R-90-18

MAPPING BACKWATER HABITAT ON THE GREEN RIVER AS RELATED TO THE OPERATION OF FLAMING GORGE DAM USING REMOTE SENSING AND GIS

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INTRODUCTION

The long-term impact of the operation of Flaming Gorge Dam on fish populations in the Green River is unknown. However, dams may alter historic flow and temperature regimes and eliminate flood events (Tyus et al., 1987; Graf, 1980). In response to reduced peaking conditions, the Green River bankfull channel width has decreased substantially following construction of the Flaming Gorge Dam (Andrews, 1986), and the abundance of endemic fish species in the Green River has decreased subsequent to the construction of Flaming Gorge Dam in 1962 (Tyus et al., 1987). These species included the endangered Colorado squawfish (*Ptchoecheilus lucius*), the humpback chub (*Gila cypha*), and the rare but unlisted razorback sucker (*Xyrauchen texanus*).

Studies conducted by the FWS (U.S. Fish and Wildlife Service) concluded that backwaters in the Green River are preferred nursery habitat for yoy (young-of-the-year) Colorado squawfish (Holden and Stalnaker, 1975; Holden, 1977; Tyus and McAda, 1984; Tyus et al., 1987). Colorado squawfish spawn during mid- to late-summer and their larvae become distributed in shallow backwater habitat reducing predation and protecting larvae from adverse flow events (Tyus et al., 1987). This evidence suggests that maximizing backwater habitat during summer will increase the survival rate of young Colorado squawfish and, therefore, would be an important factor in the management and preservation of this species.

A technique was required to accurately map backwater habitat in response to various Green River flows. The IFIM (instream flow incremental method) has not proven adequate to calculate backwaters on large, turbid, hydrologically complex rivers such as the Green River (Rose and Hann, 1989). IFIM uses PHABSIM (physical habitat simulation models) to calculate physical habitat, assuming that velocity, depth, and substrate in a river system behave as independent hydraulic variables. On the contrary it is believed that these variables interact continuously along the length of a river by varying turbulence and shear stresses and it is doubtful that they may be considered independent (Gore and Nestler, 1988). In addition, PHABSIM uses velocity to calculate physical habitat and, because backwaters have little or no velocity, it is impossible to model them accurately. Attempts to model backwaters using IFIM on the Green River were not successful (Rose and Hann, 1989). Therefore, it was decided to use remote sensing techniques and a GIS (Geographic Information System). Pucherelli et al. (1987) used large-scale aerial photography and a GIS to map backwater habitat and changes in river morphology as a function of riverflow.

This study examined the relationship between flow and the number and area of backwaters on the Green River in Utah. The objective was to establish a data base to assist in determining the optimal Green River flows needed for maximum backwater availability during summer and fall.

STUDY SITES

Five study sites (fig. 1) were selected by the FWS and the Bureau of Reclamation because they were known to contain important backwater habitat for yoy Colorado squawfish (Tyus et al., 1987). The Island Park site is located just upstream from Split Mountain in Dinosaur National Monument; the Jensen site is located just downstream from Split Mountain; the Ouray site is located in Ouray National Wildlife Refuge; the Sand Wash site is just above Desolation Canyon; and the Mineral Bottom site is located about 80 kilometers upstream from the confluence of the Colorado and Green Rivers.

METHODS

The number and area of backwaters were examined during seven flows at the Island Park, Jensen, Ouray, and Sand Wash sites during 1987: 142 on May 30, 1987; 71 on July 7, 1987; 55 on July 19, 1987; 53 on July 22, 1987; 46 on August 17, 1987; 45 on August 1, 1987; and 37 m^3/s August 9, 1987. These flows were selected to establish upper and lower limits around what are considered potential summer releases from Flaming Gorge Dam. Three flows were examined at the Mineral Bottom site: 108 on August 1, 1987; 98 on July 7, 1987; and 79 m^3/s on July 1, 1987.

Flows were controlled by varying releases from Flaming Gorge Dam. The USGS (U.S. Geological Survey) Jensen gauge - approximately 30 km below Island Park, 10 km above Jensen, 64 km above Ouray, and 124 km above Sand Wash - was used to estimate flows at the four upper sites. This was the closest gauge available to each site in the study and it may reflect flow at some sites more accurately than others. Flows at Mineral Bottom were estimated by the USGS Green River, Utah, gauge located about 112 km above the site.

Flows were gradually stepped down during late spring and summer to mimic the descending limb of a "natural" Green River hydrograph. When flows were stabilized at each site, color infrared aerial photography was acquired at an approximate scale of 1:4,000. However, because of weather conditions the 46 m^3/s flow was not photographed in proper sequence and was actually the last flow attained. This incident may have effected backwater availability because they did not form during a gradually descending hydrograph.

Field trips were taken to familiarize the photointerpreter with backwater delineation and to place panel markers at specified distances at each site to verify and correct photographic scale. The photointerpreter was on the river at each site (except Mineral Bottom) during each flow event. Three backwaters were examined in the field at each site, during each flow (except Mineral Bottom) and were later identified on aerial photographs using USGS quadrangles. Ground-truth information assisted the photointerpreter in recognizing backwaters as they appeared on aerial photographs. The river channel, backwaters, and sandbars were delineated on mylar overlays fitted on the aerial photographs. Backwaters were separated according to area: ≤ 20, $>20 \leq 200$, $>200 \leq 500$, $>500 \leq 1{,}000$, and $>1{,}000$ m^2.

To maintain interpretation accuracy, map bases of the same scale as the photography were created using roads and other prominent features delineated on photographs. These were compared to USGS 1:24,000 quadrangles to provide geographic reference. Following transfer of photointerpreted data to map overlays, the information was digitized into a GIS utilizing Geographic Entry System software. Digitization was done in vector format using a digitizing tablet linked to a display screen. Software and peripherals were run by a minicomputer.

Regression analyses (Bailey, 1981) were conducted for flow versus backwater area and flow versus backwater number at the four upper sites. Linear regression was not conducted on Mineral Bottom data because only three flows were mapped and flows at this site are difficult to control because of its distance from Flaming Gorge Dam. Linear regression of flow versus area was analyzed for flows from 37 to 71 m^3/s for the Island Park, Jensen, and Ouray sites. Regressions were run with and without the 142 m^3/s flow, acquired during the spring, because it was outside the range of normal operations for the summer season when yoy Colorado squawfish are entering backwaters. The 46 m^3/s flow was also deleted at the Sand Wash site because this flow had not reached the site when the photography was acquired.

RESULTS

Island Park

No significant regressions occurred at any site when the 142 m^3/s flow was included in the analysis. However, when this flow was deleted from the analysis, a significant ($P \leq 0.10$), negative regression occurred at Island Park (r^2 = -0.76). Backwater area generally increased as flow was decreased from 142 to 37 m^3/s (table 1). Two substantial increases occurred: while flows dropped from 71 to 55 m^3/s (30-percent increase) and from 46 to 45 m^3/s (50-percent increase). Backwater area was maximized at 37 m^3/s.

The relationship between riverflow and backwater number was not as clear as the flow/area relationship, and there was no significant regression for flow versus number of backwaters at any site. However, backwater number was maximized at 45 and 37 m^3/s, and the lowest number of backwaters occurred at 71 m^3/s. The $>20m^2<200m^2$ size class consistently represented the highest number of backwaters. Very large backwaters ($>1,000$ m^2) were more abundant at lower flows. Backwater number per km was the greatest of any site. Backwater area per kilometer at Island Park was second to the Ouray site. The average size of all backwaters usually increased at lower flows, and was maximized at 37 m^3/s.

Jensen

A significant negative regression ($P \leq .05$) also occurred at Jensen (r^2 = -0.82) when 142 m^3/s was deleted from the analysis. The largest increases in backwater area occurred between 71 and 55 m^3/s when backwater area increased 49 percent and between 46 and 45 m^3/s when area increased 37 percent (table 2). The backwater area was maximized at 45 m^3/s.

Total number of backwaters was greatest at 53 m^3/s (table 2). Backwaters were generally more prevalent at the lower flows and were least abundant at 142 and 71 m^3/s. The $>20\leq200m^2$ size class contained the most backwaters. The largest backwaters ($>1,000$ m^2) generally increased in number at lower flows. Total backwaters per km were slightly less than at Island Park (table 2).

Ouray

The relationship between flow and backwater area at Ouray was not consistent and the linear regression was not significant (r^2 = +0.09). There was a large, steady increase in backwater area from 142 m^3/s to 53 m^3/s; however, decreases in area occurred between 53 m^3/s and 46 m^3/s, and between 46 and 45 m^3/s (table 3).

Total backwaters were maximized at 45 m^3/s and were also high at 53 and 46 m^3/s (table 3). Again the $>20\leq200m^2$ size class contained the most backwaters. However, Ouray had a disproportionately high number of large backwaters ($>1,000$ m^2) at all flows except 142 m^3/s.

The average size of all backwaters at Ouray was much larger than at Island Park and Jensen. Backwater area per kilometer was also larger at Ouray than at Island Park and Jensen.

Sand Wash

Flow at Sand Wash was difficult to determine because the Duchesne and White Rivers enter the Green River between Sand Wash and the USGS Jensen gauge. Additionally, examination of flow data indicated that the 46 m^3/s flow had not reached the Sand Wash site when photography was acquired and the actual flow at this time was probably less than 37 m^3/s. Regression at Sand Wash [$r^2 = 0$, backwater area = 9,150 + (99.8) flow] indicated there was no relationship between flow and area. However, the smallest backwater area at Sand Wash occurred at the highest flow studied (table 4). Sand Wash was unique because backwater number was maximized at the highest flow. Furthermore, backwater numbers were much more evenly distributed among the various size classes than at the upper sites. Generally, the Sand Wash site had substantially fewer backwaters and less backwater area per kilometer than the three upper sites.

Mineral Bottom

Backwater area and number at Mineral Bottom were maximized at 98 m^3/s (table 5). Mineral Bottom had substantially fewer and smaller backwaters than all other sites and is indicative of sites on the lower river.

DISCUSSION

The use of the USGS Jensen gauge to estimate flows may have complicated the results at Ouray and Sand Wash. It is apparent that flows at Island Park, which is 30 kilometers above the gauge, and Jensen, which is only 10 kilometers below the gauge, were accurately reflected by the Jensen gauge. There are no tributaries and no irrigation diversion that occur between the gauge and Island Park and no tributaries occur between the gauge and Jensen. This may explain why the regressions of flow and backwater area at these sites are relatively significant. However, Ouray and Sand Wash are much farther from the gauge and flows at these sites may be affected by ground water recharge and irrigation diversion and return. Flows at Sand Wash are further complicated by the Duchesne and White Rivers which enter the Green River between Ouray and Sand Wash. Their combined flows varied from 72 (May 30, 1987) to 20 m^3 (July 7, 1987) which produced a substantial affect on flows at Sand Wash. This may explain why it is increasingly difficult to correlate flows with backwater area as they move from Jensen to Ouray and then to Sand Wash. Site specific gauges would provide a more accurate estimate of flows at Ouray and Sand Wash.

Given the problems associated with gaging, the data indicated a range of flows which produced maximal backwater area and numbers under the conditions of the study. When the four upper sites were considered, a range of flows from 37 to 55 m^3/s produced substantially greater backwater area and higher numbers than did 142 and 71 m^3/s flows. The large differences in backwater area from 46 to 45 m^3/s at each site may be attributed to the chronological order of these flows. Backwaters at 45 and 37 m^3/s were allowed to form during a gradually descending hydrograph. The 46 m^3/s flow was obtained immediately after the lowest flow of the season (approximately 34 m^3/s). Furthermore, this flow only occurred for 1 day and was not allowed to stabilize which very likely affected backwater availability.

The Ouray and Sand Wash sites had more backwater area at slightly higher flows. Closer analysis of individual backwaters at Ouray indicated that a few extremely large backwaters (5,000 to 10,000 m^2) at 53 m^3/s did not occur at lower flows which reduced backwater area substantially.

Flows at Mineral Bottom are difficult to control given the distance of the site from Flaming Gorge Dam. Additionally, the San Rafael River occurs between the USGS gauge at Green River, Utah, and Mineral Bottom. Because Mineral Bottom and other lower Green River sites are important nursery areas for Colorado squawfish, future studies should be conducted to determine the effect of recommended flows at the USGS Jensen gauge on sites in the lower river.

Our data indicate that flows above 55 to 71 m^3/s have a detrimental effect on backwater habitat availability. Tyus et al. (1987) found marked decreases in nursery (backwater) habitat with high flows and reported a decrease in the Colorado squawfish yoy catch rate as flows in the Green River were increased. If this situation occurs during the primary nursery season, the growth and survival of yoy Colorado squawfish could be adversely effected.

Remote sensing is an effective technique for obtaining data on backwater availability relative to varying riverflows. Remote sensing techniques cannot replace IFIM techniques for modeling river systems. However, for backwater habitat delineation and monitoring, remote sensing is a more efficient and accurate method on which to base management decisions. Modeling several backwaters with IFIM to characterize hundreds of backwaters on a large system would be difficult as backwaters vary tremendously in their size, depth, and permanence.

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Table 1. - Green River backwater number, area, and average size under seven flows at the Island Park site

Backwater descriptors	Flow (m^3/s)						
	142	71	55	53	46	45	37
Size class (m^2)							
<20	6	0	8	4	5	9	11
>20<200	22	22	26	22	26	32	29
>200<500	6	5	7	6	6	6	3
>500<1000	6	4	2	4	1	3	4
>1000	0	1	2	2	3	6	5
Number of backwaters	40	32	45	38	41	56	52
Backwaters/km	4.4	3.5	4.9	4.2	4.5	6.1	5.7
Total area (m^2)	7,859	8,575	11,160	12,131	13,349	20,070	22,153
Area (m^2)	857	935	1,217	1,323	1,456	2,188	2,415
Average size (m^2)	196	268	248	319	326	358	426

Table 2. - Green River backwater number, area, and average size under seven flows at the Jensen site

Backwater descriptors	Flow (m^3/s)						
	142	71	55	53	46	45	37
Size class (m^2)							
<20	4	3	7	11	3	6	1
>20<200	20	27	27	29	22	23	27
>200<500	5	6	8	12	10	5	12
>500<1000	1	3	3	1	4	4	10
>1000	2	1	3	5	3	8	4
Number of backwaters	32	40	48	58	42	46	54
Backwaters/km	2.9	3.6	4.4	5.2	3.8	4.2	4.8
Total area (m^2)	7,716	7,328	10,944	12,747	15,014	20,569	19,039
Area (m^2)	695	660	986	1,148	1,352	1,853	1,715
Average size (m^2)	241	183	228	220	357	447	353

Table 3. - Green River backwater number, area, and average size under seven flows at the Ouray site

	Flow (m^3/s)						
Backwater descriptors	142	71	55	53	46	45	37
Size class (m^2)							
<20	3	0	4	8	3	10	2
>20<200	24	36	27	32	32	33	24
>200<500	7	8	11	10	13	17	12
>500<1000	5	7	9	8	5	4	5
>1000	5	9	9	12	13	10	14
Number of backwaters	44	60	60	70	66	74	57
Backwaters/km	2.4	3.4	3.4	3.9	3.7	4.1	3.2
Total area (m^2)	18,789	41,722	49,852	52,608	39,944	30,849	41,177
Area (m^2)	1,043	2,315	2,766	2,919	2,216	1,712	2,285
Average size (m^2)	427	695	831	741	605	417	722

Table 4. - Green River backwater number, area, and average size under seven flows at the Sand Wash site

	Flow (m^3/s)						
Backwater descriptors	142	71	55	53	46	45	37
Size class (m^2)							
<20	3	1	1	2	0	0	1
>20<200	14	8	3	4	4	3	2
>200<500	3	1	2	4	2	3	3
>500<1000	1	1	2	1	4	1	2
>1000	1	4	5	4	1	5	3
Number of backwaters	22	15	13	15	11	12	11
Backwaters/km	3.6	2.4	2.1	2.4	1.8	2.0	1.8
Total area (m^2)	4,962	8,466	11.147	9,428	5,713	10,877	9,270
Area (m^2)	812	1,385	1,823	1,542	934	1,779	1.516
Average size (m^2)	226	564	857	629	519	906	843

Table 5. - Green River backwater number, area, and average size under three flows at the Mineral Bottom site

Backwater descriptors	Flow (m^3/s) 108	98	79
Size class (m^2)			
<20	2	8	1
>20<200	12	10	11
>200<500	2	0	1
>500<1000	0	3	1
>1000	0	0	0
Number of backwaters	16	21	14
Backwaters/km	1.5	1.9	1.3
Total area (m^2)	1,749	3,224	1,675
Area (m^2)	162	299	155
Average size (m^2)	109	154	120

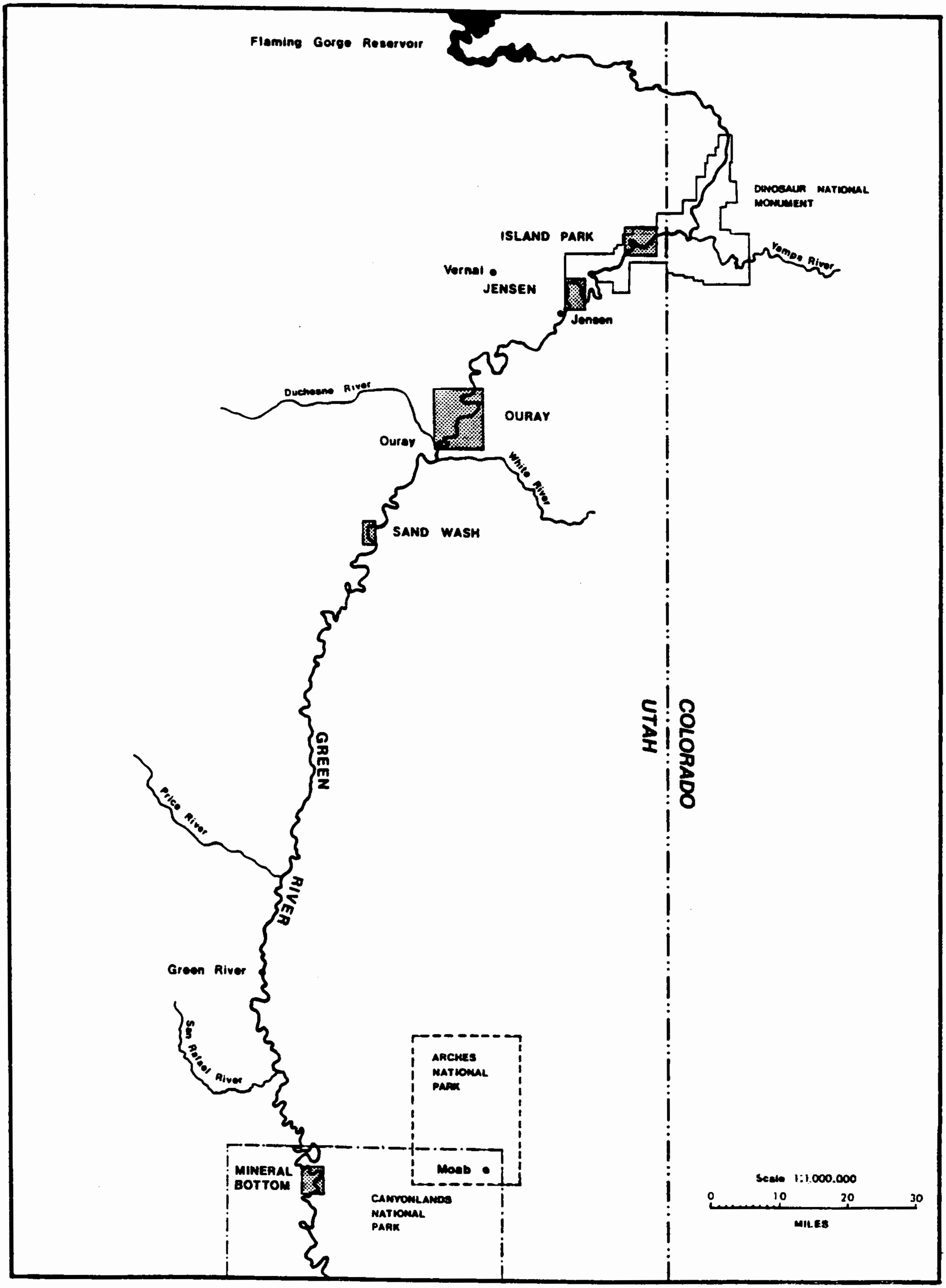

Figure 1. - Green River backwater study.

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16. ABSTRACT

Remote sensing techniques were used by the Bureau of Reclamation to evaluate the relationships between flow and the amount of backwater habitat at five sites on the Green River in Utah. Relationships between flow and backwater area appear to be site specific; negative regressions occurred at two upper sites (backwater area increased as flow decreased) while regressions at two lower sites were not significant. The data suggest a strong relationship between backwater area and flow with maximization of habitat area occurring at the lowest flow studied (37 m^3/s). Regressions of flow to numbers of backwaters were not significant; however, backwater numbers were generally maximized at the lowest flows.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS-- backwaters\ remote sensing\ GIS (Geographic Information System)\ fish populations

b. IDENTIFIERS-- Flaming Gorge Dam\ Green River

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