Some effects of Clark Canyon Reservoir on the limnology of the Beaverhead River in Montana
by Kenneth Michael Smith

A thesis submitted to the Graduate Faculty in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE in Fish and Wildlife Management
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Abstract:
A study to determine the effects of Clark Canyon Reservoir on the Beaverhead River was conducted during the summers 1971 and 1972 and intervening winter. Sampling stations were established on each of the two tributaries to the reservoir and on the Beaverhead River from the dam site to 43 km downstream. Discharge and water temperature were the most altered physical parameters. Postimpoundment flows for 24 km downstream from the dam were less than preimpoundment flows during the autumn and winter seasons and greater during spring and summer.

Diel temperature fluctuations below the dam were negligible while fluctuations in the reservoir tributaries covered a ten degree (C) range. During August 1971, 1972 and September 1971, monthly mean temperatures were (3-4°C) higher immediately below the reservoir than in the major tributary to the reservoir. Mean dissolved oxygen levels in the tailwaters were well above saturation levels (108-148%) while the reservoir tributaries had mean saturation levels below or near saturation (89-99%). The pH increased slightly below the dam when compared to levels observed in the tributaries. Ammonia and nitrite increased while nitrate decreased in the tailwaters. Periphytic phytoplankton was greatly reduced while planktonic types of algae increased immediately below the reservoir. Forty-five kilometers below the dam the planktonic types were nearly nonexistent while most of the periphytic types were restored to levels similar to those observed in the reservoir tributaries. A substantial increase in zooplankton (Daphnia and Cyclops) was noted immediately below the dam but decreased considerably within 24 km downstream.

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Signature *Kenneth Michael Smith*

Date *May 24, 1972*

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Head, Major Department

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ABSTRACT

A study to determine the effects of Clark Canyon Reservoir on the Beaverhead River was conducted during the summers 1971 and 1972 and intervening winter. Sampling stations were established on each of the two tributaries to the reservoir and on the Beaverhead River from the dam site to 43 km downstream. Discharge and water temperature were the most altered physical parameters. Postimpoundment flows for 24 km downstream from the dam were less than preimpoundment flows during the autumn and winter seasons and greater during spring and summer. Diel temperature fluctuations below the dam were negligible while fluctuations in the reservoir tributaries covered a ten degree (C) range. During August 1971, 1972 and September 1971, monthly mean temperatures were (3-4°C) higher immediately below the reservoir than in the major tributary to the reservoir. Mean dissolved oxygen levels in the tailwaters were well above saturation levels (108-148%) while the reservoir tributaries had mean saturation levels below or near saturation (89-99%). The pH increased slightly below the dam when compared to levels observed in the tributaries. Ammonia and nitrite increased while nitrate decreased in the tailwaters. Periphytic phytoplankton was greatly reduced while planktonic types of algae increased immediately below the reservoir. Forty-five kilometers below the dam the planktonic types were nearly nonexistent while most of the periphytic types were restored to levels similar to those observed in the reservoir tributaries. A substantial increase in zooplankton (*Daphnia* and *Cyclops*) was noted immediately below the dam but decreased considerably within 24 km downstream.

INTRODUCTION

Clark Canyon Dam, on the Beaverhead River in southwestern Montana, was constructed in 1964. The impoundment created by this dam covers the lower portions of Red Rock River and Horse Prairie Creek which previously joined to form the Beaverhead River 0.48 km above the present dam site. Personnel of the Montana Fish and Game Department initiated studies in 1969 to determine the fish population of the reservoir and the effects of the reservoir and altered stream flow patterns on the fish populations on the Beaverhead River.

I conducted field research during the summers of 1971 and 1972 and intervening winter on the limnology of the river with emphasis on chemical analysis but discharge, water temperatures and plankton were also considered. A concurrent study was conducted by Rodney Berg on the limnology of the reservoir.

DESCRIPTION OF STUDY AREA

Red Rock River drains an area of 4,092 km^2 with half of the drainage on the slopes of the Continental Divide. The mountains are of igneous and sedimentary rocks (sandstone, limestone and quartzite) and alluvial gravels (Ryder, 1967). Upper and Lower Red Rock Lakes and Swan Lake are located in the headwater region and comprise the Red Rock Lakes National Wildlife Refuge. From the refuge to Lima Reservoir (21.9 km) the Red Rock River is a meandering, slow, aggraded stream (Fish and Wildife Service, 1956. Henceforth abbreviated F. W. S.). Below Lima Reservoir, the river is approximately 15.24 m wide with an average gradient of 5.7 m/km and meanders through mountain meadows for almost the entire distance (48.4 km) to its termination at Clark Canyon Reservoir (F. W. S., 1958). The principle land use in the Red Rock Valley is farming and many irrigation diversions are present below Lima Reservoir (F. W. S., 1956). Flows at Dell, 25.9 km above Clark Canyon Reservoir, varied from a high of 41.9 m^3/sec on June 9, 1944 to a low of zero during May, 1961 (U. S. Geol. Surv., 1967). No annual mean flow data is available due to winter ice conditions. Water temperatures at Dell for the period 1949-65 had a maximum and minimum of 17.8° C and 0.6° C, respectively (Aagaard, 1969).

Horse Prairie Creek drains approximately 1,765 km^2 and is about 103 km long with an average width of 10.6 m (F. W. S., 1956, 1958). The gradient of the lower one-half of the stream is 7.2 m/km. Maximum and minimum discharge flows for the upper one-half of Horse Prairie Creek for the period 1946-53 were 25.2 and 0.34 m^3/sec, respectively (U. S. Geol. Surv., 1953). The lower half of the stream is severely dewatered by irrigation during the summer and fall months (Wipperman, 1964). Spot observations on water temperature for the period 1963-64, near the reservoir site, showed a maximum of 23.9° C on June 24, 1964 and a minimum of near freezing on many days during the winter months (Aagaard, 1969).

The Beaverhead River is presently formed at the outlet from Clark Canyon Reservoir. The river is 99.75 km in length with a total drainage area of about 12,950 km^2 (F. W. S., 1956) and an average stream gradient of 3.6 m/km. Maximum and minimum flow data for the period 1907-60 at Barretts 24.4 km below the dam (Fig. 1) were 105 and 1.9 m^3/sec, respectively, with a 53-year average of 11.5 m^3/sec (U. S. Geol. Surv., 1960). Maximum and minimum water temperatures at Barretts were 21.6° C and 0° C, respectively, for the period 1949-67 (Aagaard, 1969). Within the study area, Grasshopper Creek is the main tributary, draining an area of approximately 906 km^2. This creek has a 22-year average discharge of 1.49 m^3/sec (U. S. Geol. Surv., 1960).

Clark Canyon Dam and Reservoir, along with Barretts Diversion Dam, the East Bench Canals, irrigation laterals and drains, constitute the Bureau of Reclamation's East Bench Unit at Dillon (Fig. 1). The

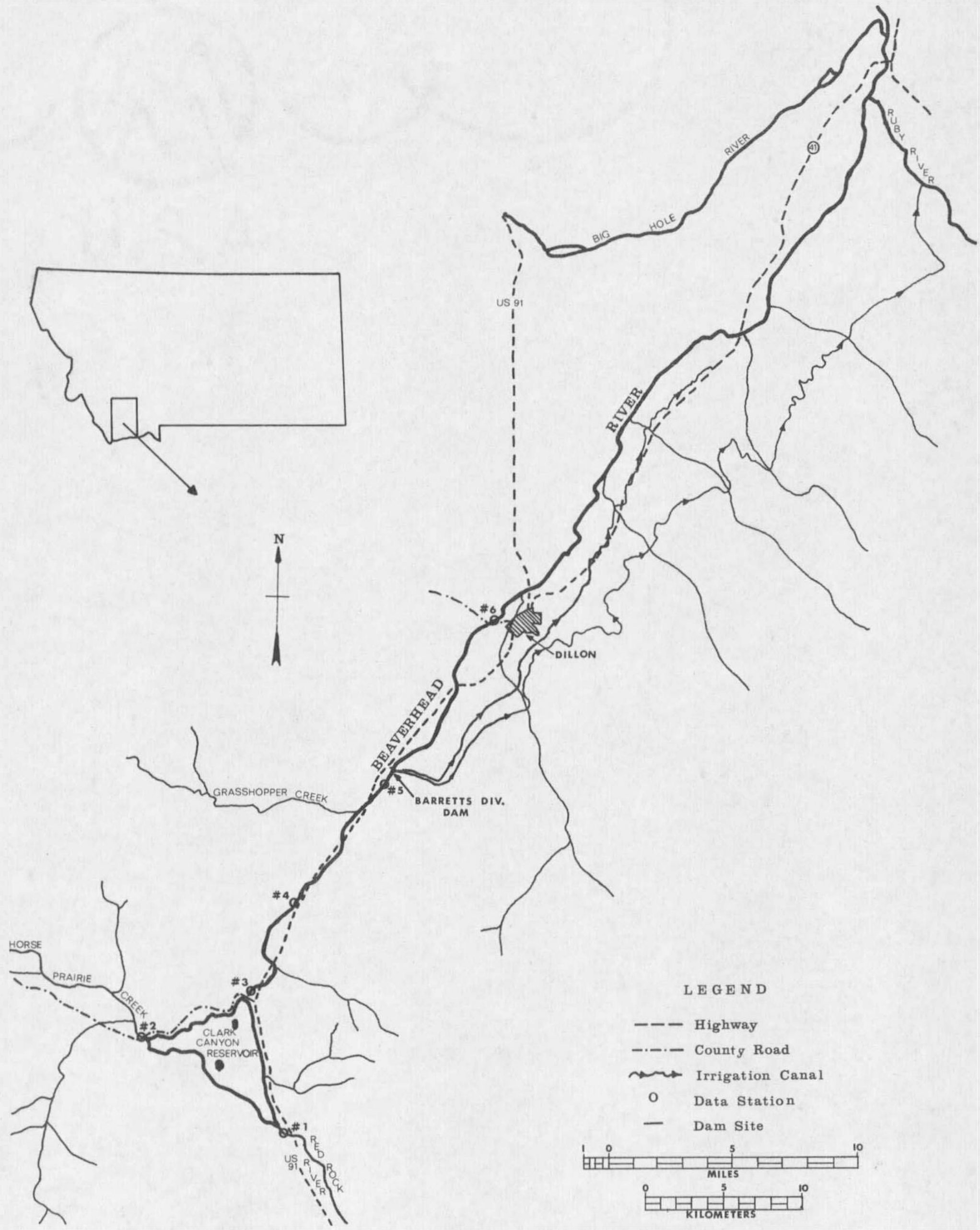

Figure 1. Map of the Beaverhead River drainage area showing the location of sampling stations.

primary functions of Clark Canyon Dam are flood control and irrigation with some recreation and fish and wildlife functions (Dinzick, personal communication).

The dam is 40.53 m high with the invert outlet located 0.15 m above the old stream bed (Table 1). When filled to the top of the irrigation storage level (1689.23 m above mean sea level) the reservoir holds 198.97 x 10^6 m^3 of water and covers an area of 20.24 km^2 (Dinzick, personal communication). The impoundment inundated the farming community of Armstead and important stream fisheries in 12.07 km of Red Rock River, 13.8 km of Horse Prairie Creek and 0.48 km of Beaverhead River (F. W. S., 1958).

Past and present flows in the Beaverhead River drainage are somewhat different from other drainages in Montana. Fall and winter runoff is proportionally greater during this period on a total annual flow basis. Consequently, the Bureau of Reclamation's reservoir operation plan calls for storage of water in the period from November through April. During this period releases may be as low as 0.71 m^3/sec or equal to or greater than the total inflow when storage approaches the 176 x 10^6 m^3 level. Releases from the dam for irrigation purposes generally occur from mid-May through September but may extend two weeks on either side of this period (Dinzick, personal communication).

Table 1. Elevations and capacities of Clark Canyon Reservoir and Dam.

	Elevation* (m above mean sea) (level)	Height (m)	Capacity* ($m^3 \times 10^6$)	Surface Area* (km^2)
Top of Dam	1,700.2	37.7	-----	----
Top of Flood Control Storage	1,694.8	32.3	317.2	23.9
Top of Joint Use Storage (Normal Operation Elev.)	1,689.2	26.7	194.5	20.0
Top of Active Conservation Storage	1,687.3	24.8	157.4	18.2
Top of Inactive Storage	1,667.5	5.0	2.4	0.8
Top of Dead Storage (Bottom of Outlet Works)	1,662.6	0.1	0.08	0.1
Stream Bed	1,662.5	----	-----	----

*From U. S. Dept. of the Interior, Bureau of Reclamation, Missouri River Basin Project, Three Forks Div. - East Bench Unit-Montana, Clark Canyon Dam, Reservoir Area, Denver, Colorado, May 2, 1966, #699-D-198.

METHODS

Sampling stations were located on Red Rock River, Horse Prairie Creek and the Beaverhead River (Fig. 1). Station one was on Red Rock River, 4.3 km upstream from the 1,689 m, normal operation elevation of Clark Canyon Reservoir. Station two was on Horse Prairie Creek, 0.24 km from the operation elevation. Stations three through six were on the Beaverhead River at 0.40, 10.0, 24.2 and 43.5 km downstream from the dam. Stations one through five were established in June, 1971, while station six was established in April, 1972.

Discharge data were collected from U. S. Geological Survey records, where applicable, from the following locations: Beaverhead River near Grant, at my station three; Beaverhead River at Barretts, at station five; and Beaverhead River at Dillon, at station six. Reservoir release and inflow data were supplied by the Bureau of Reclamation.

Continuous water temperature recordings were obtained through the use of Taylor and Foxboro recording thermographs at all six stations from June 16, 1971 through August 31, 1972.

Sampling for turbidity, conductivity and water chemistry was done at near biweekly intervals from June 29 through September 15, 1971 and June 16 through August 26, 1972, and at monthly intervals from September 15 to December 21, 1971 and in April and May, 1972.

Water samples for physical and chemical analyses were collected in twice-rinsed: 0.9 l plastic bottles with plastic caps; 300 ml glass dissolved oxygen bottles; and 250 ml standard glass bottles with glass stoppers. The 250 ml water sample was used for the orthophosphate determination and the 300 ml sample was used for the dissolved oxygen analysis, while all other analyses were accomplished from the 0.9 l water sample. The containers were completely immersed in the water and filled to maximum capacity, capped and immediately returned to a field laboratory in Dillon for analyses.

Analyses for turbidity, conductivity, pH, dissolved oxygen, total alkalinity, total hardness, orthophosphate, nitrate, nitrite and ammonia were carried out at near periodic intervals at all stations (Table 8). Difficulties in analytical procedures precluded the use of October 9 and November 20, 1971 data for orthophosphate; the entire summer, 1971, and September 15, 1971 data for nitrate and nitrite; and the entire summer and winter, 1971 data with the exception of May 6, 1972 for ammonia.

Hourly readings for each day were taken from the thermograph records and analyzed for daily maximum, mean and minimum and monthly maximum, mean and minimum. This analysis was carried out by the use of the Montana State University Computer Center's Sigma-7 Computer.

Turbidity was measured in a HACH Field Kit using the HACH DR Colorimeter.

Conductivity was determined by the use of a Solu-Bridge Conductivity Meter (Model RB3-338-Y147).

The pH was measured with an Orion Ionalyzer (Model 407) using a Sargent combination pH electrode.

Dissolved oxygen determinations were carried out via the Standard Winkler Method (Alsterberg modification) using phenylarsene oxide instead of sodium thiosulfate as the titrant solution (HACH, 1969). A nomogram from Mortimer (1956) was used to convert ppm DO to percent saturation.

Total alkalinity, total hardness and ammonia determinations were made as described by the American Public Health Association (1965).

The orthophosphate, nitrate and nitrite analyses were carried out as outlined by HACH (1969). A Bausch & Lomb Spectronic 20 was used for the various colorimetric measurements.

For analytical purposes the turbidity, conductivity and chemistry data were divided into three groups: group one, first summer, contained five sampling periods dating from June 29 through September 1, 1971; group two, winter, contained six sampling periods, from September 15, 1971 through May 6, 1972, exclusive of January through March, 1972; group three, second summer, contained six sampling periods dating from June 16 through August 26, 1972 (Table 8). Data for the two summers, groups one and three, were combined into a summers mean for comparing differences between stations.

Plankton samples were collected only during the spring and summer of 1972, during eight sampling dates from April 8 through August 26, 1972 (Table 8). For each collection five liters of river water were passed through a #20 plankton net and each sample was adjusted to 125 ml and preserved with Lugol's solution for later analysis. Phytoplankton were identified and enumerated by genera for each sample. Percent relative abundance was computed for each genus from a total count of 300 cells per sample. Phytoplankton genera with at least five percent relative abundance during any sampling were compared for significant differences using a modified Binomial Confidence Interval with a level of probability of 0.05. Five percent was used as a cut off point for comparisons because the lower part of the confidence interval was less than zero. The confidence interval was calculated for all necessary percentages using the equation:

$$\text{Confidence interval} = p \pm \sqrt{2}\ \frac{p(1-p)}{n} \times 1.96$$

p = proportion (percentage)
n = sample size

Zooplankton were identified to genera, counted in a rotating grooved chamber (Ward, 1955) and converted to number of organisms per liter.

RESULTS

The complete results of all determinations except flows, temperatures and plankton for all dates at all stations are given in the Appendix (Tables 8 through 18).

Physical Parameters

To determine the effect of the reservoir on flows of the Beaverhead River, comparisons were made between the pre- and postimpoundment flows at station five (Barretts) and station six (Dillon) and between reservoir inflows and releases. The preimpoundment data for station five and station six encompassed the 1950 water year to July 1964, and the 1950, '51 and 1963 water years, respectively. Postimpoundment data extended from July 1964 to September 1972 for station five and to October 1970 for station six. Above and below flow data were obtained from reservoir inflow and discharge records from September 1964 through August 1972.

Runoff from October 1963 to September 1972 in the Beaverhead River drainage was high when compared to the 53-year (1907-60) preimpoundment discharge mean at station five. These highwater years had 76% and 24% greater maximum and mean flows, respectively, than the 53-year average. Due to postimpoundment high water years the pre- and postimpoundment flow data were averaged by month for both periods, while the above and below data were averaged by month on an annual basis. Both sets of data were converted to monthly percentage of the annual flow.

Evaluation of preimpoundment (176 months) and postimpoundment (168 months) mean discharge at station five revealed a similarity in the annual flow patterns (Fig. 2). However, postimpoundment flows were less during the low water period and greater during the high water period than preimpoundment flows. The postimpoundment December flows averaged only 74% of the preimpoundment flows. The four months of May through August had 40%, 8%, 26% and 44%, respectively, higher flows relative to preimpoundment flows.

Analysis of 32 and 88 months of pre- and postimpoundment flow data at station six showed a close conformity during May, and between the November through March and the August through September months in both pattern and magnitude of flows (Fig. 2). A three percent difference was noted for these eight months. Postimpoundment flows were less than preimpoundment flows during the months of April and October by 25% and 12% each, while June and July had a 29% and 50% increase in postimpoundment flows, respectively.

Postimpoundment calculated flows for the river immediately below the Barretts Diversion Dam (Fig. 1) for May through September were obtained by subtracting the monthly mean water diverted from the monthly mean river flow for the eight year period. These means were converted to monthly percent of annual flow. The maximum and minimum amount of river water diverted during the eight irrigation seasons was 60% and