WATER QUALITY ON THE COLORADO RIVER

GLEN CANYON DAM TO LEE'S FERRY

OCTOBER 1992

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I. Introduction

The investigation of water quality to determine the presence of fecal coliform on the fifteen mile Colorado River corridor within Glen Canyon National Recreation Area began this year (1992) as part of a series of "Interim Flow Monitoring" studies funded cooperatively by the National Park Service and the Bureau of Reclamation's Glen Canyon Environmental Studies. Water quality on the Colorado River section being monitored is controlled by four factors: 1. quality of water released from the dam; 2. erosion and runoff from beach and margin deposits; 3. recreational use; and 4. any contaminants entering from side drainages or accidents at upstream facilities. The objective of this study is to determine whether the "interim" water release patterns effect water quality at shoreline sites along the river. Factors 2 and 3 are especially of interest as they are directly effected by interim flows. The first factor is being studied by the Bureau of Reclamation.

The original proposal called for four collections to be made at 0600, 1000, 1400, and 1800 at six sites along the corridor between Glen Canyon Dam and Lee's Ferry. Each site was to be sampled once a month from April through September. Two modifications were made to this proposal, due principally to the logistics of collecting and processing of water samples. The samples were collected at six sites once a month from June through September at 0600, 1000, and 1400. These sampling times correspond roughly with the low, middle and high water releases from Glen Canyon Dam under the interim flow regime.

II. Site Description

The six sites for sampling were chosen based on a number of factors. First and foremost, sites were chosen so that sampling could be performed in relatively calm waters where bacteria could flourish if present; fast flowing water offers little opportunity for bacteria to survive and reproduce. With this in mind, all six sites are located in calm stretches of the river with large pools and/or eddies. A second requirement for each site was the presence of large concentrations of humans, a primary source for the introduction of fecal coliforms into aquatic systems in this area. Thus, five sites are located immediately offshore of established overnight camping locations, popular picnic stops, areas of high recreational fishing use or popular historical attractions. The exception was the sixth site, which possesses none of the aforementioned attributes. The beach at this site; however, does show evidence of cattle, another known vector of fecal coliforms. This sixth site is valuable as a control site to determine the effects of wildlife and cattle on water quality. Beyond these factors though, each site is distinct (see map).

The first site, at river mile 14.5, is located approximately 500 yards downstream from the dam on the right bank of the river. It is a calm eddy pool off a sandy beach. Located immediately upstream is a gravel bar which receives some use from anglers. This site is the final large beach area reached when traveling upstream towards the dam. This location is also the only water sampling point to be located upstream from the Page Water Treatment Plant, a series of sewage ponds situated some 300 yards from the eastern edge of the canyon rim. Day use only is allowed at this site.

River mile 13, river left, is the second sample site. It is located on the inside of a 90 degree turn of the river and is therefore very calm. Again, use by anglers is high due to an upstream gravel bar and gently sloping beach. Beavers (Castor canadensis), which are yet another carrier of the coliforms, have been spotted along this stretch of river rather frequently. This site is a day use site only.

Site three is located offshore of the Ferry Swale camps, mile 11, river left. This established overnight campsite receives heavy use and possesses a self contained toilet. Once again, the campsite is on the inside turn of a meander of the river and is relatively calm.

Water samples are taken near the beaching location for the Petroglyph Panel at river left, mile 10. This fourth site experiences heavy, short duration use by Wilderness River Adventures (WRA) river float trips. The beach serves as a staging area for hikes to the panel and is equipped with two self contained toilets. An eddy current causes river water to move upstream while near the beach. This site is a day use only site.

The fifth site, a beach near Finger Rock, serves as the picnic lunch area for the WRA tours (40,000 passengers in 1992). It is located at mile 7.5, river left and is occupied by several separate groups of people each day. Generally 40 to 170 people visit this site daily through the commercial trips available. The river runs deep and slow through this area and a number of rock falls project into the current to slow it even further. This site is a designated campsite area.

The sixth and final site is at river left, mile 2.5 and lies in deep, calm water off a large beach of sand dunes. Eddies and upstream flows are caused by a submerged point which originates downriver and extends parallel to the beach for some distance upstream. As noted earlier, livestock are known to use this beach. This site is a day use site only.

III. Sampling Procedures

Samples were collected by boat where the water depth was 2-4 feet. Two 100 ml samples were collected at a depth of 4 inches below the surface of the water at each site. The samples were immediately packed on ice. Water temperature, time of collection, and turbidity of the water was recorded. After the 0600 and 1000 samples were collected they were transported to the Glen Canyon National Recreation Area laboratory to be filtered and incubated using the membrane filtration techniques described in Standard Methods for the Examination of Water and Wastewater (16th edition, 1985, pp. 886-894). The third set of samples was then collected and processed. The samples were handled in this manner to reduce holding time and to insure that the samples were filtered within the six hour time limit recommended by Standard Methods (16th edition, 1985 pg. 859).

IV. Analysis

After a twenty four hour incubation period in a water bath at 44.5 C fecal coliform colonies were counted and recorded. The mFC media used for the fecal

coliform test contains analine blue dye and lactose. As the fecal coliform grow they ferment the lactose producing an acid. The acid reacts with the analine blue dye, staining the fecal coliform colonies blue. Only those colonies exhibiting the blue color were counted. Those having a cream, grey or green color are non-fecal thermophiles and were not considered.

V. Discussion

Fecal coliform is a type of bacteria (consisting of many species) found in the intestinal tracts of warm blooded animals. Generally it is not a health hazard, but may serve as an indicator organism as it is almost always present in water containing enteric pathogenic bacteria and viruses. Consequently, water that is free of coliforms is considered free of pathogens.

Due to the existence of regulatory standards for specific water uses, and the relative ease of isolation and testing for fecal coliforms, coupled with it's longevity, fecal coliform testing is used exclusively by Glen Canyon National Recreation Area as a test of the cleanliness of it's primary contact waters. A standard of 200 colonies/100 ml for primary contact waters used for full body immersion (swimming) has been set by the EPA; the states of Utah and Arizona have adopted this standard.

SITE 1

DATE	TIME	WATER TEMP (C)	TURBIDITY	COUNT
6/29/92	6:35	9	6	77
	6:35	9	6	198
	11:39	11	10	139
	11:39	11	10	122
7/27/92	6:58	9	16	133
	6:58	9	16	111
	11:14	11	11	113
	11:14	11	11	93
	2:21	10	15	125
	2:21	10	15	123
8/25/92	7:04	11	11	202
	7:04	11	11	390
	10:53	8	15	97
	10:53	8	15	124
	3:02	12	19	139
	3:02	12	19	126
9/14/92	5:52	11	19	91
	5:52	11	19	130
	10:47	11	18	118
	10:47	11	18	118
	1:46	13	22	85
	1:46	13	22	122

SITE 2

DATE	TIME	WATER TEMP (C)	TURBIDITY	COUNT
6/29/92	6:47	10	8	77
	6:47	10	8	92
	11:26	10	10	45
	11:26	10	10	88
7/27/92	7:07	10	13	132
	7:07	10	13	114
	11:04	9	11	95
	11:04	9	11	89
	2:30	10	15	44
	2:30	10	15	78
8/25/92	7:13	11	13	120
	7:13	11	13	114
	10:45	12	18	117
	10:45	12	18	140
	3:07	12	20	133
	3:07	12	20	118
9/14/92	5:58	11	17	159
	5:58	11	17	158
	10:41	12	19	119
	10:41	12	19	140
	1:53	12	18	99
	1:53	12	18	140

SITE 3

DATE	TIME	WATER TEMP (C)	TURBIDITY	COUNT
6/29/92	7:04	9	6	89
	7:04	9	6	140
	11:05	10	8	107
	11:05	10	8	114
7/27/92	7:19	9	13	71
	7:19	9	13	74
	10:48	10	12	67
	10:48	10	12	311
	2:40	11	12	66
	2:40	11	12	67
8/25/92	7:42	11	13	113
	7:42	11	13	150
	10:35	12	14	97
	10:35	12	14	142
	3:18	11	28	250
	3:18	11	28	354
9/14/92	6:07	11	16	92
	6:07	11	16	104
	10:31	12	20	87
	10:31	12	20	78
	2:00	12	23	122
	2:00	12	23	122

SITE 4

DATE	TIME	WATER TEMP (C)	TURBIDITY	COUNT
6/29/92	7:14	9	6	92
	7:14	9	6	124
	10:56	10	8	72
	10:56	10	8	100
7/27/92	7:26	10	13	60
	7:26	10	13	103
	10:38	10	13	71
	10:38	10	13	121
	2:52	10	14	87
	2:52	10	14	71
8/25/92	7:49	11	11	63
	7:49	11	11	84
	10:29	11	15	116
	10:29	11	15	98
	3:23	12	39	187
	3:23	12	39	496
9/14/92	6:13	11	16	97
	6:13	11	16	146
	10:25	12	22	98
	10:25	12	22	88
	2:05	12	18	53
	2:05	12	18	218

SITE 5

DATE	TIME	WATER TEMP (C)	TURBIDITY	COUNT
6/29/92	7:44	9	7	134
	7:44	9	7	192
	10:42	11	10	70
	10:42	11	10	116
7/27/92	7:37	9	12	81
	7:37	9	12	76
	10:22	9	12	83
	10:22	9	12	98
	3:02	10	14	91
	3:02	10	14	80
8/25/92	8:02	11	11	112
	8:02	11	11	84
	10:16	11	19	83
	10:16	11	19	80
	3:32	12	50	378
	3:32	12	50	106
9/14/92	6:23	11	19	109
	6:23	11	19	124
	10:14	12	22	97
	10:14	12	22	104
	2:13	12	20	100
	2:13	12	20	104

SITE 6

DATE	TIME	WATER TEMP (C)	TURBIDITY	COUNT
6/29/92	8:03	9	13	132
	8:03	9	13	102
	10:20	10	10	61
	10:20	10	10	122
7/27/92	8:02	9	12	73
	8:02	9	12	106
	9:54	9	12	65
	9:54	9	12	81
	3:20	11	14	93
	3:20	11	14	112
8/25/92	8:18	12	11	104
	8:18	12	11	74
	9:57	14	17	94
	9:57	14	17	144
	3:48	12	42	130
	3:48	12	42	194
9/14/92	6:39	11	18	94
	6:39	11	18	66
	9:54	12	23	84
	9:54	12	23	100
	2:29	13	21	69
	2:29	13	21	72

The number of passengers aboard Wilderness River Adventures day trips down this stretch of the river were obtained. These figures can be used as a rough indicator of how many people were on the river the days water samples were collected.

June 29	July 27	August 25	September 14
245	228	157	126

CONTROL DATA

DATE	E. COLI	E. AEROGENES	E. AEROGENES (PHOENIX)	UV	BLANK
6-29-92	TNTC	0		TNTC	
7-27-92	TNTC	TNTC	TNTC	36	
8-25-92	TNTC	29		TNTC	
9-14-92					0
					0
	TNTC	56	0	TNTC	

Analysis of Variance of Coliform Count with Time of Day as the Factor

Variable	Mean	Sample Size	Group Variance
Time 1	115.9	48	2.792E + 03
Time 2	104.3	48	1457E + 03
Time 3	137.6	36	9.172E + 03
Total	117.6	132	

Source	DF	SS	MS	F	P
Between	2	2.306E + 04	1.153E + 04	2.86	0.0596
Within	129	5.207E + 05	4.037E + 03		
Total	131	5.438E + 05			

Unweighted Least Squares Linear Regression of Count with Temperature and Turbidity as the Independent Variables

Predictor Variables	Coefficient	Std. Error	Student's T	P
Constant	113.33	48.114	2.36	0.0200
Temp	-5.3137	4.9796	-1.07	0.2879
Turb	3.8501	7.9818-01	4.82	0.0000

Cases Included	132	Missing cases	0
Degree of Freedom	129		
Overall F	13.37		
Adjusted R Squared	0.1588		
R Squared	0.1716		
Resid. Mean Square	3.492E + 03		

During the course of the four month monitoring program, only seven of the samples exceeded the 200 colonies/100 ml standard. Although the Colorado river contained within Glen Canyon National Recreation Area is not considered a swimming area due to the cold temperature of the water, the current, and the boat traffic, the standard is used by park managers as a measure of water quality protection.

The performance of controls was erratic. The positive control, Escherichia Coli, worked as it should, consistently showing growth. The Enterobacter Aerogenes showed growth on the two middle sample days: 7-27-92 and 8-25-92 and no growth on the first and last sample dates: 6-29-92 and 9-14-92. This is the negative control and should have shown no growth. The purpose of the negative control is to show that the media is selective for Escherichia Coli and that the water bath is at the right temperature, since only Escherichia Coli should turn blue, and Enterobacter Aerogenes should die at the 44.5 C water bath temperature. However, on 9-14-92 when side by side samples of Enterobacter Aerogenes from different sources were run on identical media, one sample showed growth and the other sample showed no growth. This indicates that either the plate or the sample that was filtered was somehow contaminated. This could possibly be considered as a properly working negative control. The UV control only worked on the 7-27-92 sample day. It is difficult to determine the causative factor. Next year it is recommended that the UV control be run every ten plates. By running the UV control more often it would be possible to determine if the UV sterilizer is failing to sterilize completely, and thus possibly affecting the fecal coliform counts.

Due to the inconsistent performance of the negative controls, the actual counts cannot be considered as an actual count of the total number of fecal coliform in the Colorado River. However, if we assume that all samples on a given day are equally affected these results can be used to compare relative "high" and "low" sites. Furthermore, these results do confirm the prediction: that turbidity and temperature do have a direct effect on counts. The high counts also correspond with the most highly visited sites, a factor which is true for the Lake Powell sites. Just how much the failure of the controls affected the actual data is unknown and can only be determined by comparing these results to future years.

Statistically it can be shown that coliform counts are affected to a greater or lesser degree by temperature, turbidity and time of day (rate of flow). The most significant factor is turbidity (Overall $F = 13.37$, $P < 0.0001$). This indicates that when turbidity is high, coliform counts are high. However, the r^2 is only 16%, so the data shows a lot of scatter. Temperature also seems to have some effect on high counts; however, the temperature of the water remains relatively constant year around and thus is not a significant factor.

Rate of flow has an effect and can be seen most significantly in the coliform counts from the third collection ($P = 0.06$). The first and the third counts of the day were not significantly different. The second count of the day shows a significant drop in counts. The explanation for this could be dilution. Because water flow is low during the night the counts remain high, causing the first count of the day to be relatively high. Then, as the water level rises, a certain amount of dilution begins to lower the counts. The visitation on the

river then begins, causing the counts to begin rising again. The coliform counts reach their highest point in the late afternoon; soon afterward the water flow through the dam decreases, and the dilution factor no longer has the effect it had at midday. This could have occurred at both Sites 3 and 4, the sites with the highest afternoon counts, as they are day use only sites.

The fecal coliform counts were relatively stable at all sites during June, July, and September. However; during August, the average fecal coliform count rose remarkably between the second and third sample collection at all sites but 1 and 2. On inspection there were approximately one third fewer visitors on the river during this time. The fecal coliform counts at Site 1 dropped between the first and second sampling times and rose only slightly between the second and third sample during the month of August. The fecal coliform counts at Site 2 rose between the first collection and the second, while remaining fairly constant between the second and third sample collections.

These trends might indicate that the contamination was washed downstream causing the sites downstream of Site 1 and Site 2 to have peak counts in the afternoons. This could be a case of an additive principle where sources of contamination at each site adds to the problem causing successive sites downstream to have a higher fecal coliform count. However, further sampling would be necessary to test this hypothesis, as calm sites were chosen selectively.

Site 4 had the highest average afternoon count for fecal coliform in the months of August and September. In July the counts showed an increasing count level at each successive site. There are several possible reasons for this phenomena. The first and most obvious is that this is the most used site of the six sites surveyed. It is the destination of all the Wilderness River Adventure tours and probably many of the private boats as well. This is further supported by the fact that the counts rose in the afternoons. This shows that after the sites have been used and the water level has risen, the counts rise as well. While there are two self contained toilets on the site, they may not adequately serve all the visitors who visit this site. This hypothesis is further supported by the Lee's Ferry Carrying Capacity Study (Northern Arizona University, School of Forestry, July 1992) carried out last year on the fifteen miles of river from Lee's Ferry to Glen Canyon Dam. The two sites indicated in this study: Petroglyph Access and Petroglyph Panel, labeled #17A and #17B, scored a severe impact rating and heavy impact rating respectively. At the Petroglyph Access, human waste and toilet paper were found. The second reason why Site 4 might have experienced the highest afternoon counts is that the conditions at this site are most conducive to fecal coliform growth. The water is relatively shallow for quite some distance from the beach itself. Furthermore, the water near the beach is relatively motionless due to the eddy current.

Site 3 also showed similar results to the Site 4. The afternoon counts were higher than the morning counts in August and September. This site also had the second highest average afternoon counts. The reasons for this would seem to mirror Site 4. In the Lee's Ferry Carrying Capacity Study (Northern Arizona University, School of Forestry, July 1992) Site 3, Ferry Swale sites, are indicated in this study as #19A, #19B, and #19C. All three of these sites scored a severe impact rating.

The impact rating for all the sites were as follows: Site 1-severe; Site 2-heavy; Site 3-severe; Site 4-heavy to severe; Site 5-moderate to heavy; Site 6-severe. Lee's Ferry Carrying Capacity Study (Northern Arizona University, School of Forestry, July 1992).

VI. Management Implications

There are four recommendations that can be made at the close of this four month study:

1. The study thus far has indeed indicated that there is a potential for high levels of fecal coliform in the Colorado River stretch from Lee's Ferry to Glen Canyon dam. Therefore, monitoring should continue to insure that Glen Canyon National Recreation Area is aware of potential hazards to it's visitors.

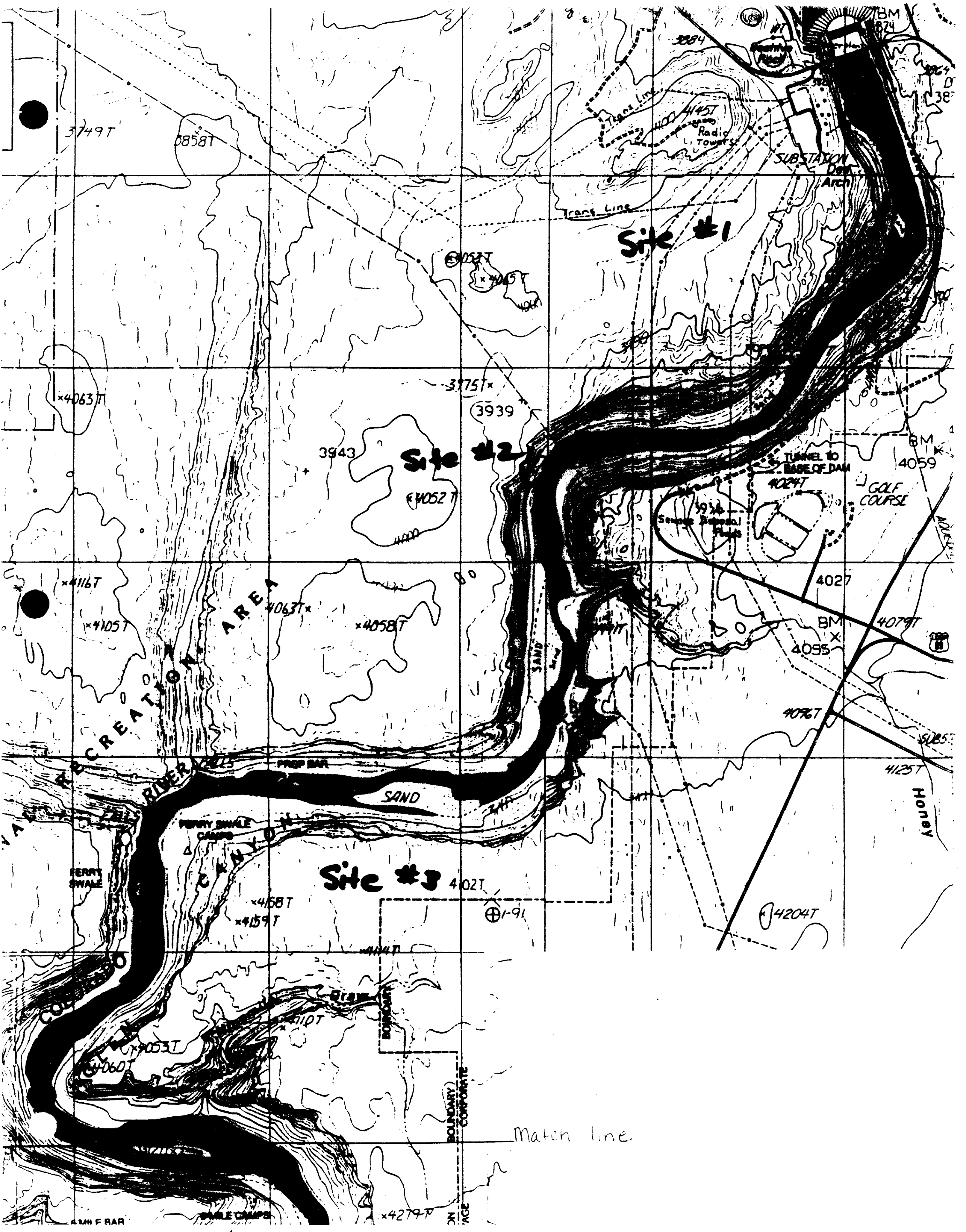
2. A concerted effort is needed to determine the feasibility of installing additional self contained toilets, particularly at the Petroglyph Panel and Ferry Swale, as evidenced by the Lee's Ferry Carrying Capacity Study (Northern Arizona University, School of Forestry, 1992.) The present ones are not adequate to serve the public need. While this would necessitate a capital outlay, the benefits toward public health, and preservation of the environment would definitely outweigh the monetary costs. The Recreation Area at present has the ability to institute preventative measures to avoid ever having a problem on the river, a luxury no longer afforded on Lake Powell. The manpower, time, and expense of responding to a contamination problem is certainly more expensive to the Recreation Area in the long run than the preventive measures provided for by additional toilet facilities.

3. Some steps should be taken to decide what response will be taken should the fecal coliforms counts ever exceed 200 colonies/100 ml consistently at any one site.

4. Although the water that comes through Glen Canyon Dam is taken from the bottom of Lake Powell, a sample taken within the dam could be quite useful in determining if Lake Powell is a source of contamination for the Colorado River. This type of sample taking was last conducted by the Bureau of Reclamation in the early 1980's.

VII. Conclusion

In general the Colorado River Water Quality program provided useful information about the cleanliness of the river water. For the amount of intensive day use that the river receives, the river remains remarkably clean. It would behoove Glen Canyon NRA to take measures to maintain and improve this valuable resource.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RECREATION AREA
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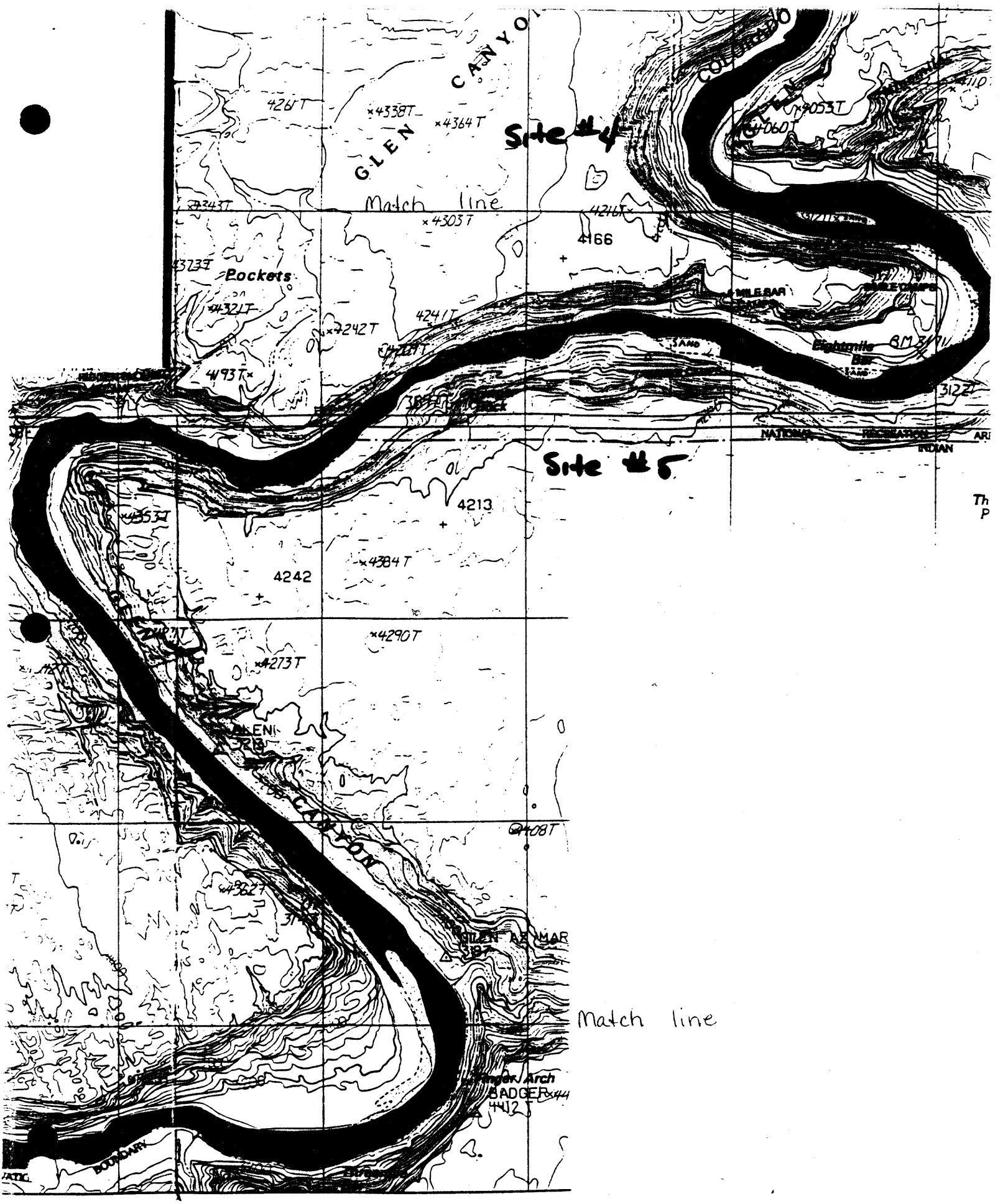
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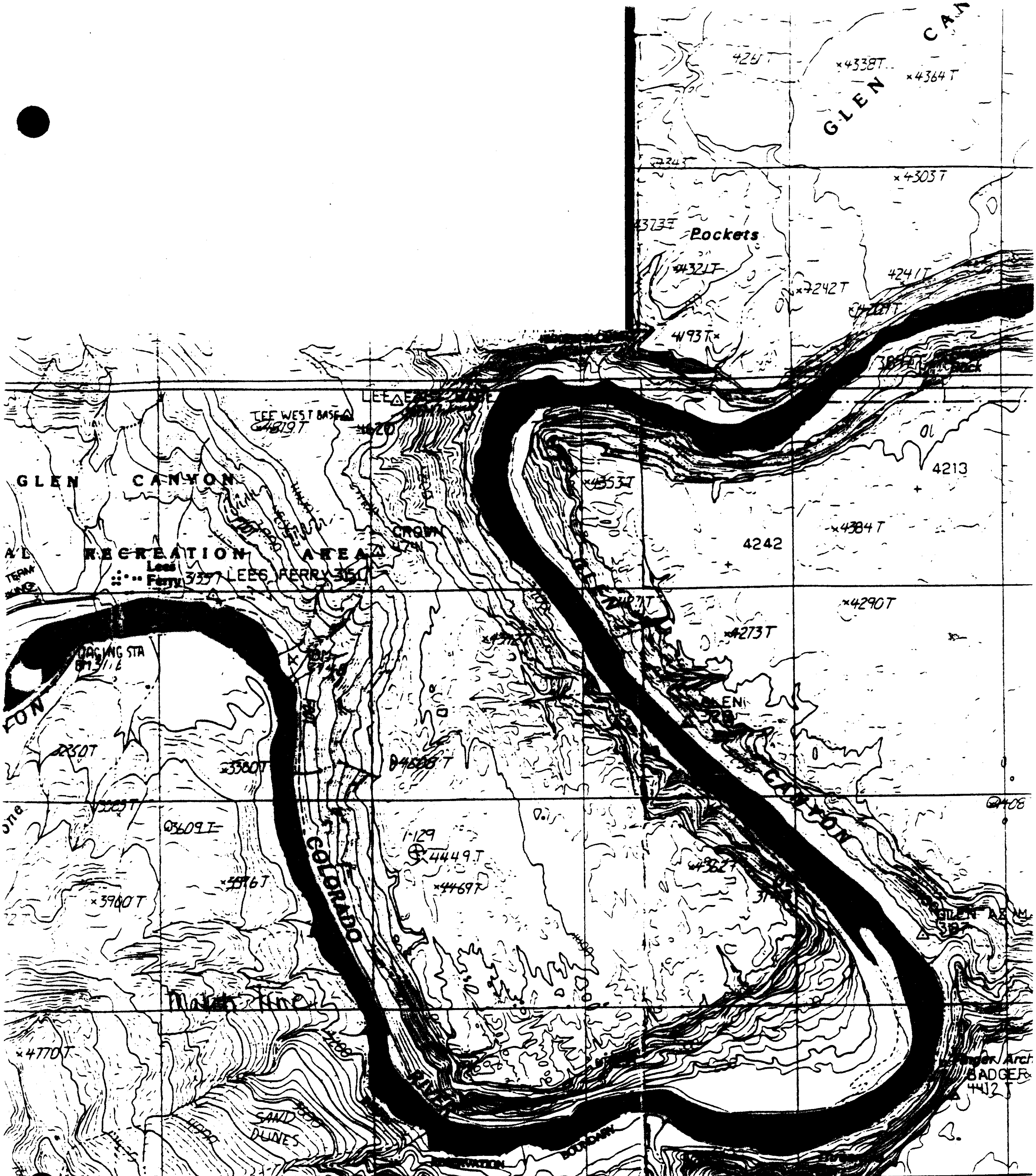

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Site #6