COLORADO RIVER FLOOD RISK ANALYSES

at

Connected Lakes
Duke Lake
30 Road Pond
Corn Lake
Island Acres Ponds
Parachute Pond
Rifle Rest Area Pond

for 2040

the Colorado Division of Wildlife

by

the Colorado Water Conservation Board

January 1995

STATE OF COLORADO

Colorado Water Conservation Board
Department of Natural Resources

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February 3, 1995

Mr. Perry Olson, Director
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Dear Perry:

The Colorado Water Conservation Board (CWCB) is pleased to submit ***"The Colorado River Flood Hazard Analyses at Connected Lakes, Duke Lake, 30 Road Pond, Corn Lake, Island Acres Ponds, Parachute Pond and Rifle Rest Area Pond"***. This cooperative effort between our agencies has generated important flood risk and mitigation data. This information can be used to guide future project development, fisheries enhancement and decision-making related to the Endangered Species Act for these reaches of the Colorado River.

The CWCB would like to thank the DOW field staff, and in particular Mr. Eddie Kochman, for the assistance and background information for the sites which they provided.

Sincerely,

Daries C. Lile, Director
Colorado Water Conservation Board

Preface

This report provides the Colorado Division of Wildlife with floodplain information on the Colorado River to quantify the flood risk and with recommendations for dealing with that risk. The CWCB analysis provides technical information for eight ponds along the Colorado River in Garfield and Mesa Counties in Colorado. Because there are four Endangered Species of fishes in the Colorado River, there is concern about the risk that a program of stocking non-native fish in the eight ponds might pose to the native fish in the river.

Acknowledgements

The Colorado Water Conservation Board would like to acknowledge the assistance of the following individuals and agencies in the preparation of this report. Their help ranged from providing historical accounts of flooding at the pond sites and making aerial photos of historic flooding available to providing surveying assistance in the field visits to the individual sites to providing engineering information for evaluating the flood risk at specific sites.

Emilio Rios	J.F. Sato & Associates, Inc.
Jeff Simonson	Schmueser, Gordon, Meyer, Inc.
Jim Wieger	Consultant
Region VIII	Federal Emergency Management Agency
Sacramento District	U.S. Army Corps of Engineers
Eddie Kochman	Colorado Division of Wildlife
Bill Elmblad	Colorado Division of Wildlife
Richard Fletcher	Colorado Division of Parks and Outdoor Recreation
Ruth Burlinson	Colorado Division of Parks and Outdoor Recreation
Larry Lang	Colorado Water Conservation Board
Mark Matulik	Colorado Water Conservation Board
Brian Hyde	Colorado Water Conservation Board
Joe Crocker	Mesa County
Keith Corey	Mesa County
David Rousseau	Town of Parachute

Introduction

The report has been prepared by the Colorado Water Conservation Board (CWCB) at the request of the Colorado Division of Wildlife (DOW). It provides DOW with information regarding the potential for flooding from the Colorado River at 8 ponds between Grand Junction and Rifle (*the 2 Connected Lakes, Duke Lake, 30 Road Pond, Corn Lake, Island Acres Ponds, Parachute Pond, and Rifle Rest Area Pond*). DOW is working cooperatively with the U.S. Fish and Wildlife Service to develop management strategies for all of their facilities in the Colorado River basin (including these 8 facilities). The management strategies need to meet the objectives of the Endangered Species Act and contribute to the recovery of 4 Endangered Species of fishes in the Colorado River basin.

Purpose

The purpose of the CWCB investigation was to determine the flood risk at the 8 ponds along the Colorado River in Garfield and Mesa Counties. The 8 ponds are proposed to be stocked with non-native fish by DOW. The concern is that during a flood the non-native fish could have access to the Colorado River, thereby posing competition and a possible threat to endangered fishes in the river. The report quantifies the possibility of a flood connecting the ponds with the river. The investigation that preceded the report included research of existing information, field inspections of the sites, hydrologic and hydraulic determinations to describe specific flood risks.

The quantification of flood risk should assist DOW in determining whether a plan to mitigate the effects of flooding is needed for any of the ponds. The report also includes an engineering evaluation to describe specific flood protection deficiencies at each pond. The report goes on to provide DOW with some preliminary recommendations for flood protection measures which might limit the adverse effects of a flood for each pond.

Organization

The report is divided into the following 5 sections:

Section 1 describes previous related studies for floodplain information wherever they are available. Those studies provide hydrologic and hydraulic information that can be used to describe the flood risk at a particular pond site.

Section 2 summarizes the hydrologic information and recent flood history for the Colorado River from Connected Lakes State Park (just downstream of the confluence with the Gunnison River at Grand Junction) upstream to Rifle Rest Area Pond (just upstream of the confluence with Rifle Creek at Rifle). The flood history describes the Colorado River floods of 1983, 1984, and 1993.

Section 3 provides general hydraulic information for the Colorado River from Connected Lakes State Park upstream to Rifle Rest Area Pond for the selected pond sites.

Section 4 describes the criteria used by the CWCB to evaluate mitigation alternatives for addressing the flood risk at the 8 ponds.

Section 5 list specific flood information for each pond along with a mitigation analysis for that pond. Section 5 includes 6 Site Reports for the 6 pond sites (the 2 Connected Lakes and Duke Lake are all included in the same Site Report). For each site report there are four subsections.

> **Subsection 5.1** includes aerial photos from 1983, 1984 and/or 1993 to show what effect the river had on the ponds in those high flow events.
>
> **Subsection 5.2** describes field surveys conducted in January 1995 at each site by CWCB staff. It also describes the sources of hydraulic information for evaluating the flood risk at each site. Supporting information attached to Subsection 5.2 includes profile sheets with existing ground elevations compared to 100-year flood elevations and floodplain maps.
>
> **Subsection 5.3** describe the specific flood risk at each site in terms of flood depths and risk of erosion damage.
>
> **Subsection 5.4** offers some preliminary recommendations for mitigation of the flood problems at each site.

Section 1 Related Studies

Two major flood hazard identification studies were used to determine flood risks at each of the 8 ponds. One study is the *Flood Insurance Study, Mesa County, Colorado, Unincorporated Areas*, revised July 15, 1992 (FIS). It was prepared after the 1984 flood on the Colorado River to update floodplain delineations in the Grand Junction area. The contractor's scope for that effort also included revisions to the Flood Insurance Studies (F.I.S.') for Palisade, Grand Junction, and Fruita, but those other studies were not used for this report. In addition to the FIS itself, the CWCB staff used the *Hydrology Report, Flood Insurance Studies in Mesa County, Colorado*, dated May 1989 prepared by J.F. Sato & Associates, Inc. as part of the FIS revision contract and the topographic mapping used to delineate the floodplain boundaries.

The other study has not yet been published. When it is published, it will be entitled *Floodplain Information Report, Colorado River from Glenwood Springs to DeBeque Canyon, Garfield and Mesa Counties, Colorado*. The Sacramento District of the U.S. Army Corps of Engineers is working with the CWCB to map the floodplain of the Colorado River from Glenwood Springs downstream to the upstream (east) end of DeBeque Canyon. Preliminary floodplain maps have been prepared, but there is no final report at this time. CWCB staff used two sets of related documents: 1) The 1985 Hydrology Report prepared by the Corps of Engineers and 2) The topographic mapping prepared with funding from the Colorado Department of Local Affairs for the floodplain identification effort. A third related document is a report prepared for the Town of Parachute by its own private consultant. *Floodplain Information Report, Parachute Creek, Colorado River in the Town of Parachute, Colorado*, prepared in October 1989, delineates the floodplain of Parachute Creek and the Colorado River in and around the town. The report used the unpublished Corps of Engineers information for the Colorado River.

There is a gap of about 12 river miles between these two studies. Floodplain maps were not prepared for the DeBeque Canyon. Because there is not a great deal of existing development or development potential in that canyon, it was left out of the scope of both studies. Island Acres State Park is in DeBeque Canyon, so CWCB staff had to approach that site differently than the other sites. The hydrologic and hydraulic analyses for Island Acres will be described later in this report.

In addition to the two floodplain studies described above, CWCB staff used other sources of information. Survey control information provided by the Mesa County Surveying Department facilitated field surveys. Engineering information prepared for the City of Rifle by Schmueser, Gordon, Meyer delineated the changes to the floodplain caused by the Colorado Department of Transportation's I-70 Rest Area at Rifle. The Town of Parachute provided historical information and aerial photography of the flooding at the Parachute Pond in 1983 and 1984. Colorado Division of Parks and Outdoor Recreation staff provided information about historic flooding at their facilities (Corn Lake and Island Acres State Park). DOW staff provided aerial photography of all of the ponds during the 1993 flood.

Section 2 Flood Hydrology and Recent Flood History

Subsection 2.1 Flood Hydrology

The determination of the flood threat at the 8 ponds is based on the determination of peak flood flows for the reach of the Colorado River from Connected Lakes State Park upstream to Rifle. Two hydrologic analyses were used for that determination. A flood hydrology analysis for the reach of the river from just below Fruita upstream to just upstream of Palisade was prepared by J.F. Sato & Associates, Inc. in 1989 as part of the revisions to the FIS' in the Grand Junction area. A separate flood hydrology analysis had already been performed by the Corps of Engineers in 1985 for the reach of the Colorado River from the upstream end of DeBeque Canyon upstream to Glenwood Springs. The Sato analysis took account of the earlier work by the Corps of Engineers, so the two reports are consistent. Both reports are based on gage records for gages at Glenwood Springs, Newcastle, DeBeque, Cameo and the Colorado/Utah stateline. At two particular hydrologic points the peak flows computed by each study are identical: 1) The Cameo stream gage and 2) A point just downstream of the confluence of the river with Plateau Creek. Although the hydrologic analyses are continuous from Glenwood Springs to Fruita, there is a gap in floodplain mapping. That gap will be addressed in Section 3 of this report.

Seven hydrology points on the Colorado River are relevant to the 8 ponds. They are:

1) The gage at Glenwood Springs (*below the Roaring Fork River confluence*),
2) A point below Mamm Creek (*above the Rifle Creek confluence*),
3) A point below Rifle Creek (*above the Parachute Creek confluence at Parachute*),
4) The gage near DeBeque (*above the Roan Creek confluence*),
5) The gage near Cameo (*above the confluence with Plateau Creek*),
6) The gage at Palisade (*below the confluence with Plateau Creek*), and
7) The Stateline gage (*downstream of the confluence with the Gunnison River*).

The Corps projections for the 0.1 % chance (10-year), 0.02 % chance (50-year), and 0.01 % chance (100-year) flows for each of those hydrology point are listed below in Table 1. In addition, the peak flows measured at the Glenwood Springs, Cameo and Stateline gages during the floods of 1983, 1984 and 1993 are listed. The Palisade gage was only operated after 1991, so the 1983 and 1984 values there were estimated by adding the 1983 peak flow on Plateau Creek, 5010 cfs, to the Cameo gage readings. (Unfortunately the Plateau Creek gage did not operate in 1984 or 1985, so the 1983 value had to used as an estimate for 1984.) There were no estimates of peak flows during those floods at either of the two hydrology points in the Rifle/Parachute area. The historic flows themselves were included in Table 1 below so they could be compared to computed peak flow values for the 10-year, 50-year and 100-year flood events. Details on the effects of those historic events are provided in Subsection 2.2.

TABLE 1

FLOOD HYDROLOGIC INFORMATION FOR THE COLORADO RIVER
Glenwood Springs to the Colorado/Utah Stateline

Location	10 yr.	50 yr.	100 yr.	1983	1984	1993
Glenwood Spgs. *d/s Roaring Fork R.*	26,800	36,000	39,900	27,900	31,500	17,700
Rifle *u/s Rifle Ck.*	28,600	38,100	42,200	------	------	------
Parachute *u/s Rifle Ck.*	29,100	38,700	42,900	------	------	------
DeBeque *u/s Roan Ck.*	30,200	40,000	44,200	32,300	38,200	22,900
Cameo *u/s Plateau Ck.*	31,200	41,800	46,300	36,000	39,300	23,300
Palisade *d/s Plateau Ck.*	32,900	44,400	49,300	41,010*	44,310*	27,400
Fruita/Stateline	50,600	73,100	83,700	62,100	69,800	44,300

* Flow estimated by adding Cameo gage flow to 1983 peak flow on Plateau Creek

Subsection 2.2 Recent Flood History

As shown in Subsection 2.1 the Colorado River experienced significant flooding in 1983 and 1984. In 1993 there was also high water with minor flooding, although not nearly as much as in 1983 or 1984. These historic events provide some indication of the risk of flooding at the 8 ponds, so a general description of what happened on the Colorado River is given below. This information was correlated to flood frequencies by examining the measurements made at the gaging stations along the Colorado River with basin hydrology. Those quantitative correlations are provided in Table 2 below. Then the general descriptions for the three floods on the Colorado River will be given. Individual descriptions of the flooding at each pond site are included in each of the site reports in Section 5.

TABLE 2

ESTIMATED FREQUENCY OF RECENT FLOODS

Location	1983 Flood	1984 Flood	1993 Flood
Connected Lakes/Duke Lake	22 yr. - 25 yr.	40 yr.	2 yr. - 5 yr.
30 Road Pond	22 yr. - 25 yr.	40 yr.	2 yr. - 5 yr.
Corn Lake	22 yr. - 25 yr.	40 yr.	2 yr. - 5 yr.
Island Acres Ponds	22 yr. - 25 yr.	40 yr.	2 yr. - 5 yr.
Parachute Pond	12 yr. - 14 yr.	40 yr.	2 yr. - 5 yr.
Rifle Rest Area Pond	12 yr. - 14 yr.	25 yr. - 40 yr.	1.5 yr. - 2 yr.

General descriptions of flooding experienced in each of these three events, to the extent that they are available, are provided below.

1983 Flood

The 1983 flood on the Colorado River was a large event; however, it was less severe than the 1984 flood. It was more severe than the flood of 1993. Due to a very large flow on Plateau Creek, the magnitude of the Colorado River peak flow was greater from the Plateau Creek confluence downstream to the Utah stateline than it was upstream of the Plateau Creek confluence (from the Cameo stream gage upstream to Rifle and Glenwood Springs). Even though the magnitude of the flood was smaller upstream of the Plateau Creek confluence, there was flood damage in 1983 at one of the two sites in that upstream reach (Parachute Pond). Damage at three of the four sites downstream of that confluence (Island Acres Ponds, Corn Lake and Connected Lakes/Duke Lake) was substantial. 30 Road Pond experienced damage, but it was minor. One of the effects of the 1983 flood was to render many sections of streambank more vulnerable to erosion when the 1984 flood came the very next year.

1984 Flood

The 1984 flood was the flood of record at several Colorado River gages. A heavy snowpack followed by an abrupt and sustained hot spell during the last week of May led to significant flood damage throughout western Colorado. Erosion damage was severe at many locations due to the prolonged high water and the already-mentioned susceptibility to erosion following the 1983 flood. All of the ponds other than Rifle Rest Area Pond experienced flood damage in 1984. Even at the Rifle pond there was flooding nearby.

The 1983 flood opened many secondary flow paths on the Colorado River. Those secondary flow paths were, therefore, readily available to the 1984 floodwaters. Had the 1983 flood not occurred and made those flow paths so accessible, the flood stages on the Colorado River in 1984 would have been higher.

1993 Flood

The 1993 flood was initially expected to be more severe than the 1984 flood. In many locations the 1993 snowpack was higher than the 1984 snowpack. Fortunately when spring and early summer came, there was no sustained hot spell. so the runoff was more gradual than had been feared. The result was high water and some erosion but very little of the damage seen in 1983 and 1984. Although there was high water in the river next to several of the ponds, there was no record of inundation at any of the ponds. Erosion continued to be a problem at certain sites, especially Connected Lakes/Duke Lake.

Section 3 Hydraulic Characteristics for the Study Stream Reach

Using the flood hydrology described above and detailed topographic mapping (from 1985 aerial photography for the reach between Palisade and Fruita and from 1982 aerial photography for the reach between Glenwood Springs and the east end of DeBeque Canyon), other parties (FEMA and the Corps of Engineers) prepared detailed hydraulic analyses that can be used for all of the 8 ponds except Island Acres Ponds. At Island Acres a local approximate hydraulic analysis had to be conducted since no floodplain study had been performed. 100-year and 50-year flood depths at each site except Island Acres were computed by comparing flood elevations from the detailed hydraulic analyses cited above to ground elevations at the site.

CWCB staff conducted field surveys and inspections of existing ground elevations at each site. At Parachute Pond available topographic mapping was deemed satisfactory for determining ground elevations. At Connected Lakes State Park (2 Connected Lakes and Duke Lake) a partial field survey was conducted because of time constraints. The survey of high ground extended from the upstream end of the park to a point about halfway downstream in the park. No data were collected from there downstream to the west end of the park. High ground elevations are unknown for the west end of the park.

For all of the ponds except for Island Acres Ponds the surveys consisted of ground profiles for the "ridge" of high ground between the ponds and the Colorado River (parallel to the direction of flow). For Island Acres Ponds the survey consisted of a cross-section (perpendicular to the direction of flow) through the middle of the State Park. The cross-section started at the opposite side of the river from the park (the south bank of the river) and then extended through the park to high ground near I-70. From that single cross-section one can only derive an approximate estimate of flood elevations and flood depths at Island Acres State Park.

For each pond except the Island Acres Ponds a profile sheet comparing existing ground elevations to 100-year flood elevations is included. In each case a profile of high ground parallel to the Colorado River was field surveyed. Since that "ridge" of high ground is the feature that would provide protection to the pond, it is the feature that needs to be compared to flood elevations. The profile sheets are included in Section 5 (Subsection 5.2) along with a discussion of the flood depths at each site. It is important to remember that the elevation of that ground is not the only characteristic that determines whether flooding would be a problem at a particular site. The width of the "ridge", the steepness of its side slopes, its permeability to water, and its stability in the face of erosive forces must also be considered. Those parameters will also be considered in Section 5.

CWCB staff did not find any detailed topographic mapping of the DeBeque Canyon, including Island Acres State Park. No detailed floodplain mapping of the canyon has been prepared. In order to estimate flood conditions at Island Acres, another approach had to be taken. A cross-section of the river, including the overbank area where the state park is located, was surveyed. The Cameo stream gage is only a few miles upstream of the park, so the peak flow values at that site could be used for an approximate hydraulic analysis. That analysis provided a preliminary estimate of the depth of flooding at Island Acres (at least at the location of the cross-section) during a 50-year and a 100-year flood. Since the park is about 0.5 mile long, it would be helpful to have more topographic information than a single cross-section to describe the flood risk there.

Details of the flood risk at each site are provided in Section 5 (Subsection 5.3). It is possible to make a few general observations about the reach of the Colorado River from Connected Lakes to Rifle. All of the ponds would be affected by a 100-year flood. A 50-year flood would affect most of them, through overtopping, through groundwater seepage, or through erosion of embankments. Most of the ponds would experience limited damage or no damage during a 10-year flood. The 1983 and 1984 floods are described in Subsection 2.2 (Recent Flood History). Speaking generally, those floods showed that many low areas along the river, including some of these ponds, are subject to inundation and/or bank erosion during floods smaller than a 50-year or 100-year flood. In looking at what happened at each site in 1983 and 1984 it is important to note that several of the sites underwent significant man-made topographic changes after the floods (i.e regrading of gravel and other materials) so the flood response might be different during the next flood. At the same time, the changes were not specifically engineered with flood resistance, particularly resistance to erosion, in mind. Some sites might look just the same during the next flood as they did in 1983 or 1984 because of this lack of flood engineering. Every site would need some mitigation to protect it from a 50-year or a 100-year flood. Section 5 (Subsection 5.4) will provide detailed information on possible mitigation measures for each site.

Section 4 Mitigation Criteria and Standards

Section 5 of this report includes Site Reports for each of the pond sites. The first three subsection of each of those Site Reports describe historic flooding, the field surveys conducted by the CWCB and the flood risk at each site. The final subsection of each Site Report provides preliminary recommendations for mitigation at each site.

Section 4 explains the criteria and standards used by CWCB staff in recommending particular mitigation strategies. These criteria and standards, which are presented in Table 3 below, are in compliance with those commonly used by state and federal agencies with responsibilities in floodplain management, river mechanics and stream morphology. Because the 8 ponds are existing facilities, any mitigation will involve retrofitting. Retrofitting inherently limits flexibility when compared to new construction. The strategies recommended for the 8 ponds are limited in their scope and design as a result of their having to be retrofit strategies.

TABLE 3

RECOMMENDED MITIGATION DESIGN CRITERIA AND STANDARDS

MITIGATION MEASURES	RECOMMENDED STANDARDS		
LEVEE SYSTEMS			
Design Flood	**Side Slope**	**Top Width**	**Freeboard**
- 10 YEAR	not recommended		
- 50 YEAR	3H:1V	10 FT	2 FT
- 100 YEAR	3H:1V	10 FT	3 FT
- 500 YEAR	3H:1V	10 FT	3 FT
STREAMBANK PROTECTION			
- Velocity less than 7 fps	Soft Treatment:		
	Flatter side slope (4H:1V) Need vegetative cover; can also include organic matter		
- Velocity greater than 7 fps	Hard Treatment:		
	Rock lining, rock jetty, concrete, etc.		
OTHER MEASURES			
Flood warning system	Warns of flood event greater than the 10-year event		
Relocation activities	not applicable		
Siting of recreational facilities	Locate at or above the 10-year flood		
Lowest floor of residential structures	Build at or above the 100-year flood		

Section 5 Site Flood Risk and Mitigation Analyses

This section addresses the specific flood problems at the 6 sites (8 ponds) on a case-by-case basis. For each site there is a separate **Site Report** with four subsections: **Subsection 5.1** Flood photos from 1983, 1984 and/or 1993; **Subsection 5.2** Field inspection and hydraulic determination; **Subsection 5.3** Flood risk to the site; **Subsection 5.4** Mitigation measures.

For all 6 sites the format described above for Section 5 is the same. For each site the Site Report is intended either to stand on its own or to be a part of the entire report. The sites are listed below:

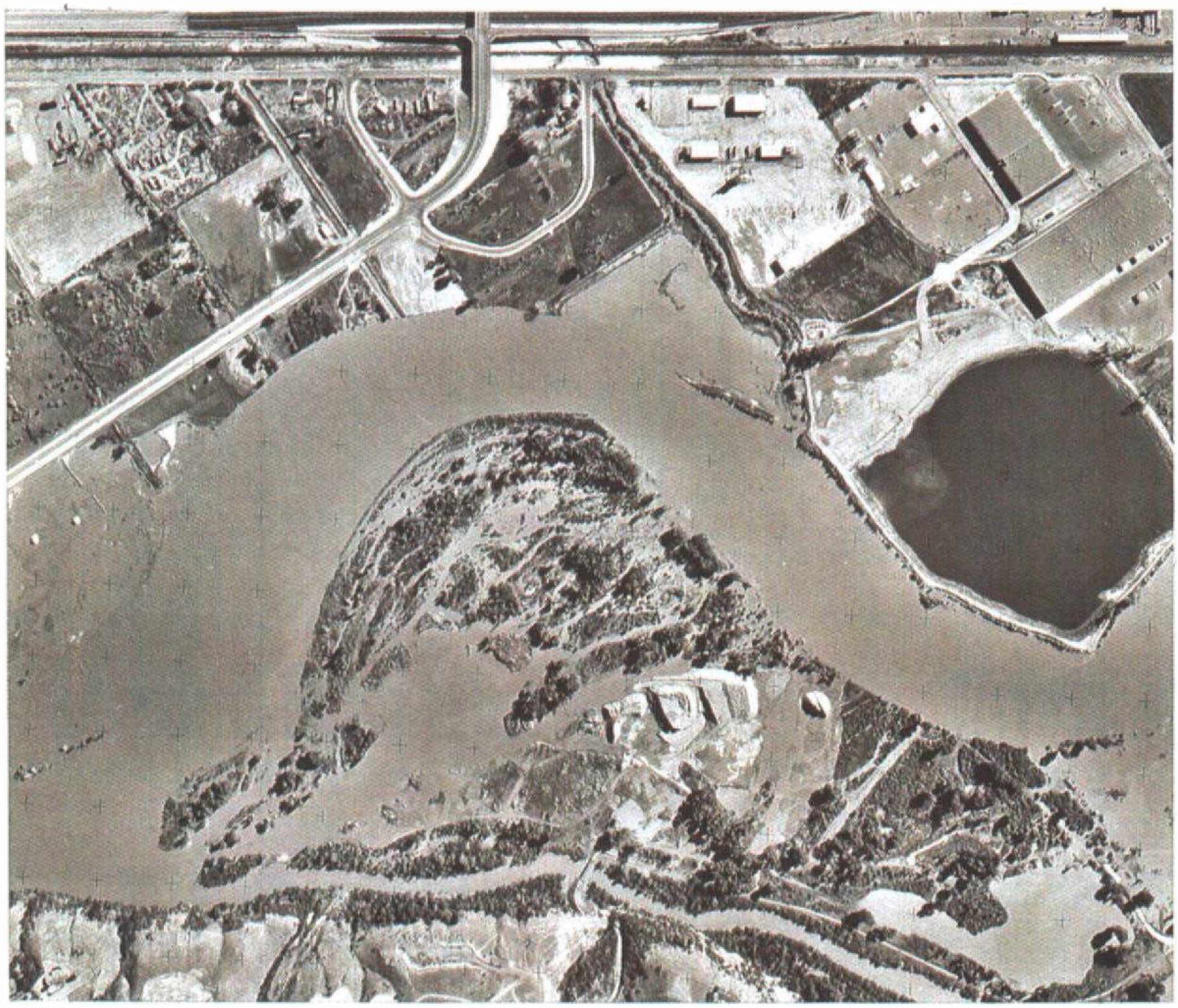
Site 1 Connected Lakes/Duke Lake (3 ponds)
Site 2 30 Road Pond
Site 3 Corn Lake
Site 4 Island Acres Ponds
Site 5 Parachute Pond
Site 6 Rifle Rest Area Pond

CONNECTED LAKES STATE PARK

SITE REPORT

CONNECTED LAKES STATE PARK

Connected Lakes (2) and Duke Lake

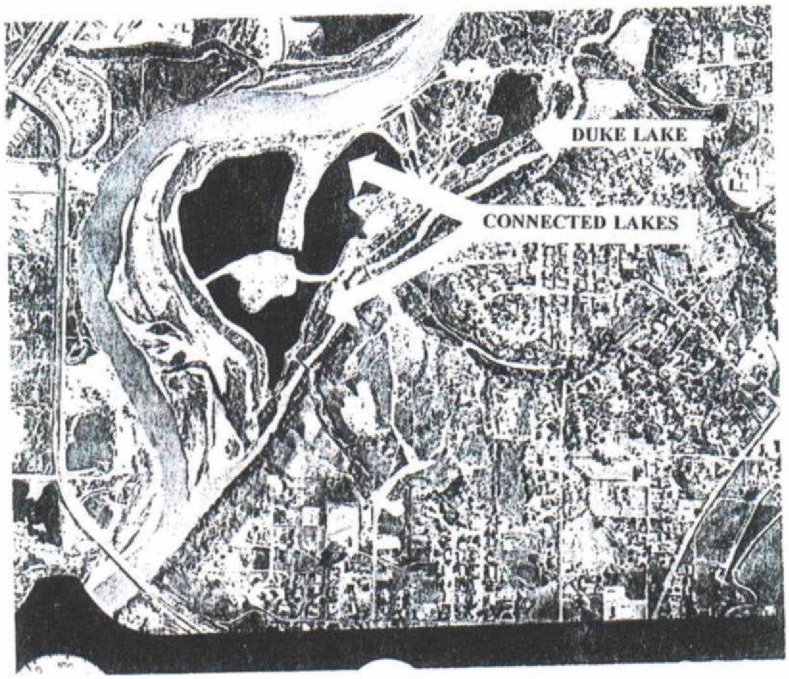


1984 Flooding

CONNECTED LAKES STATE PARK

Connected Lakes (2) and Duke Lake

1993 Flooding



1994 Condition

Section 5 Site Flood Risk and Mitigation Analysis

Site 1 Connected Lakes/Duke Lake

Subsection 5.1 Flood Photos

Aerial photographs of flooding at Connected Lakes in 1984 and 1993 and a photograph of present conditions at the state park are included on the preceding two pages.

Connected Lakes and Duke Lake were entirely inundated in 1983 and 1984. Due to the protection provided by the levee system constructed for Connected Lakes in 1991 and by the Pepsi-Cola Plant levee system and due to smaller flows, no flood inundation occurred during the 1993 flood event. That levee construction led to higher stream velocities. This reach of the Colorado River was already subject to severe bank erosion and channel migration before the levee construction. During the 1983 and 1984 floods part of the river was flowing through the site. The constriction caused by the levee work has made those problems more severe because of the higher flood stages and velocities. The entire area lies within the 100-year floodplain.

During high stages in the river there is an additional risk at Connected Lakes and Duke Lake. The groundwater table is higher than normal in those circumstances, leading to an increased risk of high lake levels which will lead to overflow.

Subsection 5.2 Field Inspection and Hydraulic Determinations

The field survey conducted on January 19, 1995 at Connected Lakes State Park included an examination of existing conditions along the river bank and an elevation survey of the levee surrounding most of the state park. The elevation survey did not extend to the very downstream (west) end of the Connected Lakes. Without such a survey it is not clear that the dike around the Connected Lakes is above the 100-year flood elevation all the way to the west end of the park. Even if it is high enough, there is still a low area near Duke Lake where floodwaters could enter the site. That is exactly what happened in 1983 and 1984. Once floodwaters entered Duke Lake, they would have access to the Connected Lakes also.

The entire Connected Lakes/Duke Lake site was studied as part of the 1992 FEMA restudy for Mesa County. The FEMA hydraulic analysis was used by the CWCB staff to evaluate the flood risk at the site. Once a preliminary risk assessment had been made, it became clear that the effects of regrading and levee construction in the stream reach since 1984 had to be considered. There was visible evidence at the site of continuing streambank erosion. The upstream (east) end of the state park is immediately adjacent to the outside of a bend in the Colorado River. The erosive forces along the outside of that bend were severe in 1983 and 1984 and the potential for future erosion remains great.

The field review and the review of the floodplain maps showed that the levee construction had substantially reduced the width of the floodplain at Connected Lakes. The CWCB decided to

examine the potential effects of those changes. To evaluate the effects of the regrading and the construction of the levee around much of the state park subsequent to the 1984 flood event, the CWCB contracted with J.F. Sato & Associates, study contractor for the 1992 FIS revisions, to modify the computer model of the Colorado River floodplain that they assembled for those 1992 revisions. Sato & Associates modified the FEMA analysis to take account of the levee system constructed at the state park and the levee system at the Pepsi-Cola plant in 1991.

In Sato's modified analysis, performed for the CWCB, it was assumed that the regrading and the levee construction would prevent floodwaters from entering the state park and that the changes would remain intact even with significant erosive forces. The CWCB analysis has determined that flood depths would increase approximately 2 feet. The velocities in the river channel during a 100-year flood would experience a substantial increase (an average increase from 6 feet per second to 12 feet per second). Table 4 below shows these changes in flood stage and velocity for six cross-sections from the downstream face of the Redlands Parkway bridge over the river upstream to the Pepsi-Cola levee. In light of these predicted changes, any assumptions about the levees withstanding erosive forces must be subject to serious scrutiny.

TABLE 4

FLOOD DEPTHS AND VELOCITIES FOR CONNECTED LAKES AND DUKE LAKE (With and Without Levees)

Location	Cross-Section	Levee El.	100-yr. El. W/O Levee	100-yr. El. W/ Levee	100-yr. Vel. W/O Levee	100-yr. Vel. W/ Levee
D/S Redlands Pkwy.	W	N.A.	4533.3	4533.3	7.2 fps	7.2 fps
West end of Connected Lakes State Park	X	?	4535.9	4535.9	5.3 fps	5.9 fps
Middle of Park	Y	4540.8	4537.0	4537.8	6.5 fps	13.0 fps
Middle Duke Lake	Z	4540.4	4540.7	4542.3	8.5 fps	9.2 fps
East end Park	AA	4542.5	4543.4	4545.4	3.7 fps	6.6 fps
Pepsi-Cola Levee	BB	4557.0	4547.6	4549.8	10.2 fps	11.0 fps

Note: Velocities greater than 7.0 fps will cause major erosion problems and streambank instability.

The profile sheet for the Connected Lakes and Duke Lake, which is included at the end of this section, shows the levee around a portion of the State Park, as it exists today. It also shows the currently effective 100-year flood elevation from the FIS without incorporating the effects of the 1991 levees on those elevations.

Subsection 5.3 Flood Risk

During a 50-year and a 100-year flood there would be a problem at Connected Lakes and Duke Lake. If the existing levee were not modified and reinforced with riprap on the river face, there would severe erosion to the levee protecting the Connected Lakes. There would also be failure with overflows into Duke Lake. There would be a direct connection between the lakes and the

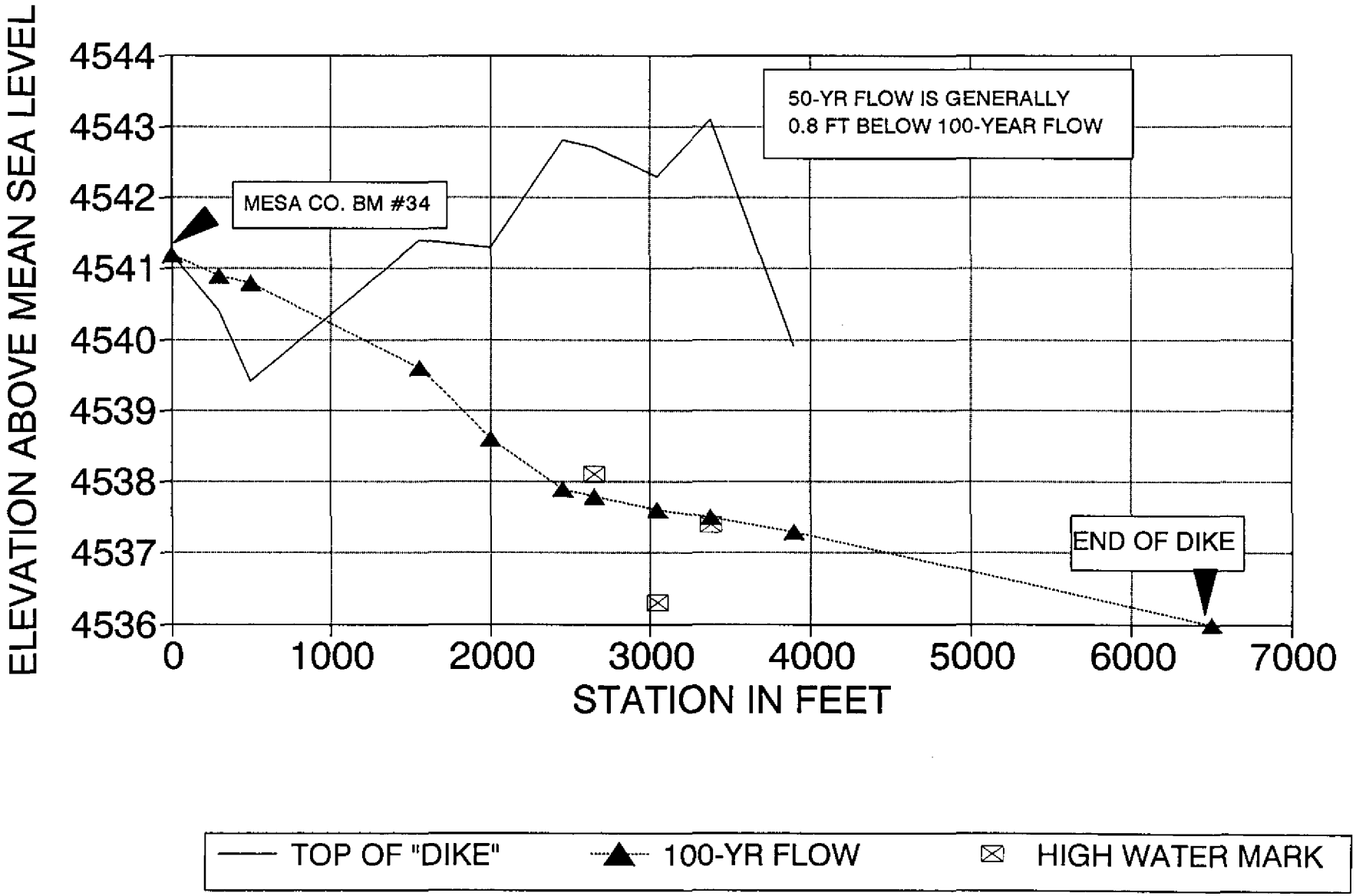
Colorado River, so non-native fish could easily enter the Colorado River. In addition to the likelihood of floodwaters entering the three lakes, there are clear signs that bank erosion is a major concern at Duke Lake and Connected Lakes. The site has historically been a part of the Colorado River floodplain and it has experience substantial channel migration in the past. Bank protection measures undertaken by Mesa County since 1984 have themselves experienced erosion damage. The dikes that were constructed since 1984 as part of the park improvements do not appear to have been designed to withstand erosion from a 50-year or a 100-year flood. While some sections of the levee are above the 100-year flood elevation and provide an aesthetically pleasing place to walk or fish, they do not provide 50-year or 100-year flood protection. In addition, they were not designed with higher velocities or higher flood stages resulting from floodplain constriction in mind. The levee would not experience overtopping during a 10-year flood, but there would be streambank erosion if no additional bank protection were installed.

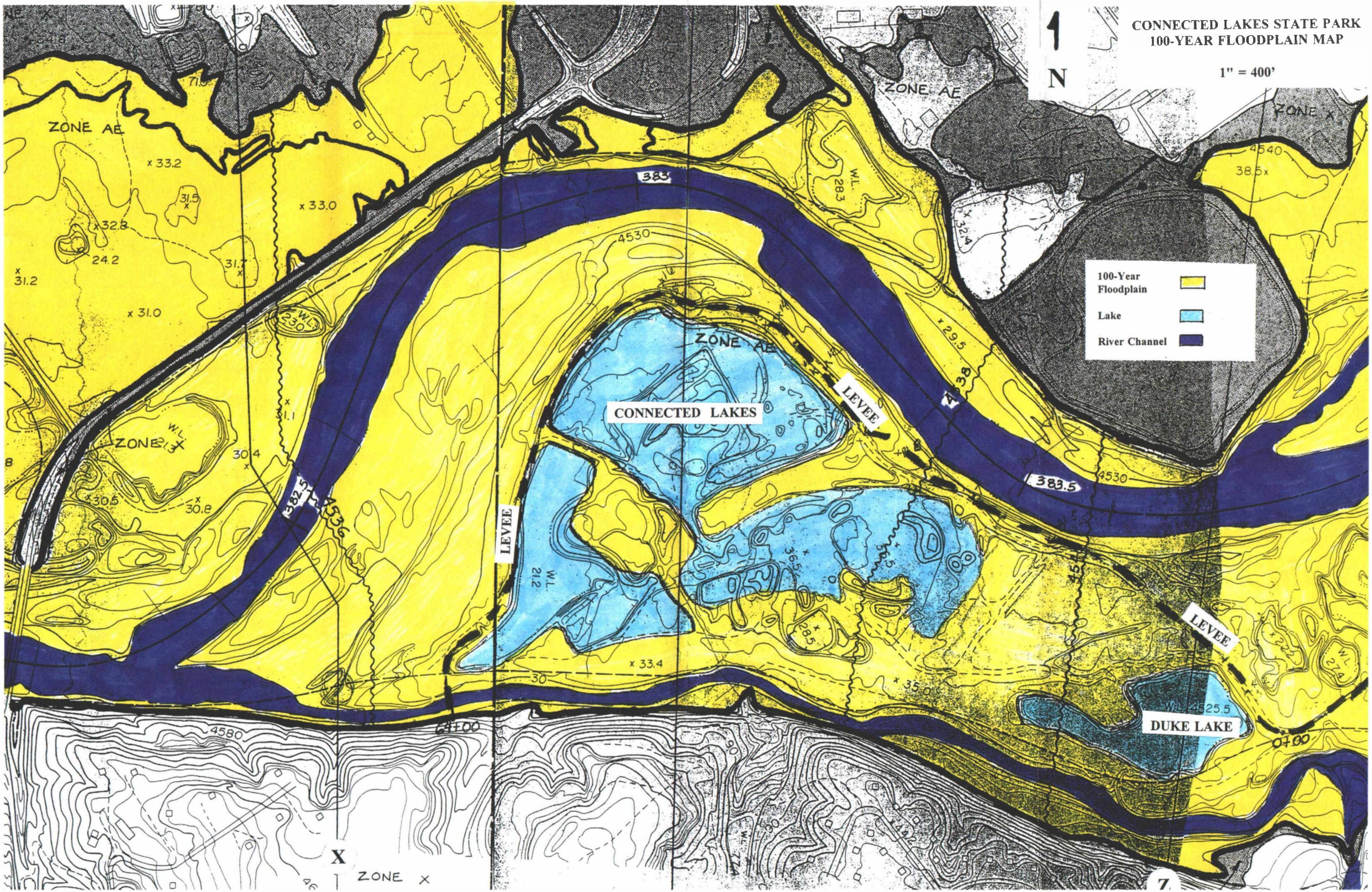
Subsection 5.4 Mitigation Analysis

Even with the substantial work that has been done at the state park, at the residential areas within the Connected Lakes subdivision and at the Pepsi-Cola Plant since 1984, there is additional work that would have to be done to provide 50-year and 100-year flood protection. The levee system would need to be raised to keep Duke Lake (and, therefore, Connected Lakes) out of the 50-year floodplain. That levee and the existing dike around the remainder of the site would clearly require erosion and slope protection. The erosion protection would need to be engineered to mimimize the risk of undermining by a flood. There would need to be additional freeboard in some locations. Before such mitigation measures were undertaken, an engineering analysis would be needed. A 50-year flood protection project may be feasible for the stream reach from the Redlands Parkway upstream to Highway 340.

CONNECTED LAKES STATE PARK

COLORADO RIVER "DIKE" PROFILE

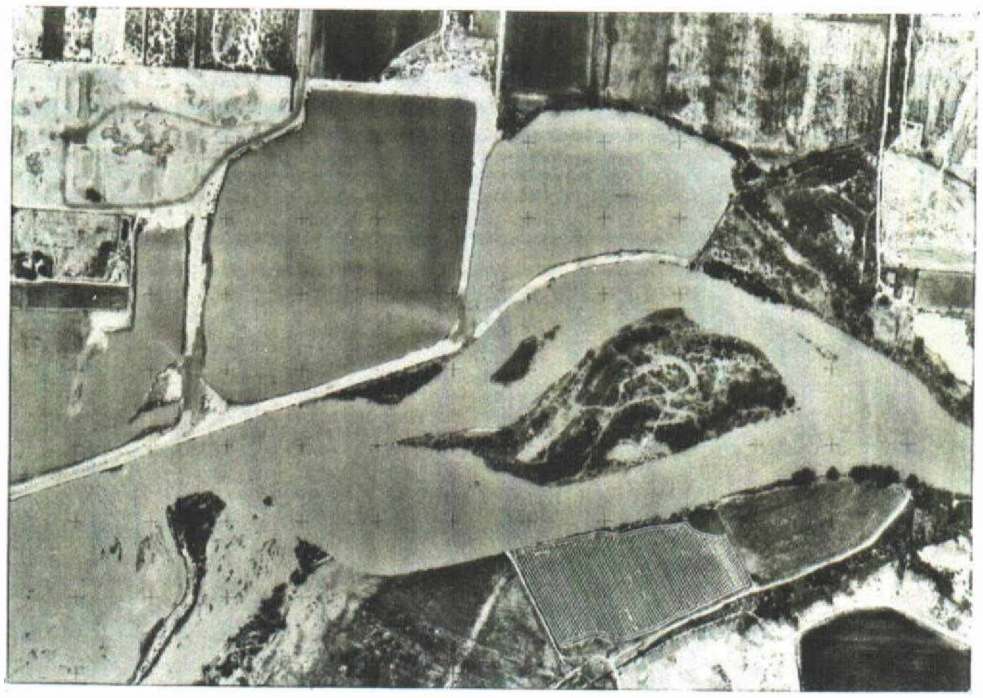



CONNECTED LAKES STATE PARK
100-YEAR FLOODPLAIN MAP
1" = 400'
N
100-Year Floodplain
Lake
River Channel
CONNECTED LAKES
DUKE LAKE
LEVEE
LEVEE
LEVEE
ZONE AE
ZONE AE
ZONE AE
ZONE X
ZONE X
383.5
X
Z

30 ROAD POND

SITE REPORT

30 ROAD POND



1983 Flooding

1993 Flooding

Section 5 Site Flood Risk and Mitigation Analysis

Site 2 30 Road Pond

Subsection 5.1 Flood Photos

Aerial photographs of flooding at 30 Road Pond in 1983 and 1993 are included on the preceding page.

30 Road Pond experienced some flooding in 1983 and 1984. The pond is located on a historic meander path of the river along with the pond to its immediate east (upstream) and to its immediate west (downstream). Floodwaters entered the meander path and then continued into the first pond, the one just east of 30 Road Pond. Water then overflowed to the west into 30 Road Pond and then into the third pond to the west. There was also some underground conveyance through the levees separating the ponds from one another. 30 Road Pond had an overflow back into the river at its southwest corner. The aerial photo shows all of this except the underground flow.

Subsection 5.2 Field Inspection and Hydraulic Determinations

A field survey was conducted at 30 Road Pond on January 20, 1995. It included an elevation survey of the levee along the southern edge of the pond immediately east of 30 Road Pond and along the southern edge of 30 Road Pond itself (between the ponds and the river) and of the levee along the western edge of 30 Road Pond. The eastern edge of the pond immediately east of 30 Road Pond, where surface floodwaters initially entered the system of ponds in 1983 and 1984, was not surveyed.

30 Road Pond is within the geographic scope of the 1992 FEMA restudy for Mesa County. The FEMA analysis was used by the CWCB staff to evaluate the risk at 30 Road Pond.

The profile sheet for 30 Road Pond is included at the end of this section. It shows current levee elevations and the effective 100-year flood elevations from the F.I.S.

Subsection 5.3 Flood Risk

During a 50-year or a 100-year flood it appears that 30 Road Pond would remain safe from floodwaters in the river directly overtopping the levee along the southern pond embankment. There is currently no bank protection, so the risk of erosion should be considered as a potential problem during a large flood.

In 1984 the pond embankment next to the river was approximately 1 foot above the 100-year flood elevations, but the embankment was not designed to accepted levee standards. Since that time it appears that the embankment has been raised another two feet. The pond is still shown as being in the 100-year floodplain in the Mesa County Flood Insurance Study.

From looking at the USGS quadrangle map of the site and from an examination of the 1983 flood photo the three ponds lie along a historic meander path of the Colorado River, as was discussed earlier. The flooding problem at the three-pond system starts with floodwater entering the upstream (easternmost) pond by the surface and underground. The levees between the three ponds keep the water levees at the ponds different (higher in the east pond, lower in the west pond). Floodwaters then continue toward the west, above ground and below ground. Some water returns to the river directly from 30 Road Pond and some returns to the river after flowing through the western pond first. 30 Road Pond cannot be thought of as hydraulically separate from the river during a 50-year or a 100-year flood. The ponds are beyond the limits of the 10-year floodplain.

Subsection 5.4 Mitigation Analysis

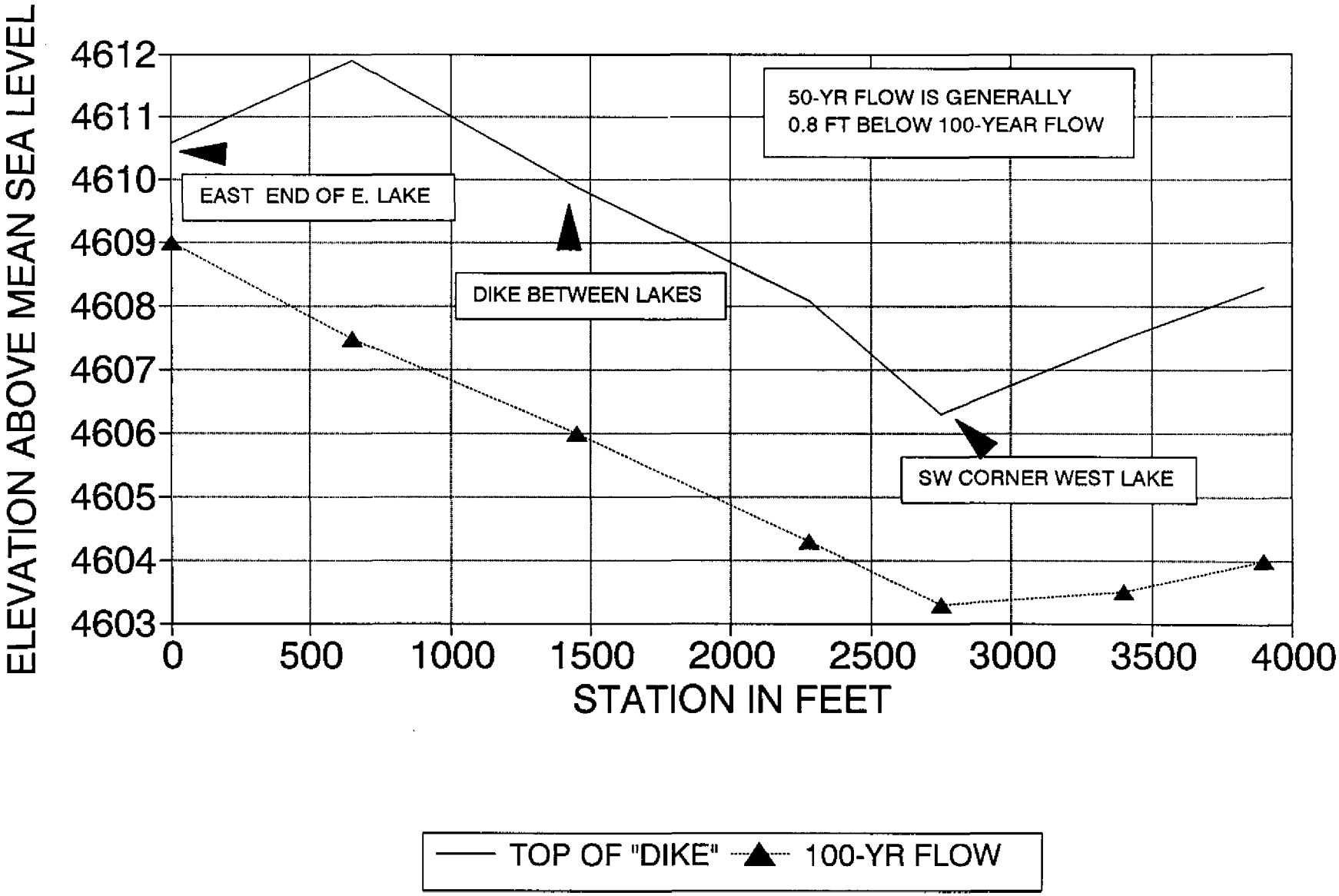
The southern pond embankment can currently provide 100-year protection with some freeboard. At the upstream (eastern) end of the three-pond system a tieback levee would be needed to prevent floodwater from entering the ponds via the historic meander path.

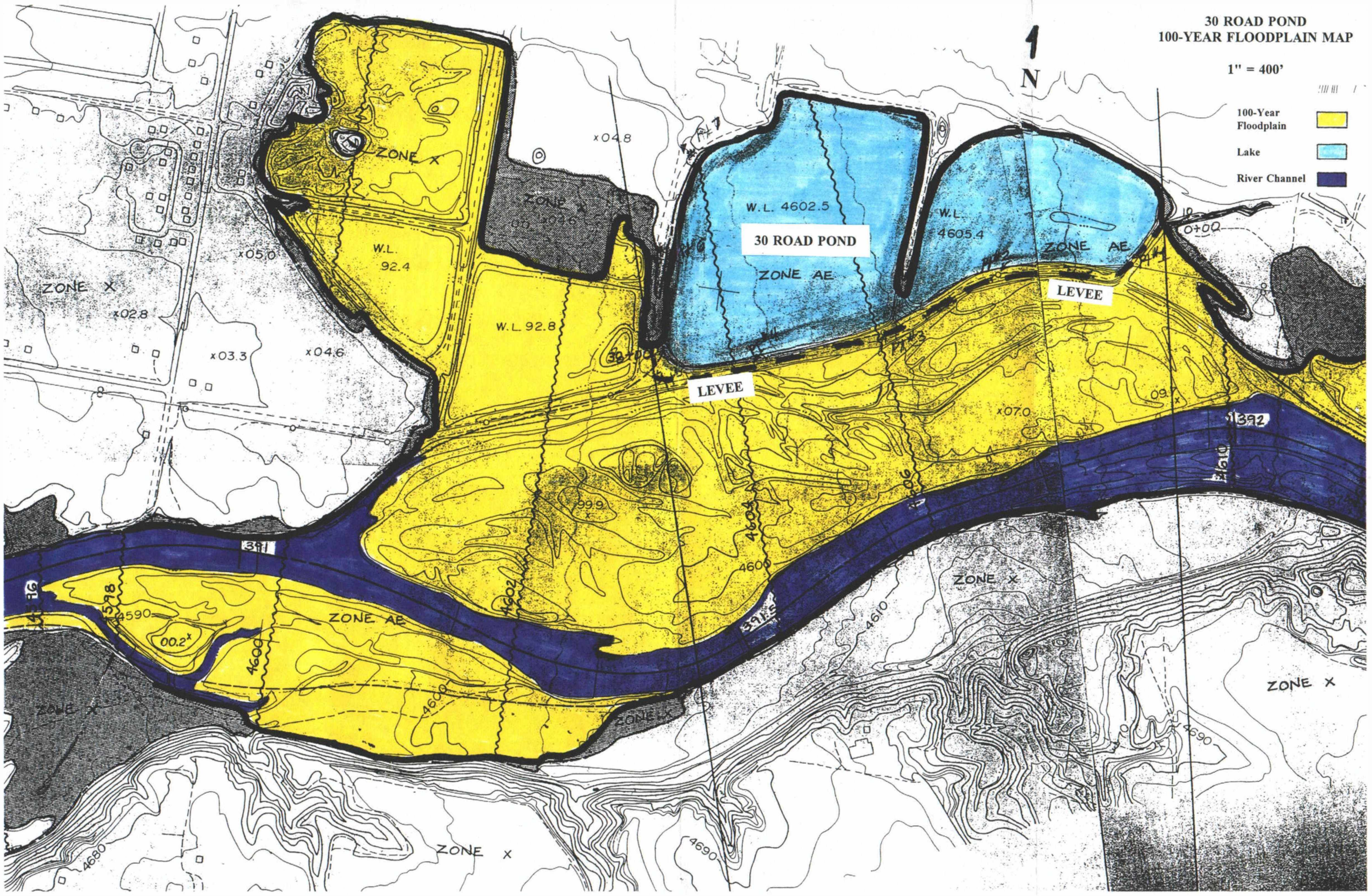
There is no erosion protection and no protection from seepage. The embankment could be improved to protect it from erosion and seepage. A flatter side slope (approximately 1 on 3) toward the south (toward the river) could be provided by filling along the embankment. Willows planted at the toe of that fill slope should stabilize it.

At the western end of the three-pond system and at the western end of 30 Road Pond the levee needs to be elevated to prevent rising pond water from spilling into the Colorado River during periods of high groundwater.

These three components of a mitigation system would be needed to properly protect 30 Road Pond and the ponds on either side of it. Before such measures were considered seriously, an engineering analysis would be needed. Providing 50-year flood protection to the pond appears feasible.

30 ROAD LAKE
COLORADO RIVER "DIKE" PROFILE

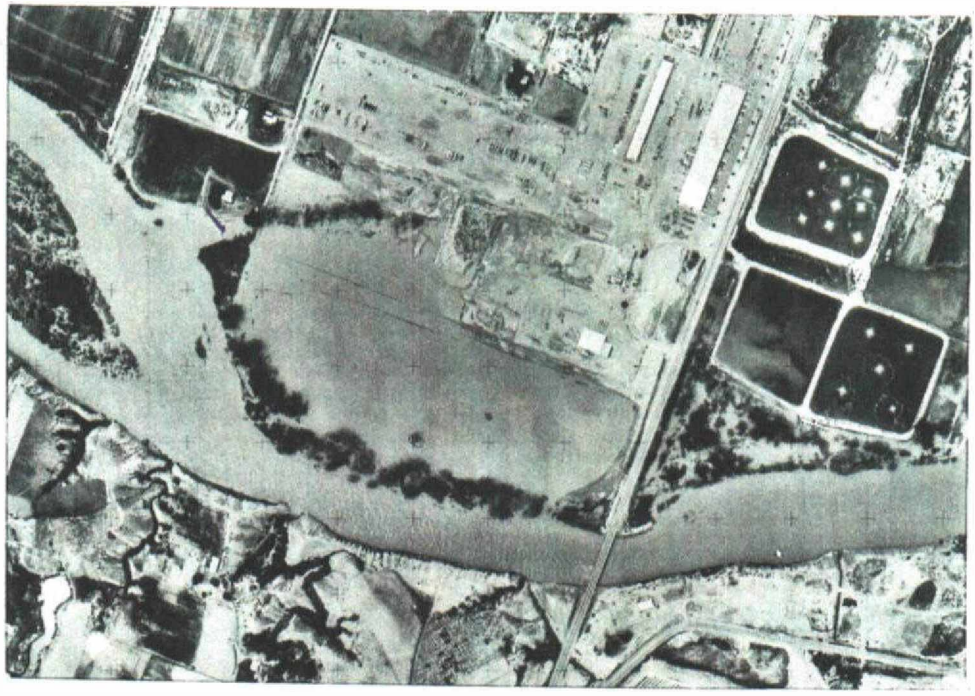



30 ROAD POND
100-YEAR FLOODPLAIN MAP
1" = 400'
N
100-Year Floodplain
Lake
River Channel
30 ROAD POND
W.L. 4602.5
W.L. 4605.4
ZONE AE
LEVEE
LEVEE
ZONE X
W.L. 92.4
W.L. 92.8
x04.8
x05.0
x02.8
x03.3
x04.6
x07.0
99.9
00.2
4590
4600
4602
4604
4606
4610
4680
4690
ZONE AE
391
392
391.5

CORN LAKE

SITE REPORT

CORN LAKE



1983 Flooding

1993 Flooding

Section 5 Site Flood Risk and Mitigation Analysis

Site 3 Corn Lake

Subsection 5.1 Flood Photos

Aerial photographs of flooding at Corn Lake in 1983 and 1993 are included on the preceding page.

Corn Lake was completely inundated in 1983. In 1984 the water was even deeper. In 1993 the river came partway up the levee embankment, but it did not overflow the levee. It appeared that bank erosion was a problem, but not a major problem.

Subsection 5.2 Field Inspection and Hydraulic Determinations

A field survey was conducted at Corn Lake on January 20, 1995. It included an examination of existing conditions along the river bank and an elevation survey of the levee on the east, south and west sides of the lake.

Corn Lake is within the geographic scope of the 1992 FEMA restudy for Mesa County. The FEMA analysis was used by the CWCB staff to evaluate the flood risk at Corn Lake.

The profile sheet for Corn Lake is included at the end of this section. It compares levee elevations and the effective 100-year flood elevations from the F.I.S.

Subsection 5.3 Flood Risk

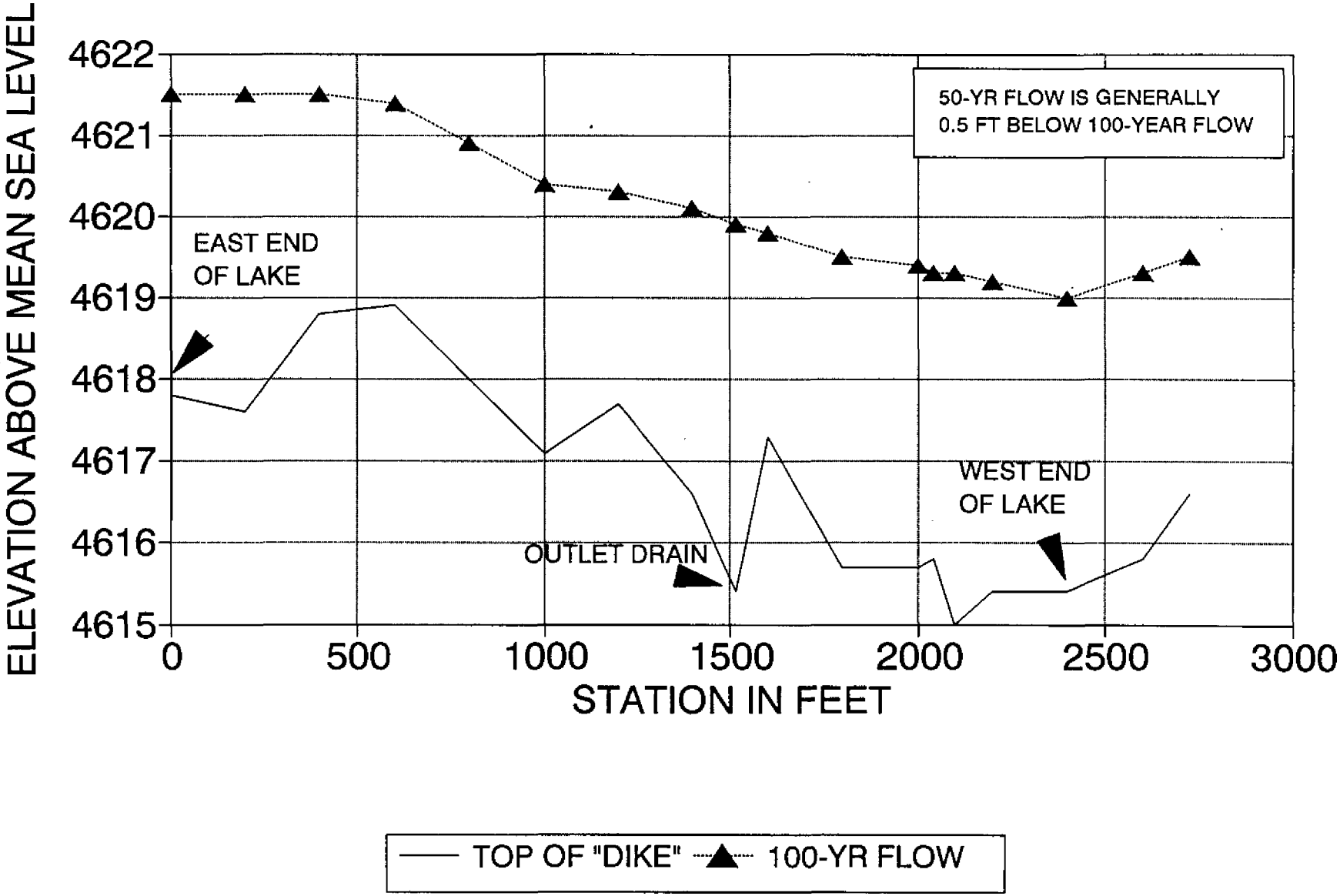
During a 10-year, a 50-year and a 100-year flood there would be a problem at Corn Lake. The levee (it is really more of a landform) does not provide much flood protection. The levee is approximately 3.5 to 4.5 feet below 50-year flood elevations and about 4 to 5 feet below the 100-year flood elevations. Corn Lake is entirely in the 50-year and 100-year floodplain. 10-year, 50-year or 100-year floods would completely inundate the pond and provide a direct connection with the Colorado River. The site is a part of the Colorado River floodplain, so it is to be expected that there would be some erosion potential in addition to the problem of inundation. Corn Lake is subject to a high risk of flood inundation and damage to its contents.

Subsection 5.4 Mitigation Analysis

To provide 100-year protection at Corn Lake, a 7 foot high levee system would be required, which would be an expensive project. A levee to protect Corn Lake from a 50-year flood would also be very expensive. A 2800 foot long levee system with an average height of 5 feet would be required. The levee system would require erosion protection as well. There may be no cost-effective mitigation measures for the flood hazard at Corn Lake. Before such a conclusion was finalized, an engineering analysis would be needed.

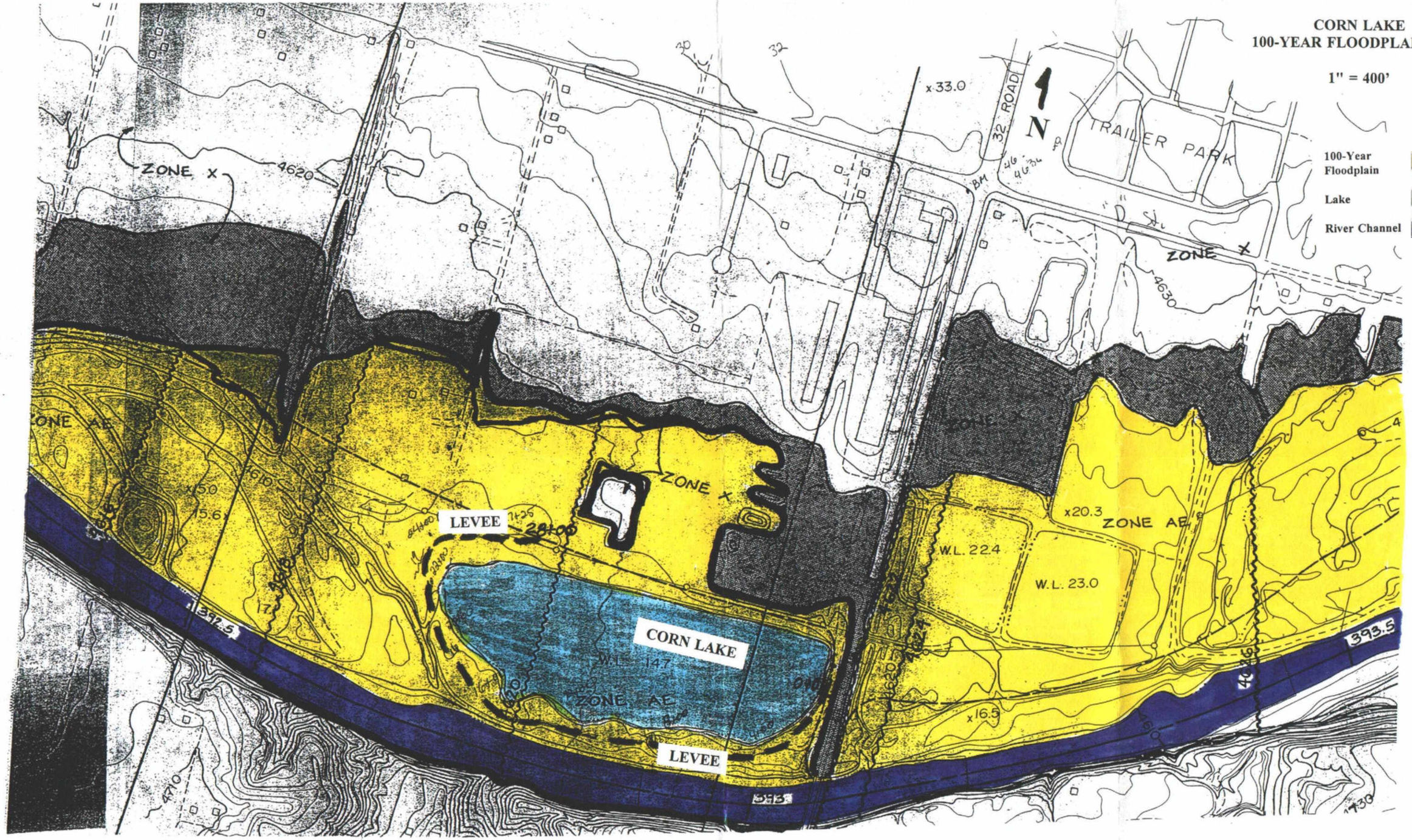
CORN LAKE STATE PARK

COLORADO RIVER "DIKE" PROFILE



CORN LAKE
100-YEAR FLOODPLAIN MAP

1" = 400'



ISLAND ACRES PONDS

SITE REPORT

ISLAND ACRES STATE PARK

1993 Flooding

Section 5 Site Flood Risk and Mitigation Analysis

Site 4 Island Acres Ponds

Subsection 5.1 Flood Photos

An aerial photo of flooding at Island Acres State Park in 1993 is included on the preceding page. Unfortunately no photos of flooding in 1983 or 1984 were available. There was some anecdotal information about the flooding there, however. In both years the site was inundated. In 1984 the flood damage was severe enough to warrant emergency recovery assistance from FEMA as part of the Presidential Disaster Declaration. The one pond that was in the park at that time was inundated. (The other ponds were excavated after the 1984 flood.) The pre-existing levee that had been destroyed was rebuilt through that project. In 1993 floodwaters came within 2 or 3 feet of overtopping the levee which was constructed along the riverbank in 1985. In the 1993 photo it appears that the southernmost pond (the pond that is the furthest downstream) experienced seepage from the river, indicating a need for greater protection above ground and below ground.

Subsection 5.2 Field Inspection and Hydraulic Determinations

A field survey was conducted at Island Acres State Park on January 19, 1995. The survey was different than the surveys for all of the other pond sites because there is no detailed topographic mapping at Island Acres and because no detailed floodplain analysis has been conducted there. The field survey had to provide a representative cross-section so an approximate hydraulic analysis could be performed. The access road that splits the park in two halves, the northern half and the southern half (between the northern pond and the three southern ponds) was selected as the most appropriate location for a representative cross-section. Ground elevations on the west side of the Colorado River extended from the railroad tracks down to the river's edge. On the east side of the river elevations extended from the river's edge up the bank to the top of the levee and then into the park itself all the way to the paved road along the eastern edge of the park (the old highway). There was not sufficient time to survey other cross-sections or to survey the top of the levee along the north edge of the park (the southern riverbank). For that reason an approximate hydraulic analysis had to be performed instead of a detailed analysis.

To perform that approximate analysis the peak flow values from the Cameo gage (approximately 4 miles upstream on the river) were used. By combining those Cameo flows with the surveyed data at the park 50-year and 100-year flood elevations were estimated at the cross-section. Since no other cross-sections were surveyed, the one cross-section had to be used to represent the entire park until better topographic data become available.

Subsection 5.3 Flood Risk

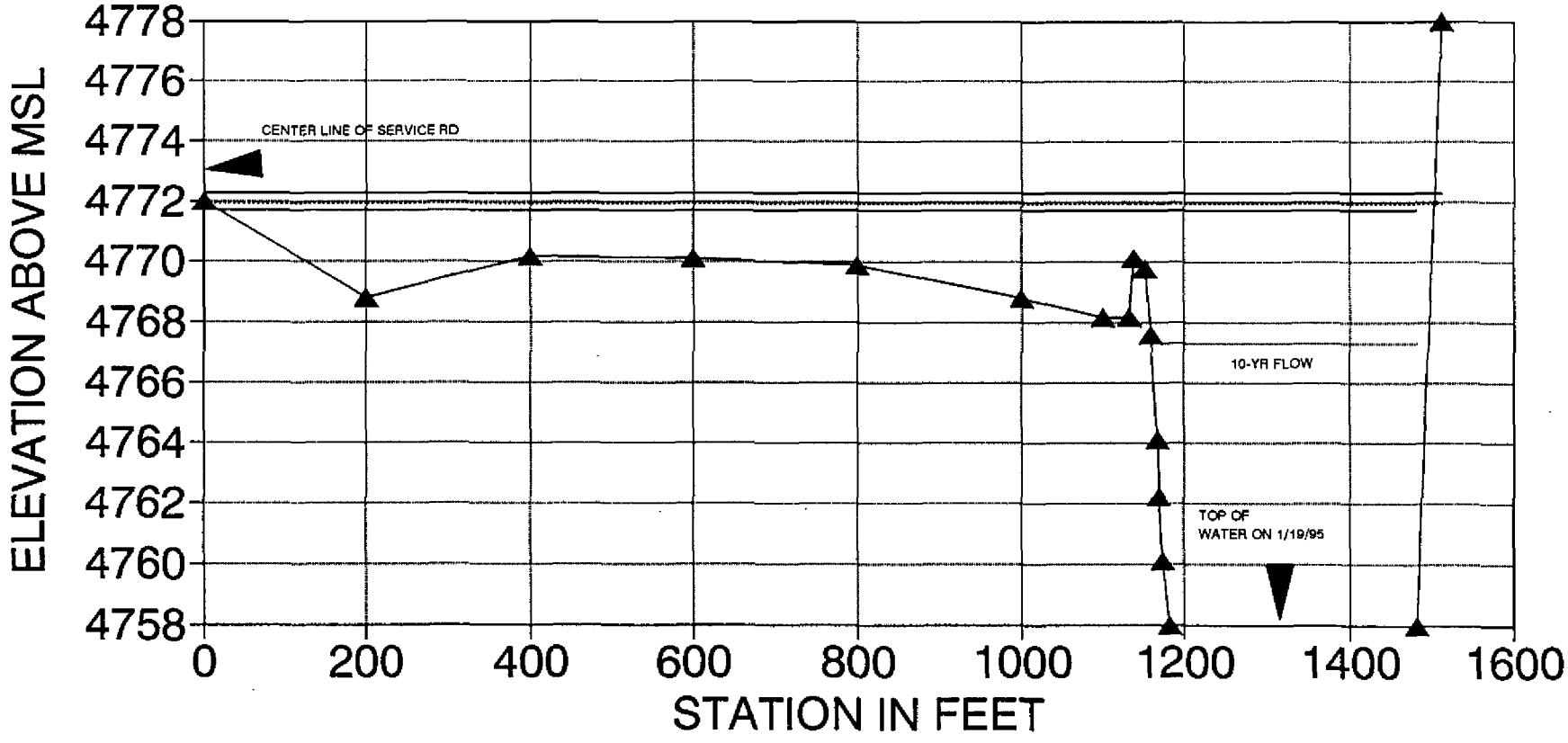
During a 50-year or a 100-year flood there would be a problem at Island Acres. The 4 ponds at in the State Park, along with almost all of the park, are in the 50-year and 100-year floodplain. The levee along the southeast bank of the Colorado River does not provide 50-year protection. 50-year and 100-year floods would create a direct connection between the pond and the Colorado River. The park and its contents are subject to high flood risk. The existing levee, rebuilt with FEMA disaster recovery funds, was not designed to meet 50-year or 100-year flood protection standards and may even fail during a 10-year flood event.

Subsection 5.4 Mitigation Analysis

The existing levee is too low to provide 50-year flood protection. It does provide 10-year flood protection but with no freeboard and no seepage and erosion protection. The levee could be raised (generally 2 - 3 feet) to protect the park from a 50-year flood. Erosion and seepage protection would be needed. A levee project would need to extend the full length of the state park to assure no problems. Before such measures were considered seriously, an engineering analysis would be needed.

ISLAND ACRES STATE PARK

COLORADO RIVER CROSS-SECTION



CROSS-SECTION LINE
10-YR FLOW
50-YR FLOW
100-YR FLOW
1984 FLOW

ISLAND ACRES PONDS
100-YEAR FLOODPLAIN MAP

1" = 2000'

100-Year Floodplain

Lake

River Channel

ISLAND ACRES PONDS

LEVEE

LEVEE

62+00

04+00

Cameo Siding

Cameo

Siding

Siphon

Mine

Orchard Mesa Siphon

Palisade Res No 1

Irrigation Diversion Dam

VABM 6649

BM 4776

BM 4755

BM 4811

Jerry Canyon

Coal Canyon

Coal Gulch

Mount Lincoln

Coal Creek

Rapid Creek

Bailey Point

MAIN FLATS

HIGHLINE CANAL

GOVERNMENT HIGHLINE CANAL

DENVER AND RIO GRANDE WESTERN RAILROAD

COLORADO RIVER

TUNNEL NO 1

TUNNEL NO 2

TUNNEL NO 3

TUNNEL NO 4

TUNNEL NO 5

T 1 N

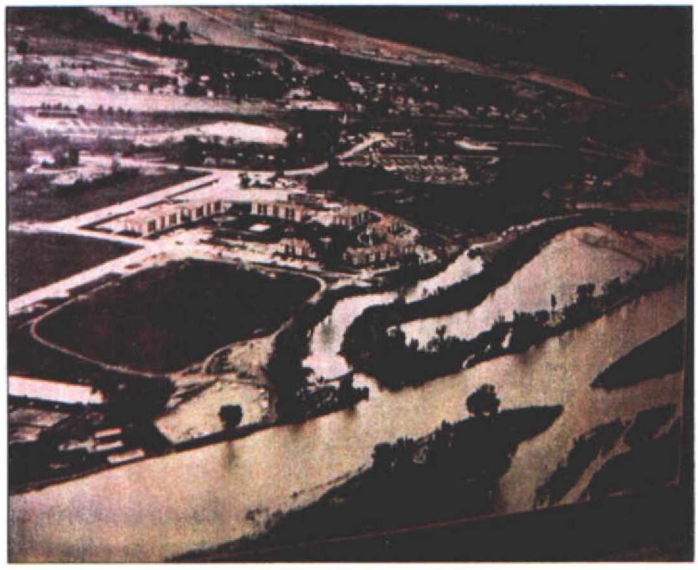
R 98 W

R 97 W

PARACHUTE POND

SITE REPORT

PARACHUTE POND



1984 Flooding

1993 Flooding

Section 5 Site Flood Risk and Mitigation Analysis

Site 5 Parachute Pond

Subsection 5.1 Flood Photos

Aerial photos of flooding at Parachute Pond in 1984 and 1993 are included on the preceding page. The pond was completely surrounded by floodwaters during the 1983, 1984, and 1993 flood events. The main river channel was just south of the pond, with a narrow levee (landform) separating it from floodwaters. An old oxbow channel approaches the pond from the east, continues its course just north of the pond, and then turns south to rejoin the river just west of the pond. That oxbow channel carried floodwaters in all three events. The 1984 photo shows that the groundwater table rose so much that water flowed out of the pond into the river during the flood. The frequency of the 1984 flood was estimated at 40 years. In addition, there was streambank erosion to the pond embankment which required emergency action to protect the pond.

Subsection 5.2 Field Inspection and Hydraulic Determinations

A field survey was conducted at Parachute Pond on January 18, 1995. It included an examination of the existing condition of the riverbanks, a field survey of the elevations of the levee surrounding the pond and an examination of the outlet works for the pond and existing flood mitigation measures. The north riverbank (the one nearest the pond) has some erosion protection in the form of broken concrete and rock.

There is detailed hydraulic information for Parachute Pond. The Corps of Engineers developed floodplain information for the unpublished *Floodplain Information Report, Colorado River from Glenwood Springs to DeBeque Canyon, Garfield and Mesa Counties, Colorado*. That information was in turn used for the *Floodplain Information Report, Parachute Creek, Colorado River in the Town of Parachute, Colorado*. The Corps of Engineers analysis was used for the CWCB review of Parachute Pond.

The Profile Sheet for Parachute Pond is included at the end of this section. It shows the levee elevations derived from the Parachute Floodplain Information Report.

Subsection 5.3 Flood Risk

During a 50-year or a 100-year flood the pond will be isolated from high ground because it will be encircled by floodwaters. The levee between the pond and the main channel is generally about 3 feet lower than the 100-year flood elevation and about 1 foot lower than the 50-year flood elevation. That means the pond would first be encircled by rising waters and then inundated as the waters overtopped the levee. The pond is in the 50-year floodplain of the Colorado River and

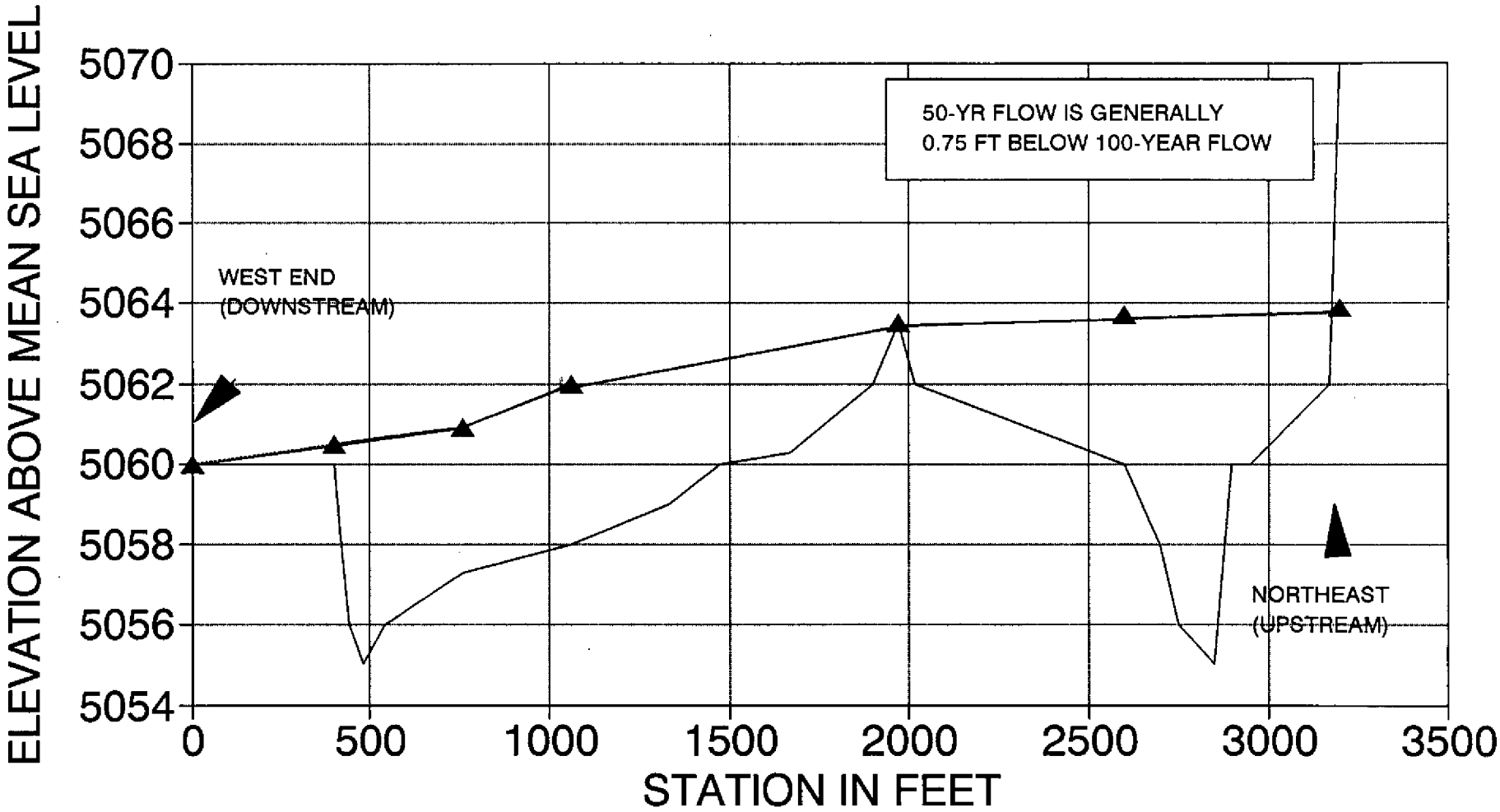
remembered that the 1984 flood on the Colorado River was approximately a 40-year event at Parachute Pond and the pond did not wash out, either from overtopping or from erosion damage. There was, however, a discharge of water from the pond into the river. That discharge was caused by a high groundwater table and by an upstream inflow. It is reasonable to assume that a 10-year flood would not inundate the pond. Based on the above description and on the profile in the Floodplain Information Report, the pond lies in a critical part of the 100-year floodplain of the Colorado River.

Subsection 5.4 Mitigation Analysis

It would be difficult to provide 50-year or 100-year protection to the Parachute Pond because it is located in the middle of the Colorado River floodplain. The shoreline of the pond on all sides is subject to inundation and erosion from a 50-year flood or a 100-year flood. There is also a path for water to flow around the other side of the pond (on the north). To upgrade the levee along its existing alignment would be expensive because of its location in the floodplain and because of the need for erosion protection. If a 50-year level of protection were not required, 10-year protection could be provided simply by improving the existing erosion protection on the north bank of the river. Before such measures were considered seriously, an engineering analysis would be needed.

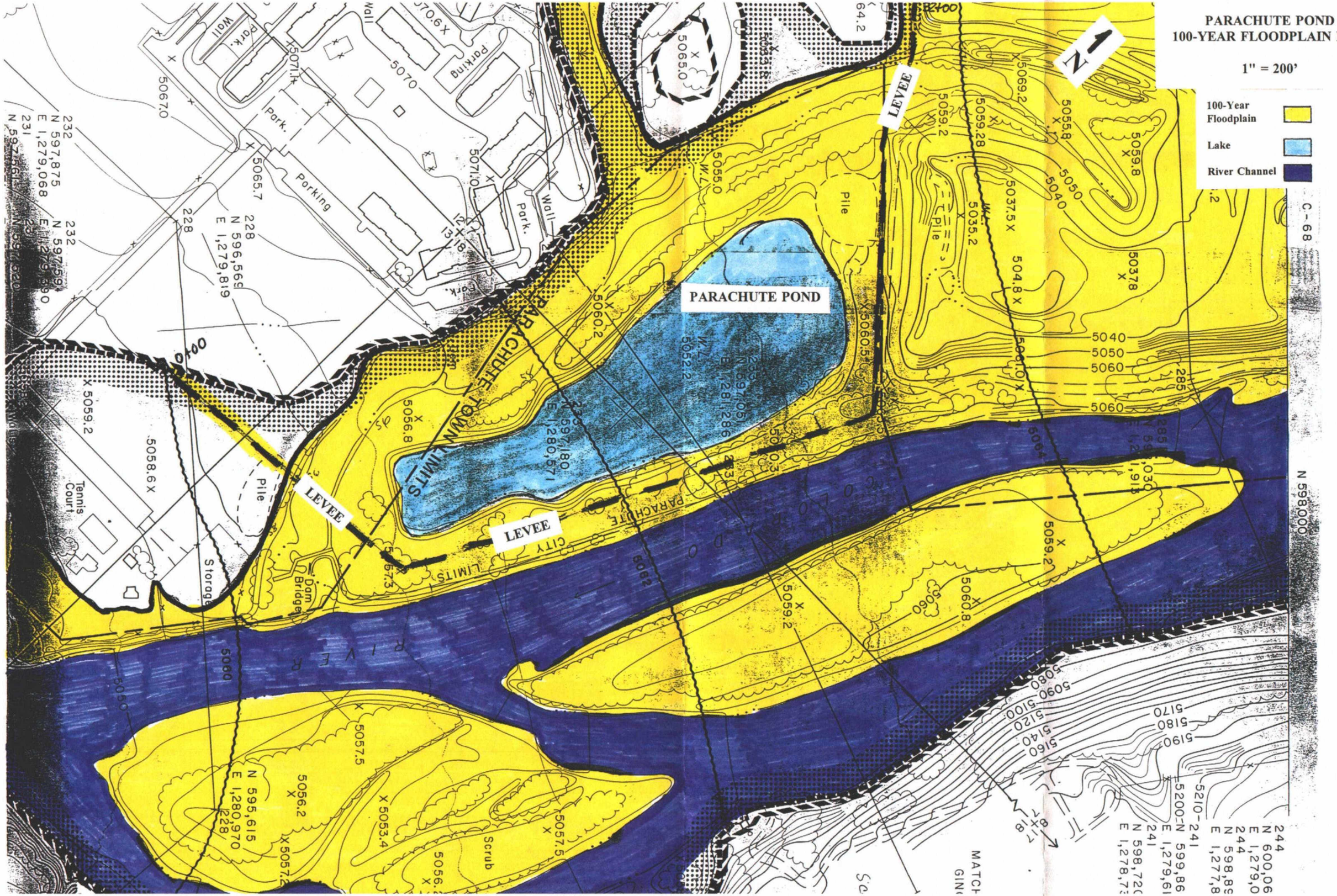
PARACHUTE POND

COLORADO RIVER "DIKE" PROFILE



PARACHUTE POND
100-YEAR FLOODPLAIN MAP

1" = 200'

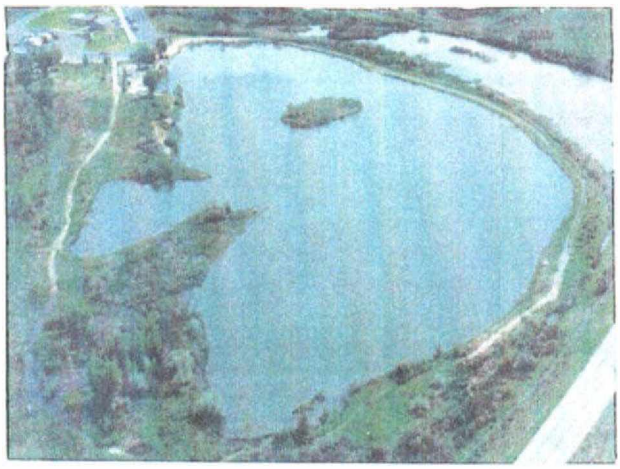


RIFLE REST AREA POND

SITE REPORT

RIFLE REST AREA POND

1993 Flooding



1993 Flooding

Section 5 Site Flood Risk and Mitigation Analysis

Site 6 Rifle Rest Area Pond

Subsection 5.1 Flood Photos

Aerial photos of flooding at Rifle Rest Area Pond in 1993 are included on the preceding page. No photos of flooding in 1983 and 1984 were available. Based on anecdotal accounts of flooding in the Rifle area in 1983 and 1984, there was high water in the general vicinity of the Rest Area, but none of the high water reached the pond. There is no official record of flooding of the Rifle Rest Area Pond in 1983, 1984 or 1993.

Subsection 5.2 Field Inspection and Hydraulic Determinations

A field survey was conducted at Rifle Rest Area Pond on January 18, 1995. The survey included a ground elevation survey of the high ground between the river and the pond. The survey followed part of the access road into the Rest Area, part of the parking lot and some vegetated high ground north of the pond itself. The survey continued around the west end of the pond and tied into the embankment for westbound I-70.

There is detailed hydraulic information for Rifle Rest Area Pond. The Corps of Engineers developed floodplain information for the unpublished *Floodplain Information Report, Colorado River from Glenwood Springs to DeBeque Canyon, Garfield and Mesa Counties, Colorado.* Subsequent to the Corps of Engineers hydraulic analysis the Colorado Department of Transportation (CDOT) constructed the Rest Area within the 100-year floodplain. The City of Rifle retained an engineering consultant to analyze the effects of the filling and grading performed by CDOT in the construction of the Rest Area. The city's consultant, Schmueser, Gordon, Meyer (SGM), revised the Corps of Engineers hydraulic analysis at the Rest Area to reflect the CDOT changes. The flood elevations are slightly different from the Corps of Engineers elevations. The Corps of Engineers analysis and the SGM revision were used together for the CWCB review of Rifle Rest Area Pond.

The profile sheet summarizing hydraulic information for Rifle Rest Area Pond is included at the end of this section. It presents the 100-year flood elevations and the existing levee elevations.

Subsection 5.3 Flood Risk

From a review of the CWCB field surveys, the Corps of Engineers/SGM hydraulic analysis and the Corps of Engineers/SGM floodplain maps it was determined that the entire pond is in the 100-year floodplain. There are a few areas of high ground in and around the Rest Area, but generally the site would be subject to inundation during a 100-year flood. There are currently two locations for 50-year flood flows to reach the pond. The 50-year floodplain would be shallower and substantially narrower than the 100-year floodplain.

The access road built by CDOT acts as a levee, but it is a 50-year levee for only a short distance near the entrance to the Rest Area. At the upstream (east) end of the pond the access road to the Rest Area and the Rest Area itself are low, allowing connection to the pond during a 50-year flood. Water could enter the pond from the northeast. Farther west, at the Rest Area itself, the road and parking lot act as a 50-year levee which then ties into a ridge of high ground parallel to the north bank of the pond for most of its length. That ridge is slightly higher than the 50-year flood elevation except for a section about 100 - 150 feet long near the west end of the pond. That section of low ground provides the second entry into the pond for 50-year floodwaters. At the west end of the pond the ground is higher than the 50-year flood elevation all the way to the embankment of I-70.

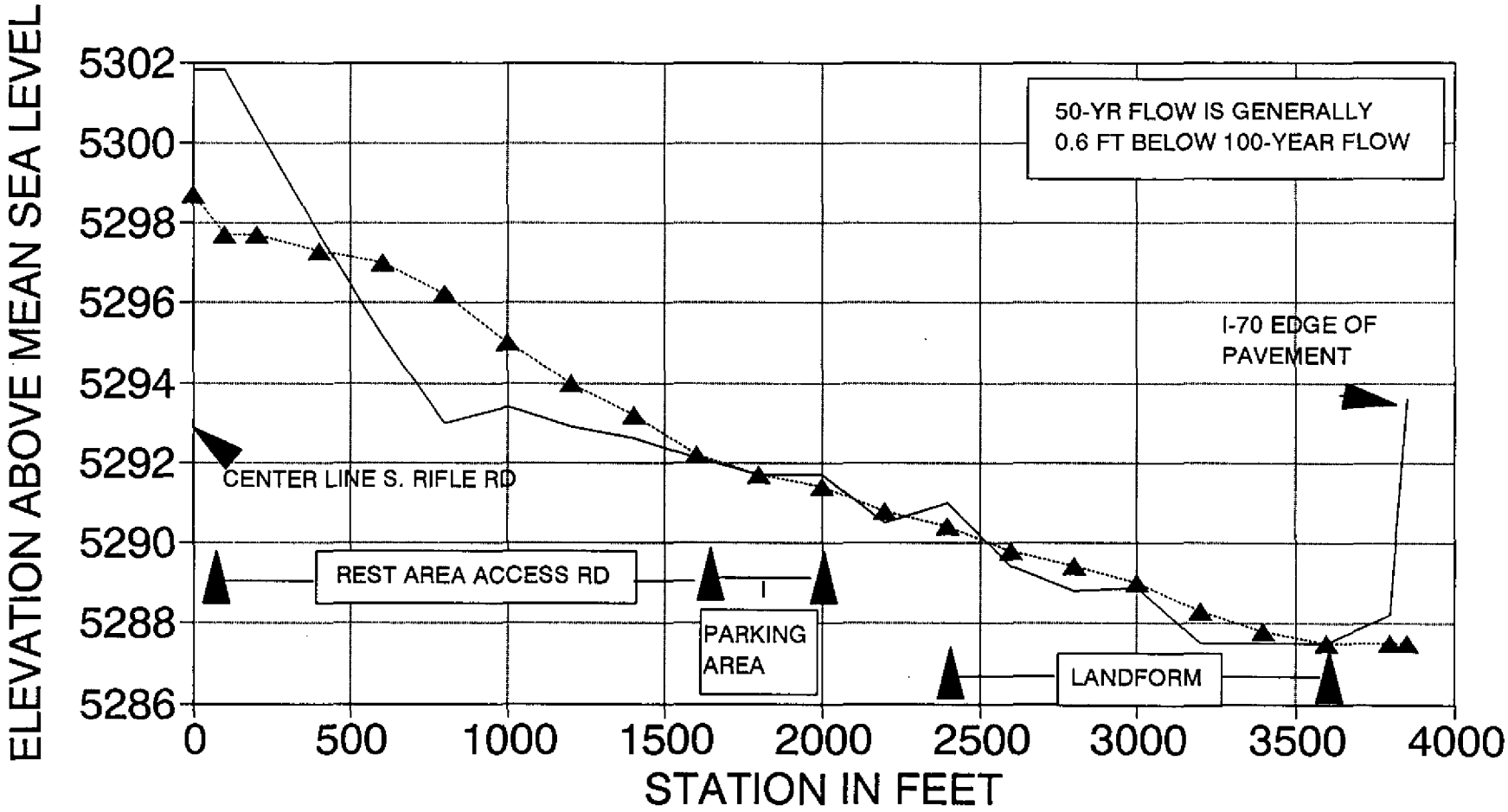
There were no signs that streambank erosion is a problem at the site. Although the site has historically been a part of the Colorado River floodplain, it appears that the roadway into the Rest Area and the high ground north of the pond have provided the site with a 25-year level of flood protection.

Subsection 5.4 Mitigation Analysis

100-year flood protection would require complete reconstruction of the existing levee system. To upgrade the existing 4000 foot levee system to achieve 50-year protection would not be nearly as difficult. Approximately 0.25 mile of the access road is too low to provide 50-year flood protection. The road could be raised (generally 1 - 2 feet) or a levee could be constructed next to the road. The high ground near the west end of the pond that is too low could be raised to provide 50-year protection there. Before such measures were considered seriously, an engineering analysis would be needed.

RIFLE REST AREA POND

COLORADO RIVER "DIKE" PROFILE



RIFLE REST AREA POND
100-YEAR FLOODPLAIN MAP

1" = 200'

N

100-Year Floodplain

Lake

River Channel

LEVEE

RIFLE REST AREA POND

LEVEE

40+00