Upper Shields River Watershed

Water Supply and Irrigation Efficiencies Investigations
1999-2005

Montana Department of Natural Resources and Conservation and
Upper Shields Watershed Association

DNRC Report: WR 3.B.3 USR Upper Shields River
Helena, Montana
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Introduction

The Upper Shields Watershed Association is a group of local citizens that seeks to manage natural resources in the watershed in a way that preserves the rural and ranching way of life. The work of the Association is supported by the Park County Conservation District, and state and federal agencies also provide assistance. The Association's area encompasses the Shields River watershed upstream of Clyde Park, Montana.

This project was initiated by the Association to address the following goal in its 2000 watershed plan: "To optimize streamflows within the watershed to maximize benefits to fish, wildlife, and agricultural users". In the plan, improving delivery system and on-farm irrigation water use efficiencies and increasing water availability during the late summer have been identified as ways towards reaching these goals.

This report describes the water supply and demands for irrigation from the Shields River upstream of the headgate for the Big Ditch as depicted in Map 1. It describes the irrigation systems and the efficiencies of these systems. Recommended improvements for offsetting some of the water supply problems are identified at the end of this report.

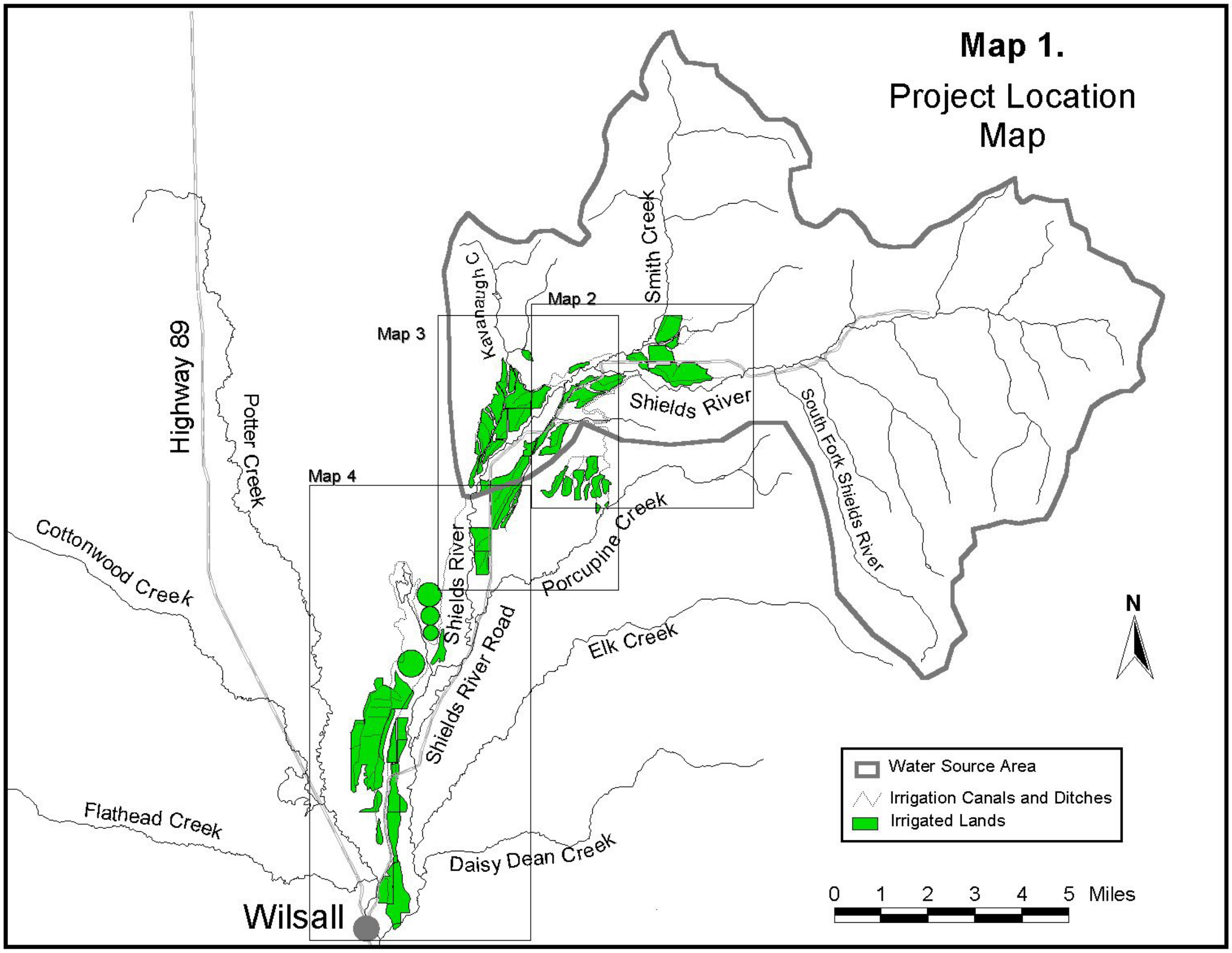
Project Design

The project began with site reconnaissance and preliminary data collection during the 1999 irrigation season. Streamflow and canal measuring sites were established during 2000, with data collected during the 2000 through 2005 irrigation seasons. Data were collected to describe the following: (1) the water supply, (2) the water demands for irrigation, and (3) the efficiencies of the irrigation systems. Only streamflow data were collected during the 2005 season. The potential for new reservoir storage in the watershed also was assessed.

To determine the water supply, inflows to the project area were measured. A continuous stream gaging station was established and operated during the 2000-2005 seasons on the Shields River at the county road bridge near the Rennie Ranch (see Photo 1 and Map 2). This upper Shields gage provides a good record of Shields River inflows to the project area from higher elevations, with the exception of some water that is diverted from the South Fork of the Shields to irrigate lands in the Porcupine Creek drainage. Inflows from Smith Creek, the largest tributary of the Shields in the study area, were monitored about once every two weeks during the irrigation season. Other tributary inflows were measured or estimated periodically.

The Hoyem family monitored flows in the Shields River further downstream at the Hoyem Bridge during the 2000, 2001 and 2002 seasons (see Map 3). The U.S. Geological Survey (USGS) operated a stream gage in the vicinity of the present location of the Hoyem Bridge from 1935-1957, and the data collected here during 2000-2002 were valuable in making comparisons to these older streamflow records. The amount of water leaving the project area via the Shields River was monitored at a continuous gaging station that was installed just below the diversion for the Big Ditch on the Holliday Ranch (Map 4).

Map 1. Project area location map.



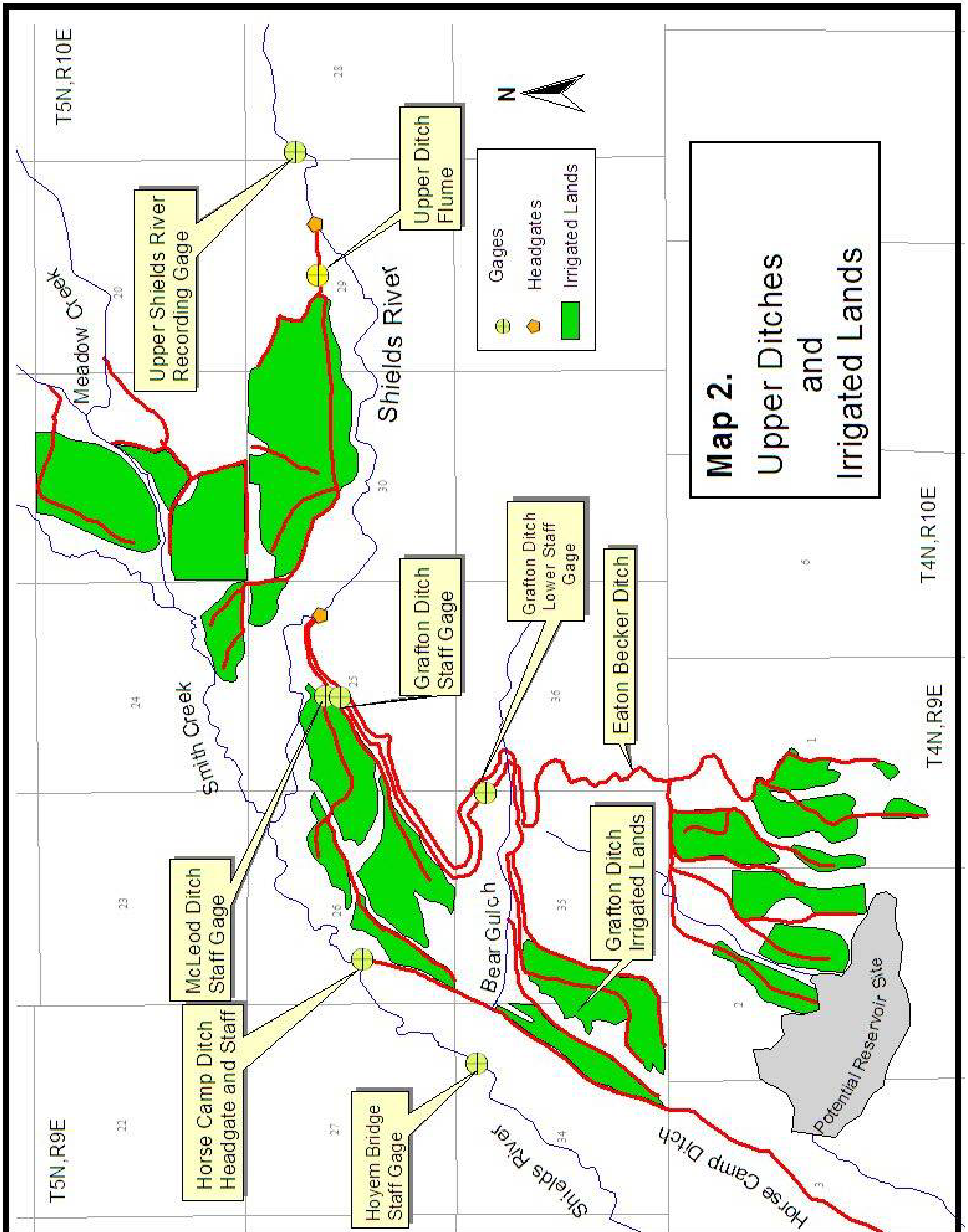
Irrigation diversions on most of the ditches were measured during the 2000-2004 seasons. Diversions that were not measured were estimated by comparing upstream and downstream measured flows on the Shields River system. A continuous recording station was established to determine diversions down the Big Ditch, the largest irrigation canal in the project area (photo 2). Other measuring stations were established on the ditches during the course of the study to determine diversions and ditch losses.

Project area irrigated lands were mapped and categorized with a geographical information system (GIS). The first source of irrigated lands and canal information for the GIS was a water resources survey that was conducted by the state of Montana during the 1950s (State Engineer's Office 1951). The irrigated lands and canals mapped in this survey still are surprisingly representative of today, but changes have occurred. Some flood irrigation systems have been changed to sprinkler systems; some were converted during the duration of this study. Aerial photographs, field checks, NRCS data, and information from discussions with irrigators were used to update the irrigated lands inventory in the GIS. The irrigated lands and canals in the project are depicted in Maps 2, 3, and 4, as they existed at the start of this project.

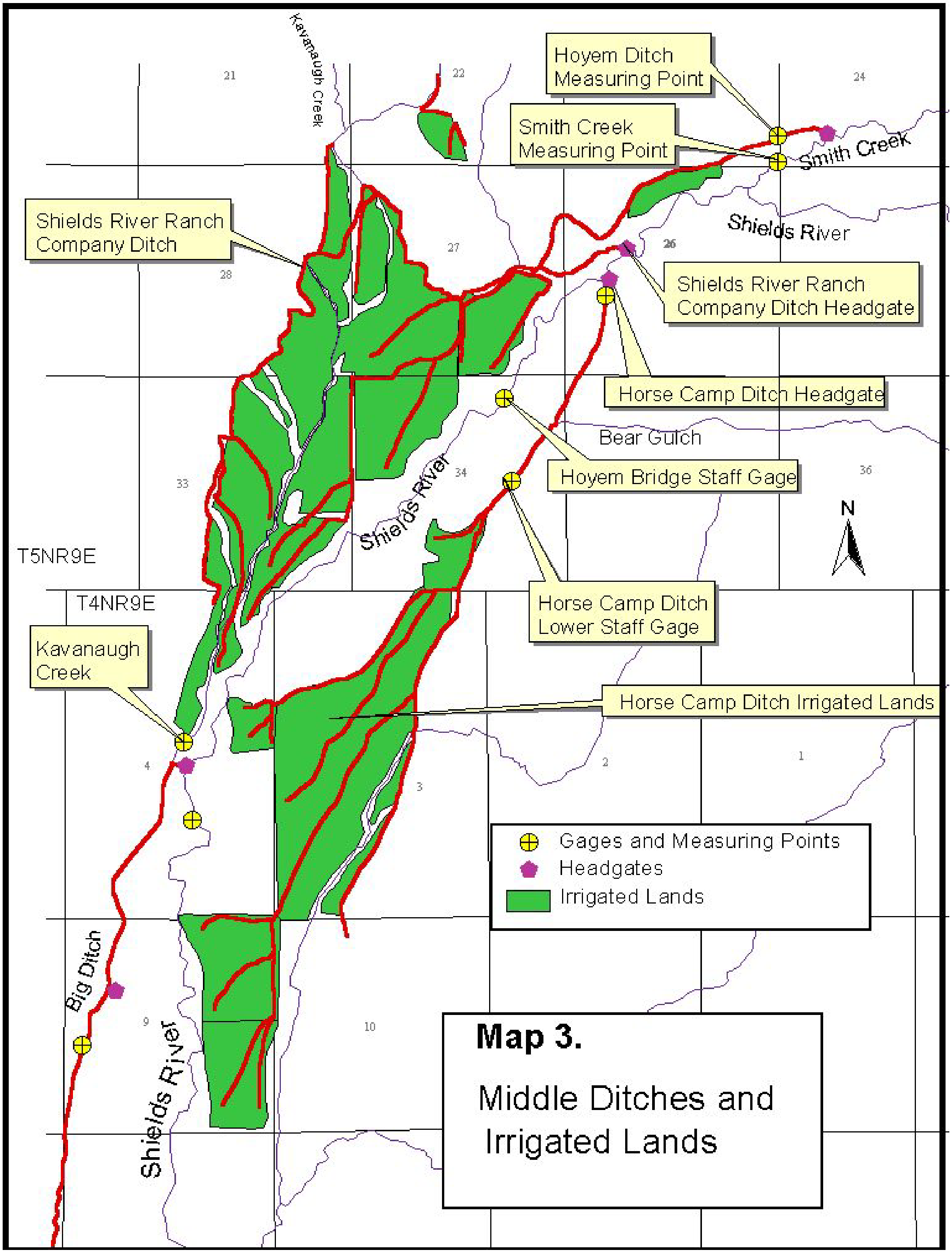
Photo 1. Upper Shields River Flow Monitoring Site.

Photo 2. Big Ditch below second headgate flow monitoring station.

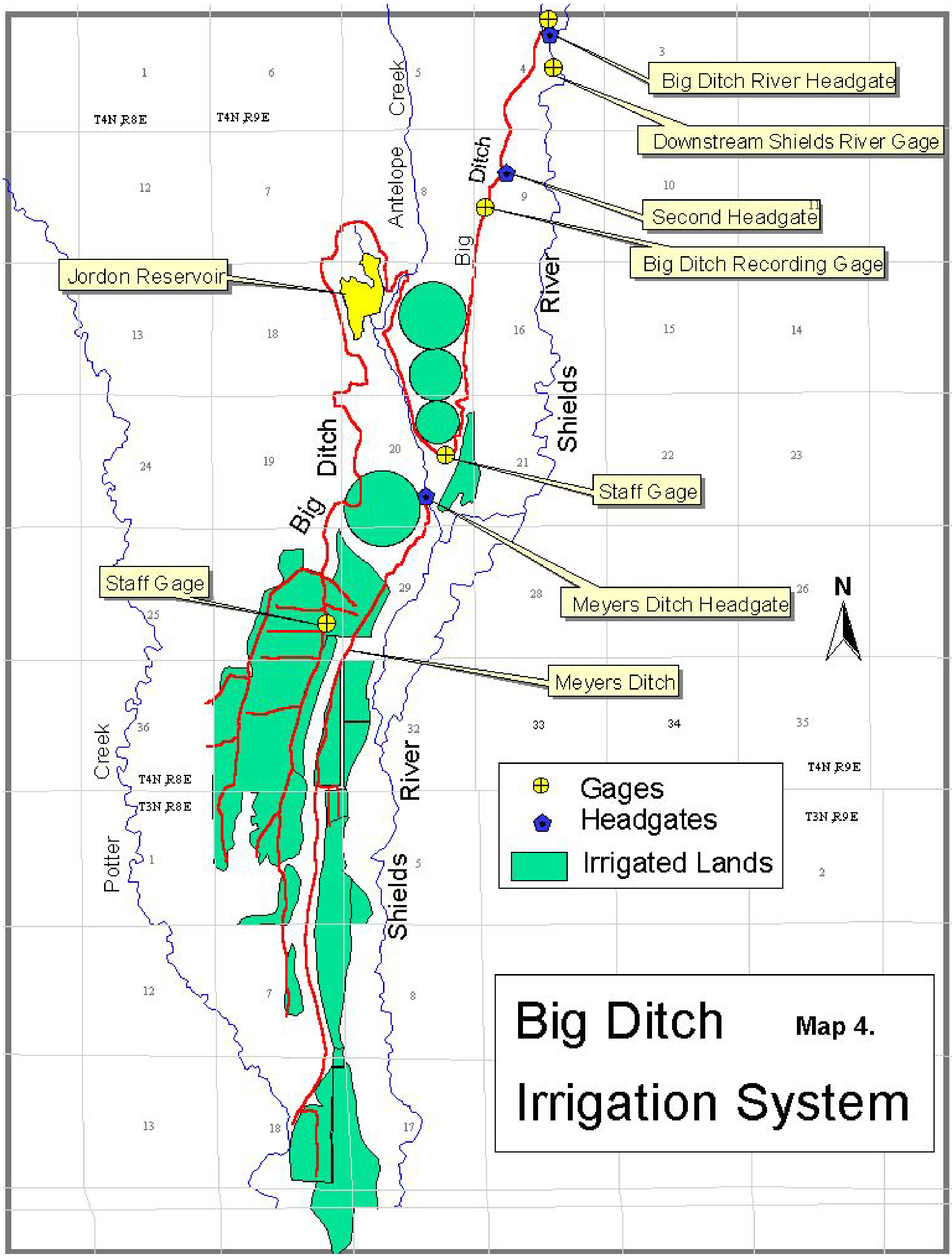
Map 2. Irrigated lands, stream, and ditches in upper portion of project area.



Map 3. Irrigated Lands, streams, and ditches in the middle portion of the project area.



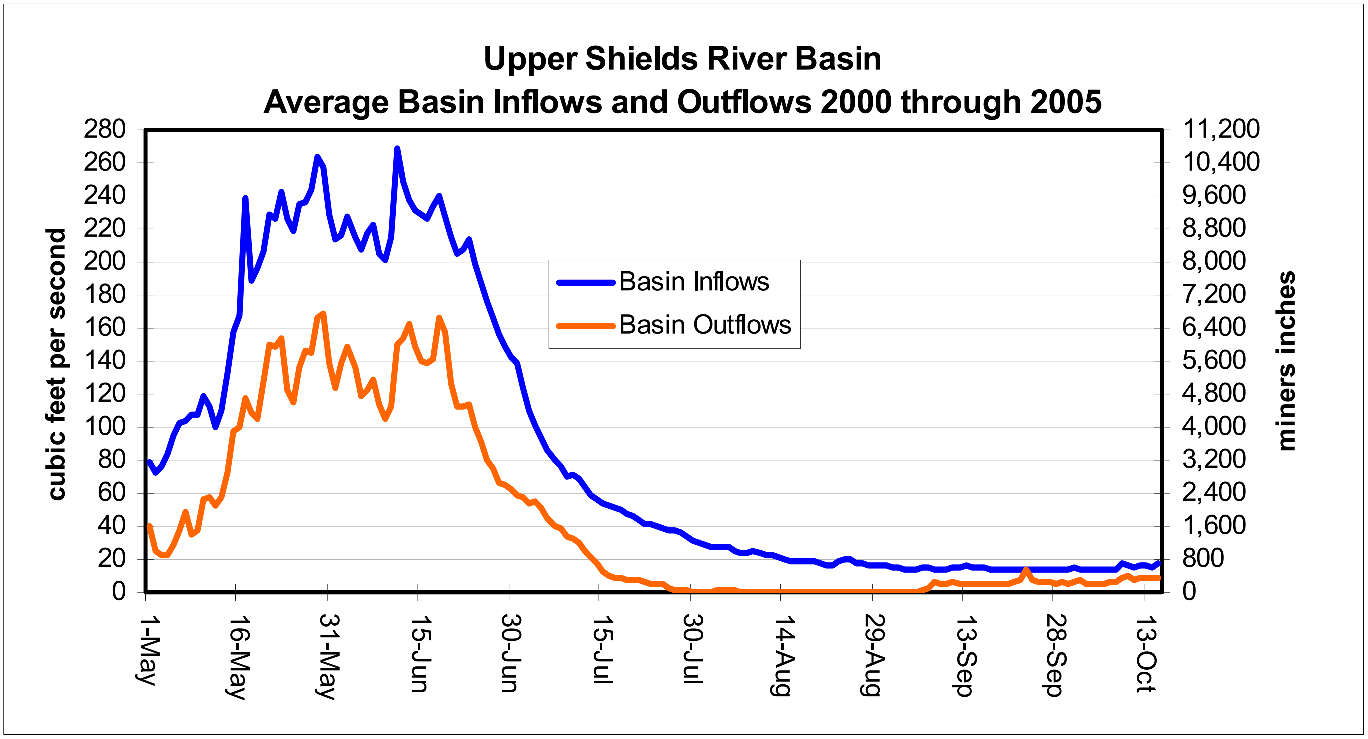
Map 4. Big Ditch irrigation system.



Water Supply

Most inflows to the project area are accounted for at the Shields River upper gaging station and Smith Creek measuring sites. Kavanaugh Creek and other smaller tributaries contribute flows to the basin early in the season and following rain, but during most of the time the contributions from these sources are small if any. The combined upper Shields River and Smith Creek inflows for the 2000 to 2005 period are graphed in Figure 1 and compared to measured outflows from the project area at the Shields River at Holliday's gaging site, just below the Big Ditch diversion. In Appendix A, similar flow graphs for each year of the 2000-2005 period are presented. Tabular flow data for the upper Shields River, Hoyem's, lower Shields, and Smith Creek stations are summarized in Appendix B.

Figure 1. Average upper Shields River basin inflows and outflows during the 2000 through 2005 period.



To characterize what types of a flow years 2000 through 2005 were, we compiled data from the U.S. Geological Survey (USGS) gaging station on the Shields River at its confluence with the Yellowstone River and compared the 2000-2005 flow data for the station to the longer-term irrigation season flow statistics (see Table 1). Total flows volumes for the May through September period were below the 1978-2005 average and median (middle) during all six years of the project. The 80th percentile flow is representative of flows during a dry year (flows would only be drier during 1 of every 5 years in the period of record). Two of the years during 2000-2005 were drier than the 80th percentile, and the 2004 flow volume was similar to the 80th percentile. Also telling is that the May through September flow volumes for 2000 and 2001 seasons were the two lowest during the entire 1978-2005 period that the USGS gage was operated.

Table 1. Shields River near Livingston USGS gaged monthly average flows in cubic feet per second (cfs) for 2000-2005 seasons compared to period of record (1978-2005) flow statistics for the station.

	May	June	July	August	September	Total May-September Volume (acre-feet)
2000	239	275	108	38.2	52.3	43,150
2001	224	294	108	40.5	44.5	43,036
2002	421	600	155	83.4	93.8	81,809
2003	854	512	98	46.5	53.5	95,022
2004	127	512	170	56.7	90.4	57,547
2005	569	718	203	65	73	98,513
1978-2005 Average	782	751	305	125	127	126,697
Median	717	658	203	97	113	111,885
80^{th} percentile	393	285	116	58	70	54,330

Water Demands Compared to the Water Supply And Irrigation Efficiencies

This project evaluated water use for about 5,100 acres of lands that are irrigated with water originating in the upper Shields River basin. About 600 acres of land in the Porcupine Creek drainage is irrigated with water diverted from the South Fork of the Shields River, but this irrigation was not evaluated. During 2000-2004, about 90% of the 5,100 acres of land was irrigated to grow grass or alfalfa hay, with the remaining 10% in grain. At the beginning of the study, about 80% of the land was irrigated with flood systems, about 12% with side-roll sprinklers, and the remaining 8% with center-pivot sprinklers. These ratios have changed some, because some new sprinkler systems have been installed. This section describes the overall demands, supplies, and efficiencies for the irrigation in the project area, followed by discussions that are specific to some of the individual irrigation systems.

The water demand for irrigation is a combination of the water needed for the crop to grow, and the water it takes to get that water from the river, over the field, and to the crop. Figure 2 is a generalized diagram that depicts where the water that is diverted for irrigation can go. Some diverted water can be lost to canal seepage. Excess water applied to a field can infiltrate below the root zone. But either of these forms of "lost" water could reach the groundwater table and later return to the stream as groundwater return flow. Extra water that is applied to carry water across a field during flood irrigation also can run off the bottom of a field and eventually return to a stream as surface return flow. Losses that can not be recovered could include evaporative losses from the surface of a canal, or water that is used by phreatophytes that grow along the edge of a canal or along the margins of an irrigated field.

The two general types of irrigation in the Shields River Watershed are flood and sprinkler irrigation. Sprinkler irrigation systems generally are operated to meet shorter-term crop demands by applying water to a field, when it is needed, at a uniform rate. In contrast, flood irrigated fields generally are irrigated less frequently and the water is applied at a much higher rate. With flood irrigation, the goal is to store as much water as possible in the soil so that there is adequate moisture to see the crop through until the field can be irrigated again. Because sprinkler systems generally require less water to be diverted per acre than flood systems, they are considered to be more efficient. The efficiency of the delivery system may not match that of the field system. For instance, water is often conveyed from the river through old earthen ditches to efficient new center-pivot sprinkler systems. As depicted in Figure 2, much of the water that is “lost” due to field or delivery system inefficiencies will eventually return to the stream as surface or groundwater return flow.

Figure 2: A generalized irrigation water supply diagram.

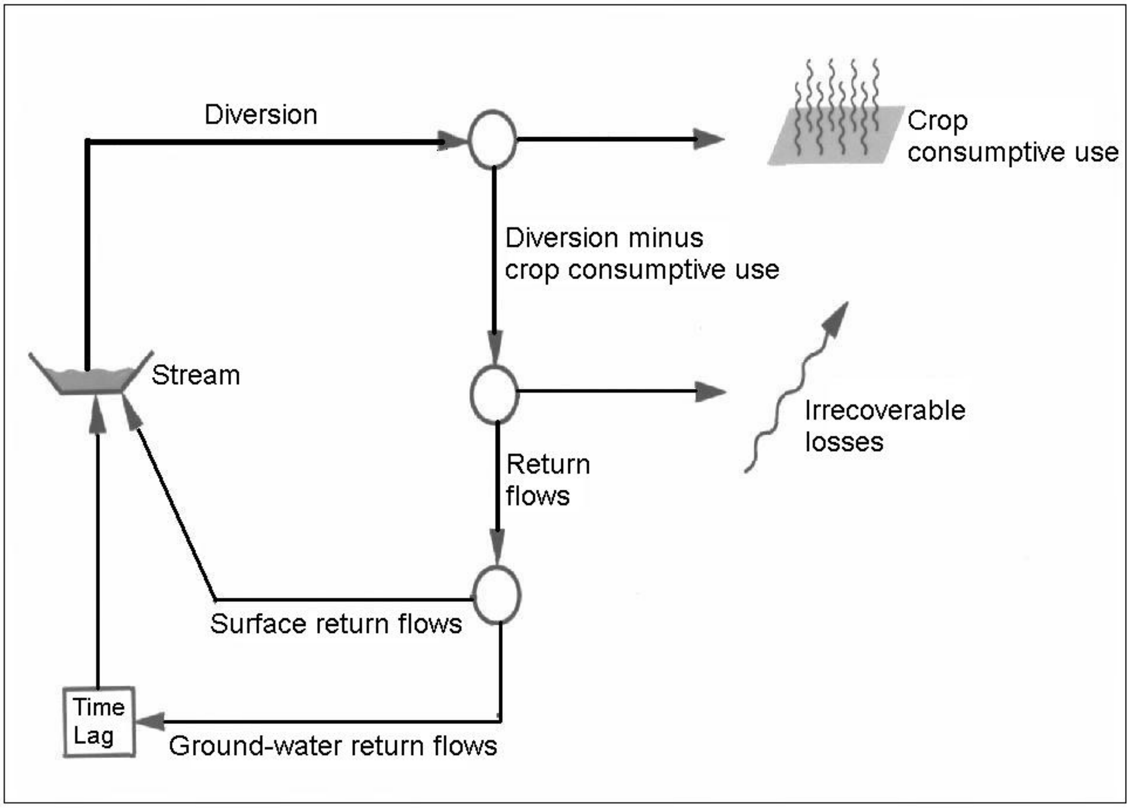


Table 2 contains estimates of overall irrigation water requirement, total water diversions, and available water supplies for the Upper Shields River Watershed by month. The irrigation requirements were estimated by:(1) computing the theoretical maximum net irrigation requirements for a dry year with the NRCS TR-21 program and multiplying this requirement by a factor of 0.7 to account for down time due to haying and other operational constraints; (2) applying this irrigation requirement to the full 5,100 acres of irrigated land for May, June and early July, but to only 4,100 acres later in the season (because much of the land in the upper portion of the project area is not irrigated past the first cutting of hay and some of the land is in grain); and (3) dividing this irrigation requirement by an estimated overall irrigation efficiency of 30 percent. The 30 percent is an approximate efficiency for this watershed where 80 percent of the land is in flood irrigation (where a typical efficiency might be 25 percent) and the remaining 20 percent of the area is sprinkler irrigation (where a typical efficiency might be 50 percent). Also, the 30 percent seems reasonable because the computed annual irrigation volume at this efficiency is similar to that diverted, if we take into account that irrigators would have diverted more water during late July, August, and September had it been available. The average water supply for the 2000-

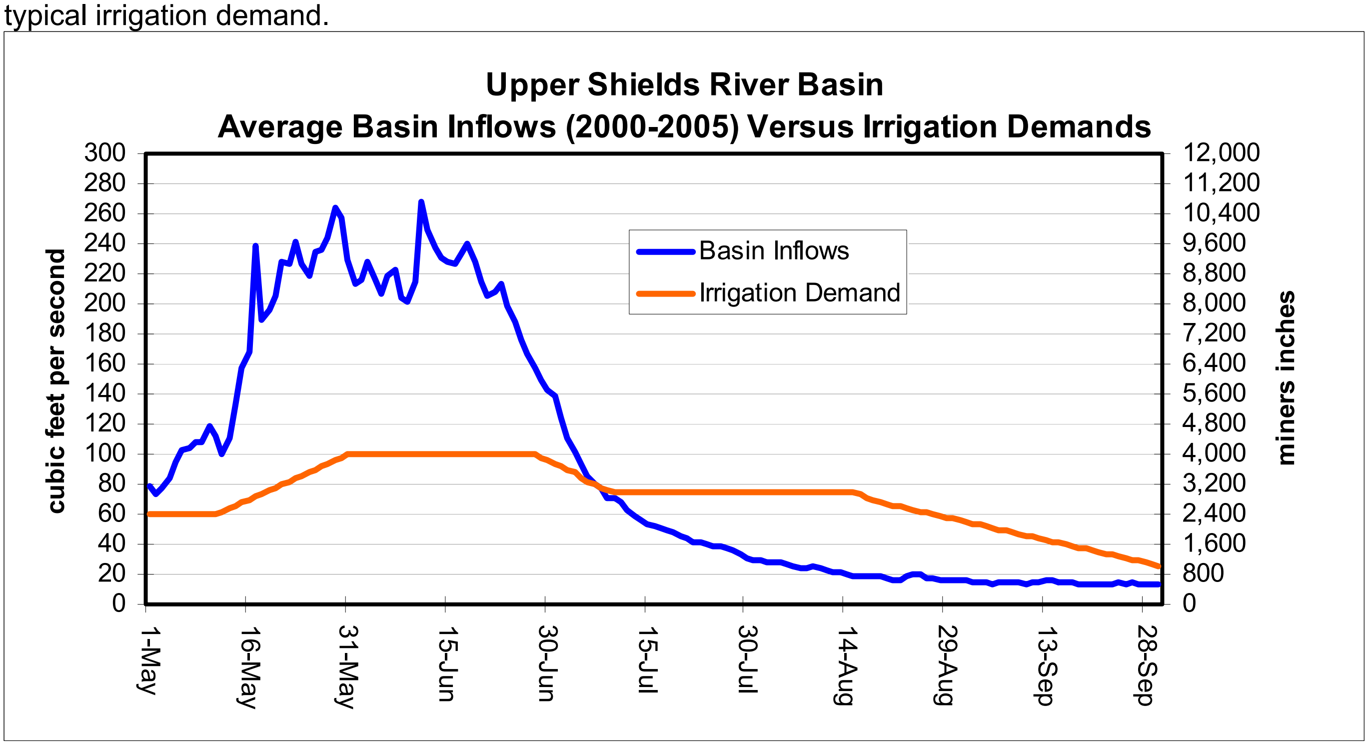
2004 seasons is presented in the table, as is that for the driest year. It is interesting to compare the water supply to the water demands and actual diversions.

Table 2. Water diversions and the average water supply for the 2000-2004 irrigation season, and 2001 season compared to computed irrigation water requirements (all values are in acre-feet).

Month	Estimated irrigation requirement (acre-feet)	Average water Diverted during the 2000-2004 irrigation season	Average water Supply during the 2000-2004 Seasons	Water supply during the driest season (2001)	Water diverted during the 2001 irrigation season
May	2,200	3,800	9,500	9,200	5,700
June	3,500	5,900	11,200	9,400	4,900
July	5,500	2,900	3,400	3,300	2,500
August	3,900	1,100	1,200	1,100	1,200
September	1,900	400	800	700	650
Totals	17,000	14,100	26,100	23,700	15,000

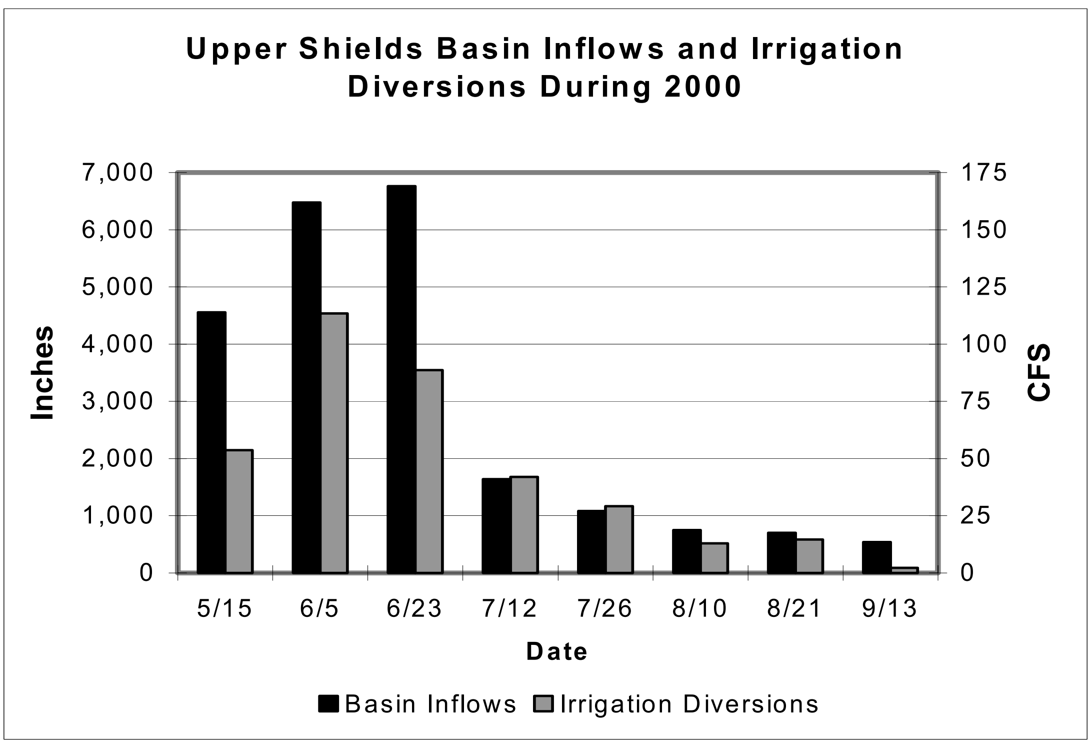
The monthly and annual water diversions in Table 2 were computed using measured and estimated canal flows. Similarly, the total water supply values were computed using flow data collected during 2000-2004 for the Shields River and Smith Creek. We found that irrigation demands usually started in early May and peaked at about 100 cfs during late May and June. Following about the first of July, demands decreased some because many fields are not irrigated past the first cutting of hay. By mid July, there usually was not enough water to supply all the demands and this condition persisted to the end of the irrigation season. This is demonstrated graphically in Figure 3 where typical irrigation demands (based on Table 2 and inflow-outflow measurements) are compared to the average water supply for the period.

Figure 3. Upper Shields River basin average water supply for the 2000-2005 period compared to a typical irrigation demand.



During the 2000 through 2004 irrigation seasons, streamflows and canal flows were measured about once every two or three weeks. Figure 4 depicts basin inflows and irrigation diversions, during the time of each field visit for the 2000 season. Similar graphs for other years of the study are presented in Appendix C. Note that diversions exceeded 100 cfs (4,000 inches) during June. Diversions were high then because irrigators were taking as much water as possible, while it was available, to flood irrigate fields. Although all of this water was not immediately needed by the crop, some of it was stored in the soil profile and available for later use. Another reason that May-June, 2000 diversions were high was because the spring was unusually warm and dry. After the first cutting of hay in early July, the water supply was not enough to meet the irrigation demand, water users were diverting less, and some ditches were turned off. This was generally the case in other years too: by about early July, the irrigation demand began to exceed the water supply. By late August of 2000, the available water was less than one-fifth of what may have been needed to meet demands, and these conditions persisted into early September. Flows improved some during the latter part of September, when it finally rained, but by that time most of the irrigation ditches had long since been shut down and few were reopened. Similar irrigation patterns occurred in the other years. Also note that at times the computed diversions were greater than the computed supply. This was probably due to the reuse of irrigation return flows, although return flows from much of the irrigation return to the Shields River below the study area.

Figure 4. Basin inflows versus irrigation during the time of 2000 site visits to the project area.



Discussion specific to the major irrigation ditches and the lands that they supply

Big Ditch

The Big Ditch is the largest irrigation canal in the project area and water rights for it are relatively early in priority date. The ditch is about 12 miles long. It supplies water to about 2,200 acres of irrigated land and some of this land is almost as far downstream as Wilsall. Most of this land is on the Jordan Bench, which is about 150 feet higher than the Shields River valley. Because the water has to get to this higher bench by gravity, the headgate for the Big Ditch is located quite a ways upstream from most of the land that is eventually irrigated. The Big Ditch feeds a system of smaller ditches. The largest is the Meyers Ditch, which supplies water to lower lands on the edge of the Shields River valley. Water is also diverted from the Big Ditch into Jordon Reservoir where about 900 acre-feet can be stored for later release into the Meyers Ditch. About 85% of the land in the system is irrigated for alfalfa or grass hay, and about 15% grain. About 53% of the lands are flood irrigated, 20% with center-pivot sprinklers, 25% with wheel line sprinklers, and 2% with gated pipe. Irrigation return flows and wastewater from the Big Ditch system go to the Shields River downstream of the project area, and can go to the east and the Shields River valley proper, or to the west into the Potter Creek drainage. Map 4 depicts the Big Ditch irrigation system.

Big Ditch average diversions for the 2000-2004 period are graphed in Figure 5. These are the flows diverted into the ditch at the second headgate shown on Map 2. This water is mostly from the Shields River, but also can include minor flows from the Kavanaugh Creek drainage and Cole Creek, which are captured by the Big Ditch. Further, some of the flows in the first segment of the Big Ditch bypass the second headgate and are sent back to the Shields River. Because the operations of the two headgates and tributary inflows complicate diversions, Table 3 has been included as an example to depict what the flow balance can be like during an irrigation season. Early during the season, Kavanaugh Creek inflows can be of some consequence. However, a substantial amount of water can be wasted back to the Shields River at the second headgate. By late in the season, neither of these factors was significant, and flow diverted from the Shields at the first headgate and that measured below the second were close to the same. Cole Creek flows are not included because they are generally much less than 1 cfs.

Referring back to Figure 5, diversions down the Big Ditch are highest during May and June, and generally peak at about 55 cfs (2,200 inches). This is due to irrigation demands, the need to fill Jordon Reservoir, and the desire to take advantage of available water supply while it lasts. Diversions then steadily decline as the available flows dropped. Usually by late August, there is little water to divert down the ditch and most of the ditch users have stopped irrigating.

Figure 5. Average Big Ditch diversions during the 2000-2004 irrigation season.

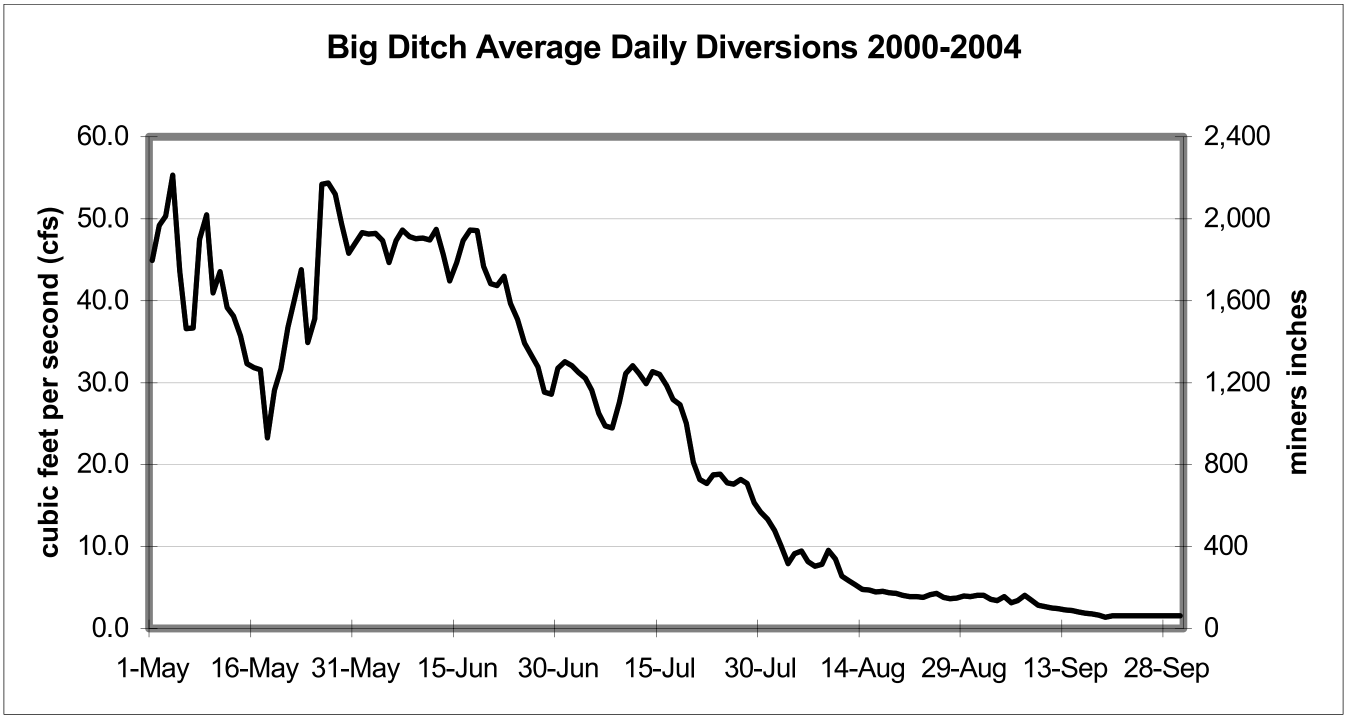


Table 3. Big Ditch flow balance during the 2000 irrigation season in cfs and (inches).

Date	Measured diversion down Big Ditch below second headgate (A)	Inflow from Kavanaugh Creek (B)	Wasted back to Shields River (C)	Estimated flow diverted from Shields River at first headgate (A-B+C)
April 28	38.1 (1,520)	3.8 (150)	11.9 (480)	46.2 (1,850)
June 5	51.7 (2,070)	13.6 (540)	5.6 (220)	43.7 (1,750)
July 11	24.8 (990)	2* (80)	1* (40)	23.3 (950)
July 26	17 (680)	1* (40)	0.5* (20)	16.5 (660)

* visual estimate of flow rate

In Table 4, the water diverted down the ditch by month is compared to the computed demands. The methods used to compute these demands are the same as those described at the beginning of this section for the watershed in its entirety. The amount of water diverted down the ditch early in the irrigation season exceeded the theoretical demand for the reasons described above. After early July, irrigation demands exceeded the available water supply. During August, the water supply was far below that needed, and no water was used during September. Releases of water from Jordon Reservoir probably ease late-season shortages, but the reservoir water only can be used on lower lands in the river valley, and not on the Jordon Bench.

Table 4. Computed irrigation need compared to the amount of water diverted down the Big Ditch during the 2000-2004 irrigation seasons.

Month	Computed Irrigation Need (acre-feet)	Diverted 2000 (acre-feet)	Diverted 2001 (acre-feet)	Diverted 2002 (acre-feet)	Diverted 2003 (acre-feet)	Diverted 2004 (acre-feet)
May	1,000	2,100	2,900	1,000	100	2,900
June	1,500	2,700	2,200	2,700	2,400	2,100
July	2,400	1,400	1,600	1,600	1,400	2,600
August	1,700	300	300	700	120	740
September	800	70	100	200	70	0
Total	7,400	6,600	7,100	6,200	4,090	8,340

There are several ranches that irrigate with Big Ditch water. The ditch users generally share the flow of water in the ditch based on their estimated crop need and visual estimates of the flow at various points on the system. However, the division of flow was generally based on visual estimates and not measured. At the request of the ditch users, DNRC installed a flume on the lower portion of the Big Ditch prior to the 2002 irrigation season in Section 30, Township 4 north, Range 8 east (see Photo 3). The flume can be used to balance flow distribution between the users on the upper and lower portions of the ditch.

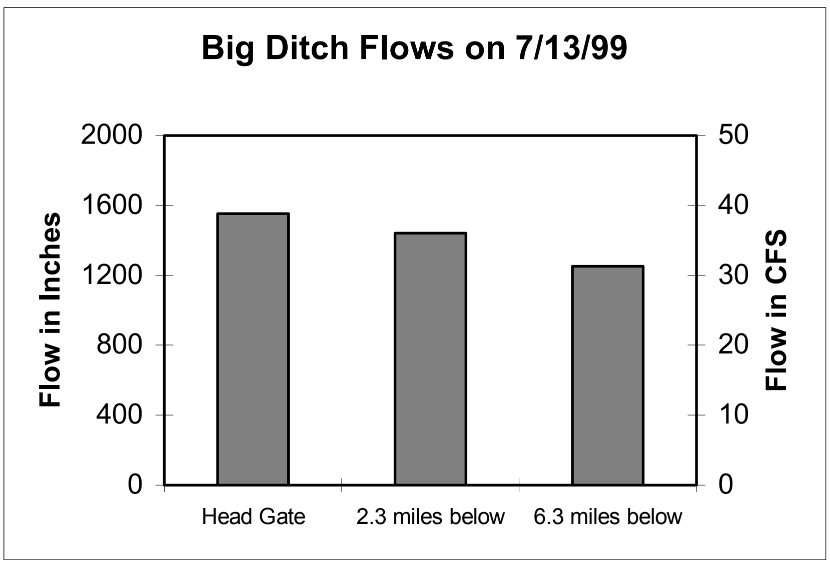
Photo 3. Ramp flume that was installed on the Lower Big Ditch.

The water users on the Big Ditch have long suspected that a substantial amount of the water that they divert is being lost to ditch seepage. We investigated seepage losses by measuring the Big Ditch at various locations--accounting for the many turnouts--to estimate a water balance for the system. The first measurements were taken in 1999 for the first 6.3-miles of the canal, from the headgate to where after the ditch flows around Jordon Reservoir. There was no water being removed from this segment at the time, and a loss of about 20 percent was computed (see Figure 6). We took more comprehensive measurements of the ditch system on

June 25, 2002; July 31, 2002; and July 1, 2003. These measurements are summarized in Appendix B. We computed total ditch losses to be from about 25% to 40% of the water diverted, with a highest absolute loss of about 12 cfs (490 inches) when about 43 cfs (1,700 inches) was being diverted down the ditch.

It is important to keep in mind that these ditch losses are not necessarily gone from the system. Some of the losses could have flowed into Jordon Reservoir or Antelope Creek, where they could be recaptured and used. There are seepage areas in the Shields Valley down-gradient of the Jordon Bench, it has been postulated that the water source for these seeps is leakage from the Big Ditch. It also is possible that water in the seepage zones originates, in part, from excess irrigation water that has been applied to the fields on the Jordon Bench.

Figure 6. Big Ditch seepage flow losses during 7/13/99.



Horse Camp Ditch

The Horse Camp Ditch supplies water to about 760 acres. All of the fields were flood irrigated at the beginning of the study, but the lowermost fields in Section 9 (see Map 3) were converted to wheel-line sprinkler irrigation during 2003 and 2004. This ditch has one of the earliest priority water rights in the project area. Generally, about 85% of the land irrigated by the Horse Camp Ditch is in hay and the remainder is in grain. In Table 5, estimates of flow diversions down the Horse Camp Ditch during 2000-2004 are compared to computed irrigation demands. The monthly diversion estimates we present for the Horse Camp Ditch and the remainder of the ditches are not as accurate as those for the Big Ditch because they are based on periodic ditch flow measurements (once every two-to-three weeks during the irrigation season) rather than continuous recorded flow data.

Table 5. Estimated Monthly diversions down the Horse Camp Ditch compared to computed irrigation demands.

Month	Computed Irrigation Demand (acre-feet)	Estimated 2000 Diversions (acre-feet)	Estimated 2001 Diversions (acre-feet)	Estimated 2002 Diversions (acre-feet)	Estimated 2003 Diversions (acre-feet)	Estimated 2004 Diversions (acre-feet)
May	360	800	570	140	70	800
June	520	780	350	840	400	580
July	810	630	600	310	660	630
August	580	350	610	360	570	380
September	280	110	330	220	250	0
Totals:	2,550	2,670	2,460	1,870	1,950	2,390

This information indicates that water supplies in this ditch generally are more than adequate to supply demands early during the irrigation season, but often less than adequate late in the season. However, from a seasonal standpoint, the water diverted down the ditch approximates the computed demand. For the flood irrigated fields, some of the excess water that is applied early might be stored in the soil profile and available to the crop later in the season, when there is less irrigation water available.

Flows on the Horse Camp Ditch at the headgate and where the Shields River Road crosses the ditch about one mile downstream were compared. On average, the ditch gained about 1.4 cfs (56 inches). The sources of this gained water are springs and possibly return flows from higher irrigated lands, such as those irrigated by the Grafton Ditch.

Grafton Ditch

About 160 acres of hay is flood irrigated with water supplied by the Grafton Ditch. The ditch was generally only operated from when it cleared of snow and ice during the spring, until the first cutting of hay in early July. In Table 6, estimated monthly irrigation diversions are compared to computed demands. Note that annual irrigation diversions are quite a bit higher than estimated crop needs. This probably is due, in a large part, to high ditch losses. The ditch is about 3 miles long (see Map 2). Diversions into the ditch were measured and compared to the ditch flow about 1.6 miles downstream, just before the ditch crosses Bear Gulch and before any irrigation turnouts (Table 7). Water losses from the first half of the ditch were measured to be from about 25-to-35 percent. Some of these losses could be through ditch seepage, but surface leakage was observed at several locations.

Table 6. Estimated Monthly diversions down the Grafton Ditch compared to computed irrigation demands.

Month	Computed Irrigation Demand (acre-feet)	Estimated 2000 Diversions (acre-feet)	Estimated 2001 Diversions (acre-feet)	Estimated 2002 Diversions (acre-feet)	Estimated 2003 Diversions (acre-feet)	Estimated 2004 Diversions (acre-feet)
May	70	100	260	50	60	460
June	110	700	220	510	540	400
July	190	0	0	30	130	50
Totals:	370	800	480	590	730	910

Table 7. Flows diverted into the Grafton Ditch compared to flows measured 1.6 miles downstream.

Date	Flow at Headgate	Flow near Bear Gulch
7/13/99	6.81 cfs (272 inches)	4.44 cfs (178 inches)
6/5/00	10.1 cfs (404 inches)	7.45 cfs (298 inches)
6/23/00	16.2 cfs (648 inches)	10.8 cfs (432 inches)

McLeod Ditch

The McLeod Ditch supplies water to about 260 acres of flood irrigated hay fields (see Map 2). Diversions during the early part of the study were below crop needs, but were similar during the latter part of the study (see Table 8). The ranch had changed managers during the time of this project, and this could be a reason for the change in water use patterns.

Table 8. Estimated Monthly diversions down the Grafton Ditch compared to computed irrigation demands.

Month	Computed Irrigation Demand (acre-feet)	Estimated 2000 Diversions (acre-feet)	Estimated 2001 Diversions (acre-feet)	Estimated 2002 Diversions (acre-feet)	Estimated 2003 Diversions (acre-feet)	Estimated 2004 Diversions (acre-feet)
May	110	30	80	50	30	280
June	180	110	80	380	320	300
July	310			20	90	20
Totals:	600	140	160	450	440	600

Hoyem Ditch

The Hoyem Ditch diverts water from Smith Creek to a side-roll sprinkler system to irrigate about 80 acres of hay (see Map 3). Another 26 acre field is sub-irrigated with seepage water from the Hoyem Ditch. The Hoyem Ditch is about 2 miles long. Flows in the Hoyem Ditch during 2000-2004 were measured and these measurements are summarized in Table 9.

Measured ditch losses for the upper portions of the ditch were 20 to 25 percent (Table 10). Water was observed to be leaking or seeping from the ditch in several places. Leakage was especially evident where the ditch crosses a rocky hillside, starting at about one-half mile downstream from the headgate. High ditch losses is a likely reason why the measured diversions are usually higher that the computed irrigation requirements.

Table 9. Estimated Monthly diversions down the Hoyem Ditch compared to computed irrigation demands.

Month	Computed Irrigation Demand (acre-feet)	Estimated 2000 Diversions (acre-feet)	Estimated 2001 Diversions (acre-feet)	Estimated 2002 Diversions (acre-feet)	Estimated 2003 Diversions (acre-feet)	Estimated 2004 Diversions (acre-feet)
May	50	550	210	90	190	350
June	70	330	260	350	120	410
July	110	80	50	30	10	90
August	80		120			50
September	40					
Totals:	350	960	640	470	320	900

Table 10. Flows Measured in the Hoyem Ditch during the 2000 irrigation season.

Date	Near Headgate	Downstream
May 15	11.5 cfs (460 inches)	9.2 cfs (368 inches): about .5 miles downstream
June 23	5 cfs (200 inches)	3.77 cfs (51 inches): about 1.1 miles downstream

Shields River Ranch Company Ditch

The Shields River Ranch Company Ditch is about 5.5 miles long and irrigates about 790 acres of land. It was generally operated until about the first cutting of hay in early July. The ditch was measured during the 2001, 2003, and 2004 seasons and measured flows are summarized in Table 11. Some of the lands that are irrigated by this ditch also can receive water from the Kavanaugh Creek drainage, but flow from this drainage generally is only available very early during the irrigation season.

Table 11. Estimated Monthly diversions down the Hoyem Ditch compared to computed irrigation demands.

Month	Computed Irrigation Demand (acre-feet)	Estimated 2001 Diversions (acre-feet)	Estimated 2003 Diversions (acre-feet)	Estimated 2004 Diversions (acre-feet)
May	350	1,100	0	1,000
June	540	1,000	900	1,100
July	940		250	400
Totals:	1,830	2,200	1,150	2,500

Diversions were generally a little higher than the computed demands (Table 9). This is likely because the ditch is long and conveyance losses may be high, and also because almost all of the lands on this ditch system are irrigated with flood systems.

Other Ditches

Some of the ditches in the upper portion of the study area were not measured throughout the project. Diversions by these ditches were usually estimated in composite, by subtracting the measured canal diversions and flows at the Hoyem Bridge or the lower Shields River at Holliday's gage from measured Shields River plus Smith Creek inflows. Analysis of this data indicate that flow reductions due to these ditches were up to about 800 inches (20 cfs) during May, June, and early July. Return flows from these irrigation systems probably return to the river within the project area, or to tributaries where they could be captured by ditches. After the first cutting of hay in early July, most of these ditches were shut off. The exception was the Eaton Becker Ditch which had water diverted down it throughout the season at a rate that was estimated visually to be under 100 inches (2.5 cfs) late in the season.

In 2004, a steel ramp flume was installed on the largest of these ditches--the first diversion from the Shields River below the upper gaging station (see Map 2). This ditch irrigates about 470 acres of land and generally was operated until the first cutting of hay in early July. Ditch flow observations during 2004 were as follows: May 11, 7.5 cfs (300 inches); May 25, 8.5 cfs (340 inches); June 25, 10 cfs (400 inches). At these flow rates the ditch would be diverting about 1,000 acre-feet of water during an irrigation season, which would be similar to a computed May through July demand.

It was also pointed out by one of the local irrigators that we had missed a small ditch in the lower portion of the study area during our analysis. In 2004 we located this ditch and took a couple of flow readings from a parshall flume on the ditch. It irrigates about 30 acres and water was being diverted down it early and late during the irrigation season. Diversions ranged from a high of about 5.5 cfs (220 inches) in early May, to about one-half of a cfs (20 inches) during September. Generally diversions down it were between 1 and 2 cfs (40 and 80 inches).

Potential for New Reservoir Storage

Because there are flows that leave the watershed during spring runoff, the Watershed Association asked that the potential for new water storage be assessed. There have been several potential storage sites identified in the watershed in the past (Montana Water Resources Board, 1969). And water users point out that Jordon Reservoir and Cottonwood Reservoir are two examples of storage projects in the watershed that have provided substantial benefits. To investigate the potential for new water storage in the basin, from a water-supply standpoint, a possible site that was identified by some Watershed Association members was assessed.

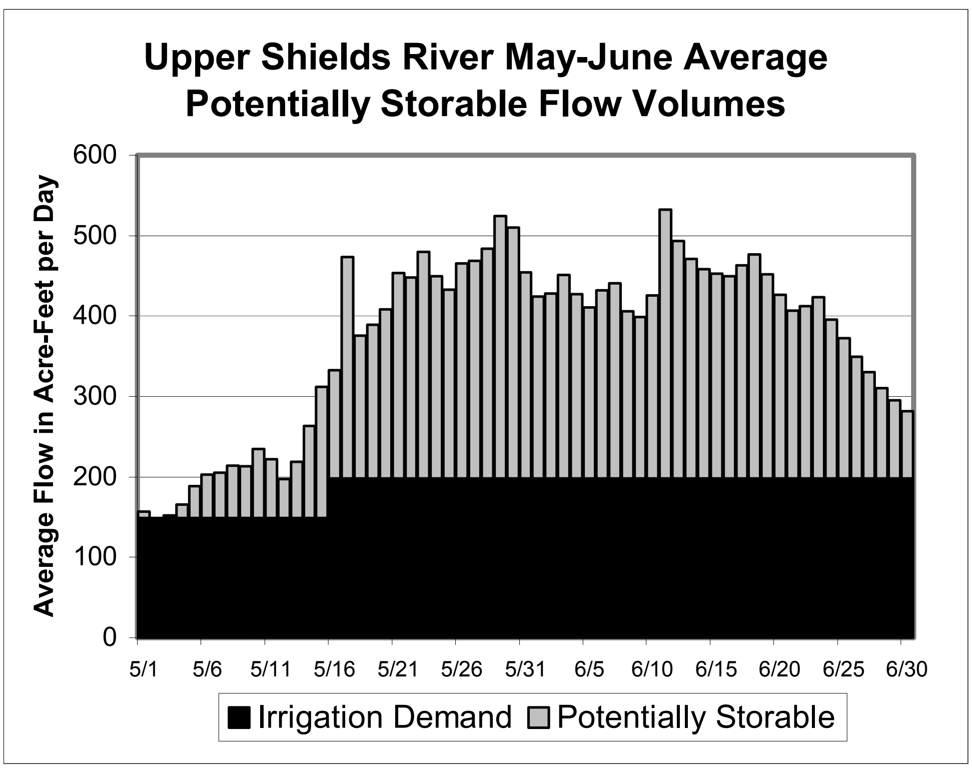
This potential site would be for an off-stream reservoir in Sections 2 and 3 Township 4 north, Range 9 east (see Map 2). Shields River water would be conveyed to the reservoir site along the route of the Grafton and adjacent Eaton Becker ditches for a distance of about 2.6 miles. Preliminary investigations indicate that a reservoir at the site might be able to store about 3,000 acre-feet at a dam height of about 25 feet. Water would be released from the reservoir and conveyed by a ditch to the Shields River, or into existing irrigation ditches.

The NRCS, evaluated the geology of the site to assess its suitability for a dam and identified further information that would be needed before a final determination on the suitability of the site could be made (Garsjo, 2000). Because this would be off-stream storage and because the drainage area at the proposed dam site is relatively small, the spillway requirements would be much smaller than if the dam were on the Shields River proper.

The best time to store water in a reservoir would be during May and June, when the snowmelt is occurring and when the water supply in the Shields River often exceeds the irrigation demands. Storing water off-stream any earlier in the spring at this site might be difficult because the ranchers say that typically the irrigation ditches at this elevation are generally not clear of snow and ice before May.

The combined Shields River and Smith Creek flow data collected at the upstream gaging station during 2000-2005 season were used as a starting point in determining how much water might be available for storage during May and June. Analysis of diversion and crop demand data indicate that, on average, about 3,000 inches (75 cfs) might need to be by-passed during early May, and about 4,000 inches (100 cfs) during late May and June to meet downstream irrigation demands. In Figure 7, average flows at the upstream gage during the 2000-2005 season are compared to estimated irrigation demands, with the remainder graphed as the potentially storable volume. On average of about 11,400 acre-feet of water may have been storable during May and June for the 2000-2005 period. In reality, it would be difficult to store all this water because the capacity of the supply canal would not be enough to convey the highest flows.

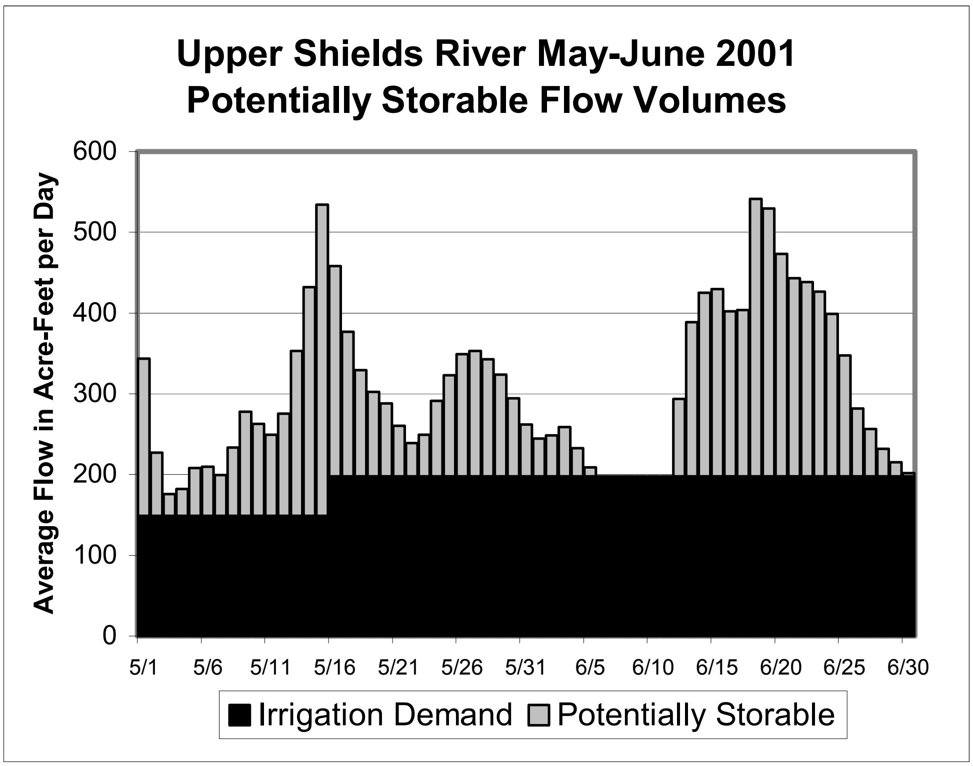
Figure 7. Upper Shields River Average May and June potentially storable flows (2000-2005 data).



Another way of approaching this same question would be to start with the volumes of Shields River water that left the study area during 2000-2005 period. This volume was recorded at a continuous gage that was operated on the Shields River at the Holliday Ranch, just below the headgate for the Big Ditch (see Map 4 and Figure 1). Again, it should be pointed out that some of the highest flows probably could not be stored due to supply canal capacity limitations. With this method of calculation, a similar volume of about 12,800 acre-feet on average may have been storable.

Another consideration is how much water might be available for storage during the driest of years. The year during this study that had the lowest May through June inflows was during 2001. Figure 8 summarizes potentially storable flows by day for 2001. During this year, about 7,200 to 8,700 acre-feet may have been available to store during May and June

Figure 8. Upper Shields River Average May and June potentially storable flows, 2001 data.



So far, these computations have not taken into consideration the water needs for downstream rights. The Montana Department of Fish, Wildlife and Parks has an instream flow reservation, with a 1978 priority date, for 41 cfs (1,640 inches) during May and 111 cfs (4,440 inches) during June. This reservation is for the Shields River at the mouth of Elk Creek near Wilsall. Because the Shields River would gain some flow from tributaries between the diversion for the Big Ditch and the mouth of Elk Creek, a rough estimate would be that a minimum flow of 25 cfs would be needed below the Big Ditch diversions during May and 80 cfs during June to meet this instream flow right. Subtracting these instream flow reservations would reduce the volume that could be stored by 6,300 acre-feet over the May through June period. The water needed for other irrigation water rights below the study area also would need to be investigated.

It has been pointed out that high spring flows serve a purpose for channel maintenance because they transport bedload in the stream and flush sediments, thereby maintaining fish habitat. These high flows also serve a function in maintaining riparian habitat. Concern has been expressed that diversions to storage, in conjunction with existing irrigation diversions, could reduce or eliminate runoff peaks, with resulting impacts to fisheries and riparian habitat. Before storable flow volumes could be quantified with more certainty, the flow rates and volumes needed for channel maintenance flows in the upper Shields River would need to be identified.

The question also came up as to whether it might be possible to store water during the winter. Besides the problems with snow and ice, there might only be limited opportunities for storing winter flows because of instream flow rights. The Montana Department of Fish, Wildlife and Parks has instream flow reservation for the upper Shields River of 11 cfs during November, 10 cfs during December, 7 cfs during January and February, and 9 cfs for March. The flow data we have collected indicate that natural inflows during the winter may not be much higher than these rates.

The water that is stored in a reservoir would likely be released when it was most needed due to low natural inflows, which generally would be from about mid-July through mid-September. For example, 3,000 acre-feet of stored water could be supplied at an average rate of about 34 cfs (1,300 inches)over 45 days. This amount may not be sufficient to erase the late season water supply problems in the basin, but it could help to ease water shortages or to provide some water for instream flows.

Recommendations

Improving irrigation efficiencies is often suggested as a method for easing water supply problems in a watershed, but care should be taken with this approach or unintended consequences could result. In the case of the Upper Shields River watershed, even at 100 percent irrigation efficiency the late season irrigation demands would still be much greater than the available water supply. For instance, to irrigate about 5,000 acres of irrigated land in the project area during August, when the crop irrigation requirement is about 5 inches, would require about 34 cfs (1,360 inches) of flow at 100 percent efficiency. This rate of flow was never available during August of the 2000 through 2004 seasons, and only during the first few days of August, 2005. In some ways, flood irrigation systems are an adaptation to the flow patterns of the Shields River and flood irrigation has some advantages for irrigators, especially to those with late priority date water rights. Flood irrigators take water when it is available, during May and June, and then spread it onto their fields in quantities that can far exceed the immediate demand. This may seem wasteful, but some of this excess water (perhaps 4-to-6 inches for a 3-foot loam soil) can be stored in the soil for later use by the crop. This same 4-to-6 inches of water could supply approximately a month of the crop demand, later during the summer when irrigation water is much scarcer. Sprinkler systems may not have the capacity to deliver early season water to the field in this quantity. And if they are operated to meet the more short-term needs of the crop, sprinkler systems might increase late-season irrigation demands on the river. It is important to keep in mind too that losses due to inefficient irrigation or ditch seepage are usually only temporary. Most of this water eventually will return to the Shields River, a tributary to the river, or will be intercepted by another ditch.

Water measuring devices could allow irrigators to better manage their water and could be used to distribute water by priority. As part of this project, a number of flumes were installed on main supply ditches and turnouts. We also established temporary measuring devices at the headgates for most of the ditches by installing staff gages and rating staff gage levels to measured canal flows. More permanent measuring devices could be installed at the headgates for the Big Ditch, Horse Camp Ditch, Grafton Ditch, McLeod Ditch, Hoyem Ditch, and Shields River Ranch Company Ditch.

Discussed below are some other recommendations specific to the various ditches and lands that they supply. Also included are other more general water management options that the Association may want to consider pursuing.

Big Ditch System

Knowing how much water is being diverted down the Big Ditch and what the flow is at key downstream locations is helpful to the Big Ditch users in managing their water. A gage was installed and operated below the second headgate on the Big Ditch during this study, but this gage was temporary and a more permanent measuring device should be constructed. The new measuring device could be used in conjunction with the concrete ramp flume that was constructed during 2002 on the lower portion of the ditch, and other smaller flumes that were installed on some of the turnouts.

Flows are diverted from the Big Ditch to fill Jordan Reservoir, and it would be helpful to have a measuring device to measure the diversions into Jordon Reservoir. This could be used in conjunction with a steel ramp flume that was installed below Jordan Dam to allow measurement of reservoir outflows into the Meyers Ditch.

A substantial amount of the water diverted down the Big Ditch is lost to seepage. The ditch users have done some work to control seepage at the places where it is most obvious. In a report to the Upper Shields Watershed Association, Compston (2002) described measures that had been taken to control seepage on the ditch in the past, and identified spots where higher rates of seepage are occurring and recommended some remedial measures. Controlling seepage losses elsewhere on the ditch would be more expensive because results of the synoptic flow measurements indicate that much of the seepage is occurring at relatively uniform rates along the entire length of the ditch (see Appendix D). PAM, a polyacrylamide sealant, was applied to the Big Ditch from the second headgate to Jordan Reservoir in an attempt to control seepage. With subsequent ditch flow measurements, we were not able to conclusively verify any decreases in seepage due to this treatment. However, area ranchers did indicate that they noticed an appreciable decrease in wet seepage spots down-gradient of the ditch following the treatment. We identified another spot where the ditch is visibly seeping up to about 0.5 cfs (20 inches) at a sharp bend where a coulee intersects the ditch ($NE^{1/4}$,$SE^{1/4}$,$NE^{1/4}$ Section 17, Township 4 North, Range 9 East). In instances where high rates of seepage are occurring on relatively short stretches of the ditch, it may be cost effective to install an impermeable liner such as the High Density Polyethylene type.

Over half of the land supplied by the Big Ditch system is flood irrigated. Converting land to sprinkler irrigation could increase the overall efficiency of the system, but also would have some potential drawback. For instance, converting to sprinkler irrigation (and possibly from a grass hay mixture to a solid stand of alfalfa) might increase late-season irrigation needs. Even with the early priority date for the Big Ditch, there often would not be adequate late season flows in the Shields River to meet all the demands. Compston (2002), identified in his report some fields to consider for conversion from flood to sprinkler irrigation and some other improvements that could be made to make the ditch system more efficient.

Early during the irrigation season, there can be inflows to the Big Ditch from Kavanaugh Creek downstream of the Shields River headgate. On the other hand, at times a significant amount of water is wasted back to the Shields River at the second headgate. Measuring devices could be installed on the ditch at the first and second headgates so that the ditch operator could then compare the flows between the two headgates and better balance them. The result could be lower initial diversions from the Shields River and less water wasted back to the river at the second headgate.

There is no formal administrative structure in place for operating the Big Ditch system. This can result in some misunderstandings regarding how much water needs to get to various locations on the ditch. The users should consider implementing some type of formal structure, such as a ditch association, so that operations can be standardized and formalized.

Horse Camp Ditch

Because water is diverted down this ditch throughout the irrigation season, it may be possible to add some flow to the about 3 miles of the Shields River between here and the Big Ditch by increasing the irrigation efficiencies on some fields supplied by the Horse Camp Ditch. The primary user on the ditch already has converted some land, at the lower end of the system, to sprinkler irrigation. The ditch users could assess the performance of these sprinkler systems and decide whether any further conversions would be beneficial.

Hoyem Ditch

Ditch losses from the Hoyem Ditch of 20-to-25 percent were measured. Reducing this loss could decrease the amount of water that needs to be diverted, and thereby increase the flow available downstream. There are some obvious leakage points in the ditch that could be sealed initially. The most evident is a stretch of the ditch where it crosses a rocky hill slope starting at about 1/2 mile downstream of the headgate. It might be cost effective to install an impermeable ditch liner along this section of the ditch, however some hay meadows down gradient of the ditch may be benefiting from this seepage. If the most obvious leakage points on the Hoyem Ditch are repaired, ditch conveyance efficiency could be measured again to determine if the leakage has been sufficiently reduced or if further work is justified.

Grafton Ditch

Ditch losses of 25-35 percent were measured in the upper segment of the Grafton Ditch, and it is likely that losses in the lower ditch are also high. There are many locations along the upper ditch where leakage is occurring. As with the Hoyem Ditch, the first step would be to walk the ditch and identify and repair the most obvious points of leakage. This could be followed by concurrent flow measurements to see how effective the repairs were and to determine if additional work is justified. Another possibility would be to combine this ditch and the Eaton-Becker Ditch--which runs parallel to it for about 2 miles--into a new improved ditch that more efficiently supplies the water needs for both systems.

Drought Management

The 2000-2005 irrigation seasons were relatively dry and two of the years were exceptionally so. During all years, irrigation demands generally started to exceed the supply by early July. And in some years, there were severe water shortages during early May, prior to the peak runoff. Although the irrigators communicate with one another and work through water short years as best they can, there is no coordinated plan for dealing with drought. The watershed group should consider drafting a drought plan. The plan could identify how water shortages are to be shared, and to set target flows at various points on the river for irrigation and instream needs.

Potential for New Reservoir Storage

During May and June of most years, there likely is water in the upper Shields River that could be stored, even after taking into account existing water rights. In this report, the potential water supply for a reservoir was analyzed, but there are many other questions that would need to be addressed before a water storage project could be built. If the Association decides to further pursue reservoir storage, the following issues would need to be investigated. Some of these issues are specific to the storage project that was examined as an example in this report; others pertain to potential water storage projects in general.

- A detailed topographic survey of any site would be needed to accurately determine how much water could be stored.

- For off-stream sites, the route of the water supply canal would need to be evaluated in detail. For the potential project presented in this report, one possibility would be to consolidate the Grafton and Eaton-Becker ditches into a single ditch that could supply the needs of these two ditches and also be used to fill the reservoir. The new ditch could be lined so that seepage losses would be minimized.

- Reservoir evaporation rates would need to be estimated to determine how significant such losses might be.

- For the example site, a topographic survey is needed to determine where water that would be released from the reservoir could be diverted back into the Shields River or to other ditches in the system.

- A detailed analysis of the geology at any potential site is needed to determine water-holding suitability, and for engineering and safety considerations.

- Water demands and prior rights downstream of the project area would need to be examined to more accurately determine how much water can be stored and when.

- An assessment of potential environmental impacts of a reservoir would be needed. This would include an analysis of how the reservoir might affect the instream flow right of the Montana Department of Fish, Wildlife and Parks. It also would need to include an analysis of the flows needed for channel maintenance requirements.
- For any storage site, easements from the landowners, on whose property the reservoir and the supply ditches would be located, would need to be obtained.
- Because water storage projects are expensive, it would need to be demonstrated that the project was financially sound and that there are funds to build it. Cost estimates would need to be prepared and compared to potential project benefits. Funding would need to be secured.

Instream Flow Leasing

During the 2000-2005 irrigation seasons, late summer flows in the Shields River were very low and late summer demands far exceeded the natural flows produced by the Shields River. Existing water rights ensure that a little flow remains in the river as far downstream as the Big Ditch, but there isn't enough water in the Shields River to meet all of the irrigation demands and to also provide for an instream flow below the Big Ditch diversion.

If more water were allowed to remain in the Shields River for instream flows, it would reduce that available for irrigation. Water leasing could be a way to provide an instream flow, while compensating ranchers for the value of this water. It might be possible for ranchers to offer leases for some of their late season irrigation water rights; or it might be possible to lease water that has been conserved by irrigation system improvements. A lease from a senior water user would be most valuable, because it could be protected downstream.

The Association may want to contact the Montana Department of Fish, Wildlife and Parks or private groups such as Trout Unlimited or the Montana Water Trust to see if they may be interested in leasing water from ranchers for instream flows in the Shields River. Individual ranchers could voluntarily lease water, if there is an interest.

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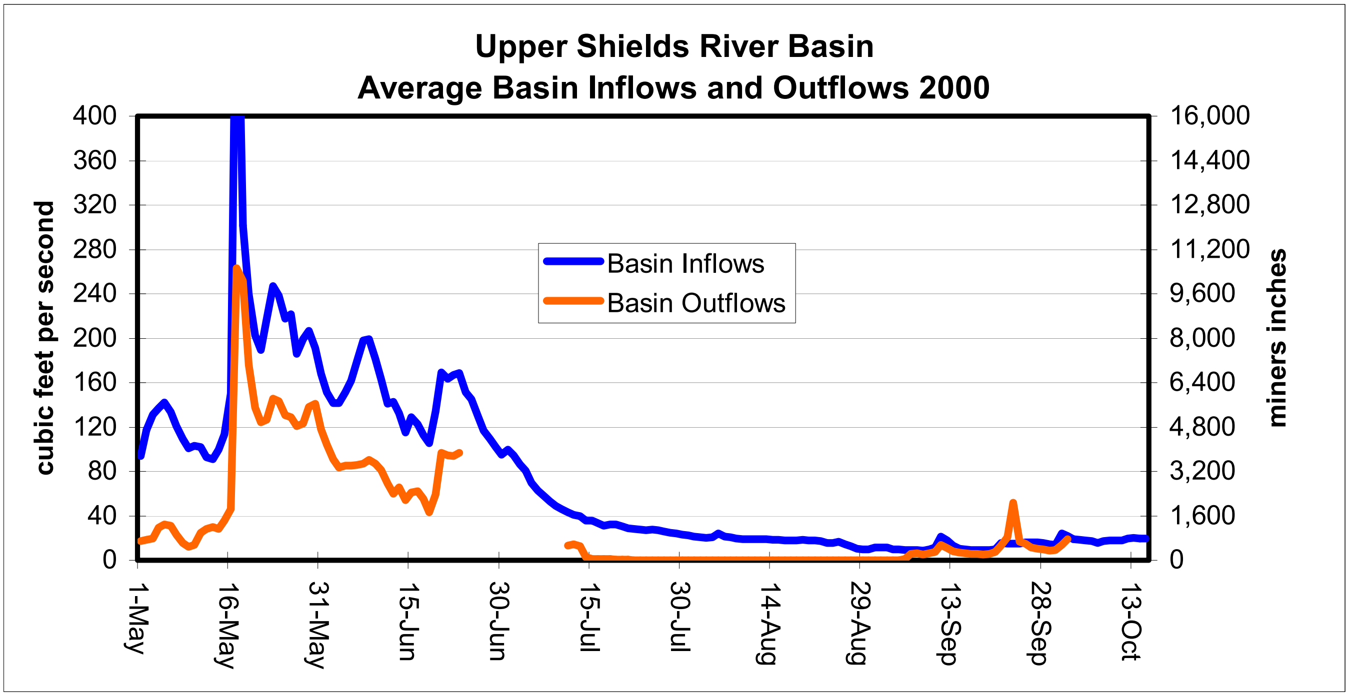
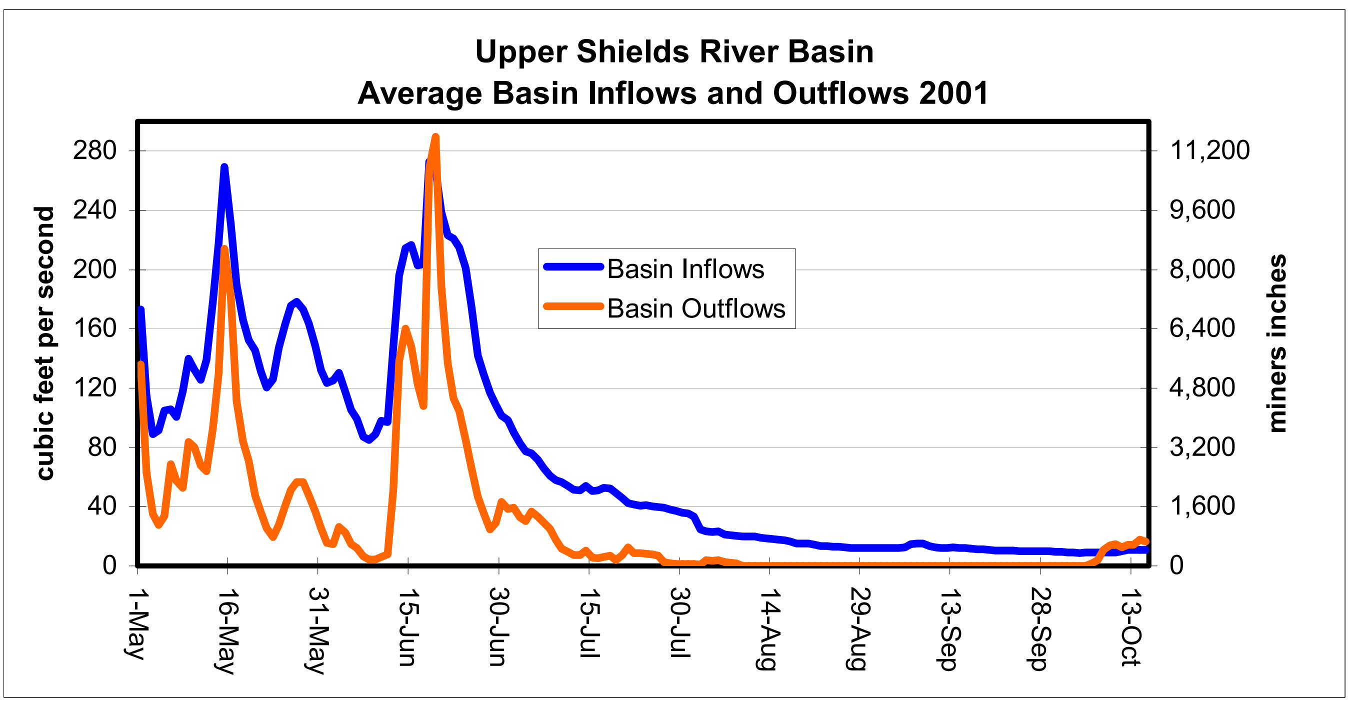
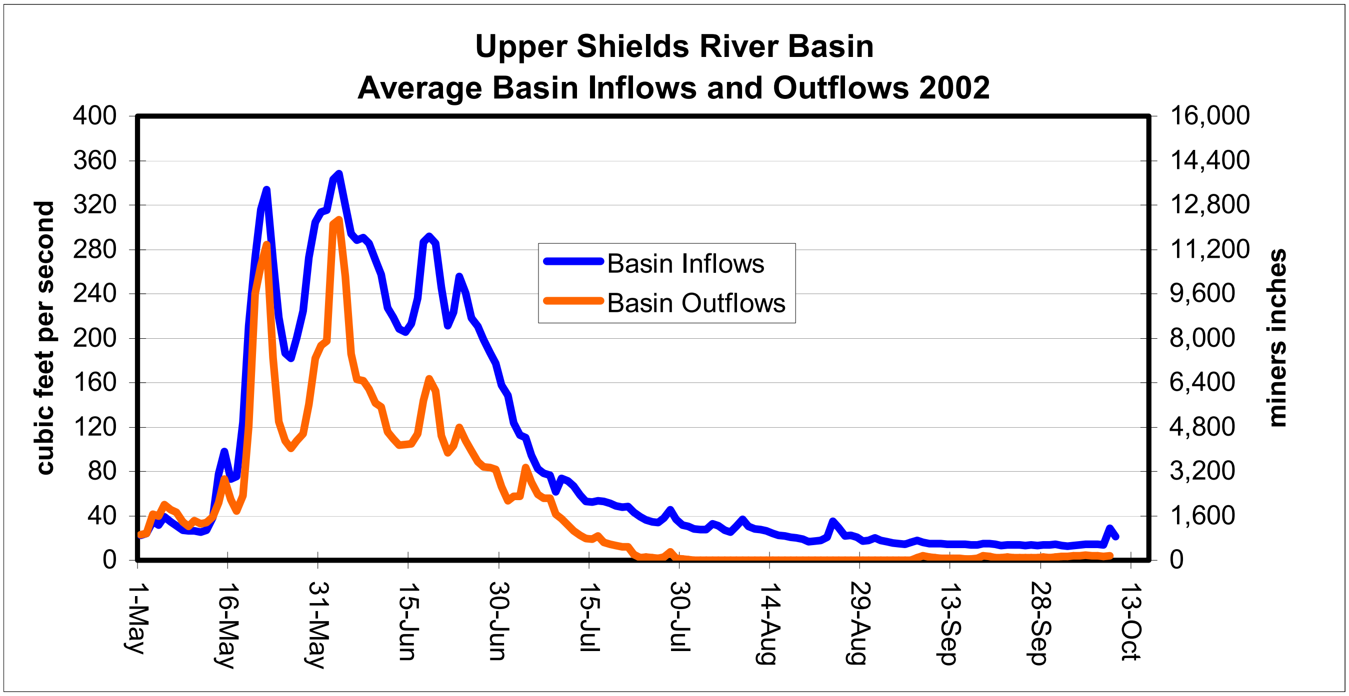
Contributors

Larry Dolan of the Montana Department of Natural Resources and Conservation (DNRC) prepared this report for the Irrigation Efficiencies and Dewatering/Irrigation Storage Committees of the Upper Shields Watershed Association. The help of Robin Fuson of the USDA Natural Resources Conservation Service was invaluable in getting the project started. Robin obtained the cooperation of the ranchers and access to their lands, and helped with installing the stream gaging stations and with some of the early data collection. Zack Sarrazin, a summer intern with the NRCS, devotedly assisted with water measurements during the 2000 irrigation season. Matt Long of the Watershed Association collected much of the river and canal flow data during the 2001 through 2005 irrigation seasons, and provided conscientious help and good company throughout the project. Amy Miller of the Watershed Association kept the project alive through her enthusiastic encouragement and by obtaining grant funds. I'd also like to thank all the ranchers in the Shields River Valley who helped and cooperated with this project including Ken, Ron and Les Arthun, George Boyd, Duane and Rod Clark, Coral Holliday, Gary Hoyem, Alan Johnstone, Matt Levers, Bruce and Peggy McLeod, Steve Tomschin and Ned Zimmerman. I owe much of my understanding of the practical aspects of irrigation to them, and I respect them for being so candid and sincere. They really made it worth the drive from Helena to work on this project. Thanks also to the U.S. Bureau of Reclamation, Montana Area Office, whom provided much of the funding for this project.

Appendix A – Inflow /Outflow Hydrographs for Each Year of the Project






Upper Shields River Basin
Average Basin Inflows and Outflows 2002
cubic feet per second
miners inches
Basin Inflows
Basin Outflows
400
360
320
280
240
200
160
120
80
40
0
16,000
14,400
12,800
11,200
9,600
8,000
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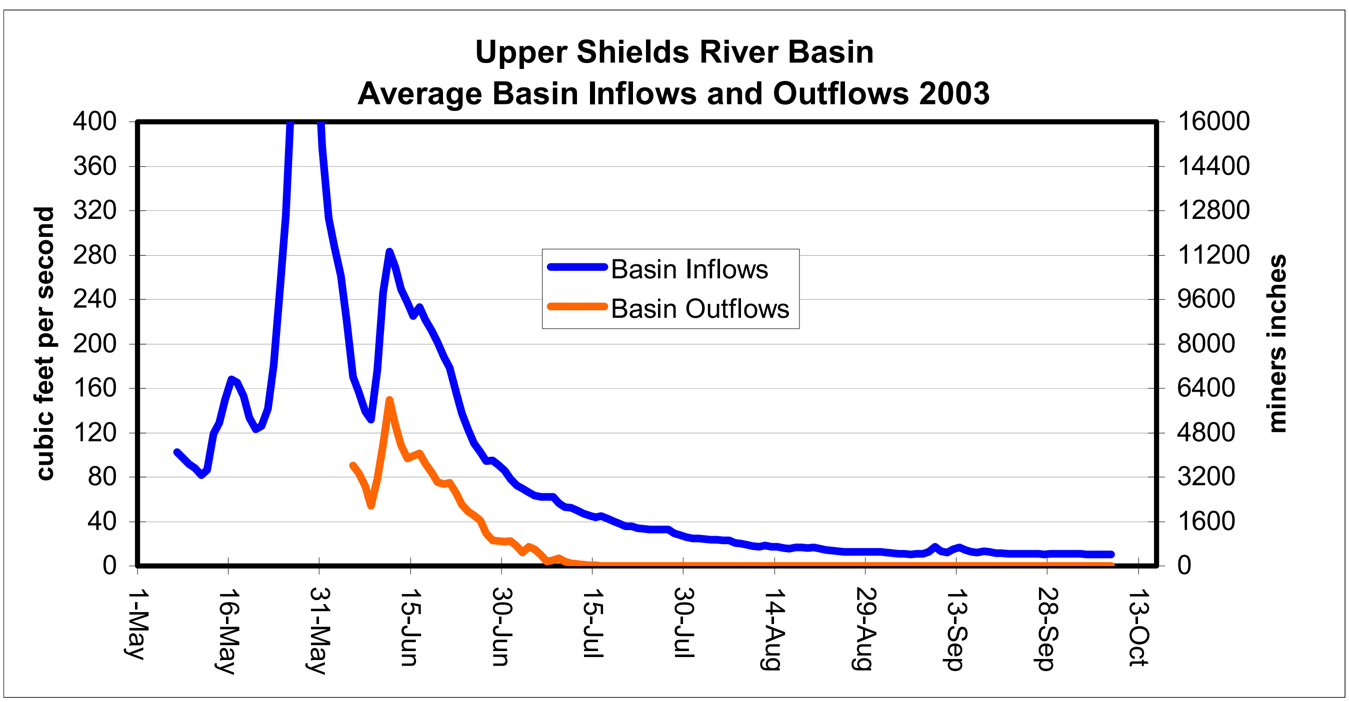
13-Sep
28-Sep
13-Oct


Upper Shields River Basin
Average Basin Inflows and Outflows 2003
cubic feet per second
miners inches
Basin Inflows
Basin Outflows
400
360
320
280
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160
120
80
40
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14400
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11200
9600
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6400
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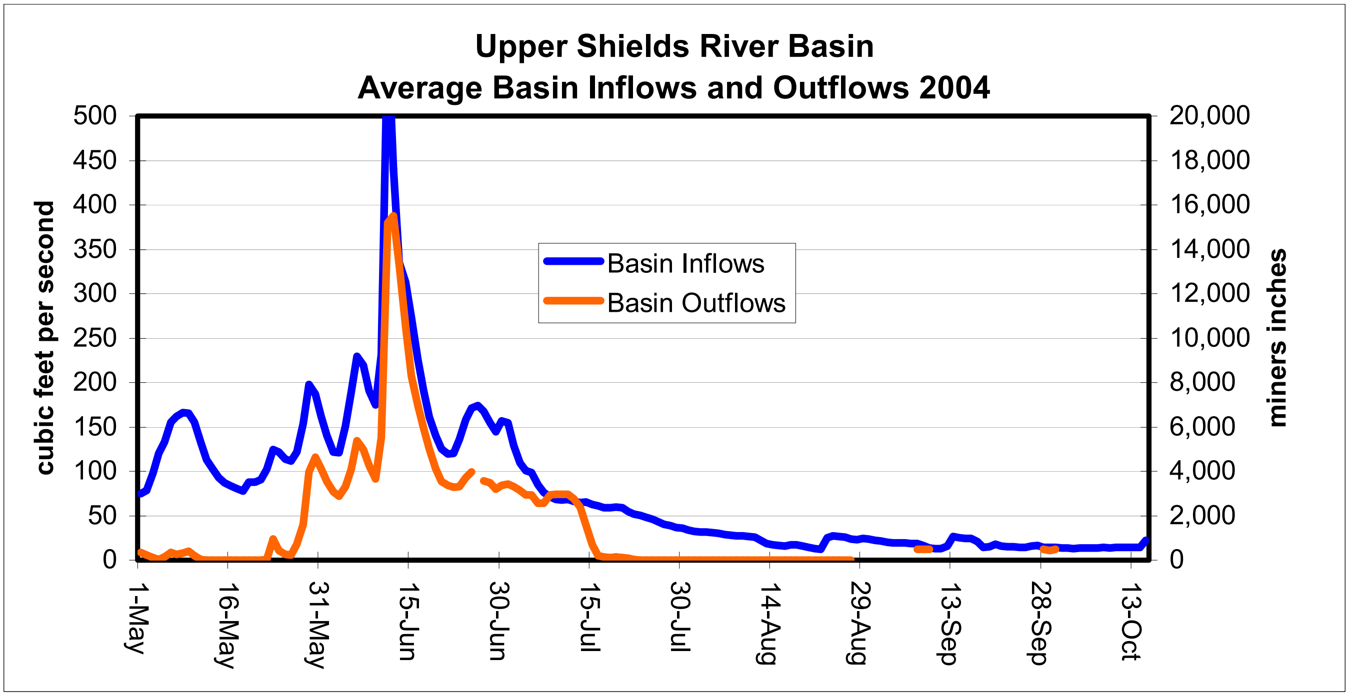
13-Sep
28-Sep
13-Oct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Average Basin Inflows and Outflows 2004
cubic feet per second
miners inches
Basin Inflows
Basin Outflows
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300
350
400
450
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2,000
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6,000
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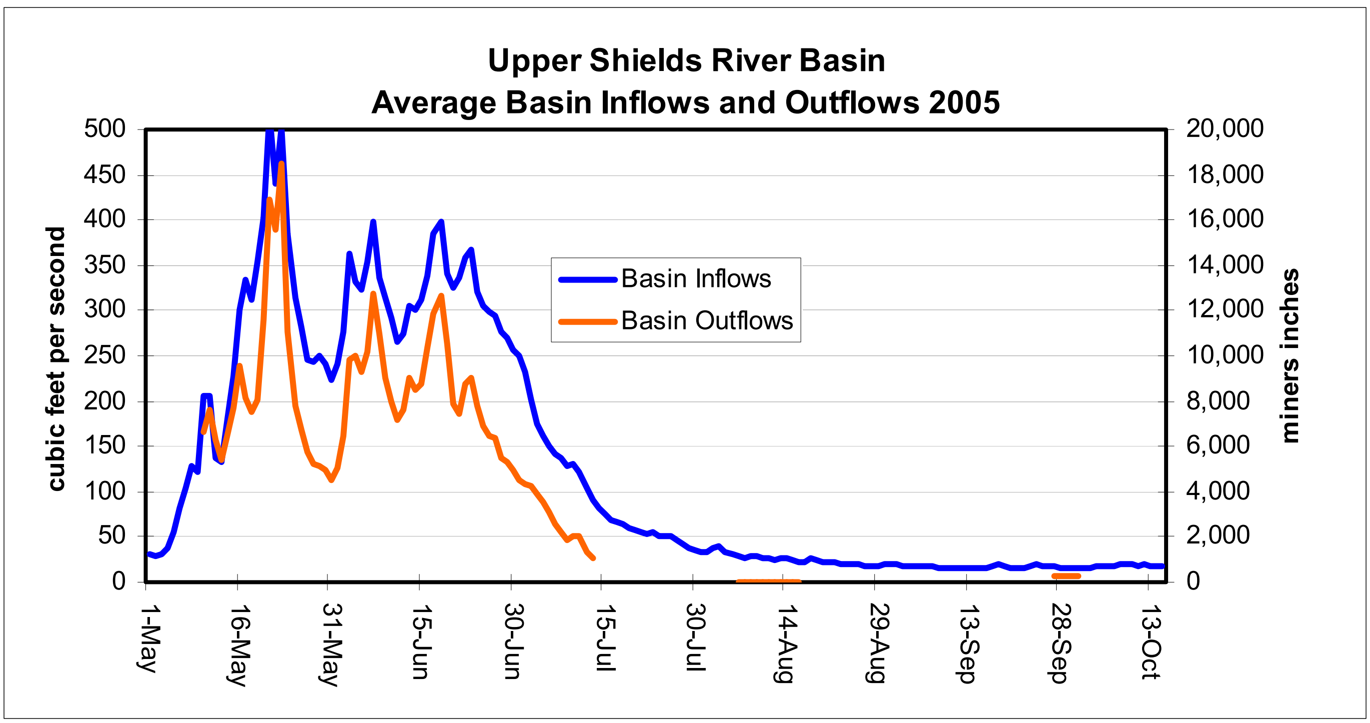
Upper Shields River Basin
Average Basin Inflows and Outflows 2005
cubic feet per second
miners inches
Basin Inflows
Basin Outflows
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100
150
200
250
300
350
400
450
500
0
2,000
4,000
6,000
8,000
10,000
12,000
14,000
16,000
18,000
20,000
1-May
16-May
31-May
15-Jun
30-Jun
15-Jul
30-Jul
14-Aug
29-Aug
13-Sep
28-Sep
13-Oct

Appendix B: 2000-2005 Streamflow Data for the Shields River and Smith Creek.

Shields River Upper Gage (at Rennie Ranch)

Day	Daily Average Streamflows in Cubic Feet Per Second (CFS) by year					
	2000	2001	2002	2003	2004	2005
1-Apr		10.7			49.9	
2-Apr		10.9			44.4	
3-Apr		9.6			31.3	
4-Apr		10.4			36.6	
5-Apr		10.7			47.7	
6-Apr		11.3			52.6	16.9
7-Apr		12.1			53.7	18.2
8-Apr		12.6			57.6	23.2
9-Apr		11.8			51.2	19.8
10-Apr		11.1			43.3	15.6
11-Apr		11.5			40.9	13.2
12-Apr		10.7			44.1	16.1
13-Apr		8.1			52.5	23.0
14-Apr		9.1			57.4	24.9
15-Apr		6.9			55.9	17.4
16-Apr		10.9	21.3		52.3	18.5
17-Apr		11.7	12.8		50.2	24.9
18-Apr		17.1	9.1		48.8	28.5
19-Apr		18.9	10.4		48.1	23.6
20-Apr		18.6	9.1		52.5	20.9
21-Apr		18.3	8.6		52.8	19.8
22-Apr		18.5	8.2		55.4	21.2
23-Apr		18.6	9.7		57.1	28.2
24-Apr		19.5	8.2		58.2	39.8
25-Apr		24.4	8.1		55.0	59.5
26-Apr	55.1	45.1	7.9		56.9	61.4
27-Apr	58.8	85.0	7.9		68.8	54.1
28-Apr	75.3	126.0	7.7		84.5	32.2
29-Apr	88.1	170.2	8.1		71.9	29.3
30-Apr	72.1	146.1	10.5		65.4	26.7
1-May	78.7	149.5	10.3		61.4	25.5
2-May	100.5	98.0	11.9		64.5	24.5
3-May	112.6	74.2	22.9		81.1	25.6
4-May	118.0	76.9	19.7		100.9	32.5
5-May	112.1	89.2	26.7		111.7	49.8
6-May	104.5	90.0	22.2		131.7	74.8
7-May	93.2	84.9	19.1	86.6	135.6	94.5
8-May	82.6	100.7	14.9	81.9	139.4	117.4
9-May	74.7	120.7	14.2	76.9	137.6	111.0
10-May	76.8	114.2	14.1	73.3	128.5	182.9
11-May	75.9	107.8	13.3	67.9	107.7	182.5
12-May	67.3	118.0	14.9	72.0	90.5	125.3
13-May	65.5	152.0	26.2	102.1	80.6	120.1
14-May	73.6	184.6	63.6	110.7	71.5	162.9
15-May	86.4	226.2	82.2	129.0	66.0	201.2
16-May	119.3	194.6	58.9	145.1	63.1	255.0
17-May	449.1	160.5	60.6	142.7	60.1	277.2
18-May	245.6	139.0	105.4	132.2	57.8	263.0
19-May	196.7	127.2	180.1	115.0	67.2	289.6
20-May	165.6	120.1	229.7	105.6	67.0	318.4
21-May	155.0	107.4	263.2	108.2	69.5	374.3
22-May	178.1	97.9	276.9	122.0	80.5	338.4
23-May	203.2	102.7	227.6	155.8	100.8	367.5
24-May	196.0	121.4	185.2	213.5	97.8	308.5
25-May	179.3	135.3	158.2	264.8	91.0	264.2
26-May	182.8	146.4	153.8	355.2	88.8	240.5
27-May	153.2	148.2	169.0	388.0	97.9	215.4

Shields River Upper Gage (continued)

Day	Daily Average Streamflows in Cubic Feet Per Second (CFS) by year					
	2000	2001	2002	2003	2004	2005
28-May	164.4	143.7	189.1	376.8	126.6	212.8
29-May	171.1	135.3	228.0	393.9	164.8	218.2
30-May	157.9	122.1	252.6	378.2	155.5	210.7
31-May	138.5	107.5	259.3	310.0	133.5	197.1
1-Jun	124.0	99.5	260.4	262.8	114.4	210.7
2-Jun	115.6	101.3	281.2	242.9	98.0	238.8
3-Jun	115.9	105.9	284.7	222.4	97.4	295.6
4-Jun	125.0	93.9	263.0	189.6	124.2	276.0
5-Jun	134.5	82.8	242.8	146.9	157.1	269.8
6-Jun	149.4	77.6	238.6	134.7	190.8	290.8
7-Jun	165.4	66.7	240.1	119.0	182.3	316.6
8-Jun	166.3	64.6	236.5	112.2	158.1	278.8
9-Jun	151.5	68.5	224.2	150.8	145.1	263.8
10-Jun	135.3	77.3	213.8	208.3	192.7	248.5
11-Jun	116.3	77.0	189.7	237.3	457.1	230.5
12-Jun	118.2	122.9	182.4	225.8	351.3	236.8
13-Jun	108.9	164.5	173.8	209.6	274.6	257.8
14-Jun	93.4	180.4	171.5	199.1	257.3	255.4
15-Jun	105.9	182.6	177.9	189.0	226.1	262.9
16-Jun	100.2	171.1	197.0	195.0	188.5	280.0
17-Jun	91.5	172.1	237.6	185.1	158.8	309.2
18-Jun	84.3	228.9	241.6	176.8	132.7	316.2
19-Jun	111.2	224.4	236.7	167.9	114.4	281.2
20-Jun	141.7	201.6	205.2	157.0	101.2	271.0
21-Jun	136.9	189.2	176.5	148.6	95.7	278.4
22-Jun	139.7	187.5	186.7	131.0	96.6	293.3
23-Jun	141.5	182.7	212.9	113.9	110.6	298.2
24-Jun	126.2	171.3	200.9	101.2	130.5	269.5
25-Jun	120.8	149.6	182.4	89.8	142.1	259.1
26-Jun	107.5	121.0	176.3	83.4	144.6	253.2
27-Jun	95.3	109.9	166.3	76.0	139.0	249.9
28-Jun	88.5	98.6	157.2	77.0	127.9	238.6
29-Jun	81.6	91.5	148.9	74.5	119.1	232.8
30-Jun	75.3	85.2	132.4	70.6	130.1	223.4
1-Jul	77.9	79.4	118.0	63.9	120.6	217.9
2-Jul	73.5	72.9	98.2	59.0	99.8	204.6
3-Jul	67.0	67.1	89.8	56.8	84.6	180.0
4-Jul	62.3	62.7	88.3	53.6	78.1	157.0
5-Jul	53.4	61.9	75.4	51.1	76.6	144.9
6-Jul	48.8	58.3	65.9	49.8	65.6	137.0
7-Jul	45.0	53.7	63.3	49.8	59.2	128.6
8-Jul	40.8	49.5	62.1	49.4	55.4	125.0
9-Jul	37.7	47.0	50.0	44.7	53.3	117.1
10-Jul	35.0	46.1	60.1	41.4	53.6	118.2
11-Jul	32.8	43.8	58.1	41.2	54.5	110.6
12-Jul	33.5	41.8	54.3	38.6	53.2	94.9
13-Jul	32.4	41.4	48.1	36.4	52.1	81.9
14-Jul	29.2	43.8	43.4	34.6	53.3	74.6
15-Jul	28.9	41.3	42.8	33.4	50.8	68.3
16-Jul	27.2	41.5	43.5	33.8	49.7	62.5
17-Jul	25.5	43.0	43.0	32.0	48.0	60.1
18-Jul	26.3	42.8	41.8	29.9	48.1	57.1
19-Jul	26.3	40.2	39.7	28.3	48.8	53.4
20-Jul	24.8	37.2	39.0	26.9	47.8	50.4
21-Jul	23.7	34.1	39.4	26.9	44.6	48.2
22-Jul	23.0	33.0	35.1	25.6	42.3	46.2
23-Jul	22.5	32.1	31.8	25.1	40.8	48.9

Shields River Upper Gage (continued)						
	Daily Average Streamflows in Cubic Feet Per Second (CFS) by year					
Day	2000	2001	2002	2003	2004	2005
24-Jul	22.1	32.4	29.9	24.7	39.6	45.0
25-Jul	22.5	31.2	28.3	25.2	37.9	44.7
26-Jul	22.2	30.6	27.9	25.3	35.0	45.6
27-Jul	21.4	30.2	30.8	25.1	32.9	40.5
28-Jul	20.5	28.8	37.2	22.9	31.6	36.4
29-Jul	19.7	27.8	29.9	21.6	29.8	33.2
30-Jul	18.9	26.6	26.0	20.1	28.9	30.4
31-Jul	18.4	25.9	24.8	19.5	27.1	28.5
1-Aug	17.4	23.9	23.0	19.5	25.8	27.8
2-Aug	17.0	17.0	22.6	19.0	25.1	31.3
3-Aug	16.6	16.0	22.8	18.8	25.0	34.2
4-Aug	17.1	15.9	26.8	19.2	24.3	27.9
5-Aug	19.7	16.1	25.3	18.3	23.8	25.5
6-Aug	17.3	14.7	22.3	18.9	22.8	23.3
7-Aug	16.8	14.2	20.8	17.0	22.1	22.8
8-Aug	16.2	14.2	24.8	16.5	21.7	23.1
9-Aug	15.8	13.9	29.9	15.6	21.4	22.9
10-Aug	15.4	14.1	25.0	14.9	20.7	22.3
11-Aug	15.6	14.1	23.0	14.3	20.2	21.7
12-Aug	15.4	13.8	22.5	15.3	17.5	20.6
13-Aug	15.5	13.4	21.9	14.2	14.3	21.5
14-Aug	15.2	13.2	20.0	14.4	13.1	21.0
15-Aug	15.0	13.0	18.6	13.4	12.4	19.1
16-Aug	14.8	12.8	17.8	13.0	12.2	18.2
17-Aug	14.8	12.1	17.3	13.7	13.4	18.2
18-Aug	14.7	11.2	16.7	13.8	13.3	22.6
19-Aug	15.3	11.1	15.6	13.4	12.4	20.6
20-Aug	14.7	11.6	14.0	13.6	11.5	18.2
21-Aug	14.5	11.0	14.3	12.7	10.5	17.1
22-Aug	14.1	10.4	14.8	12.1	10.2	16.6
23-Aug	12.7	10.2	17.2	11.3	20.8	16.1
24-Aug	12.7	10.1	28.7	11.0	22.1	15.4
25-Aug	13.9	10.1	23.9	10.7	21.5	15.0
26-Aug	12.1	10.1	17.8	10.4	21.4	14.6
27-Aug	10.6	9.9	18.5	10.4	19.3	14.1
28-Aug	8.7	9.9	16.9	10.6	19.0	13.9
29-Aug	8.4	10.0	14.4	10.3	19.9	13.5
30-Aug	8.2	10.1	14.6	10.6	19.3	15.2
31-Aug	9.4	10.1	16.4	10.4	18.3	15.8
1-Sep	9.5	10.0	14.8	10.1	17.5	14.5
2-Sep	9.8	9.9	13.6	9.8	16.9	13.8
3-Sep	8.2	10.0	12.7	9.3	15.8	13.1
4-Sep	8.1	10.0	12.6	9.0	15.8	12.9
5-Sep	7.7	10.5	12.1	8.8	15.8	13.0
6-Sep	7.6	12.3	13.3	9.0	15.3	12.7
7-Sep	7.6	12.4	14.6	9.2	15.1	12.4
8-Sep	7.5	12.4	13.1	10.4	13.7	12.2
9-Sep	8.0	11.0	12.4	14.4	11.5	11.9
10-Sep	9.5	10.3	12.5	11.0	10.9	11.7
11-Sep	17.6	10.1	12.4	10.1	10.5	12.0
12-Sep	14.5	10.1	12.0	12.4	13.0	11.9
13-Sep	11.2	10.2	12.0	13.7	21.6	12.0
14-Sep	8.7	10.2	11.8	11.9	20.7	11.7
15-Sep	8.2	10.0	11.8	10.4	20.3	11.7
16-Sep	7.8	9.7	11.6	10.2	20.0	11.5
17-Sep	7.7	9.3	11.2	11.1	17.1	12.5
18-Sep	7.6	9.2	12.4	10.4	12.1	14.6

Shields River Upper Gage (continued)						
	Daily Average Streamflows in Cubic Feet Per Second (CFS) by year					
Day	2000	2001	2002	2003	2004	2005
19-Sep	7.9	9.0	12.4	9.8	12.7	12.7
20-Sep	8.1	8.6	11.8	9.4	15.0	11.8
21-Sep	12.9	8.7	11.0	9.1	13.3	11.4
22-Sep	12.3	8.7	11.3	9.1	12.6	11.4
23-Sep	12.3	8.5	11.4	9.1	12.4	12.8
24-Sep	12.1	8.4	11.5	8.9	11.9	16.4
25-Sep	13.4	8.4	11.2	9.1	11.9	14.3
26-Sep	13.5	8.4	11.3	9.1	13.0	13.1
27-Sep	13.4	8.3	11.1	8.8	13.6	12.4
28-Sep	12.6	8.4	11.4	8.9	12.2	11.9
29-Sep	11.7	8.3	11.5	9.0	11.8	12.2
30-Sep	11.6	7.9	12.1	9.0	12.0	11.6
1-Oct	20.1	7.8	10.8	9.0	11.3	11.1
2-Oct	18.0	7.7	10.7	8.9	11.3	11.4
3-Oct	15.8	7.5	10.8	9.0	11.0	12.1
4-Oct	15.0	7.1	11.6	8.8	11.6	12.4
5-Oct	14.8	7.6	11.7	8.8	11.3	12.7
6-Oct	14.4	7.7	11.8	8.6	11.1	12.8
7-Oct	13.0	7.7	11.9	8.5	11.4	12.9
8-Oct	14.3	7.6	11.4	8.7	11.9	14.9
9-Oct	14.7	7.6	23.7		11.1	16.5
10-Oct	14.7	7.7	17.5		11.7	15.1
11-Oct	14.7	8.3			12.0	14.2
12-Oct	16.2	8.9			12.1	14.5
13-Oct	16.5	9.1			12.0	13.9
14-Oct	16.0	9.1			11.8	13.1
15-Oct	16.1	8.8			18.4	12.7
16-Oct	16.0				18.5	12.2
17-Oct	15.9				17.5	12.2
18-Oct	15.6				15.5	12.0
19-Oct	15.3				13.9	12.1
20-Oct	15.1				14.2	12.3
21-Oct	15.3				16.7	12.3
22-Oct	15.4				15.8	12.2
23-Oct	14.6				14.8	12.2
24-Oct	14.8				14.6	12.1
25-Oct	16.6				11.8	
26-Oct	17.2					
27-Oct	16.3					
28-Oct	15.9					
29-Oct	15.4					
30-Oct	15.4					
31-Oct	15.2					

Shields River Lower Gage (at Holliday Ranch)

Day	Daily Average Streamflows in Cubic Feet Per Second (CFS) by year					
	2000	2001	2002	2003	2004	2005
1-Apr					69.9	
2-Apr					69.7	
3-Apr					55.7	
4-Apr					57.0	
5-Apr					52.4	
6-Apr					47.2	5.3
7-Apr					48.0	
8-Apr					56.1	
9-Apr					49.5	
10-Apr					38.2	
11-Apr					30.5	
12-Apr					25.8	
13-Apr					35.6	
14-Apr					48.6	
15-Apr					53.9	
16-Apr					46.1	
17-Apr					44.0	
18-Apr					40.4	
19-Apr					48.2	
20-Apr					68.0	
21-Apr					64.8	
22-Apr					39.4	
23-Apr					13.6	
24-Apr					15.5	
25-Apr					11.6	
26-Apr					8.0	
27-Apr	16.9				10.9	
28-Apr	25.3				20.5	
29-Apr	37.3				16.0	
30-Apr	23.6				12.4	
1-May	17.2	136.1	23.3		8.8	
2-May	18.5	63.2	24.3		5.7	
3-May	19.8	34.8	41.4		2.8	
4-May	29.4	27.7	39.7		1.0	
5-May	32.5	33.6	50.1		3.5	
6-May	31.2	68.5	45.7		8.3	
7-May	23.0	57.3	42.9	117.0	6.8	
8-May	15.8	52.8	34.3		7.8	
9-May	11.9	83.7	30.7		10.2	
10-May	13.8	80.3	35.9		5.4	166.4
11-May	24.5	67.6	32.8		0.8	190.6
12-May	28.1	63.9	34.1		0.1	156.7
13-May	30.0	92.6	38.9		0.1	135.1
14-May	28.3	129.7	51.9		0.0	164.7
15-May	35.7	214.2	73.3		0.0	191.6
16-May	46.2	181.7	54.4		0.0	238.0
17-May	263.0	111.5	44.3		0.0	203.0
18-May	251.3	84.3	58.3		0.0	187.4
19-May	176.2	70.6	120.7		0.0	200.5
20-May	137.7	47.6	240.3		0.0	289.0
21-May	124.5	36.5	265.2		0.1	421.8
22-May	126.7	25.6	284.4		0.6	389.0
23-May	145.6	19.4	182.3		23.8	461.9
24-May	143.4	27.8	124.8		10.4	277.2
25-May	130.9	40.5	107.5		6.2	194.6
26-May	128.7	51.2	100.7		5.7	169.1
27-May	121.0	56.5	107.4		18.1	144.7

Shields River Lower Gage (continued)						
	Daily Average Streamflows in Cubic Feet Per Second (CFS) by year					
Day	2000	2001	2002	2003	2004	2005
28-May	123.0	56.4	113.7		40.0	130.6
29-May	138.4	47.7	140.4		99.4	127.7
30-May	140.9	36.7	181.8		115.8	124.4
31-May	118.2	25.6	193.6		103.1	112.4
1-Jun	104.3	15.6	197.7		88.8	126.1
2-Jun	91.2	14.6	302.6		76.8	161.7
3-Jun	83.5	26.2	306.9		72.0	246.6
4-Jun	85.5	22.3	255.4		82.7	250.2
5-Jun	85.1	14.6	185.8	90.2	102.0	231.5
6-Jun	85.5	12.0	162.8	83.6	134.9	255.1
7-Jun	87.0	6.6	161.5	72.1	124.2	318.6
8-Jun	90.1	4.3	154.1	54.0	106.8	273.7
9-Jun	86.9	4.2	141.8	78.2	91.3	226.0
10-Jun	81.4	6.2	138.2	109.6	138.2	198.3
11-Jun	69.1	7.9	115.5	149.5	379.9	178.7
12-Jun	59.6	51.6	109.1	127.3	387.6	190.1
13-Jun	65.7	137.9	103.3	108.9	332.1	224.6
14-Jun	54.1	160.0	104.2	96.5	263.1	211.8
15-Jun	60.8	148.1	104.8	99.1	207.3	220.1
16-Jun	62.0	122.6	114.1	101.2	174.8	259.4
17-Jun	55.2	107.8	144.1	91.8	149.1	297.0
18-Jun	43.1	268.0	163.7	83.9	125.3	316.5
19-Jun	59.5	289.6	152.8	75.2	102.7	262.6
20-Jun	96.7	188.8	112.2	73.8	88.8	196.5
21-Jun	94.3	136.8	96.6	74.8	84.3	185.4
22-Jun	93.7	113.2	103.2	65.8	81.9	218.6
23-Jun	96.6	104.4	119.5	55.4	82.9	225.0
24-Jun		85.1	107.6	49.0	93.1	194.2
25-Jun		65.9	98.3	45.6	99.5	172.4
26-Jun		46.6	88.4	40.8		161.1
27-Jun		35.7	84.1	29.5	89.4	159.1
28-Jun		24.7	83.7	23.3	86.9	136.3
29-Jun		28.9	81.5	22.5	80.1	133.4
30-Jun		43.3	65.9	22.0	84.3	124.1
1-Jul		38.4	53.8	22.2	85.7	112.4
2-Jul		39.2	57.7	17.9	82.8	108.4
3-Jul		32.9	57.5	12.3	78.4	107.0
4-Jul		30.2	83.3	17.2	73.4	97.7
5-Jul		36.8	70.5	15.0	73.4	87.6
6-Jul		33.4	59.2	9.8	63.9	77.0
7-Jul		29.2	55.8	4.2	64.1	64.6
8-Jul		25.0	55.6	5.2	73.5	55.6
9-Jul		17.8	41.7	7.1	73.9	46.3
10-Jul		11.7	37.3	3.8	73.8	50.3
11-Jul	13.1	9.4	31.7	2.1	73.8	51.4
12-Jul	14.4	7.3	26.7	1.6	68.9	32.9
13-Jul	12.7	7.5	22.3	1.0	59.6	26.0
14-Jul	2.7	10.2	19.8	0.6	39.8	
15-Jul	1.1	5.5	19.3	0.4	17.2	
16-Jul	1.0	5.1	21.8	0.1	5.2	
17-Jul	0.9	5.9	16.0	0.1	3.8	
18-Jul	0.9	7.0	14.4	0.0	3.1	
19-Jul	0.8	3.9	13.1	0.0	3.9	
20-Jul	0.7	7.5	11.9	0.0	3.1	
21-Jul	0.7	12.7	12.2	0.0	2.0	
22-Jul	0.0	8.7	5.3	0.0	0.7	
23-Jul	0.0	8.6	2.1	0.0	0.3	

Shields River Lower Gage (continued)						
	Daily Average Streamflows in Cubic Feet Per Second (CFS) by year					
Day	2000	2001	2002	2003	2004	2005
24-Jul	0.0	8.3	3.1	0.0	0.3	
25-Jul	0.0	7.6	2.1	0.0	0.1	
26-Jul	0.0	6.8	1.6	0.0	0.1	3.2
27-Jul	0.0	2.7	3.1	0.0	0.1	
28-Jul	0.0	1.6	7.5	0.0	0.0	
29-Jul	0.0	1.4	2.0		0.0	
30-Jul	0.0	1.1	1.1		0.0	
31-Jul	0.0	1.5	0.9		0.0	
1-Aug	0.0	1.5	0.0		0.0	
2-Aug	0.0	0.9	0.0		0.0	
3-Aug	0.0	3.8	0.0		0.0	
4-Aug	0.0	3.6	0.0		0.0	
5-Aug	0.0	3.9	0.0		0.0	
6-Aug	0.0	2.8	0.0		0.0	
7-Aug	0.0	2.3	0.0		0.0	
8-Aug	0.0	1.9	0.0		0.0	
9-Aug	0.0	0.0	0.0		0.0	
10-Aug	0.0	0.0	0.0		0.0	
11-Aug	0.0	0.0	0.0		0.0	0.0
12-Aug	0.0	0.0	0.0	0.0	0.0	
13-Aug	0.0	0.0	0.0		0.0	
14-Aug	0.0	0.0	0.0		0.0	
15-Aug	0.0	0.0	0.0		0.0	
16-Aug	0.0	0.0	0.0		0.0	
17-Aug	0.0	0.0	0.0		0.0	
18-Aug	0.0	0.0	0.0		0.0	
19-Aug	0.0	0.0	0.0		0.0	
20-Aug	0.0	0.0	0.0		0.0	
21-Aug	0.0	0.0	0.0		0.0	
22-Aug	0.0	0.0	0.0		0.0	
23-Aug	0.0	0.0	0.0		0.0	
24-Aug	0.0	0.0	0.0		0.0	
25-Aug	0.0	0.0	0.0		0.0	
26-Aug	0.0	0.0	0.0		0.0	
27-Aug	0.0	0.0	0.0		0.0	
28-Aug	0.0	0.0	0.0			
29-Aug	0.0	0.0	0.0			
30-Aug	0.0	0.0	0.0			
31-Aug	0.0	0.0	0.0			
1-Sep	0.0	0.0	0.0			
2-Sep	0.0	0.0	0.0			
3-Sep	0.0	0.0	0.0			
4-Sep	0.0	0.0	0.0			
5-Sep	0.9	0.0	0.0	0.0		
6-Sep	5.6	0.0	0.0			
7-Sep	6.2	0.0	2.6			
8-Sep	5.4	0.0	3.9		12.0	
9-Sep	6.3	0.0	3.0			
10-Sep	7.7	0.0	2.4			
11-Sep	13.7	0.0	2.0			
12-Sep	11.1	0.0	1.7			
13-Sep	8.0	0.0	1.6			
14-Sep	7.0	0.0	1.5			
15-Sep	6.2	0.0	1.3			
16-Sep	5.7	0.0	1.2			
17-Sep	5.6	0.0	1.6			
18-Sep	5.3	0.0	3.9			

Shields River Lower Gage (continued)						
	Daily Average Streamflows in Cubic Feet Per Second (CFS) by year					
Day	2000	2001	2002	2003	2004	2005
19-Sep	5.7	0.0	3.7			
20-Sep	7.5	0.0	2.4			
21-Sep	13.3	0.0	2.2			
22-Sep	21.0	0.0	2.7			
23-Sep	51.7	0.0	2.4			
24-Sep	16.6	0.0	2.4			
25-Sep	15.1	0.0	2.4			
26-Sep	11.4	0.0	2.5			
27-Sep	10.6	0.0	2.4			
28-Sep	9.7	0.0	2.8			
29-Sep	8.9	0.0	2.0		10.7	6.97
30-Sep	9.4	0.0	3.1			
1-Oct	13.8	0.0	3.7			
2-Oct	19.0	0.0	3.6			
3-Oct		0.0	3.9			
4-Oct		0.0	4.1			
5-Oct		0.0	4.6			
6-Oct		1.7	4.2			
7-Oct		3.9	4.0			
8-Oct		11.0	3.7	0.0		
9-Oct		13.7	3.8			
10-Oct		14.8				
11-Oct		12.6				
12-Oct		14.2				
13-Oct		14.2				
14-Oct		17.5				
15-Oct		16.6				
16-Oct						
17-Oct						
18-Oct						
19-Oct						
20-Oct						
21-Oct						
22-Oct						
23-Oct						
24-Oct						13.7
25-Oct					13	
26-Oct						
27-Oct						
28-Oct						
29-Oct						
30-Oct						
31-Oct						

Shields River at Hoyem's

Day	Streamflows in Cubic Feet Per Second (CFS) by year		
	2000	2001	2002
1-Apr			
2-Apr			
3-Apr			
4-Apr			
5-Apr			
6-Apr			
7-Apr		19.2	
8-Apr			
9-Apr			
10-Apr			
11-Apr			
12-Apr			
13-Apr			
14-Apr			
15-Apr		13.9	
16-Apr			
17-Apr			
18-Apr			
19-Apr			
20-Apr			
21-Apr			
22-Apr			
23-Apr			
24-Apr			
25-Apr			
26-Apr	63.4	71.5	
27-Apr			
28-Apr	61.1	151.3	
29-Apr	70.0	193.4	
30-Apr	51.2		
1-May	47.5	171.6	
2-May		132.6	
3-May	61.1	87.6	
4-May	70.0	84.8	
5-May			
6-May	70.0		
7-May	70.0	84.8	
8-May	59.0		
9-May	49.3		
10-May	44.0	151.3	
11-May		112.9	
12-May			
13-May	67.7	236.8	
14-May	63.3	268.8	
15-May	72.4	340.3	
16-May	88.2	274.4	
17-May	577.7	175.8	
18-May	280.9	129.0	122.3
19-May	252.6	106.1	266.7
20-May	201.5		393.1
21-May	178.6	84.8	427.6
22-May	178.6	69.0	674.0
23-May	221.1	74.5	
24-May			221.4
25-May		106.1	
26-May			177.0
27-May			207.5

Day	Streamflows in Cubic Feet Per Second (CFS) by year		
	2000	2001	2002
28-May			226.2
29-May		96.5	
30-May			
31-May	178.6	69.0	177.0
1-Jun	157.3	53.3	393.1
2-Jun	119.6		674.0
3-Jun		62.0	
4-Jun	123.1		
5-Jun	141.5	52.1	299.8
6-Jun	139.0		
7-Jun	137.7	35.3	272.0
8-Jun			
9-Jun	149.3	36.9	245.9
10-Jun	116.2		
11-Jun	82.6	38.6	168.9
12-Jun	80.0	106.1	
13-Jun	80.0	346.8	
14-Jun	67.7		172.9
15-Jun		309.3	
16-Jun		231.7	
17-Jun	72.4	231.7	
18-Jun	63.3	429.8	
19-Jun			245.9
20-Jun		327.7	
21-Jun	137.7		
22-Jun	137.7	252.5	
23-Jun			216.7
24-Jun	109.5	193.4	
25-Jun		151.3	172.9
26-Jun	85.4	102.9	
27-Jun		76.6	131.0
28-Jun			106.6
29-Jun	70.0		
30-Jun			
1-Jul		57.5	
2-Jul	70.0		
3-Jul			
4-Jul	67.7		
5-Jul	63.3	64.2	103.6
6-Jul		53.3	
7-Jul			
8-Jul			
9-Jul			66.2
10-Jul			
11-Jul			55.1
12-Jul	42.2		
13-Jul			
14-Jul			
15-Jul			
16-Jul	32.9		
17-Jul			
18-Jul			
19-Jul		39.4	
20-Jul			
21-Jul			
22-Jul			
23-Jul			

Day	Streamflows in Cubic Feet Per Second (CFS) by year		
	2000	2001	2002
24-Jul			
25-Jul	24.5		
26-Jul	19.9		
27-Jul		19.2	
28-Jul			
29-Jul		18.1	29.3
30-Jul			
31-Jul			
1-Aug	15.9		
2-Aug		16.5	
3-Aug			
4-Aug			
5-Aug			
6-Aug			
7-Aug			
8-Aug			
9-Aug			
10-Aug	15.2		
11-Aug			
12-Aug	7.8		
13-Aug			
14-Aug			
15-Aug			14.6
16-Aug			
17-Aug			
18-Aug			
19-Aug	6.5		
20-Aug		4.3	
21-Aug	5.4		
22-Aug			
23-Aug			
24-Aug			
25-Aug			
26-Aug			
27-Aug			12.3
28-Aug			
29-Aug			
30-Aug			
31-Aug			
1-Sep			
2-Sep			
3-Sep			
4-Sep		2.7	
5-Sep			
6-Sep			
7-Sep			
8-Sep			
9-Sep	12.6		
10-Sep			
11-Sep			
12-Sep			15.4
13-Sep	14.8		
14-Sep			
15-Sep			
16-Sep			
17-Sep			
18-Sep			

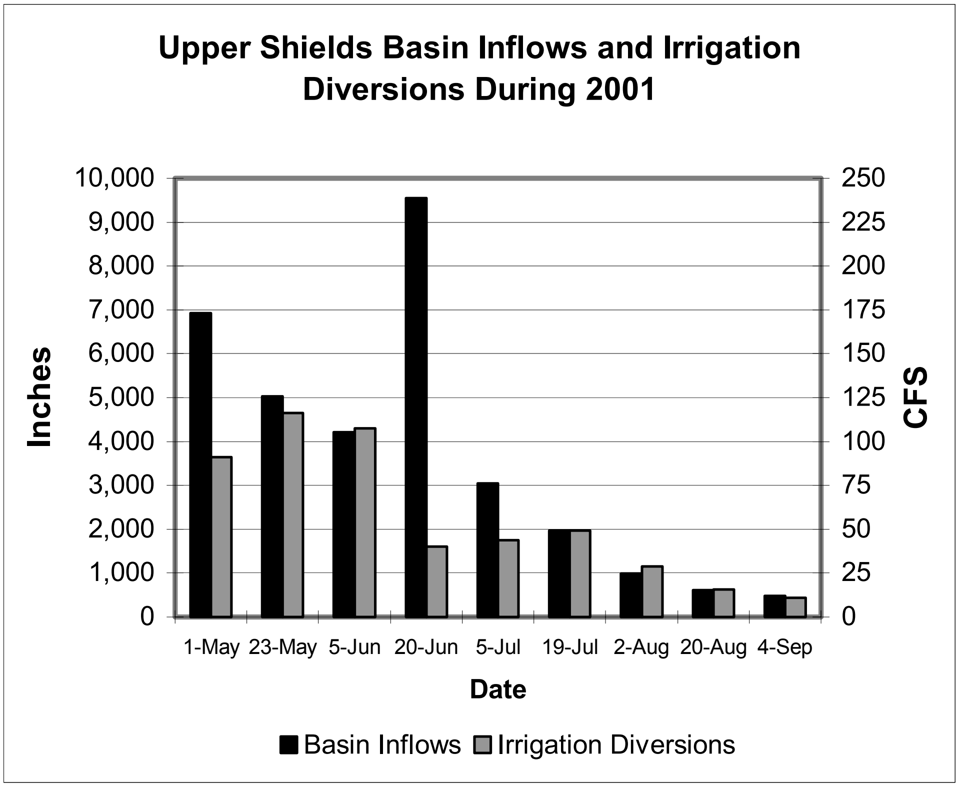
Day	Streamflows in Cubic Feet Per Second (CFS) by year		
	2000	2001	2002
19-Sep			
20-Sep			
21-Sep			
22-Sep			
23-Sep			
24-Sep			
25-Sep			
26-Sep			
27-Sep			
28-Sep			
29-Sep			
30-Sep			
1-Oct		3.5	
2-Oct	17.1		
3-Oct	15.9		
4-Oct			
5-Oct			
6-Oct			
7-Oct			
8-Oct			
9-Oct			
10-Oct			
11-Oct			
12-Oct			
13-Oct			
14-Oct			
15-Oct			
16-Oct			
17-Oct			
18-Oct			
19-Oct			
20-Oct			
21-Oct			
22-Oct	17.1		
23-Oct			
24-Oct			
25-Oct			
26-Oct			
27-Oct			
28-Oct			
29-Oct			
30-Oct			
31-Oct			

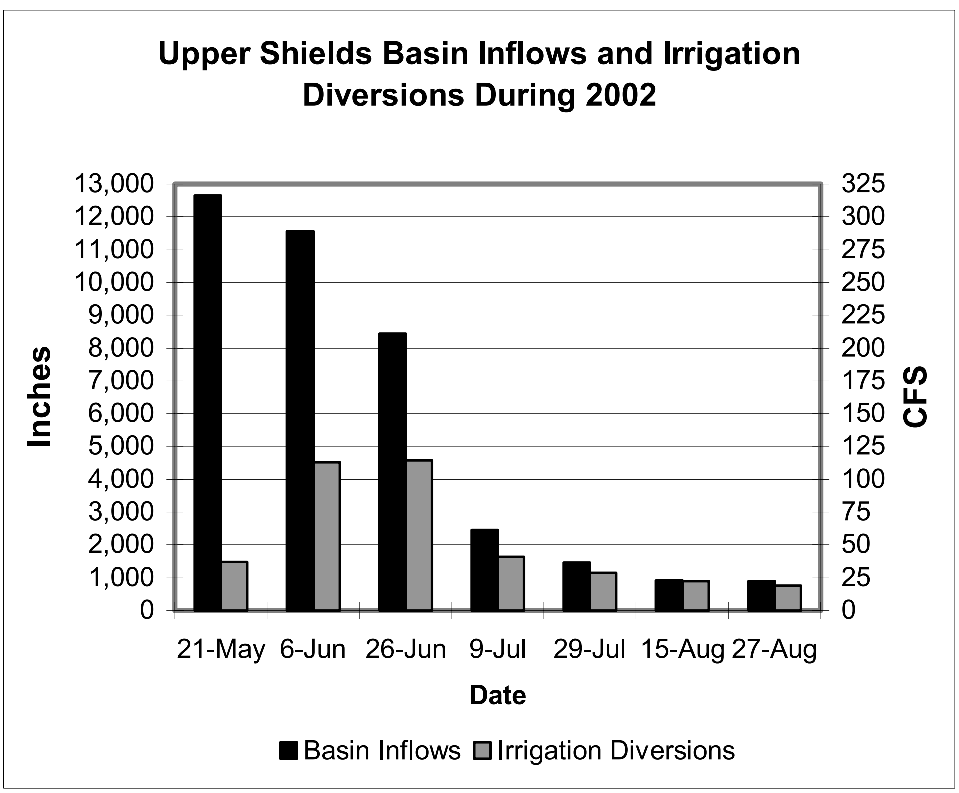
Streamflow measurements and observations for Smith Creek.

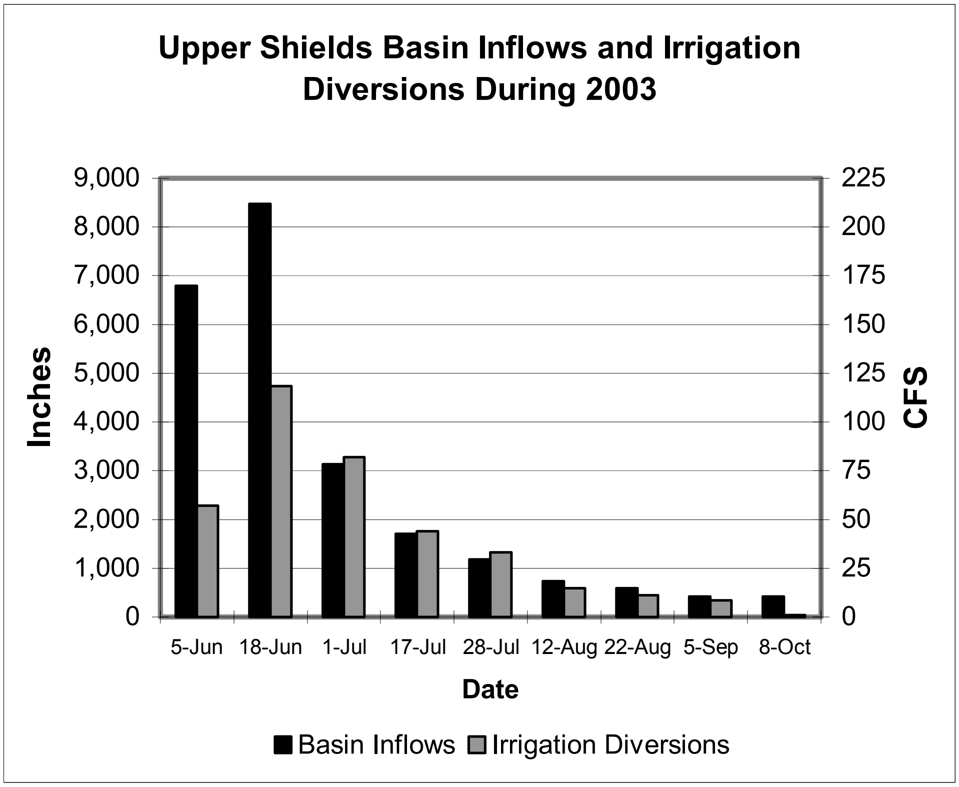
Date	Flow in cubic feet per second (CFS)	Date	Flow in cubic feet per second (CFS)
4/28/2000	21.6	6/5/2003	37.2
5/15/2000	19.4*	6/18/2003	15.6*
6/6/2000	17.0*	7/1/2003	15.5
6/23/2000	20.0*	7/17/2003	4.71
7/12/2000	8.92	7/28/2003	3.52*
7/26/2000	5.14	8/12/2003	3.38
8/10/2000	3.73	8/22/2003	2.90*
8/21/2000	2.78	9/5/2003	2.12
9/13/2000	3.46*		
10/2/2000	4.84*		
5/1/2001	49.8	3/30/2004	13.3*
5/23/2001	9.77*	4/29/2004	12.9*
6/5/2001	6.73*	5/11/2004	11.7
6/20/2001	53.0*	5/25/2004	20.9
7/5/2001	13.7	6/7/2004	21.6*
7/19/2001	10.3*	6/25/2004	16.5*
8/2/2001	2.12*	6/30/2004	10.8*
8/20/2001	4.84*	7/23/2004	5.38
9/4/2001	1.83	8/12/2004	2.67*
10/1/2001	1.06*	8/27/2004	4.73
		9/29/2004	2.82
5/21/2002	45.8	5/26/2005	37.3
6/6/2002	43.8*	6/15/2005	58.1
6/26/2002	27	6/30/2005	27.3
7/9/2002	14.5	7/26/2005	7.18
7/29/2002	8.16	8/11/2005	4.74
8/15/2002	5.32*	09/29/05	3.26
8/27/2002	4.21*	10/24/2005	3.77
9/12/2002	3.6		

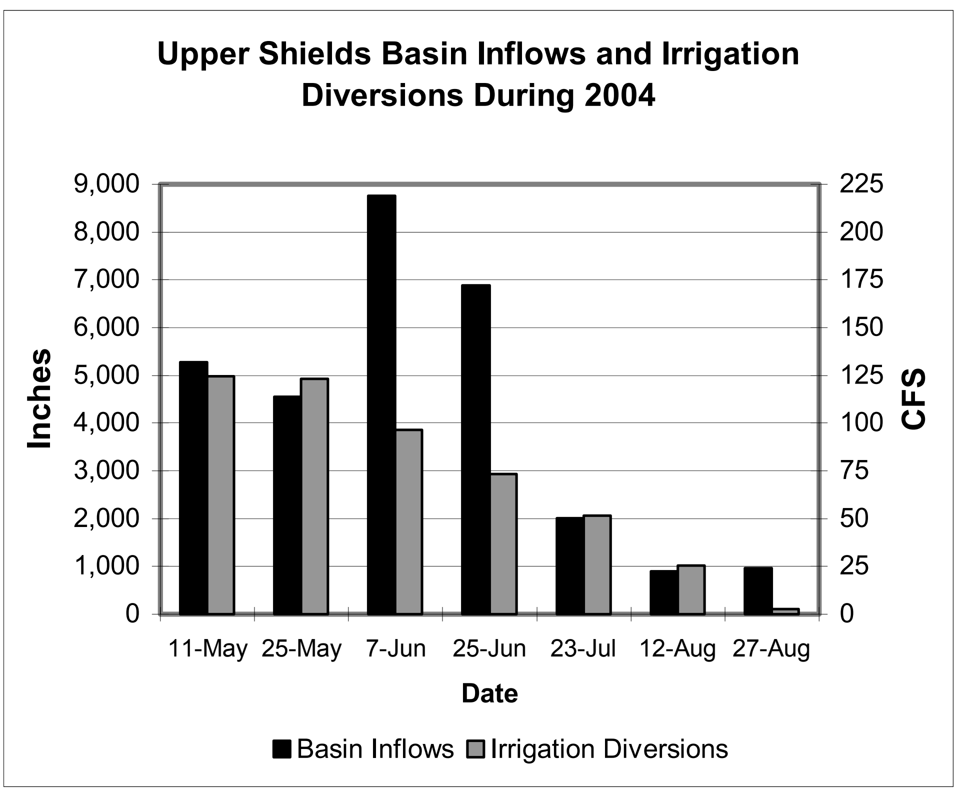
* These flows were estimated based on stage /discharge rating curve; all other flows are from actual discharge measurements.

Appendix C: Project Area Water Balance Observations by Year

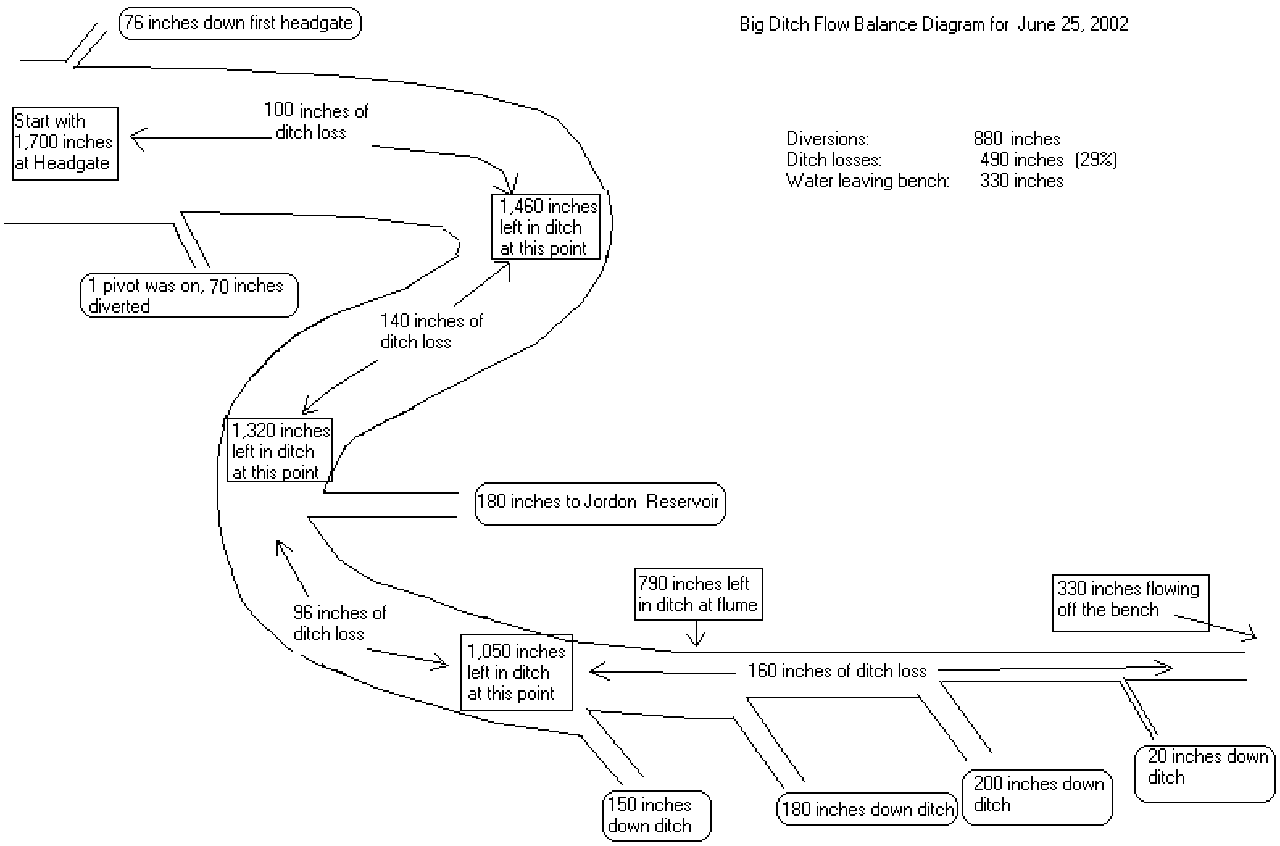




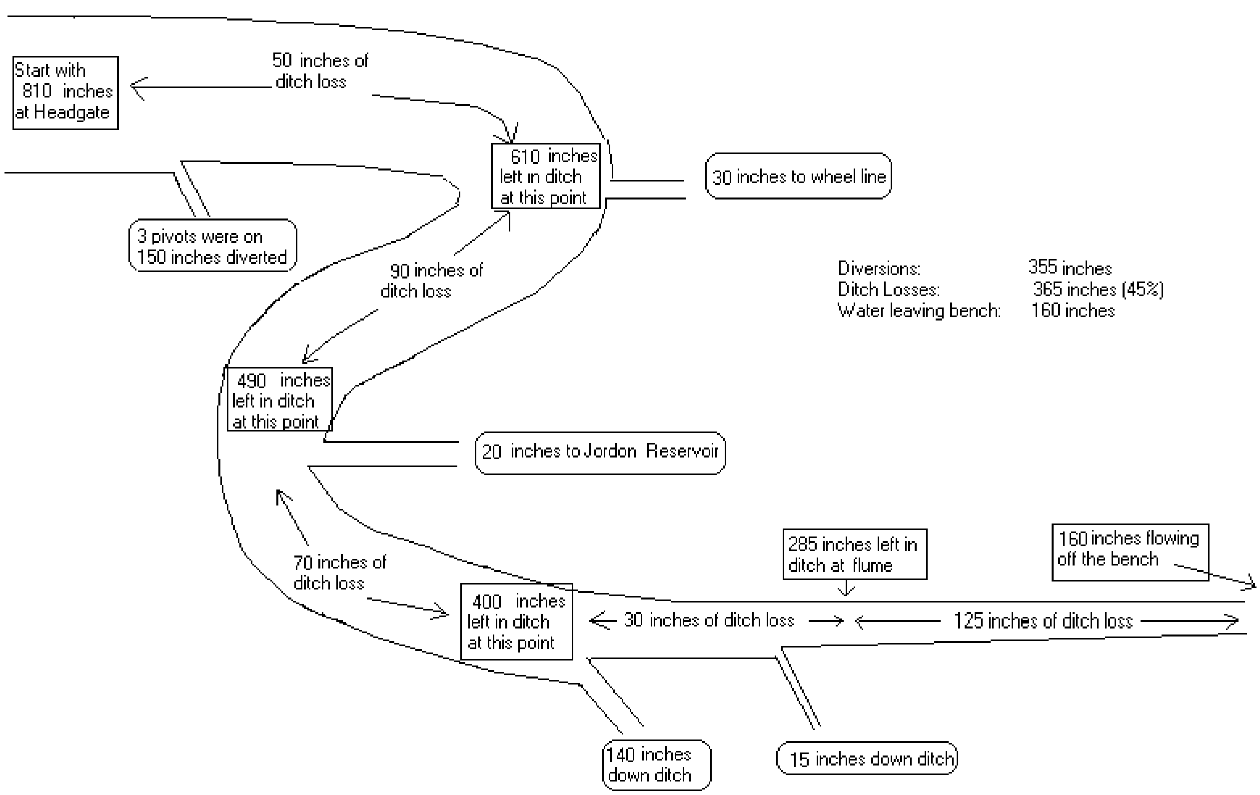

Upper Shields Basin Inflows and Irrigation Diversions During 2003
Inches
CFS
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
225
200
175
150
125
100
75
50
25
0
5-Jun
18-Jun
1-Jul
17-Jul
28-Jul
12-Aug
22-Aug
5-Sep
8-Oct
Date
Basin Inflows
Irrigation Diversions

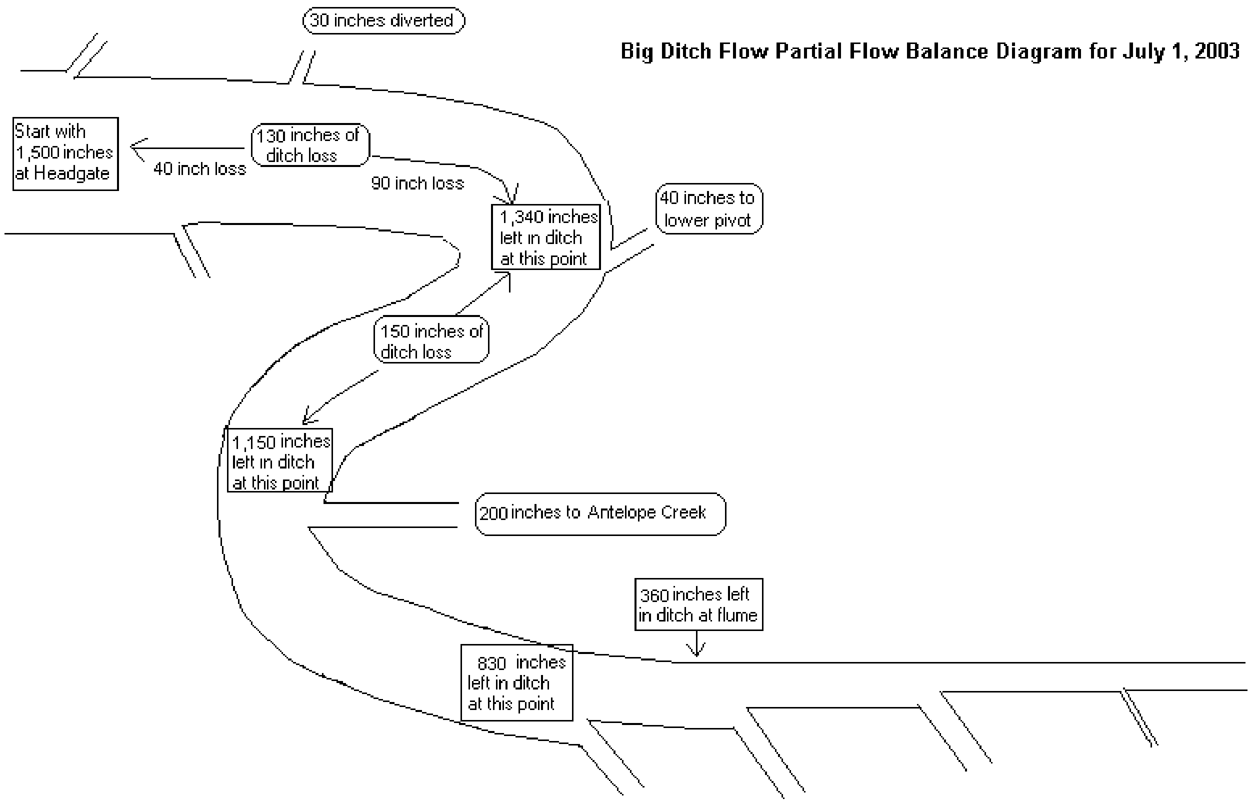

Upper Shields Basin Inflows and Irrigation Diversions During 2004
Inches
CFS
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
225
200
175
150
125
100
75
50
25
0
11-May
25-May
7-Jun
25-Jun
23-Jul
12-Aug
27-Aug
Date
Basin Inflows
Irrigation Diversions

Appendix D – Big Ditch Seepage Measurement Run Results.



Big Ditch Flow Balance Diagram for July 31, 2002




30 inches diverted
Big Ditch Flow Partial Flow Balance Diagram for July 1, 2003
Start with 1,500 inches at Headgate
130 inches of ditch loss
40 inch loss
90 inch loss
1,340 inches left in ditch at this point
40 inches to lower pivot
150 inches of ditch loss
1,150 inches left in ditch at this point
200 inches to Antelope Creek
360 inches left in ditch at flume
830 inches left in ditch at this point