Fish loss to irrigation canals and methods to reduce these losses on the West Gallatin River, Montana
by Eric William Reiland

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Fish and Wildlife Management
Montana State University

Abstract:
Agriculture and recreational fisheries are important to Montana's economy, however they compete for the state's water resources. Conflicts over the number of trout entering irrigation canals, and subsequently being lost from a river's fishery, prompted concern, in Montana, as early as 1893. Yet few studies have examined the effects of fish loss to irrigation diversions on trout populations. I estimated the number of trout (≥ 150mm) in gravity-fed irrigation canals on the West Gallatin River, Montana, by trapping and electrofishing, in 1993 and 1994. It was presumed that fish entering the canals were lost from the West Gallatin River fishery. Trout abundance was related to habitat types and canal characteristics and operations. Multiple regression was used to assess the relationship between these factors and population abundance. Trout population densities varied from 0-16 fish/100m (median 1.5 fish/100m). Total trout populations ranged between 0 and 1,905 fish/canal (median 215 fish). Repeated electrofishing of identical transects found no significant differences between trout populations in 1993 and 1994 (P-values>0.26, Betas≥0.92) or between June 1994 and September 1994 (P-values >0.12, Betas ≥0.83). Most trout entered the irrigation canals during periods of maximum river flow. I measured the following canal characteristics: headgate size, manipulation, construction materials and habitat; intake size, habitat and angle in relation to the river's thalweg; and flow; which were used to develop a predictive model of the number of trout found in a canal. The model contained headgate area, intake angle in relation to the river's thalweg and intake length [canal populations = -2,429.7 + 0.7246(earea) + 0.5405(l/50m angle) - 0.3287(sqrt(intake length))] (model R^2= 0.87, P-value = 0.00483). Large canals, with short intake channels, located on the outside of river bends captured more fish than canals with opposite characteristics. A jackknife bias-estimation procedure indicated that the model overfit the data (R^2 = 0.25, P-value > 0.80). The model predicted canal trout populations to be four times greater than the West Gallatin River's study area trout population (140,353 and 34,132, respectively). Two canals contained 87% of the model's predicted trout abundances, and the headgate area variables for both canals were above the range of data collected in the study canals. Rapid (90%) and staged (30%) drawdown regimes were evaluated to encourage trout movement. Among the regimes examined, reducing canal flow by 90% while leaving adequate flows for fish movement was most effective in stimulating up-canal movement. Therefore, altering the time of canal openings to avoid a river's period peak discharge and reducing canal flows by 90%, with leaving the remaining flow at least 2 d before completely closing the headgate, might decrease the numbers of fish stranded in canals at the end of an irrigation season.

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Eric William Reiland

This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

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Date 29 August 1997

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ABSTRACT

Agriculture and recreational fisheries are important to Montana's economy, however they compete for the state's water resources. Conflicts over the number of trout entering irrigation canals, and subsequently being lost from a river's fishery, prompted concern, in Montana, as early as 1893. Yet few studies have examined the effects of fish loss to irrigation diversions on trout populations. I estimated the number of trout ($\geq$ 150mm) in gravity-fed irrigation canals on the West Gallatin River, Montana, by trapping and electrofishing, in 1993 and 1994. It was presumed that fish entering the canals were lost from the West Gallatin River fishery. Trout abundance was related to habitat types and canal characteristics and operations. Multiple regression was used to assess the relationship between these factors and population abundance. Trout population densities varied from 0 - 16 fish/100m (median 1.5 fish/100m). Total trout populations ranged between 0 and 1,905 fish/canal (median 215 fish). Repeated electrofishing of identical transects found no significant differences between trout populations in 1993 and 1994 (P-values >0.26, Betas $\geq$0.92) or between June 1994 and September 1994 (P-values >0.12, Betas $\geq$0.83). Most trout entered the irrigation canals during periods of maximum river flow. I measured the following canal characteristics: headgate size, manipulation, construction materials and habitat; intake size, habitat and angle in relation to the river's thalweg; and flow; which were used to develop a predictive model of the number of trout found in a canal. The model contained headgate area, intake angle in relation to the river's thalweg and intake length [canal populations = -2,429.7 + 0.7246(e^{area}) + 0.5405(1/50m angle) - 0.3287(sqrt(intake length))] (model R^2 = 0.87, P-value = 0.00483). Large canals, with short intake channels, located on the outside of river bends captured more fish than canals with opposite characteristics. A jackknife bias-estimation procedure indicated that the model overfit the data (R^2 = 0.25, P-value > 0.80). The model predicted canal trout populations to be four times greater than the West Gallatin River's study area trout population (140,353 and 34,132, respectively). Two canals contained 87% of the model's predicted trout abundances, and the headgate area variables for both canals were above the range of data collected in the study canals. Rapid (90%) and staged (30%) drawdown regimes were evaluated to encourage trout movement. Among the regimes examined, reducing canal flow by 90% while leaving adequate flows for fish movement was most effective in stimulating up-canal movement. Therefore, altering the time of canal openings to avoid a river's period peak discharge and reducing canal flows by 90%, with leaving the remaining flow at least 2 d before completely closing the headgate, might decrease the numbers of fish stranded in canals at the end of an irrigation season.

INTRODUCTION

Long before effective water management plans were developed in the western United States, ranchers and farmers had acquired water rights. As resource demands have increased, so have conflicts between recreational user groups and the agricultural industry. Concern has escalated over the potential effects of removing water from a stream (dewatering), including the loss of fish to irrigation canals. One solution to fish being lost to irrigation canals is fish screening programs, which began in New York in 1865 (Leitritz 1952). Fish screening consists of installing and maintaining devices (i.e.- types of screens) which prevent fish from entering irrigation diversions. Most screening program evaluations have concentrated on anadromous species, and only a few studies have evaluated resident fish losses. Anadromous salmonids, which migrate to the ocean and return to freshwater to spawn, have different life histories than resident fish, which remain within a freshwater system throughout their life cycle. This study was initiated to address resident fish loss to irrigation canals.

The irrigation of Montana's crops by Euro-American settlers began in 1842 in the Bitterroot River Valley (Howard 1992). By 1864, settlers were establishing farms in the Gallatin Valley, and in 1865 the Gallatin Valley's first "ditch company" was formed (Howard 1992). A resident fish screening program was implemented in 1893 when legislation was passed requiring screens to be placed in irrigation canals from 1

September to 1 March, a period when irrigators use little or no water (Clothier 1953a). This legislation was repealed in 1897, for it had no practical value. Other screening programs in Montana have been adopted, but installation and maintenance costs have restricted their use. It is currently the responsibility of Montana Department of Fish, Wildlife and Parks (MDFWP) to fund, construct and maintain any device to prevent fish from entering irrigation ditches (Fish and Wildlife 1993) (Appendix A).

Where resident fish losses to irrigation withdrawals are large, Montana's streams may not be providing their full recreational potential. Montana's world-renowned recreational fishing/tourism industry produces a multi-million dollar market. Many small towns rely on tourism as their primary source of revenue. Duffield et al. (1987) calculated the total 1985 expenditures for Montana's resident and non-resident stream anglers to be $52.4 million and the overall net economic benefit from stream fishing at $122 million. In the Gallatin River, angler expenditures were $4.5 million (Duffield et al. 1987). There are approximately 1,585km (984 miles) of irrigation canals in the Gallatin River Valley alone, and every major drainage in Montana contains irrigated cropland.

Agriculture is also a principal source of revenue and a strong source of Montana's heritage. Over the past century, Montana's agricultural industry has grown to a $2.1 billion commodity market (Montana Agricultural Statistics Service 1994). The Gallatin County agricultural market produces a gross receipt of approximately

$56 million annually (Montana Agricultural Statistics Service 1994). Agriculture is currently the largest revenue source for Gallatin County, as well as the state of Montana (U. S. Department of Commerce 1992). As resource demands continue to burden Montana's waterways (i.e.- irrigation and recreation), methods of evaluating and resolving resource conflicts will need to be incorporated into management strategies.

Biologists in other areas were concerned over the declining anadromous stocks in the early 1900's, which prompted many western states to begin screening irrigation diversions. However, the effects of fish losses were rarely understood because no quantitative data were obtained (Wales 1948; Schill 1984). Wales (1948) reported that California began screening streams used by anadromous species, although low numbers of juveniles did not justify the costs associated with the program. Gebhards (1958, 1959) sampled irrigation canals in the Salmon River drainage, Idaho. He estimated that a screening program could save over one million chinook smolts (*Onchorhynchus tschawytscha*) in years of heavy downstream migration. Sixty Salmon River canals were electrofished to identify the diversions with the largest numbers of juvenile salmon and to prioritize the placement of fish screens (Gebhards 1958). Although only 60 canals were sampled, Gebhards' study resulted in the screening of over 200 diversions on the Salmon River drainage in 8 years (1958-1966) (Herring 1983, in Schill 1984).

Screening evaluations were conducted to ascertain the number of fish entering and safely bypassing the Idaho canals. Between 1960-62, Corley trapped 147 rainbow trout (*O. mykiss*) in 8 canals, 971 rainbows in 14 canals, and 651 rainbows in 17 canals in 1960, 1961, and 1962, respectively (Corley 1962, in Schill 1984). No distinctions were made between juvenile rainbow trout and steelhead trout (*O. mykiss*). Corley also estimated that 91,500 and 279,000 juvenile chinook salmon were bypassed by 84 irrigation canal screens in 1961 and 1962, respectively. To determine the percentage of total downstream migrants entering canals, marked juvenile chinook salmon and steelhead trout were released above irrigation diversions (Reingold 1967a and 1967b, in Schill 1984; Reingold 1971). Population losses were estimated at 0.3 - 6.5% for juvenile chinook salmon (average 2.6%) and 1.3 - 5.9% for steelhead trout (average 2.6%).

Several authors have documented the need for devices to prevent anadromous species from entering canals (Gebhards 1958, 1959; Corley 1962; Reingold 1967a, 1967b, in Schill 1984; Reingold 1971; Herring 1983, in Schill 1984; Fleming et al. 1987). Sullivan and Mattice (1986) found that no single protection system is reliable, economically feasible, and biologically effective. Rotary drum, traveling, and stationary screens are the most common fish protection technologies. Rotary screens on the Sunnyside Canal (Yakima River, Washington), Wapato Canal (Yakima River), and Toppenish Canal (Toppenish Creek, Washington) were found to be 98%, 99%, and 99% efficient, respectively (Neitzel et al. 1986, 1990a). Rotary drum screens cost $2,000 - $4,000 per 0.28 m^3/s (10 cfs) and the average installation cost for smaller canals is $25,000 (Chuck Keller, Idaho Department of Fish and Game, personal communication). The value of these fisheries and the listing of anadromous stocks under the Endangered Species Act (Nehlsen et al. 1991) justifies the cost of installing fish protection devices (Schill 1984). These technologies have been extensively used to protect anadromous species in the Pacific Northwest and California, but Sullivan and Mattice (1986) concluded that screening could not be justified for resident fisheries due to high costs. It is important to note that, due to different behavioral patterns, it would not be reliable to apply the results of studies on anadromous species to resident trout populations.

Although much work has been done on anadromous fish, losses of resident fish to irrigation diversions are not well documented. Although fish may be capable of leaving the irrigation canals and returning to the river, fish loss refers to the number of fish found (or estimated) in the irrigation canals. In 1904, MDFWP estimated a single canal's loss in the thousands (Clothier 1953a), but little quantitative information was obtained. Clothier (1953a, 1954) and Spindler (1955) confirmed fish losses in irrigation canals on the West Gallatin River, Montana. Fleming et al. (1987) recorded resident fish losses that nearly equaled those of anadromous species in several irrigation canals (3700 rainbow trout and 4100 chinook salmon). Evarts et al. (1991) studied fish losses in canals operated by the Flathead Agency Irrigation Division, Montana, recovering 8,679 trout over 4 years (1988-1991) while electrofishing 16 canals. They also reported that they recovered over 20,000 fish (various species) from these canals, which was only a fraction of the fish present, and that the reservations fisheries would not reach their potential until these canals were screened. Other attempts to document resident fish losses were either vague or not the primary purpose of the investigation, and resident fish losses were therefore reported as supplementary information.

The variability between trout densities in irrigation canals makes it difficult to ascertain the effects of irrigation canals on resident salmonid populations. To gather more specific information on impacts to resident trout, Clothier (1953a) sampled 13 canals on the West Gallatin River (1950 and 1951) and estimated a loss of 2,835 catchable sized trout (total length ≥180mm). Only 9 of the 13 canals he sampled contained salmonid species. In 1954, Clothier found 2,002 salmonids of all sizes (including mountain whitefish - *Prosopium williamsoni*) in four West Gallatin River irrigation canals (West Gallatin, Farmers, Spain & Ferris and Lower Middle Creek canals). Densities ranged from 0.023 - 0.295 fish/m (average - 0.186 fish/m) for all size classes of trout. Spindler (1955) found 168 catchable sized salmonids (total length ≥ 180mm) and 400 smaller salmonids in 11 of the canals sampled by Clothier. Thurow (1980) conducted population estimates on the Allen Ranch Diversion in Idaho and calculated a cutthroat trout (*O. clarki*) density of 0.053 fish/m. Only 63 cutthroat trout were sampled, with 68% of these being juveniles. Culpin (1961, in Thurow 1980) observed low numbers of cutthroat trout (10 adults and 250 juveniles) in this same canal. Both Clothier (1953a, 1954) and Spindler (1955) noted that trout population densities were greatest in the upper 1.6 km of most canals.

Young-of-the-year (YOY) salmonids are lost to irrigation canals, as well as adult fish. In 1992, Clancy estimated the number of juvenile rainbow trout entering a Blodgett Creek irrigation canal. Blodgett Creek is a tributary of the Bitterroot River, Montana. He found this canal to be capturing 41% of the tributary's YOY rainbow trout (Chris Clancy, MDFWP, personal communication). Clancy also reported large losses (9,579) of rainbow trout YOY to irrigation canals on a Jefferson River tributary, Montana. Good and Krongberg (1986) estimated that 2,787 salmonids were lost to a single canal on the Bitterroot River. Of these, 2,440 (88%) were YOY salmonids, primarily whitefish, and eight (0.3%) were bull trout (*Salvelinus confluentus*), a species of special concern in Montana. The remaining 11.7% were legal sized salmonids (total length ≥150mm). Good and Krongberg (1986) suggested that YOY salmonids may be incapable of escaping the velocity of water at the canal's headgate (a water control intake structure).

Physical factors of irrigation diversions and their intake structures may contribute to the number of fish entering canals (Figure 1). Headgate characteristics considered by Spindler (1955) were: headgate location, construction materials and method of manipulation (i.e. - lifting gates, sideways sliding gates, check damming boards, etc.). The intake characteristics he considered were: intake gradient, width, depth, velocity, discharge, diversion dam position, substrate, amount of cover,

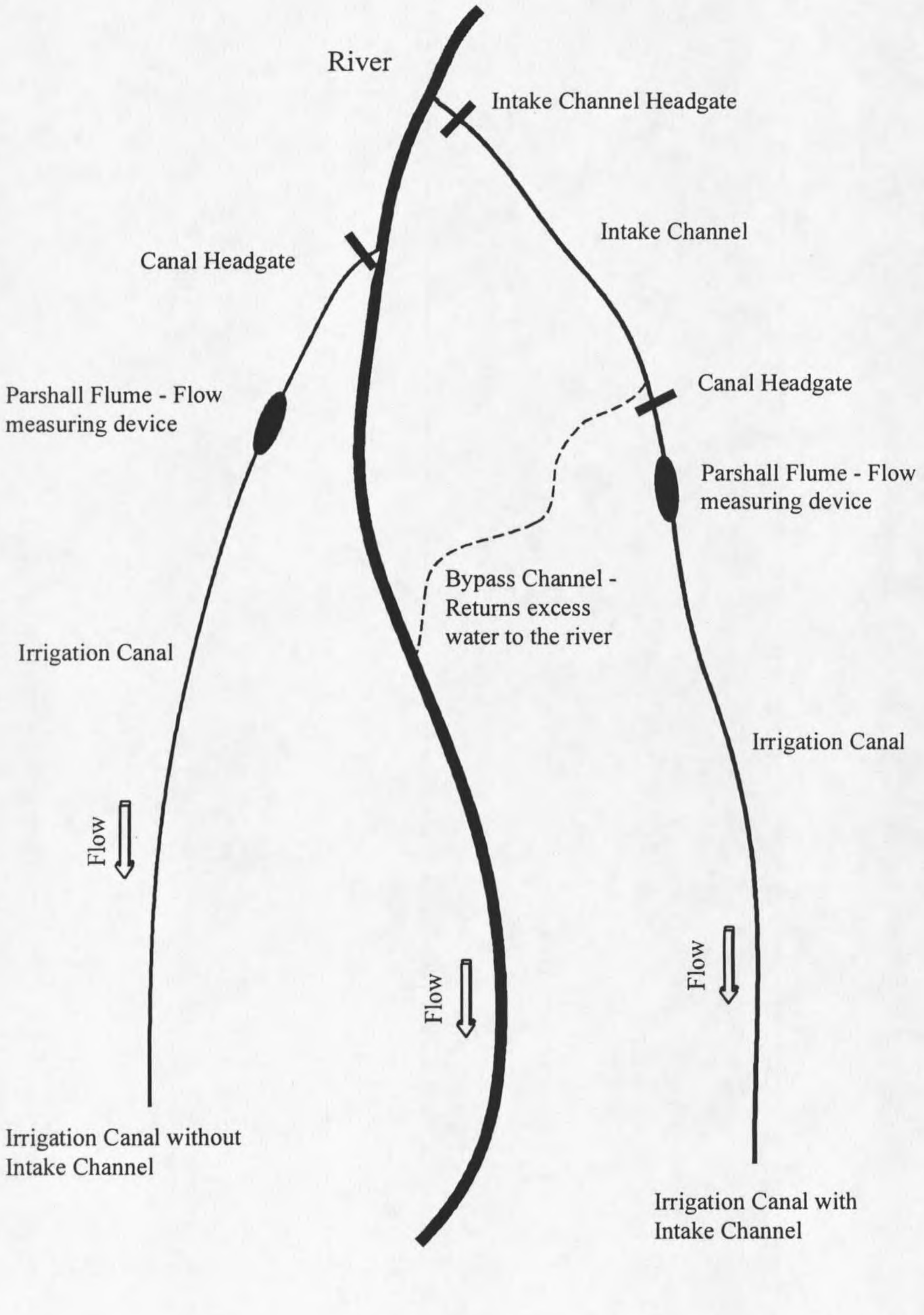

Figure 1. Diagram of the types of irrigation canals and their intake structures. Irrigation water passing through the canal's headgate is not returned to the river.

flow ratio and the intake's location in relation to direction of river flow. Spindler (1955) found that canals with high flow ratios (percentage of river flow diverted) and intake structures located on the outside of river meanders have the highest fish loss. Thurow (1980) indicated that fish densities in canals appeared to be influenced by the quantity of water in the river. Clothier (1953b, 1954) recorded increased fish losses in canals with structure (habitat) in the upper 1.6 km. Hiding cover provides security and may reduce fish movement out of irrigation canals (Clothier 1953b, 1954; Evarts et al. 1991).

Staged drawdowns are one possible method to reduce the number of fish stranded or lost in canals at the end of the irrigation season. Drawdowns are accomplished by incrementally decreasing canal flow after the irrigation season. Adult fish respond to decreasing flows through upstream migration (Clothier 1953a, 1954; Fuller 1981). Clothier (1953a, 1953b, 1954) found drawdowns to be an effective method for moving fish out of canals, although habitat and headgate velocities could impede movements (Clothier 1954). Although no quantitative data were obtained, Shepard (1990) reported a reduction in the number of fish stranded when irrigators employed staged flow reduction procedures on irrigation canals of the Bighole River drainage, Montana. Clothier (1953a, 1954) found up-canal movement of fish in irrigation canals when three equal reductions in water volume were used as a method to close these canals. Staged reductions may concentrate fish and ease salvage operations, but without reliable accessibility and volunteer assistance, salvages can only be justified through public relation benefits (Good 1990).

Resident fish are known to enter irrigation canals, but no studies have quantified the importance of the loss of those fish to the stream populations. Therefore, I designed this study to examine some of the unresolved questions about trout loss to irrigation canals. The West Gallatin River was selected for this study because of its irrigation diversion data, past fisheries data, and availability for study. The objectives of this project were to: (1) review and summarize the literature on salmonid losses to irrigation canals; (2) measure resident salmonid losses to irrigation canals on the West Gallatin River; (3) determine the factors associated with fish loss in canals; (4) test and evaluate irrigation ditch drawdown procedures as a method of reducing fish losses; and (5) develop canal selection criteria that could be used to predict which canals would have large fish losses.

STUDY SITE

The study was conducted in the West Gallatin River drainage of southwestern Montana. The West Gallatin River trout fishery extends from its headwaters in Yellowstone National Park, approximately 139 km (84.5 miles) downstream to Amsterdam Road in the Gallatin Valley. I constructed the study area boundaries around the region of greatest irrigation withdrawal which still contains an excellent trout fishery because: (1) irrigation withdrawal is limited upstream of the mouth of the Gallatin canyon, and (2) the number of trout and angling pressure declines downstream from Amsterdam Road. I made the upper study site boundary (T4S R4E S5 SW1/4) the mouth of the Gallatin canyon and the lower boundary (T1S R4E S33 SW1/4) at Amsterdam Road (Figure 2). There are 26 irrigation canals extracting water from the West Gallatin River between these boundaries (Appendix B). The elevation of the study region ranges from 1,570 - 1,350 m (5,150 - 4,430 ft) and encompasses 38.7 km (24.2 mi.) of the West Gallatin River.

The fluvial geomorphology of the West Gallatin River changes within the study area. In the upper reaches of the study area, the river is a single channel comprised of riffles with an occasional scour-pool located at bends and/or constrictions. The channel has a 2 - 4% gradient and low sinuosity (Rosgen channel type B, Rosgen 1994, 1996). The river gradually changes to a braided channel approximately 10 km below

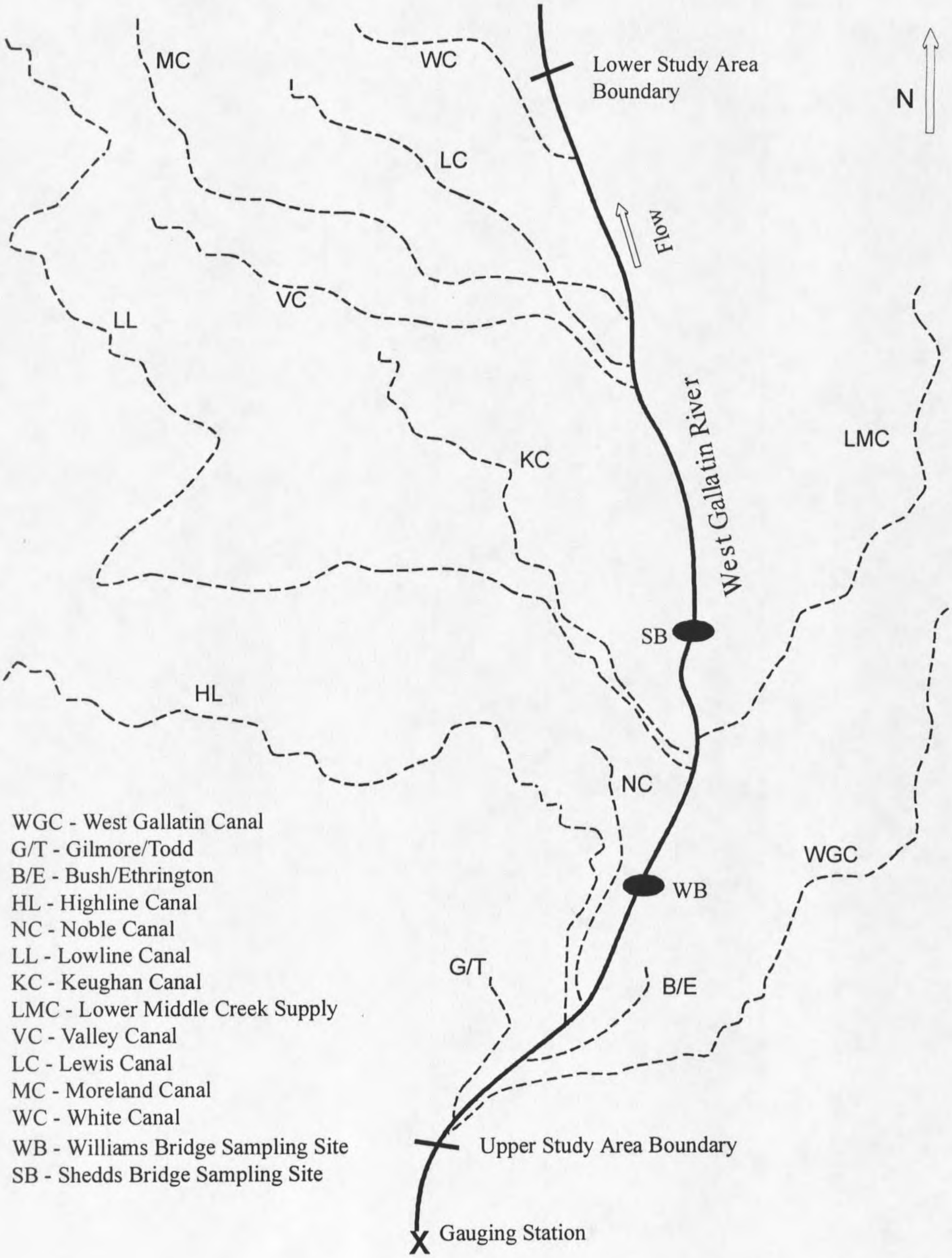

Figure 2. Location of the study canals and the USGS gauging station on the West Gallatin River, Montana.

the upper boundary. The braided region is laterally active and carries an abundant sediment load (Rosgen channel type D, Rosgen 1994, 1996). Substrate in the upper reaches is characterized by boulder/cobble mix and changes to cobble/gravel in the lower reaches. The riparian area ranges from 0.5 - 1.9 km wide (0.3 - 1.2 mi.) and is dominated by cottonwoods (*Populus* spp.), willows (*Salix* spp.), and dogwoods (*Cornus* spp.).

Fish species in the study area include rainbow trout, brown trout (*Salmo trutta*), cutthroat trout, brook trout (*Salvelinus fontinalis*), Arctic grayling (*Thymallus arcticus*), mountain whitefish, white sucker (*Catostomus commersoni*), longnose sucker (*C. catostomus*), mottled sculpin (*Cottus bairdi*), and longnose dace (*Rhinichthys cataractae*) (Clothier 1953a). The numerous rainbow/cutthroat hybrids present in the area (Clothier 1953a) were classified as rainbow trout or cutthroat trout, depending on dominant traits. The West Gallatin River trout population is primarily rainbow trout in the upper reaches of the study area and progressively changes to predominantly brown trout downstream. The West Gallatin River is not thought to be recruitment-limited (Dick Vincent, MDFWP, personal communication).

The West Gallatin River drains 2,146 km^2 (825 mi^2), most of which is Gallatin National Forest land (Shields et al. 1993, 1994). Its average annual flow is 22.8 m^3/s (806 cfs), and ranges from 11.6 - 33.3 m^3/s (408 - 1,184 cfs). The average flows for the

1993 and 1994 field seasons (May - November) were 29.9 m^3/s (1,055 cfs) and 19.4 m^3/s (683 cfs), respectively (Figures 3 and 4). The historic maximum flow was recorded in 1974 at 254.2 m^3/s (8,970 cfs). The 1993 maximum flow was at 155.6 m^3/s (5490 cfs) and the 1994 peak at 106.8 m^3/s (3,770 cfs) (Figure 5). The historic minimum flow was recorded in 1931 at 4.9 m^3/s (174 cfs). Minimum flows for 1993 and 1994 were 5.6 m^3/s (197 cfs) and 8.5 m^3/s (299 cfs), respectively. These discharge readings were taken from U. S. Geological Survey - Water Resources Division (USGS) gauging station (number 06043500) located 0.5 km downstream from the mouth of Spanish Creek on the West Gallatin River. The West Gallatin River drains approximately 85% of the Gallatin River Valley.

The primary land use in the Gallatin Valley is agriculture and the valley is sparsely developed (U. S. Department of Commerce 1992). Gallatin Valley irrigators produce hay, small grains and commodity food crops (Howard 1992). Cropland comprises 104,678 ha (258,593 acres) in the Gallatin Valley with 40,865 ha (100,950 acres) under irrigation (U. S. Department of Commerce 1992). An additional 162,744 ha (402,036 acres) are classified as grazing lands (U. S. Department of Commerce 1992). Hay and barley comprise 84% of the irrigated lands with wheat, seed potatoes, and oats planted on the remaining irrigated lands (Montana Agricultural Statistics Service 1994).

West Gallatin River irrigation water is removed by gravity-fed canals and applied by above ground sprinkler systems and flood irrigation (Howard 1992). The