PREDICTING THE RESPONSE OF WOODY RIPARIAN VEGETATION TO CHANGES IN INSTREAM FLOWS THROUGH INTEGRATED MONITORING OF STREAM HYDROLOGY AND RIPARIAN VEGETATION

PRELIMINARY REPORT

15 April, 1991

Michael Scott, Gregor Auble and Larry Martin[1]

US Fish and Wildlife Service
National Ecology Research Center
4512 McMurray Ave.
Fort Collins, CO 80525

[1]Present Address: National Park Service
Water Resoruces Division
301 S. Howes St., Room 353
Fort Collins, CO 80521

Abstract

The establishment, growth and mortality of woody riparian vegetation along a reach of Boulder Creek has been monitored for two years. Permanent vegetation plots were established in association with instream flow transects and groundwater wells that allowed direct ordination of the vegetation along a gradient of flooding, based on instream flow hydraulic models. We recognized three zones based on the variable influence of surface and ground water on the vegetation: (1) a surface-water inundation zone; (2) a ground water mediated zone; and (3) an unaffected zone (vegetation unaffected by surface-water). Within the surface-water inundation zone (active channel) we found a strong correspondence of vegetation (species and species groups) to hydraulic position and frequency of inundation. The establishment of Cottonwood (*Populus fremontii*) and Sandbar willow (*Salix exigua*) is limited to this zone. Woody exotics are important components of this zone. The ground water mediated zone and unaffected zone in this strongly gaining reach are similar with respect to ground water and vegetation. These zones are characterized by a high ground water table and the vegetation is dominated by the exotic Crack willow (*Salix fragilis*) that persists by root sprouting; Green ash (*Fraxinus pennsylvanica*) and Box elder (*Acer negundo*) dominate seedling and sapling size classes. Vegetation impacts here are likely to come from land use and ground water changes (not related to discharge). Identification of relations between surface and ground water and vegetation dynamics will provide better predictions of riparian vegetation response to changes in instream flows.

Introduction

This report summarizes hydrologic and riparian vegetation studies done to date at the Boulder Open Space known as "The Cottonwood Grove." As with other creeks and rivers within the South Platte basin, riparian vegetation has always been an integral part of these ecosystems. Native woody species like the plains Cottonwood, peach leaf willow and sand bar willow were adapted to the seasonal flooding associated with snowmelt runoff. However, the abundance, distribution and composition of present-day riparian communities are fundamentally different than they were historically (Knopf and Scott 1990). As we have altered aspects of stream hydrology, so too have we altered the physical and biological conditions that shape riparian plant associations. Boulder Creek at "The Cottonwood Grove" provides an example of hydrologic, geomorphic and vegetation processes that occur in a variety of situations throughout the South Platte basin. Results from this study have provided important insights into factors and processes that will need to be considered in order to predict the response of riparian vegetation to changes in stream flows.

Site Overview

The Cottonwood Grove was chosen for this study because it is fenced, has limited access, has been free of cattle grazing for at least a decade and the active channel through the site has not been stabilized. Locations of hydrologic transects, ground-water monitoring wells and upland vegetation plots, within the 8 hectare (20 acre) site, are illustrated in Figure 1. Within the active channel, 0.5m x 1m permanent monitoring plots for woody and herbaceous vegetation, were established along the hydrologic cross-sections.

Hydrologic Zones

Based on our surface and ground-water monitoring results we identified hydrologic zones within the study area, including (1) an Unaffected Ground-water Zone where ground-water is not influenced by Boulder Creek, (2) a Ground-water Mediated Zone where seasonal ground-water mounding below Boulder

Creek creates an area of elevated ground-water, and (3) a Surface-water Inundation Zone where geomorphic and vegetation processes are shaped by discharge in Boulder Creek. The distribution of these three zones is illustrated in Figure 2. These zones represent patterns of interaction between surface and ground-water; these interactions vary seasonally, based on surface water stage and depth to ground-water.

Vegetation Zones

The hydrologic zones described above correspond to two distinct vegetation zones identified in this study. These vegetation zones include (1) an Upper Terrace Stand within the Unaffected and Groundwater-mediated Zones, and (2) an Active Channel Edge and Floodplain Stand, within the Active Channel Zone.

Historically, vegetation associated within the Active Channel Zone would have occurred more extensively as the unconfined channel meandered over a wide floodplain. However, with changes in hydrology and bank stabilization along Boulder Creek, this zone is now confined within a much narrower channel that has also down-cut as much as 5 feet in response to channel modifications (e.g. channel straightening and bank rip rapping).

Characterization of the upper terrace vegetation

A few large Plains Cottonwood (*Populus fremontii*) exist within the Cottonwood Grove, however, the stand is overwhelmingly dominated by the exotic tree species Crack willow (*Salix fragilis*) (Figure 3). The Crack willow in this stand may also be a hybrid between White willow (*Salix alba*) and Crack willow (W.A. Weber, pers. com.). We observed no reproduction by seed, rather, this species appears to persist vegetatively within the stand; this conclusion is based on the abundance of stems >25cm in diameter at breast height (dbh) and the lack of stems <10cm dbh (see Figure 3). Cruz and Bock (1975), suggest that the Cottonwood Grove is dominated by plains and "narrow-leaved" Cottonwood; however, it is likely that what they were calling "narrow-leaved" Cottonwood was in fact what we are calling Crack willow, which upon superficial inspection might be confused with Narrowleaf Cottonwood (*Populus angustifolia*). Although we found both the Narrowleaf and the hybrid Cottonwood (*Populus*x*acuminata*) in the grove, they occurred in very low numbers.

Green ash (*Fraxinus pennsylvanica*) and Box elder (*Acer negundo*), which were likely rare historically, are important understory species in the grove (Figure 3). As on portions of the South Platte (Snyder 1987), Green ash may be gaining in importance in the grove, based on the large numbers of seedlings and small stems found in the upland stand (Figure 4).

The present structure and composition of the upland stand at the Cottonwood Grove is characteristic of stands that occur on floodplains in more humid regions of the U.S. The stand is now isolated from surface-water flows in Boulder Creek and woody vegetation in the stand in influenced by local groundwater conditions and precipitation. Additionally, stand dynamics are driven primarily by successional processes (e.g. competition for light, tree gap regeneration) and is relatively independent of surface water flows. As a result, the future character of this stands will be primarily influenced by local seed sources, adjacent land-use activities, and changes in the local ground-water (e.g., the Goose Creek drainage).

Characterization of the vegetation within the active channel

In contrast to the vegetation in the upland stand, the character of the vegetation within the active channel is strongly dependent upon the physical disturbances imposed by flooding, erosion and deposition of alluvial material.

Much of the herbaceous and woody vegetation within is common to low elevation sites in Colorado and throughout the western and northern high plains and Great Basin. A preliminary list of the species identified within the grove is presented in Table 1. Some of the more common native woody species include: Plains Cottonwood; Peach leaf willow and Sand bar willow. These species are adapted to the historical conditions of seasonal flooding associated with snow-melt runoff. However, because of the sites proximity to and upstream urban area, there are also a number of exotic woody species including Russian-olive (*Elaeagnus angustifolia*), Crack willow (*Salix fragilis*), Black locust (*Robinia pseudoacacia*) and Chinese Elm (*Ulmus pumila*). Crack willow and Chinese Elm appear to be quite well adapted to conditions within the active channel and are likely to be persistent elements of this vegetation zone.

The distributions of a number of woody species are interpretable in terms of site hydrology; for example, Sandbar willow seedlings and sprouts occupy frequently inundated sites next to the active channel whereas larger stems occupy less frequently inundated sites on forming floodplain surfaces or low elevation sites in overflow channels (Figure 5). In contrast, Cottonwood seedlings and saplings tend to occupy less frequently inundated sites (Figure 6). A few cohorts of saplings occupying relatively high elevation sites date to the high runoff year of 1983 (Figure 7).

Site surface-water dynamics

Despite rather extensive channel and hydrologic modifications within the basin, the surface water hydrology of the site is still relatively dynamic (Figure 7). Boulder Creek still exhibits a snowmelt hydrograph with appreciable temporal variability in flow; for example, the peak flow of 1983 and the low flows during 1989. The peak flows in June of 1990 were in the neighborhood of 500 cfs and produced appreciable change in channel cross-sections throughout the site (Figure 8). These channel changes were particularly noticeable in locations downstream of tree stems that lean out into or over the channel (Figure 9). Trees overhanging the channel controls the routing of water and sediments during high flows and is the source of large, instream organic debris. The physical and biological effects of trees and woody debris to stream ecosystems, particularly in more humid regions, has been well documented (Swanson et al. 1976, Sedell and Triska 1977, Swanson et al. 1982).

Vegetation dynamics

Herbaceous vegetation showed considerable differences in composition and cover, primarily in response to flooding and deposition of alluvial material within the active channel during 1990. Some herb species such as Reed Canarygrass (*Phalaris arundinacea*) showed condiderable increases in cover between 1989 and 1990, in response to burial by fine alluvial material.

We recorded no Cottonwood recruitment during the 1989 growing season, however, following the June flooding in 1990 (coincident with seed dispersal) we recorded extensive seedling establishment. Subsequent survival of seedlings was relatively low and was associated with sites having sparse cover and a relatively high seasonal water table (further analysis of Cottonwood seedling recruitment and mortality is in progress). These sites tended to occur on the lower edges of open gravel bars (see photos of seedlings, Figure 10a&b).

Needs for future work

Whereas a direct gradient approach captures and integrates many of the important processes involved in structuring riparian vegetation assemblages, our work on Boulder Creek has pointed up factors and processes that could be profitably incorporated into models predicting the response of vegetation to changes in stream flow. For example, the reciprocal influence of vegetation on geomorphology and geomorphology on vegetation is a complex yet important process. This important interaction is illustrated within the Cottonwood Grove in the case of overhanging trees. Such features control channel morphology and influence the routing of water and sediment (Keller and Swanson 1979). At Boulder Creek the process of instream bar formation associated overhanging trees increases the sinuosity of the channel, particularly at lower flows. Development of a more sinuous channel typically reduces the rate of sediment movement through the reach but may also increase the rate of lateral channel migration (Swanson et al. 1982). Additionally, development of instream bars provides new substrates for the establishment of riparian vegetation and the creation of new floodplain surfaces. By documenting the rate at which such channel features develop, we can better predict the areal extent of future riparian communities or cover types.

Another process involved in the development and response of riparian vegetation involves the sequencing of physical events. For example, the seasonal timing, frequency, magnitude and duration of flooding and the subsequent availability of soil moisture, is critical to the establishment of riparian species. This was illustrated by the differences in recruitment of Cottonwood seedlings in permanent plots between 1989 and 1990. By examining rates of recruitment and survival, over time, and across a range of conditions, we will be better able to describe and predict the sets of conditions under which riparian vegetation will or will not establish and grow.

Finally, we need to better understand how the life history traits of key riparian species will influence their distribution and abundance following changes in stream flow, and therefore, conditions within the riparian zone.

We are currently planning additional research aimed at addressing these questions in more detail.

Literature Cited

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Swanson, F.J., G.W. Lienkamper, and J.R. Sedell. 1976. History, physical effects and management implications of large organic debris in western Oregon streams. USDA For. Serv. Gen. Tech. Rep. PNW-56. 15 pgs.

Swanson, F.J., S.V. Gregory, J.R. Sedell and A.G. Campbell. 1982. Land-water interactions: the riparian zone. Pages 267-291 *in* R.L. Edmonds, ed. Analysis of coniferous forest ecosystems in the western United States. US/IBP Synthesis Ser. 14. Hutchinson Ross Publ. Co., Stroudsburg, PA.

Table 1. Preliminary list of herb species from Boulder Creek, August 1989

1	Agropyron repens
2	Agropyron sp
3	Agrostis gigantea
4	Agrostis palustris
5	Alopecurus aequalis
6	Ambrosia artemisiifolia
7	Ambrosia trifida
8	Anchusa sp
9	Arctium minus
10	Artemesia ludoviciana
11	Aster hesperius
12	Aster sp
13	Bidens cernua
14	Bidens frondosa
15	Bromus inermis
16	Bromus japonicus
17	Bromus tectorum
18	Capsella bursa-pastoris
19	Carex praegracilis
20	Carex sp
21	Centaurea picris
22	Chenopodium sp
23	Chrysanthemum leucanthemum
24	Cirsium arvense
25	Conyza canadensis
26	Cynoglossum officinalis
27	Cyperus aristatus
28	Dactylis glomerata
29	Dipsacus sylvestris
30	Echinochloa crus-galli
31	Eleocharis sp
32	Elymus canadensis
33	Erigeron sp
34	Euphorbia glyptosperma
35	Festuca arundica?
36	Helianthus sp
37	Hepaticae
38	Hesperis matronalis
39	Hordeum brachyantherum
40	Hypericum perforatum
41	Impatiens capensis
42	Iris sp
43	Juncus articulatus
44	Juncus interior
45	Juncus saximontanus
46	Juncus sp
47	Lactuca serriola
48	Lactuca sp
49	Leersia oryzoides
50	Leonurus cardiaca
51	Linaria vulgaris
52	Lobelia cilliata
53	Lychnis alba
54	Lycopus americanus
55	Medicago lupulina
56	Melilotus sp

Table 1, continued.

57	Mentha arvensis
58	Muhlenbergia racemosa
59	Musci
60	Myosotis verna
61	Nepeta cataria
62	Oenotheria strigosa
63	Oxalis stricta
64	Oxylis sp
65	Panicum capillare
66	Parthenocissus quinquefolia
67	Phalaris arundica
68	Plantago lanceolata
69	Plantago major
70	Poa compressa
71	Poa palustris
72	Poa sp
73	Polygonum aviculare
74	Polygonum coccineum
75	Polygonum convolvulus
76	Polygonum lapathifolium
77	Polygonum persicaria
78	Polygonum sp
79	Polanisia trachysperma
80	Portulaca oleracea
81	Prunella vulgaris
82	Ranunculus macounii
83	Ranunculus sp
84	Rhus radicans
85	Rorippa sp
86	Rosa sp
87	Rudbeckia laciniata
88	Rumex acetosella
89	Rumex crispus
90	Salsola collina
91	Saponaria officinalis
92	Sedum stenopetalum
93	Setaria glauca
94	Setaria viridis
95	Solidago sp
96	Sonchus sp
97	Sporobolus cryptandrus
98	Taraxacum officinalis
99	Tragopogon sp
100	Trifolium pratense
101	Trifolium repens
102	Trifolium sp
103	Unk Brassicaeae
104	Unk Brassicaceae1
105	Unk Brassicaceae2
106	Unk Asteraceae
107	Unk Fabaceae
108	Unk Poaceae
109	Unk Apiaceae
110	Unk sp
111	Unk sp2
112	Unk sp3

Table 1, concluded.

113	Unk sp4
114	Veronica anagallis-aquatica
115	Verbena bracteata
116	Verbena hastata
117	Verbascum thapsis
118	Viola sp
119	Vitus sp

List of Figures

Figure 5. Density (stems/ha) of Sand-bar Willow seedlings and saplings relative to the stream discharge (cubic feet per second) estimated to first inundate the plots in which the stems are found. All stems were sampled within permanent plots located within the active channel and along Instream Flow Incremental Methodology (IFIM) hydraulic cross-sections.

Figure 6. Density (stems/ha) of Plains Cottonwood seedlings and saplings relative to the stream discharge (cubic feet per second) estimated to first inundate the plots in which the stems are found. All stems were sampled within permanent plots located within the active channel and along Instream Flow Incremental Methodology (IFIM) hydraulic cross-sections.

Figure 7. Estimated 7-day averages of stream flow in Boulder Creek at the Cottonwood Grove. Estimates were obtained by taking records of flow from the Orodell Gage at the mouth of the canyon and correcting for all known take-outs and returns that occur between the gage and the study site.

Figure 8. Surveyed cross-sections of Boulder Creek within the Cottonwood Grove from 1989 and 1990. The figure illustrates the change in the channel cross-section (both erosion and deposition) that occurred during this period. Such erosion and deposition occurred consistently throughout the reach of Boulder Creek within the grove.

Figure 9. A picture of Boulder Creek from within the Cottonwood Grove, illustrating a Crack Willow overhanging the channel. Stems such as this are instrumental in changing the routing of water and sediments through the site; in this way the process of erosion and deposition of alluvial material along the active channel is perpetuated.

Figure 10. A. A cohort of Plains Cottonwood saplings on a bar adjacent to the channel of Boulder Creek. Natural regeneration of native riparian species along Boulder Creek, and within the Cottonwood Grove now takes place in an incised, narrow active channel zone subject to surface-water inundation (see Figure 2). Successful establishment of cottonwood and other native riparian species is largely dependent upon the creation of fresh deposits of alluvial material following. B. A first-year cottonwood seedling on an open alluvial deposit that formed following the flooding in June of 1990.

COTTONWOOD GROVE, BOULDER, COLORADO

Location of Monitor Wells, Channel Cross-Sections, and Upland Vegetation Plots

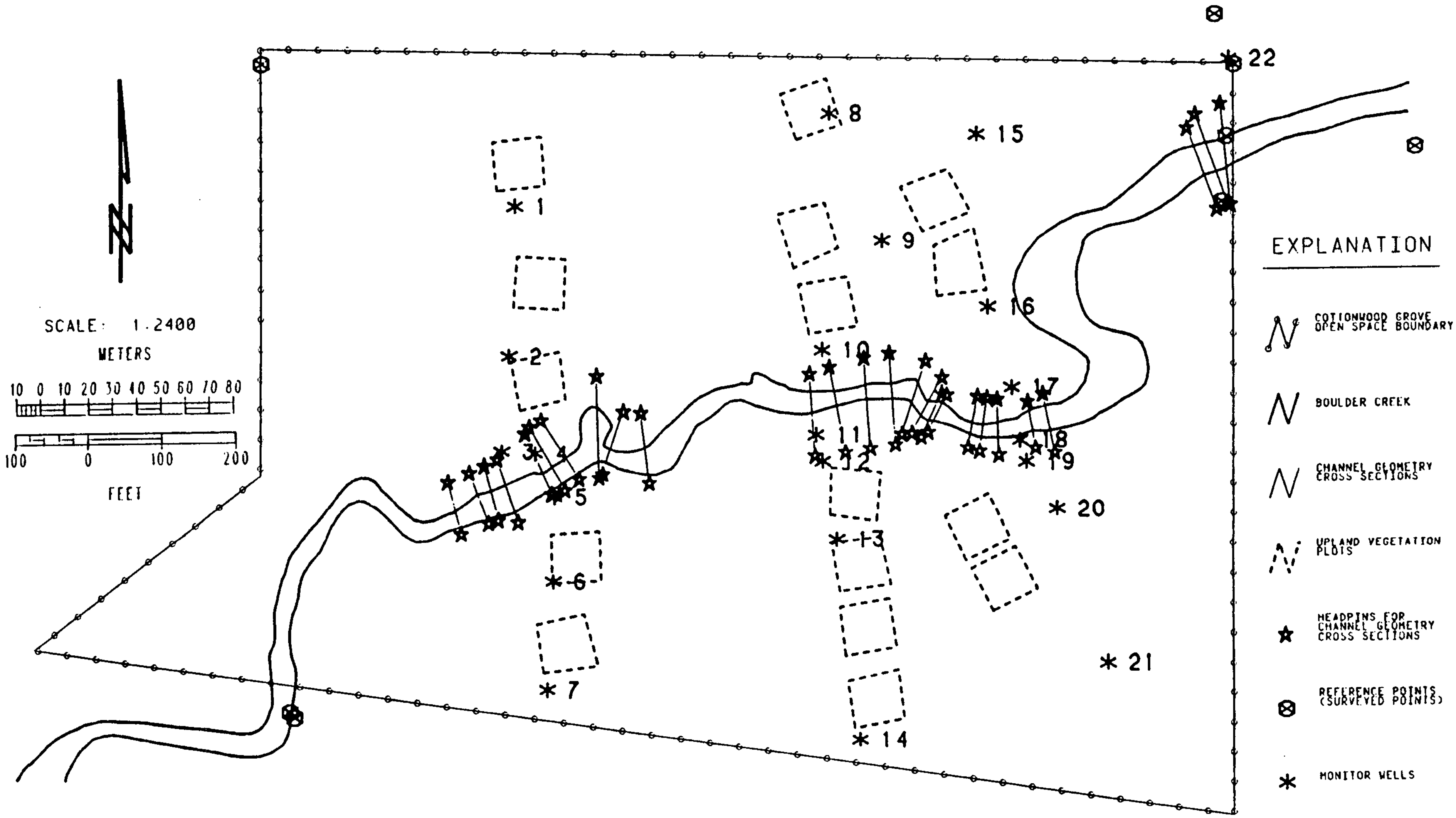


Figure 1.

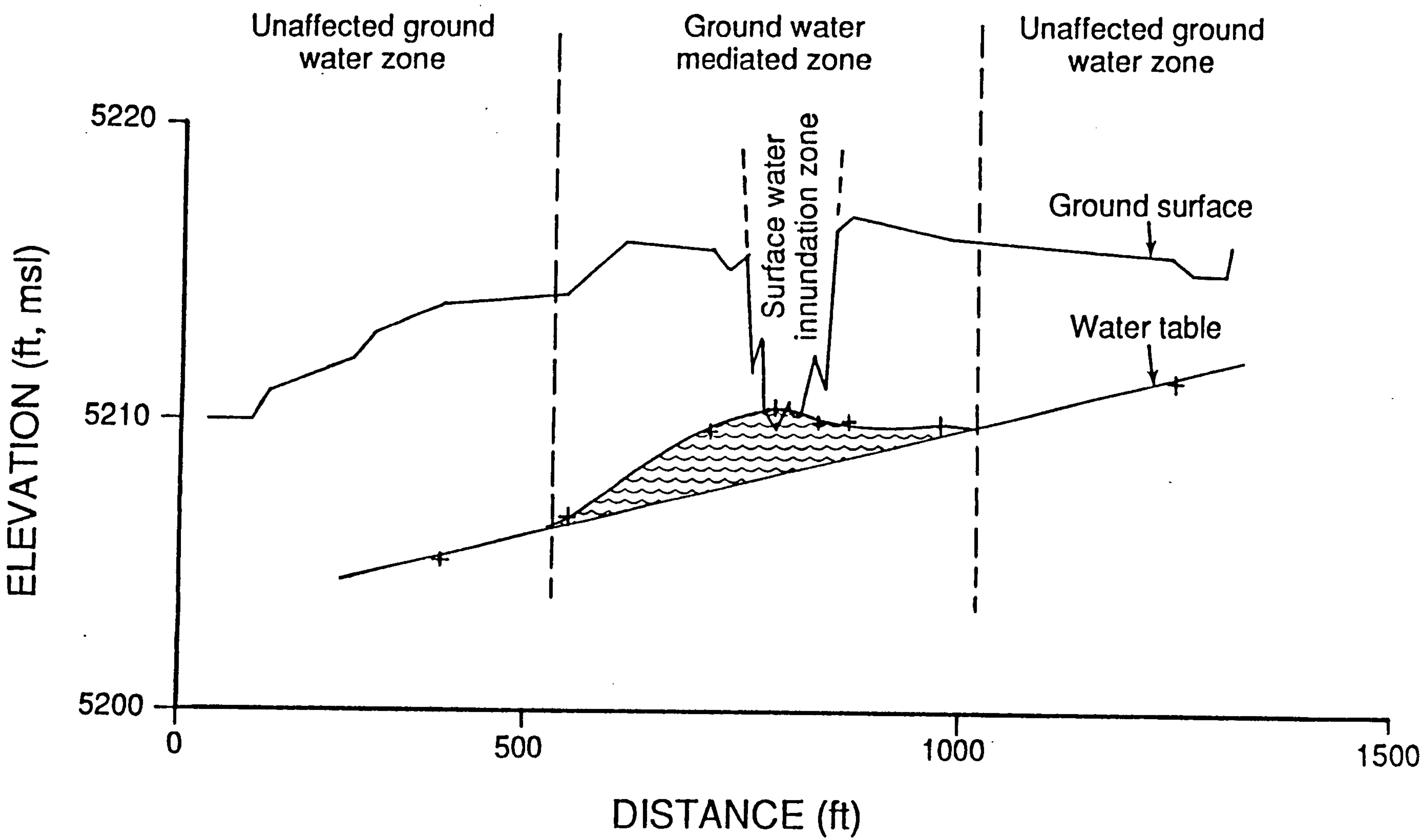

Unaffected ground water zone
Ground water mediated zone
Unaffected ground water zone
Surface water innundation zone
Ground surface
Water table
5220
5210
5200
0
500
1000
1500
ELEVATION (ft, msl)
DISTANCE (ft)

FIGURE 2.

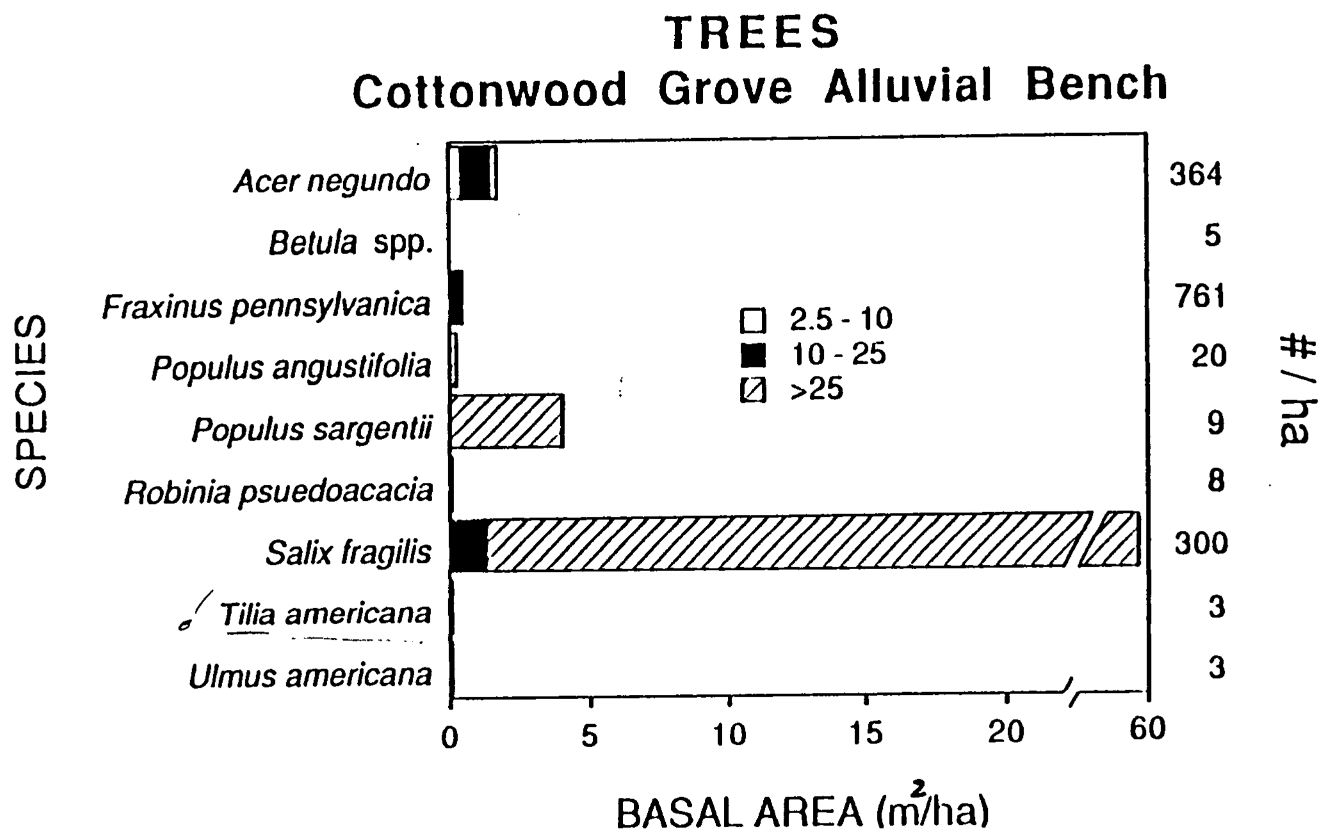

TREES
Cottonwood Grove Alluvial Bench
SPECIES
Acer negundo
Betula spp.
Fraxinus pennsylvanica
Populus angustifolia
Populus sargentii
Robinia psuedoacacia
Salix fragilis
Tilia americana
Ulmus americana
2.5 - 10
10 - 25
>25
364
5
761
20
9
8
300
3
3
/ ha
0
5
10
15
20
60
BASAL AREA (m²/ha)

FIGURE 3.

Fraxinus pennsylvanica
Size Distribution on Alluvial Bench

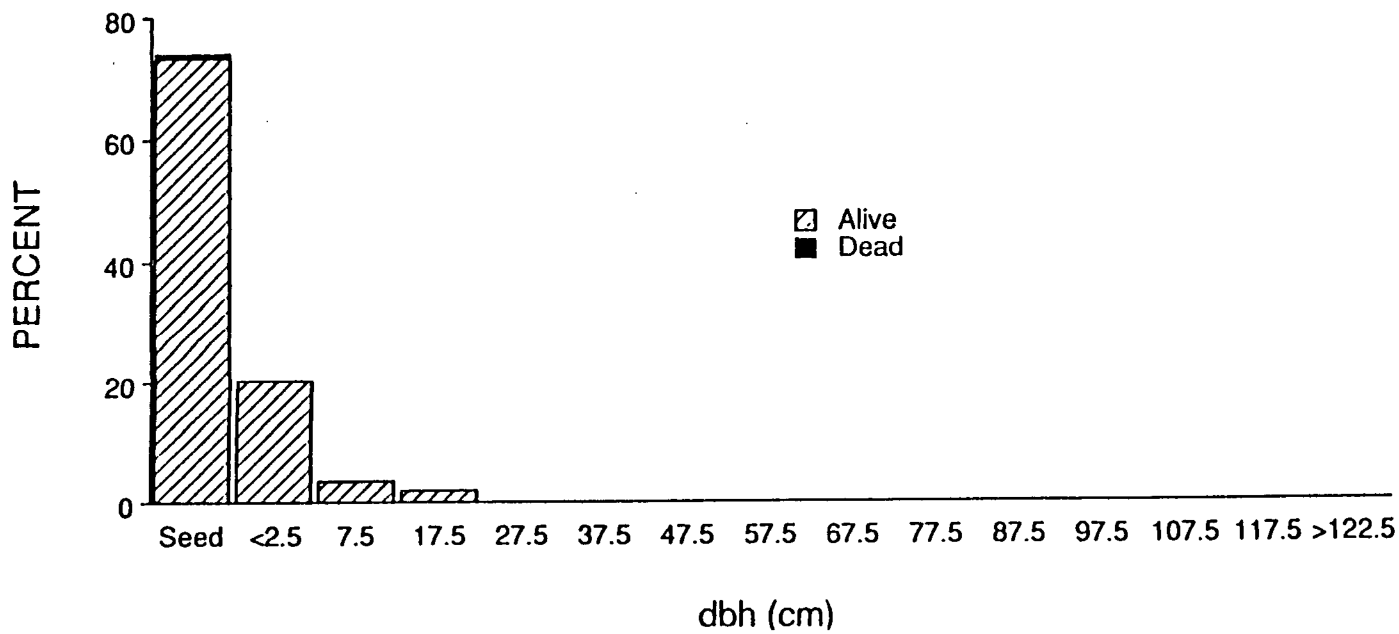


FIGURE 4.

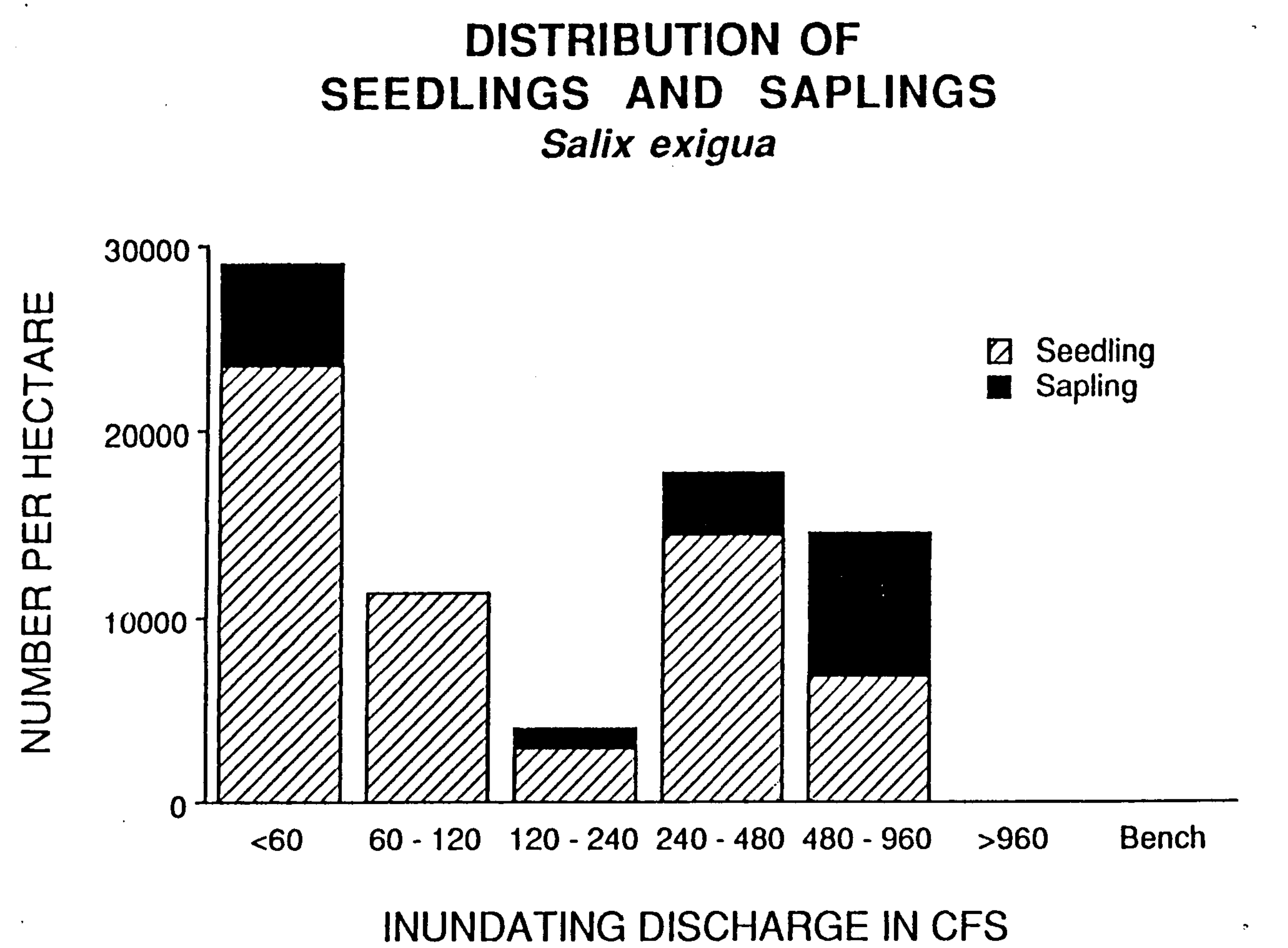
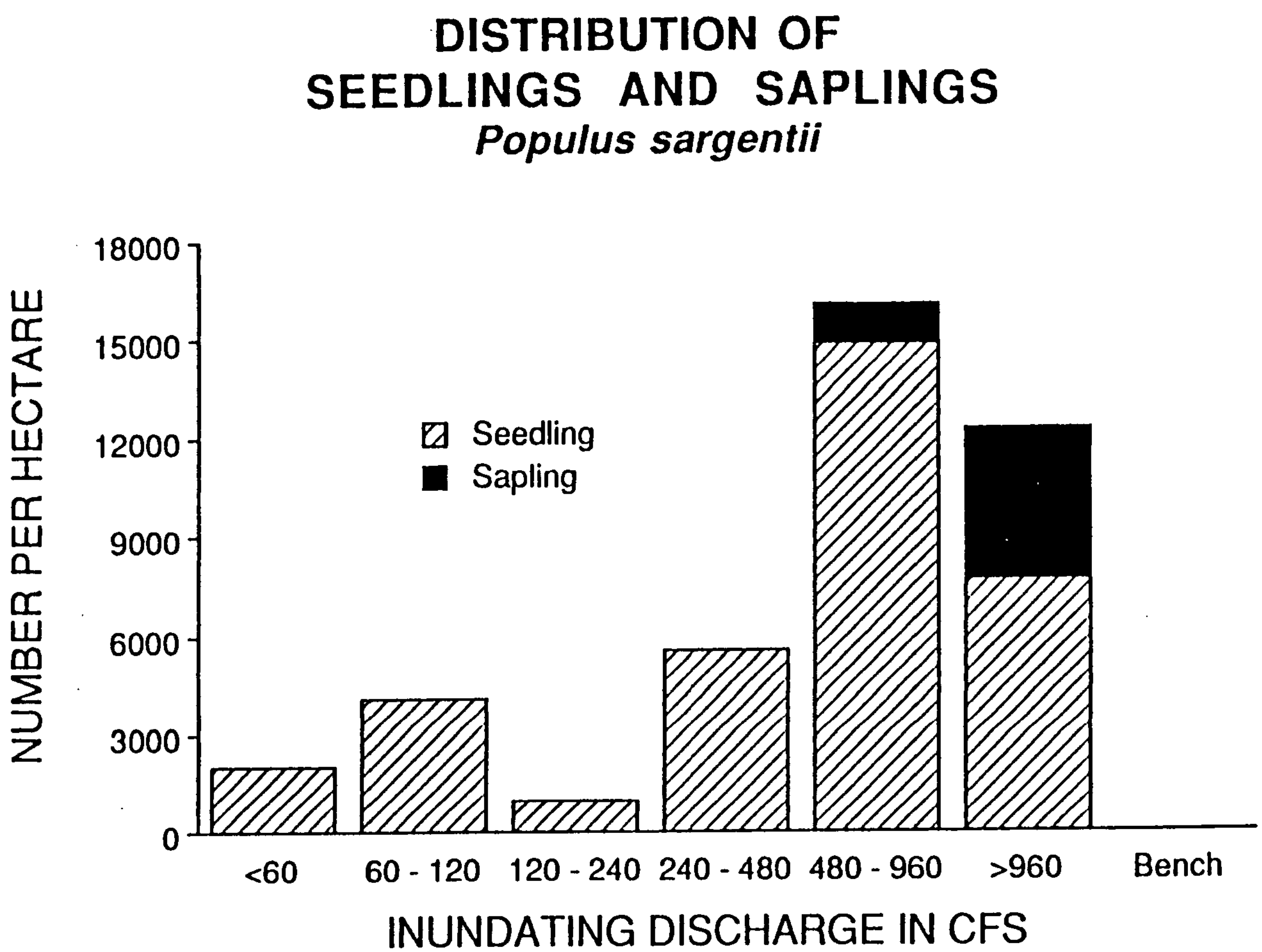

DISTRIBUTION OF
SEEDLINGS AND SAPLINGS
Salix exigua
NUMBER PER HECTARE
30000
20000
10000
0
Seedling
Sapling
<60
60 - 120
120 - 240
240 - 480
480 - 960
>960
Bench
INUNDATING DISCHARGE IN CFS

FIGURE 5.



DISTRIBUTION OF
SEEDLINGS AND SAPLINGS
Populus sargentii
NUMBER PER HECTARE
18000
15000
12000
9000
6000
3000
0
Seedling
Sapling
<60
60 - 120
120 - 240
240 - 480
480 - 960
>960
Bench
INUNDATING DISCHARGE IN CFS

FIGURE 6.

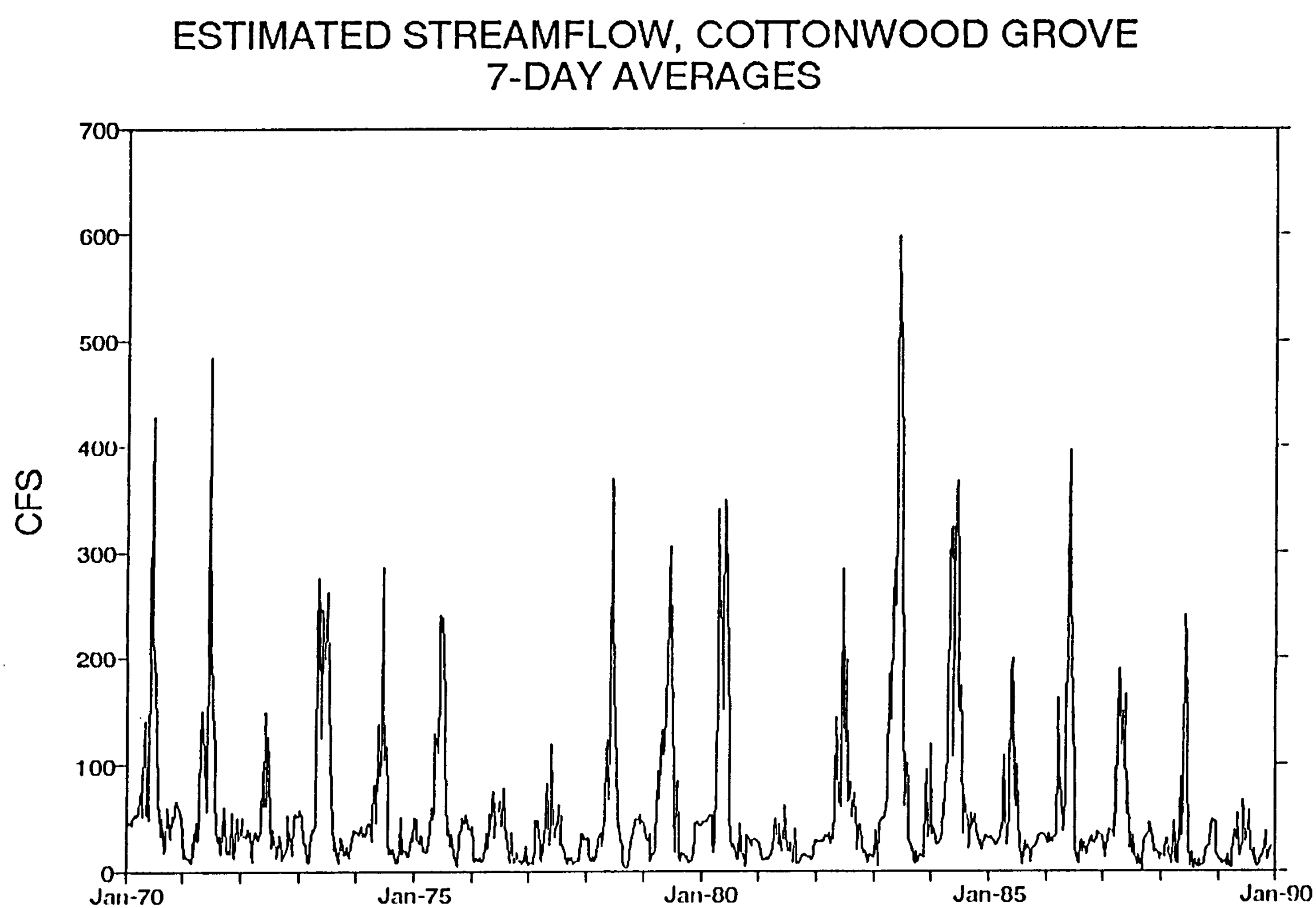

ESTIMATED STREAMFLOW, COTTONWOOD GROVE
7-DAY AVERAGES
CFS
0
100
200
300
400
500
600
700
Jan-70
Jan-75
Jan-80
Jan-85
Jan-90

FIGURE 7.

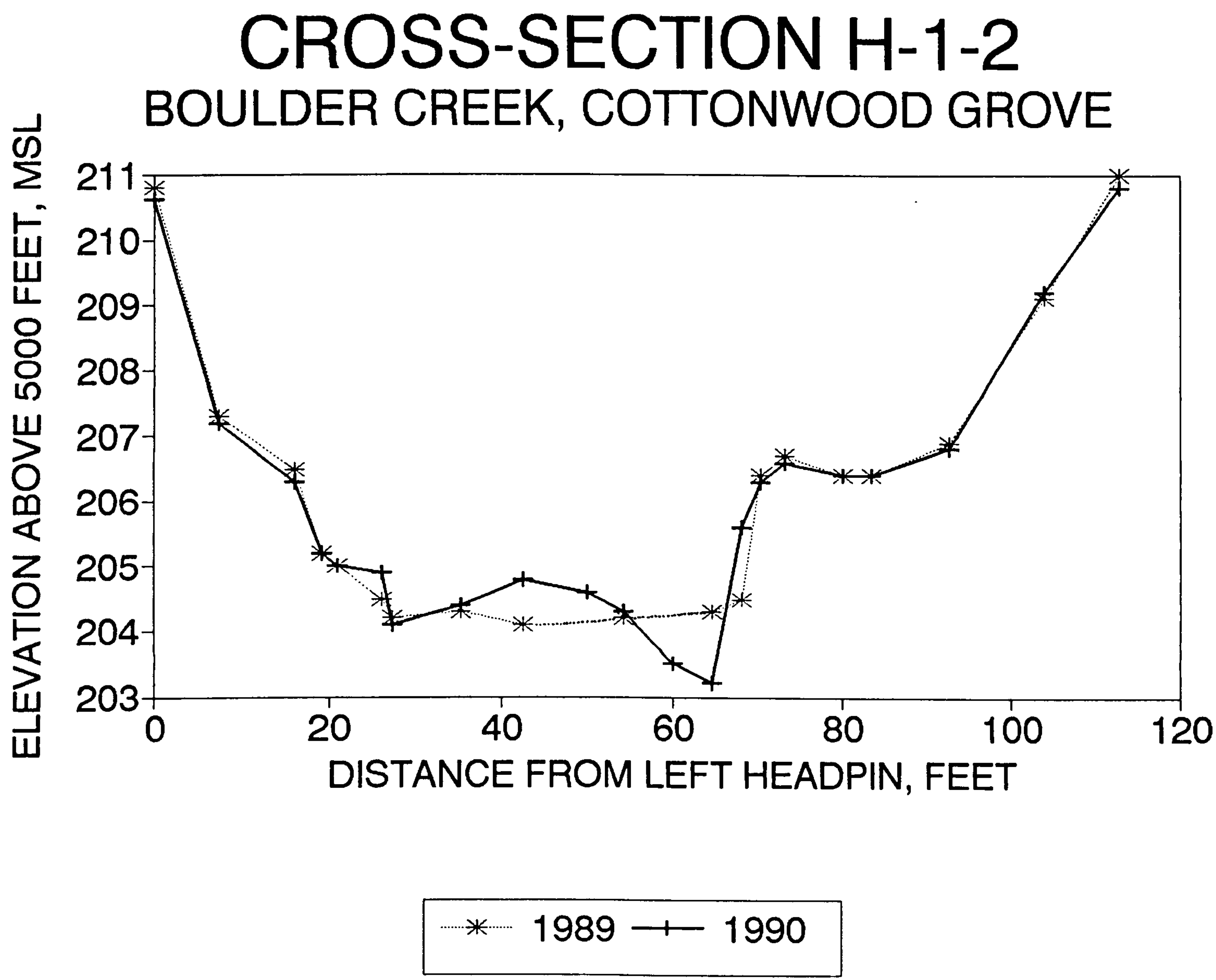

CROSS-SECTION H-1-2
BOULDER CREEK, COTTONWOOD GROVE
ELEVATION ABOVE 5000 FEET, MSL
211
210
209
208
207
206
205
204
203
0
20
40
60
80
100
120
DISTANCE FROM LEFT HEADPIN, FEET
1989
1990

FIGURE 8.

FIGURE 9

A.

B.

FIGURE 10.

United States Department of the Interior
FISH AND WILDLIFE SERVICE
NATIONAL ECOLOGY RESEARCH CENTER

4512 McMurray Ave.
Fort Collins, Colorado 80525-3400

April 22, 1991

Mark Gershman
Wetlands and Wildlife Coordinator
City of Boulder
Boulder, CO 80306

Dear Mark:

Enclosed is a preliminary report that summarizes some of our work at the Cottonwood Grove, in keeping with the terms of our Cooperative Agreement (14-16-0009-89-957). We will complete intensive sampling at the site this summer and will then begin to prepare the data for publication. As this work is completed, we will provide you with copies. Additionally, my offer to give a talk describing our work to date still stands.

I hope you find the enclosed report helpful. If there is anything else we might be able to provide you with at this point, please do not hesitate to give me a call.

Sincerely,

Mike Scott

Michael L. Scott, Ph.D.
Riverine and Wetland Ecosystems Branch

cc: Ischinger, regarding Work Unit 212, Task # 6130.W122