Morrison Ditch Seepage Analysis
Monitoring Report

Mike Roberts, Hydrologist
Montana Department of Natural Resources and Conservation
Helena, Montana

Introduction

The Montana Department of Natural Resources and Conservation (DNRC) was requested to provide technical assistance in the determination of conveyance efficiency of the Morrison Ditch. Morrison Ditch diverts irrigation water from Racetrack Creek, a tributary to the upper Clark Fork River near Warm Springs. This assistance is an outgrowth of the Upper Clark Fork Basin Steering Committee's ongoing efforts to assist local water users and water interests to better meet the needs and objectives of basin water management.

The goal of this monitoring report is to quantify the conveyance efficiency of Morrison Ditch by determining the magnitude and location of seepage gains and losses during operation. The data presented can then be used to determine the potential for system savings and provide a basis for evaluating future water conservation measures in Racetrack Creek.

Study Area

Racetrack Creek is an east flowing tributary of the upper Clark Fork River near Warm Springs, Montana in the Deer Lodge Valley (Figure 1). The Morrison Ditch diverts water from the north bank of Racetrack Creek approximately 7.5 miles upstream from it's mouth. The ditch winds for approximately seven miles roughly contouring northward along the foothills of the Flint Creek Mountains to the terminus of the study reach. The ditch flows through three distinct geologic formations. The first mile of ditch is relatively high gradient (1-3%) as it dissects Quaternary glacial moraine deposits before flattening out into Quaternary alluvium for another 3.8 miles (Konizeski *etal* 1968). The lower 2.2 miles of the study reach flows through Tertiary fluvial deposits.

Surface inflows to the Morrison Ditch include its diversion on Racetrack Creek, two small intermittent drainages between the Prison Farm fence and Dempsey Creek, and a return ditch below the Johnson pumpsite. Outflows include an early season diversion below the moraine, a diversion into Dempsey Creek that is part of a water "exchange", the Fleming diversion approximately 4.5 miles below the headgate, the Johnson pumpsite a mile above the terminus, and the terminal parshall flume near the county road.

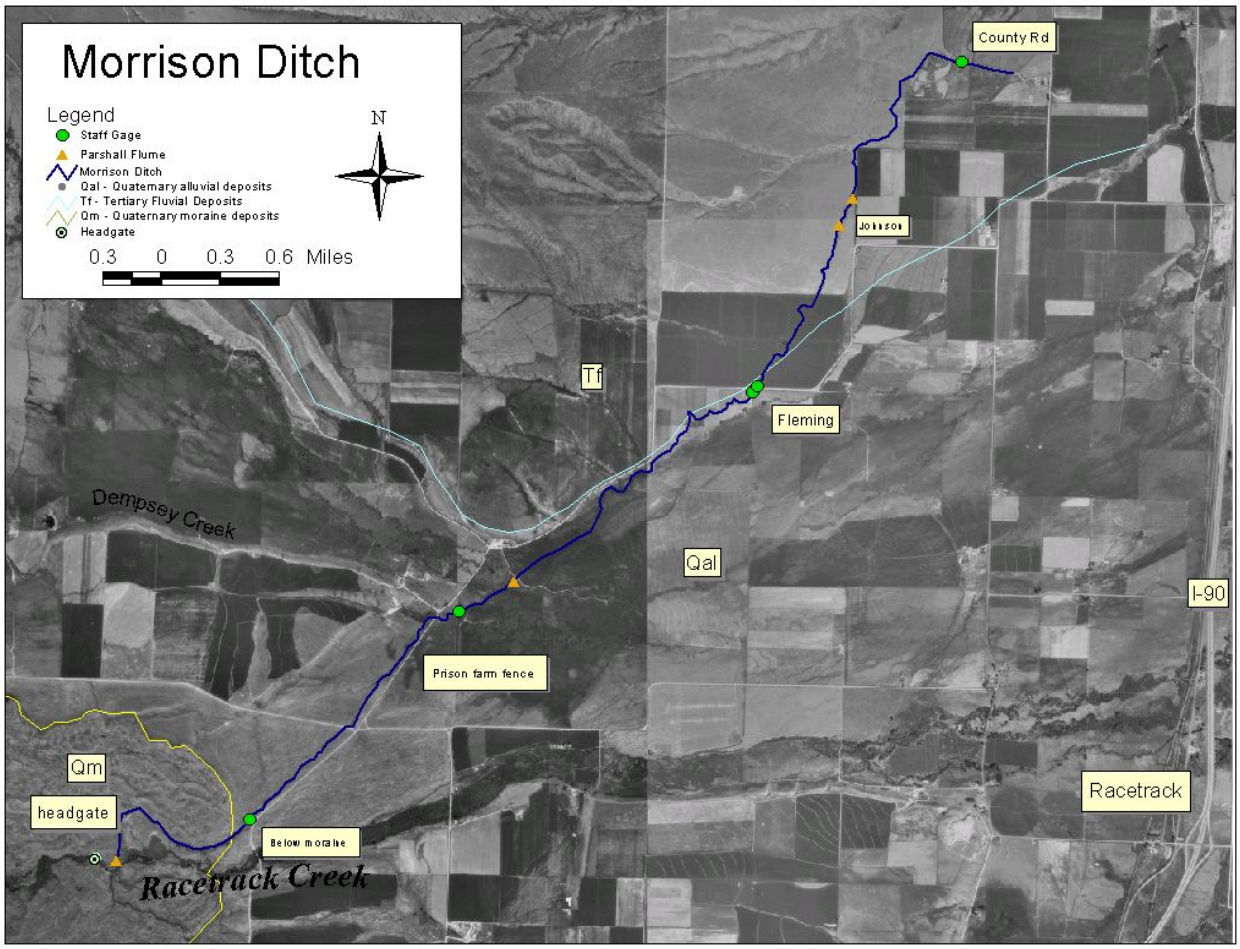


Figure 1. Study reach of Morrison Ditch.

Methods

Several streamflow measurement stations were established at various locations in the study reach. Stations were located directly below the headgate, above and below outflows (e.g. turnouts, pumps), and at the terminus of the study reach (Table 1). Staff gages were installed where measuring devices (parshall flumes) were not already present. Stage-discharge relationships were established and rating tables developed for the staff gage sites. Parshall flumes were tested for accuracy with flowmeter discharge measurements.

To determine conveyance efficiency, seepage loss was quantified over the full distance of the study reach by conducting synoptic measurement runs during the irrigation season to provide a "snapshot" of existing flow conditions. The following equation was used:

$$gain/loss = (outflow - inflow) + losses\ due\ to\ diversions$$

A portable flowmeter (Marsh-McBirney Model 2000) and standard USGS methodology were used for collecting discharge measurements.

Approximately 65 cfs is appropriated at the Morrison Ditch point of diversion. In 2003, the ditch operated from early May to early September. During May and June, near ditch full conditions of about 40 cfs were observed. Ditch flows decreased in July and August corresponding to declining flows in Racetrack Creek.

Table 1. Station Locations

Station	***Location***	***Distance (mi)***	***Substrate***
headgate	6N10W16CC	0	Quaternary moraine deposits
below moraine	6N10W16DA	1.1	Quaternary alluvium
Prison Ranch fence	6N10W10DA	2.6	Quaternary alluvium
Dempsey Creek	6N10W11BD	3	Quaternary alluvium
above Fleming	6N10W1CA	4.8	Quaternary alluvium
below Fleming	6N10W1BD	4.8	Quaternary alluvium
Johnson Flume	7N10W36DA	5.8	Tertiary fluvial deposits
Johnson Diversion	7N10W36DA	5.9	Tertiary fluvial deposits
Terminus near County Rd	7N9W30DD	7.1	Tertiary fluvial deposits

Results

Two of the three parshall flumes tested for accuracy were deemed adequate for water measurement (Table 2). The third, a four-foot parshall flume located on Prison Ranch property near Johnson's pump site, consistently underestimates flows by several cubic feet per second (cfs). This flume is out of level, tilting slightly forward, thus causing lower stage readings on the mounted staff gage, correspondingly low discharge readings, and a relatively consistent negative shift in the rating table of 0.134. Using the present network of flumes on Morrison Ditch may lead to an overestimation of seepage loss due to this particular flume. The terminal parshall flume located near the county road is submerged and therefore not useable.

Table 2. Parshall flume accuracy

Parshall Flume below headgate (4')

date	time	stage	measured Q	estimated Q	offset
5/7	1115		19.48		
8/13	1020	0.71	9.45	9.32	negl.

Dempsey Creek Turnout (1.5')

date	time	stage	measured Q	estimated Q	offset
5/30/2003	1100	1.34	9.2	9.4	0.02

Parshall Flume near Johnson (4')

date	time	stage	measured Q	estimated Q	offset
5/30	930	0.94	17.2	14.51	-0.11
6/11	1200	1.04	20.49	17.02	-0.13
7/3	1110	0.77	13.8	10.59	-0.14
7/17	850	0.52	8.65	5.7	-0.16
8/13	820	0.35	4.99	3.05	-0.13
				mean =	-0.134

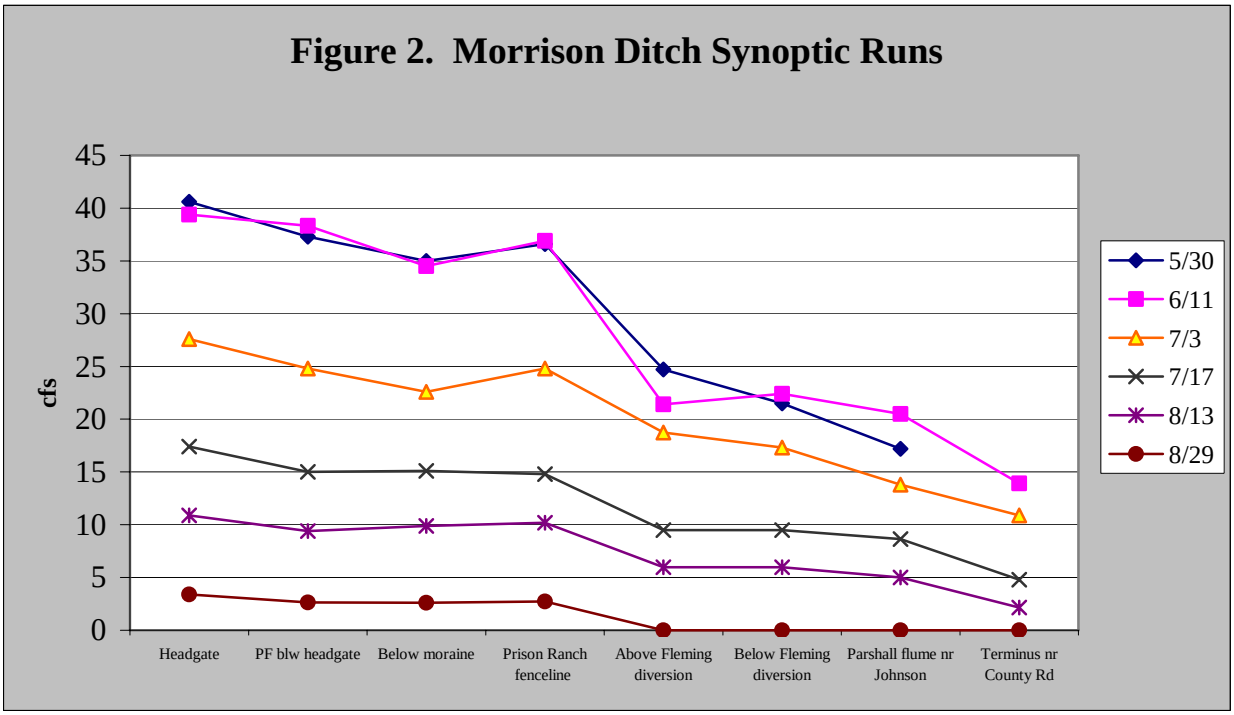
A total of seven synoptic runs were conducted between early May and late August of 2003. Two of these runs were conducted prior to the use of the full extent of the ditch. Discharge measurements are presented in Table 3.

Table 3. Morrison Ditch 2003 Discharge Measurements (cfs)

	5/7	5/30	6/11	7/3	7/17	8/13	8/29
Racetrack Cr abv Morrison Div	35.8	>150*	>150*	76.3	53.8	59.7	33.6
Below headgate	19.4	40.6	39.4	27.6	17.4	10.9	3.4
Parshall flume blw headgate	16.5	37.3	38.3	24.8	15.0	9.4	2.7
Below moraine	13.9	35.0	34.5	22.6	15.1	9.9	2.6
- Parshall flume outflow blw moraine	8.9	0.0	0.0	0.0	0.0	0.0	0.0
Prison Ranch fence line		36.6	36.9	24.8	14.8	10.2	2.7
- Inflows abv Dempsey Cr		0.4	0.0	0.0	0.0	0.0	0.0
Dempsey parshall flume - exchange		9.5	9.6	5.0	4.8	2.1	2.8
Above Fleming diversion		24.7	22.4	18.7	9.5	6.0	0.0
Below Fleming diversion		21.5	22.4	17.3	9.5	6.0	0.0
Parshall flume nr Johnson		17.2	20.5	13.8	8.7	5.0	0.0
- Parshall flume to Johnson pump			4.6	2.5	3.6	2.0*	0.0
- return ditch @ Johnson Pump			1.4	0.0	0.0	0.0	0.0
Near County Road			13.9	10.9	4.8	2.2	0.0

*field estimates

Figure 2 displays discharge measurements at each station during the synoptic runs of 2003. Losses and gains shown between stations is a function of surface and ground water inflows, diversions, and natural seepage.

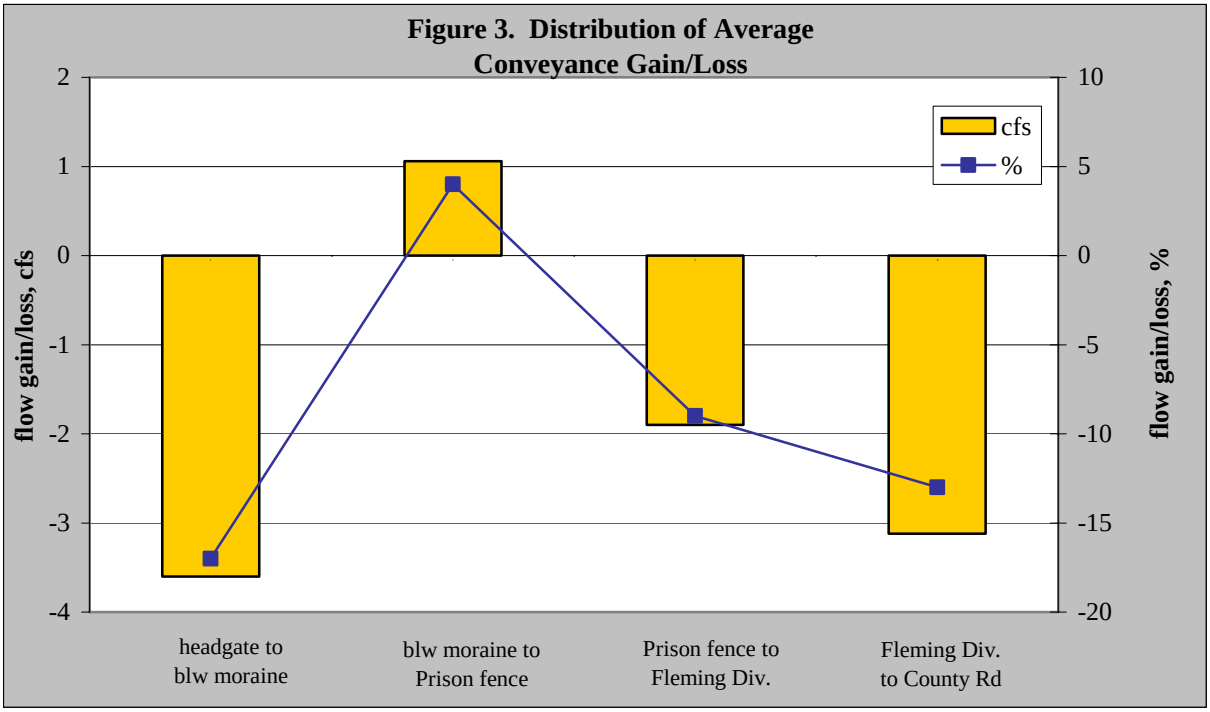


Conveyance losses attributed to diversion and natural seepage were determined for each synoptic run (Table 4).

Table 4. Morrison Ditch conveyance losses by diversion and seepage.

	Total	Losses by Diversion		Losses by Seepage	
date	Inflows	cfs	% of Inflows	cfs	% of Inflows
6/11	40.8	13.2	32.5	11.6	28.5
7/3	27.6	8.9	32.3	10.6	38.5
7/17	17.4	8.4	48.2	4.2	24.3
8/13	10.9	5.9	53.7	2.9	26.5
8/29	3.4	2.8	82.6	0.6	17.4

The distribution of average flow gains and losses were determined over four reaches (Figure 3). The reaches roughly correspond to the geologic boundaries discussed before. The first reach, headgate to blw moraine, flows through the Quaternary moraine deposits. The next two reaches are located in Quaternary alluvium, and the lower reach below the Fleming diversion, flows through Tertiary fluvial deposits.



Discussion:

Seepage losses were observed during all synoptic runs on Morrison Ditch. They ranged from 17 to 38%. This equates to approximately 5 cfs at low flow conditions to approximately 12 cfs under ditch-full conditions.

The greatest loss of flows due to seepage occurs between the headgate and the station located below the moraine. Gains were consistently observed in the reach immediately below the moraine to the Prison fence. Below the Prison fence, seepage losses were again observed, increasing towards the terminus of the study reach near the county road. Spatial variations in conveyance efficiency can partially be explained by geologic substrate and by adjacent land use practices. For example, one possible cause of the flow gains in the reach below the moraine to the Prison fence may be subsurface contribution resulting from fields irrigated on the hillside directly above this reach.

The consequences of a piping project could result in potential gains up to 12 cfs during high flow periods. During low water periods, however, gains would be substantially less. The fate of any water savings resulting from implemented water conservation strategies on Morrison Ditch would need to be investigated to determine the potential for instream benefits.