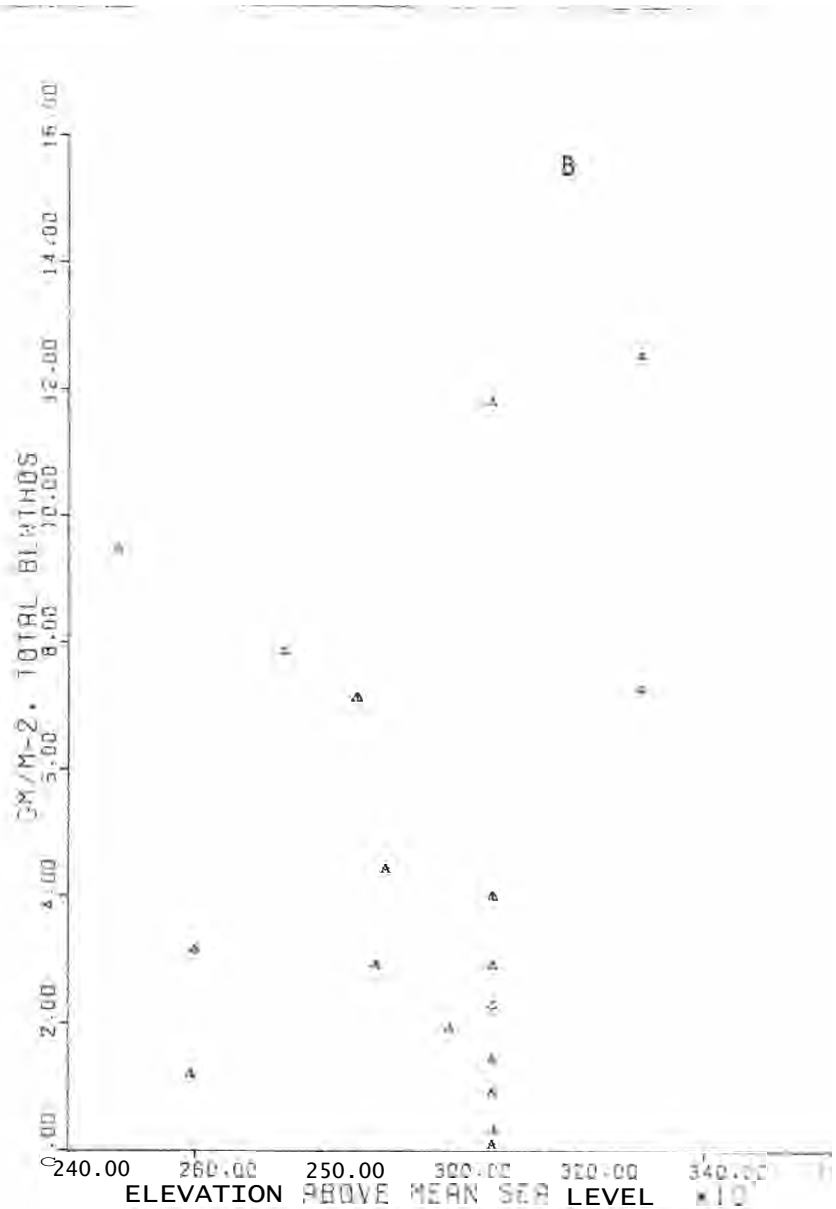

B
GM/M-2, TOTAL BENTHOS
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
240.00
260.00
250.00
300.00
320.00
340.00
ELEVATION ABOVE MEAN SEA LEVEL *10
ARAVAIPA CREEK, ARIZONA

Table 4. Data for selected samples of benthic invertebrates (Surber Sampler) from Aravaipa Creek, Graham and Pinal counties, Arizona, and Turkey Creek, Graham County, Arizona.

Period	No. Samples	No. Taxa	Gm/m^2	No./m^2
August 1976 (AC)	3	23 (12 [illegible])	2.1 1/ (0.9 - 4.0)	3,006 (2,206 - 3,907)
September 1976 (AC)	3	20 (6 - 11)	4.1 (1.1 -11.8)	1,045 (333 - 1,527)
October 1976 3/ (AC)	5	24 (9 - 13)	3.5 (1.0 - 7.8)	2,540 (1,111 - 9,344)
October 1976 (AC)	4	26 (9 - 16)	2.9 (1.9 - 4.4)	5,513 (1,194 -11,194)
January 1977 (AC)	2	26 (11 - 20)	11.0 (9.5 -12.5)	10,183 (6,846 -13,520)
Septgmber 1976 (IC)	3	23 (11 - 13)	12.4 (11.9 -23.5)	1,280 (344 - 1,280)
January 1976 (TC)	1	14	14.7	2,325

1/ All benthos weights are "wet weight", blotted dry on tissue.

/ Ranges for all data are in parentheses

3/ Includes some samples taken after a slight rise in one segment of the creek, hence the low values given in ranges and a somewhat suppressed mean for weights and numbers.

/ Includes samples taken before the small spate mentioned in footnote #3.

Fishes

Quantitative sampling of fishes in Aravaipa Creek was attempted by seining and by electrofishing. Seines followed by electrofishing indicated an error as high as 20% in estimates of number, and far more than that in estimation of biomass, especially when seining was done in areas of heterogenous bottoms and variable depths. That technique was therefore discontinued except for qualitative purposes.

Electrofishing apparatus was used repeatedly in blocked, measured segments of stream to assess its efficiency. Ninty-nine per cent, or more, of total numbers and biomass obtained in 6 to 10 "passes" through 3 separate stream segments was taken in the first 3 passes (Table 5). Larger fishes (Catostomus, Pantosteus, and Gila) were most susceptible to the electrical field, and small, bottom-dwelling species (especially Tiaroga cobitis) were least efficiently sampled. Only in the largest pools was the electrofishing unit obviously inefficient, when deeper water and turbidity hampered recovery of stunned animals.

Numbas and weights of fishes taken from selected segments in three sampling periods were variable, especially in February when only four localities were collected (Table 6). Comparison of data for October 1976 and April 1977, however, indicated a remarkably similar order of magnitude of numbers of each of the seven native species. Ranking of numerical abundance was identical on both of those dates, with Agosia being dominant and Gila as being the least abundant species. Ranking of weights per hectare also were the same in October and April, in all but the catostomids (which exchanged dominance of biomass; Table 6). In autumn, juvenile Catostomus move readily onto riffles, where they

Table 5. Percentages of total numbers (above) and weights (below) of fishes taken in consecutive "passes" of electrofishing apparatus in Aravaipa Creek, Graham and Pinal counties, Arizona, based upon sampling of three separate stream segments.

Species	"Pass" Number 1	2	3	4	5	6-10
Catostomus insignis	82.7	14.0	2.6	0.7		
	93.8	2.6	3.0	0.6		
Pantosteus clarki	91.0	6.6	1.7	0.3	0.3	0.1
	92.4	5.4	0.7	0.5	0.6	0.4
Agosia chrysogaster	90.0	7.9	1.7	0.1 1/	--	0.3
	92.2	6.1	1.5	Tr.	--	0.3
Rhinichthys osculus	86.8	11.3		0.6		1.3
	89.2	9.3		0.6		0.9
Tiaroga cobitis	53.8	30.8	7.7		7.7	
	20.0	60.0	8.0		12.0	
Meda fulgida	88.7	2.4	8.1		0.8	
	94.3	1.6	3.2		1.0	
Gila robusta grahami	100.0					
	100.0					
Total numbers and weights (gm)	3,224	289	69	7	4	8
	10,768.8	453.0	233.1	55.9	28.6	21.4
Over-all Percentages	89.5	8.0	1.9	0.2	0.1	0.2
	93.2	3.9	1.9	0.5	0.2	0.2

1/Tr. = less than 0.05 per cent.

live with adults and juveniles of Pantosteus. In spring, C. insignis tends to occupy the deepest available water during the day, where electrofishing was most inefficient.

Estimates of numbers of fishes per hectare in October (15,000+) and April (ca. 11,000) are consistent with an expected decrease through the year, and the similarity of biomass per hectare (105 kg) in each period also seems reasonable.

Table 6. Summary of fishes per hactare indicated by sampling Aravaipa Creek, Graham and Pinal counties, Arizona; numbers of individuals above, weights below (in parentheses).

Species	Sampling Methods and Periods			
	October 1976		February 1977	April 1977
	Seines		Electrofishing	
Catostomus insignis	446 (19.9)	734 (27.7)	1,382 (78.1)	701 (46.6)
Pantosteus clarki	446 (7.2)	3,284 (54.8)	4,244 (83.8)	2,009 (27.8)
Agosia chrysogaster	11,800 (17.8)	8,643 (15.7)	2,122 (6.7)	6,238 (17.4)
Rhinichthys osculus	15,659 (16.3)	2,064 (2.6)	592 (1.3)	1,413 (2.5)
Tiaroga cobitis	134 (0.2)	119 (0.2)	2,287 (5.4)	202 (0.5)
Meda fulgida	848 (1.4)	312 (0.5)	1,102 (1.9)	287 (0.8)
Gila robusta grahami	(- -)	83 (2.6)	115 (1.8)	96 (9.2)
Chaenobryttus cyanellus	(- -)	9 (0.9)	(- -)	(- -)
Totals	29,333 (62.8)	15,249 (105.0)	11,844 (178.9)	10,946 (104.6)

Percentages of each species' number and weights in individual collections are in Tables 7 and 8, respectively, and absolute data per hectare are plotted in Figure 24.

Of fishes taken, only Agosia and Pantosteus tended to be generally distributed throughout the stream, Agosia was most abondant in the upper and lower parts. Pantosteus varied from being concentrated in the mid-section in October, upper section in February, and downstream in April. Catostomus was commonest in middle sections in October and April, and somewhat concentrated upstream in February. Rhinichthys obviously preferred upstream habitats. Tiaroga tended to be very widely distributed, but rare, and Meda and Gila were most abundant in the middle, canyon sections of the stream. Distributions of biomass resembled those for numerical abundance.

Diversity (number of species per locality) was obviously lower at extreme up- and downstream stations, and highest within and adjacent to the canyon section of the stream.

Both gross numbers and biomass of fishes per hectare, as estimate from individual electrofishing samples, was greatest upstream, lowest within and near the canyon segment, and intermediate downstream (Fig. 24).

Table 7. Summaries of relative abundance (as percentages of total numbers of fishes taken by electrofishing apparatus) at various sites on Aravaipa Creek, Graham and Pinal counties, Arizona, 1976-77; see Table for comparable data on weights of fishes taken.

Species	October 1976						
	3200	3170	3150	2595	2460	2400	Over-all
Catostomus insignis	4.8		10.7	7.0	12.3	5.4	4.8
Pantosteus clarki	19.0	4.3	28.4	29.4	67.0	19.8	21.5
Agosia chrysogaster	16.2	73.1	6.7	58.8	10.3	71.5	56.7
Rhinichthys osculus	59.0	22.6	29.4				13.5
Tiaroga cobitis	1.0		4.9	1.9	1.0	0.2	0.8
Meda fulgida		----	11.7	2.3	8.7		2.0
Gila robusta grahami		----	7.9	0.5			0.5
Chaenobryttus cyanellus					0.5		0.1

Species	February 1977				
	3200	3090	2480	2300	Over-all
Catostomus insignis	20.4	11.8	11.7		11.7
Pantosteus clarki	57.4	39.2	22.8	25.0	35.8
Agosia chrysogaster	7.4	2.4	47.4	75.0	17.9
Rhinichthys osculus		7.5	1.2		5.0

Table 7. Concluded

Species	February 1977 (concluded)			
	3200	3090	2480	2300	Over-all
Tiaroga cobitis	1.9	26.4	11.1	19.3
Meda fulgida	9.3	12.2	4.1	9.3
Gila robusta grahami	3.7	0.4	1.8	1.0

Species	April 1977							
	3300	3200	3170	3150	2485	2400	2300	Over-all
Catostomus insignis	0.4			25.4	18.2	11.2		6.4
Pantosteus clarki		7.5	7.4	43.7	63.6	31.7	20.0	18.4
Agosia chrysogaster	68.9	75.0	75.3	1.4		50.9	80.0	57.0
Rhinicnthys osculus	30.7	15.0	16.7	5.6				12.9
Tiaroga cobitis		2.5	0.6	9.9		0.9		1.8
Meda fulgida				9.2	18.2	4.5		2.6
Gila robusta grahami				4.9		0.9		0.9

Table 9. Summaries of relative abundance (as percentage of total weights of fishes taken by electrofishing apparatus) at various sites on Aravaipa Creek, Graham and Pinal counties, Arizona, 1976-77; see Table for comparable data on numbers of fishes taken,

Species	October 1976						
	3200	3170	3150	2595	2460	2400	Over-all
Catostomus insignis	4.8		55.7	30.8	23.1	21.7	26.4
Pantosteus clarki	75.5	19.9	28.4	51.1	72.7	43.8	52.2
Agosia chrysogaster	6.4	68.3	0.9	13.7	1.1	34.4	14.9
Rhinichthys osculus	13.1	11.8	2.6			----	2.5
Tiaroga cobitis	0.2		0.4	0.5	0.1	0.1	0.2
Meda fulgida			1.0	0.5	0.5		0.4
Gila robusta grahami	---		11.0	3.5			2.5
Chaenobryttus cyanellus	--		----	----	2.4		0.9

Species	February 1977				
	3200	3090	2480	2300	Over-all
Catostomus insignis	46.7	47.0	20.6		11.7
Pantosteus clarki	50.1	46.4	46.0	38.2	38.2
Agosia chrysogaster	0.7	0.4	25.1	61.8	17.9
Rhinichthys osculus	----	0.8	0.8		0.7

SRP10836

Quarterly Progress Report
(November 1977)

On Project Entitled

ECOLOGICAL ANALYSIS OF ARAVAIPA CREEK AND ENVIRONS RELATIVE TO PAST AND FUTURE LAND AND WATER USE

Submitted by

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Department of Zoology, Arizona State University

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to

Bureau of Land Management
U. S. Department of the Interior

Reference: Contract No. YA-512-CT6-98

INTRODUCTION

The following report consists of a summation of vegetation and flora of the Aravaipa Creek Canyon area, prepared by William G. Kepner, Arizona State University. It has been compiled mostly from original data collected by Kepner, Rodney G. Engard, Desert Botanical Garden, Phoenix, Arizona, personnel ot the present project, and some herbarium records from the Arizona State University Herbarium. The last was provided by Elinore Lehto and Donald Pinkava, Department of Botany and Microbiology, Arizona State University.

Complete floras of any area in Arizona have yet to be compiled, and especially in desert regions. Habitat diversity and seasonal variations play a great role in determining the year-to-year flora, and with tendencies toward increasing moisture in 1977-78, many new records for the area are anticipated with coming of spring. The present listing will be updated in the final report.

SRP10838

VEGETATION AND FLORA OF THE ARAVAIPA CREEK PRIMITIVE AREA, GRAHAM AND PINAL COUNTIES, ARIZONA

by

William G. Kepner

In Support of U.S. Bureau of Land Management Grant
Safford, Arizona District

ARIZONA STATE UNIVERSITY

ACKNOWLEDGMENTS

I wish to thank Mr. Rodney G. Engard, Supervisor of the Desert Botanical Garden in Phoenix, for his aid in the identification and classification of flora within the Aravaipa Creek Primitive Area plus his cooperation in critically reviewing this report and making certain literature available to me.

INTRODUCTION

Aravaipa Creek in Graham and Pinal counties, Arizona, is a unique desert riparian community which intergrades the Upper and Lower Sonoran Life-zones (life-zones based on C. H. Merriam, et al., 1910). It is administered by the Bureau of Land Management as a Primitive Area. Adjacent properties which provide access to the Aravaipa Canyon Natural Area are owned by the Defenders of Wildlife and set aside as the George Whittell Wildlife Reserve. Together, these two areas comprise approximately 3,237.5 hectares (8,000 acres) along more than 17.7 km. (11 miles) of Aravaipa Creek.[20]

The creek drains the northern Galiuro Mountains and percolates through the sand/gravel aquifer of Aravaipa Valley until it arises at a point approximately 6 km. northwest of Klondyke at an a elevation of 1,007 m. (3,303 ft.).[2] It remains perennial for a distance of 35 to 45 km. before returning underground. On occasion, during periods of high discharge, the creek will reach its confluence with the San Pedro River, elevation 658 m. (2,160 ft.). But the periods are restricted to winter storms of long duration, heavy spring runoff, and/or heavy summer thunderstorms.

At about 8 km. downstream from Klondyke, Aravaipa Creek enters a canyon cut in the mid-Tertiary Galiuro Volcanics, a series of alternating tuffs, rhyolites, and andesites.[18,24,25] The canyon interior is characterized by having numerous side canyons, large boulders, and steep canyon walls which can exceed vertical heights of 250 m. from the streambed. Near Woods Ranch, elevation 792 m. (2,600 ft.), the canyon begins to widen into a streamcourse of decreased gradient under a broken to open riparian canopy. It later passes over the bajada onto alluvial sediments and most generally returns subsurface before reaching the San Pedro River.

Air temperatures for the Aravaipa area range enywhere from -5 C, during the winter coolness of January, to daytime highs of more than 38 C in the summer months of June and July.[2] Total annual precipitation is variable, but typically is highest in July and August and lowest in April through May. Mean annual precipitation for the upper Aravaipa Creek area near Klondyke is 34.7 cm.[19] whereas the lower Aravaipa Creek area receives an average 38.1 cm. (Dudleyville weather station, 21 km. west of Woods Ranch).

VEGETATION

Aravaipa Creek occurs within the Sonoran Desert which covers most of southwestern Arizona and, as indicated earlier, is characterized by a hot, arid climate with a bi-seasonal rainfall regime, winter and summer precipitation with spring and fall drought.

The source of Aravaipa Creek is located within the Upper Sonoran Life-zone, a zone which ranges from 1,067 or 1,219 m. (3,500 or 4,000 ft.) in elevation to as high as 2,134 m. (7,000 ft.) and includes grassland, chaparral, and open woodland communities.[15]

Within this zone, upper Aravaipa Creek is best characterized as a desert-grassland, a highly diverse type of community where grasses are comingled with various shrubs e.g., yuccas (Yucca spp.), sotol (Dasylirion wheeleri), jojoba (Simmondsia chinensis) and beargrass (Nolina microcarpa), and where junipers (Juniperus monosperma) are scattered on the north-facing slopes. This type of community most generally occurs on shallow-soiled, gravelly to rocky hills and slopes. It often represents a grass-dominated transition between either the open woodland or chaparral above and the desert-scrub below. As a transitional area, desert-grassland receives between 25.4 and 38.1 cm. (10 and 15 inches) of precipitation annually and occupies Arizona landscapes from below 1,067 m. and prevails upward to approximately 1,524 m. (5,000 ft.) in elevation.[16]

Downstream, desert-grassland grades into the desert-scrub of the Lower Sonoran Life-zone. In Arizona, total annual precipitation and elevation within this zone range from 7.6 cm. to 25.4 cm. precipitation and from 30.5 m. to approximately 1,219 m. elevation, according to slope exposure.

The Lower Sonoran desert vegetation represents approximately 9% of the Arizona flora (≈303 spp.) and is most widely characterized by two principal life-forms: (1) open, well-spaced microphyllous shrub vegetation that is either predominant or exclusive; and (2) spinose, succulent and/or microphyllous short tree vegetation, collectively called desert-scrub.[12]

The first is most clearly represented by creosote bush (Larrea divaricata) communities in which trees are usually lacking and shrubs and dwarf shrubs are dominant and widely scattered, This is a climax community which is characterized by soils of fine texture that are often alkaline and which inhabits areas of low relief i.e., the desert floor.

The second is most often represented by, but not restricted to, paloverde-saguaro (Cercidium-Cereus) communities. In this community, plants are comprised of small-leaved trees, as well as shrubs and numerous cacti. Best development is attained on rocky hills and coarse-soiled slopes i.e., the bajada, where the substratum is on or near the parent bedrock material. Plant morphology is highly diverse with leafless, drought deciduous, and evergreen species. Community biomass and productivity are greater here than in the creosote bush communities on the valley fill of the plains below, Shrubs are more varied than the trees, and although the foothill understory may be predominantly of a single species e.g., triangle-leaf bursage (Ambrosia deltoidea) or brittlebush (Encelia farinosa), it is often comprised of a mixture of 5 to 15 or more shrub and dwarf shrub species in the form of a layered understory.

Riparian habitats are distinct biotic communities associated with perennial or intermittent watercourses. They are unique reservoirs of

plant and animal diversity which extend From the desert-scrub of the Lower Sonoran to the fir forests of the Canadian Life-zone. These habitats consist of different life-forms or species other than those of the immediately surrounding non-riparian climax.[10] Riparian communities in Arizona have been reduced or eliminated by past and present land management to the point where it is estimated that total riparian area comprises only 113,152.6 hectares (279,600 acres) within the state, of which 40,752.7 hectares (100,700 acres) are adjacent to the Gila River.[1]

Following the classification outlined in Brown and Lowe (1974a), Aravaipa Creek best represents the Temperate Riparian Deciduous Biome, a warm-temperate, winter deciduous woodland. Because riparian communities generally exhibit a predictable vertical zonation where composition and form of the riparian woodland changes with elevation, this biome can be subdivided into two major communities: Mixed Broadleaf and Cottonwood-Willow.

Mixed broadleaf communities are usually found along rubble-bottomed perennial and semiperennial streams and are characterized in Aravaipa by a cottonwood (Populus fremonti), willow (Sal ix spp.), sycamore (Platanus wrightii), velvet ash (Fraxinus pennsylvanica subsp. velutina), walnut (Juglans major), and box elder (Acer negundo) canopy with a thick, luxuriant understory. A continuum condition exists in the Aravaipa area, where broadleaf species occur throughout the drainage but are most prevalent at the upper reaches.

Although no discreet boundaries exist downstream between species aggregations, vegetation within Aravaipa Canyon grades into a community dominated by cottonwood and willows (Sal ix gooddingii, S. bonplandiana).

The understory may be a dense stand of riparian tree regeneration or shrubs to relatively open and parklike areas. Willows, principally Salix gooddingii, outnumber cottonwood, and seep willow (Baccharis salicifolia) is the principal shrub of the understory. Cat-tail (Typha sp.) and watercress (Rorippa nasturtium-aquaticum) may be found growing in the creek itself along with a' ae which demonstrate seasonal trends of abundance, mostly encrusting diatoms (Bacillariophyceae) or filamentous Cladophoraceae (Cladophora

At the lower reaches, the floodplains are vegetated by winter deciduous microphylls e.g., mesquite (Prosopis velutina) and catclaw (Acacia greggii), which form a distinct border association that separates the riparian and desert-scrub climax communities. This transitional vegetation zone is often classified as a distinct community, the Subtropical Deciduous Woodland Biome. Within the Sonoran Desert, it is largely restricted to elevations below 1,067 m. where it attains maximum development on the alluvium of old flood-plains.[6] In the past, annual and perennial grasses and herbs formed the ground cover below mesquite dominated bosques and the understory was relatively open. But today, as on the Aravaipa floodplain, introduced annual forbs e.g., heron-bill (Erodium cicutarium), mustards e.g., London skyrocket (Sisymbrium irio), and grasses e.g., Bermuda grass (Cynodon dactylon), red brome (Bromus rubens), and Mediterranean grass (Schismus barbatus), are frequently encountered as understory species. Introduction of saltcedar (Tamarix pentandra) from the San Pedro River drainage is threatening to invade the Aravaipa area with its aggressive ability to outcompete the native riparian species such as seep willow and burro bush (Hymenoclea monogyra).

METHODS

Several collecting trips were made through the Aravaipa Canyon Primitive Area during the course of a year. Emphasis was placed on identifying the flora of Aravaipa Creek from the confluence of Turkey Creek to Woods Ranch and adjacent hillsides, with the listing expanded to include specimens from above and below these boundaries. Plant species were recorded according to personal observation and those specimens collected and processed were deposited at the Desert Botanical Garden herbarium (DES) Phoenix, Arizona. Identifications were made according to Kearney, Peebles, and collaborators (1960), except for the Cactaceae which followed Benson (1969). Certain other groups are treated according to recent revisions and monographic treatments.

The vascular flora listed for the Aravaipa Creek Primitive Area consists of 150 species in 128 genera representing 58 families. Each species listed in the flora catalogue is grouped by family and followed by its author and common name, if available. The sequence of families follows that of Kearney and Peebles in Arizona Flora and the genera within each family are arranged by alphabetical order. All species listed have been reviewed for recent taxonomic revisions according to Lehr (1978) and their most current synonomy has been included. Plant specimens that were not in flower at the time of observation could not be keyed to species and are therefore listed in the catalogue at the generic level only. I have included them here in an effort to make the catalogue as complete as possible, fully realizing that this best represents a partial list of the actual flora present for the Aravaipa area.

CATALOGUE OF VASCULAR PLANTS OCCURRING IN THE ARAVAIPA CREEK PRIMITIVE AREA

DIVISION: PTERIDOPHYTA. Ferns and Fern Allies

POLYPODIACEAE. Fern Family

Adiantum capillus-veneris L. Southern maidenhair fern

Asplenium resiliens Kunze. Small spleenwort

Cvrtomium auriculatum (Underw.) Morton.

Thelypteris puberula (Baker) Morton var. sonorensis A. Reid Smith.

DIVISION: SPERMATOPHYTA. Flowering Plants

CLASS: GYMNOSPERMAE

CUPRESSACEAE. Cypress Family

Juniperus monosperma (Engelm.) Sarg. One-seed juniper

CLASS: ANGIOSPERMAE

SUBCLASS: MONOCOTYLEDONEAE

TYPHACEAE. Cat-tail Family

Typha sp. Cat-tail

GRAMINEAE. Grass Family

Bromus rubens L. Red brome

Cynodon dactylon (L.) Pers. Bermuda grass

Schismus barbatus (L.) Thell. Meditteranean grass

LEMNACEAE. Duckweed Family

Lemna sp. Duckweed

AGAVACEAE. Agave Family

Agave chrysantha Peebles. Century plant

Dasylirion wheeleri Wats. Desert spoon, sotol

Nolina microcarpa Wats. Beargrass

SUBCLASS: DICOTYLEDONEAE

SALICACEAE. Willow Family

Populus fremonti Wats. Fremont cottonwood

Salix bonplandiana H.B.K. Bonpland willow

Salix gooddingii Ball. Goodding willow

JUGLANDACEAE. Walnut Family

Juglans malor (Torr.) Heller. Arizona walnut

FAGACEAE. Beech Family

Quercus turbinella Greene. Scrub oak

Quercus

ULMACEAE. Elm Family

Celtis pallida Torr. Desert hackberry

Celtis reticulata Torr. Net-leaf hackberry

MORACEAE. Mulberry Family

Morus microphylla Buckl. Texas mulberry

VISCACEAE. Mistletoe Family

Phoradendron californicum Nutt. Desert mistletoe

Phoradendron tomentosum (DC.) Gray (P. flavescens (Pursh) Nutt.). Inierto

POLYGONACEAE. Buckwheat Family

Eriogonum abertianum Torr.

Polygonum lapathifolium L. Willow smartweed

Polygonum sawatchense Small.

Rumex sp. Dock

CHENOPODIACEAE. Goose Foot Family

Atriplex canescens (Pursh) Nutt. Four-wing saltbush

Salsola iberica Sennen and Pau (S. kali L. var. tenuifolia (Tausch) Aellen). Russian thistle, tumbleweed

AMARANTHACEAE. Amaranth Family

Amaranthus fimbriatus (Torr.) Benth. Fringed amaranth

NYCTAGINACEAE. Four O'Clock Family

Allionia incarnata L. Trailing four o'clock

PHYTOLACCACEAE. Pokeberry Family

Rivina humilis L. Rouge plant, coralito

BERBERIDACEAE. Barberry Family

Berberis trifoliata Moric. Algerita

CRUCIFERAE. Mustard Family

Lesquerella gordoni (Gray) Wats. Gordon bladderpod

Lesquerella purpurea (Gray) Wats.

Rorippa nasturtium-aquaticum (L.) Schinz and Thell. Water-cress

Sisymbrium irio L. London skyrocket

PLATANACEAE. Plane Tree Family

Platanus wrightii Wats. Arizona sycamore

CROSSOSOMATACEAE. Crossosoma Family

Crossoma bigelovii Wats. Bigelow ragged rock flower

ROSACEAE. Rose Family

Prunus sp.

LEGUMINOSAE. Pea Family

MIMOSOIDEAE. Mimosa Subfamily

Acacia constricta Benth. White-thorn acacia

Acacia greggii Gray var. arizonica Isley (A. greggii Gray). Catclaw

Calliandra eriophylla Benth. Fairy duster

Desmanthus sp. Bundleflower

Mimosa biuncifera (Benth.) Britt. and Rose. Wait-a-minute bush

Prosopis velutina Woot. (P. juliflora (Swartz) DC. var. velutina (Woot.) Sarg.). Velvet mesquite

CAESALPINIOIDEAE. Senna Subfamily

Cassia covesii Gray. Desert senna

Cercidium floridum Benth. Blue paloverde

Cercidium microphyllum (Torr.) Rose and Johnst. Yellow or little-leaf paloverde

PAPILIONOIDEAE. Bean Subfamily

Amorpha fruticosa L. var. occidentalis (Abrams) Kearn. and Peeb. Bastard indigo

Astragalus sp. Loco weed

Lotus rigidus (Benth.) Greene. Desert rock pea, deer vetch

Lupinus sp. Lupine

Medicago sativa L. Alfalfa

Trifolium sp. Clover

GERANIACEAE. Geranium Family

Erodium cicutarium (L.) L'H'r. Heron-bill

OXALIDACEAE. Wood Sorrel Family

Oxalis sp.

ZYGOPHYLLACEAE. Caltrop Family

Larrea divaricata Cav. Creosote bush

RUTACEAE. Rue Family

Choisya arizonica Standl. Star-leaf

Ptelea trifoliata L. subsp. angustifolia (Benth.) V. L. Bailey (P. angustifolia Benth.). Narrowleaf hoptree

MALPIGHIACEAE. Malpighia Family

Janusia gracilis Gray.

EUPHORBIACEAE. Spurge Family

Acalypha ostryaefolia Riddell. Hornbeam three-sided mercury

Croton texensis (Klotzsch) Muell. Arg. Dove-weed

Euphorbia sp. Spurge

SIMMONDSIACEAE. Jojoba Family

Simmondsia chinensis (Link) Schneid. Jojoba
* usually included in the Buxaceae Family

ANACARDIACEAE. Cashew Family

Rhus radicans L. var. rydbergii (Small) Rehder. Poison ivy

Rhus trilobata Nutt. Skunk-bush, squaw-bush

ACERACEAE. Maple Family

Acer negundo L. var. interius (Britt.) Sarg. Box elder

SAPINDACEAE. Soapberry Family

Sapindus saponaria L. var. drummondii (Hook. and Arn.) Benson. Western soapberry

MELIACEAE. Melia Family

Melia azedarach L. China-berry tree

RHAMNACEAE. Buckthorn Family

Rhamnus californica Esch. subsp. ursina (Greene) Wolf. California buckthorn

Rhamnus crocea Nutt. var. ilicifolia (Kell.) Greene. Hollyleaf buckthorn

Sageretia wrightii Wats.

Zizyphus obtusifolia (Hook. ex Torr. and Gray) Gray var. canescens (Gray) M. C. Johnst. (Condalia lycioides (Gray). Graythorn

VITACEAE. Grape Family

Vitis arizonica Engelm. Canyon grape

MALVACEAE. Mallow Family

Anoda cristata (L.) Schlecht. Spurred anoda

Malva parviflora L. Cheeseweed

Sphaeralcea ambigua Gray. Desert mallow

TAMARICACEAE. Tamarix Family

Tamarix pentandra Pall. Saltcedar

PASSIFLORACEAE. Passion Flower Family

Passiflora mexicana Juss. Passion flower

CACTACEAE. Cactus Family

Cereus gigantens Engelm. (Carnegiea gigantea (Engelm.) Britt. and Rose). Saguaro

Echinocereus spp. Hedgehog

Ferocactus wislizenii (Engelm.) Britt. and Rose. Fish-hook barrel

Mammillaria spp. Pincushion

Opuntia acanthocarpa Engelm. and Bigel. Buckhorn cholla

Opuntia bigelovii Engelm. Teddybear cholla

Opuntia fulaida Engelm. Chain-fruit cholla

Opuntia kleiniae DC. var. tetracantha (Tourney) W. T. Marshall (O. tetracantha) Tourney). Klein cholla

Opuntia leptocaulis DC. Christmas cactus

Opuntia phaeacantha Engelm.

var. discata (Griffiths) Benson and Walkington (O. engelmanni Salm-Dyck). Engelmann prickly pear

var. laevis (Coult.) L. Benson (O. laevis Coult.).

Opuntia stanlyi Engelm. Devil cholla

ONAGRACEAE. Evening Primrose Family

Zauschneria californica Presl subsp. latifolia (Hook.) Keck. Hummingbird trumpet

UMBELLIFERAE. Parsley Family

Bowlesia incana Ruiz and Pavon. Hairy bowlesia

PRIMULACEAE. Primrose Family

Anagallis arvensis L. Scarlet pimpernel

PLUMBAGINACEAE. Plumbago Family

Plumbago scandens L. Leadwort

FOUQUIERIACEAE. Ocotillo Family

Fouquieria splendens Engelm. Ocotillo

OLEACEAE. Olive Family

Fraxinus pennsylvanica Marsh. subsp. velutina (Torr.) G. N. Miller. Velvet ash

ASCLEPIADACEAE. Milkweed Family

Asclepias linaria Cav. Milkweed

CONVOLVULACEAE. Morning Glory Family

Cuscuta La. Dodder

POLEMONIACEAE. Phlox Family

Phlox tenuifolia E. Nels.

VERBENACEAE. Vervain Family

Verbena sp. Vervain

LABIATAE. Mint Family

Marrubium vulgare L. Horehound

Salvia amissa Epling. Sage

Stachys coccinea Jacq. Texas betony

SOLANACEAE. Potato of Nightshade Family

Datura meteloides DC. Sacred datura, jimson weed

Lycium pallidum Miers. Wolfberry

Nicotiana glauca Graham. Tree tobacco

Petunia parviflora Juss. Wild petunia

Physalis acutifolia (Miers) Sand. (P. wrightii Gray). Wright ground cherry

Solanum douglasii Dunal. Nightshade

SCROPHULARIACEAE. Figwort Family

Maurandya antirrhiniflora Humb. and Bonpl. Blue snapdragon vine

Mimulus dentilobus Robins. and Fern. Monkey flower

Veronica anagallis-aquatica L. Water speedwell

ACANTHACEAE. Acanthus Family

Carlowrightia arizonica Gray.

RUBIACEAE. Madder Family

Cephalanthus occidentalis L. var. californicus Benth. Button bush

Galium aparine L. Bedstraw

CUCURBITACEAE. Gourd Family

Marah gilensis Greene. Wild cucumber

CAMPANULACEAE. Bellflower Family

Lobelia cardinalis L. subsp. graminea (Lam.) McVaugh. Cardinal flower

COMPOSITAE. Sunflower Family

Acourtia wrightii (Gray) Reveal and King (Perezia wrightii Gray). Brownfoot

Ambrosia ambrosioides (Cav.) Payne (Franseria ambrosioides Cav.). Canyon ragweed

Ambrosia confertiflora DC. (Franseria confertiflora (DC.) Rydb.). Slimleaf bursage

Ambrosia deltoidea (Torr.) Payne (Franseria deltoidea Torr.). Triangle-leaf bursage

Artemisia ludoviciana Nutt. Sagebrush

Aster subulatus Michx. var. ligulatus Shinners (A. exilis Ell.). Aster

Baccharis salicifolia (Ruiz and Pavon) Pers. (B. glutinosa Pers.). Seep willow

Baccharis sarothroides Gray. Desert broom

Baileya multiradiata Harv. and Gray. Desert marigold

Bebbia juncea (Benth.) Greene. Chuckawalla's delight

Bidens p11052 L. Bur marigold

Brickellia californica (Torr. and Gray) Gray. Pachaba, brickel bush

Encelia farinosa Gray. Brittle bush

Ericameria cuneata (Gray) McClatchie var. spathulata (Gray) Hall (Haplopappus cuneatus Gray var. spathulata (Gray) Blake). Desert rock goldenbush

Erigeron divergens Torr. and Gray. Spreading fleabane

Erigeron oreophilus Greenm.

Gnaphalium sp. Cudweed

Haplopappus spinulosus (Pursh) DC.

Haplopappus tenuisectus (Greene) Blake. Burroweed

Helenium thurberi Gray. Sneeze weed

Hymenoclea monogyra Torr. and Gray. Burro bush

Hymenothrix wislizenii Gray.

Hymenothrix wrightii Gray.

Machaeranthera sensu Cronquist and Keck

Perityle lemmoni (Gray) Macbride (Laphamia lemmoni Gray and L. dissecta Torr. sensu Kearn. and Peeb.).

Porophyllum gracile Benth. Odora

Psilostrophe cooperi (Gray) Greene. Paperflower

Solidago wrightii Gray. Goldenrod

Stephanomeria pauciflora (Torr.) A. Nels. Desert straw

Viguiera multiflora (Nutt.) Blake. Golden eye

Xanthium strumarium L. (X. saccharatum Wallr.). Cocklebur

SUMMARY BY MAJOR TAXA OF THE
KNOWN VASCULAR FLORA OF ARAVAIPA CREEK PRIMITIVE FLORA

Major Taxa	Families	Genera	Species
Pteridophyta	1		4
Spermatophyta			
Gymnospermae	1	1	1
Angiospermae			
Monocotyledonae	4	8	8
Dicotyledonae	52	115	137
Totals	58	128	150

LIST OF AUTHOR NAME ABBREVIATIONS

Benth.	G. Bentham
Bigel.	J. Bigelow
Britt.	N. L. Britton
Britt. and Rose	N. L. Britton and J. N. Rose
Buckl.	S. B. Buckley
Cav.	A. J. Cavanilles
Coult.	J. M. Coulter
DC.	A. P. de Candolle
Ell.	S. Elliot
Engelm.	G. Engelmann
Esch.	J. R. Eschscholtz
Fern.	M. L. Fernald
Greenm.	J. M. Greenman
H.B.K.	F. W. H. von Humboldt
Harv.	W. H. Harvey
Hook.	W. J. Hooker
Hook. and Arn.	W. J. Hooker and G. A. W. Arnott
Humb. and Bonpl.	F. W. H. von Humboldt and A. J. A. Bonpland
Jacq.	N. J. von Jacquin
Johnst.	I. M. Johnston
M. C. Johnst.	M. C. Johnston
Juss.	A. L. de Jussieu
Kearn. and Peeb.	T. H. Kearney and R. H. Peebles
Kell.	A. Kellogg
L.	C. Linnaeus
Lam.	J. B. de Lamarck
L'Hgr.	C. L. L'Hgritier de Brutelle
Marsh.	H. Marshall
Michx.	A. Michaux
Moric.	M. E. Moricand
Muell. Arg.	J. Mueller
A. Nels.	A. Nelson
E. Nels.	E. E. Nelson
Nutt.	T. Nuttal
Pall.	P. S. Pallas
Pers.	C. H. Persoon
Robins.	B. L. Robinson
Ruiz and Pavon	H. R. Lopez and J. A. Pavon
Rydb.	P. A. Rydberg
Sandw.	N. Y. Sandwith
Sarg.	C. S. Sargent
Schlecht.	D. F. L. von Schlechtendal
Schneid.	C. K. Schneider
Standl.	P. C. Standley
Then.	A. Thellung
Torr.	J. Torrey
Torr. and Gray	J. Torrey and A. Gray
Underw.	L. M. Underwood
Wallr.	C. F. W. Wallroth
Wats.	S. Watson
Woot.	E. O. Wooton

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