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NAME: THE EFFECTS OF INTERIM FLOWS FROM GLEN CANYON DAM ON RIPARIAN VEGETATION ALONG THE COLORADO RIVER IN GRAND CANYON NATIONAL PARK, ARIZONA: DRAFT 1993 ANNUAL TECHNICAL AND ADMINISTRATIVE REPORT

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INTRODUCTION

Riparian vegetation is structurally adapted to the flooding frequency of the river system in which it occurs (Odum 1981, Nilsson 1985, Stevens 1989); however, impoundment alters the frequency, magnitude, duration and seasonal timing of flooding disturbance. Discharge from Glen Canyon Dam affects riparian vegetation along the Colorado River downstream in Glen Canyon National Recreation Area and in Grand Canyon National Park (Carothers et al. 1979, Stevens and Waring 1988, Stevens 1989, Stevens and Ayers 1993). These effects include altered establishment patterns of marsh and other shoreline plant communities by influencing erosion of alluvial sediment deposits, seed dispersal and seedling establishment, water relations of streamside plants, and the population dynamics of exotic plant species.

Riparian vegetation is widely recognized as supporting high levels of biodiversity and generating high levels of bioproductivity. In the Southwest, riparian habitat comprises less than 0.05 percent of the landscape but supports more than 50 percent of the species in that landscape (Simcox and Zube 1985, Stevens in prep.). In Grand Canyon National Park, more than 5,000 species of plants and animals rely on desert riparian habitats. For this reason, Grand Canyon National Park established maintenance of riparian vegetation in the Colorado River corridor as a primary management objective.

On 1 August, 1991, the Secretary of the Interior mandated implementation of experimental Interim Flows criteria, a program of reduced maximum flows and reduced fluctuation from Glen Canyon Dam. Interim Flows criteria, which were officially implemented in November, 1991, have been designed to mitigate impacts of dam operations on downstream riverine resources until a Record of Decision is reached for the Glen Canyon Dam Environmental Impact Statement process. Interim flows consist of low-, medium-, and high-volume months, with low flows during the spring and late fall, moderate flows in June, September and November, and high flows during mid-summer and mid-winter. Interim flows have a minimum flow of 141.5 m^3/s (5,000 cfs), a maximum discharge of 566 m^3/s (20,000 cfs), a reduced range of daily fluctuation, and reduced up-ramping and down-ramping rates. Interim flow criteria were designed to limit sediment loss, thereby allowing riparian ecosystem processes to proceed unaffected by dam operations and in accord with the National Park Service management objectives until the Record of Decision. Thus, finding little change in resource states signifies that the purposes for which interim flows were established are being achieved.

We are monitoring the effects of interim flows on riparian vegetation composition and structure using comparably collected data from the Glen Canyon Environmental Studies Phase II program (Patten 1990). This study provides data on interim flows effects on the rate and trajectory of the riparian plant community development, fluvial/terrestrial ecosystem interactions, population changes in exotic plant species, and the risk status of listed, endemic and introduced plant species.

Objectives

The objectives of this study are to determine whether interim flows are limiting the impacts of Glen Canyon Dam operations on riparian vegetation resources in the Grand Canyon.

1. Monitor the effects of interim flows from Glen Canyon Dam on the distribution, extent and development of fluvial marshes along the Colorado River from Glen Canyon Dam to Diamond Creek, AZ.

2. Monitor the effects of interim flows from Glen Canyon Dam on the distribution and development of other new high water zone plant assemblages between Glen Canyon Dam and Diamond Creek, AZ.

3. Prepare monitoring data for inclusion into the GCES/NPS GIS database.

METHODS AND RESULTS

Study Area

A series of long-term quadrats were established during GCES-II. Twenty mainstream study areas and 24 tributary control sites that had been established in Grand Canyon during the Glen Canyon Environmental Studies Program Phase II (Stevens and Ayers 1993) were monitored during 1993 (Table 1, Fig. 1). Each study area contains 5 m x 10 m permanent quadrats in the following geomorphic environments: marsh, bar platform, channel margin and debris fan habitats (Fig. 2). The quadrats lying in the mainstream lower riparian zone were censused in fall, 1993, and provide a consistent database for monitoring dam discharge impacts on riparian vegetation development.

1993 Logistics

We conducted 6 research river trips in 1993 (Table 2) in accord with our proposed schedule for vegetation mapping. Staffing and equipment costs on these trips were borne by this project, and

Table 1: Study sites in the Colorado River corridor, Grand Canyon National Park.

MILE/ SIDE*	TYPE OF STUDY SITE	USE IN THIS STUDY
0.0R*	Mapping	Veg. Mapping
0.7R	Paria River Tributary	LT Tributary Quads
8.0L	LTS**	LT Quads
8.0L	Badger Cr. Tributary	LT Tributary Quads
19.9L	Marsh	LRZ Marsh MIPS Analysis
20.5R	North Cyn. Tributary LTS	LT Tributary Quads
26.0R	Marsh	Off-river MIPS Control Site
30.0L	30 Mile Cyn. Tributary	LT Tributary Quads
31.5R	LTS	LT Quads
31.8R	Vaseys Tributary LTS	LT Tributary Quads
37.0L	Marsh	LRZ Marsh MIPS Analysis
43.1L	Marsh, Mapping	Marsh Transects, Veg. Mapping, LRZ MIPS, PWP
47.0R	Saddle Cyn. Tributary	LT Tributary Quads
50.0L	Marsh, PWP	LRZ Marsh MIPS Analysis, PWP
51.3L	Marsh, Mapping, LTS	LT Quads, LRZ Marsh MIPS Analysis, Veg.Mapping
51.6L	Marsh, Mapping	LRZ Marsh MIPS Analysis, Veg. Mapping
51.9R	Little Nankoweap Cyn. Tributary	LT Tributary Quads
52.2R	Nankoweap Cr. Tributary	LT Tributary Quads
53.0R	Marsh	LRZ Marsh MIPS Analysis
55.5R	Marsh, Mapping	LRZ Marsh MIPS Analysis, Veg. Mapping,
61.0	Mapping	Veg. Mapping
61.0R	Little Colorado R. Tributary	LT Tributary Quads
64.7R	Carbon Cr. Tributary	LT Tributary Quads
68.2R	Mapping, LTS	LT Quads, Veg. Mapping
71.0L	Marsh, Mapping, LTS	LT Quads, LRZ Marsh MIPS Analysis, Veg. Mapping
76.5R	Marsh	Off-river MIPS Control Site
98.0R	Crystal Cr. Tributary	LT Tributary Quads

Table 1 (cont'd.)

MILE/ SIDE	TYPE OF STUDY SITE	USE IN THIS STUDY
103.9R	LTS	LT Quads
106.0L	Serpentine Cyn. Tributary	LT Tributary Quads
109.0R	Shinumo Cr. Tributary	LT Tributary Quads
119.0R	LTS	LT Quads
122.1R	122-Mile Cyn. Tributary	LT Tributary Quads
122.1R	LTS, Mapping	LT Quads, Veg Mapping
122.8L	Marsh, Mapping, LTS	LT Quads, LRZ Marsh MIPS Analysis, Veg. Mapping
126.0L	126 Mile Cyn. Tributary	LT Tributary Quads
133.5R	Tapeats Cr. Tributary	LT Tributary Quads
136.0L	Deer Cr. Tributary	LT Tributary Quads
136.5R	Marsh	LRZ and Off-river Control MIPS Sites
137.0R	LTS, Mapping	LT Quads, Veg Mapping
143.5R	LTS, Mapping	LT Quads, Veg Mapping
143.5R	Kanab Cr. Tributary	LT Tributary Quads
145.0L	LTS	LT Quads
148.0L	Matkatamiba Cr. Tributary	LT Tributary Quads
157.0L	Havasu Cyn. Tributary	LT Tributary Quads
166.0	Mapping	Veg. Mapping
171.5L	Marsh, PWP	LRZ Marsh MIPS Analysis, PWP
171.5L	Mohawk Cyn. Tributary	LT Tributary Quads
172.1L	LTS	LT Quads
179.5L	Marsh, PWP	Off-river Control MIPS Analysis
182.7R	LTS	LT Quads
194.1L	Marsh, LTS, Mapping, PWP	LRZ Marsh MIPS, LT Quads, Veg Mapping, PWP
198.0R	Marsh	LRZ Marsh MIPS Analysis
198.5R	Parashant Cyn. Tributary	LT Tributary Quads
209.0	Mapping	Veg. Mapping

Table 1 (cont'd.)

MILE/ SIDE	TYPE OF STUDY SITE	USE IN THIS STUDY
213.0R	LTS	LT Quads
219.9R	LTS	LT Quads
220.0R	220 Mile Cyn. Tributary	LT Tributary Quads
225.0R	Marsh	LRZ Marsh MIPS Analysis
225.7L	Diamond Cr. Tributary	LT Tributary Quads

* Left or Right side of the river, looking downstream
** LTS - Long-term studies

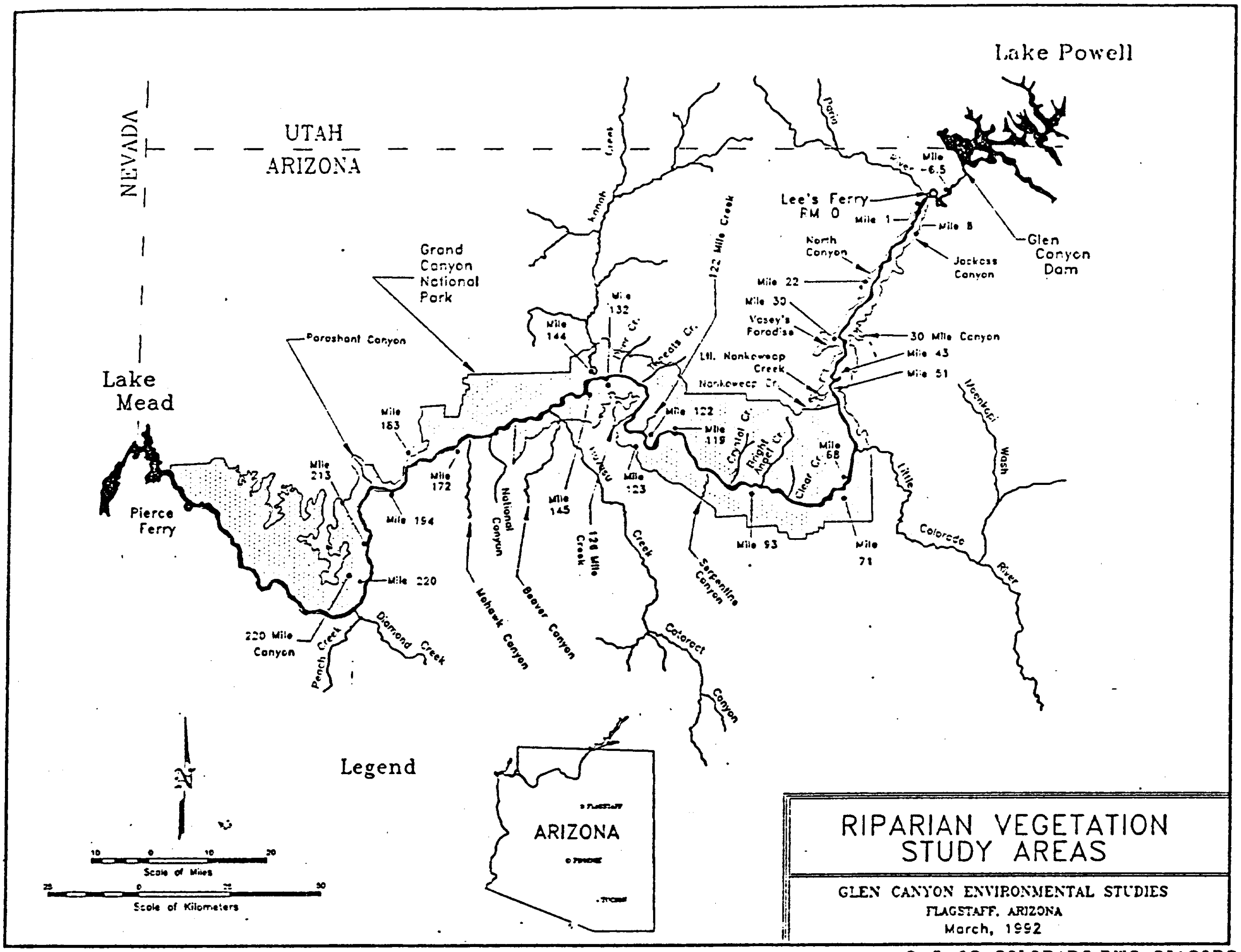

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Figure 1: Map of study areas and specific study sites used in interim flows monitoring, Grand Canyon National Park, Arizona.

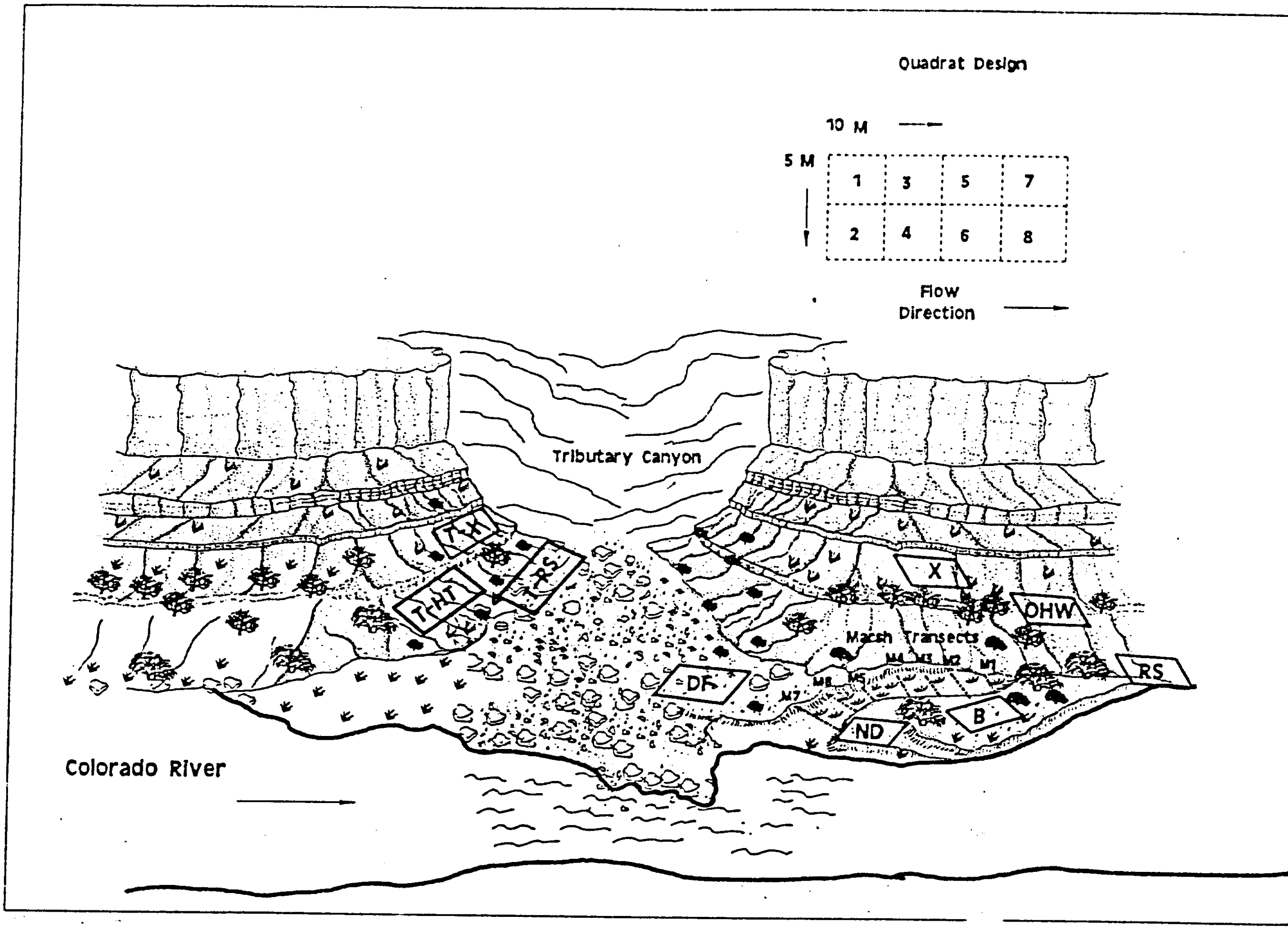


Figure 2: Schematic diagram of geomorphic settings and locations of marsh transects and 5 m x 10 m quadrats in a typical recirculation zone associated with a tributary confluence in the Colorado River downstream of Glen Canyon Dam in Grand Canyon National Park, Arizona.

Table 2: Research river trips summary, 1993.

TRIP DATES	PURPOSE OF TRIP	NUMBER OF NAU STAFF	NUMBER OF VIP'S (HR OF WORK)	NUMBERS OF BR, NPS AND OTHER STAFF
4-20 May	Spring marsh and trib monitoring, mapping, PWP, surveying	7	14 (1904)	3
2-14 June	Mapping, light measurement PWP, tributary plots wrap-up	3.5	6 (624)	2
8-19 July	Mapping, light measurement PWP	3	6 (576)	2
8-24 Sept.	Mainstream plot monitoring, marsh inventory, mapping, PWP, surveying	5	7 (952)	7
[1-20 Oct.	PWP	1	1 (53)	0]
29 Oct-14 Nov	Fall marsh monitoring, mapping, PWP wrap-up, productivity wrap-up	7	7 (952)	4
10-12 Dec.	Complete Lees Ferry sites	1	0 (0)	1

logistics were provided by O.A.R.S., Inc and the Bureau of Reclamation Glen Canyon Environmental Studies office. We received a total of 5,061 hours of field assistance from dedicated, well-trained volunteers, who were supported through the Volunteer In Park Program at Grand Canyon National Park. Our safety record is exceptionally good, and only two field crew members sustained minor injuries in 1993.

Objective 1: Monitor the effects of interim flows from Glen Canyon Dam on the distribution, extent and development of fluvial marshes along the Colorado River from Glen Canyon Dam to Diamond Creek, AZ.

Study Approaches

We are monitoring the effects of interim flows on fluvial marsh development through several approaches, including: classification of marsh plant associations using TWINSPAN (Hill 1979); an inventory of Colorado River fluvial marshes between Lees Ferry and Diamond Creek, Arizona; a map image processing system (MIPS) analysis of annual aerial photographs of 24 marshes from 1988 through 1993; monitoring of permanent belt transects; and plant water potential of Salix exigua at 4 marsh sites.

Marsh Plant Associations

A preliminary classification of marsh plant associations was derived using TWINSPAN (Hill 1979) analysis of a matrix of basal area of 76 species in 307 1.0 m^2 plots. This FORTRAN program arranges a multivariate species x plots matrix in an ordered two-way table to produce a classification of species groups.

Four preliminary groups were distinguished through the TWINSPAN classification. The first TWINSPAN division distinguished a wet marsh assemblage from a phreatophyte/dry marsh assemblage (Table 3). The second TWINSPAN division of the wet marsh vegetation distinguished a cattail/rush/reed association (Typha domingensis, Juncus spp., Phragmites australis) from a non-clonal herbaceous and grass horseweed association (Conyza canadensis, Cynalon dactylon). The phreatophyte/dry marsh group separated a woody perennial association (Tamarix ramosissima, Pluchea sericea) and a dry marsh association (Equisetum laevigatum x hymale, Salix exigua).

Table 3: Four marsh plant associations derived from TWINSPAN analysis of 307 1.0 plots in 7 fluvial marshes, and associated mean inundation frequency, mean soil texture, mean total basal area (cm^2/m^2) and mean species richness/m^2.

MARSH ASSOCIATION	MEAN INUNDATION FREQUENCY (n, 1 sd)	MEAN SOIL TEXTURE	MEAN TOTAL BASAL AREA (cm^2/m^2) (1 sd)	SPECIES RICHNESS (S/m^2) (1 sd)
1. CLONAL WET MARSH (CATTAIL/REED) Typha domingensis, Phragmites australis, Juncus torreyana, Carex aquatilis, Equisetum arvense, Scirpus validus, Agrostis stolonifera, Echinochloa crus-gallii, Veronica anagallis-aquatica	0.54 (50, 0.251)	silty loam	52.9 (80.931)	4.6 (2.914)
2. NONCLONAL WET MARSH (HORSEWEED) Conyza canadensis, Polygonum aviculare, Cynodon dactylon, Melilotus alba, M. officinale	0.17 (43, 0.17)	loamy sand	14.7 (14.554)	4.9 (2.320)
3. WOODY PHREATOPHYTE (TAMARISK/ARROWWEED) Tamarix ramosissima, Pluchea sericea, Alhagi camelorum, Artemisia ludoviciana, Aster spinosus, Baccharis salicifolia, Bromus rubens, Centaurium calycosum, Epilobium adenocaulon, Erigeron divergens, Gnaphalium chilense, Gutierezzia sarothrae, Hordeum jubatum, Oenothera hookeri, O. pallida, Salix gooddingii, Salsola iberica, Sonchus asper, Sporobolus cryptandrus, Sporobolus contractus, Xanthium strumarium	0.16 (68, 0.197)	sand	39.9 (86.812)	4.5 (2.465)

(Table 3, cont'd.)

MARSH ASSOCIATION	MEAN INUNDATION FREQUENCY (n, 1 sd)	MEAN SOIL TEXTURE	MEAN TOTAL BASAL AREA (cm^2/m^2) (1 sd)	SPECIES RICHNESS (S/m^2) (1 sd)
4. DRY MARSH (HORSETAIL/WILLOW) Equisetum laevigatumxhymale, Salix exigua,	0.18 (146, 0.194)	sand	16.4 (19.456)	4.7 (2.459)
Ambrosia sp., Andropogon glomeratus, Artemesia dracunculus, Aster subulatus, Baccharis emoryi, Bromus tectorum, Bromus wildenowii, Chrysothamnus nauseosus, Corispermum nitidum, Dicoria brandegei, Elymus canadensis, Juncus sp., Lepidium latifolium, Muhlenbergia asperifolia, Plantago lanceolata, Plantago major, Polypogon monspeliensis, Solidago canadensis, Sporobolus flexuosus, Taraxacum officinale				

Fluvial Marsh Inventory

We replicated our 1991 inventory of fluvial marshes between Lees Ferry and Diamond Creek. All marshes were identified as to location, side of the river, composition, and approximate size. Vegetation data were compiled and compared with the 1991 data. Glen Canyon Dam flow data were compiled for the period from 1989 through 1993 (Fig. 3), and flow duration data have been calculated (Fig. 4).

In 1993 we found 895 cattail/rush/reed fluvial marsh patches (7.03 ha) in the lower riparian zone of the Colorado River between Lees Ferry and Diamond Creek, not counting 33 marshes (3.48 ha) associated with tributary mouths or springs (Table 4).

The 1993 data represents 3.5 fold increase in cattail/rush/reed marsh patch density, up from 253 in 1991, but a 22 percent decrease in marsh area, down from 9.0 ha in 1991 (Table 4). The great increase in cattail/rush/reed marsh density/km reflects the large number of small, wet marsh patches that are presently colonizing the river corridor. Despite this large increase in density, total marsh area decreased between inventories. The reaches downstream from the Little Colorado River that had been inundated and scoured by the January-February 1993 floods decreased in area most strongly, with marsh area losses of up to 90 percent in some narrow reaches. In contrast, the four unflooded reaches upstream from the Little Colorado River generally exhibited a slight gain in marsh area.

As in 1991, marsh area is strongly correlated with channel width and other geomorphic relationships (Stevens and Ayers 1993).

MIPS Marsh Area Analysis

To assess changes in the area of individual fluvial marshes between years, we examined serial video- and still image aerial photographs for 20 lower riparian zone (LRZ), and four adjacent, but off-river, spring-fed marshes (off-river) using Map and Image Processing System (MIPS; Tables 1, 5). The LRZ marshes were distributed throughout the river corridor, and were selected on the basis of distribution within geomorphic reaches established by Schmidt and Graf (1990). The four off-river marshes constituted a set of control sites against which to evaluate changes in wetland vegetation not induced by dam operations.

The photo series included: 28 May, 1988 (still photography, variable flow); 4-5 June, 1990 (still photography, constant 141.5 m^3/s); July 28-29, 1991 (video, constant 141.5 m^3/s); 10-11

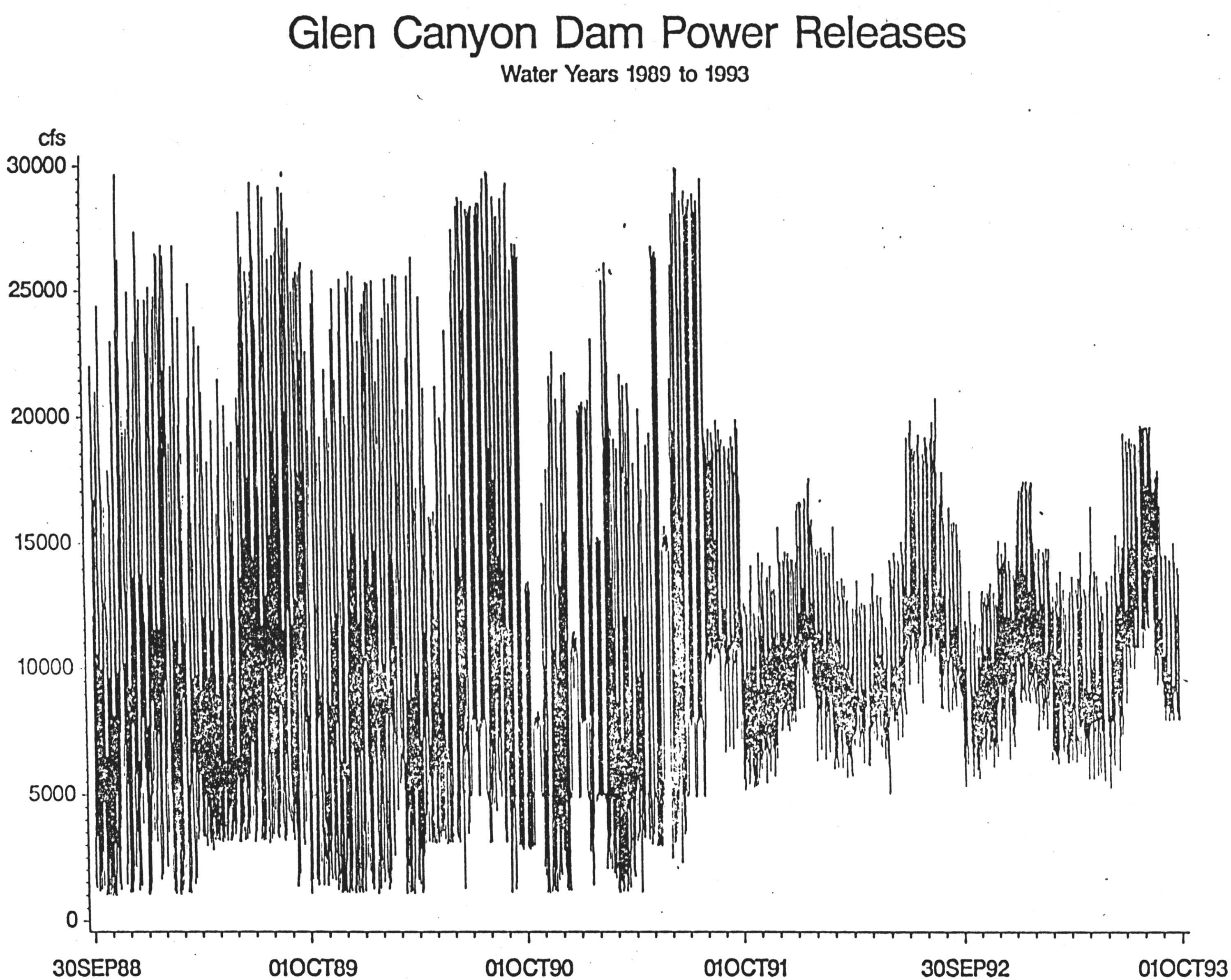
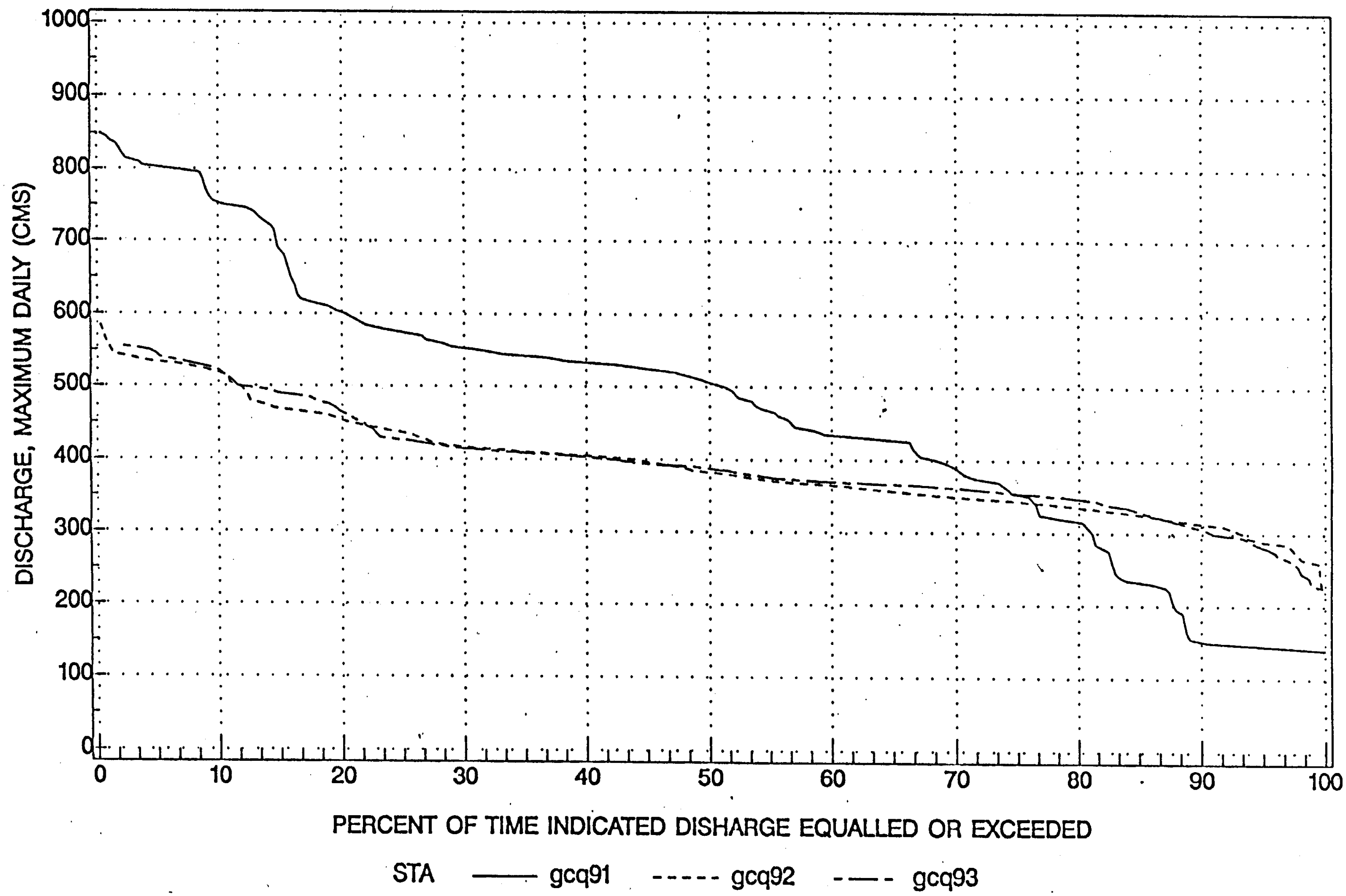


Figure 3: Glen Canyon Dam discharges, water years 1989 through 1993, as measured at Glen Canyon Dam. Data courtesy of the Bureau of Reclamation.



Increments – 5 cubic meters per second (cfs = cms *35.3)

Figure 4: Flow duration curves from Glen Canyon Dam for water year 1991 (a near-normal discharge pattern) and water years 1992 and 1993 (Interim Flows releases).

Table 4: Geomorphic characteristics and 1991 and 1993 lower riparian zone fluvial marsh inventory in 11 reaches of the Colorado River between Lees Ferry and Diamond Creek, Grand Canyon National Park, Arizona, excluding marshes associated with springs or tributaries. Reach descriptions follow Schmidt and Graf (1990). One sd for mean area data is included parenthetically.

REACH	RCH LENGTH (KM)*	MEAN RCH WIDTH (M)**	1991 MSH DEN/ KM	1993 MARSH DEN/ KM	MEAN 1991 MSH AREA (HA)	MEAN 1993 MSH AREA (HA)	1991 MSH CVR (HA/KM)	1993 MSH CVR (HA/KM)	1991 TOTAL MSH AREA (HA)	1993 TOTAL MSH AREA (HA)
Permian Reach	17.7	85.3 W	.51	2.32	.10 (.120)	.02 (.029)	.04	.04	.71	.67
Supai Gorge	18.5	64.0 N	.22	1.73	<.01 (.010)	<.01 (.005)	<.01	<.01	.05	.06
Redwall Gorge	28.0	67.1 N	.07	3.25	.01 (.015)	<.01 (.002)	<.01	<.01	.08	.10
Lower Marble Canyon	34.6	106.7 W	1.88	6.94	.05 (.118)	.01 (.069)	.08	.08	2.76	2.78
Furnace Flats	25.4	118.9 W	1.18	2.56	.04 (.060)	.01 (.003)	.04	.03	1.02	.73
Up. Granite Gorge	64.8	57.9 N	.05	0.14	.02 (.018)	<.01 (.013)	<.01	<.01	.06	.06
Aisles Reach	12.2	70.1 N	.16	0.33	.02 (.014)	<.01 (.002)	<.01	<.01	<.01	<.01

Table 4 (continued)

REACH	RCH LENGTH (KM)*	MEAN RCH WIDTH (M)**	1991 MSH DEN/ KM	1993 MARSH DEN/ KM	MEAN 1991 MSH AREA (HA)	MEAN 1993 MSH AREA (HA)	1991 MSH CVR (HA/KM)	1993 MSH CVR (HA/KM)	1991 TOTAL MSH AREA (HA)	1993 TOTAL MSH AREA (HA)
Mid. Granite Gorge	23.0	64.0 N	.04	1.22	.08 (-)	<.01 (.019)	<.01	<.01	.13	.13
Muav Gorge	32.0	54.9 N	.19	1.34	.01 (.015)	<.01 (.018)	<.01	<.01	.13	.13
Lower Canyon Reach	86.6	94.5 W	1.34	3.72	.03 (.034)	<.01 (.016)	.04	.03	3.46	2.32
Low. Granite Gorge	18.7	73.2 N	.75	1.07	.04 (.046)	<.01 (.004)	.03	<.01	.56	<.01
TOTALS OR GRAND MEANS	362.8	79.0	.70	2.47	.04 (.071)	0.008 (0.039)	.02	.02	8.99	7.03

* Distance downstream from Lees Ferry, Arizona
** Reported by Schmidt and Graf (1990): N = narrow reach; W = wide reach.

Table 5: MIPS analysis of marsh area change of 20 fluvial and 4 off-river marshes between 1988 and 1993 in the Colorado River corridor in Grand Canyon National Park, AZ

MILE/SIDE*	DEPOSITIONAL ENVIRONMENT**	FLUVIAL OR OFF-RIVER MARSH	MARSH AREA (HA) 1988	1990	1991	1992	1993
-6.5R	RCC	F	0.1764	0.2507	---	0.2702	0.3067
19.9L	RCC	F	0.0	0.006	---	0.0066	0.001
25.5R	CM	F	0.0017	0.0099	0.0053	0.0107	0.0194
25.5R	SPRING	OR	0.0166	0.0112	0.0180	0.0227	0.0246
43.1L	RCC+BP	F	0.0133	0.0406	0.06	0.0681	0.065
50.0L	RCC+BP	F	0.0113	0.1760	0.3149	0.4991	0.5099
51.2L	RCC+BP	F	0.0230	0.1806	0.2942	0.4011	0.4206
51.4L	RCC+BP	F	---	0.1009	0.1114	0.1805	0.1797
53.0R	SD+RCC	F	---	0.1475	0.1571	0.2048	0.1956
55.5R	BP	F	0.063	0.4927	0.7879	1.0904	0.9865
71.1L	RCC+BP	F	---	0.2828	0.3338	0.4257	0.3969
76.5R	CM	F	0.0086	0.029	0.0907	0.1230	0.1002
76.5R	SPRING	OR	0.3047	0.3296	0.2791	0.3661	0.3338
122.8L	RCC	F	0.0	0.0233	0.0665	0.07	0.0153
136.5R	CM	F	0.0171	0.0633	0.0865	0.1542	0.0927
136.5	SPRING	OR	0.5671	0.6508	0.6686	0.5903	0.5895
171.5L	RCC+BP	F	---	0.036	0.0727	0.1429	0.1051
172.1L	RCC+BP	F	0.0088	0.1672	0.1781	0.2217	0.0744
179.4L	SPRING	OR	0.9699	0.9135	1.0015	0.9919	1.0975
194.1L	RCC+BP	F	0.0056	0.124	0.2648	0.3727	0.4086
198.0R	RCC+BP	F	0.0101	0.071	0.1728	0.2318	0.1733
213.0L	RCC+BP	F	0.0	0.0221	0.1067	0.1677	0.0576
225.2R	RCC+BP	F	0.0079	---	0.0913	0.1646	0.1325

* Side looking downstream
** CM - channel margin deposit; RCC - return current channel, RCC+BP - return current channel + bar platform; SPRING - spring source.

October, 1992 (still photography, constant 141.5 m^3/s); and 28-31 May, 1993 (still photography, constant 226.5 m^3/s).

Several of the study marshes were under study by Stevens in 1984-1986. The 1991 video imagery was collected immediately prior to implementation of interim flows on 1 August, 1991, and therefore provides a good baseline for the analysis of interim flows effects. The May, 1993 photograph series was taken 3 months after recession of three 10-year flows in the Little Colorado River drainage, and therefore provide information on flood impacts, with controls above the LCR having no flood effects.

Marsh area was mapped at approximately 1:4,800 scale from the photographs and scanned into MIPS. Two or more hard points that were identifiable on all photographs were measured in the field, and the data were transferred to MIPS. Plan view area measurements of marshes were then calculated. Video images were digitized directly off the MIPS screen. Mean marsh area was calculated for LRZ marshes by pooling all fluvial marsh sizes.

LRZ area data were analyzed using the nonparametric Friedman test Marsh area was interpolated for ranking for the few cases in which aerial images were uninterpretable because of shadows. Off-river marsh area was analyzed separately and similarly.

Fluvial marsh area increased significantly from 1988 through 1992, and then decreased significantly in 1993 [Friedman $T_{4,76} = 385.255$, $p < 0.001$; critical rank sum difference between blocks (years) = 7.362 exceeded by all pairwise comparisons of rank sum values for 1988, 1990, 1991, 1992, and 1993 which were 20,41,59,95 and 85, respectively; Table 5; Fig. 5]. In contrast, the off-river marshes showed no significant change through time ($T_{4,15} = 6.0$, $p = 0.199$; Table 5, Fig. 5).

The pattern of marsh area decrease between 1992 and 1993 was partially the result of January-February, 1993 flooding in the Little Colorado River (LCR) drainage. This flood raised mainstream river discharge to 935 m^3/s (33,000 cfs) for several weeks and scoured vegetation that had become established under Interim Flows from low-lying portions of sand bars. Ten of 11 marshes below the Little Colorado River decreased in area in 1993 as compared to 1992.

Interim Flows also appears to be negatively influencing marsh area. Five of 9 mainstream marshes upstream from the LCR confluence also decreased in size from 1992 to 1993. Because these marshes lie upstream from the LCR, they were not scoured by flooding, and therefore represent a negative effect of interim flows on marsh development. MIPS analyses show that marshes were steadily increasing between 1990 and 1991, a period of nearly

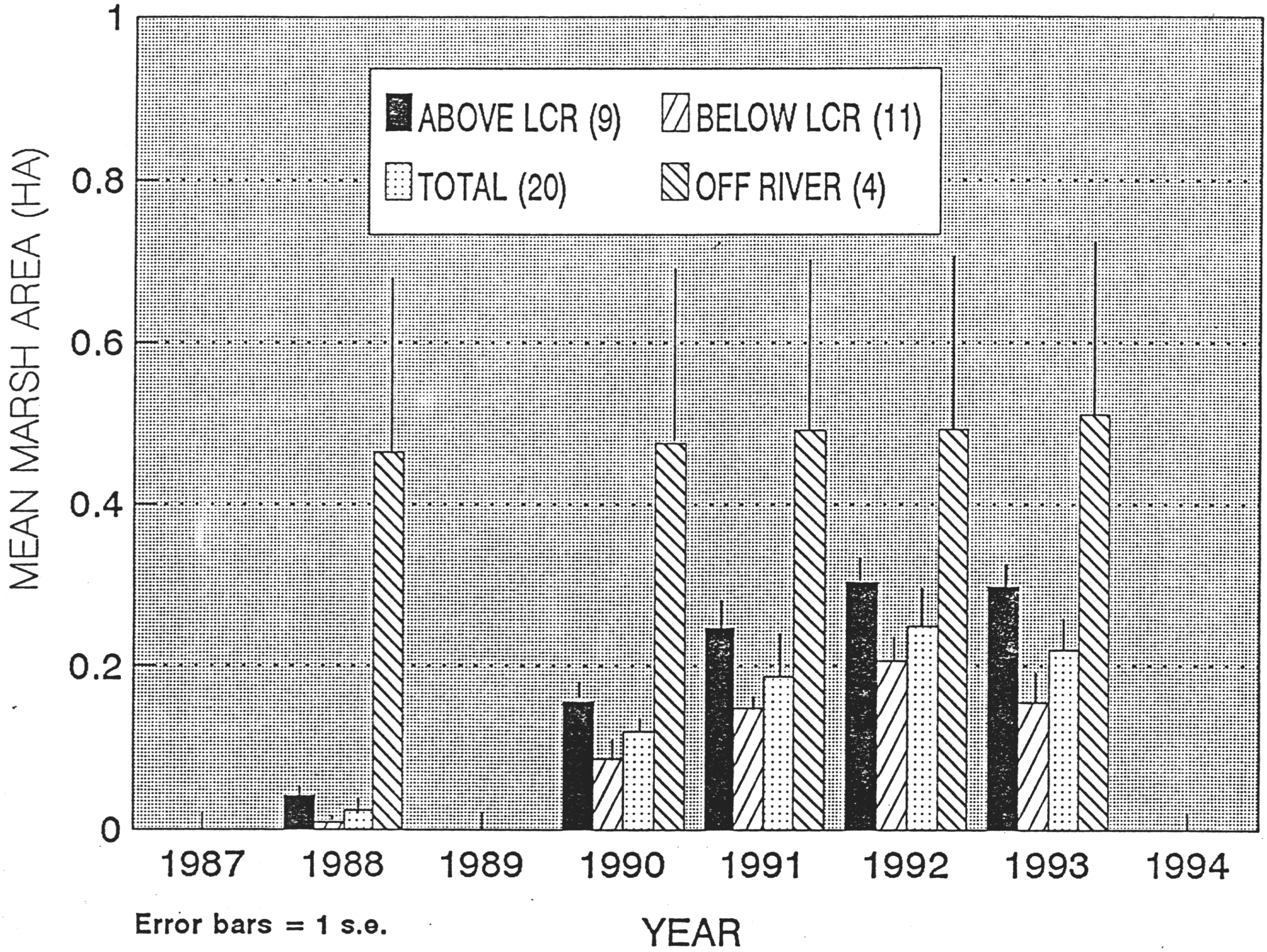


Figure 5: Mean marsh area of 20 riverine and 4 off-river marshes from 1988 through 1993. Bars include mean riverine marsh area upstream from the Little Colorado River confluence, downstream from the LCR confluence, total mean values, and mean values of 4 off-river marshes.

"normal operations", and between 1991 and 1992. We are currently considering other marsh sites to analyze in MIPS to verify this pattern. We also intend to extend this analysis to include May, 1994 aerial photographs when they become available.

Fluvial Marsh Transects

Fluvial marsh transects established during the GCES-II program were monitored in May and October-November, 1993 (Tables 1, 2). One m-wide, 10+ m-long belt transects had been established at 10 m intervals perpendicular to the flow axis in return current channel marshes (Fig. 2). A grid of 1.0 m plots was established and censused on bar platform marshes, such as Mile 55.5R and 71L marshes. All species on each 1.0 m^2 plot were identified and counted, and basal area was measured. Change in elevation was measured by re-surveying marsh transect lines with electronic surveying equipment. Elevational changes are being related to inundation frequency data derived from flow duration curves for the nearest USGS gauges (e.g. Fig. 4). Data entry and QA/QC are nearing completion for these data (Appendix A). Analysis of changes in marsh plant densities, basal areas and species composition on transects are underway for the data between 1991 and 1992, and between 1992 and 1993 using repeated measures AOV.

Plant Water Potential Responses of Salix exigua

Coyote willow (SALICACEAE: Salix exigua) is a shallow-rooted, native, clonal willow that occupies the peripheries of fluvial marshes in the Grand Canyon. From research on Salix exigua in GCES-II, plant water potential (PWP) is known to be affected by temperature, relative humidity and somewhat on river stage. The water relations of this species are sufficiently well known to permit it to be used as an indicator species for monitoring water relations in marshes (Stevens and Ayers 1993).

In 1993 nighttime plant moisture stress levels of coyote willow were sampled at four sites in high-volume (July), medium-volume (June, September) and low-volume (May, October) interim flow release months to determine whether substantial moisture deficit gradients were forming that might influence marsh development.

The four sites selected for censusing (Mile 43L, 50.0L, 171.5L and 194L) differ from our original proposal because use of the 50-51L area, Nankoweap Creek and Cardenas Creek marshes was restricted by high recreational use and closure for endangered species monitoring, respectively, and because coyote willow distribution in and around the marshes was not sufficient to guarantee the success of the monitoring effort.

Plant water potential (PWP) relations for Salix exigua provide a good indication of habitat moisture stress. Salix exigua grows around the peripheries of fluvial marshes and operates in a physiologically similar range of plant water potential as most of the marsh species. Unfortunately, water potential is virtually impossible to measure on marsh macrophytes directly because of irregular stem cross-sections (e.g. triangular stems of Scirpus and Carex, or flat stems of Typha domingensis). We evaluated the significance of water stress levels on willow growth and determined that coyote willow was an appropriate indicator of marsh drought stress (Stevens and Ayers 1993).

Plant water potential was measured on 20 or more tagged Salix exigua individuals at each of three or more stage elevations (low, medium and high within the range of normal dam operations) at four marsh sites during a consecutive day and night data collection session using a Schollander-type pressure bomb (Schollander et al. 1969). Standard electronic surveying protocol was employed to provide accurate documentation of elevation and stage of the marked plants at these sites. Marshes were visited during each of the three interim flow types (low, medium and high monthly volumes), and high water surface elevations were staked. Hypsometric relationships are being determined from these survey data and will be reported for each fluvial marsh. Changes in topography related to aggradation or degradation were documented. To ensure that PWP measurements associated with interim flows were documenting actual stress levels of significance to the willows, we also measured nodal growth and leaf size on each tagged plant, and leaf production on nearby randomly sampled plants at the end of the growing season.

The growth and PWP data collected in this monitoring effort are under analysis. In the present monitoring effort we observed a nocturnal moisture gradient at all of the study sites, and that gradient decreased with higher monthly flow volumes. We noted a pronounced die-back of high zone Salix exigua at the 43L and 194L sites, and die-back of Typha domingensis at high stage elevations at the Mile 43L site.

We are compiling PWP data and intend to continue studying PWP changes in these marshes in the daytime hours only during the May low-volume month in 1994. Nighttime PWP levels are too low to provide accurate assessment of stress.

Objective 2: Monitor the effects of interim flows from Glen Canyon Dam on the distribution and development of other new high water zone plant assemblages between Glen Canyon Dam and Diamond Creek, Arizona.

Long-term Study Quadrats

All quadrats lying below the approximate 1,700 m^3/s stage were recensused in the fall of 1993. Quadrats had been divided into eight subplots for mapping purposes. Data collected in each quadrat included species composition, seedling densities, growth rates and tiller production, soil changes, ground cover, shrub cover, and litter production and decomposition rates. In addition, these quadrats provided data on colonization of non-native species. Spot sampling in the vicinity of these quadrats will be used to detect and monitor the distribution of critical native plant species in the river corridor. All 1993 long-term quadrat data have been entered in electronic form (Appendix A), and we are in the process of quality controlling these data before analysis.

The new dry zone quadrats established in our study areas were devoid of vegetation at the inception of Interim Flows, as determined from close-level aerial photographs taken in mid-summer, 1991. Quadrat analyses in 1992 suggested that the new dry zone was extremely productive, and had become almost as densely colonized as the bar platform (general beach) zone, with little detectable difference in basal area of plant life or stem density between the two zones ($F_{1,21} = 2.979$, $\underline{p} = 0.099$; total basal area data were arcsine squareroot transformed). The new dry zone exhibited comparable basal areas of all assemblages except woody non-clonal phreatophytes when compared to the bar platform zone. The bar platform and new dry zones support only about 50 percent of the species richness and basal area of the other geomorphic settings under study, a finding in accord with the conclusions of Stevens and Ayers (1993).

We performed a preliminary analysis on 12 pairs of mainstream channel margin and "new dry" (lying between the 566 and 890 m^3/s stages) quadrats in 1993. This analysis allows us to assess the effects of interim flows on the long-term river corridor quadrats. We analyzed the effects of stage zone (channel margin at > 800 m^3/s stage <u>versus</u> "new dry" stage at < 800 m^3/s) on: the number of annual species, number of perennial species, number of perennial seedlings, and number of perennial stems (Table 6). MANOVA analysis failed to detect differences between the two zones (Wilk's lambda = 0.741, approximate $F_{4,17} = 1.484$, $\underline{p} = 0.251$). Although this is a small portion of the 1993 data set, it indicates that recolonization of the new dry zone following the January 1993 LCR floods has been extremely rapid.

Table 6: Comparison of "New Dry" <u>versus</u> Channel Margin 5m x 10m plots along the Colorado River in 1993.

MILE	SIDE	PLOT	#ANNSPP	#ANNIND	ANN.BA	#PERSPP	#PERSDL	#PERIND	PER.BA	TOTAL.BA	'93.GERM
8	L	GB	4	84	1.75	6	0	330	862.33	864.08	84
8	L	ND	4	32	9.47	1	0	1	0.07	9.54	32
22	R	GB	2	27	0.64	2	0	4	49.37	50.01	27
22	R	ND	3	178	35.54	1	0	1	0.2	35.74	178
43	L	GB	0	0	0	1	0	69	222.67	222.67	0
43	L	ND	0	0	0	2	0	14	7.49	7.49	0
94	R	GB	3	83	8.63	2	0	10	7.63	16.26	83
94	R	ND	1	27	0.24	2	0	4	1.46	1.7	27
119	R	GB	7	197	0.79	3	5	119	163.39	164.18	202
119	R	ND	0	0	0	1	0	130	43.34	43.34	0
122	R	GB	3	38	8.47	5	0	51	356.07	364.54	38
122	R	ND	3	45	78.68	5	0	309	516.91	595.59	45
137	L	GB	4	648	3.15	6	0	133	2288.493	2291.643	648
137	L	ND	1	10	0.02	1	0	11	64.79	64.81	10
172	L	GB	8	580	5.89	9	0	367	355.11	361	580
172	L	ND	2	99	47.65	2	20	171	9.78	57.43	119
194	L	GB	2	27	0.22	2	0	16	44.21	44.43	27
194	L	ND	5	186	43.64	5	0	468	89	132.64	186
213	L	GB	3	142	7.8	6	0	42	504.3	512.1	142
213	L	ND	0	0	0	0	0	0	0	0	0
220	L	GB	0	0	0	3	0	932	758.85	758.85	0
220	L	ND	1	18	120.19	2	0	2430	124.99	245.18	18

We detected no critical (endemic or endangered) plant species in the vicinity of our plots, or anywhere within the range of dam operations within the river corridor, except a small population of Flaveria mcdougallii at Mile 147.8R in a spring. These findings corroborate those of Stevens and Ayers (1993) who reported no plant species at risk from dam operations in the Grand Canyon.

Numerous new, flood-laid, fine alluvial bars were deposited downstream from the LCR after the January-February events. These new deposits underwent 2.5 months of desiccation before Tamarix ramosissima seeds were released in May, 1993. As a result of this desiccation, few dense Tamarix seedling beds became established along the river. Tamarix seedling beds (tama2risk "lawns") were noted at 122.1R, 194.2L, and in a few other locations, but overall Tamarix germination was not much higher than in other years. This observation demonstrates that flooding can be used as a management strategy for reshaping sand bars without causing widespread expansion of the Tamarix population. However, the speed at which sand bar sediments desiccate following flooding is not yet known. How much less than 2.5 months is required? Such information would assist with planning the timing of flood flows more accurately.

Productivity and Soil Analyses

We have completed data reduction on standing crop and litter accumulation rate in the different geomorphic settings (1-3 samples/quadrat), as well as plot soil geochemistry. Productivity differences are considerable between geomorphic settings (Fig. 6). Soils data are being compiled. These data contribute to understanding the role of geomorphic zonation and potential contribution of autochthonous carbon from the riparian zone to the river for GCES GIS and related mapping.

Random Stops

To gain insight into diversity and stem density patterns in the new dry and new high water zones in coarse versus fine sediments, we again conducted a series of reach-based random stops throughout the river corridor. These random stops provide a measure of the representativeness of the quadrats database, as well as a larger data set with which to evaluate reach-based vegetation changes, particularly in the channel margin habitat.

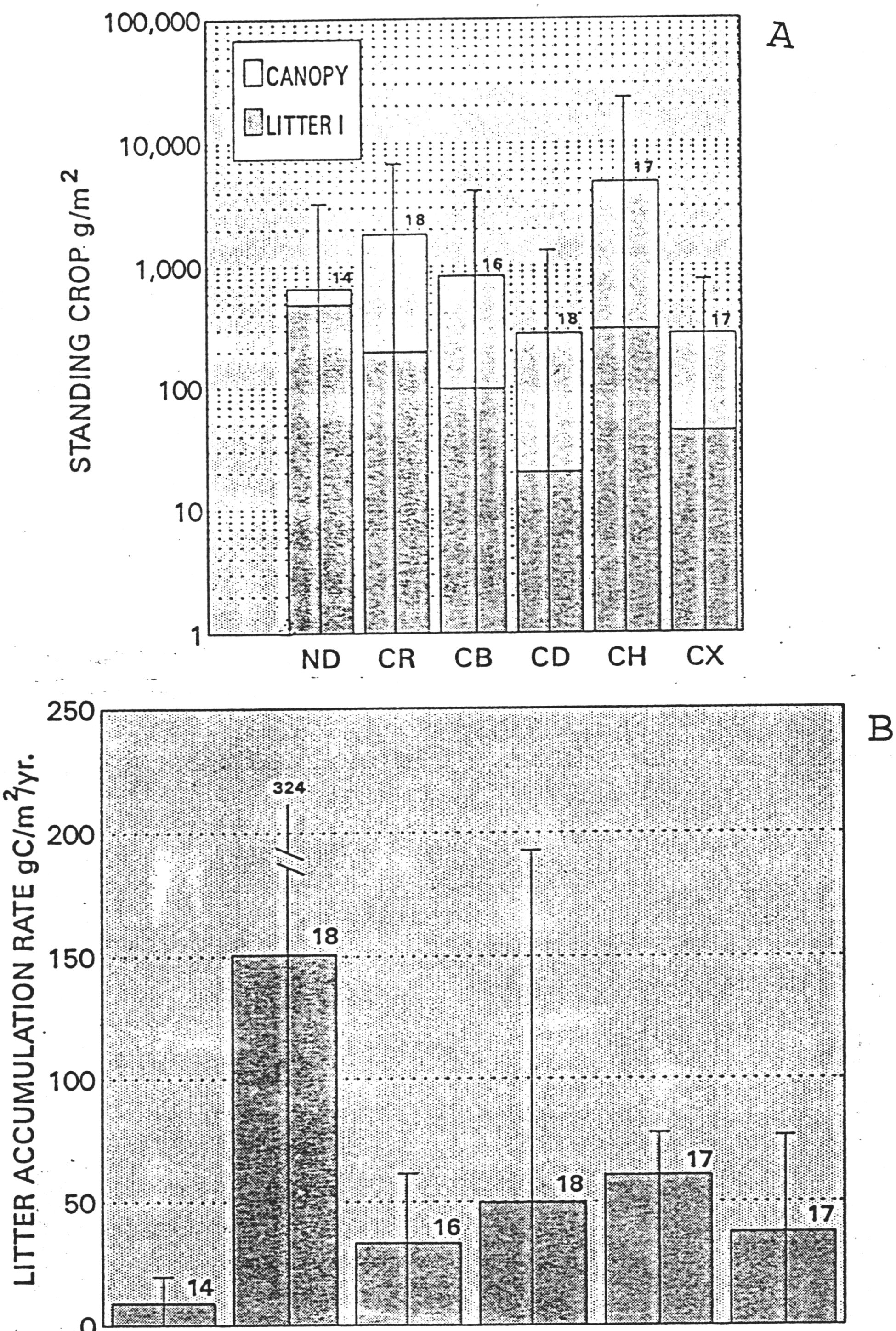


Figure 6: A. Mean Colorado River riparian vegetation litter ("Litter I") and canopy ("Canopy") standing crop/m² (± 1 sd) from long-term study plots in 6 geomorphic zones: ND-Interim Flows "new dry", CR - channel margin; CB-bar platform; CD-debris fan; CH-high terrace (old high water zone); and CX-xeric zone. B. Litter accumulation rate (AFDM g C/m²/yr ± 1 sd) between geomorphic settings.

As in 1992, in October-November, 1993 we made eight random stops in each of the geomorphic reaches defined by Schmidt and Graf (1990). Four stops/reach were made at randomly selected fine-grained sediment deposits and four stops were made at randomly selected coarse-grained (cobble, talus or bedrock) sites. Two of the "fine-grain" stops were in the new dry zone, and the other two were in the lower riparian zone. Similarly, two of the "coarse-grain" stops were in the new dry zone, and the other two were in the lower riparian zone. At each stop we censused a 5m x 10 m quadrat. On each random quadrat the number of individuals in seedling, sapling and mature (reproductive) size classes of each perennial plant species was recorded, along with the number of annual species and measures of relative soil texture, percent ground cover, percent shrub cover, azimuth and dip angle.

A preliminary analysis of stem density and species composition on this large set of quadrat data is being undertaken using a multivariate three-factor (zone, grain-size, year) analysis of covariance (distance from Glen Canyon Dam as a covariate). Although this analysis is not yet completed, like the long-term quadrats data set, we observed that the new dry zone has been quickly colonized, particularly by clonally expanding phreatophytes and perennial grasses. Stem density is significantly greater in lower stage deposits and in silt/sand deposits, while diversity (species richness) exhibits opposite but non-significant trends. Species diversity is positively correlated with distance from the dam, percent ground cover and percent shrub cover, and shows a trend of increasing values in coarse substrata, corroborating Stevens and Ayers (1992) findings. Both fine and coarse substrata are dominated by reproductively mature individuals of perennial taxa (clonal phreatophytes, particularly herbaceous <u>Equisetum</u> spp. and woody <u>Salix exigua</u>) and perennial bunch grasses. The largest proportion of species found in all zones are clonal herbaceous or woody phreatophytes, while annual grasses and phreatophytes are almost uniformly distributed across stage and soil texture gradients.

Non-Native Species

Although not funded by this contract, mechanical control of ravenna-grass (POACEAE: <u>Saccharum ravennae</u>) was initiated in March 1993. Ravenna-grass is a rapidly spreading, Eurasian bunchgrass that poses a considerable threat to the mainstream and tributary riparian habitats throughout the Grand Canyon. Volunteers from Prescott College, Prescott, Arizona helped remove more than 1,300 plants in 53 populations in March, 1993. Control efforts were also initiated in the source area around Wahweap Bay on Lake Powell in December, 1993 (J. Spence, personal

Table 7: List of ravenna-grass locations along the Colorado River in the Grand Canyon.

FIELD BOOK #	PAGE	LOCATION	# OF PLANTS
VII	94	0.2	100
VII	94	0.3	10
VII	94	0.5	2
VIII	19	0.6	500
VI	109	1.3	1
VIII	19	1.3	1
VII	94	2.51	1
VI	71	3.51	1
VI	72	5.3	2
VII	95	6	6
VII	1	6.2	1
VI	72	7.51	1
VIII	21	7.8	1
VII	96	9.9	1
VII	96	10.71	1
VIII	36	41.3	1
VII	16	48.5	1
VI	119	48.7	1
VII	110	48.91	1
VIII	46	50.51	1
VIII	125	50.91	1
VIII	48	51.9	2
VIII	125	52	3
VIII	48	52.41	2
VIII	49	54.3	1
VIII	51	56	1
VIII	125	56	1
VII	113	58.81	1
VIII	53	68.3	1
VIII	53	69	1
VIII	54	69.41	1
VIII	58	71	2
VIII	55	71	6
VIII	62	118.6	1
VII	128	129	3
VII	34	137.01	4
VI	74	169.51	1
VII	36	171	4
VII	117	171.1	10
VI	74	178.5	1
VII	119	178.6	1
VIII	82	178.8	1
VII	37	179	1
VII	120	183.6	7
VII	37	186	1
VII	120	186.3	4
VII	120	186.3	4
VII	120	186.5	1
VII	63	186.5	1
VII	63	186.6	1
VII	120	187.8	2
VI	74	188	1
VII	63	190.01	1
VII	121	192.5	6
VII	122	192.51	12
VII	122	192.81	24
VII	123	195.11	1
VII	123	195.5	1
VII	124	196.51	2
VII	124	200.3	1
VII	126	204.6	3
VI	141	205.01	1
VII	127	208.07	1
VII	128	215.41	1
VII	128	217.11	1
VII	128	217.21	1
VIII	100	222.3	1
	TOTAL # OF PLANTS		763

communication). Stevens will conduct a second ravenna-grass removal trip in early April, 1994 to remove the more than 760 plants that remain along the Colorado River in the Grand Canyon (Table 7).

Objective 3. Prepare monitoring data for inclusion into the GCES/NPS GIS database.

Inclusion of Long-term Quadrats Data into the GCES GIS

The data collected and compiled in this project are being compiled into the GCES/NPS GIS data base and mapping effort. This requires close coordination with the GCES/NPS GIS team, and we have begun input long-term study area maps at a 1:2,400 scale of vegetation, geomorphology and grain size into the GCES GIS (Table 8). This mapping effort will contribute to the Glen Canyon Environmental Studies program GIS data base development, and will provide an unparalleled database for rapid turn-around monitoring of riparian vegetation. Priority (GIS) sites and secondary (non-GIS) sites have been identified. Survey ground control was established at these sites in 1993. This effort is scheduled to be completed in June, 1994.

Normal color 1992 3x enlarged photos or LASER xeroxed prints were used as base maps for this mapping effort. Shadows made photo interpretation difficult in the images, and in several cases we have had to resort to using May 1993 true color photographs. In the field we mapped particle size and geomorphology according to the designations listed in Table 9. We are presently engaged in generating a comprehensive vegetation classification for the river corridor and tributaries combined, to aid in this mapping.

We assessed our mapping accuracy by comparing our newly drafted maps with a GIS vegetation map of the Lees Ferry site in GIS Reach 2. This comparison of mapping techniques demonstrated that our error was less than 1.0 m, well within the accuracy prescribed by the GCES GIS program. Tests of the accuracy of transfer between mylar field maps to GIS using surveyed ground control points revealed a transfer accuracy RMS error of 0.043 (1.118 m), well within the accuracy standards for the GCES GIS.

The maps are being digitized and rectified for input into the GIS, whereupon analysis will be initiated. We intend to analyze the distribution of various vegetation types across the smorgasbord of geomorphic settings in which riparian vegetation occurs in this system.

Table 8: Mapping efforts completed at long-term study sites along the Colorado River in the Grand Canyon.

MILE	GIS REACH	GCP'S	FIELD MAPPING			ENTERED INTO GIS		
			GEOMORPH	GRAINSIZE	VEGETATION	GEOMORPH	GRAINSIZE	VEGETATION
-6.5	14	X	X	X	X	X	X	X
0	2	X			X			
2.6					X			
8		X			P			
43	3	X	X	X	X			X
51	4	X	X	X	X			X
55	4				X			
61	5				X			
68	5	X	X	X	X			X
71	5		X	X	X			
88		X			X			
93	6	X	X	X	X			
122.2	7	X			X			X
122.7	7	X	X	X	X			
138	8				X			
144	9	X			X			
172		X			X			
194		X			X			
209	11		X	X	X			
213		X			X			
220					P			
225	12	X			P			

Table 9: Grain size and geomorphic classification scheme for GIS mapping of long-term study sites.

Grain Size	Depositional Environment
1. **Clay** rolls between fingers	51. **Channel Margin Deposit**
2. **Silt** up to .06mm	52. **Separation Deposit**
3. **Sand** up to 2mm	53. **Reattachment Deposit**
4. **Fine Gravel** up to 10mm	55. **Debris Fan**
5. **Coarse Gravel** up to 10cm	56. **Talus slope**
6. **Cobble/Small Boulder** up to 100cm	57. **Return Channel**
7. **Boulder** larger than 100cm	58. **Tributary Channel**
8. **Bedrock**	59. **Bedrock**
9. **6 + 2**	
10. **6 + 3**	
11. **6 + 4**	
12. **6 + 7**	
13. **6 + 8**	
14. **7 + 2**	
15. **7 + 3**	
16. **2 + 3**	
17. **4 + 3**	

PRESENTATIONS AND PUBLICATIONS

The following presentations and papers were produced from this project in 1993:

1. Ayers, T.J., R. Scott, L.E. Stevens, K. Warren and A.M. Phillips III. New plant taxonomic records from the Grand Canyon region, northern Arizona. Submitted to Madrono.

2. Bechtel, D.A., L.E. Stevens, M.J. Kearsley and T.J. Ayers. 1993. Geomorphic and hydrologic controls on riparian vegetation in the Grand Canyon, Arizona. August,1993 Ecological Society of America meeting, Madison, WI.

3. Kearsley, M.J., L.E. Stevens, and T.J. Ayers. 1993. Geomorphic and hydrologic controls on riparian vegetation along the dam-regulated Colorado River in the Grand Canyon, Arizona. April 1993 Arizona Riparian Council meeting, Tucson, AZ.

4. Stevens, L.E., M.J. Kearsley, and T.J. Ayers. Riparian vegetation composition and structure along the dam-regulated Colorado River in Grand Canyon National Park, Arizona. 27 October, 1993, Second Biennial Conference of Research on the Colorado Plateau.

5. Stevens, L.E., J.C. Schmidt, T.J. Ayers and B.T. Brown. 1994. Fluvial marsh development along the dam-regulated Colorado River in the Grand Canyon, Arizona. In review in Ecological Applications.

GENERAL CONCLUSIONS AND MANAGEMENT CONSIDERATIONS

1) Preliminary TWINSPAN analysis demonstrates the presence of three major marsh associations: wet marsh cattail/rush/reed and horseweed associations, and a dry marsh horsetail/willow association.

2) Comparison of MIPS analysis of marsh area at 24 sites between 1988 and 1993 reveals a great increase in fluvial marsh area through time up to 1992; however, marsh area declined significantly between 1992 and 1993 as a result of Little Colorado River flooding and probably also because of decreased inundation frequency of marsh vegetation at higher stage elevations. These analyses suggest that Interim Flows are having the hypothesized effect of reducing marsh area and concentrating marsh growth along channel margins and return current channel mouths.

3) Further evidence of Interim Flows and tributary flooding on marsh distribution is provided by the 1993 marsh inventory, in which marsh abundance/km of channel increased 3.5-fold from 1991 to 1993, but marsh area declined by 22 percent. More, smaller marshes have developed through flooding impacts and Interim Flows effects. If these developing marshes are permitted to grow, marsh area can be expected to increase again dramatically; however, flooding planned in March, 1995 will undoubtedly scour most of these new marshes, as well as other "new dry" zone vegetation, from the river corridor.

4) We found that LCR flooding resulted in aggradation of return current channels at marsh sites in the lower Grand Canyon. The amount of in-filling appears to be sufficient to reduce marsh habitat are by up to 90 percent in narrow reaches.

5) Plant water potential studies support using Salix exigua as an indicator of fluvial marsh moisture stress resulting from interim flows. Preliminary analyses suggest that plant moisture stress and growth rates are negatively correlated in Salix exigua and, by extension, to the upper stage elevation fluvial marshes.

6) The "new dry" zone, lying between the interim flows maximum flow stage (566 m^3/s stage) and the "normal operations" stage (ca. 850 m^3/s stage), is being actively colonized by riparian plants, particularly clonal phreatophytes and perennial grasses.

7) GIS related mapping of long-term study areas is proceeding on schedule and we anticipate results of GIS analyses by July, 1994 for most sites.

8) Flooding in the LCR drainage in January-February, 1993 was sufficiently early to allow new, flood-deposited soils to desiccate sufficiently to prevent a widespread Tamarix ramosissima germination event. The status of non-native Saccharum ravennae has changed rapidly in response to changes in flow regimes, and NPS control efforts are planned to mechanically remove 763 ravenna grass plants still remaining along the river.

From the data analyzed thus far, the initial 2.25 yr of Interim Flows are beginning to reduce marsh area of wetland vegetation in the Colorado River corridor downstream from Glen Canyon Dam. The Interim Flows criteria were designed to limit negative effects of dam operations during the GCD/EIS process, and while that objective prevents scouring flows, it also reduces the inundation frequency in backwater marshes, and will have the long-term effect of concentrating vegetation at the 566 m^3/s shoreline, where such vegetation is more susceptible to flooding disturbance, either planned or unplanned.

PROBLEMS ENCOUNTERED

No significant problems have been encountered during this year, and the project is on schedule as per our original proposal.

ACTION REQUIRED BY NPS

No action is presently requested from the NPS other than continued administrative support of this project. However, monitoring associated with this project will end in May, 1994, as we begin preparation of the draft final report. The Secretary of Interior's record of decision on the Glen Canyon Dam EIS will not be implemented at least until spring, 1995. To prevent monitoring data gaps, the National Park Service may wish to consider a continuation of the monitoring effort until the ROD is implemented.

FUTURE PLANS

We intend to continue our monitoring efforts as described in the contract. We intend to conduct the following research river trips in 1993:

15 April-1 May, 1994: reduced marsh transect monitoring, daytime marsh water stress measurements, long-term tributary plot monitoring and light measurement, and vegetation mapping verification.

May, 1994: experimental verification of Salix exigua stomatal closure and wilting responses; mapping plant diversity on 8 study sites; limited PWP measurement.

June, 1994: experimental verification of Salix exigua stomatal closure and wilting responses; mapping plant diversity on 8 study sites; limited PWP measurement.

The component project results are being analyzed and prepared for inclusion in the draft final report, with individual chapters under preparation for peer-reviewed publication. We anticipate submission of the papers for peer-reviewed publication on the following topics: fluvial marsh succession in a regulated river; water relations of marshes in response to interim and fluctuating flows; riparian vegetation structure and processes along the Colorado River in Grand Canyon. We intend to submit these papers during and shortly after completion of this contract.

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APPENDIX A:

MANAGEMENT RECORD AND STORAGE FORMAT INFORMATION ON PROJECT DATA FOR:

"THE EFFECTS OF INTERIM FLOWS FROM GLEN CANYON DAM ON RIPARIAN VEGETATION ALONG THE COLORADO RIVER IN GRAND CANYON NATIONAL PARK, ARIZONA: DRAFT 1994 ANNUAL TECHNICAL REPORT"

(COOPERATIVE AGREEMENT: CA 8021-8-0002)

LTP DATA FILES ON DISK 940101
Availability of LTP data files in various formats as of Jan. 1 1993.

Time = time of year censused: SP = spring, SU = summer, FA = fall.
Formats: * = not censused, V = veghead, V2 = veghead2, A = annuals file,
S# = # of summary files, SS = SYSTAT substrate file.

		1991		1992		1993	
Mile	Plot	Time	Format	Time	Format	Time	Format
0.0	RST	FA	V,A,S6	*	* SS	FA	V2
	OHW	FA	V,A,S6	*	* SS	*	*
	XER	FA	V,A,S6	*	* SS	*	*
2.6	NDR	*	*	FA	V2	*	*
	RST	FA	V,A,S6	FA	V2,SS	FA	V2
	BCH	FA	V,A,S6	FA	V2,SS	FA	V2
	DFN	FA	V,A,S6	FA	V2,SS	FA	V2
	OHW	FA	V,A,S6	*	SS	*	*
	XER	FA	V,A,S6	*	SS	*	*
8.0	NDR	*	*	FA	V2	FA	V2
	RST	FA	V,A,S6	FA	V2,SS	FA	V2
	BCH	FA	V,A,S6	FA	V2,SS	FA	V2
	DFN	FA	V,A,S6	*	* SS	FA	V2
	OHW	FA	V,A,S6	*	* SS	*	*
	XER	FA	V,A,S6	*	* SS	*	*
21.8	NDR	*	*	FA	V2	FA	V2
	RST	FA	V,A,S6	*	* SS	*	*
	BCH	FA	V,A,S6	*	* SS	FA	V2
	DFN	FA	V,A,S6	*	* SS	FA	V2
	OHW	FA	V,A,S6	*	* SS	*	*
	XER	*	*	FA	V2	*	*
31.5	NDR	*	*	FA	V2	FA	V2
	RST	FA	V,A,S6	*	* SS	FA	V2
	BCH	*	*	FA	V2	*	*
	DFN	SU	V,A,S6	*	*	FA	V2
	OHW	SP	V,A,S6	*	* SS	*	*
	XER	FA	V,A,S6	*	* SS	*	*

		1991		1992		1993	
Mile	Plot	Time	Format	Time	Format	Time	Format
41.0	RST	FA	V,A,S6	*	* SS	FA	V2
	BCH	*	*	*	*	FA	V2
	DFN	FA	V,A,S6	*	* SS	FA	V2
43.1	RST	SU	V,A,S6	FA	V2,SS	FA	V2
	BCH	SU	V,A,S6	FA	V2,SS	FA	V2
	DFN	FA	V,A,S6	FA	V2,SS	FA	V2
	OHW	SU	V,A,S6	*	* SS	*	*
	XER	SU	V,A,S6,	*	* SS	*	*
47.0	NDR	*	*	FA	V2	FA	V2
51.5	NDR	*	*	FA	V2	*	*
	RST	FA	V,A,S6	SU	V2,SS	FA	V2
	BCH	FA	V,A,S6	FA	V2,SS	FA	V2
	DFN	FA	V,A,S6	FA	V2,SS	FA	V2
	OHW	FA	V,A,S6	*	* SS	*	*
	XER	FA	V,A,S6	*	* SS	*	*
68.1	NDR	*	*	FA	V2	*	V2
	RST	SU	V,A,S6	FA	V2,SS	FA	V2
	BCH	SU	V,A,S6	FA	V2,SS	FA	V2
	DFN	*	*	FA	V2,SS	FA	V2
	OHW	SU	V,A,S6	*	* SS	*	*
	XER	SU	V,A,S6	*	*	*	*
71.5	RST	FA	V,A,S6	FA	V2,SS	FA	V2
	DFN	FA	V,A,S6	FA	V2,SS	FA	V2
	OHW	FA	V,A,S6	*	* SS	*	*
	XER	FA	V,A,S6	*	* SS	*	*
93.9	NDR	*	*	FA	V2	FA	V2
	RST	FA	V,A,S6	FA	V2,SS	FA	V2
	BCH	FA	V,A,S6	FA	V2,SS	FA	V2
	DFN	FA	V,A,S6	FA	V2,SS	FA	V2
	OHW	FA	V,A,S6	*	* SS	*	*
	XER	FA	V,A,S6	*	* SS	*	*

		1991		1992		1993	
Mile	Plot	Time	Format	Time	Format	Time	Format
103.9	RST	FA	V,A,S6	FA	V2,SS	FA	V2
	BCH	FA	V,A,S6	FA	V2	FA	V2
	DFN	FA	V,A,S6	FA	V2,SS	FA	V2
	OHW	*	*	*	*	*	*
	XER	FA	V,A,S6	*	* SS	*	*
119.0	NDR	*	*	FA	V2	FA	V2
	RST	FA	V,A,S6	FA	V2	FA	V2
	BCH	FA	V,A,S6	FA	V2	FA	V2
	DFN	*	*	FA	V2	FA	V2
	OHW	FA	V,A,S6	*	* SS	*	*
	XER	*	*	FA	V2	*	*
122.1	NDR	*	*	FA	V2	FA	V2
	RST	FA	V,A,S6	FA	V2,SS	FA	V2
	BCH	FA	V,A,S6	FA	V2,SS	FA	V2
	DFN	FA	V,A,S6	FA	V2,SS	FA	V2
	OHW	FA	V,A,S6	FA	V2,SS	*	*
	XER	FA	V,A,S6	*	* SS	*	*
122.8	NDR	*	*	FA	V2	*	*
	RST	SU	V,A,S6	FA	V2	FA	V2
	BCH	SU	V,A,S6	*	*	FA	V2
	DFN	SU	V,A,S6	FA	V2	FA	V2
	OHW	SU	V,A,S6	*	*	*	*
	XER	SU	V,A,S6	*	*	*	*
137.0	NDR	*	*	FA	V2	FA	V2
	RST	FA	V,A,S6	FA	V2,SS	FA	V2
	BCH	*	*	FA	V2	FA	V2
	DFN	*	*	FA	V2	FA	V2
	OHW	FA	V,A,S6	*	* SS	*	*
	XER	*	*	FA	V2	*	*

		1991		1992		1993	
Mile	Plot	Time	Format	Time	Format	Time	Format
144.0	RST	FA	V,A,S6	FA	V2,SS	FA	V2
	BCH	FA	V,A,S6	FA	V2,SS	FA	V2
	DFN	*	*	FA	V2	FA	V2
	OHW	FA	V,A,S6	*	* SS	*	*
	XER	*	*	FA	V2	*	*
145.0	NDR	*	*	FA	V2	FA	V2
	RST	FA	V,A,S6	FA	V2,SS	FA	V2
	BCH	FA	V,A,S6	FA	V2,SS	FA	V2
	OHW	FA	V,A,S6	*	* SS	*	*
172.1	NDR	*	*	FA	V2	FA	V2
	RST	SU	V,A,S6	FA	V2,SS	FA	V2
	BCH	SU	V,A,S6	FA	V2,SS	FA	V2
	DFN	SU	V,A,S6	FA	V2,SS	FA	V2
	OHW	SU	V,A,S6	*	* SS	*	*
	XER	SU	V,A,S6	*	* SS	*	*
183.3	RST	FA	V,A,S6	FA	V2,SS	FA	V2
	BCH	FA	V,A,S6	FA	V2,SS	FA	V2
	OHW	FA	V,A,S6	*	* SS	*	*
194.1	NDR	*	*	FA	V2	FA	V2
	RST	FA	V,A,S6	FA	V2,SS	FA	V2
	BCH	FA	V,A,S6	FA	V2,SS	FA	V2
	DFN	FA	V,A,S6	FA	V2,SS	FA	V2
	OHW	FA	V,A,S6	*	* SS	*	*
	XER	FA	V,A,S6	*	* SS	*	*
213.3	NDR	*	*	*	*	FA	V2
	RST	SU	V,A,S6	FA	V2,SS	FA	V2
	BCH	SU	V,A,S6	FA	V2,SS	FA	V2
	DFN	SU	V,A,S6	FA	V2,SS	FA	V2
	OHW	SU	V,A,S6	*	* SS	*	*
	XER	SU	V,A,S6	*	* SS	*	*

		1991		1992		1993	
Mile	Plot	Time	Format	Time	Format	Time	Format
220.0	NDR	*	*	*	*	FA	V2
	RST	FA	V,A,S6	FA	V2	FA	V2
	BCH	FA	V,A,S6	*	*	FA	V2
	DFN	FA	V,A,S6	FA	V2	FA	V2
	OHW	FA	V,A,S6	*	*	*	*
	XER	FA	V,A,S6	*	*	*	*

IA. COOPERATIVE AGREEMENT: CA 8021-8-0002

NAME: THE EFFECTS OF INTERIM FLOWS FROM GLEN CANYON DAM ON RIPARIAN VEGETATION ALONG THE COLORADO RIVER IN GRAND CANYON NATIONAL PARK, ARIZONA: 1994 ANNUAL ADMINISTRATIVE REPORT

PRINCIPAL INVESTIGATOR: LAWRENCE E. STEVENS AND TINA J. AYERS

GOVERNMENT TECHNICAL REPRESENTATIVE: DR. PETER G. ROWLANDS

SHORT TITLE OF WORK: ANNUAL MANAGEMENT REPORT

STARTING DATE: 15 June, 1992

DURATION: 27 Months

DATE OF THIS REPORT: 1 January, 1994

FUNDING AMOUNT: $262,410.00

SUPPORTED BY: The Bureau of Reclamation
Glen Canyon Environmental Studies Program
P.O. Box 22459
Flagstaff, AZ 86002-2459

SUBMITTED TO: The National Park Service
Cooperative Parks Studies Unit
Northern Arizona University
Flagstaff, AZ 86011

ADMINISTRATIVE REPORT
BIO 35J3

ITEM		FY92		FY93		FY94		TOTAL	
		ESTIMATE	ACTUAL	ESTIMATE	ACTUAL	ESTIMATE	ACTUAL	ESTIMATE	ACTUAL
SALARY	Co-PI Ayers	$6700	-0-	$11,300	$6420	$6700		$24,700	
	Benefits		-0-		$965				
	Crew leader	$8000	$877	$30,000	$23,735	$20,000		$58,000	
	Benefits		$263		$7511				
	Photo Analyst	$4000	-0-	$16,000	$18,461	-0-		$20,000	
	Benefits		-0-		$3762				
	Field Crew	$17,200	$15,165	$39,200	$56,440	$19,100		$75,500	
	Benefits	$2370	$1219	$5650	$4217	$2190		$10,140	
subtotal		$38,270	$17,524	$102,150	$121,511	$47,990		$188,340	
TRAVEL		$1000	$335	$1700	$1764	$1500		$4200	
EQUIPMENT		$4000	-0-	$1040	$5296	$500		$5540	
FIELD SUPPLIES		$2000	$1066	$2000	$4031	$1030		$5030	
OFFICE SUPPLIES & ACCOUNTING		$3000	-0-	$4500	-0-	$3500		$11,500	
SOIL ANALYSES		$1500	-0-	$3000	-0-	-0-		$4500	
TOTAL DIRECT COSTS		$49,770	$18,925	$114,390	$132,602	$54,520		$218,680	
TOTAL INDIRECT (20% NAU)		$9950	$3785	$22,880	$29,045	$10,090		$43,730	
TOTAL		$59,720	$22,710	$137,270	$161,647*	$65,420		$262,410	

* With rollover from FY92, total project expenditure equals $184,357 as of 1 Oct 1993, of the $196,990 projected through FY93.

ACCOUNT BIO 35J3 FROM 7/1/92-CURRENT

ACCOUNT RECAP

CATEGORY	Budget	Amount Encum	Amount Expended	Encum + Expenditures	Available Balances	% USED
Salaries - Full Time						
Kearsley		11,926.34	30,713.31	42,639.65		
Weber		0.00	18,461.33	18,461.33		
Ralston		0.00	4,250.00	4,250.00		
Ayers		6,000.00	6,420.00	12,420.00		
Salaries - Occasional			79,578.06	79,578.06		
Salaries - Student Wage			3,827.55	3,827.55		
TOTAL SALARIES	178,200.00	17,926.34	143,250.25	161,176.59	17,023.41	90%
E.R.E. - Full Time						
Kearsley		3,907.43	9,533.21	13,440.64		
Weber		0.00	3,761.51	3,761.51		
Ralston		0.00	16.53	16.53		
Ayers		0.00	964.76	964.76		
ERE - Occasional			6,480.64	6,480.64		
ERE - Student Wage			27.06	27.06		
TOTAL ERE	10,210.00	3,907.43	20,783.71	24,691.14	(14,481.14)	242%
OPERATIONS	21,570.00	94.88	10,449.76	10,544.64	11,025.36	49%
TRAVEL	4,200.00	115.00	2,097.19	2,212.19	1,987.81	53%
ANALYSES	4,500.00	1,237.50	0.00	1,237.50	3,262.50	28%
TOTALS	218,680.00	23,281.15	176,580.91	199,862.06	18,817.94	91%
INDIRECT	43,730.00	8,095.70	35,634.30	43,730.00	0.00	100%

GLEN CANYON INTERIM FLOWS - BIO 35J3

Obj Code	Date	Vendor	RX/PD 3BI035J3#	PC 93#	Documented	Pre-Encumbered	Amount Encumbered	Amount Expended	Explanation
7322/20	08/21	Jacks Plastic Welding	RX 002					185.07	waterproof bags
7322/20	11/06	Fisher	RX 003					387.45	top loading balance
7322/20	09/01	Lisa Kearsley	PD 001					108.63	food for river trip
7322/20	09/03	Amy Holm	PD 002					80.85	first aid supplies,
	09/23	Michael Kearsley	PD 003					159.62	film, food, bags, ha
7322/20	10/13	Liquid Air	PD 004					10.75	nitrogen
7322/20	10/19	Amy Holm	PD 005					141.27	garbage bags, pruner
7322/20	10/23	Liquid Air	PD 006					10.75	nitrogen
7322/20	11/04	Lisa Kearsley	PD 007					79.92	food, camera battery
7322/20	11/16	Michael Kearsley	PD 008					51.35	survey flags, marker
7351/20	11/04	Office Copy Machine						0.95	
7322/20	12/21	Forestry Suppliers	RX 004	BS0000928				6.50	sling psychrometers
7322/20	01/23	IDB/Bilby						420.00	ignition testing
7322/20	12/08	Larry Stevens	PD 009					106.60	
	01/25	Office Copy Machine						2.70	
7322/20	02/22	Tina Ayers	PD 010					47.50	Utah Flora book
7322/20	02/22	Larry Stevens	PD 011					283.54	
	02/28	Office Copy Machine						1.25	
7320/20	03/08	Microcomputer Power	PD 012					293.64	Canoco software
7350/20	04/08	Photo Outfitter	PD 013					8.88	fixer
	04/26	Michael Kearsley	PD 014					206.18	computer cases, film
7320/20	04/13	Bookstore						252.24	Lotus, Systat
7320/20	04/13	Grid Systems Corp	RX 005	LW0002483				962.33	penpal software, lic
7351/20	03/02	Office Copy Machine						0.60	
7322/20	04/28	Fisher	PD 015					124.74	thermometers
	05/24	Michael Kearsley	PD 016					68.38	survey flags, rulers
7331/30	06/15	Michael Kearsley	PD 017					80.00	cleaning laptop comp
7331/30	06/17	Mark Easter	PD 018					20.00	fabricate instrument
7351/20	05/04	Office Copy Machine						1.35	
	06/30	MBRS FAX charges						3.50	
7322/20	07/26	VWR	PD 001					412.63	soil sieves
7350/20	07/28	Michael Kearsley	PD 002					81.13	film, processing
	07/31	Dean's Copy Machine						0.21	
7320/10	08/16	AST Research (GRID)	PD 004					79.00	communication utilit
7330/20	08/16	Tina Ayers	PD 003					104.32	water line parts
7351/20	08/14	Office Copy Machine						2.05	
	09/15	Michael Kearsley	PD 005					311.30	photocopying, mylar,
	10/13	VWR	PD 006					90.59	soil sieve
	10/27	IX 4BI035J3001						-47.34	BIO 32F5/1117 waterl
	10/07	Department FAX charges						2.00	
	10/04	Office Copy Machine						1.85	
	11/19	Michael Kearsley	PD 007				179.19		ruler, batteries, el
	12/09	IX 4BI01117023			52.88				stockroom supplies
	11/03	Office Copy Machine						9.00	
	12/03	University Stores			42.00				toner cartridge
		Operations Totals			94.88	0.00	179.19	5,153.28	

Obj Code	Date	Vendor	RX/PD 3BI035J3#	PC 93#	Documented	Pre-Encumbered	Amount Encumbered	Amount Expended	Explanation
	09/14	Tina Ayers	TAO	01				335.00	
	03/01	Robert Weber	TAO	02				259.10	
	03/19	Robert Weber	TAI	01				63.75	
	04/23	Michael Kearsley	TAI	02				391.89	
	07/31	Diana Kimberling						292.60	
	07/31	Douglas Bechtel	TAO	04				502.60	
	08/03	Michael Kearsley	TAO	03				252.25	
	12/07	Michael Kearsley	TAI	01			115.00		
		Travel Totals			0.00	0.00	115.00	2,097.19	

Obj Code	Date	Vendor	RX/PD 3BI035J3#	PC 93#	Documented	Pre-Encumbered	Amount Encumbered	Amount Expended	Explanation
7830/20	04/13	Bookstore						2010.56	Zenith 325L portable
7830/20	04/13	Grid Systems Corp	RX 005	LW0002483				3285.92	pen computer
		Equipment Totals			0.00	0.00	0.00	5,296.48	

Obj Code	Date	Vendor	RX/PD 4BI035J3#	PC 94#	Documented	Pre-Encumbered	Amount Encumbered	Amount Expended	Explanation
7510/90	12/08	IAS Laboratories	RX 001	CS0002219	1237.50				soil sample analysis
		Analyses Totals			1,237.50	0.00	0.00	0.00	