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THE COLORADO SATELLITE-LINKED WATER RESOURCES MONITORING SYSTEM

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THE COLORADO SATELLITE-LINKED WATER RESOURCES MONITORING SYSTEM

The Colorado satellite-linked monitoring system provides real-time water resources data on a continuous basis from key gaging stations across the State of Colorado. The computerized system can be accessed by computer terminal from any location via phone communications. These data and appropriate applications software provide for more effective water rights administration, computerized hydrologic records development, flood warning, and water resources management.

The system was provided to the State Engineer by the Colorado Water Resources and Power Development Authority. The Authority's Board was convinced through a two-year demonstration project in the Arkansas River and Rio Grande basins that the system could be an important tool in water resources management. Since the enhancement of water resources management is one of its goals, the Authority elected to fund the installation of the system and its first year of operation at a total cost of $1.8 million.

The Authority awarded the contract, under competitive procurement, to the Sutron Corporation, Herndon, Virginia, in May, 1984. The original contract called for Sutron to provide a turn-key system including remote data collection hardware for 82 stations, receive site, central computer, and operating/applications software. In March 1985, the Authority approved an expansion of the monitoring network by an additional 68 stations. This effectively brought the statewide network to 150 stations. The system acceptance test was successfully run on August 8, 1985. The system was formally dedicated on October 4, 1985. At that time, the Authority turned the system over to the State of Colorado under the jurisdiction of the Office of the State Engineer.

The Colorado satellite-linked water resources monitoring system received national merit awards in 1985 and 1986. The National Society of Professional Engineers selected the system as one of ten outstanding national engineering achievements for 1985. The Council of State Governments selected the system as one of eight of the top innovative programs instituted by state government in the nation for 1986. Colorado remains the only state in the nation to operate a statewide monitoring system of this type. Colorado remains in the forefront in utilization of this technology with other western states in the planning process to install and operate similar systems. These states include Utah, Texas, California, Idaho, Washington, Arizona, and New Mexico.

The interest in real-time data collection for monitoring water resources and other natural resources data is growing at an incredible rate due to the need for such data and the cost effectiveness. Various federal agencies, water conservancy districts, municipalities, and private entities now operate over 150 satellite-linked data collection stations in Colorado in addition to the state operated network.

I. PROGRAM DESCRIPTION

A. System Configuration

The system is comprised of seven basic components:

1. Gaging stations
2. Remote data collection hardware
3. Transmission receive hardware
4. Central computer
5. Applications software
6. Computer terminals for field staff
7. Satellite communications link

The remote data collection hardware is generally installed at pre-existing stream and reservoir gaging stations. The hardware interfaces with on-site sensors. The sensor may be either a float operating in a stilling well hydraulically connected to the stream or reservoir, a manometer or other type of pressure transducer with an orifice positioned in the water, or a direct discharge meter.

The remote site data collection hardware installed in these gaging stations includes a Data Collection Platform (DCP), an incremental analog-to-digital shaft encoder, an environmentally secure NEMA enclosure, a Yagi antenna, a 12-volt battery, a solar panel, and complimentary cables. The DCP is comprised of a sensor interface module, a microprocessor, and a UHF transmitter. The sensor interface module is capable of handling up to 16 sensors. The microprocessor provides for programmable input of data measurement and transmission scheduling, data manipulation, and data storage. The DCP is programmable by utilizing a portable terminal via an RS-232 port. The DCP measures approximately 10"x8"x4". The shaft encoder converts incremental stage values from analog to digital in hundredth of a foot intervals. The shaft encoder communicates directly with the DCP. The unit measures approximately 8"x6"x6". The NEMA enclosure houses the DCP and the battery. The unit measures approximately 24"x20"x10".

The transmission receive hardware basically consists of a 5-meter parabolic dish, downconverter, receiver, amplifier, multiplexor, and eight frequency agile programmable demodulators. This Direct Readout Ground Station is located at the Centennial Building, the Office of the State Engineer.

The central computer is comprised of a DEC VAX 11/750 computer with two 456 MByte hard disks, two 9-track tape drives (100 ips streamer mode 25 ips), four multifunction communications boards with eight serial ports each, and 32 modems. The VAX utilizes the VMS operating system. The system is designed to handle in excess of 300 DCP's. The central computer is located in the Centennial Building at the Office of the State Engineer.

The software, HYDROMET, was developed by the system contractor, Sutron Corporation. It is comprised of real-time data processing and archiving programs, alert/warning programs, reports and graphics output programs, and system performance monitoring programs. The software is written in Fortran.

Three ISC 2427 color CRT terminals, a Sanyo MBC-775 color CRT terminal, a Tektronix 4105A color CRT terminal, an LA 120 console printer, a 600 LPM printer, and an ISC X-Y color plotter are located in the Division of Water Resources' Denver office. Each of the seven Division offices has been provided with a Wang PC-XC3 computer having 256 KBytes of CPU. A memory expansion board increases the memory by 512 KBytes. Each unit has a software communications and productivity package, color display CRT terminal, printer, and modem. Thirty-two EPSON HX-20 portable remote terminals have been distributed to field staff and Water Commissioners through the Division offices. These terminals are capable of programming the DCP's via an RS-232 port and, being equipped with acoustic couplers, can provide for system access via phone communications.

Figure 1 illustrates the system configuration.

Figure 2 illustrates the configuration of the Direct Readout Ground Station.

Figure 3 illustrates the central computer hardware configuration.

Figure 4 illustrates the data management software configuration.

The communications link for data transmissions is the Geostationary Operational Environmental Satellite (GOES). GOES is a federal communications satellite operated by the National Oceanic and Atmospheric Administration, National Environmental Satellite, Data, and Information Service (NOAA-NESDIS). The GOES satellites are in an equatorial, geostationary orbit at a point 22,500 miles in space. This type of orbit allows for a continuous line-of-sight to be maintained with both remote transmitters and the Direct Readout Ground Station. NOAA-NESDIS has provided the Colorado State

Engineer's Office with 183 transmission slots allowing for 183 DCP's to transmit self-timed transmissions at separate 4-hour intervals, on channel 062. NOAA-NESDIS provided the use of a random reporting channel (118) for transmitting emergency messages.

Originally, the complete use of channel 062 was given to the Colorado State Engineer's Office. This provided for 240 individual transmission slots. The State Engineer chose to cooperate with the Northern Colorado Water Conservancy District, the City of Colorado Springs, and the Bureau of Reclamation - Loveland Projects Office, in sharing 57 transmission slots for use by these entities in collecting and transmitting real-time water resources data in Colorado.

B. System Operations

Data measurements are taken at the remote stations at 15-minute intervals. These data are stored and transmitted at 4-hour intervals in the standard transmission mode. The Division of Water Resources is authorized to transmit on GOES-CENTRAL, channel 062, 401.7925 MHz, with a bandwidth of 1.5 KHz. Random reporting (emergency transmissions) parameters are programmed directly into the DCP, including an alert level, warning level, data rate-of-change criteria, and the desired emergency transmission interval. When these user defined thresholds are met or surpassed, the random reporting mode activates. Random transmissions, down to 2-minute intervals, are made to update the user of significant hydrologic conditions. The computer can then signal interested users. This can be accomplished by sending a message to a remote terminal, setting off an alarm at a remote terminal, or by calling a phone and giving a voice synthesized message to the answerer.

The system operates on a continuous basis and can be accessed by computer terminal via any phone line. The VAX 11/750 is equipped with 32 modems, enabling the handling of 32 users simultaneously. The Division of Water Resources has negotiated with the U. S. Geological Survey-Water Resources Division (Denver) and the Northern Colorado Water Conservancy District (Loveland) to utilize their downlinks as backups.

The primary operations goal is to maintain data base integrity. Real-time data are of no value unless the data are accurate. Considerable effort is maintained to ensure that the remote hardware-sensor interface remains in calibration. This effort becomes compounded by the fact that over half of these gaging stations are operated by other entities that generally are not utilizing the data to make real-time decisions. Data values that fall outside of normal operating ranges are flagged to alert the data base manager.

The Division of Water Resources is responsible for system maintenance. Each Division office was provided with two sets of replacement hardware. If a component is determined to be malfunctioning, that component is replaced and returned to the manufacturer for repair. Field personnel received special training in DCP programming and in system diagnostics.

C. System Software (HYDROMET)

The HYDROMET software package is comprised of a series of programs that provide for transmission receive, raw data processing, data conversions, data archiving, data retrieval in various reports and graphics formats, and system diagnostics. The following is a description of the basic programs utilized by the user:

1. DAYFILES maintains and provides access to the real-time data being collected for a given station. This program performs raw data processing, data conversions, shift applications, and archiving of the real-time data. Figure 5 is an example of a DAYFILES report.

2. ARCHIVES computes and stores mean daily values for a given data type for a given station. Figure 6 is an example of an ARCHIVES report.

3. ANNUAL provides a yearly summary of mean daily values for a given data type for a given station. It also summarizes by month the total, mean, minimum, maximum, and any special conversions, i.e. mean daily discharge to acre-feet. The format matches that established by the U. S. Geological Survey-Water Resources Division and accepted by the Colorado Division of Water Resources for publication purposes. Figure 7 is an example of an ANNUAL report.

4. PLOT provides for the development of graphical displays of data values plotted against time. In the case of discharge data, this produces a hydrograph. Figure 8 is an example of a plot of DAYFILES

data. FIGURE 9 is an example of a plot of ARCHIVES data. Figure 10 is an example of a plot of ANNUAL data.

5. SCHEMATICS provides for a graphical display of the relative locations of monitoring stations along with the most recent data for each station. Figure 11 represents the lower reaches of the Division 3 monitoring network.

6. DIAGNOSTICS provides a detailed daily summary of the operating characteristics for a network of stations. This includes such things as missed transmissions, parity errors, missing data values, remote battery power, transmission power, and data base quality flags.

D. System Capabilities

The ability to collect data remotely on a real-time basis is the most fundamental capability of the system. The latest data values are never more than four hours old. Random (emergency) transmissions update the data base at intervals down to two minutes if user defined thresholds are met or surpassed. Data are processed in an automated fashion on a real-time basis. Data are automatically screened and appropriately flagged if they fall outside of a user defined normal range. If river conditions surpass flood warning levels, the system automatically sends out warning messages to designated personnel by either computer-to-computer communications or by giving a voice-synthesized message over the phone. Up to 32 users can access the system simultaneously. The system evaluates incoming transmissions and prepares a detailed summary of pertinent operating characteristics. The remote data collection hardware can interface with up to 16 sensors simultaneously.

E. Future System Developments

The expansion of the state's monitoring network over the next one to two years will be limited to five to ten stations. However, it is anticipated that other water resources management entities will install and operate stations statewide. Those stations that are of interest to the Office of the State Engineer will be monitored by the state's system. As the cost of purchasing and installing GOES-linked data collection hardware is only about $5,000 per station, more non-state entities will realize that this is a practical investment on their part.

Although network expansion by the State will be limited, the capabilities of the system will be enhanced by the addition of other sensor types. Water users statewide have indicated a need for additional types of data on a real-time basis, including precipitation, air temperature, soil moisture, snow depth, snow moisture equivalence, and conductivity. This need for additional data must be coupled with funds from the State of Colorado and from various water user groups to cover the costs of these additional sensors.

The input of historic flow data into the system's data base for key gaging stations in Colorado is expected to be completed by mid-1987. This will allow comparisons of recent data with data covering 20-30 year periods of record. Present flow conditions can be compared with wet and dry conditions.

The Office of the State Engineer has discussed with the Soil Conservation Service-Central Forecast Center (Portland, Oregon) the potential to input SNOTEL data for Colorado directly into the system's data base. Although the state's receive system cannot receive SNOTEL data transmissions, the processed data can be transferred daily to Colorado by computer-to-computer link. This would be extremely useful in assessing current snowpack conditions and short-term runoff.

The ability to extract information from the enormous amounts of real-time data being collected can be enhanced through the development of more sophisticated software. Currently, several Division offices are developing various water resources accounting programs. Programs in the area of short-term forecasting are of special interest. Program development will come slow over the next one to two years but will gradually increase momentum.

F. Monitoring System Network

The real-time hydrologic data collection network operated by the State of Colorado is comprised of 151 stations. These stations were selected by the State Engineer, Division Engineers, and Water Commissioners with an emphasis on the need for real-time data for water rights administration. The following is a tabulation of the location of these stations by division/river basin:

Division 1 / South Platte River Basin, 34 stations

Division 2 / Arkansas River Basin, 43 stations

Division 3 / Rio Grande Basin, 17 stations

Division 4 / Gunnison River Basin, 12 stations

Division 5 / Colorado River Basin, 22 stations

Division 6 / Green River Basin, 8 stations

Division 7 / Dolores and San Juan River Basins, 15 stations

A detailed list of these stations is included in Table 1. In the network development, the primary considerations are administrative importance, utility in project management, and the interrelationship of each station to other stations in a subnetwork. The goal was to incorporate those stations that satisfied as many of these requirements as possible in order to obtain maximum benefits from real-time data collection. The most important element in network development is in establishing station interrelationships. Rather than selecting stations, it is more important to incorporate integrated subnetworks. Data collected from one station are not as useful as information extracted from a subnetwork of stations. This is critical for compact administration, project management, developing water resources accounting systems, and in developing water resources management programs. Changes in the network can be made at any time and have been made in the last 12 months as a result of an evaluation of the utility of real-time data for a given station or due to a change in specific water rights administration. The remote data collection hardware is easily removed and installed at a substitute gaging station.

Considerable cooperation was necessary in developing this network. Ninety-eight (98) of the 151 gaging stations installed with remote data collection hardware by the State of Colorado are owned and operated by non-state entities. Access and installation agreements were negotiated with the following:

Entity	Number of Stations
U. S. Geological Survey - Water Resources Division	29
U. S. Bureau of Reclamation	18
Denver Water Board	9
Northern Colorado Water Conservancy District	4
Farmers Reservoir and Irrigation Company	1
North Sterling Irrigation District	1
Riverside Irrigation Company	1
U. S. Army Corps of Engineers	2
City of Colorado Springs	2
City of Pueblo	5
Highline Canal Company	1
Twin Lakes Canal Company	1
Catlin Canal Company	2
Fort Lyon Canal Company	3
Oxford Farmers Canal Company	1
Rocky Ford Highline Canal Company	1
Colorado Canal Company	1
Holbrook Canal Company	1
Upper Yampa Water Conservancy District	1
Water Supply and Storage Company	2
Lower Latham Ditch Company	1
Lamar Canal Company	1
Union Ditch Company	1
Mutual Irrigation Company	1
Terrace Irrigation Company	1
South Canal Company	1
Grand Valley Water Conservancy District	1
Grand Valley Water Users Association	1
Silt Water Conservancy District	2
MVI Diversion Company	1
La Plata and Cherry Creek Ditch Company	1

The cooperation that has been extended to the Office of the State Engineer by these entities is invaluable and demonstrates the interest by the water user community in the satellite monitoring system.

Various entities involved with water resources management and development within the State of Colorado have installed and are operating hydrological real-time data collection hardware in Colorado utilizing the GOES satellite as a communications link. As this is a federal satellite, all resource data transmitted through the satellite data collection system are in the public domain. The State Engineer's Office can schedule its Direct Readout Ground

Station to receive and process these raw transmissions. As of December 1, 1986, there were 85 such stations being monitored. The State Engineer's Office is cooperating with these entities in planning network expansion to maximize utility of real-time data collection without redundancy. A list of these stations is included in Table 1.

TABLE 1

SATELLITE-LINKED DATA COLLECTION NETWORK
MONITORED BY THE STATE OF COLORADO
DIRECT READOUT GROUND STATION

Stations Operated by the State of Colorado
Office of the State Engineer

	Station	Data Type
	DIVISION 1 (South Platte River Basin)	
1.	South Platte River at Waterton	S
2.	South Platte River near Kersey	S
3.	South Platte River at Balzac, South Channel, #1	S
4.	South Platte River at Balzac, North Channel, #2	S
5.	South Platte River at Julesburg, Channel #4	S
6.	South Platte River at Julesburg, Channel #2	S
7.	South Platte River near Weldona	S
8.	Big Thompson River at Mouth near La Salle	S
9.	St. Vrain Creek at Lyons	S
10.	St. Vrain Creek at Mouth near Platteville	S
11.	Cache La Poudre at Mouth of Canyon near Fort Collins	S
12.	Cache La Poudre near Greeley	S
13.	Harold D. Roberts Tunnel	S
14.	Moffat Water Tunnel	S
15.	Alva B. Adams Tunnel	S
16.	Burlington-Wellington Canal at the Headgate	S
17.	North Sterling Canal at the Headgate	S
18.	Riverside Canal at Reservoir Inlet Gage	S
19.	Boulder Creek near Orodell	S
20.	Laramie Poudre Tunnel	S
21.	Grand River Ditch	S
22.	Big Thompson River above Lake Estes	S
23.	Olympus Tunnel	S
24.	North Fork Big Thompson River at Drake	S
25.	Hoosier Pass Tunnel	S
26.	South Platte River at Fort Lupton	S
27.	Lower Latham Ditch	S
28.	Union Ditch	S
29.	South Platte River below Strontia Springs	S
30.	South Platte River below Chatfield Reservoir	S
31.	Metro Sewage Effluent Outlet Gage	S
32.	Big Thompson River at Mouth of Canyon	S
33.	Cheesman Reservoir	SE
34.	South Boulder Creek below Gross Reservoir	S
	Division 2 (Arkansas River Basin)	
1.	Arkansas River at Portland	S
2.	Arkansas River above Pueblo	S
3.	Arkansas River near Nepesta	S

Division 2 (Arkansas River Basin) cont.

		Data Type
4.	Arkansas River near Avondale	S
5.	Arkansas River near Wellesville	S
6.	Arkansas River at La Junta	S
7.	Arkansas River at Las Animas	S
8.	Purgatoire River near Las Animas	S
9.	Fountain Creek near Pinon	S
10.	Purgatoire River near Thatcher	S
11.	Lake Fork Creek above Turquoise Lake	S
12.	John Martin Reservoir	SE
13.	Arkansas River at Catlin Dam near Fowler	S
14.	Purgatoire River at Ninemile Dam near Higbee	S
15.	Charles H. Boustead Tunnel	S
16.	Homestake Tunnel	S
17.	Busk-Ivanhoe Tunnel	S
18.	Twin Lakes Tunnel	S
19.	Ewing Ditch	S
20.	Kicking Bird Canal	S
21.	Purgatoire River below Trinidad Reservoir	S
22.	Purgatoire River at Madrid	S
23.	Fort Lyon Storage Canal	S
24.	Cheyenne Creek near Stateline	S
25.	Pueblo Water Works Diversion	DM
26.	Lake Creek below Twin Lakes	S
27.	Lake Fork Creek below Sugar Loaf	S
28.	Timpas Creek near Rocky Ford	S
29.	Amity Canal	S
30.	Lamar Canal	S
31.	Crooked Arroyo near Swink	S
32.	Arkansas River at Granada	S
33.	Wurtz Ditch	S
34.	Columbine Ditch	S
35.	Pueblo Reservoir	SE
36.	Larkspur Ditch	S
37.	Arkansas River below John Martin Reservoir	S
38.	Fort Lyon Canal at the Headgate	S
39.	Catlin Canal at Gage Downstream from Catlin Dam	S
40.	Oxford Farmers Ditch at Headgate	S
41.	Rocky Ford Highline Canal at Headgate	S
42.	Colorado Canal at Headgate	S
43.	Holbrook Canal at Headgate	S

Division 3 (Rio Grande Basin)

1.	Rio Grande near Del Norte	S
2.	Rio Grande near Lobatos	S
3.	Rio Grande at Thirty-Mile Bridge near Creede	S
4.	Conejos River near Mogote	S
5.	Conejos River near La Sauses, North Channel	S
6.	Conejos River near La Sauses, South Channel	S
7.	Los Pinos River near Ortiz	S

Data Type

Division 3 (Rio Grande Basin) cont.

		Data Type
8.	San Antonio River at Ortiz	S
9.	Alamosa Creek above Terrace Reservoir	S
10.	Conejos River below Platoro Reservoir	S
11.	Closed Basin Project Outlet	S
12.	Terrace Reservoir	SE
13.	Rio Grande above the Mouth of Trinchera Creek	S
14.	Saguache Creek near Saguache	S
15.	La Jara Creek near Capulin	S
16.	South Fork Rio Grande at South Fork	S
17.	Rio Grande at Alamosa	S

Division 4 (Gunnison River Basin)

1.	Surface Creek near Cedaredge	S
2.	Leroux Creek near Lazear	S
3.	Kannah Creek near Whitewater	S
4.	Surface Creek at Cedaredge	S
5.	Muddy Creek above Paonia Reservoir	S
6.	Muddy Creek below Paonia Reservoir	S
7.	Cimarron River near Cimarron	S
8.	South Canal	S
9.	Uncompaghre River near Ridgway	S
10.	Dallas Creek near Ridgway	S
11.	Smith Fork at Crawford	S
12.	San Miguel River at Naturita	S

Division 5 (Colorado River Basin)

1.	Blue River below Dillon	S
2.	Dillon Reservoir	SE
3.	Blue River below Green Mountain Reservoir	S
4.	Green Mountain Reservoir	SE
5.	Williams Fork below Williams Fork Reservoir	S
6.	Colorado River at Hot Sulphur Springs	S
7.	Eagle River below Gypsum	S
8.	Fryingpan River near Ruedi	S
9.	Colorado River near Dotsero	S
10.	Williams Fork Reservoir	SE
11.	Colorado River below Lake Granby	S
12.	Lake Granby	SE
13.	Willow Creek Reservoir	SE
14.	Shadow Mountain Reservoir	SE
15.	Willow Creek Pump Canal	S
16.	Government Highline Canal	S
17.	Grand Valley Canal	S
18.	Plateau Creek near Cameo	S
19.	Rifle Creek below Rifle Gap Reservoir	S
20.	Grass Valley Canal	S
21.	Fryingpan River near Thomasville	S
22.	Willow Creek below Willow Creek Reservoir	S

	Data Type
Division 6 (Green River Basin)	
1. Pot Creek near Vernal, UT	S
2. Illinois River near Rand	S
3. Elk River at Clark	S
4. Yampa River near Oak Creek	S
5. Michigan River near Gould below the Confluence of the North and South Forks	S
6. Little Snake River near Slater	S
7. Roaring Fork River near Delaney Butte	S
8. Bear Creek near Toponas	S
Division 7 (Dolores and San Juan River Basins)	
1. Lost Canyon Creek near Dolores	S
2. Navajo River below Oso Diversion Dam	S
3. Rio Blanco below Blanco Diversion Dam	S
4. La Plata River at Hesperus	S
5. La Plata River at Colorado-New Mexico Stateline	S
6. Dolores River at Dolores	S
7. Dolores Tunnel	S
8. MVI II Diversion	S
9. Azotea Tunnel Outlet near Chama, NM	S
10. Mancos River near Mancos	S
11. Dolores River below McPhee Reservoir	S
12. Florida River below Lemon Reservoir	S
13. Florida River above Lemon Reservoir	S
14. La Plata and Cherry Creek Ditch	S
15. Pine River below Vallecito Reservoir	S

Stations Operated by the
U. S. Army Corps of Engineers (Omaha District)

Division 1 (South Platte River Basin)	
1. Bear Creek at Kittredge	P
2. Bear Creek at Morrison	S,P
3. Bear Creek Reservoir	SE,P
4. Bear Creek at Sheridan	S,P
5. Chatfield Reservoir	SE,P
6. Cherry Creek at Parker	P,AT
7. Clear Creek at Blackhawk	P
8. Clear Creek at Derby	S,P
9. Clear Creek at Georgetown	P,AT
10. Clear Creek near Golden	S,P
11. Conifer	P
12. South Platte River below Cheesman Reservoir	S,P
13. South Platte River at Denver	S
14. North Fork South Platte River at Grant	S,P,AT
15. South Platte River above Elevenmile Reservoir	S,P,AT
16. South Platte River at Henderson	S,P
17. South Platte River at South Platte	S,P
18. Plum Creek at Larkspur	P

Stations Operated by the National Weather Service, Colorado River Forecast Center (Salt Lake City)

	Data Type
Division 4 (Gunnison River Basin)	
1. Blue Mesa Reservoir	P,A,SE
2. Crested Butte	P,AT
3. Gunnison River at Delta	S,P,AT
4. East River at Almont	S,P,AT
5. Gunnison River near Grand Junction	S,AT
6. Ouray	P,AT
7. Paonia	P,AT
8. San Miguel River near Placerville	S,P,AT
9. Sargents	P,AT
10. North Fork Gunnison River near Somerset	S,AT
11. Taylor River at Almont	S,AT
12. Gunnison River near Gunnison	S,P,AT
13. Dolores River near Bedrock	S,P,AT
14. Taylor Park Reservoir	P,SE
15. Uncompaghre River near Colona	S,P
Division 5 (Colorado River Basin)	
1. Breckenridge	P,AT
2. Colorado River near Cameo	S
3. Colorado River below Glenwood Springs	S,P,AT
4. Colorado River near Kremmling	S
5. Colorado River near Colorado-Utah Stateline	S,AT
6. Dillon	P,AT
7. Grand Lake	P,AT
8. Meredith	P,AT
9. Roaring Fork River near Aspen	S,P,AT
10. Roaring Fork River at Glenwood Springs	S
11. Ruedi Reservoir	SE,P,AT
12. Winter Park	P,AT
Division 6 (Green River Basin)	
1. White River near Meeker	S,P,AT
2. Yampa River near Maybell	S,AT
3. Little Snake River near Lily	S,P
4. Little Snake River near Dixon, WY	S,P,AT
5. North Platte River near Northgate	S
Division 7 (Dolores and San Juan River Basins)	
1. Animas River at Durango	S,P,AT
2. San Juan River at Pagosa Springs	S,P,AT
3. Vallecito Reservoir	SE,P,AT

Stations Operated by the U. S. Geological Survey - Water Resources Division

	Data Type
Division 1 (South Platte River Basin)	
1. Jefferson Creek near Jefferson	S
2. Michigan Creek above Jefferson	S
3. South Platte River above Spinney Mountain Reservoir	S
4. Tarryall Creek near Como	S
Division 2 (Arkansas River Basin)	
1. Arkansas River near Coolidge, KS	S
2. Frontier Ditch near Coolidge, KS	S
Division 5 (Colorado River Basin)	
1. Crystal River above Avalanche Creek near Redstone	S
Division 7 (Dolores and San Juan River Basins)	
1. Animas River near Cedar Hill, NM	S
2. San Juan River at Farmington, NM	S

Stations Operated by the U. S. Bureau of Reclamation

	Data Type
Division 5 (Colorado River Basin)	
1. Lincoln Creek below Grizzly Reservoir	S,P,SR,AT
2. Roaring Fork River above Lost Man Creek	S,P,SR,AT
3. Mormon Control House	DM,P,SR,AT
4. Chapman Control House	DM,P,SR,AT

Stations Operated by the Northern Colorado Water Conservancy District

	Data Type
Division 5 (Colorado River Basin)	
1. Upper Fraser River above Winter Park	S
2. Lower Fraser River near Winter Park	S
3. St. Louis Creek above Fraser	S
4. Ranch Creek above Tabernash	S
5. Crooked Creek at Tabernash	S
6. Ten Mile Creek near Granby	S
7. Strawberry Creek near Granby	S
8. Vasquez Creek at Winter Park	S
9. Berthoud Pass Meteorological Station	SW,ST,SMU,SML,P,AT,SR
10. Arrow Meteorological Station	SW,ST,SMU,SML,P,AT
11. Fraser Meteorological Station	SW,ST,SMU,SML,P,AT

Division 5 (Colorado River Basin) cont.	Data Type
12. Meadow Creek Meteorological Station	SW,ST,SMU,SML,P,AT
13. Cottonwood Pass Meteorological Station	SW,ST,SMU,SML,P,AT
14. Granby Meteorological Station	SW,ST,SMU,SML,P,AT

Stations Operated by the
City of Colorado Springs

Division 2 (Arkansas River Basin)	
1. Fountain Creek at Fountain	S
2. Fountain Creek at Pueblo	S
3. Fountain Creek at Security	S

Station Operated by the
Santa Maria Reservoir Company

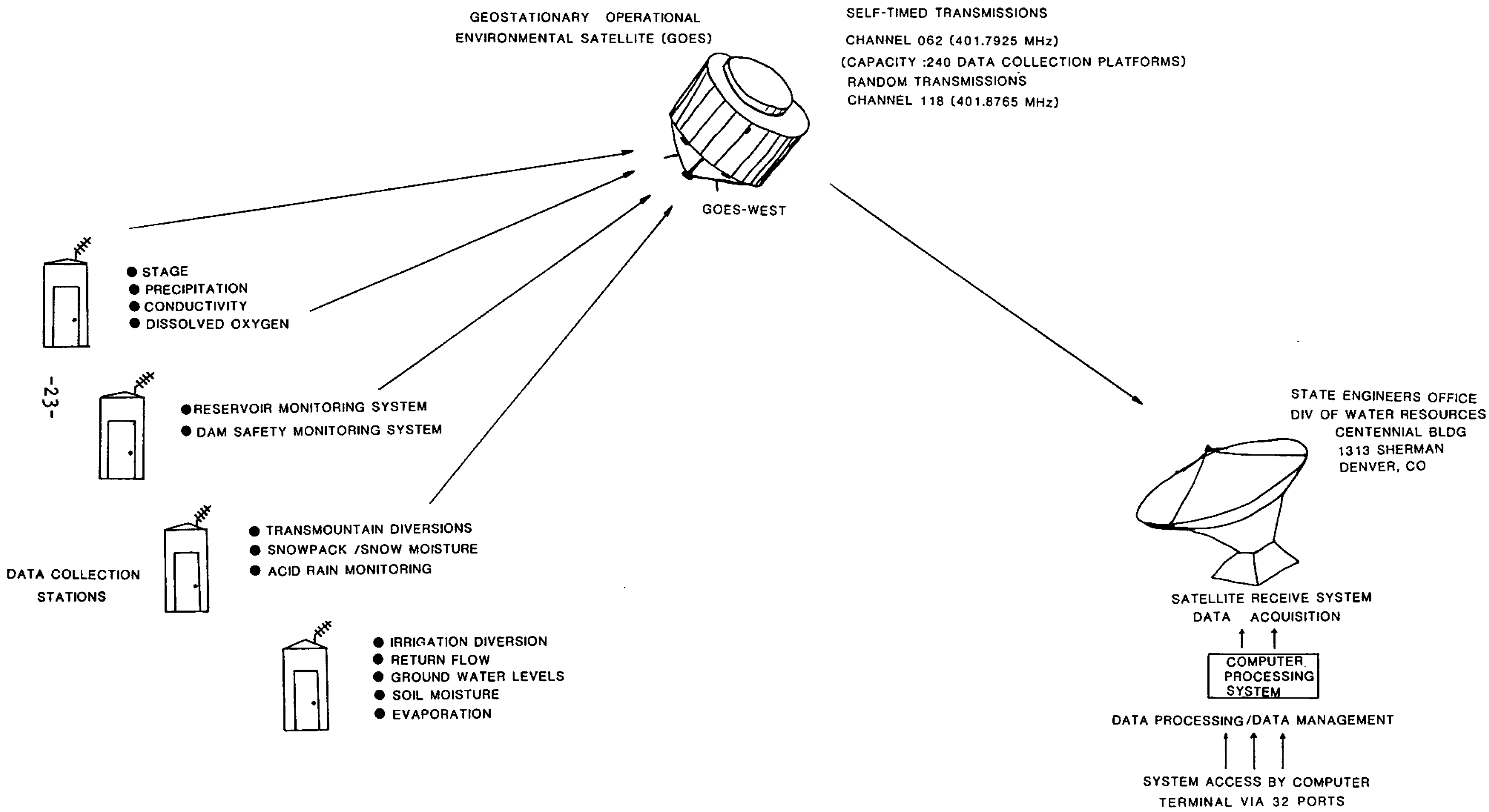
Division 3 (Rio Grande Basin)	
1. Continental Reservoir	SE

Station Operated by the
Rio Grande Water Users Association

Division 3 (Rio Grande Basin)	
1. Rio Grande Canal	S

Data Type Abbreviations

S	Stage
SE	Stage Elevation (Reservoir)
DM	Discharge Meter
P	Precipitation
AT	Air Temperature
SR	Solar Radiation
SW	Snow Water
ST	Snow Temperature
SMU	Soil Moisture Upper
SML	Soil Moisture Lower



MONITORING SYSTEM CONFIGURATION

Figure 1

GOES SATELLITE RECEIVE SITE ELECTRONICS

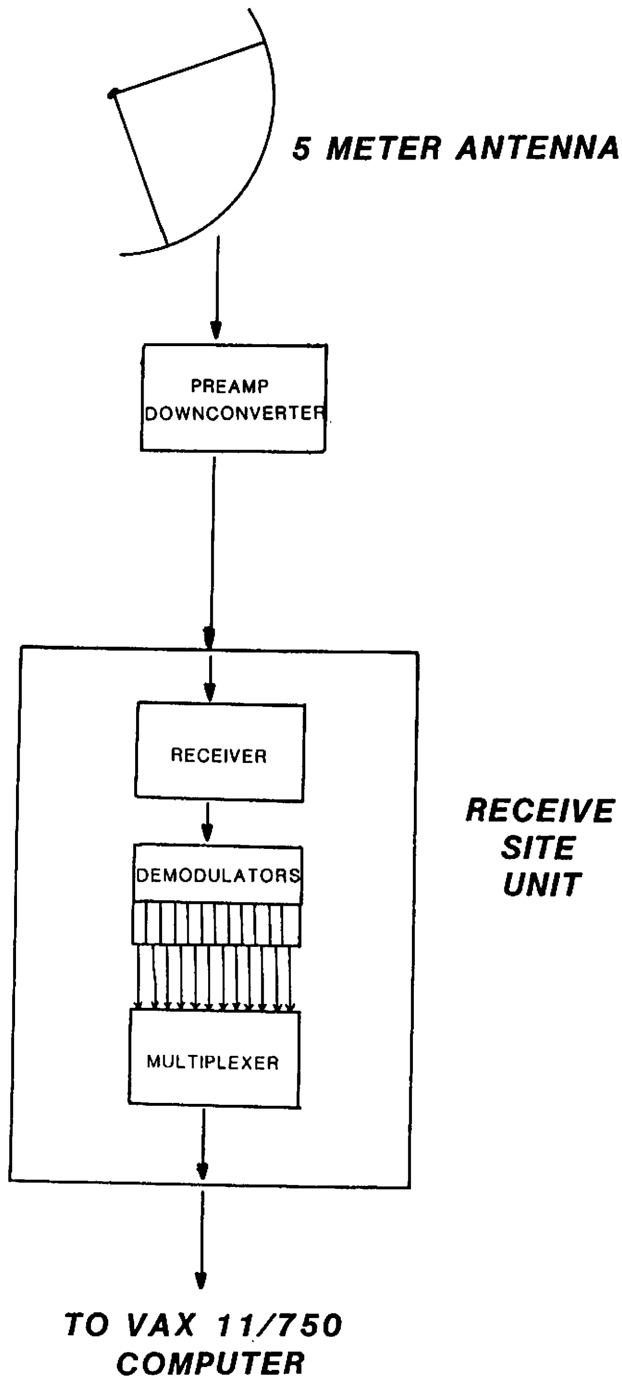


Figure 2

VAX 11/750 COMPUTER AND COMMUNICATIONS HARDWARE

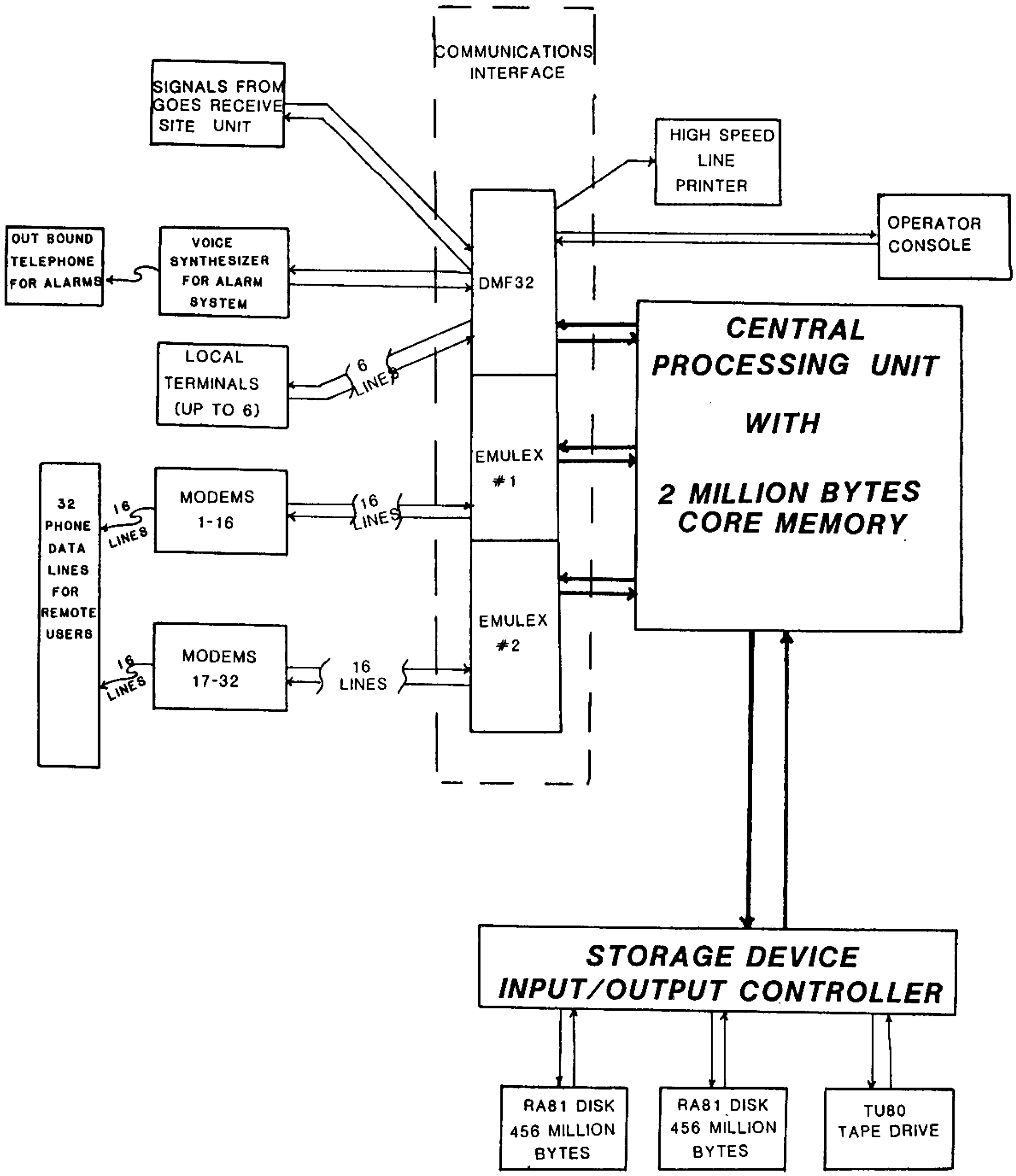
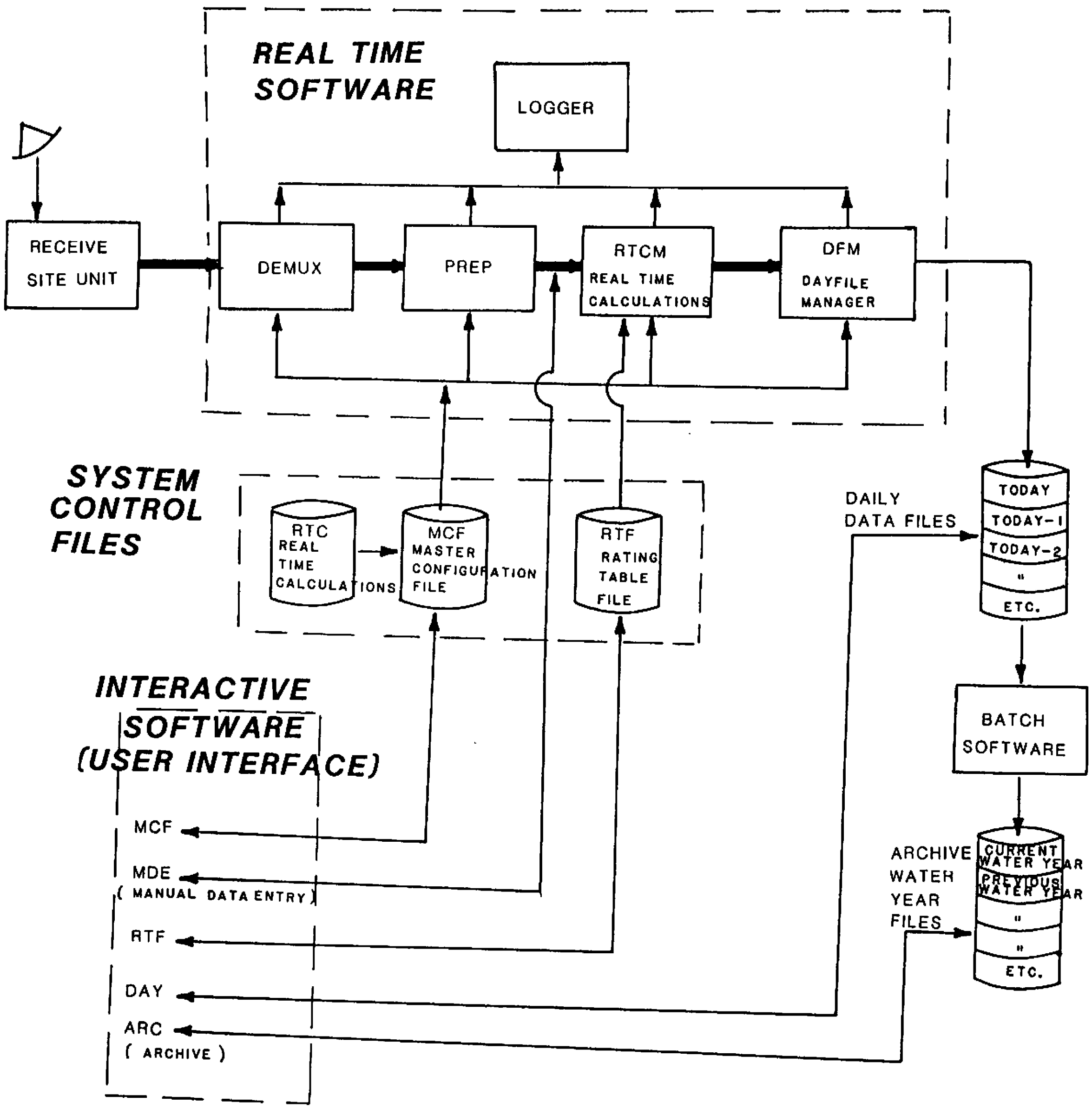


Figure 3

DWR DATA MANAGEMENT SYSTEM



THE OPERATION AND SCHEDUALING OF ALL PROCESSES, INCLUDING USER ACCESS AND ACCOUNTING , IS CONTROLLED BY THE VAXVMS (VIRTUAL MEMORY SYSTEM) OPERATING SYSTEM

Figure 4

DAYFILES REPORT

	STATION NAME	DATE	TIME		DATA TYPE	DATA VALUE			SHIFT VALUE
1	COLUTACO	JUN 15	00:00	#	GAGE_HT	7.88	#	SHIFT	-0.04 #
				#	DISCHRG	22800.00	#		
2	COLUTACO	JUN 15	01:00	#	GAGE_HT	7.91	#	SHIFT	-0.04 #
				#	DISCHRG	23000.00	#		
3	COLUTACO	JUN 15	02:00	#	GAGE_HT	7.91	#	SHIFT	-0.04 #
				#	DISCHRG	23000.00	#		
4	COLUTACO	JUN 15	03:00	#	GAGE_HT	7.93	#	SHIFT	-0.04 #
				#	DISCHRG	23000.00	#		
5	COLUTACO	JUN 15	04:00	#	GAGE_HT	7.93	#	SHIFT	-0.04 #
				#	DISCHRG	23000.00	#		
6	COLUTACO	JUN 15	05:00	#	GAGE_HT	7.90	#	SHIFT	-0.04 #
				#	DISCHRG	22900.00	#		
7	COLUTACO	JUN 15	06:00	#	GAGE_HT	7.91	#	SHIFT	-0.04 #
				#	DISCHRG	23000.00	#		
8	COLUTACO	JUN 15	07:00	#	GAGE_HT	7.86	#	SHIFT	-0.04 #
				#	DISCHRG	22800.00	#		
9	COLUTACO	JUN 15	08:00	#	GAGE_HT	7.88	#	SHIFT	-0.04 #
				#	DISCHRG	22800.00	#		
10	COLUTACO	JUN 15	09:00	#	GAGE_HT	7.87	#	SHIFT	-0.04 #
				#	DISCHRG	22800.00	#		
11	COLUTACO	JUN 15	10:00	#	GAGE_HT	7.86	#	SHIFT	-0.04 #
				#	DISCHRG	22800.00	#		
12	COLUTACO	JUN 15	11:00	#	GAGE_HT	7.81	#	SHIFT	-0.04 #
				#	DISCHRG	22600.00	#		
13	COLUTACO	JUN 15	12:00	#	GAGE_HT	7.86	#	SHIFT	-0.04 #
				#	DISCHRG	22800.00	#		
14	COLUTACO	JUN 15	13:00	#	GAGE_HT	7.82	#	SHIFT	-0.04 #
				#	DISCHRG	22600.00	#		
15	COLUTACO	JUN 15	14:00	#	GAGE_HT	7.83	#	SHIFT	-0.04 #
				#	DISCHRG	22600.00	#		
16	COLUTACO	JUN 15	15:00	#	GAGE_HT	7.79	#	SHIFT	-0.04 #
				#	DISCHRG	22500.00	#		
17	COLUTACO	JUN 15	16:00	#	GAGE_HT	7.82	#	SHIFT	-0.04 #
				#	DISCHRG	22600.00	#		
18	COLUTACO	JUN 15	17:00	#	GAGE_HT	7.84	#	SHIFT	-0.04 #
				#	DISCHRG	22700.00	#		
19	COLUTACO	JUN 15	18:00	#	GAGE_HT	7.84	#	SHIFT	-0.04 #
				#	DISCHRG	22700.00	#		
20	COLUTACO	JUN 15	19:00	#	GAGE_HT	7.89	#	SHIFT	-0.04 #
				#	DISCHRG	22900.00	#		
21	COLUTACO	JUN 15	20:00	#	GAGE_HT	7.91	#	SHIFT	-0.04 #
				#	DISCHRG	23000.00	#		
22	COLUTACO	JUN 15	21:00	#	GAGE_HT	7.99	#	SHIFT	-0.04 #
				#	DISCHRG	23300.00	#		
23	COLUTACO	JUN 15	22:00	#	GAGE_HT	8.04	#	SHIFT	-0.04 #
				#	DISCHRG	23500.00	#		
24	COLUTACO	JUN 15	23:00	#	GAGE_HT	8.04	#	SHIFT	-0.04 #
				#	DISCHRG	23500.00	#		

DAYFILES >

COLUTACO= Colorado River Near the Colorado-Utah Stateline

Figure 5

ARCHIVES REPORT

WATER YEAR 1986

** JUN **

COLUTACO

	SUN	MON	TUE	WED	THU	FRI	SAT
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	COLUTACO						
DISCHRG	25100.48	25452.75	25194.88	27511.65	30157.28	30993.68	32063.67
GAGE_HT	8.46	8.54	8.48	9.03	9.58	9.75	9.96
SHIFT	-0.06	-0.06	-0.06	-0.05	-0.05	-0.05	-0.05
	(8)	(9)	(10)	(11)	(12)	(13)	(14)
	COLUTACO						
DISCHRG	32942.50	31176.86	29227.04	26238.97	23511.54	22463.66	22747.17
GAGE_HT	8.43	9.78	9.39	8.73	8.05	7.79	7.86
SHIFT	-0.05	-0.05	-0.05	-0.05	-0.05	-0.04	-0.04
	(15)	(16)	(17)	(18)	(19)	(20)	(21)
	COLUTACO						
DISCHRG	22881.46	23627.21	23656.99	23710.96	23655.93	23266.63	22088.70
GAGE_HT	7.89	8.07	8.08	8.08	8.06	7.95	7.65
SHIFT	-0.04	-0.04	-0.04	-0.03	-0.02	-0.01	0.00
	(22)	(23)	(24)	(25)	(26)	(27)	(28)
	COLUTACO						
DISCHRG	21671.92	998877.00	998877.00	998877.00	998877.00	19543.46	19817.65
GAGE_HT	7.54	998877.00	998877.00	998877.00	998877.00	6.96	7.02
SHIFT	0.00	998877.00	998877.00	998877.00	998877.00	0.05	0.06
	(29)	(30)					
	COLUTACO						
DISCHRG	19311.40	18841.98					
GAGE_HT	6.89	6.76					
SHIFT	0.06	0.07					

ARCHIVES >

COLUTACO=Colorado River Near the Colorado-Utah Stateline

Note: 998877 values are default flags where the actual data was outside of user determined normal range

Figure 6

ANNUAL REPORT

09163500 COLORADO RIVER NEAR COLORADO-UTAH STATE LINE

DISCHRG WATER YEAR OCTOBER 1985 TO SEPTEMBER 1986
MEAN VALUES

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	7930.	6729.	---	5243.	6880.	7485.	13190.	16206.	25100.	18399.	7873.	5854.
2	7904.	6607.	---	5078.	6871.	7393.	14503.	18747.	25453.	17419.	7597.	5924.
3	7103.	6481.	---	5040.	6884.	7453.	16235.	21221.	25195.	16948.	7248.	5939.
4	6567.	6304.	---	5030.	6923.	7620.	14171.	23870.	27512.	16717.	7011.	5945.
5	6264.	6302.	---	4874.	6525.	7734.	12497.	26323.	30157.	18107.	6922.	5757.
6	6286.	6360.	---	4578.	6427.	7830.	11438.	26349.	30994.	20188.	6941.	5545.
7	6310.	6415.	---	4497.	6360.	7135.	10947.	24245.	32064.	19415.	6636.	5347.
8	7401.	6307.	---	4504.	6245.	6995.	11109.	23081.	32943.	17828.	6576.	5291.
9	10682.	6310.	---	4448.	6317.	7575.	11517.	21414.	31177.	17450.	6365.	5557.
10	9605.	6398.	---	4391.	6223.	8153.	11818.	20519.	29227.	17120.	6324.	6434.
11	9780.	6484.	---	4604.	5977.	7922.	11815.	19104.	26239.	16615.	5850.	7904.
12	10503.	6862.	---	4736.	5591.	7750.	11766.	18663.	23512.	15048.	5369.	7577.
13	10312.	7155.	---	4659.	5832.	7501.	12130.	18274.	22464.	14088.	5487.	7163.
14	9797.	7246.	---	5273.	6089.	7427.	12246.	17704.	22747.	14380.	5697.	6937.
15	8798.	7540.	---	6243.	6112.	7250.	11418.	17957.	22881.	14896.	5571.	6687.
16	8283.	7307.	---	6214.	6713.	7273.	11005.	19585.	23627.	14158.	5411.	6572.
17	7792.	7180.	---	6341.	6763.	7172.	11413.	20312.	23657.	14896.	5303.	6353.
18	7582.	7180.	---	6420.	6586.	7124.	11909.	19718.	23711.	14553.	5129.	6168.
19	7174.	7167.	---	6571.	6514.	6438.	11812.	18980.	23656.	13472.	4854.	6106.
20	7059.	7150.	---	6772.	7245.	6037.	11115.	19070.	23267.	13049.	4918.	6245.
21	7138.	7012.	---	6533.	7885.	5965.	10763.	21136.	22089.	13100.	4745.	6082.
22	7183.	6678.	---	6556.	7135.	5705.	11683.	23860.	21672.	12567.	5009.	5846.
23	7240.	6460.	---	6557.	6767.	5981.	13951.	25265.	20519.	12274.	5069.	5909.
24	7143.	---	---	6589.	6664.	6323.	16182.	26092.	19104.	11828.	5090.	6939.
25	7096.	---	---	6614.	6788.	6794.	16829.	25811.	18663.	11364.	5315.	8137.
26	7030.	---	5275.	6573.	7102.	7192.	17120.	25847.	18274.	10933.	5758.	8117.
27	7030.	---	5109.	6560.	7365.	7407.	16615.	27530.	19543.	10579.	5694.	8540.
28	7031.	---	5003.	6609.	7534.	7939.	15048.	28110.	19818.	9955.	5281.	7959.
29	7117.	---	4972.	6615.		8633.	14088.	28016.	19311.	9301.	5465.	8526.
30	7122.	---	5076.	6668.		9429.	14380.	27698.	18842.	8610.	5255.	8300.
31	7026.	---	5167.	6729.		10539.		25789.		8218.	5527.	
TOTAL	241290.	155633.	30602.	178117.	186317.	229174.	390713.	696497.	646856.	351327.	181291.	199662.
MEAN	7784.	6767.	5100.	5746.	6654.	7393.	13024.	22468.	24879.	14053.	5848.	6655.
MAX	10682.	7540.	5275.	6772.	7885.	10539.	17120.	28110.	32943.	20188.	7873.	8540.
MIN	6264.	6302.	4972.	4391.	5591.	5705.	10763.	16206.	18842.	8218.	4745.	5291.

WTR YR 1986 TOTAL 3487480. MEAN 10797. MAX 32943. MIN 4391.

Note: Missing values in Nov-Dec are due to ice effects on Stage Sensor

Figure 7

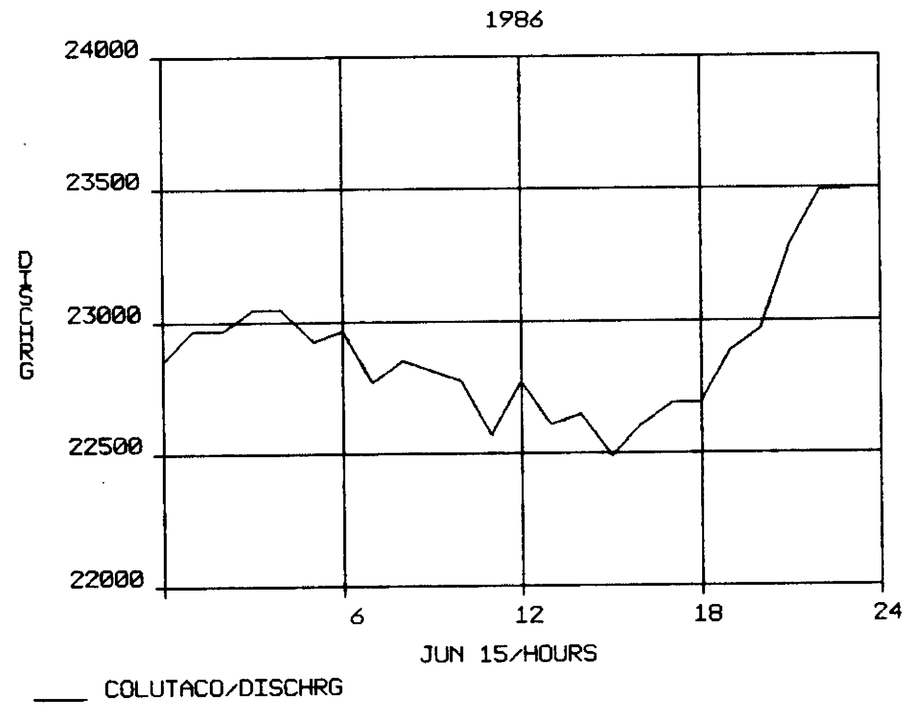


Figure 8
DAYFILES PLOT

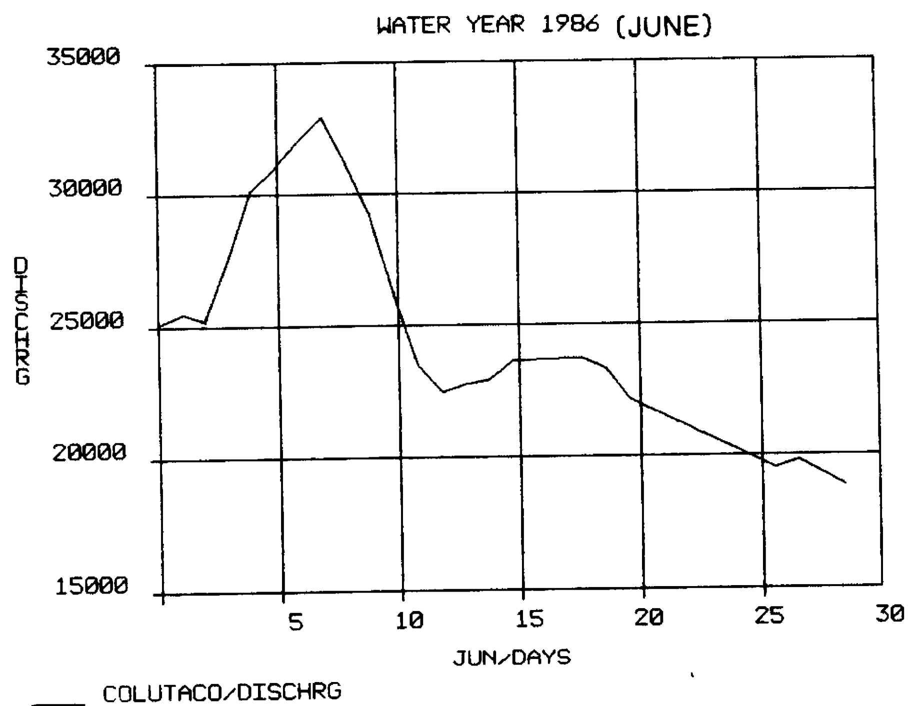
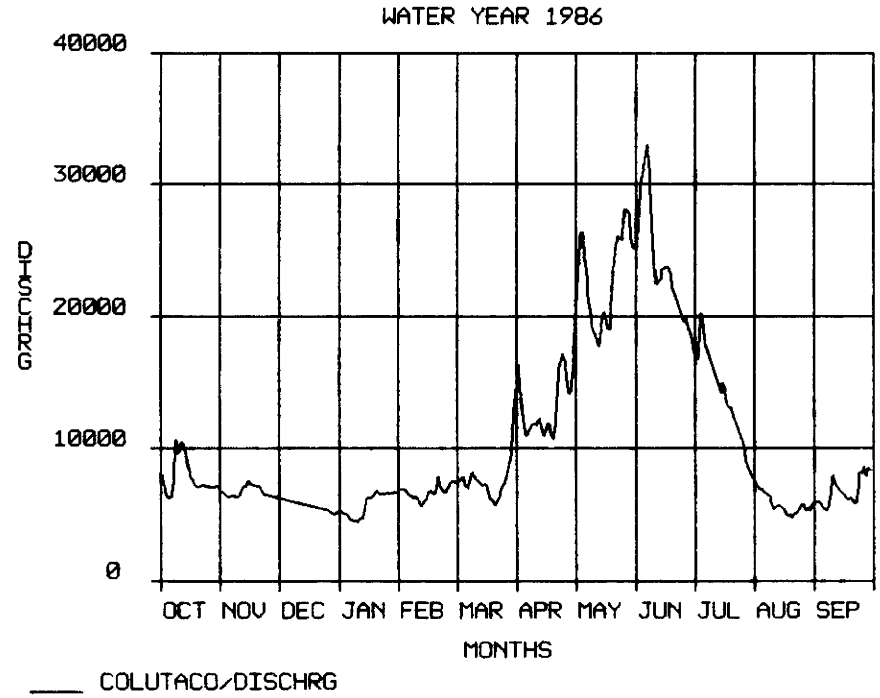


Figure 9
ARCHIVES PLOT

Figure 10
ANNUAL PLOT



COLUTACO=Colorado River Near the Colorado–Utah Stateline

SCHEMATIC

```
 |
 |
 * RIOTRICO         RIO GRANDE RIVER ABOVE
 | 10:45 DEC18      THE MOUTH OF TRINCHERA CRE
 | STAGE:  3.35 ft  DISCHARGE:     504. cfs
 |
 |
 |          |
 |          * CONPLACO         CONEJOS RIVER BELOW
 |          | 10:45 DEC18      PLATORO RESERVOIR, CO CONE
 |          |  STAGE:  1.98 ft  DISCHARGE:     360. cfs
 |          |
 |          |
 |          * CONMOGCO         CONEJOS RIVER NEAR
 |          | 11:15 DEC18      MOGOTE, CO.
 |          | STAGE:  0.71 ft  DISCHARGE:     148. cfs
 |          |
 |          |          |          |
 |          |          |          * LOSORTCO         LOS PINOS RIVER NEAR
 |          |          |          | 10:45 DEC18      ORTIZ, CO.
 |          |          |          | STAGE:  2.38 ft   DISCHARGE:     113. cfs
 |          |          |          |
 |          |          |<----<----+
 |          |          |
 |          |          |
 |          |          * SANORTCO         SAN ANTONIO RIVER AT
 |          |          | 10:45 DEC18      ORTIZ, CO.
 |          |          | STAGE:  0.86 ft  DISCHARGE:     198. cfs
 |          |          |
 |          |<----<----+
 |          |
 |          |
 |          * NORLASCO         NORTH CHANNEL CONEJOS
 |          | 09:00 DEC18      RIVER NEAR LASAUSES, CO.
 |          | STAGE:  2.85 ft  DISCHARGE:     130. cfs
 |          |
 |          |
 |          * SOULASCO         SOUTH CHANNEL CONEJOS
 |          | 10:00 DEC18      RIVER NEAR LASAUSES, CO.
 |          | STAGE:  1.02 ft  DISCHARGE:       1. cfs
 |          |
 |<----<----+
 |
 |
 * RIOLOBCO         RIO GRANDE NEAR LOBATOS,
   09:00 DEC18      CO.
   STAGE:  3.20 ft  DISCHARGE:    1580. cfs
```

Figure 11

II. SYSTEM APPLICATIONS

A. Water Rights Administration

The primary utility of the Colorado satellite-linked monitoring system is for water rights administration. The availability of real-time data from a network of key gaging stations in each major river basin in Colorado provides an overview of the hydrologic conditions of the basin that was previously not available. By evaluating real-time data for upstream stations, downstream flow conditions can typically be predicted 24 to 48 hours in advance. This becomes an essential planning tool in the hands of the Division Engineers and Water Commissioners. The "river call" can be adjusted more precisely to satisfy as many water rights as possible.

The administration of water rights in Colorado is becoming increasingly more complex due to increased demands, implementation of augmentation plans, water exchanges, transmountain diversions, and minimum streamflow requirements. One point that must not be overlooked is that Colorado is currently in the high point of a wet cycle. Historical and statistical evidence strongly indicate that Colorado can expect to experience a downturn in this cycle. As the availability of water decreases, the necessity of the system for water rights administration increases.

There is considerable interest in monitoring transmountain diversions, both by western slope water users and the eastern slope entities diverting the water. Transmountain diversion water is administered under different laws than water originating in the basin. In general, this water may be claimed for reuse by the diverter until it is totally consumed. Fourteen transmountain diversions are monitored by the system.

Water exchanges between water users are becoming increasingly frequent. These exchanges can provide for more effective utilization of available water resources in high demand river basins, but can be difficult to administer. The satellite-linked monitoring system has proven to be an integral component in monitoring and accounting of these exchanges.

Many municipalities and major irrigation companies have reservoir storage rights. Generally, these entities can call for release of stored water on demand. The Division Engineer must be able to delineate the natural flow from the storage release while in the stream. He then must track the release and insure that the proper delivery is made. The system has demonstrated to be effective in this area.

The utility of the system in the administration of interstate compacts is an especially important application. The State Engineer has the responsibility to deliver defined amounts of water under the terms of the various interstate compacts, but not to over-deliver and deprive Colorado of its entitlement. Fifteen stations incorporated in the statewide monitoring network are utilized for the effective administration of these interstate compacts.

The majority of the large, senior water rights in Colorado belong to irrigation companies. These rights are often the calling right in the administration of a water district. The direct diversion rights exercised can effect significantly the hydrology of the river. Twenty-one major irrigation diversions are monitored by the system.

Recently, water rights have been acquired by federal and state agencies to guarantee minimum streamflow for both the recreational and fisheries benefits. The availability of real-time data is essential in assuring that these minimum streamflows are maintained.

B. Hydrologic Records Development

Specialized software programs provide for the processing of raw hydrologic data on a real-time basis. Conversions such as stage-discharge relationships and shift applications are performed on a real-time basis as the data transmissions are received. Mean daily values are computed automatically each day for the previous day. Missing values can be added and invalid data values corrected by the respective hydrographer for that station using data editing functions. Data can be retrieved and displayed in various formats including the standardized U. S. Geological Survey-Water Resources Division annual report format adopted by the Colorado Division of Water Resources for publication purposes. An advantage of real-time hydrologic data collection is in being able to monitor the station for on-going valid data collection. If a sensor or recorder fails, the hydrographer is immediately aware of the problem and can take corrective action before losing a significant amount of data.

C. Water Resources Accounting

There is a growing need for the ability to perform automated water resources accounting. Currently, the satellite-linked monitoring system is being utilized for such accounting for the Colorado Big Thompson Project, the Dolores Project, and the Fryingpan-Arkansas Project Winter Water Storage. The ability to input real-time data into these accounting programs allows for current and on-going tabulations. Since the computations are performed on a computer, the accuracy is increased significantly.

D. Dam Safety

Dam safety monitoring has developed in recent years into a major issue. Numerous on-site parameters are of interest to the State Engineer in assessing stability of a dam. At this time, the system monitors seven reservoirs in Colorado. Currently, the parameters monitored are limited to inflow, outflow, and stage elevation. These data do, however, provide a basis for evaluating current operating conditions as compared to specific operating instructions. The installation and operation of additional sensor types could provide essential data on internal hydraulic pressure, vertical and horizontal movement, and seepage rates.

E. Automated Flood Warning System

The Office of the State Engineer, Division of Water Resources, in cooperation with the National Weather Service - Central Forecast Office (NWS-CFO) in Denver, operates a statewide flood warning system utilizing 78 stream gaging stations that are part of the Colorado satellite-linked water resources monitoring network operated by the State Engineer. The NWS-CFO, which operates on a 24-hour basis, is alerted to changing flow conditions. If conditions warrant, either a flood WATCH or a flood WARNING is issued.

Table 2 listing the incorporated stream gaging stations with the designated alert levels used to flag high water conditions is attached. A synopsis of how the system operates follows:

1. Remote Data Collection/Data Transmission

Stream stage levels are measured and recorded every fifteen minutes for transmission at standard 4-hour intervals. If stage alert levels are surpassed, emergency transmissions are made at random intervals of from 2-10 minutes. All transmissions are sent via the Geostationary Operational Environmental Satellite. Transmissions are received and processed at the receive site located in Denver operated by the State Engineer.

2. Flagging High Water Levels

Data are screened in an automated fashion by the system's central computer to flag high water levels. The central computer automatically contacts the NWS-CFO by phone giving a voice-synthesized message that relays pertinent information. The transmission is not completed until the message is received and verified. A file is generated in the computer that lists all stations reporting high water levels during the last hour.

3. Hydrologic Conditions Assessment

The NWS-CFO OFFICIAL-IN-CHARGE (OIC) immediately accesses by computer terminal the satellite monitoring system data base to further evaluate overall upstream and downstream flow conditions for the effected watershed. Sophisticated software including color graphics capability allows the user to effectively evaluate the data. The OIC follows up by consulting with the NWS regional offices of Pueblo, Grand Junction, Colorado Springs, and Alamosa. Radar coverage is utilized to identify and determine the intensity of precipitation events. The appropriate county sheriff offices and official spotters are contacted for verification of hydrologic conditions.

4. Watch/Warning Dissemination

If flooding is considered a possibility, a WATCH is issued. If flooding is considered to be imminent, a WARNING is issued. The National Warning System (NAWAS), utilizing the Colorado State Highway Patrol and the Colorado Division of Disaster Emergency Services' (DODES) communications networks, is utilized to contact the various law enforcement agencies and county emergency preparedness offices. These agencies in turn provide a "fanout" to secondary points of contact including hospitals, schools, etc. Public announcements are made over the National Weather Service designated VHF-FM radio frequencies, known as the National Weather Radio (NWR), and through the news media via the Automation of Field Operations and Services (AFOS) national weather wire. In the Denver metropolitan area, the Metropolitan Emergency Telephone System (METS) is utilized.

TABLE 2

SATELLITE MONITORING SYSTEM
FLOOD WARNING NETWORK

STATION	ALERT LEVEL (FT)	DISCHARGE (CFS)
Division 1 / South Platte River Basin		
1. Bear Creek at Morrison	5.50	345
2. Clear Creek at Golden	4.00	345
3. Boulder Creek near Orodell	3.50	590
4. St. Vrain Creek at Lyons	5.60	1,610
5. North Fork Big Thompson near Drake	4.60	172
6. Cache La Poudre at Canyon Mouth near Fort Collins	4.50	2,000
7. South Platte River at Denver	6.00	3,930
8. South Platte River at Henderson	9.00	4,450
9. South Platte River near Kersey	7.00	6,560
10. South Platte River near Weldona	7.00	4,200
11. South Platte River near Balzac (Channel-South)	7.00	2,230
12. South Platte River near Julesburg (Channel-Right)	7.00	4,280
13. Cache La Poudre at Greeley	7.00	2,500
14. Big Thompson River at Mouth of Canyon	5.00	2,400
Division 2 / Arkansas River Basin		
1. Arkansas River near Wellesville	7.90	5,000
2. Fountain Creek near Pinon	6.53	5,020
3. Arkansas River near Avondale	5.00	5,000
4. Arkansas River below Catlin Dam	7.70	10,000
5. Purgatoire River near Thatcher	11.30	10,040
6. Purgatoire River at Las Animas	8.00	2,910
Division 3 / Rio Grande Basin		
1. Alamosa Creek above Terrace Reservoir	3.50	1,480
2. Conejos River below Platoro Reservoir	3.75	1,085
3. Conejos River near Mogote	5.25	2,970
4. La Jara Creek near Capulin	4.05	211
5. Los Pinos River near Ortiz	6.25	1,840
6. Rio Grande near Del Norte	5.10	7,060
7. Rio Grande at Thirty-Mile Bridge	4.70	2,700
8. South Fork Rio Grande at South Fork	6.60	3,280
9. Saguache Creek near Saguache	4.50	540
10. San Antonio River at Ortiz	5.00	1,000
11. Rio Grande at Alamosa	8.00	3,000
12. Conejos River near La Sauses (North Channel)	6.00	1,550

FLOOD WARNING NETWORK (cont.)

	STATION	ALERT LEVEL (FT)	DISCHARGE (CFS)
Division 4 / Gunnison River Basin			
1.	Cimarron River near Cimarron	5.40	1,050
2.	East River at Almont	7.00	3,000
3.	Gunnison River at Delta	11.30	18,500
4.	Gunnison River near Grand Junction	12.85	20,540
5.	Gunnison River near Gunnison	5.00	5,760
6.	Kannah Creek near Whitewater	2.50	660
7.	Leroux Creek near Lazear	4.50	910
8.	Muddy Creek above Paonia Reservoir	7.90	2,680
9.	Muddy Creek below Paonia Reservoir	7.20	2,580
10.	North Fork Gunnison River near Somerset	7.25	7,000
11.	Surface Creek at Cedaredge	3.20	590
12.	San Miguel River at Naturita	7.00	4,600
13.	San Miguel River near Placerville	6.00	
14.	Smith Fork near Crawford	8.00	1,140
15.	Surface Creek near Cedaredge	3.40	630
16.	Taylor River at Almont	4.25	2,015
17.	Uncompahgre River at Colona	5.00	2,970
18.	Uncompahgre River near Ridgway	4.95	1,550
19.	Dallas Creek near Ridgway	5.20	540
Division 5 / Colorado River Basin			
1.	Willow Creek below Willow Creek Reservoir	5.30	1,260
2.	Colorado River at Hot Sulphur Springs	4.65	4,200
3.	Williams Fork below Williams Fork Reservoir	5.90	1,950
4.	Blue River below Dillon	3.80	1,840
5.	Blue River below Green Mountain Reservoir	9.10	2,820
6.	Eagle River below Gypsum	8.80	5,850
7.	Colorado River near Dotsero	11.70	16,120
8.	Fryingpan River near Ruedi	3.70	1,240
9.	Fryingpan River near Thomasville	4.20	1,290
10.	Rifle Gap below Rifle Gap Reservoir	2.60	90
11.	Colorado River near Kremmling	10.00	3,800
Division 6 / Green River Basin			
1.	Elk River at Clark	5.90	4,500
2.	Yampa River near Oak Creek	4.60	1,500
3.	Yampa River at Steamboat Springs	6.00	4,500
4.	Yampa River near Maybell	7.00	7,000
5.	White River near Meeker	3.90	4,150

FLOOD WARNING NETWORK (cont.)

	STATION	ALERT LEVEL (FT)	DISCHARGE (CFS)
	Division 7 / Dolores & San Juan River Basins		
1.	Rio Blanco below Blanco Diversion Dam	4.37	1,000
2.	Navajo River below Oso Diversion Dam	4.80	1,200
3.	Dolores River at Dolores	6.40	4,050
4.	Lost Canyon Creek near Dolores	6.10	500
5.	La Plata River at Hesperus	3.88	800
6.	La Plata River at Colorado-New Mexico Stateline	3.60	800
7.	Mancos River near Mancos	4.00	900
8.	Florida River above Lemon Reservoir	3.90	1,000
9.	Florida River below Lemon Reservoir	5.00	970
10.	San Juan River at Pagosa Springs	8.00	7,620
11.	Animas River at Durango	6.50	6,120

F. Future Applications

Any data that can be collected remotely can be monitored by the satellite-linked monitoring system. Future applications, based primarily on current sensor capabilities, are likely to be in the areas of runoff forecasting, water quality monitoring, and in irrigation planning. Runoff forecasting will require the addition of sensor configurations capable of monitoring liquid and frozen precipitation, air temperature, solar radiation, and soil moisture. Water quality monitoring covers an extremely wide spectrum but would likely consist of a sensor configuration capable of monitoring conductivity (total dissolved solids), water temperature, dissolved oxygen, and turbidity. Irrigation planning would require a sensor configuration capable of monitoring humidity, precipitation, soil moisture, soil temperature, air temperature, wind velocity and azimuth, evaporation rates, and solar radiation.

III. OPERATING BUDGET

A. FY 85-86 Operating Costs

The actual operating cost of the satellite-linked monitoring system for FY 85-86 was $161,085. The projected budget was $275,175. A detailed breakdown of expenditures is given in Table 3. Approximately 60% of the cost reductions realized were under four separate line items:

	ITEM	REDUCTIONS
Fixed Costs		
III-A	Metro Lines The metro lines provide unlimited telecommunication links between the seven Division offices and the system's central computer in Denver. Due to significant delays in completing line installation, the lines were available only the final few weeks of the fiscal year.	$31,108
Variable Costs		
III-C	Software Utilization Training The Sutron Corporation provided three separate training sessions for Division of Water Resources' staff at no charge.	$10,500
IV-B	Service Costs The Sutron Corporation provided an extended 1-year warranty (August 8, 1985 to August 8, 1986) on their hardware.	$ 8,092
II-B	Long Distance (Water Commissioners) The majority of the Water Commissioners began accessing the system only late in the fiscal year.	$10,943
IV-C	Replacement of Damaged/Vandalized Hardware A contingency fund of $15,000 was set aside to cover the costs of damaged/vandalized hardware. The cost to replace the remote data collection hardware at only one station is approximately $5,000. During FY 85-86, naturally occurring damage and vandalism were less than expected.	$ 5,135

The Colorado Water Resources and Power Development Authority approved the expenditure of $42,340 in unused operations and maintenance funds from FY 84-85 for hardware and software purchases essential to the operation of the system in FY 85-86. All purchases were made directly by the Authority. The Authority provided funding to cover all system operating costs for the first year of operation, FY 84-85.

B. FY 86-87 and FY 87-88 Budgets

Projected operating costs of the system for FY 86-87 and FY 87-88 are $232,741 and $243,955, respectively. Note that projected costs for FY 86-87 are $42,434 less than the original projected costs for FY 85-86. This reflects a better understanding of necessary operating costs based upon actual experience. FY 87-88 projected costs are basically increased by 5% to cover inflation. A detailed breakdown of projected costs is given in Table 4.

TABLE 3

SATELLITE MONITORING SYSTEM
FY 85-86
BUDGET

ITEM	FY 85-86 (projected)	FY 85-86 (actual)
FIXED EXPENSES		
I. PERSONNEL COSTS (2 FTE)	87,812	86,925
II. HARDWARE MAINTENANCE CONTRACTS		
A. DEC VAX 11/750 Computer	13,325	12,300
B. Direct Readout Ground Station	6,000	1,600
C. Air Conditioning and Power Supply Systems	3,100	1,785
	22,425	15,685
III. TELECOMMUNICATIONS		
A. Metro Lines	33,888	2,780
B. 16 Incoming Modem Lines	5,280	5,280
	39,168	8,060
IV. COMPUTER OPERATIONS	14,000	3,983
TOTAL FIXED EXPENSES	$163,405	$114,653
VARIABLE EXPENSES		
I. TRAVEL & PER DIEM		
A. Vehicle Operations & Maintenance	5,000	1,275
B. Travel	3,000	1,466
C. Per Diem	7,200	4,546
	15,200	7,287
II. TELECOMMUNICATIONS		
A. Long Distance (Central Office)	1,200	945
B. Long Distance (Water Commissioners)	14,000	3,057
	15,200	4,002
III. TRAINING		
A. DEC System Training	2,500	1,477
B. Hardware Operations & Maintenance	3,000	2,500
C. Software Utilization Training	13,000	2,500
	18,500	5,477

TABLE 3 (cont.)
FY 85-86
BUDGET

ITEM	FY 85-86 (projected)	FY 85-86 (actual)
IV. SYSTEM HARDWARE & MAINTENANCE		
A. Diagnostic Hardware	1,500	1,609
B. Service Costs	9,000	908
C. Replacement of Damaged/Vandalized Hardware	15,000	9,865
D. Supplementals to Divisions to Cover Travel Costs to Maintain System	14,000	12,000
E. Shaft Encoder Modifications	4,120	0
F. Sensor Interface Hardware	1,000	0
G. Gaging Station Modifications	4,000	0
H. Computer Terminals	8,000	0
	56,620	24,382
V. MISCELLANEOUS	6,250	4,284
TOTAL FIXED EXPENSES	111,770	46,432
COMBINED TOTALS	$275,175	$161,085

TABLE 4

SATELLITE MONITORING SYSTEM
FY 86-87 and FY 87-88
BUDGETS

ITEM	FY 86-87 (projected)	FY 87-88 (projected)
FIXED EXPENSES		
I. PERSONNEL COSTS (2 FTE)	92,208	97,000
II. HARDWARE MAINTENANCE CONTRACTS		
A. DEC VAX 11/750 Computer	13,500	14,250
B. Direct Readout Ground Station	1,500	1,575
C. Air Conditioning and Power Supply Systems	1,500	1,575
	16,500	17,400
III. TELECOMMUNICATIONS		
A. Metro Lines	35,088	36,588
B. 16 Incoming Modem Lines	5,445	5,717
	40,533	42,305
IV. COMPUTER OPERATIONS	5,000	5,250
TOTAL FIXED EXPENSES	$154,241	$161,955
VARIABLE EXPENSES		
I. TRAVEL & PER DIEM		
A. Vehicle Operations & Maintenance	1,500	1,600
B. Travel	2,000	2,100
C. Per Diem	4,500	4,700
	8,000	8,400
II. TELECOMMUNICATIONS		
A. Long Distance (Central Office)	1,000	1,050
B. Long Distance (Water Commissioners)	12,000	12,600
	13,000	13,650
III. TRAINING		
A. DEC System Training	2,000	1,000
B. Hardware Operations & Maintenance	4,000	3,000
C. Software Utilization Training	5,000	6,450
	11,000	10,450

TABLE 4 (cont.)
FY 86-87 and FY 87-88
BUDGETS

	ITEM	FY 86-87	FY 87-88
IV.	SYSTEM HARDWARE & MAINTENANCE		
	A. Diagnostic Hardware	1,500	1,000
	B. Service Costs	10,000	10,500
	C. Replacement of Damaged/Vandalized Hardware	16,000	16,800
	D. Supplementals to Divisions to Cover Travel Costs to Maintain System	14,000	16,000
		41,500	44,300
V.	MISCELLANEOUS	5,000	5,200
	TOTAL VARIABLE COSTS	78,500	82,000
	COMBINED TOTALS	$232,741	$243,955

IV. FUNDING SOURCES

A. FY 85-86 Funding

Eighty-six thousand seven hundred eleven dollars ($86,711) was appropriated from the General Fund for the operation of the satellite-linked monitoring system for FY 85-86. This is $13,932 less than the original General Fund appropriation of $100,643. A total of $269,846 was approved for total program expenditures in FY 85-86. The remaining $183,135 was to be collected from user fees, pursuant to Section 37-80-111.5(c), C.R.S. (1985 Supplement).

In FY 85-86, user fees amounting to $100,900 were collected from the following:

Southeastern Colorado Water Conservancy District	$35,000
Colorado River Water Conservation District	$25,000
Rio Grande Water Conservation District	$15,000
Dolores Water Conservancy District	$ 6,500
Southwestern Water Conservation District	$ 6,000
Lower South Platte Water Conservancy District	$ 5,000
Denver Board of Water Commissioners	$ 2,400
Urban Drainage District	$ 1,200
Animas-La Plata Water Conservancy District	$ 1,200
City of Durango	$ 1,200
Florida Water Conservancy District	$ 1,200
Bureau of Reclamation (San Juan Chama Project)	$ 1,200
TOTAL	$100,900

Total funds available for FY 85-86 was $187,611. Of this amount, $26,526 in user fees was carried over into FY 86-87 to cover the projected deficit.

B. FY 1986-87 Funding

Eighty-six thousand one hundred thirty-five dollars ($86,135) was appropriated from the General Fund for the operation of the satellite-linked monitoring system for FY 86-87. A total of $274,764 was approved for total program expenditures for FY 86-87. With the FY 86-87 budget projected at $232,741, the balance to be allocated from user fees is $146,606. With a carry-over of $26,526 from FY 85-86, the amount needed to be collected in user fees in FY 86-87 is $120,080. Users contributing fees in FY 85-86 are expected to provide similar fees for FY 86-87. More users are being sought to obtain the additional $19,180 needed to meet the budget.

C. FY 87-88 Funding

The Office of the State Engineer, Division of Water Resources, has submitted a budget proposal requesting that beginning in FY 87-88 (July 1, 1987 to June 30, 1988), the entire operating budget of the Colorado satellite-linked water resources monitoring system be allocated from the General Fund. The FY 87-88 operating budget is projected to be $243,955. The amount of General Funding increase needed will be $157,820 over the current level of funding, $86,135.

The water user community has expressed the opinion that the administration of the state's water resources is a public responsibility. The satellite monitoring system is effectively being utilized in daily water rights administration, hydrologic records development, flood monitoring, water resources accounting, and in the administration of interstate compacts. All of these tasks are carried out for the benefit of the public. By having the entire operating budget allocated from the General Fund, the cost of operating the system can be borne by all water users while ensuring its continued operation.

The satellite monitoring system represents a $1,800,000 investment by the State of Colorado to apply space-age technology to the administration and management of the state's most valuable natural resource. The allocation of General Funds to operate the system will provide all interested users the opportunity to directly utilize the system's capabilities, which is a primary objective of the Office of the State Engineer. Non-Colorado water users, i.e. the State of Kansas, will be provided access only on a user fee basis. Users being provided with special services, i.e. the receiving and processing of data transmissions from privately operated data collection hardware, will still be required to pay for the actual cost of those services.

V. COST-BENEFIT CRITERIA

It is estimated that the Colorado satellite-linked water resources monitoring system provides benefits to the State of Colorado amounting to between $1,336,760 and $1,504,760 per year. These benefits will increase as the system becomes further assimilated into the statewide administration and management of water resources. Benefits will also increase dramatically during periods of water shortages as compared to current periods of water surpluses. Since the cost to operate the system is projected to be $331,061 for FY 86-87 ($232,741 in direct costs and $98,320 in indirect costs), the net benefit to the State of Colorado is between an estimated $1,005,699 and $1,173,699. If the original capital cost of the system of approximately $1,500,000 is amortized simply over a 5-year period, net benefits realized are between approximately $705,000 and $875,000 per year.

Direct and indirect benefits are calculated as follows:

1. Approximately $5,290,000 per year is budgeted by the Office of the State Engineer for statewide water rights administration. If the operation of the satellite-linked monitoring system conservatively increases effectiveness by 10%, that equates to a benefit of $529,000 per year. Direct benefits are attained by Water Commissioners having more time for water administration and reduction in over-time to accomplish ever increasing workloads. Indirect benefits relate to the ability to be more effective in water rights administration. This leads to greater cooperation among water users and fewer legal problems.

2. It is calculated that in an average year, between 42,000 and 56,000 acre-feet of water can be saved for use in Colorado through utilization of the system. At a conservative price of $12.00 per acre-foot of water, this amounts to between $504,000 and $672,000 per year. In years of water scarcity, the amount that is actually saved for consumption may be greater. The value of the water in a dry year would naturally be higher.

3. Cost savings in the area of hydrologic records development are calculated to be $69,600 per year.

a. Automated data processing and data entry 150 stations/2 hours per month @ $12 per hour	$43,200
b. Data archiving and retrieval $1,000 per month	$12,000
c. Cost of lost data 150 stations/8 hours per year @ $12 per hour	$14,400

4. Water resources accounting programs utilizing the system have been set up for the Dolores Project, the Colorado-Big Thompson Project, and the Fryingpan-Arkansas River Project. Savings are estimated to be 40 hours per month @ $12 per hour or $5,760 per year.

5. The benefits attributed to the system from flood warning are calculated to be $175,000 per year. If a real-time flood monitoring network of 50 stations is considered essential, and the operating cost for each station is $3,500 per year, this amounts to $175,000 per year.

6. An estimated $53,400 per year is saved in reduced manpower and travel costs in manually reading stream gages.

a.	Manpower savings 150 stations/8 hours per month @ $12 per hour	$14,400
b.	Travel savings 150 stations/1 trip per week 25 miles per trip @ $0.20 per mile	$39,000

It is necessary to point out that certain indirect costs in operating the system are also realized. These indirect costs, absorbed by the Division of Water Resources, amount to approximately $98,320 per year as follows:

1.	Manpower to maintain the monitoring network 7 divisions/40 hours per month @ $12 per hour	$40,320
2.	Travel costs to maintain remote data collection hardware	$16,000
3.	Office space and secretarial support for 2 FTE's $1,000 per month	$12,000
4.	Computer room and utilities for VAX 11/750 computer $1,000 per month	$12,000
5.	Support from the Information Services Branch $1,000 per month	$12,000
6.	Administrative costs $500 per month	$ 6,000

VI. EFFECTS OF LOSS OF FUNDING FOR FY 87-88

The satellite-linked water resources monitoring system, without adequate funding, would not be able to function satisfactorily and would likely be deactivated within eighteen months. The system is an integration of various essential components that cannot function with the loss of any one of those components. This would effectively mean the loss of a $1.8 million investment by the State of Colorado.

The FY 87-88 budget of $243,955 is broken down into two categories; fixed expenses amounting to $161,955, and variable expenses amounting to $82,000. The variable expense items are 34% of the budget and would be the first cuts made. These cuts would mean curtailment of:

1. Long-distance phone access by the Water Commissioners.
2. Repair of malfunctioning remote data collection hardware.
3. Replacement of damaged, vandalized, or stolen remote data collection hardware.
4. Timely maintenance and calibration of remote data collection hardware.
5. Training for system users relative to data base access and software utilization.
6. Travel to Division offices, system users, and cooperating Federal agencies.

Fixed expense items would be the second area for budget cuts. The effects of these cuts would be as follows:

1. Personnel eliminations

Two full-time employees would be eliminated from the program, the Program Manager and the System Analyst. The effects of the elimination of the Program Manager position would include the following:

a. The loss of statewide interagency coordination.

b. The loss of intraagency coordination.

c. The loss of coordination with system users.

d. The loss of coordination in network expansion.

e. The loss of coordination in system enhancement.

f. The loss of coordination in system operation and utilization.

The effects of the elimination of the System Analyst position would be as follows:

a. The loss of coordination in central computer and Division personal computer utilization.

b. The loss of coordination in data base management.

c. The loss of coordination of data base access and software utilization.

d. The loss of coordination in software development.

2. Elimination of system maintenance contracts.

3. The elimination of telecommunications access to the system.

The resultant cumulative effects on the general operations of the system would be as follows:

1. During the first twelve months, an estimated 20%, or thirty of the remote data collection stations, would be taken off-line due to malfunctioning, damaged, or stolen hardware.

2. As a result of the above, the State of Colorado would have thirty transmission slots on GOES revoked by the National Environmental Satellite Data Information Service due to inactivity.

3. Maintenance of remote data collection hardware would face 2-3 week delays.

4. Data quality would deteriorate.

5. Down-time of the Direct Readout Ground Station and central computer would be in excess of six weeks per year.

6. As the system became less dependable, it would be utilized less and less.

7. Hydrologic records would cease to be developed on the system requiring manual records development.

8. Real-time data would not be available requiring additional staff and travel to manually read remote gages.

VII. SYSTEM USERS

The following is a list of users of the satellite-linked water resources monitoring system:

A. Office of the Colorado State Engineer

1. Division of Water Resources

   a. Division 1, Greeley

   b. Division 2, Pueblo

   c. Division 3, Alamosa

   d. Division 4, Montrose

   e. Division 5, Glenwood Springs

   f. Division 6, Steamboat Springs

   g. Division 7, Durango

   h. Central Office, Denver

2. Water Commissioners

B. Water Conservancy Districts

1. Southeastern Colorado Water Conservancy District

2. Lower South Platte Water Conservancy District

3. Colorado River Water Conservation District

4. Southwestern Water Conservation District

5. Dolores Water Conservancy District

6. Animas-La Plata Water Conservancy District

7. Florida Water Conservancy District

8. Northern Colorado Water Conservancy District

9. Rio Grande Water Conservation District

10. North Sterling Irrigation District

C. Municipalities

1. Denver Board of Water Commissioners
2. Pueblo Water Department
3. Colorado Springs Water Department
4. Durango
5. Alamosa
6. Westminster
7. Aurora Water Department

D. State Agencies

1. Division of Disaster Emergency Services
2. Colorado Water Conservation Board
3. Colorado Water Resources and Power Development Authority
4. Division of Wildlife

E. Federal Agencies

1. Bureau of Reclamation
   a. Loveland
   b. Denver
   c. Grand Junction
   d. Albuquerque
   e. Montrose

2. USGS - Water Resources Division

   a. Denver

   b. Pueblo

   c. Grand Junction

   d. Meeker

   e. Durango

3. National Weather Service

   a. Denver

   b. Salt Lake City

4. Corps of Engineers

   a. Omaha

   b. Albuquerque

5. Soil Conservation Service

6. Colorado-Kansas Arkansas River Compact Commission

F. Associations

1. Rio Grande Water Users Association

2. Urban Drainage District

3. Arkansas River Rafters Association

G. Private Entities

1. Fort Lyon Canal Company

2. Santa Maria Reservoir Company

3. Mutual Reservoir and Irrigation Company

VIII. UTILITY OF THE SATELLITE-LINKED MONITORING SYSTEM WITHIN THE COLORADO DIVISION OF WATER RESOURCES

NARRATIVE AND SPECIFIC APPLICATION EXAMPLES

A. Division 1, Greeley, Colorado, South Platte River Basin
Alan Berryman, Division Engineer

The satellite-linked monitoring system has become an integral tool in daily water rights administration in Division 1. With increasing complexity in the administration of the South Platte River basin, the system provides the key to effective decision making.

In past years, river information needed for river administration was slow, if not difficult, to acquire because of the remote location of key gaging stations. Administration was inefficient and frustrating to the Water Commissioner and to downstream water users. With the satellite monitoring system, comprehensive river data are available to the Water Commissioner allowing him to administer water rights on a timely and accurate basis. This ability allows the water users to adjust more quickly to the changing conditions of the river system and expand the number of water rights able to divert and use water. The system allows the Water Commissioner to determine the river conditions largely on his own, not having to rely as much on data supplied by water users. This results in closer administration of water rights, potentially benefiting all water users of the area by assuring that the available supply of water is being diverted by the correct water right. Another advantage of the satellite monitoring system is that the Water Commissioner can release water downstream knowing that the amounts released reflect actual river conditions and won't have to be adjusted at a later date. The efficiency afforded to the Water Commissioner allows him to attend to more of his other duties which are ever increasing with the growth of the water rights system such as ground water administration.

With the satellite monitoring system data, the Water Commissioner can immediately evaluate river conditions both upstream and immediately above the senior rights. Subsequently, he can adjust diversions in his own district to satisfy the more senior rights or send a demand (call) to the upstream districts for more water to satisfy those rights early in the day. This is especially critical in administering water exchanges.

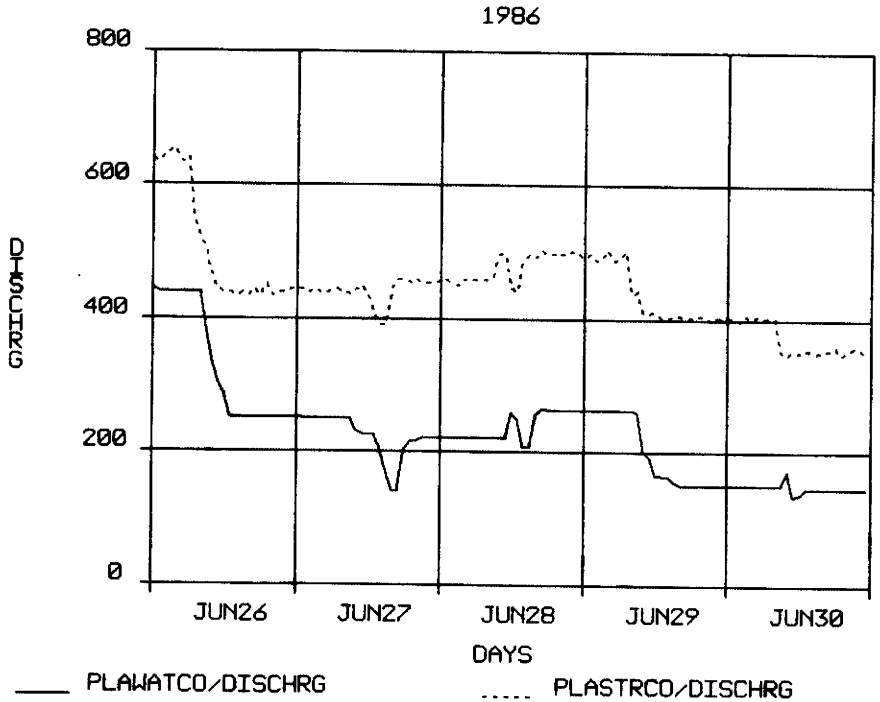
The river can be run more efficiently simply as a result of the increased knowledge of the river conditions provided by the satellite monitoring system. The readily available knowledge of river conditions also provides the Water Commissioner with "evidence" that can be beneficial when interacting with water users that question administrative practices. The system makes it easier for the Water Commissioners to interact with other district Water Commissioners in receiving or passing water through his district. The ability to monitor diversions by some of the major irrigation diversions including the Burlington-Wellington Canal, the Union Ditch, the North Sterling Canal, the Lower Latham Ditch, and the Riverside Canal, is essential since the large amounts diverted can have a significant effect on the flow of the South Platte River below Denver.

Another benefit to this division resulting from the satellite monitoring system is that water from storms (flood peaks) occurring in upstream areas can be recognized early. This allows adequate time for water users to respond to these floods and divert them for beneficial use or storage rather than have the water exit the state unused. Additionally, if flood peaks larger than 2000 cfs can be diverted and reduced to 2000 cfs or less, the sand dams employed by diverters can be spared from being washed out. Preventing their washing out allows those structures to continue diverting water rather than waiting up to one week after water levels have reduced to repair the sand dams and begin diverting again. This is very important in years with low to normal flows intermingled with flood peaks from rainstorms.

The main responsibility of the Division Engineer is to coordinate the administration of water rights for the respective division. Because of the large area covered in Division 1, many tributaries and districts are administered. In order to coordinate the administration in each of the districts, knowledge of the current river conditions for the South Platte River and its tributaries is essential. Inflow from the Big Thompson River, Cache La Poudre River, and St. Vrain Creek can provide the majority of the flow in the South Platte River below Kersey. The satellite monitoring system provides the Division 1 Engineer with the basinwide information necessary to accomplish the task outlined above. In coordinating daily administration for the division, the Division Engineer can analyze conditions for the entire area early each day. With the flow information on each tributary and at various river locations, the Division Engineer can coordinate administration between districts. As an example, the information can provide the status of diversions in District 2 (Denver to Kersey) and compare that with the amount of water available in the upstream areas to decide what adjustments need to be made to Chatfield Reservoir releases in order to satisfy the senior rights below the reservoir. The information from the system can be used to monitor water releases from reservoirs to insure that the water is reaching its proper destination. These data are incorporated directly into our flow records which previously had been worked up manually using significantly more time and resources.

As the division gets more experience in using the data and software, it is expected that additional uses will be incorporated into river administration. Included would be return flow studies, graphical analysis of flows, water quality monitoring, and development of an extensive data bank which will be invaluable as water development progresses.

The overall knowledge of river conditions made possible by the satellite monitoring system and the efficiency of administration resulting from that information have made the Water Commissioners and Division Engineer much more knowledgeable and responsive administrators. Once this level of performance is made possible, it is the consensus of all dealing with the system that anything less would be a major step backwards in river administration. The utility of the system to river administrators is reflected in more responsive adjustments to river conditions, maximization of water deliveries to water users, increased knowledge of river conditions by all water users, and in time/resource savings for the administrators. Future applications will hopefully increase these benefits by adding more uses and more complete information.



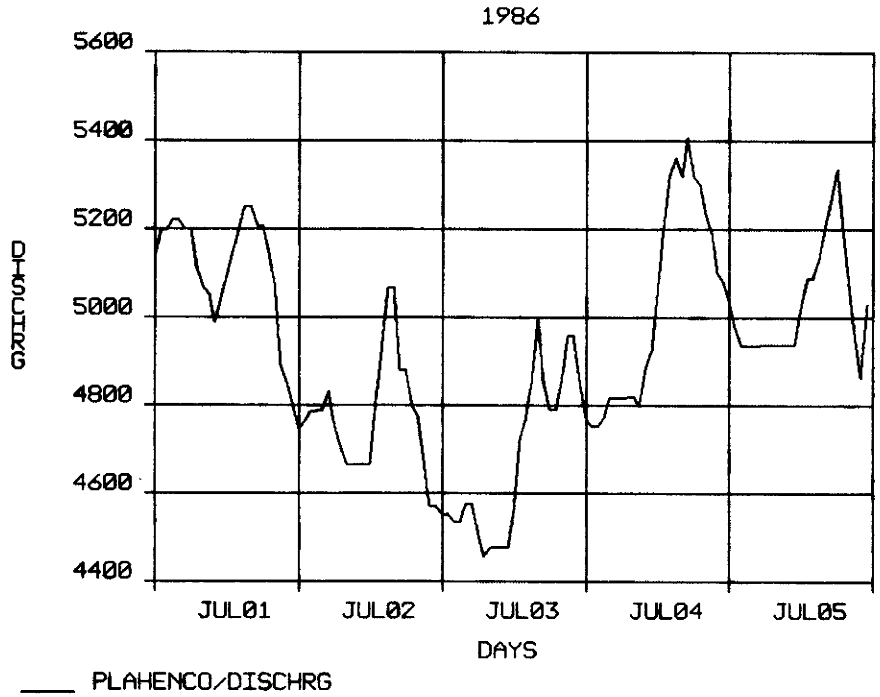
WY	STATION	CODE	HR	JUN26	JUN27	JUN28	JUN29	JUN30
86	PLAWATCO	DISCHRG	00	366.87	258.85	274.90	237.23	183.17
86	PLASTRCO	DISCHRG	00	471.20	405.78	439.70	398.56	337.31
86	DENVER			104.	147.	165.	161.	154.

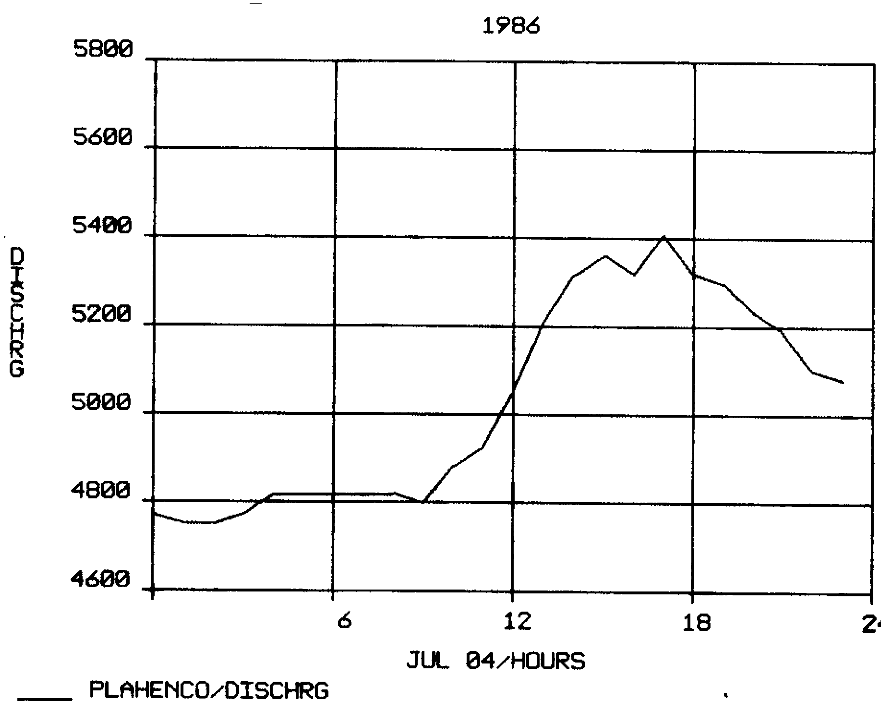
ADMINISTRATION OF THE SOUTH PLATTE RIVER, DISTRICT 8 - MONITORING RESERVOIR RELEASES AND MUNICIPAL DIVERSIONS BELOW STRONTIA SPRINGS RESERVOIR AND ABOVE CHATFIELD RESERVOIR UTILIZING REAL-TIME DATA

The administration of water rights in Division 1, District 8, in the Upper South Platte River basin has become extremely complex due to an increasing demand for water supplies by metropolitan Denver, numerous water exchanges, and varied augmentation plans. The satellite monitoring system provides real-time data from the gaging stations, South Platte River below Strontia Springs (PLASTRCO), and South Platte River at Waterton (PLAWATCO). PLASTRCO monitors releases from Strontia Springs Reservoir. PLAWATCO monitors inflow into Chatfield Reservoir. Both stations are essential in reservoir regulation and in accounting. Below PLASTRCO, the Denver Water Department exercises senior water rights of up to 200 cfs by diverting flows through the Highline Canal and the Denver Pipeline. Although neither of these two diversions is monitored directly by the satellite monitoring system, diverted flows can be indirectly calculated by subtracting the streamflow being measured at PLAWATCO from the streamflow measured at PLASTRCO.

The hydrograph shown plots real-time discharge data for PLASTRCO and PLAWATCO for the period June 26-30, 1986. The table lists the mean daily discharge for both stations for each day along with the net difference in discharge between the two stations, considered to be the amount of water diverted by Denver.

Alan Berryman, Division 1 Engineer
Kenneth Salzer, Water Commissioner, District 8





ADMINISTRATION OF THE SOUTH PLATTE RIVER, DISTRICT 2, UTILIZING REAL-TIME DATA

In District 2, the Water Commissioner's primary responsibility is in distributing water to senior ditch rights in the reach from Henderson to Platteville. The water supply for these rights comes mainly from water passed through Chatfield Reservoir and inflows from Bear Creek, Clear Creek, and the Denver Metro Sewage outfall. The key index station for the administration of these senior rights is the gaging station, South Platte River at Henderson (PLAHENCO).

The hydrograph shown in the upper left plots real-time discharge data for PLAHENCO for the period July 1-5, 1986. The most obvious characteristic of the hydrograph is unsteady flow. These flow conditions cause extreme difficulty in water rights administration. The Water Commissioner has tended to be conservative in setting the "river call" in a concern over injury to senior rights. The ability to monitor these changing flow conditions on a real-time basis allows for more effective administration. The hydrograph shown in the lower left plots real-time discharge data for PLAHENCO for July 4, 1986. The Water Commissioner, in utilizing this tool, was able to monitor the increase in discharge from 4800 cfs at 0900 hours to 5400 cfs at 1700 hours, and modify the "river call" accordingly.

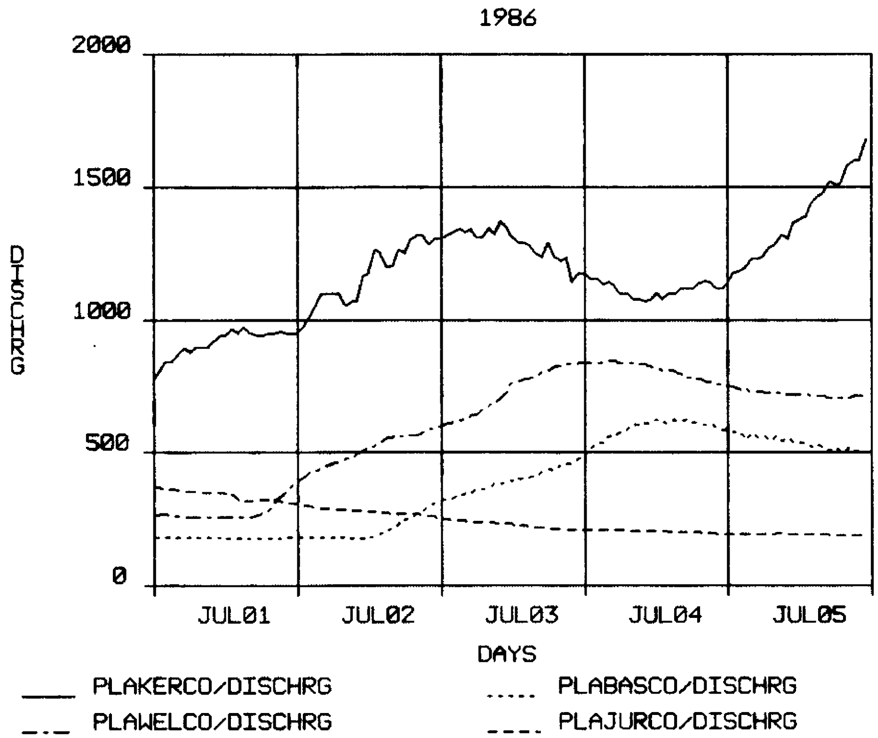
Alan Berryman, Division 1 Engineer
Keith Delventhal, Water Commissioner, District 2

ADMINISTRATION OF THE SOUTH PLATTE RIVER FROM KERSEY TO THE STATELINE UTILIZING REAL-TIME DATA

The administration of water rights in the South Platte River basin from Kersey to the stateline, Districts 1 and 64, is difficult primarily because it covers such a large geographical area. In addition, water rights in this lower reach of the South Platte River are relatively junior in comparison to upstream water rights. It is essential that these lower basin users be alerted of water availability, even short-term availability, to put all available water to beneficial use.

The hydrograph shown plots real-time discharge data for the gaging stations, South Platte River near Kersey (PLAKERCO), South Platte River at Weldona (PLAWELCO), South Platte River near Balzac (PLABASCO), and South Platte River at Julesburg (PLAJURCO), for the period July 1-5, 1986. The table lists mean daily discharge values for each station for the same period. Although flow conditions for the three upstream stations were relatively high and increasing, the flow at the stateline, measured at PLAJURCO, was relatively low and decreasing. This demonstrates the effectiveness of the satellite monitoring system in the hands of the Division 1 Engineer and the Water Commissioners in administering the available water resources for maximum beneficial use in the State of Colorado.

Alan Berryman, Division 1 Engineer
Robert Samples, Water Commissioner, District 1
Elton Watson, Water Commissioner, District 64



WY	STATION	CODE	HR	JUL 1	JUL 2	JUL 3	JUL 4	JUL 5
==	=========	=======	==	=========	=========	=========	=========	=========
86	PLAKERCO	DISCHRG	00	916.93	1171.72	1285.80	1117.29	1390.38
86	PLAWELCO	DISCHRG	00	276.31	511.03	734.46	810.10	720.50

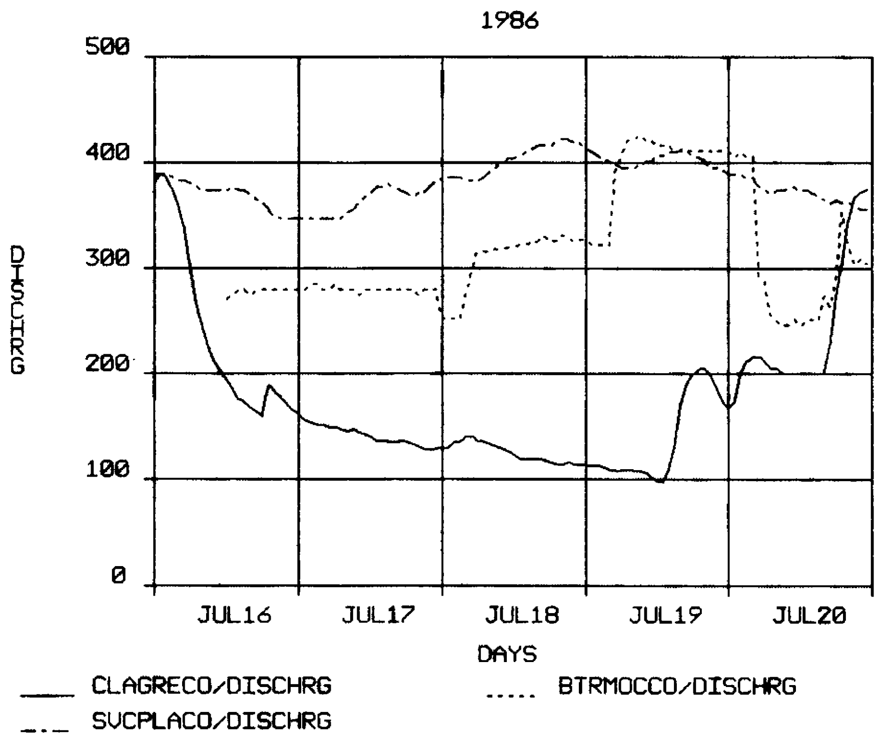
WY	STATION	CODE	HR	JUL 1	JUL 2	JUL 3	JUL 4	JUL 5
==	=========	=======	==	=========	=========	=========	=========	=========
86	PLABASCO	DISCHRG	00	177.28	210.27	395.80	591.77	537.93
86	PLAJURCO	DISCHRG	00	336.68	276.65	225.86	201.95	191.37

ADMINISTRATION OF THE SOUTH PLATTE RIVER, DISTRICT 2 - MONITORING TRIBUTARY INFLOW UTILIZING REAL-TIME DATA

The ability to monitor flow conditions of major tributaries to the South Platte River on a real-time basis is essential to effective administration of downstream water rights. Three major tributaries enter the South Platte River in the reach between Fort Lupton and Kersey (District 2). These tributaries are the St. Vrain Creek, Big Thompson River, and the Cache La Poudre River. These tributaries contribute significant flow to the South Platte River.

The hydrograph shown plots real-time discharge data for the gaging stations, St. Vrain Creek at Mouth near Platteville (SVCPLACO), Big Thompson River at Mouth of Canyon near Loveland (BTRMOCCO), and Cache La Poudre River near Greeley (CLAGRECO), for the period July 16-20, 1986. It is apparent that the St. Vrain Creek was contributing the highest flow and was holding steady while the Cache La Poudre River was contributing the least amount of flow and was fluctuating widely over the five-day period.

The table summarizes mean daily flow for each station along with the total daily contribution of the three tributaries, and essentially makes up the total flow in the river measured at the gaging station, South Platte River near Kersey (PLAKERCO).



WY	STATION	CODE	HR	WED JUL16	THU JUL17	FRI JUL18	SAT JUL19	SUN JUL20
86	CLAGRECO	DISCHRG	00	236.76	140.86	124.49	137.52	240.84
86	SVCPLACO	DISCHRG	00	370.60	364.00	404.56	402.62	371.93
86	BTRMOCCO	DISCHRG	00	274.95	279.79	311.49	395.69	301.43
	Total			882.	785.	841.	936.	914.

WY	STATION	CODE	HR	WED JUL16	THU JUL17	FRI JUL18	SAT JUL19	SUN JUL20
86	PLAKERCO	DISCHRG	00	884.85	719.16	766.02	969.03	831.09

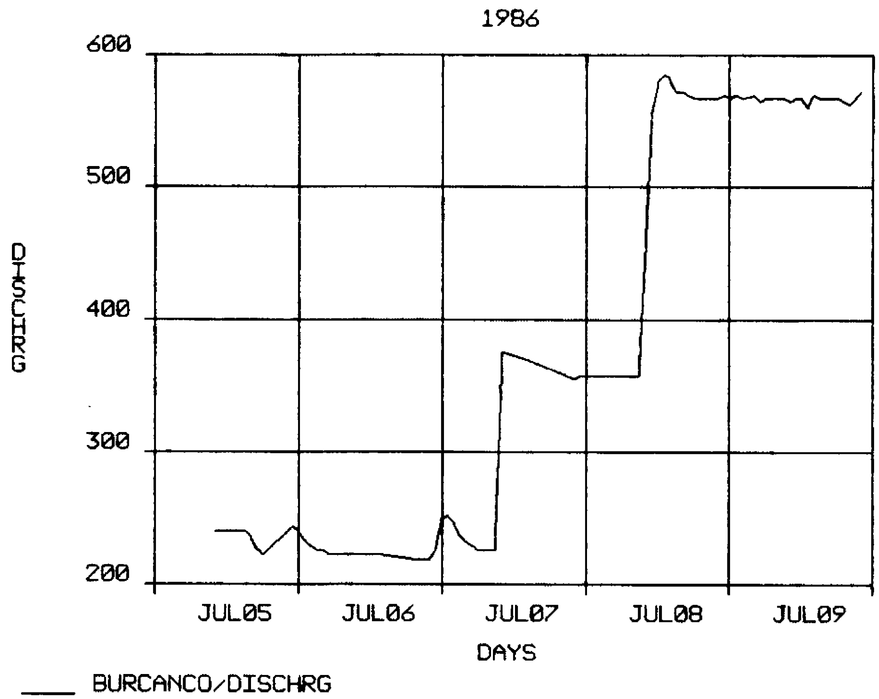
Alan Berryman, Division 1 Engineer
Keith Delventhal, Water Commissioner, District 2

MONITORING IRRIGATION DIVERSIONS IN THE SOUTH PLATTE RIVER BASIN UTILIZING REAL-TIME DATA

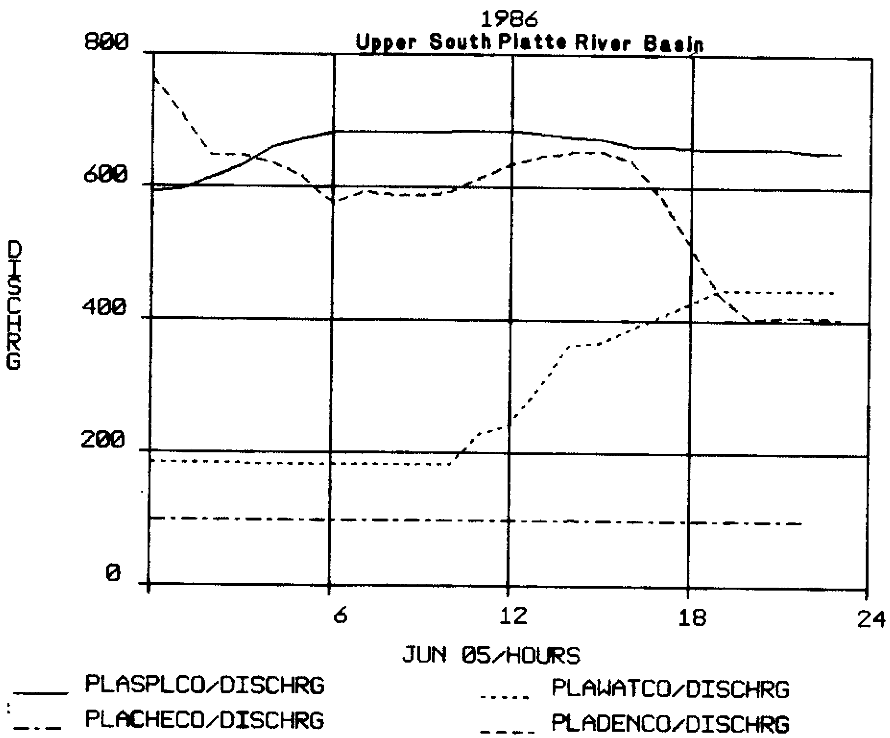
The ability to monitor irrigation diversions on a real-time basis is essential in the effective administration of the South Platte River. Downstream of Denver, over 90% of water use is for irrigation. The major irrigation canals, which include the Burlington-Wellington Canal, the Union Ditch, the North Sterling Canal, the Lower Latham Canal, and the Riverside Canal, have relatively large and senior water rights. The Burlington-Wellington Canal (BURCANCO), for example, has a direct diversion right of 377 cfs.

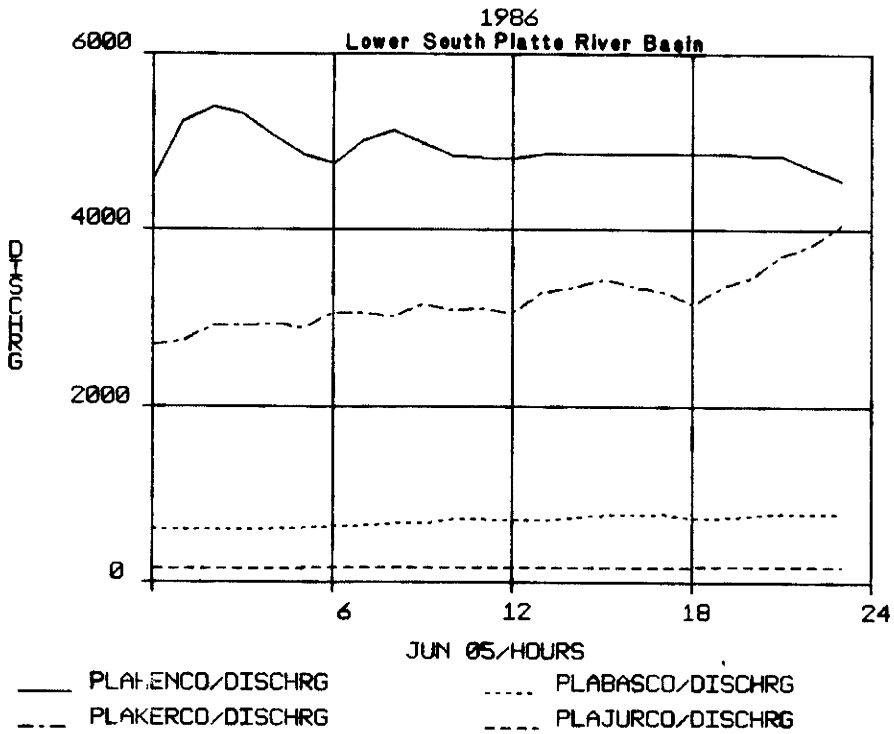
The hydrograph shown plots real-time discharge data for BURCANCO for the period July 5-9, 1986. On July 7, 1986, BURCANCO opened its diversion gates at approximately 1000 hours to take its share of water. The measured amount was 358 cfs. At 0945 hours on July 8, 1986, BURCANCO opened the gate further to divert a total of 584 cfs. The additional amount diverted was due to a reservoir release from Chatfield Reservoir that was owed to BURCANCO. The table of real-time discharge values, given at 15-minute intervals, allowed the Water Commissioner to see exactly when the diversion began and the total amount diverted.

Alan Berryman, Division 1 Engineer
Keith Delventhal, Water Commissioner, District 2



1	BURCANCO	JUL	08	08:00	#	DISCHRG	358.00	#
2	BURCANCO	JUL	08	08:15	#	DISCHRG	356.00	#
3	BURCANCO	JUL	08	08:30	#	DISCHRG	358.00	#
4	BURCANCO	JUL	08	08:45	#	DISCHRG	358.00	#
5	BURCANCO	JUL	08	09:00	#	DISCHRG	358.00	#
6	BURCANCO	JUL	08	09:15	#	DISCHRG	358.00	#
7	BURCANCO	JUL	08	09:30	#	DISCHRG	358.00	#
8	BURCANCO	JUL	08	09:45	#	DISCHRG	394.00	#
9	BURCANCO	JUL	08	10:00	#	DISCHRG	452.00	#
10	BURCANCO	JUL	08	10:15	#	DISCHRG	494.00	#
11	BURCANCO	JUL	08	10:30	#	DISCHRG	524.00	#
12	BURCANCO	JUL	08	10:45	#	DISCHRG	544.00	#
13	BURCANCO	JUL	08	11:00	#	DISCHRG	557.00	#
14	BURCANCO	JUL	08	11:15	#	DISCHRG	567.00	#
15	BURCANCO	JUL	08	11:30	#	DISCHRG	572.00	#
16	BURCANCO	JUL	08	11:45	#	DISCHRG	574.00	#
17	BURCANCO	JUL	08	12:00	#	DISCHRG	579.00	#
18	BURCANCO	JUL	08	12:15	#	DISCHRG	579.00	#
19	BURCANCO	JUL	08	12:30	#	DISCHRG	582.00	#
20	BURCANCO	JUL	08	12:45	#	DISCHRG	584.00	#
21	BURCANCO	JUL	08	13:00	#	DISCHRG	584.00	#





COORDINATION OF ADMINISTRATION OF THE SOUTH PLATTE RIVER IN DIVISION 1

The Division 1 Engineer administers water rights over a large geographic area that includes 12 separate administrative districts. To be effective, an up-to-date knowledge of the river conditions throughout the South Platte River basin is essential. With the flow information on each tributary and at various locations on the mainstem of the South Platte River, the Division Engineer can coordinate administration between districts. As an example, the system provides information on the status of major diversions in District 2 to compare that with the amount of water available in the upstream areas to determine what adjustments need to be made to Chatfield Reservoir releases in order to satisfy the senior rights below the reservoir. The system provides information used to monitor reservoir releases to insure that the water is reaching its proper destination.

The hydrograph shown in the upper left plots real-time discharge data for four upper South Platte River basin stations, South Platte River at South Platte (PLASPLCO), South Platte River below Cheesman Reservoir (PLACHECO), South Platte River at Waterton (PLAWATCO), and South Platte River at Denver (PLADENCO), for June 5, 1986. At approximately 1000 hours, the flow at PLADENCO was about 600 cfs while the flow at PLAWATCO was about 200 cfs. By 1900 hours, the flow at PLADENCO dropped to 400 cfs, while the flow at PLAWATCO increased to about 450 cfs. This indicates that an additional 250 cfs at PLAWATCO came from releases from Strontia Springs Reservoir, curtailment of diversions by Denver through the Highline Canal and Denver Pipeline, or both. The data also indicate that Chatfield Reservoir stopped releasing approximately 400 cfs above natural inflow and adjusted the outflow to the inflow.

The hydrograph shown in the lower left plots real-time discharge data for four lower South Platte River basin stations, South Platte River at Henderson (PLAHENCO), South Platte River near Kersey (PLAKERCO), South Platte River near Weldona (PLAWELCO), and South Platte River at Julesburg (PLAJURCO), for June 5, 1986. The flow at PLAHENCO and PLAKERCO, approximately 4300 cfs and 4000 cfs, respectively, was high. Flow dropped to approximately 700 cfs downstream at PLABASCO, and less than 200 cfs at PLAJURCO.

Alan Berryman, Division 1 Engineer

B. Division 2, Pueblo, Colorado, Arkansas River Basin
Robert Jesse, Division Engineer

The satellite monitoring system is being utilized effectively for water rights administration throughout Division 2. This includes the administration of direct diversion rights, storage rights, transmountain diversion water, the Arkansas River Winter Water Storage Program, and the Arkansas River Interstate Compact. Division 2 covers a large and diverse geographical area with a number of major senior rights. It is an arid, water thirsty area that typically dries up the Arkansas River at several locations during the late irrigation season.

Division 2 staff use the satellite monitoring system to keep an accounting of transmountain diversions that are delivered to storage, storage by exchange, and routed to ditches in the Lower Arkansas River Valley. The system has been valuable in determining daily diversions in a timely manner for accurate accounting and delivery. An example involves the exchange of Colorado Springs' transmountain diversion water discharged into Fountain Creek for storage in Turquoise Reservoir.

The capability to monitor inflows and outflows of reservoirs with accuracy in a timely manner has helped in the administration and accounting of reservoirs in the division. The routing of natural streamflow and reservoir releases to storage or through a reservoir is difficult and takes constant attention to maintain proper discharge and storage. The system also helps in keeping close watch on reservoir releases so that we can determine the section of the river the release is in and prevent any diversion of these releases except by the ditch or ditches calling for the water. The Division Engineer routinely utilizes the system to track reservoir releases from Clear Creek Reservoir, Pueblo Reservoir, and John Martin Reservoir.

We have had much success with the system in our exchange programs. It has been very valuable in determining the exact amounts of water available for exchanges. This permits maximum use of water available with no injury to other water rights.

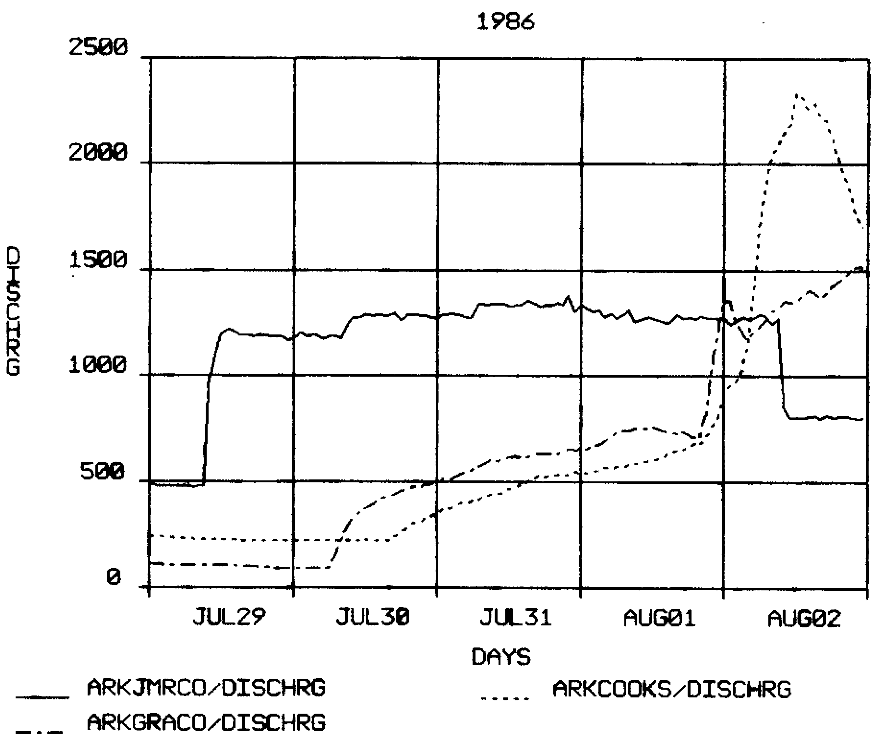
The Water Commissioners in Division 2 have found the system to be an essential tool in setting the "river call". Flow conditions can vary dramatically in the period of hours rather than days due to diurnal effects of spring runoff, major tributary inflow, flash flooding from summer precipitation events, the effects of major irrigation diversions, and a high volume of imported water (transmountain diversions). The basinwide overview provided by the system on a real-time basis is a valuable tool for both short-term and long-term planning. This allows for maximum efficiency in putting Colorado water to beneficial use in Colorado. The system has been especially effective in setting the "river call" in the lower Arkansas River basin from Pueblo Reservoir to the stateline.

The system has become a most important factor in the management of John Martin Reservoir, along with the attendant responsibilities of assuring proper deliveries to the State of Kansas and maximizing utilization of water available to Colorado diverters. John Martin Reservoir is normally in one of two postures during the irrigation season; either storing or not storing in the conservation pool. The summer storage mode must be determined by projecting when inflow will exceed demand below the reservoir by 1,000 acre-feet per day. It then becomes necessary to monitor flows headed downriver to the reservoir, giving maximum lead time possible. The system gives the capability of monitoring upstream stations on both the Arkansas and the Purgatoire Rivers with lead times of up to 48 hours. The non-storage mode creates the situation of having to route streamflows through the reservoir body to users downstream. Monitoring of inflows is just as critical in this instance. The inflow at the stations above John Martin Reservoir plays an important part in managing winter water storage and in setting summer river calls.

ADMINISTRATION OF THE ARKANSAS RIVER COMPACT UTILIZING REAL-TIME DATA

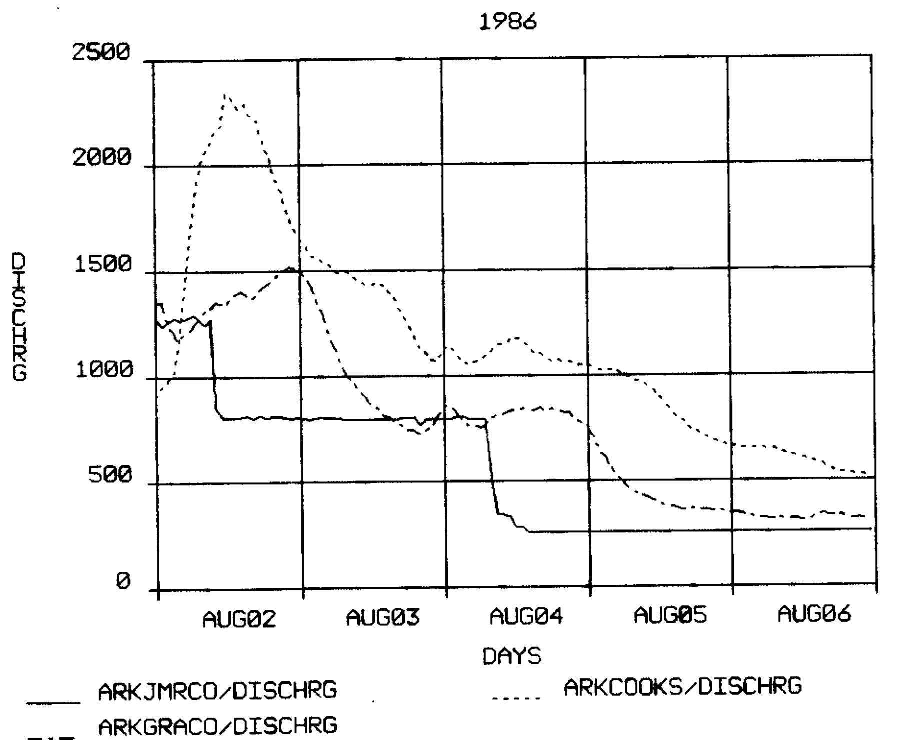
One of the most important and effective uses of the satellite monitoring system is in the administration of the Arkansas River Compact. The responsibility of assuring proper deliveries to the State of Kansas belongs to the Colorado State Engineer. Senior water rights in the reach of the Arkansas River from John Martin Reservoir to the Colorado-Kansas stateline may dry up the river at the stateline under normal conditions during the irrigation season. The bulk of the water available to Kansas is stored in John Martin Reservoir acquired during winter water storage (November 15 - March 15) or from storage during the irrigation season (March 15 - November 15) that occurs when the daily inflow to John Martin Reservoir exceeds the downstream call by 1000 acre-feet. Kansas can demand reservoir releases from their account at any time. Colorado gets credit only for water delivered at the stateline measured at the gaging station, Arkansas River near Coolidge, Kansas (ARKCOOKS). No transit loss is deducted, however, all water reaching ARKCOOKS from the initial time of arrival plus seven days after the stop of the release is credited to Colorado as a delivery to Kansas. This includes any natural flow. Colorado is credited only up to 105% of the call amount. As such, the Division 2 Engineer and the District 67 Water Commissioner strive to deliver the exact call amount, yet not under-deliver.

Kansas requested a release of 600 cfs, running for five days, beginning on July 29, 1986. The Division 2 Engineer coordinated the start of the release at 1000 hours, July 29, 1986, increasing the flow below John Martin Reservoir from 500 cfs to 1250 cfs. The additional amount released included 350 cfs out of storage for the Amity Canal. The release of this additional 350 cfs continued until August 4, 1986. The first hydrograph shown plots real-time discharge data for the gaging stations, Arkansas River below John Martin Reservoir (ARKJMRCO), Arkansas River at Granada (ARKGRACO), and ARKCOOKS, for the period July 29 to August 2, 1986. The table below this hydrograph lists mean daily discharge values for each station for that period. The 750 cfs released from storage from the reservoir beginning on July 29, 1986 and the release cutoff on August 2, 1986 are apparent on the ARKJMRCO plot. The arrival of the release at ARKGRACO approximately 24 hours later and at ARKCOOKS



WY	STATION	CODE	HR	JUL29	JUL30	JUL31	AUG 1	AUG 2
==	=========	=======	==	=========	=========	=========	=========	=========
86	ARKJMRCO	DISCHRG	00	897.63	1249.37	1325.53	1282.98	987.42
86	ARKGRACO	DISCHRG	00	106.36	314.33	600.04	773.33	1363.36
86	ARKCOOKS	DISCHRG	00	230.75	246.24	465.58	631.63	1856.61

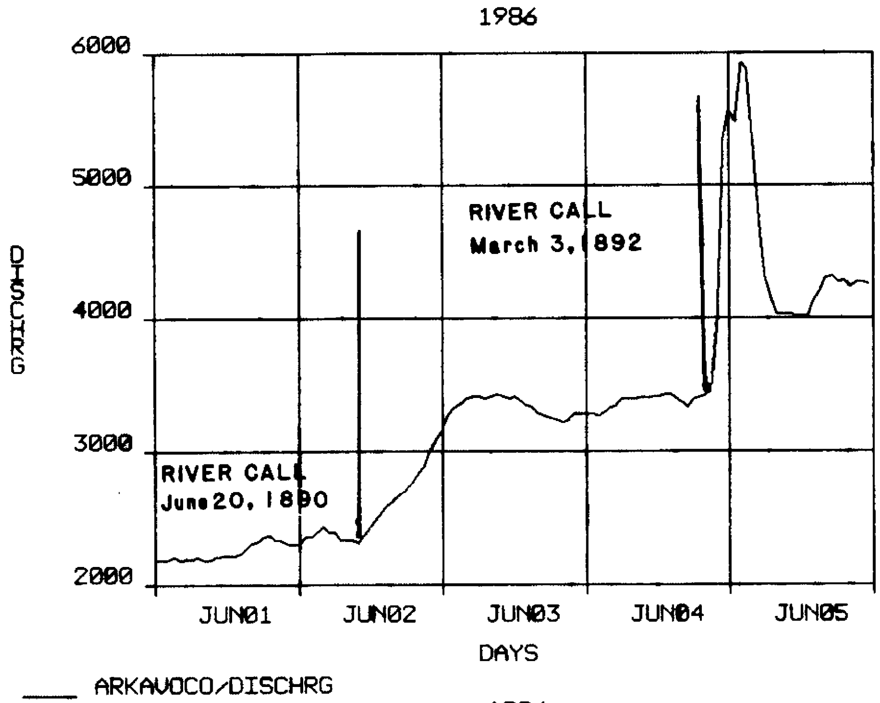
ADMINISTRATION OF THE
ARKANSAS RIVER COMPACT UTILIZING REAL-TIME DATA
(Continued)

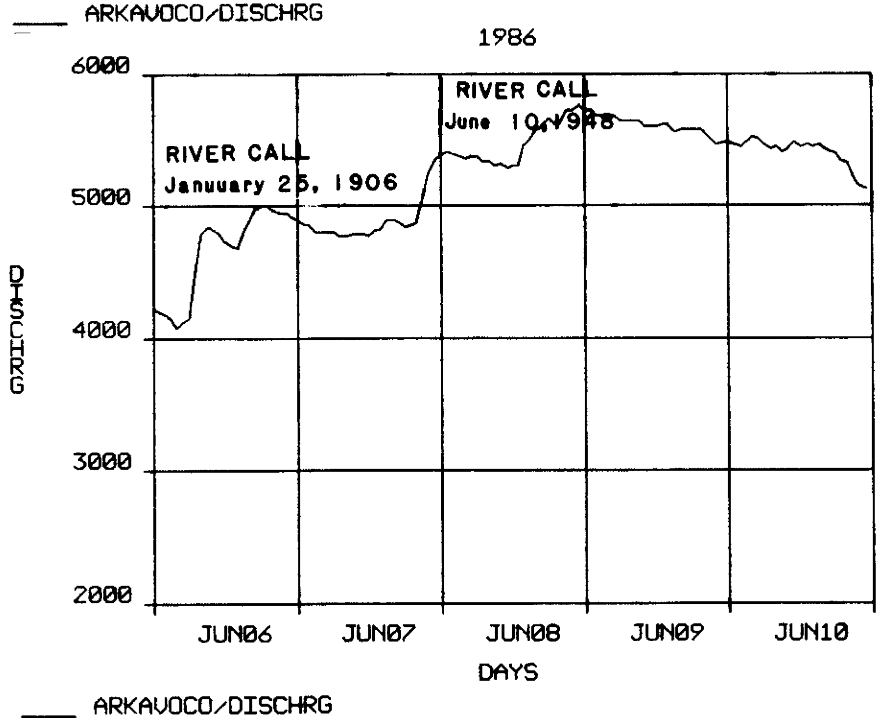


WY	STATION	CODE	HR	AUG 2	AUG 3	AUG 4	AUG 5	AUG 6
86	ARKJMRCO	DISCHRG	00	987.42	800.09	451.23	257.00	257.00
86	ARKGRACO	DISCHRG	00	1363.36	969.30	818.09	442.90	328.25
86	ARKCOOKS	DISCHRG	00	1856.61	1387.42	1107.43	875.02	596.99

approximately 32 hours later, are apparent but subtle due to attenuation of the release front. Colorado begins to receive credit for water delivered at the time the release front is recorded at ARKCOOKS. A significant precipitation event occurring on the evening of August 1, 1986, centered on the area between ARKGRACO and ARKCOOKS, increased the flow up to 1500 cfs at ARKGRACO and up to 2300 CFS at ARKCOOKS. This prompted an early stop of the reservoir release since it was obvious from the real-time discharge data that the natural flow of the river at ARKCOOKS would continue above 600 cfs for several days. This is evidenced on the second hydrograph covering the period August 2 - August 6, 1986. Mean daily discharge values calculated for that period show that Colorado delivered the required amount of water. The satellite monitoring system saved Colorado water in this case since real-time data prompted curtailment of the release one day early.

Robert Jesse, Division 2 Engineer



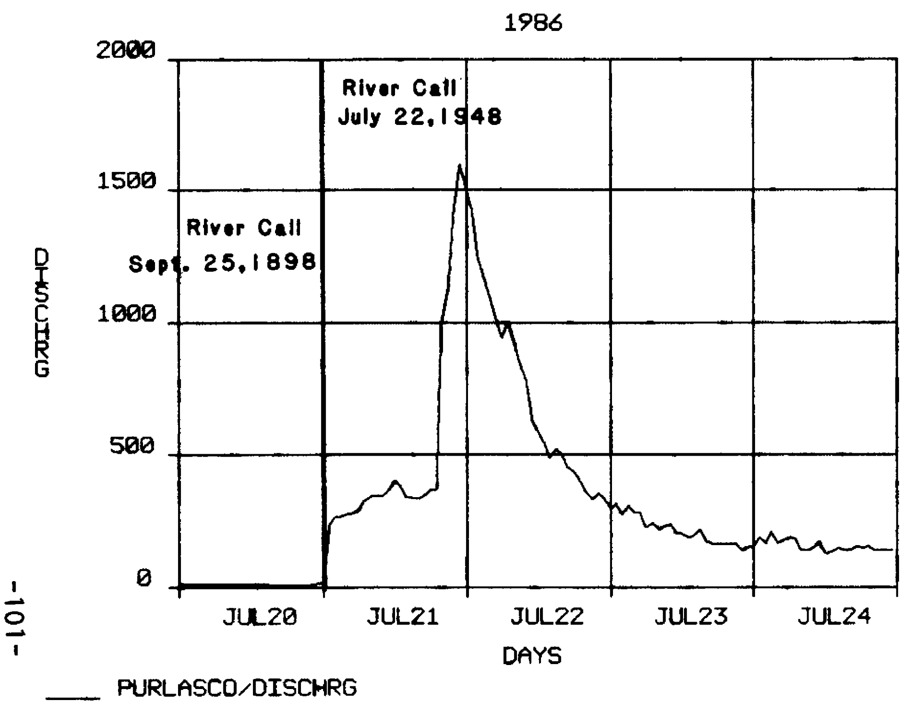


WATER RIGHTS ADMINISTRATION IN THE ARKANSAS RIVER BASIN, DISTRICTS 14 AND 17, UTILIZING REAL-TIME DATA

Districts 14 and 17 include the Arkansas River basin from Pueblo Reservoir downstream to John Martin Reservoir. Water rights administration is complicated by significantly fluctuating flow conditions due to an extremely large drainage area, several major tributaries, snowmelt runoff conditions in the May - July period, and severe precipitation events during the summer months. Real-time data assist the Water Commissioners in determining and implementing the "river call". The evaluation of flow conditions above Pueblo Reservoir allows for advance planning as the system has shown that the typical transit time between Pueblo Reservoir and John Martin Reservoir is 52 hours. Real-time monitoring of key index stations and the main irrigation diversions provides for more effective administration of the river by watching for diversions out of priority and by modifying the "river call" where necessary to satisfy as many junior water rights as possible, yet not causing unnecessary injury to senior water rights.

The hydrographs shown plot real-time discharge data for the key index station in this reach, Arkansas River near Avondale (ARKAVOCO), for the period June 1-10, 1986. On June 1, 1986, the flow was approximately 2200 cfs. The "river call" in effect was June 20, 1890. At 1000 hours, June 2, 1986, the river began rising steadily until it leveled off at approximately 3400 cfs at 0600 hours, June 3, 1986. The "river call" was changed to March 3, 1892. At 2100 hours, June 4, 1986, flow increased dramatically to nearly 6000 cfs before dropping off to approximately 4000 cfs at 1200 hours, June 5, 1986. This provided for another change in the "river call" to January 25, 1906. Flow increased steadily up to approximately 5400 cfs on June 8, 1986. Upstream conditions indicated that snowmelt runoff would result in sustained high discharge levels. On June 8, 1986, the "river call" was changed to June 10, 1948, the priority of John Martin Reservoir, and remained in effect through June 30, 1986.

Robert Jesse, Division 2 Engineer
Don Taylor, Water Commissioner, District 17
George Ridenour, Water Commissioner, District 14



1	PURLASCO	JUL	21	00:00	#	DISCHRG	14.30	#
2	PURLASCO	JUL	21	01:00	#	DISCHRG	240.00	#
3	PURLASCO	JUL	21	02:00	#	DISCHRG	267.00	#
4	PURLASCO	JUL	21	03:00	#	DISCHRG	273.00	#
5	PURLASCO	JUL	21	04:00	#	DISCHRG	279.00	#
6	PURLASCO	JUL	21	05:00	#	DISCHRG	282.00	#
7	PURLASCO	JUL	21	06:00	#	DISCHRG	294.00	#
8	PURLASCO	JUL	21	07:00	#	DISCHRG	328.00	#
9	PURLASCO	JUL	21	08:00	#	DISCHRG	346.00	#
10	PURLASCO	JUL	21	09:00	#	DISCHRG	346.00	#
11	PURLASCO	JUL	21	10:00	#	DISCHRG	346.00	#
12	PURLASCO	JUL	21	11:00	#	DISCHRG	370.00	#
13	PURLASCO	JUL	21	12:00	#	DISCHRG	402.00	#
14	PURLASCO	JUL	21	13:00	#	DISCHRG	382.00	#
15	PURLASCO	JUL	21	14:00	#	DISCHRG	339.00	#
16	PURLASCO	JUL	21	15:00	#	DISCHRG	335.00	#
17	PURLASCO	JUL	21	16:00	#	DISCHRG	335.00	#
18	PURLASCO	JUL	21	17:00	#	DISCHRG	349.00	#
19	PURLASCO	JUL	21	18:00	#	DISCHRG	367.00	#
20	PURLASCO	JUL	21	19:00	#	DISCHRG	374.00	#
21	PURLASCO	JUL	21	20:00	#	DISCHRG	1000.00	#
22	PURLASCO	JUL	21	21:00	#	DISCHRG	1130.00	#
23	PURLASCO	JUL	21	22:00	#	DISCHRG	1420.00	#
24	PURLASCO	JUL	21	23:00	#	DISCHRG	1600.00	#

MONITORING PEAK FLOWS ASSOCIATED WITH PRECIPITATION EVENTS

The Purgatoire River is a major tributary to the Arkansas River with its confluence just above John Martin Reservoir and below the upstream index station, Arkansas River at Las Animas. Flows in the Purgatoire River during the irrigation season are generally low. Flow at the gaging station, Purgatoire River near Las Animas (PURLASCO), averages less than 20 cfs for the month of July. However, due to poor natural vegetative cover, relatively impermeable clay soils, and a large drainage area of 3,503 square miles, precipitation events can result in significant yet short-term runoff events. The ability to monitor these peak flows utilizing real-time data allows for effective allocation of these flows for beneficial use downstream.

The hydrograph shown plots real-time discharge data for the gaging station, PURLASCO, for the period July 20 - July 24, 1986. Flows on July 20, 1986 were less than 5 cfs. A precipitation event resulted in a rapid increase in discharge between 0000-0100 hours, July 21, 1986. The tabulation of hourly discharge values indicates that flow increased from 14 cfs at 0000 hours to 240 cfs by 0100 hours. The discharge increased steadily to 374 cfs by 1900 hours. Beginning at approximately 2000 hours, discharge increased dramatically until peaking at 1600 cfs at 2300 hours. Discharge decreased steadily to 374 cfs by 1900 hours on July 22, 1986.

The Water Commissioners for District 17 and District 67 contacted downstream appropriators advising them of the availability of additional water supplies. The "river call" was adjusted from September 25, 1898 (in effect on July 20, 1986), to a "river call" of July 22, 1948, going into effect on July 21, 1986.

Robert Jesse, Division 2 Engineer
William Howland, Water Commissioner, District 67
Don Taylor, Water Commissioner, District 17

REAL-TIME ACCOUNTING OF EXCHANGES OF TRANSMOUNTAIN DIVERSION WATER WITH UPSTREAM NATIVE FLOW

Transmountain diversion water is unique since Colorado water law allows reuse as long as dominion and control are maintained of the return flow. This system application example involves the exchange of transmountain return flows for upstream native flow.

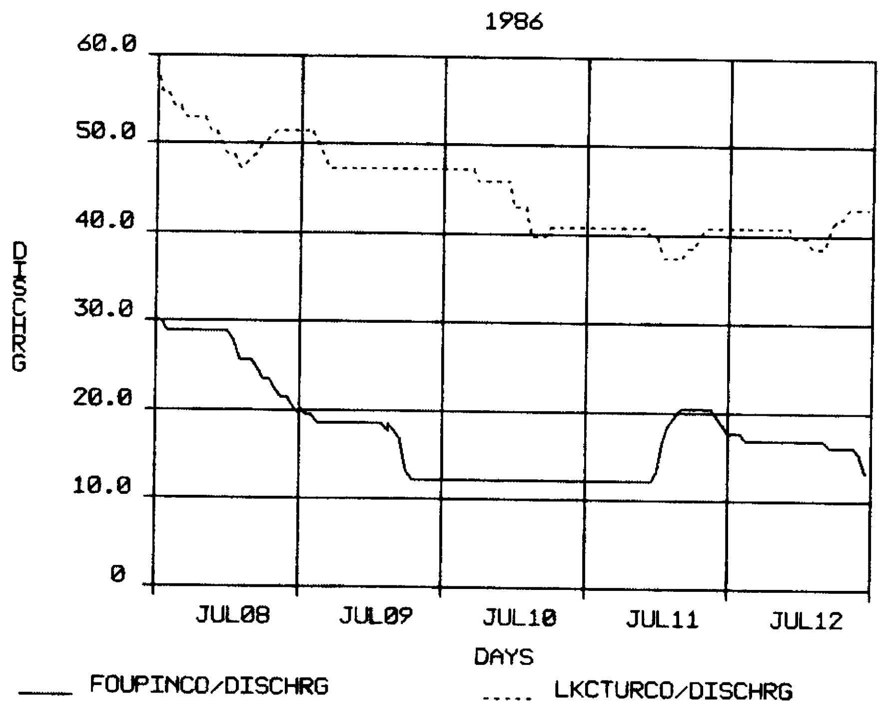
The City of Colorado Springs releases treated municipal water (return flow originating from a transmountain diversion) into Fountain Creek which flows into the Arkansas River. As Colorado Springs has no use for the water below this point, the Division 2 Engineer has approved an exchange to take place at Turquoise Reservoir in the Upper Arkansas River basin. Colorado Springs is permitted to store an amount equivalent to the volume released into Fountain Creek minus the transit loss to the confluence with the Arkansas River. The gaging station, Fountain Creek near Pinon (FOUPINCO), located above the confluence, is utilized as the index station. The following conditions must be satisfied before the exchange can take place:

1. A call must be in effect on the Arkansas River in the reach below the confluence.

2. The daily native flow into Turquoise Reservoir, measured at the gaging station, Lake Fork Creek above Turquoise Reservoir (LKCTURCO) must be equal to or greater than the net flow measured at the gaging station FOUPINCO.

The hydrograph shown plots real-time flow data measured at the gaging stations, FOUPINCO and LKCTURCO, for the period July 8-12, 1986. Note that the flow at FOUPINCO never exceeds the flow at LKCTURCO. There was no natural flow in Fountain Creek during this period.

Listed below the hydrograph is a tabulation of system derived mean daily flows for FOUPINCO and LKCTURCO and the net native flow to be released from Turquoise Reservoir back to the river.



DAILY AVERAGES

WATER YEAR	STATION	DATA/TYPE	JULY 8	JULY 9	JULY 10	JULY 11	JULY 12
86	FOUPINCO	DISCHRG (cfs)	26.41	16.79	12.09	15.67	16.45
86	FOUPINCO	VOLUME (AF)	52.38	33.30	14.07	31.08	18.43
86	LKCTURCO	DISCHRG (cfs)	51.90	47.60	43.62	39.85	40.78
86	LKCTURCO	VOLUME (AF)	102.94	94.41	86.52	79.04	80.73
86	TURQUOISE RESERVOIR RELEASE	DISCHRG (cfs)	25.49	30.80	36.52	24.18	31.40
86	TURQUOISE RESERVOIR RELEASE	VOLUME (AF)	50.56	61.11	72.45	47.96	62.30

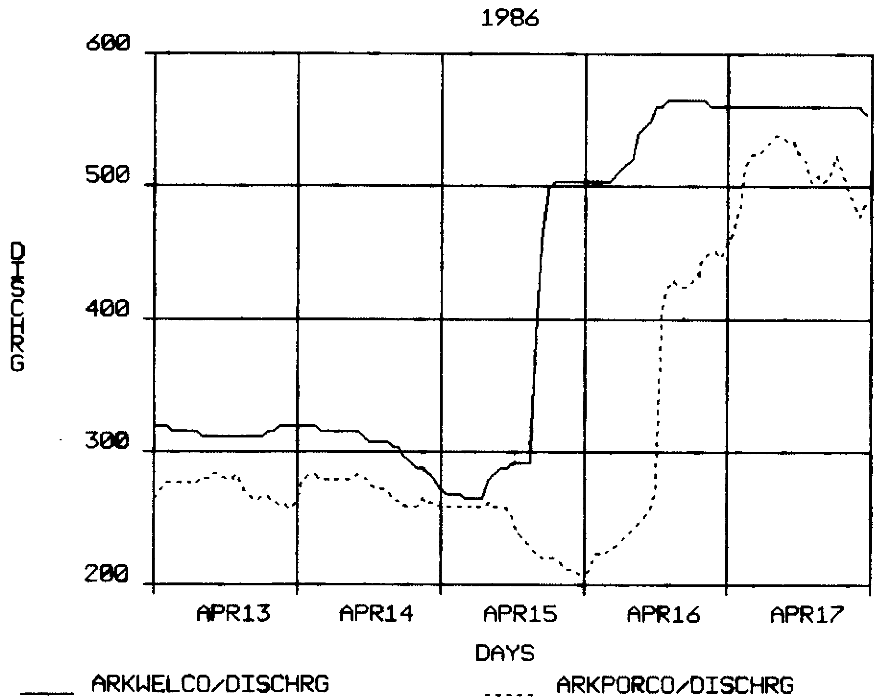
Robert Jesse, Division 2 Engineer
Tom Simpson, Engineering Technician

DETERMINING TRANSIT TIMES UTILIZING REAL-TIME DATA

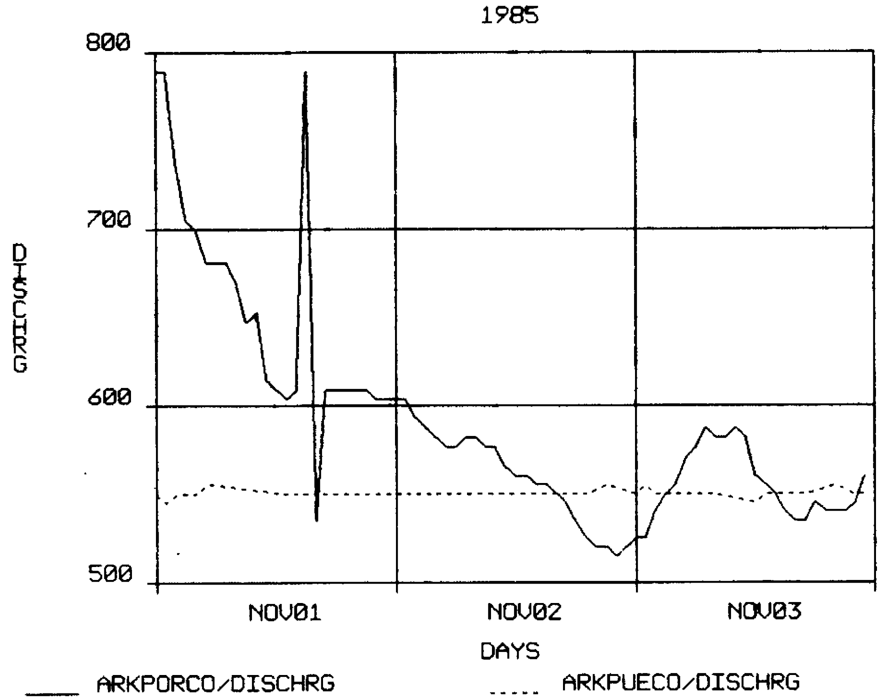
A knowledge of transit times is essential in advance planning relative to water rights administration and in tracking reservoir releases and transmountain diversions. The application example given involves a reservoir release of 225 cfs with a total of 3,000 acre-feet from Clear Creek Reservoir into the Arkansas River. The release was initiated on April 24, 1986.

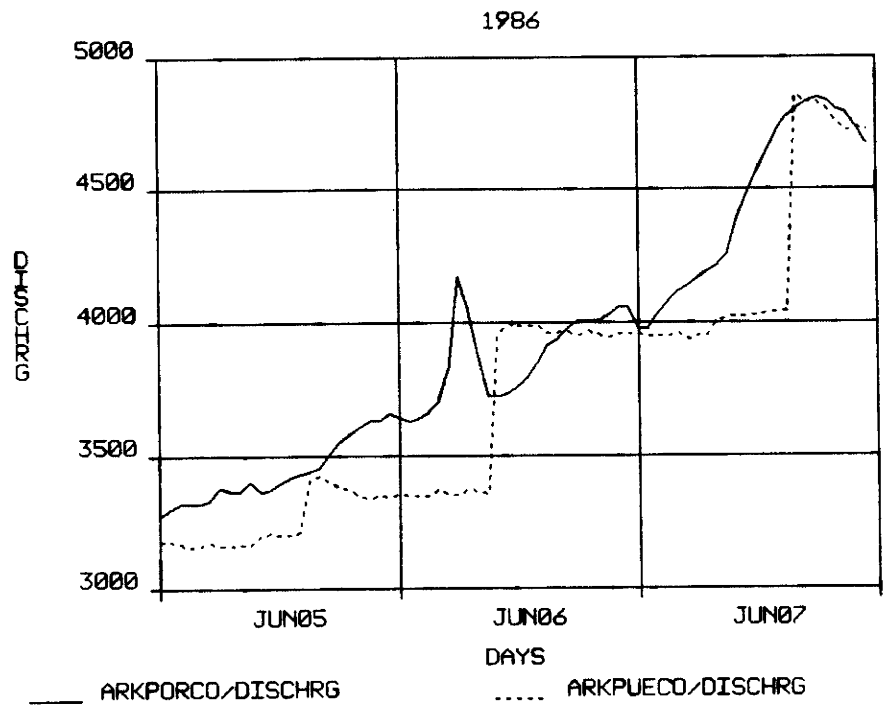
The hydrograph shown plots real-time discharge data for two gaging stations downstream from Clear Creek Reservoir, Arkansas River near Wellesville (ARKWELCO), and Arkansas River at Portland (ARKPORCO), for the period April 13-17, 1986. The arrival times of the release are apparent on both the hydrograph and the tabulation of discharge values listed at 15-minute intervals. The release arrived at the upper station, ARKWELCO, at 1600 hours, April 16, 1986. The release arrived at the lower station, ARKPORCO, at 1215 hours, April 16, 1986. the transit time is calculated to be 20.25 hours. The distance between the two stations is 71 miles.

Tom Simpson, Engineering Technician, Division 2



1	ARKWELCO	APR 15	14:00 #	DISCHRG	291.00 #	1	ARKPORCO	APR 16	11:00 #	DISCHRG	257.00 #
2	ARKWELCO	APR 15	14:15 #	DISCHRG	291.00 #	2	ARKPORCO	APR 16	11:15 #	DISCHRG	260.00 #
3	ARKWELCO	APR 15	14:30 #	DISCHRG	291.00 #	3	ARKPORCO	APR 16	11:30 #	DISCHRG	260.00 #
4	ARKWELCO	APR 15	14:45 #	DISCHRG	291.00 #	4	ARKPORCO	APR 16	11:45 #	DISCHRG	260.00 #
5	ARKWELCO	APR 15	15:00 #	DISCHRG	291.00 #	5	ARKPORCO	APR 16	12:00 #	DISCHRG	269.00 #
6	ARKWELCO	APR 15	15:15 #	DISCHRG	291.00 #	6	ARKPORCO	APR 16	12:15 #	DISCHRG	300.00 #
7	ARKWELCO	APR 15	15:30 #	DISCHRG	291.00 #	7	ARKPORCO	APR 16	12:30 #	DISCHRG	372.00 #
8	ARKWELCO	APR 15	15:45 #	DISCHRG	291.00 #	8	ARKPORCO	APR 16	12:45 #	DISCHRG	392.00 #
9	ARKWELCO	APR 15	16:00 #	DISCHRG	395.00 #	9	ARKPORCO	APR 16	13:00 #	DISCHRG	404.00 #
10	ARKWELCO	APR 15	16:15 #	DISCHRG	462.00 #	10	ARKPORCO	APR 16	13:15 #	DISCHRG	408.00 #
11	ARKWELCO	APR 15	16:30 #	DISCHRG	462.00 #	11	ARKPORCO	APR 16	13:30 #	DISCHRG	420.00 #
12	ARKWELCO	APR 15	16:45 #	DISCHRG	462.00 #	12	ARKPORCO	APR 16	13:45 #	DISCHRG	425.00 #
13	ARKWELCO	APR 15	17:00 #	DISCHRG	462.00 #	13	ARKPORCO	APR 16	14:00 #	DISCHRG	425.00 #
14	ARKWELCO	APR 15	17:15 #	DISCHRG	467.00 #	14	ARKPORCO	APR 16	14:15 #	DISCHRG	425.00 #
15	ARKWELCO	APR 15	17:30 #	DISCHRG	467.00 #	15	ARKPORCO	APR 16	14:30 #	DISCHRG	429.00 #
16	ARKWELCO	APR 15	17:45 #	DISCHRG	467.00 #	16	ARKPORCO	APR 16	14:45 #	DISCHRG	429.00 #
17	ARKWELCO	APR 15	18:00 #	DISCHRG	498.00 #	17	ARKPORCO	APR 16	15:00 #	DISCHRG	429.00 #





DAILY OPERATION OF PUEBLO RESERVOIR UTILIZING REAL-TIME DATA

During the period March 15 - November 15, Pueblo Reservoir is basically operated in a non-storing mode; that is, outflow is equivalent to inflow. The Division 2 Engineer monitors the Bureau of Reclamation in its operation of Pueblo Reservoir, utilizing the satellite monitoring system. The object is to minimize the dynamic natural flow conditions.

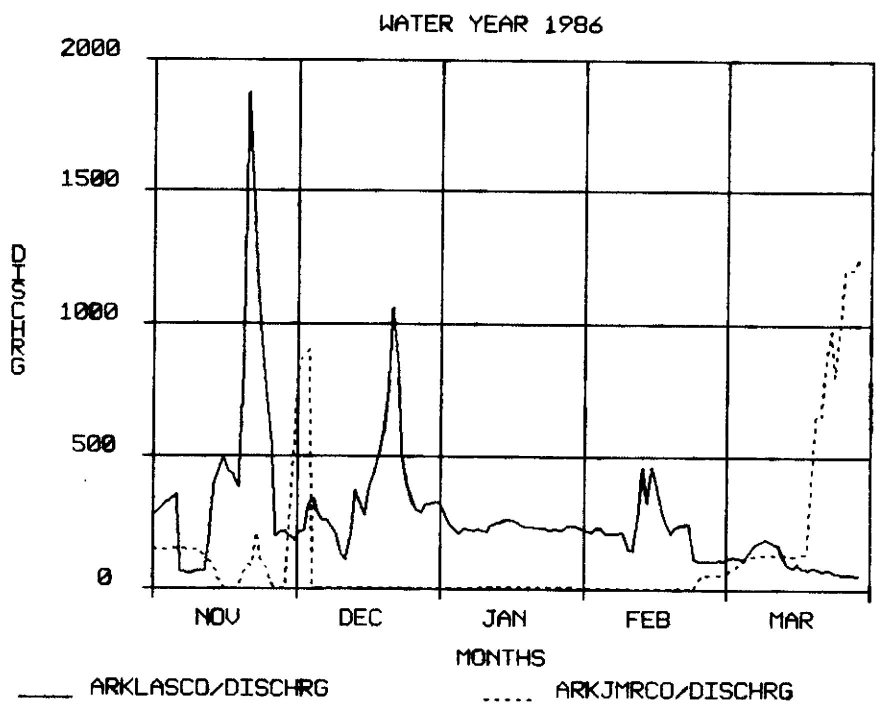
The hydrograph shown in the upper left plots real-time discharge data for the gaging stations, Arkansas River at Portland (ARKPORCO), and Arkansas River below Pueblo Reservoir (ARKPUECO), for the period November 1-3, 1985. ARKPORCO measures the inflow to the reservoir and ARKPUECO the outflow. This is considered to be a low flow period. Releases are shown to be level during this period at 550 cfs, matching closely the three-day inflow average.

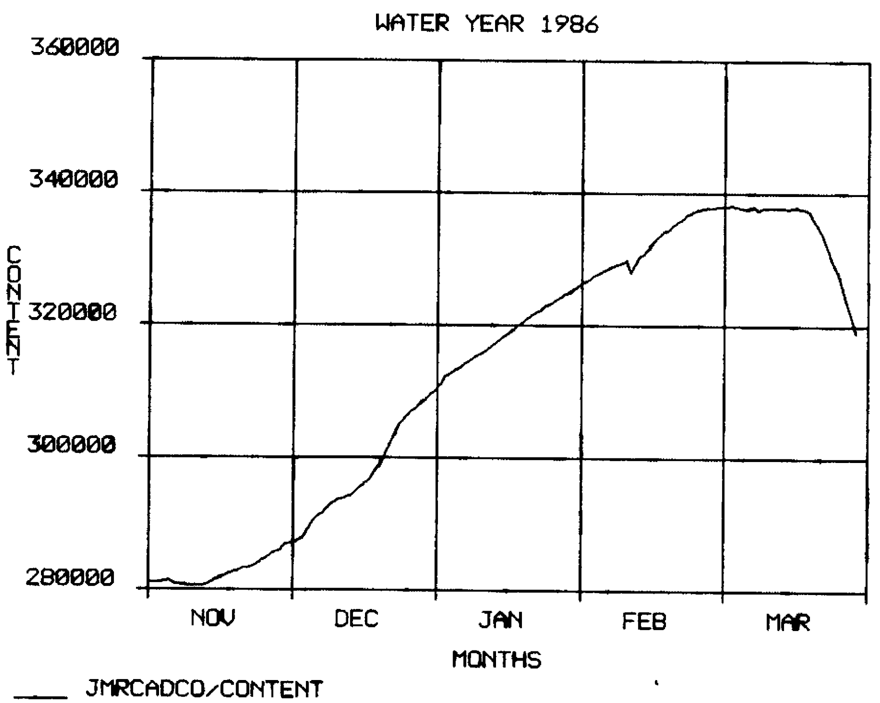
The hydrograph shown in the lower left plots real-time discharge data for the gaging stations, ARKPORCO and ARKPUECO, for the period June 5-7, 1986. This is considered to be a high flow period. Maintaining static releases is more difficult as evidenced by the daily gate adjustments made to attempt to balance inflow and outflow. During this three-day period, the mean daily outflow was less than the mean daily inflow requiring additional releases to balance the account.

Robert Jesse, Division 2 Engineer

WY	STATION	CODE	HR	NOV 1	NOV 2	NOV 3
==	=========	=======	==	=========	=========	=========
86	ARKPORCO	DISCHRG	00	651.16	558.82	555.49
86	ARKPUECO	DISCHRG	00	550.26	550.16	548.79

WY	STATION	CODE	HR	JUN 5	JUN 6	JUN 7
==	=========	=======	==	=========	=========	=========
86	ARKPORCO	DISCHRG	00	3441.22	3876.13	4474.45
86	ARKPUECO	DISCHRG	00	3251.44	3731.97	4275.20





ARKANSAS RIVER WINTER WATER STORAGE PROGRAM - THE OPERATION OF JOHN MARTIN RESERVOIR

Water users in the lower Arkansas River basin, during the November 15 - March 15 period, annually operate under a cooperative agreement that provides for the storage of flows in the Arkansas River in Pueblo Reservoir and John Martin Reservoir. As the beneficial use of this water is almost totally for irrigation, direct diversions at this time would be of no benefit. The satellite monitoring system is an essential element in the administration of this program. In the case of John Martin Reservoir, this includes a daily allocation of water based on the native flow conditions and existing water rights, and in maintaining individual storage accounts for both in-state water rights and for Kansas water rights under the Compact. Compact water is basically split 60% Colorado and 40% Kansas. Storage accounts under this program may be carried over for a maximum of 13 months.

The hydrograph shown in the upper left plots mean daily discharge values for the period November 1985 - March 1986 for the gaging stations, Arkansas River near Las Animas (ARKLASCO) and Arkansas River below John Martin Reservoir (ARKJMRCO). ARKLASCO measures inflow to the reservoir while ARKJMRCO measures outflow. Beginning on November 15, 1985, outflow was reduced to seepage (0.4 cfs) until March 15, 1986, except for three separate on-demand releases for off-site storage. These releases took place on November 20-26, 1985, 90 cfs, November 30 - December 4, 1985, 900 cfs, and February 25 - March 15, 1986, 50 cfs.

The hydrograph shown in the lower left plots mean daily contents data for John Martin Reservoir for the period November 15, 1985 - March 15, 1986. Actual system calculated reservoir content is 281,521 acre-feet on November 15, 1985, and 337,713 acre-feet on March 15, 1986. This represents a net gain in storage of 56,192 acre-feet.

Robert Jesse, Division 2 Engineer
William Howland, Water Commissioner, District 67

C. Division 3, Alamosa, Colorado, Rio Grande Basin
Steve Vandiver, Division Engineer

The satellite monitoring system, after two years of use in the Rio Grande basin in Division 3, has successfully been incorporated into daily water rights administration, water resources accounting, flood monitoring, dam safety, and in hydrologic records development.

A primary responsibility of the Division 3 Engineer is in the administration and accounting of the Rio Grande Compact. The Rio Grande Compact was written to provide for an equitable distribution of the waters of the Rio Grande between the three states of Colorado, New Mexico, and Texas. Colorado has an annual obligation to deliver water to the Colorado-New Mexico stateline based upon two delivery schedules--one for the Rio Grande and one for the Conejos River basin, a large tributary of the Rio Grande. This obligation is based on the index flows of the Rio Grande, Conejos, Los Pinos, and San Antonio Rivers. There are a total of seven stream gaging stations on those four river systems, all of which are equipped with the satellite monitoring hardware.

The satellite monitoring system is invaluable due to the fact that these gages are widely dispersed in the San Luis Valley and the flows measured at the sites are needed daily for proper administration of both the Compact and the water rights on those streams. Previous to the satellite monitoring system, our Water Commissioners spent valuable administrative time driving to these gages to ascertain the flows at these gages before the water could be properly distributed. Now this information is available at any time to them from their homes and offices. Much more time can be spent on the streams and ditches insuring that proper administration of water rights is accomplished and that New Mexico and Texas are receiving the proper amount of water and, more importantly, that Colorado water users receive all the water to which they are entitled. An example of the system's utility has been in delineating the natural flow component of the Conejos River from storage releases out of Platoro Reservoir.

The system is able to give not only real-time data, but can provide cumulative amounts of water over past periods of time. The Compact is so sensitive that 10-day updates must be done to insure proper amounts of deliveries are occurring. The computer software provided with the system does those evaluations saving both time and expense and provides us much more timely data on which to base our adjustments and projections.

Daily administration of water rights on the Rio Grande and its tributaries is more efficient and effective due to the system. This improvement has been to the benefit of water users in the basin. The majority of the monitoring stations in Division 3 are located on the Rio Grande and Conejos Rivers. By accessing the computer processed data each morning, Water Commissioners know immediately the flow in the rivers in their areas.

Computerized data processing of streamflow records on a real-time basis is an important element of the system. There are seven gaging stations used to monitor compliance with the Rio Grande Compact. The satellite monitoring system enables these totals to be computed on a real-time basis, and is much faster and more efficient than the conventional chart-working methods. The computer programming enables Division 3 to also compute monthly totals on the first of each month. The 10-day and monthly totals are sent to various agencies which monitor the Compact such as the Corps of Engineers, Bureau of Reclamation, State of New Mexico, etc. The real-time data enables Division 3 to supply information to these agencies in a more timely manner.

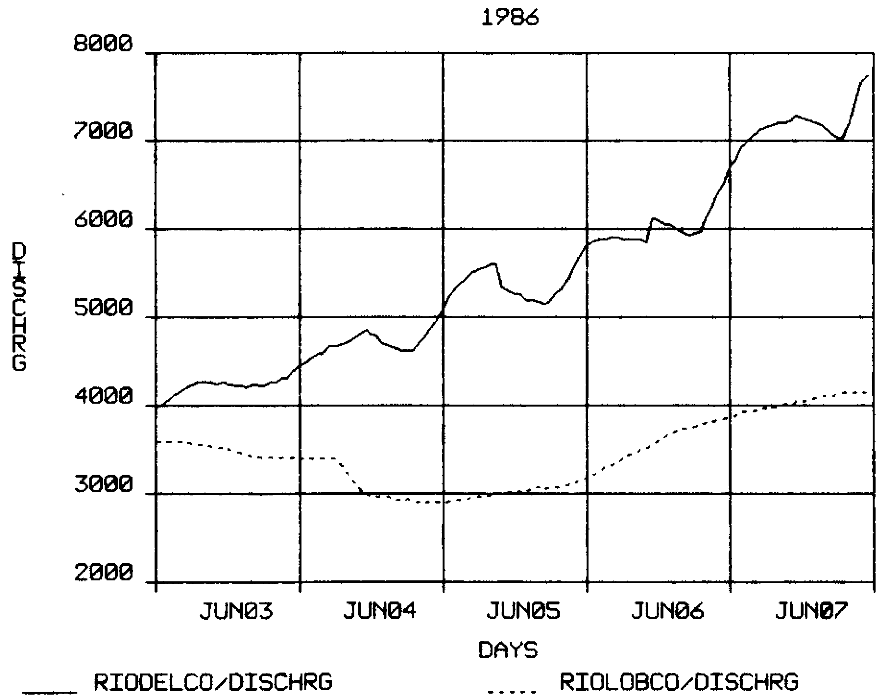
The spring runoff periods in 1985 and 1986 had exceptionally high flow amounts and put the satellite monitoring system to a real test. The system proved to be vital in monitoring the flood levels that were occurring at various towns along the Rio Grande and Conejos Rivers. We were able to detect hourly changes, daily trends, and compare day-to-day flows for changes in discharge amounts. The real-time information was critical in coordinating flood watching activities for all of the local agencies such as the state patrol, counties, cities, sheriff departments, Division of Disaster Emergency Services, and the Army Corps of Engineers. The up-to-date information from the satellite monitoring system enabled the division personnel to utilize their time for flood fighting activities rather than driving to the stations to obtain flow information. An example of this was being able to coordinate diversions to help reduce the peak flows of the system. Without this system, Division 3 could not have managed the high water as efficiently as it did.

Basic monitoring of stage elevations of reservoirs can provide information relative to dam safety. In 1984, a restriction was placed on Terrace Reservoir because of an inadequately sized spillway. The spillway capacity is insufficient to handle all of the inflow during the spring runoff. This creates a problem with enforcing the restriction level when the water cannot be released fast enough. Having real-time monitoring hardware at the reservoir has been essential in keeping the water level regulated to allow space in the reservoir for the spring runoff and keep the level within the restriction. Responses to changes in inflow can be made in a more timely manner to keep from gaining or losing too much water.

THE ADMINISTRATION AND ACCOUNTING OF THE RIO GRANDE COMPACT

Colorado has an obligation to deliver water to the Colorado-New Mexico stateline based upon two delivery schedules, one for the Rio Grande and one for the Conejos River. During selected periods of flow, the Division 3 Engineer may have to deliver up to 18% of the Rio Grande flow and 40% of the Conejos River flow to the stateline. It is to the State of Colorado's benefit not to over-deliver or under-deliver. Knowledge of real-time conditions both upstream and at the stateline delivery point is essential for planning and operations relative to the administration of the Compact. This is extremely important for the Rio Grande basin since there are no storage structures in the middle and lower reaches.

The first hydrograph shown plots real-time discharge data for the gaging stations, Rio Grande near Del Norte (RIODELCO) and the Rio Grande near Lobatos (RIOLOBCO), for the period June 3-7, 1986. From June 3 to June 7, 1986, the flow at RIODELCO increased steadily from 4000 cfs to 7700 cfs. This represents significantly high flow conditions. Flow conditions during this period at the stateline gaging station, RIOLOBCO, fluctuated from 3500 cfs on June 3, 1986 to 4100 cfs on June 7, 1986. This indicates that diversions below RIODELCO and above RIOLOBCO increased from 500 cfs on June 3, 1986 to 3600 cfs on June 7, 1986. The table lists mean daily discharge values for each station for the study period. The Division 3 Engineer and the appropriate Water Commissioners through the use of the satellite monitoring system, were able to monitor the development of significantly increasing flow conditions in the upper reach of the Rio Grande and advise downstream water users of the availability of surplus water.

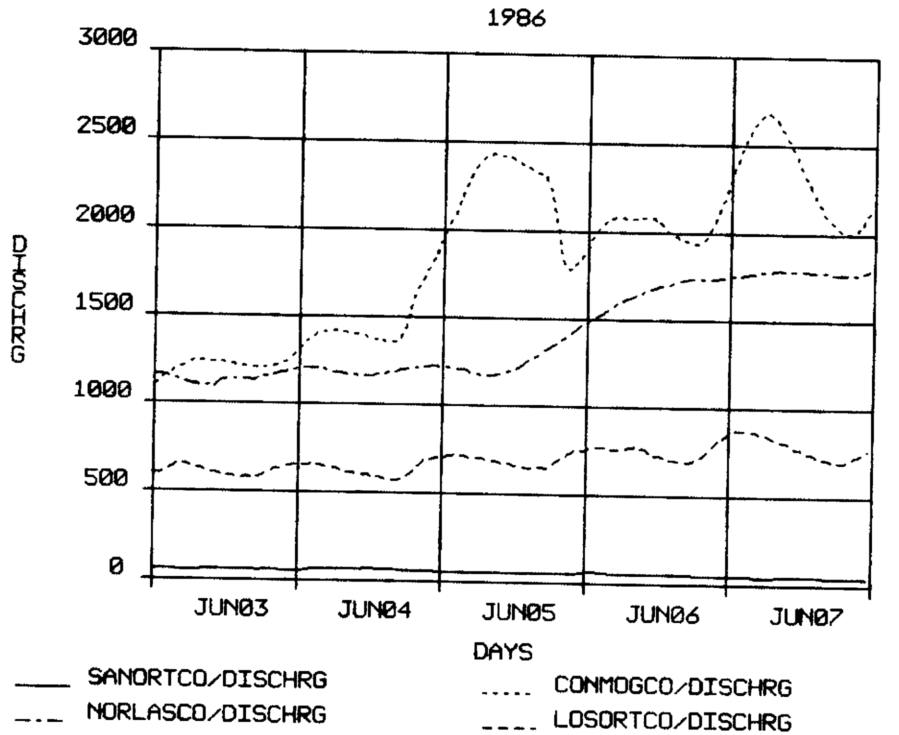


WY	STATION	CODE	HR	JUN 3	JUN 4	JUN 5	JUN 6	JUN 7
86	RIODELCO	DISCHRG	00	4225.23	4708.29	5377.39	6012.04	7186.83
86	RIOLOBCO	DISCHRG	00	3491.47	3054.26	3021.86	3551.74	4042.13

THE ADMINISTRATION AND ACCOUNTING
OF THE RIO GRANDE COMPACT
(Continued)

The second hydrograph shown plots real-time discharge data for the gaging stations, San Antonio River at Ortiz (SANORTCO), North Channel Conejos River near La Sauses (NORLASCO), Conejos River near Mogote (CONMOGCO), and Los Pinos River near Ortiz (LOSORTCO), for the period June 3-7, 1986. Significantly high flow conditions existed at both CONMOGCO and NORLASCO during this period. Two runoff peaks occurring at the upstream stations, CONMOGCO, 2500 cfs on June 5, 1986 and 2700 cfs on June 7, 1986, were effectively diverted by downstream users as indicated by the NORLASCO plot for those days. The table lists mean daily discharge values for each station for the five-day period.

Steve Vandiver, Division 3 Engineer



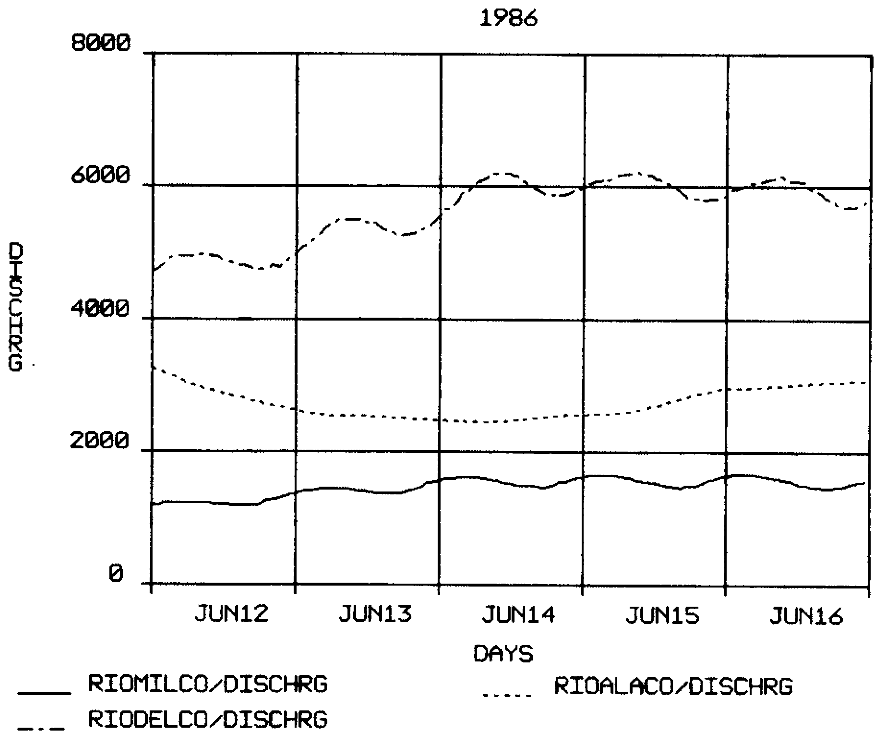
WY	STATION	CODE	HR	JUN 3	JUN 4	JUN 5	JUN 6	JUN 7
==	=========	=======	==	=========	=========	=========	=========	=========
86	SANORTCO	DISCHRG	00	55.65	63.01	52.23	51.32	43.10
86	NORLASCO	DISCHRG	00	1141.55	1189.42	1265.86	1667.61	1779.14

WY	STATION	CODE	HR	JUN 3	JUN 4	JUN 5	JUN 6	JUN 7
==	=========	=======	==	=========	=========	=========	=========	=========
86	CONMOGCO	DISCHRG	00	1214.74	1464.33	2208.27	2039.65	2327.25
86	LOSORTCO	DISCHRG	00	616.31	627.14	693.41	750.18	781.37

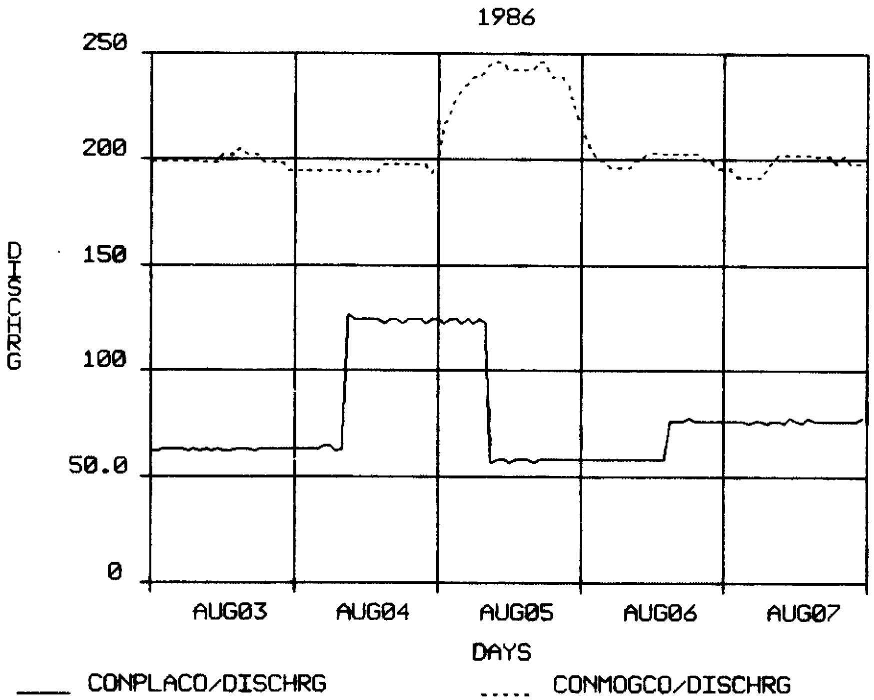
ADMINISTRATION OF THE RIO GRANDE FROM THE RIO GRANDE RESERVOIR TO ALAMOSA - DISTRICT 20, UTILIZING REAL-TIME DATA

The administration of this upper reach of the Rio Grande is complicated by the administration of Compact water, storage releases from Rio Grande Reservoir, no storage structures below Rio Grande Reservoir, transmountain diversion water, and water exchanges. The hydrograph shown plots real-time discharge data for the gaging stations, Rio Grande below Rio Grande Reservoir at Thirty-Mile Bridge (RIOMILCO), Rio Grande near Del Norte (RIODELCO), and Rio Grande at Alamosa (RIOALACO), for the period June 12-16, 1986. The flow measured at RIOMILCO held relatively steady at 1260 cfs to 1570 cfs. The plot of discharge for RIODELCO (downstream of RIOMILCO), shows high flow conditions. Tributary inflow to the Rio Grande between RIOMILCO and RIODELCO is substantial, contributing 3400 cfs to 4400 cfs over the five-day period. Between the RIODELCO and RIOALACO stations, diversions account for 1950 cfs to 3300 cfs over the five-day period. The table lists mean daily discharge values for each station over the designated period.

Steve Vandiver, Division 3 Engineer
Max Nash, Water Commissioner, District 20



WY	STATION	CODE	HR	JUN12	JUN13	JUN14	JUN15	JUN16
86	RIOMILCO	DISCHRG	00	1260.00	1410.00	1570.00	1550.00	1570.00
86	RIODELCO	DISCHRG	00	4861.89	5365.84	5979.62	6029.06	5947.36
86	RIOALACO	DISCHRG	00	2907.86	2540.89	2499.59	2733.88	3023.52



WY	STATION	CODE	HR	AUG 3	AUG 4	AUG 5	AUG 6	AUG 7
86	CONPLACO	DISCHRG	00	63.06	102.63	80.51	65.41	76.38
86	CONMOGCO	DISCHRG	00	199.66	195.49	236.56	201.00	198.28

MONITORING STORAGE RELEASES FROM PLATORO RESERVOIR UTILIZING REAL-TIME DATA

Tracking reservoir storage releases and delineating the natural flow component are essential in effective water rights administration on the Conejos River. The hydrograph shown plots real-time discharge data for the gaging stations, Conejos River below Platoro Reservoir (CONPLACO) and Conejos River near Mogote (CONMOGCO), for the period August 3-7, 1986. The release of 60 cfs began at 0900 hours, August 4, 1986, and ended at 0900 hours, August 5, 1986. The natural flow of the river was 65 cfs as evidenced by the CONPLACO data plot. The release front reached the CONMOGCO station 15 hours later. Measured discharge at both stations indicate that 5-10 cfs were lost in transit.

Steve Vandiver, Division 3 Engineer
Paul Clark, Water Commissioner, District 22

D. Division 4, Montrose, Colorado, Gunnison River Basin
Thomas Kelly, Division Engineer

Division 4 has experienced five consecutive years of above average water supply for most areas in the Division. Although the satellite monitoring system is currently being utilized for general water rights administration, in tracking reservoir releases, and in hydrologic records development, the system will be more effective during periods of average to below average water supply.

The availability of real-time data is essential in evaluating both upstream and downstream streamflow conditions in the planning and implementation of water rights administration. This is critical in Division 4 where the senior water rights are generally downstream of junior water rights. An example of this is in the Surface Creek drainage basin. There are two monitoring stations on Surface Creek, one upstream of Cedaredge and one at Cedaredge. Several important diversions are located between the two gaging stations. The satellite monitoring system has proven to be useful in delineating the natural flow at a point in a stream from flow contributed by storage releases. An example of this application is on Muddy Creek. The senior right in the district is owned by the Fire Mountain Canal holding storage rights in Paonia Reservoir. Two monitoring stations, one located above the reservoir and the other below, provide real-time data on the respective reservoir inflow and outflow. The system has allowed the Water Commissioners to be more effective in water rights administration to the satisfaction of water users in the basin. There have been definite savings in travel and time.

The recent completion of Ridgway Reservoir has provided for another application of the satellite monitoring system. Two monitoring stations above the reservoir on the Uncompaghre River and on Dallas Creek provide real-time data on inflow into the reservoir. A monitoring station on the Uncompaghre River below the reservoir provides real-time data on outflow. The Division Engineer utilizes these data for administering the filling of the reservoir.

The satellite monitoring system has been especially effective in identifying diurnal effects of snowmelt runoff and runoff from precipitation events. The Water Commissioners can notify water users of changing streamflow conditions in order to divert available water supplies for beneficial use or storage. This is critical in periods of less than adequate water supply.

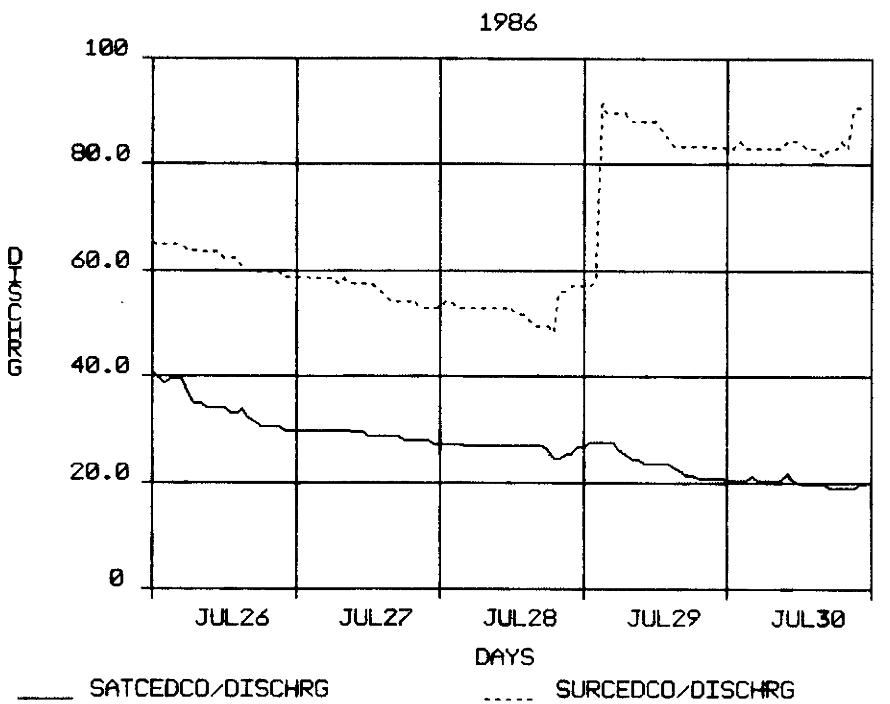
The system was also utilized in many locations this past year in terms of monitoring high water. The Uncompahgre River flows through Montrose, Delta, and Olathe. The flood warning aspect of the system was such that the occurrence of sudden high flows was automatically relayed to these communities. Fortunately this past year, the stream systems as a whole were not in an excessive flood posture; however, this potential continues to exist, and during any one of these particular circumstances, the entire system could well be worth the cost saved in one early warning of potential flooding.

ADMINISTRATION OF SURFACE CREEK UTILIZING REAL-TIME DATA

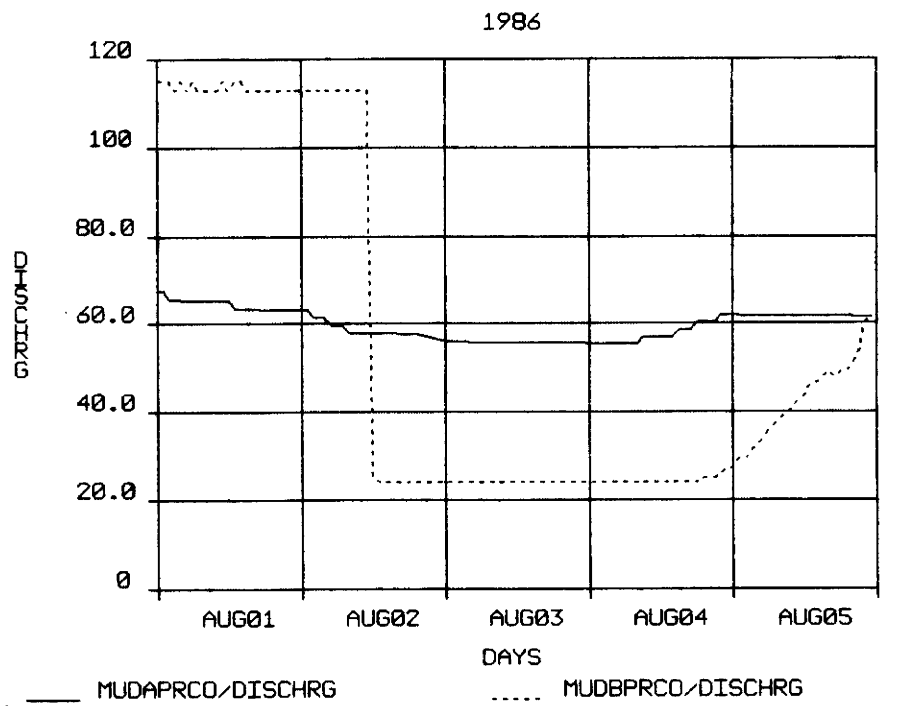
The administration of Surface Creek is complicated through over-appropriation, junior water rights held in the upper reaches of the drainage, senior water rights held in the lower reaches of the drainage, reservoir releases from a series of reservoirs on the Grand Mesa, and transbasin water imported from Plateau Creek. Water rights on Surface Creek provide for diversion of all natural flow before it flows into the Gunnison River.

The hydrograph shown plots real-time discharge data for the gaging stations, Surface Creek near Cedaredge (SURCEDCO) and Surface Creek at Cedaredge (SATCEDCO), for the period July 26 - July 30, 1986. The upstream station, SURCEDCO, and the downstream station, SATCEDCO, have similar profiles with SURCEDCO running approximately 25 cfs more than SATCEDCO, through July 28, 1986. This indicates that approximately 25 cfs is being diverted between the two stations. At 0200 hours, on July 29, 1986, a reservoir release increased the flow at SURCEDCO to 90 cfs. The flow at SATCEDCO is not effected indicating that the entire release is being diverted above SATCEDCO. The key station is SURCEDCO. This station is remote, accessible only by 1-hour walk.

Tom Kelly, Division 4 Engineer
Richard Drexel, Water Commissioner, District 40



WY	STATION	CODE	HR	JUL26	JUL27	JUL28	JUL29	JUL30
==	=========	=======	==	=========	=========	=========	=========	=========
86	SURCEDCO	DISCHRG	00	62.28	56.45	52.92	83.38	84.38
86	SATCEDCO	DISCHRG	00	34.28	28.92	26.62	24.06	20.10



WY	STATION	CODE	HR	AUG 1	AUG 2	AUG 3	AUG 4	AUG 5
==	=========	=======	==	=========	=========	=========	=========	=========
86	MUDAPRCO	DISCHRG	00	64.31	58.37	55.64	57.49	61.48
86	MUDBPRCO	DISCHRG	00	113.66	66.01	24.00	24.40	43.61

ADMINISTRATION OF MUDDY CREEK UTILIZING REAL-TIME DATA

The administration of Muddy Creek keys on a senior right held by the Fire Mountain Canal, with a point of diversion downstream of Paonia Reservoir. In addition, the Fire Mountain Canal holds storage rights in Paonia Reservoir. It is essential to delineate natural flow from storage releases.

The hydrograph shown plots real-time discharge data for the gaging stations, Muddy Creek above Paonia Reservoir (MUDAPRCO) and Muddy Creek below Paonia Reservoir (MUDBPRCO), for the period August 1-5, 1986. Inflow to Paonia Reservoir remained steady at approximately 60 cfs, as measured by MUDAPRCO. Outflow from Paonia Reservoir, as measured by MUDBPRCO, was maintained at 115 cfs until about 1200 hours on August 2, 1986, when the reservoir release was reduced to 25 cfs. As such, approximately 55 cfs was released out of storage until 1200 on August 2, 1986 when approximately 25 cfs was being put into storage. Beginning at 2100 hours, on August 4, 1986, the reservoir gates were adjusted, steadily increasing released flow from the reservoir until it matched inflow at 2200 hours on August 5, 1986.

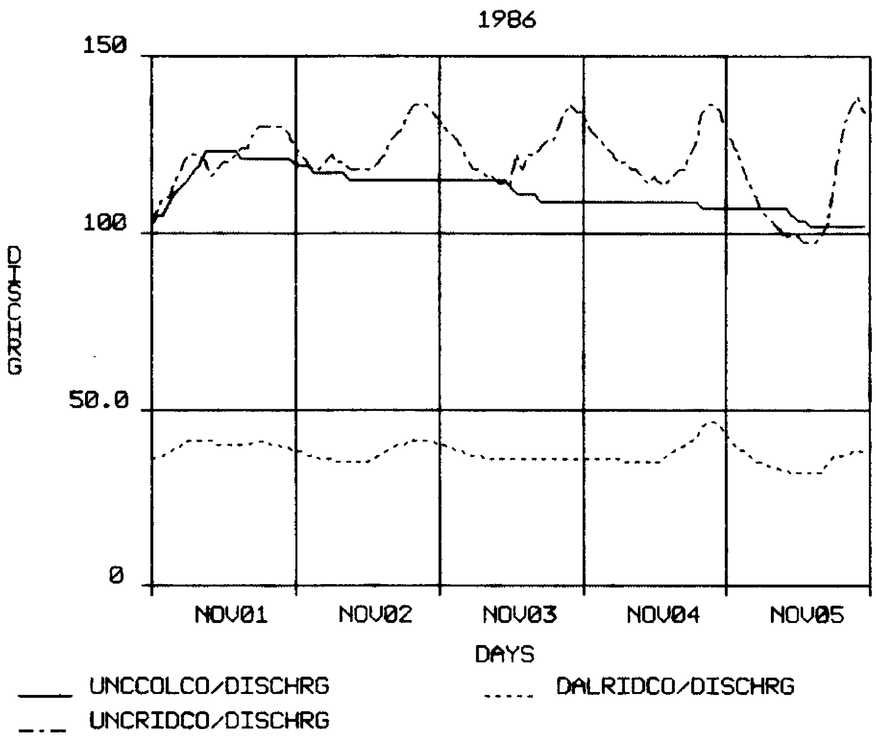
Tom Kelly, Division 4 Engineer
Richard Drexel, Water Commissioner, District 40

ADMINISTERING THE FILLING OF RIDGWAY RESERVOIR UTILIZING REAL-TIME DATA

The construction of Ridgway Reservoir was completed in October, 1986, with filling beginning immediately. The water rights for Ridgway Reservoir are relatively junior and are closely administered so as not to injure any downstream senior rights. Two gaging stations, Uncompaghre River near Ridgway (UNCRIDCO) and Dallas Creek near Ridgway (DALRIDCO), monitor inflow to Ridgway Reservoir. The gaging station, Uncompaghre River at Colona (UNCCOLCO) monitors flow below Ridgway Reservoir. By subtracting the flow measured at UNCCOLCO from the total flow measured at UNCRIDCO and DALRIDCO, the amount of water diverted to Ridgway Reservoir can be determined.

The hydrograph shown plots real-time discharge data for UNCCOLCO, UNCRIDCO, and DALRIDCO for the period November 1-5, 1986. The flow conditions at UNCRIDCO show a diurnal effect apparently caused by snowmelt runoff. Flow below the reservoir is fairly steady, flattening out the diurnal highs and lows. The table below the hydrograph lists first the mean daily discharge values for each station over the 5-day period; and secondly, lists the net contribution to Ridgway Reservoir in both mean daily discharge and in acre-feet.

Tom Kelly, Division 4 Engineer



WY	STATION	CODE	HR	NOV 1	NOV 2	NOV 3	NOV 4	NOV 5
==	=========	=======	==	=========	=========	=========	=========	=========
87	UNCCOLCO	DISCHRG	00	118.07	115.99	112.37	108.62	104.50
87	UNCRIDCO	DISCHRG	00	121.20	124.43	123.42	122.85	112.52
87	DALRIDCO	DISCHRG	00	39.81	37.68	36.79	38.38	35.52
	Net to Ridgway Res	DISCHRG		43.	46.	48.	53.	44.
		CONTENT		85.	91.	95.	104.	86.

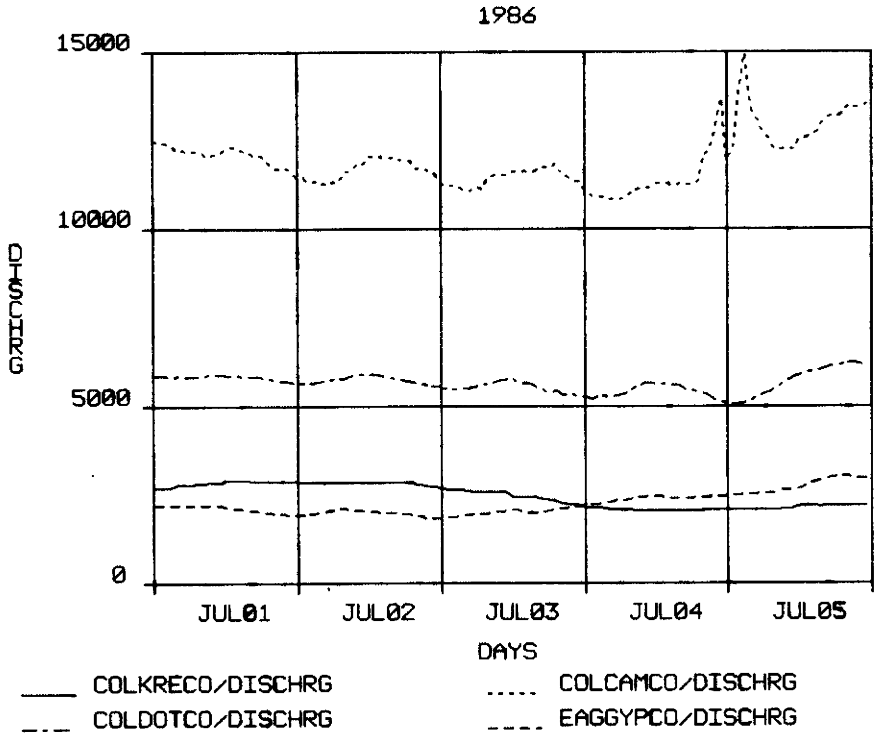
E. Division 5, Glenwood Springs, Colorado, Colorado River Basin
Orlyn Bell, Division Engineer

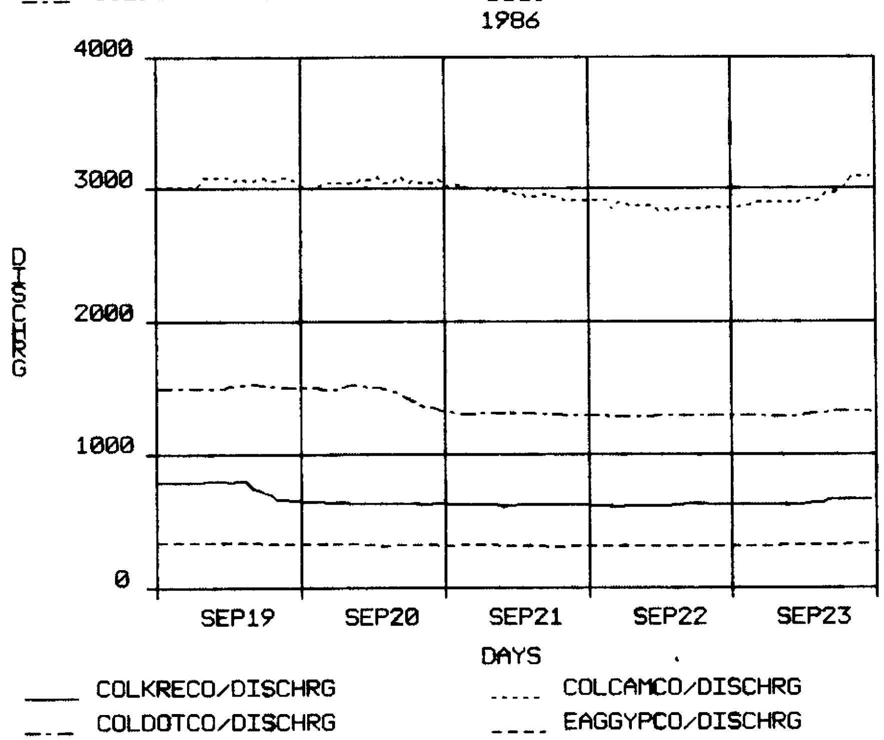
The utility of the satellite monitoring system in the Colorado River basin is developing at a rapid rate. As the only major river basin in Colorado that has significant amounts of unappropriated water, the system is becoming a powerful planning tool in the area of water resources development. The Colorado Front Range has several transmountain diversions from the Colorado River basin currently operating, with several others on the drawing board. The inevitable resurgence of the oil shale industry will definitely put added demand on the available supplies.

The Colorado River accounting system is a necessary tool for the administration of a mainstem call. It can determine which structures are in and/or out-of-priority, which owe the river, and what reservoir releases should be made for transmountain diversions, west slope depletions, and augmentation replacement. Key components of the real-time monitoring network include stations that monitor the operations of Green Mountain Reservoir and the Adams Tunnel.

The initial step in this process is the assimilation of data for direct diversions, streamflows, reservoir contents, evaporation, and precipitation. Once the data are entered into a spread sheet, needed diversion or storage adjustments can be made. Some of the data is obtained from the Water Commissioners on site checks and phone calls. The remainder is obtained from the satellite monitoring system. Although a small percentage of a Water Commissioner's structures are monitored by the system, those monitored are the majority of the ones most critical to a mainstem call, the largest, and the most likely to change from day to day. The real-time data allow us to track the river and anticipate an upward or downward trend in the river. We can reduce the lag time between a shortage or rise in flow and the corresponding adjustment to the river call. This increases the effectiveness and the efficiency of administration and saving water during critical periods.

Administration of the Blue River involves tracking a paper fill in Green Mountain Reservoir, accounting for transmountain diversions and power interference, and out-of-priority replacement from a separate basin, and upstream exchanges. The Blue River shares a Water Commissioner with the Eagle River and, therefore, is very short-handed. Because of the lack of man-power in this area, the system is valuable not only for its real-time data, but also for the daily, monthly, and annual data stored in the archives.



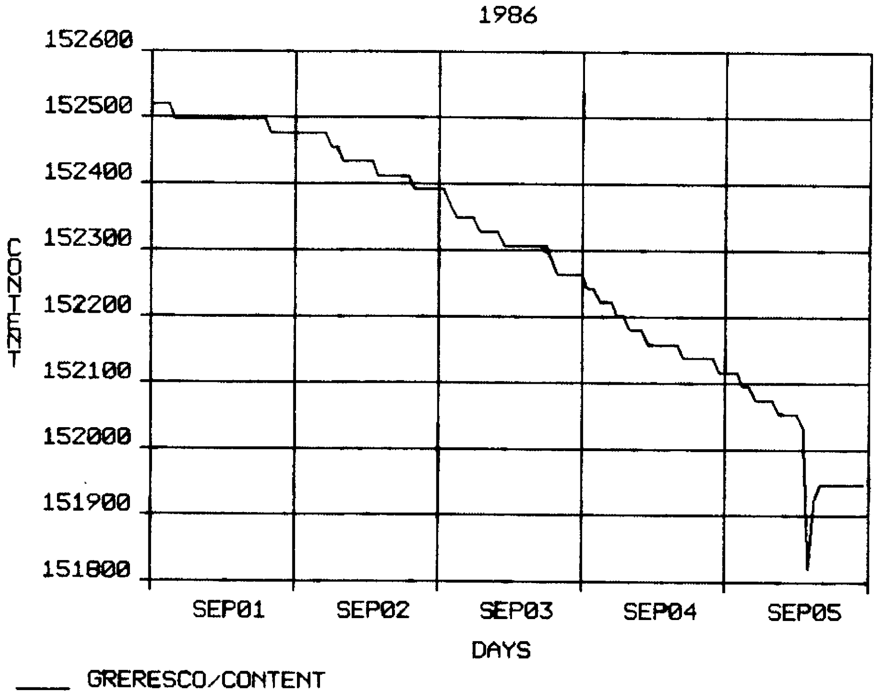


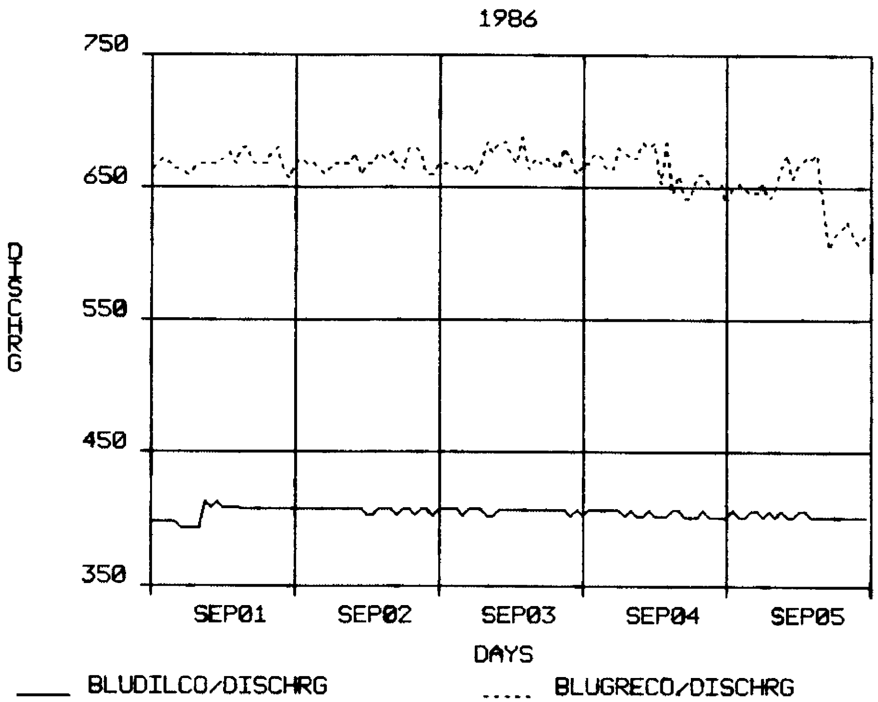
ADMINISTRATION OF THE COLORADO RIVER FROM KREMMLING TO CAMEO UTILIZING REAL-TIME DATA

The 1986 water year was one of abundant supply for the Colorado River basin. However, conditions were such that a "river call" still had to be made on occasion. The Glenwood Shoshone Power Plant, located in the Glenwood Canyon between Dotsero and Glenwood Springs, has a senior right amounting to 1250 cfs. This is the key water right and controls the administration of the Colorado River in this reach.

The first hydrograph shown plots real-time discharge data for the gaging stations, Colorado River near Kremmling (COLKRECO), Colorado River near Dotsero (COLDOTCO), Colorado River near Cameo (COLCAMCO), and Eagle River below Gypsum (EAGGYPCO), for the period July 1-5, 1986. The flow conditions during this period are significantly high. There is no call on the river. The discharge measured at COLDOTCO, above the Glenwood Shoshone Power Plant, is in excess of 5000 cfs. The second hydrograph shown plots real-time discharge data for the same four stations for the period September 19-23, 1986. Flow conditions have reduced significantly. The discharge measured at COLDOTCO dropped to 1300 cfs on September 20, 1986. Further, the flow being contributed by the Eagle River, as measured at EAGGYPCO, did not indicate any increases. This prompted the Division 5 Engineer to place a call on the river upstream from COLDOTCO to insure that the senior right for the Glenwood Shoshone Power Plant would not be injured.

Orlyn Bell, Division 5 Engineer





WY	STATION	CODE	HR	SEP 1	SEP 2	SEP 3	SEP 4	SEP 5
86	GRERESCO	CONTENT	00	152476.16	152391.48	152264.45	152115.75	151947.41
	Net Change				85.	127.	149.	168.
	Calculated Tributary Inflow	Content Dischrg			437. 220.	399. 201.	365. 184.	309. 156.

THE ADMINISTRATION AND ACCOUNTING OF GREEN MOUNTAIN RESERVOIR WATER UTILIZING REAL-TIME DATA

The administration and accounting of Green Mountain Reservoir water are key elements in the Colorado-Big Thompson Project. Outflow from Dillon Reservoir into the Blue River is monitored at the gaging station, Blue River below Dillon Reservoir (BLUDILCO). The outflow from Green Mountain Reservoir into the Blue River is monitored at the gaging station, Blue River below Green Mountain Reservoir (BLUGRECO). The storage contents are monitored at Green Mountain Reservoir (GRERESCO).

The first hydrograph shown plots real-time discharge data for BLUDILCO and BLUGRECO for the period September 1-5, 1986. The table lists mean daily discharge values for each station for the 5-day period along with the net difference in discharge and the net difference in volume. The second hydrograph shown plots real-time contents data for GRERESCO for the period September 1-5, 1986. The table lists mean daily contents for the station for the same period along with the net difference per day. By comparing the net difference in the flow (converted to volume) between BLUDILCO and BLUGRECO and the daily net change in contents in GRERESCO, it is possible to calculate the tributary inflow between BLUDILCO and GRERESCO. These values are listed in the last table given.

Alan Martellaro, Assistant Division 2 Engineer
Wayne Wells, Water Commissioner, District 36

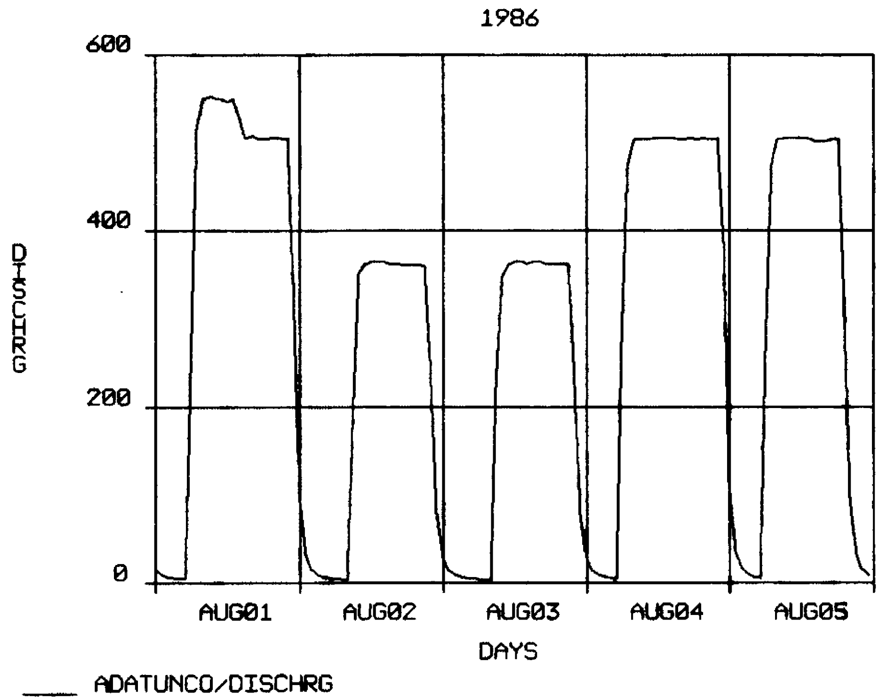
WY	STATION	CODE	HR	SEP 1	SEP 2	SEP 3	SEP 4	SEP 5
86	BLUDILCO	DISCHRG	00	403.79	406.55	406.10	404.48	403.03
86	BLUGRECO	DISCHRG	00	669.61	669.36	671.08	663.48	643.75
	Net	DISCHRG		266.	263.	265.	259.	241.
	Difference	VOLUME		527.	521.	526.	514.	477.

MONITORING TRANSMOUNTAIN DIVERSION FLOWS THROUGH THE ADAMS TUNNEL UTILIZING REAL-TIME DATA

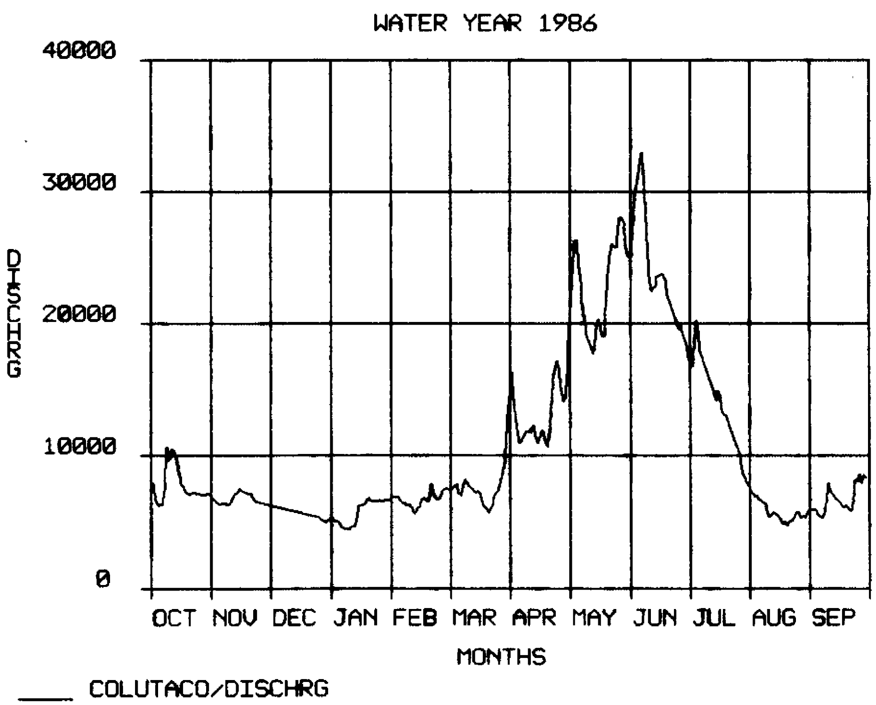
Transmountain diversions from the Colorado River basin to the South Platte River basin as accounted for under the Green Mountain Reservoir Exchange, are monitored on a real-time basis utilizing the satellite monitoring system. Several operating points on the Colorado-Big Thompson Project are monitored by the system. This application deals with the monitoring of delivered project water at the east portal of the Adams Tunnel (ADATUNCO).

The hydrograph shown plots real-time discharge data for ADATUNCO for the period August 1-5, 1986. The daily operations of the ADATUNCO are apparent. The computed mean daily values are listed in the table.

Orlyn Bell, Division 5 Engineer
Alan Martellaro, Assistant Division 5 Engineer



WY	STATION	CODE	HR	AUG 1	AUG 2	AUG 3	AUG 4	AUG 5
==	=========	=======	==	=========	=========	=========	=========	=========
86	ADATUNCO	DISCHRG	00	381.28	209.26	207.73	369.76	288.62
		Volume		756.	415.	412.	733.	572.



MONITORING THE FLOW OF THE COLORADO RIVER AT THE COLORADO-UTAH STATELINE

There is considerable interest in monitoring the flow of the Colorado River at the Colorado-Utah stateline. The Colorado River Compact of 1922 in basic terms provides that 75% of the water originating in the Colorado River basin in Colorado must pass to the lower states. Colorado is not, however, putting to consumptive use all of its entitlement under the Compact.

The hydrograph shown plots mean daily discharge values for the gaging station, Colorado River near the Colorado-Utah Stateline (COLUTACO) for the 1986 water year, which ran from October 1, 1985, through September 30, 1986. The mean daily flow for this station for water year 1986 was greater than 11,000 cfs. The mean daily flow for this station for the period 1950-1981 was 5,736 cfs.

Orlyn Bell, Division 5 Engineer

F. Division 6, Steamboat Springs, Colorado, Green River Basin
Steven Witte, Division Engineer

The administration of water rights in Division 6 is complicated not as much by demand as by limited manpower resources and geographic diversity. As such, the satellite monitoring system allows this office to become increasingly effective with limited staffing.

Currently, Water Districts 54, 55, and 56 are administered by a permanent part-time Water Commissioner who is centrally located in Craig. Although the number of water rights in this area is relatively low, access to the points-of-diversion is difficult and the distances between them is great which causes comprehensive on-site monitoring to require several man-days. Obviously, in times of administration or impending administration, this kind of delay is unacceptable to water users and could cause a breakdown of the orderly administration, regulation, and distribution of the waters of the state as required by law. For this reason, two gaging station sites have been incorporated into the monitoring network for this area.

The gaging station, Little Snake River near Slater (LSRSLACO), is located approximately 57 miles from Craig, Colorado. The administration of the Little Snake River is governed by Article XI of the Upper Colorado River Compact which relies upon a knowledge of the flow at a point downstream of the LSRSLACO station. Historically, information from this gage has not been particularly critical, however, with the advent of Wyoming's transbasin diversion to Cheyenne in 1987, administration of the Little Snake River is a future certainty. Without access to real-time information as provided by the satellite monitoring system, it would not be possible to have the current distribution of manpower and we would have to revert to the employment of an additional permanent part-time employee. Although the benefits of this installation are probably not evident to the local water users at the present time, the group most likely to realize the potential advantages is the Pot Hook Conservancy District.

The gaging station, Little Snake River near Dixon, Wyoming (LSRDIXWY) is located 42 miles from Craig. USGS owned satellite-linked remote data collection hardware is installed below the largest canal on the Little Snake River. Real-time data from this station is valuable in interstate administration.

The Division 6 Engineer administers an interstate agreement between Colorado and Utah on Pot Creek. Pot Creek near Vernal, Utah (POTVERUT) is approximately 120 miles from Craig. The operation of this gaging station is included as part of a formal agreement between Colorado and Utah concerning the administration of the Pot Creek drainage. The ability to monitor compliance with this agreement remotely provides the advantages of better administration and prevents unnecessary trips.

The North Platte River and its tributaries are the most consistently administered streams in Division 6. One Water Commissioner, stationed in Walden, Colorado, is responsible for the administration of approximately 435 structures. Historically, this Water Commissioner has relied upon the efforts of volunteer gage readers who report instantaneous readings for the Michigan and Illinois Rivers on an intermittent basis in order to determine the amount of water available for distribution and to determine where his efforts are most needed on any particular day. The problems with this arrangement are:

1. Volunteer gage readers are not always available when the information is most needed, i.e., weekends, holidays, at various times throughout the day.

2. The information provided is instantaneous in nature and does not indicate upward or downward trends.

3. The information gathering process is time-consuming causing delays in decision making and in responding to calls for water.

For these reasons, it was decided to establish two new stations; Illinois River near Rand (ILLRANCO), and Michigan River near Gould (MICGOUCO), by reallocating DCP's originally installed at less advantageous sites. A third station, Roaring Fork near Delaney Butte (RFKDELCO), is being studied for inclusion into the system. It is expected that the constituency of both the Michigan River Water Conservancy District and the Jackson County Water Conservancy District will enjoy the benefits of this change beginning in the Spring of 1987.

A network of four DCP's has been established to monitor the Yampa River and its tributaries from its headwaters down to Maybell, Colorado. The gaging stations, Bear River near Toponas (BEATOPCO), and Yampa River near Oak Creek (YAMOAKCO), are maintained primarily for administrative efficiency. By maintaining the BEATOPCO station, which measures the inflow to Yamcolo Reservoir, and YAMOAKCO, which is located at the proposed site of Stagecoach Reservoir, we will be able to reallocate manpower resources to allow one Water Commissioner to perform the same work formerly accomplished by two in this area. In addition to the anticipated time and travel savings afforded to the Water Commissioner, a real benefit is expected to accrue to the Upper Yampa Conservancy District during construction of Stagecoach Reservoir. The benefit to the district will be advance warning of flows upstream of the construction site and in the development of an operating procedure for Stagecoach and Yamcolo Reservoirs.

The gaging station, Elk River at Clark (ELKLARCO), monitors a major tributary to the Yampa. ELKLARCO is utilized as a predictor of anticipated flows for the Lower Yampa during periods of administration.

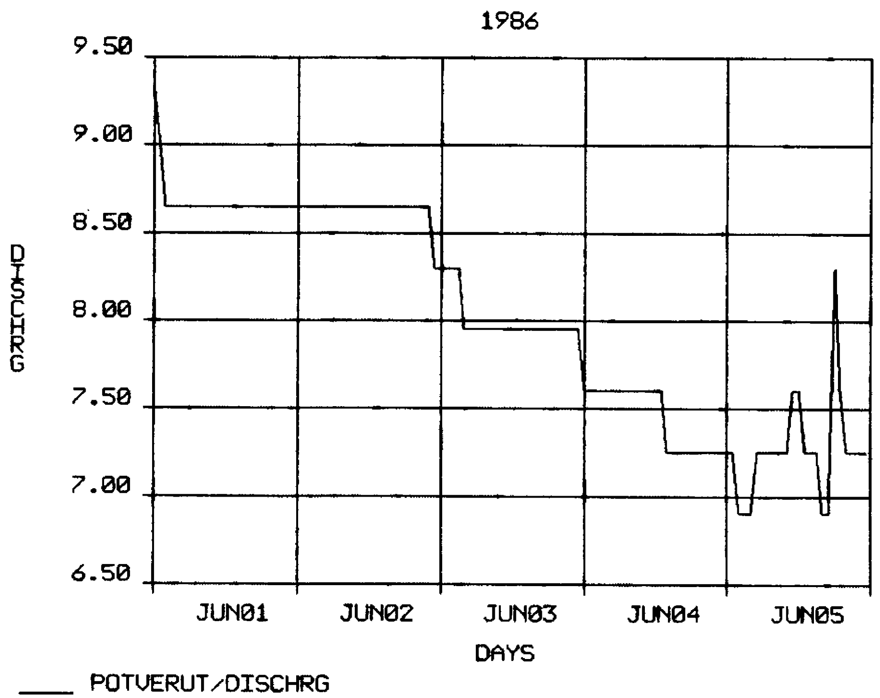
The gaging station, Yampa River near Maybell (YAMAYBCO), is a USGS owned and operated site, however, its continued operation is of vital interest to DWR for administrative purposes because of its remoteness (the Water Commissioner is stationed in Craig, 30 miles away) and due to its proximity to the Maybell Canal which placed the call that nearly caused the Yampa River to be administered in 1977. The Maybell Canal Irrigation District and the Juniper Water Conservancy District may be considered as indirect beneficiaries of the system.

THE ADMINISTRATION AND ACCOUNTING OF THE COLORADO-UTAH POT CREEK INTERSTATE AGREEMENT UTILIZING REAL-TIME DATA

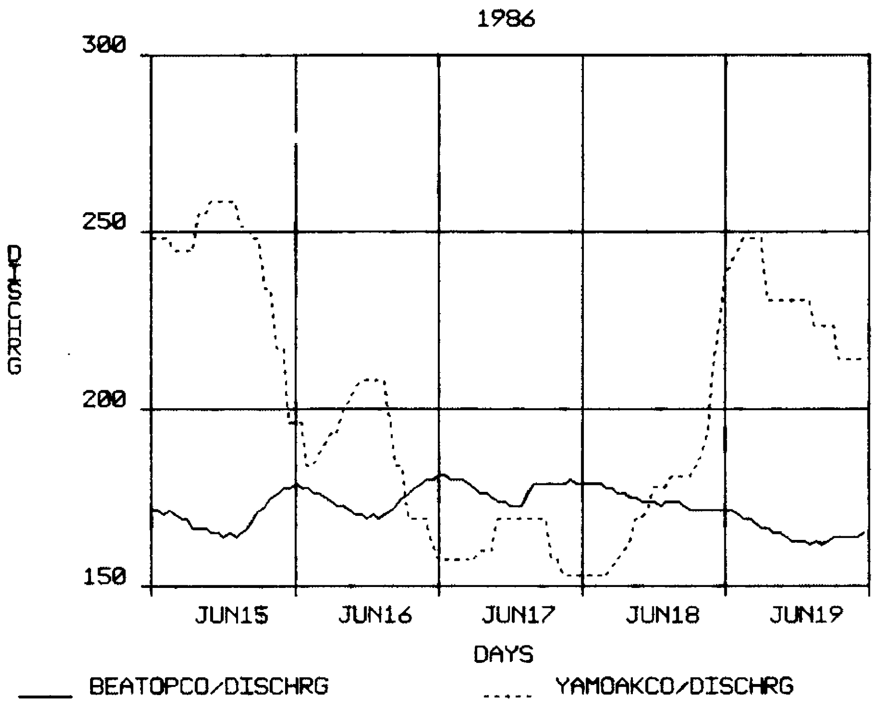
The administration of Pot Creek provides a unique example of the utility of the satellite monitoring system. Pot Creek, located in the Green River basin, flows into Colorado from Utah. An interstate agreement developed between the two states provides for Utah to receive the first 4 cfs, Colorado receives the next 6 cfs, and Utah is entitled to the excess flow. The stream runs only 4-6 weeks per year in the May-June period. The station is extremely remote, a 5-hour drive from the Division 6 office in Steamboat Springs. The gaging station, Pot Creek near Vernal, Utah (POTVERUT), measures the flow diverted by Colorado out of its account.

The hydrograph shown plots real-time discharge data for POTVERUT for the period June 1-5, 1986. The table lists mean daily discharge values for the period.

Steve Witte, Division 6 Engineer



WY	STATION	CODE	HR	JUN 1	JUN 2	JUN 3	JUN 4	JUN 5
86	POTVERUT	DISCHRG	00	8.68	8.63	8.00	7.45	7.24



WY	STATION	CODE	HR	JUN15	JUN16	JUN17	JUN18	JUN19
==	=========	=======	==	=========	=========	=========	=========	=========
86	BEATOPCO	DISCHRG	00	169.39	174.29	177.33	174.38	164.97
86	YAMOAKCO	DISCHRG	00	243.76	190.13	161.25	175.04	230.05

ADMINISTRATION OF THE BEAR-YAMPA RIVER - DISTRICT 58 UTILIZING REAL-TIME DATA

The development of two storage reservoirs in the Bear-Yampa River basin brought about the need for real-time data for water rights administration. The gaging station, Bear River near Toponas (BEATOPCO), measures inflow into Yamcolo Reservoir. The gaging station, Yampa River near Oak Creek (YAMOAKCO), measures flow at the proposed Stagecoach Reservoir site.

The hydrograph shown plots real-time discharge data for BEATOPCO and YAMOAKCO for the period June 15-19, 1986. Flow at BEATOPCO, regulated by releases from Still-water Reservoir, is relatively steady at 165-177 cfs over the 5-day period. Flow at the downstream station, YAMOAKCO, fluctuates from 155-260 cfs over the 5-day period due to tributary inflow conditions. The table lists mean daily discharge values for each station for the period.

Steve Witte, Division 6 Engineer
Truman Manes, Water Commissioner, District 58

G. Division 7, Durango, Colorado, San Juan and Dolores River Basins
Chuck Lile, Division Engineer

The satellite monitoring system is being effectively utilized in Division 7 for water rights administration, reservoir management, water resources accounting, and flood monitoring. The benefits of the system have reached the majority of water users in this division.

The McPhee Reservoir and Dolores Project administration is not as yet totally functional since the project is not complete, although there are five monitoring stations in operation. The La Plata River Compact is probably our best present use and example since it is being used on a daily basis. The San Juan-Chama Project subnetwork has been effective in monitoring the Bureau of Reclamation operations, and the Lemon Reservoir subnetwork was quite helpful this past season to monitor inflow to prevent downstream flooding.

The satellite monitoring system is being utilized for daily water rights administration relative to the Dolores Project. This includes administering allocations to the Montezuma Valley Irrigation District, Mountain Ute Indian Tribe, City of Cortez, and the Dove Creek Canal. The Division Engineer and the manager of the Dolores Water Conservancy District utilize the system in the operation of McPhee Reservoir. A water resources accounting system for the Dolores Project incorporates real-time data from five satellite monitoring stations.

The La Plata River Compact is administered on a daily basis by the Division Engineer and the District 33 Water Commissioner utilizing the satellite monitoring system. The Water Commissioner is able to access the system's data base at any time utilizing a portable computer terminal. An upstream station provides streamflow data necessary for advance planning. These conditions are typically dynamic. A station at the Colorado-New Mexico stateline gives data on actual deliveries.

Through the use of the satellite monitoring system, the Water Commissioner can operate the La Plata River on a real-time basis; he can observe the changes occurring at Hesperus and the stateline, and in turn, direct the diversions or curtailment of ditches in Colorado to meet the Compact needs. We have found that the real-time data have greatly enhanced our ability to administer the La Plata River and are of the opinion that there has been an increase in the amount of water available to Colorado users through the prompt administration of the stream. This office has realized significant savings in travel and manpower relative to this task.

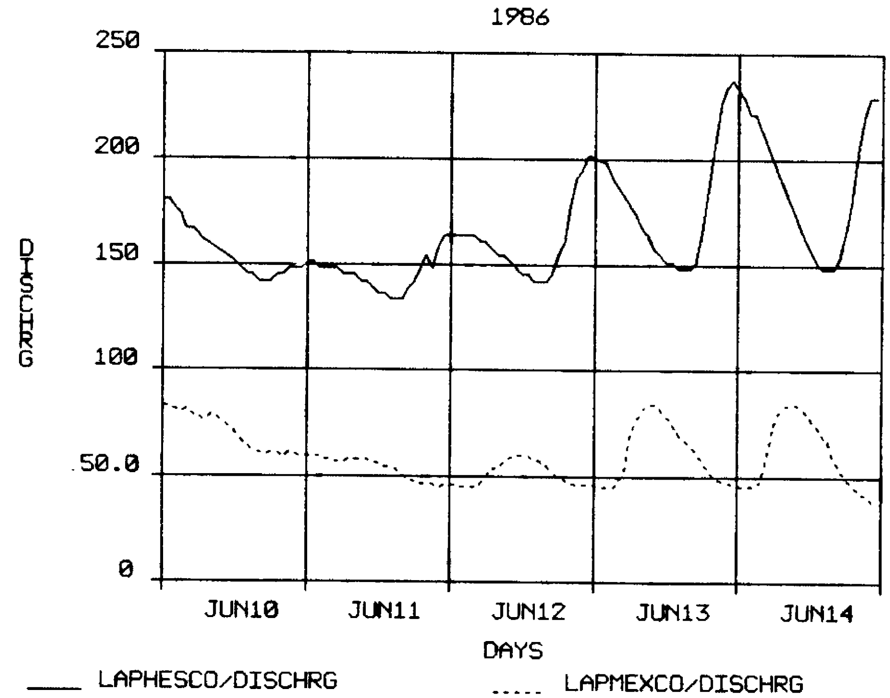
Three monitoring stations are being operated for the benefit of administering the San Juan-Chama Project and the associated interstate compact. The compact provides for the diversion of up to 1000 cfs into New Mexico. The network includes a monitoring station on the Azotea Tunnel outlet near Chama, New Mexico. The Division Engineer and the San Juan-Chama Project Manager coordinate the operation of the project utilizing real-time data. Both have access to the system's data base.

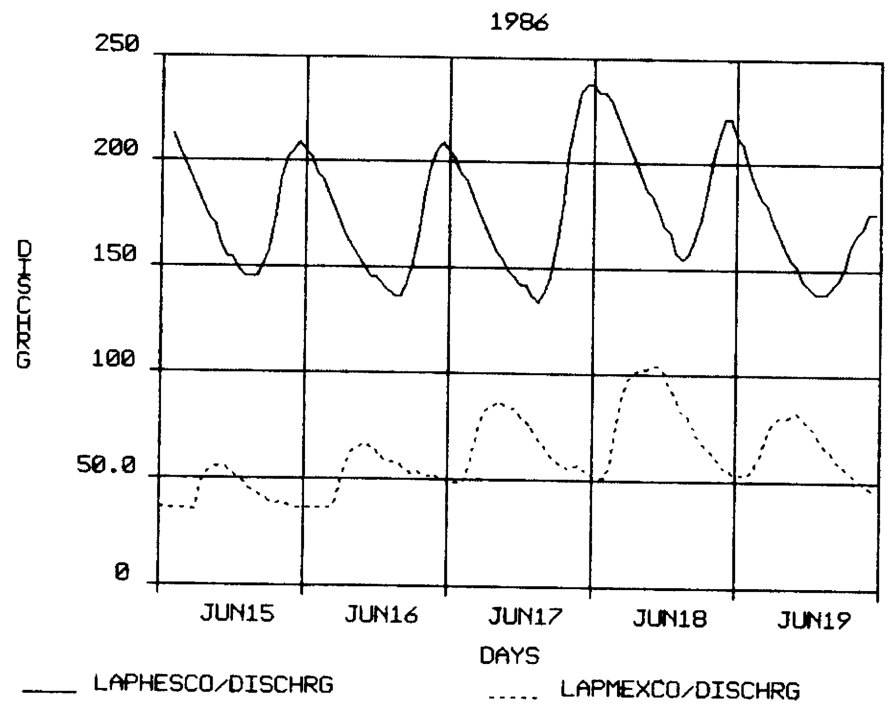
The satellite monitoring system is being utilized in the daily administration of Lemon Reservoir on the Florida River. Two monitoring stations, one above the reservoir and one below the reservoir, provide real-time data used to account for storage, delineating natural flow from storage releases, and for flood control. Diurnal inflow conditions are flattened through controlled releases.

THE ADMINISTRATION AND ACCOUNTING OF THE COLORADO-NEW MEXICO LA PLATA RIVER INTERSTATE COMPACT UTILIZING REAL-TIME DATA

Under the La Plata River Compact established in 1922, Colorado is obligated to deliver up to 100 cfs, or one-half of the flow at the Hesperus Index Gage, to the Colorado-New Mexico stateline on a daily basis. The stream system generally does not have adequate water to meet historic uses and supply New Mexico with her entitlement. The stream often has less than 30 cfs at Hesperus during July and August. Ditches in New Mexico can divert up to 90 cfs and ditches in Colorado can divert up to 250 cfs. There are no reservoirs on the river between Hesperus and the stateline. The only reservoir is on a side tributary and cannot be used to control the high diurnal fluctuation due to the snowmelt in the spring runoff. If the Water Commissioner can divert the peak flows between Hesperus and the stateline, and it is applied to irrigation, soil moisture is built up resulting in an increase in late summer return flows through seeps and springs. If he over-delivers what can be used in New Mexico, it is lost not only to Colorado but also to New Mexico. Consequently, it is very important that only the amount of water that can be used beneficially, but not in excess of New Mexico's entitlement, is delivered to the stateline.

There are two hydrographs shown to illustrate the very high diurnal flow at Hesperus and the amount delivered at the stateline during the period June 10, 1986 through June 19, 1986. Each hydrograph plots real-time discharge data for the gaging stations, La Plata River at Hesperus (LAPHESCO), and La Plata River at the Colorado-New Mexico Stateline (LAPMEXCO). Reductions in flow actually delivered to New Mexico fluctuated from 150 cfs to 60 cfs each day.





Chuck Lile, Division 7 Engineer
Russell Kennedy, Water Commissioner, District 33

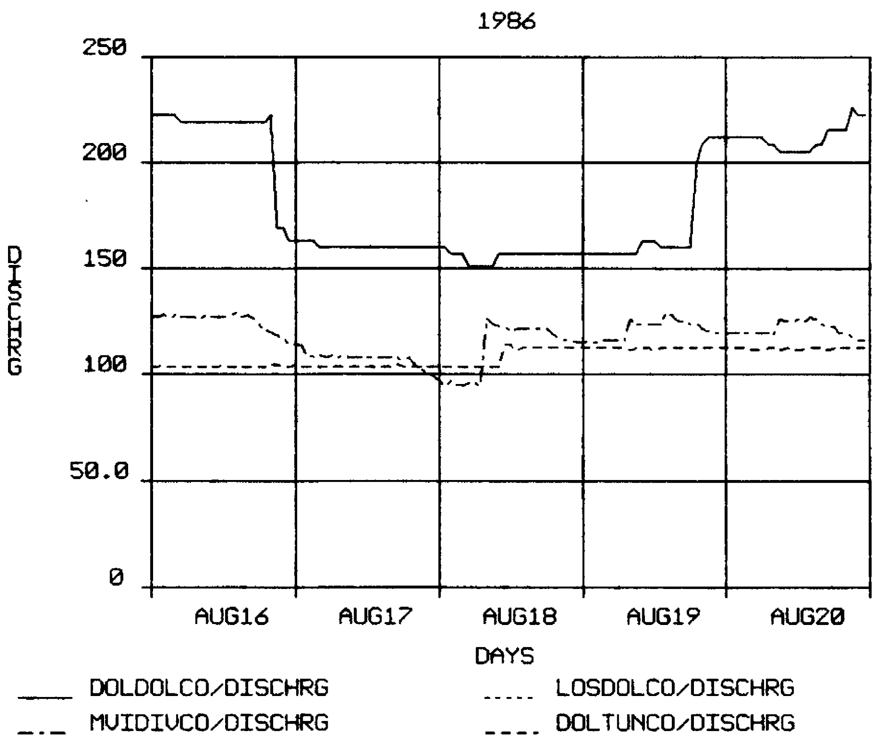
WY	STATION	CODE	HR	JUN10	JUN11	JUN12	JUN13	JUN14
86	LAPHESCO	DISCHRG	00	154.14	145.25	159.95	177.45	185.17
86	LAPMEXCO	DISCHRG	00	70.51	53.71	51.46	61.77	60.33

WY	STATION	CODE	HR	JUN15	JUN16	JUN17	JUN18	JUN19
86	LAPHESCO	DISCHRG	00	176.42	165.99	172.86	190.79	164.69
86	LAPMEXCO	DISCHRG	00	43.09	52.32	67.21	78.60	64.69

MANAGEMENT OF
McPHEE RESERVOIR - DOLORES PROJECT,
UTILIZING REAL-TIME DATA

The construction of McPhee Reservoir on the Dolores River has recently been completed. The reservoir backs water over two historical diversion points of the Montezuma Valley Irrigation District (MVI District). It also intercepts several tributaries that were not available to be diverted by the M.V.I. District. Consequently, the inflow to the reservoir can, in part, belong to the M.V.I. District which has the senior priority, or to the Dolores Conservancy District that operates McPhee Reservoir and the Dolores Project. In addition to the M.V.I. District diversion through McPhee, there are water allocations for the Ute Mountain Ute Indian Tribe, City of Cortez, Montezuma Rural Water Users, and the Dove Creek Canal. In order to establish the amount of water available to the M.V.I. System, the mainstem of the Dolores River and Lost Canyon Creek are required to be measured. The outflow of the reservoir, as well as the amount delivered to the M.V.I. System and the Dove Creek Canal are also measured to insure proper delivery on a daily basis as well as a year-to-date accumulation for contractual administration. Five monitoring stations have been installed to provide real-time data essential to effective administration of project water rights and reservoir management.

The hydrograph shown plots real-time discharge data for the gaging stations, Dolores River at Dolores (DOLDOLCO), Lost Canyon Creek at Dolores (LOSDOLCO), M.V.I. Diversion (MVIDIVCO), and the Dolores Tunnel Outlet (DOLTUNCO), for the period August 16-20, 1986. Inflow into McPhee Reservoir fluctuated from 150-375 cfs with outflow remaining steady at about 225 cfs. There is no inflow from LOSDOLCO. The table lists mean daily discharge values for the period.



WY	STATION	CODE	HR	AUG16	AUG17	AUG18	AUG19	AUG20
86	DOLDOLCO	DISCHRG	00	212.13	160.44	155.99	170.05	211.96
86	MVIDIVCO	DISCHRG	00	125.09	107.39	112.79	121.28	121.51

WY	STATION	CODE	HR	AUG16	AUG17	AUG18	AUG19	AUG20
86	LOSDOLCO	DISCHRG	00	0.01	0.01	0.02	0.02	0.02
86	DOLTUNCO	DISCHRG	00	103.77	103.68	109.09	112.87	112.70

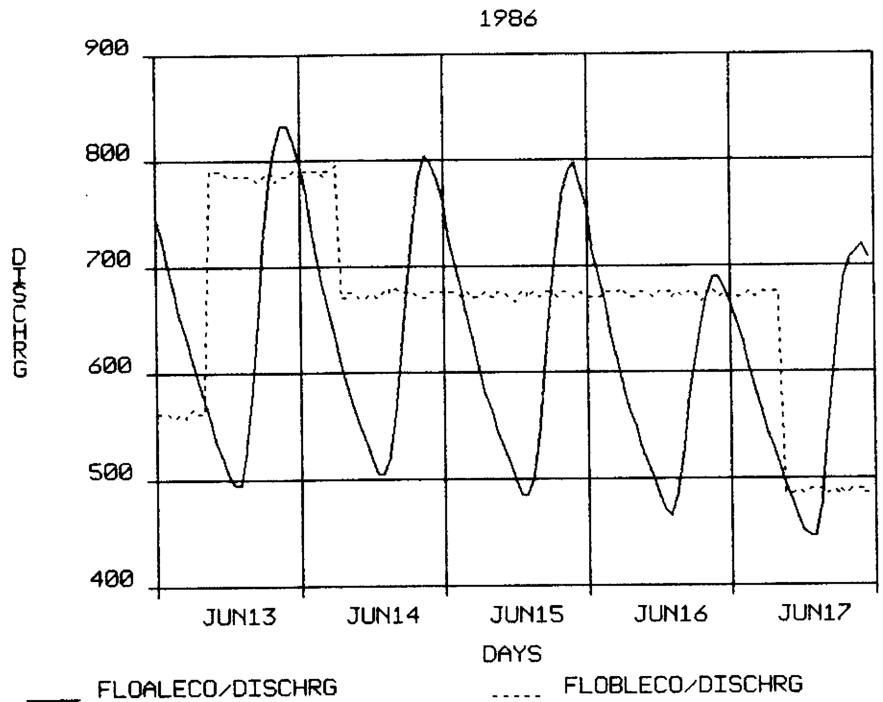
Chuck Lile, Division 7 Engineer
John Porter, Dolores Project Manager

ADMINISTRATION AND OPERATION OF LEMON RESERVOIR UTILIZING REAL-TIME DATA

Lemon Reservoir, located on the Florida River, has a capacity of 42,000 acre-feet and is used as a water supply for approximately 20,000 acres of land. Since the reservoir is on the mainstem, it is utilized in part to control flooding. During the summer months, it is necessary to pass the natural inflow to senior downstream appropriators including the City of Durango as well as deliver storage water to irrigators. There are two monitoring stations; one above the reservoir and one below. During the high spring runoff and summer thunderstorms, the real-time data are desirable for monitoring flooding and rate of fill of the reservoir to prevent uncontrolled spilling and downstream flooding. When the streamflow drops below the amount needed by the downstream seniors, it is necessary to pass the natural inflow through the reservoir. At this time, there will be demands for releases of reservoir water. The Water Commissioner is required to account for the amount of water belonging to all appropriators. Through the use of the monitoring system, he is able to reduce errors and administer water in a timely fashion.

The hydrograph shown plots real-time discharge data for the gaging station, Florida River above Lemon Reservoir (FLOALECO), and Florida River below Lemon Reservoir (FLOBLECO), for the period June 13-17, 1986. The extreme diurnal fluctuations measured at FLOALECO are the result of snowmelt runoff. These peaks are effectively flattened by controlled releases as evidenced by the outflow plot (FLOBLECO). The table lists mean daily discharge values for the period.

Chuck Lile, Division 7 Engineer
Richard Baltzell, Water Commissioner, District 30



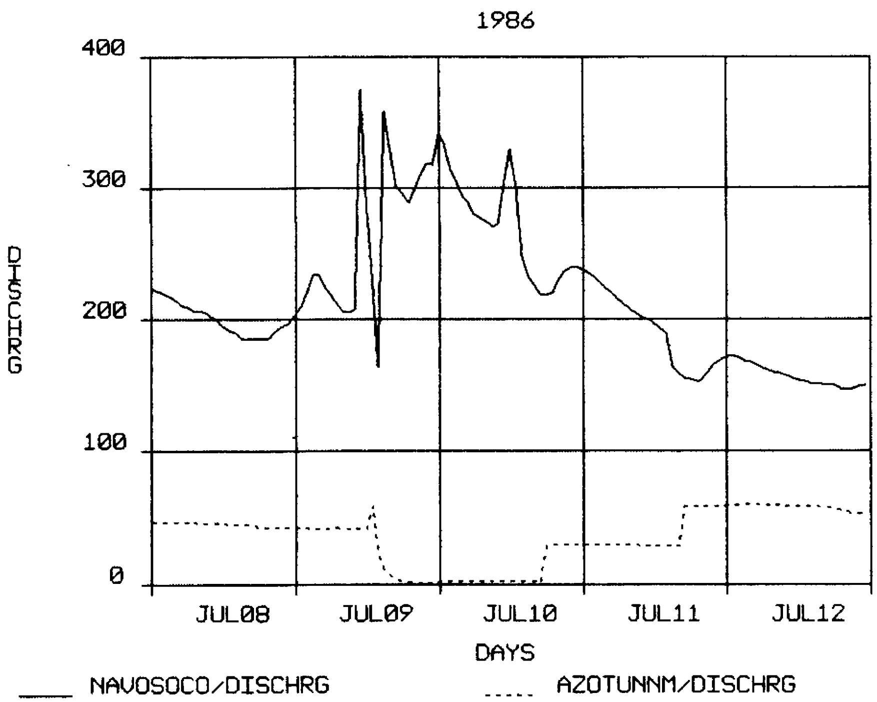
WY	STATION	CODE	HR	JUN13	JUN14	JUN15	JUN16	JUN17
==	=========	=======	==	=========	=========	=========	=========	=========
86	FLOALECO	DISCHRG	00	649.95	649.92	629.06	593.64	577.06
86	FLOBLECO	DISCHRG	00	708.70	704.14	674.41	674.55	552.74

ADMINISTRATION OF THE SAN JUAN-CHAMA DIVERSION UTILIZING REAL-TIME DATA

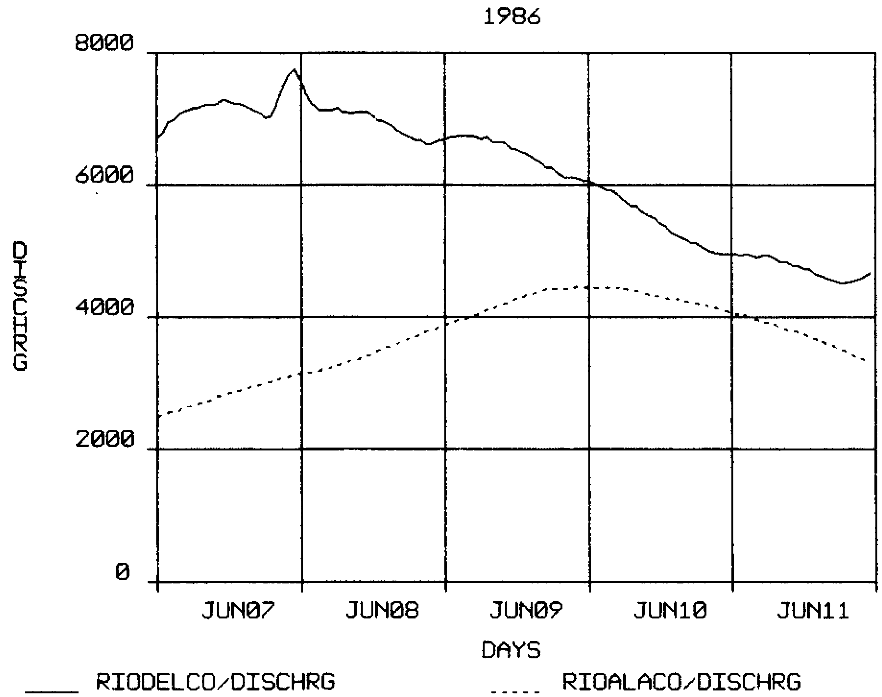
The San Juan-Chama Project is designed to divert up to 1,000 cfs from the Blanco and Navajo Rivers into New Mexico for use under the Colorado River - Upper Basin Compact. The authorizing legislation requires that there be bypasses to insure that Colorado appropriators and minimum flows are not injured. There are monitoring stations at the Blanco Diversion, Navajo Diversion, and at the outlet into New Mexico. These stations provide data as to total amount diverted and the amount being passed to Colorado users. Problems occur when the minimum bypasses are not being met, or diversions through the Project are shut off causing a very high rise in the streams. Through the use of real-time data, we can alert Colorado users of potential flooding which damages diversions, either filling them with silt or eroding the diversion dams.

The hydrograph shown plots real-time discharge data for the gaging stations, Navajo River below the Oso Diversion (NAVOSOCO), and the Azotea Tunnel Outlet (AZOTUNNM), for the period July 8-12, 1986. The fluctuations in discharge for both the diversion and bypass flows are apparent. The table lists mean daily discharge values for the period.

Chuck Lile, Division 7 Engineer



WY	STATION	CODE	HR	JUL 8	JUL 9	JUL10	JUL11	JUL12
86	NAVOSOCO	DISCHRG	00	199.48	267.16	268.52	190.45	156.47
86	AZOTUNNM	DISCHRG	00	44.64	26.24	9.66	37.92	57.66



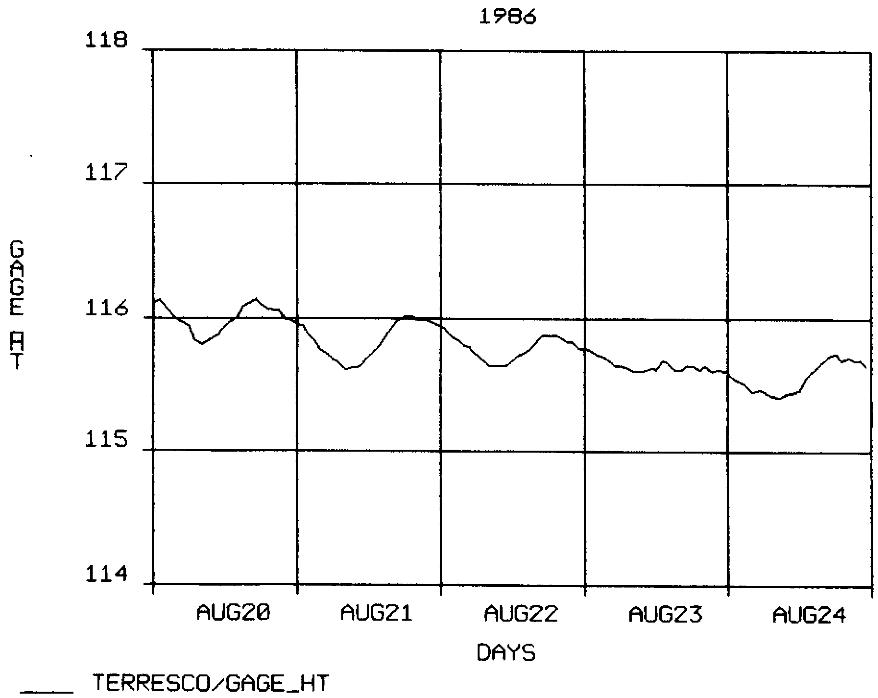
H. Flood Monitoring Utilizing Real-Time Data

The ability to obtain real-time river data through the state computer during the recent runoff season was enormously useful in aiding the National Weather Service (NWS) to satisfy the requirement put upon it by Congress to furnish flood watch and warning information to the public. There were at least three instances during the snowmelt season when a river at one of the monitoring stations reached within half a foot of the published flood stage. In two of these cases, on the Animas River at Durango and on the Cache La Poudre River near Fort Collins, the ability to monitor river levels on a continuous basis allowed the NWS to get through the peak flows without issuing spurious watches or warnings and thus unnecessarily alarming the public.

The Rio Grande in the vicinity of Del Norte and Monte Vista reached the alarm level on June 7, 1986, triggering a computer generated call to the NWS Central Forecast Office (NWS-CFO). Since the NWS-CFO was able to monitor the river levels continuously through the system's computer, the NWS-CFO was able to ascertain that the proper course of action was to issue a flood watch, indicating that slow river rises might produce overbank flows in some areas and that persons in the vicinity should be alert. However, continual monitoring made it fairly obvious that a flood warning, indicating that serious flooding was in progress or imminent, would not be required. This again meant that alarming of the public was not necessary.

The hydrograph shown plots real-time discharge data for the gaging stations, Rio Grande near Del Norte (RIODELCO), and the Rio Grande at Alamosa (RIOALACO), for the period June 7-11, 1986. Flow at the upper station, RIODELCO, reached an alert level of 7,060 cfs at 1200 hours on June 7, 1986. Flow at the lower station, RIOALACO, reached an alert level of 3,000 cfs, 0000 hours on June 8, 1987. Evaluation of upstream conditions at RIODELCO, utilizing real-time data, indicated that the flow was decreasing.

Larry Tunnell, Forecaster
National Weather Service
Central Forecast Office (Denver)

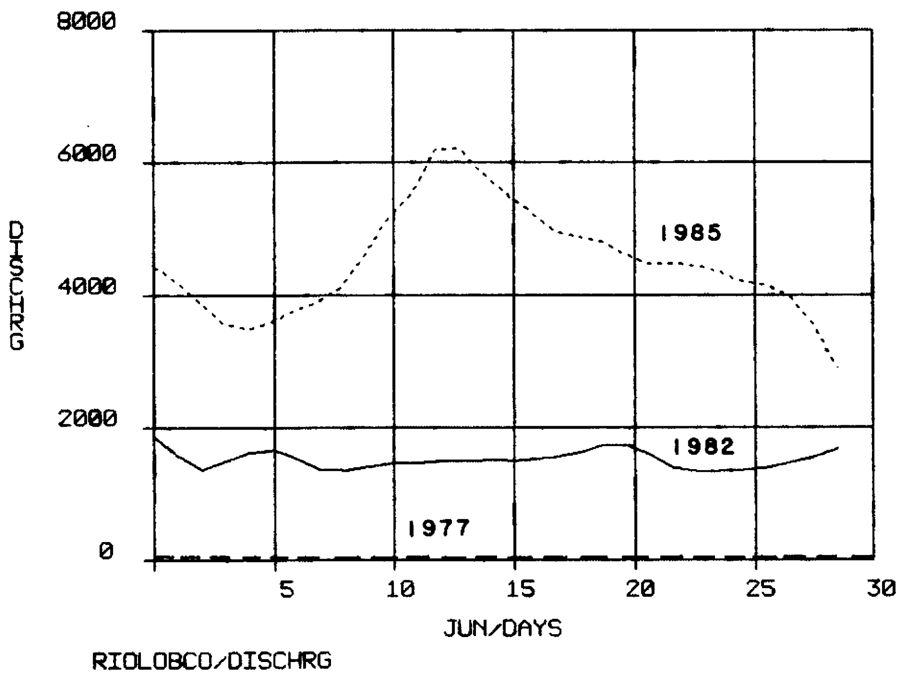


I. Dam Safety Monitoring Utilizing Real-Time Data

In 1984, the State Engineer placed a restriction on Terrace Reservoir due to an inadequately sized spillway. The discharge capacity is insufficient to handle all of the inflow during the spring runoff. The reservoir stage is limited to a maximum of 117.0 feet. This provides for adequate flood storage. As the reservoir is in a remote location, stage is monitored on a real-time basis in order to assure safety.

The hydrograph shown plots real-time stage data for Terrace Reservoir (TERRESCO), for the period August 20-24, 1986. Stage values fluctuated between 115.50 to 116.15 feet.

Wayne Schieldt, Water Resource Engineer, Division 3



J. Historic Flow Data

By mid-1987, historic flow data will be archived in the satellite monitoring system data base for key gaging stations in Colorado. These data, representing mean daily discharge, will go back as far as 50 to 60 years for some stations. The data will be on-line and accessible through the HYDROMET ARCHIVES program in both report and graphics output. The availability of these historic data will be extremely valuable in making comparisons with real-time conditions. The data will be useful in determining wet-dry cycles, periods of maximum snowmelt runoff, and the effects of storage facilities on flow conditions. Periods of average, low, and high flow conditions can be identified and used to make comparisons and projections.

Historic flow data for the gaging station, Rio Grande near Lobatos (RIOLOBCO), for 1977 and 1982, were entered into the system's data base for the purpose of comparison with real-time data collected by the system for 1985. 1977 represents a period of record low flows; 1982 represents an average flow period based on a twenty-year average; and 1985 represents a record high flow period.

The Division 3 Engineer utilized these data to show Colorado water users in the Rio Grande basin that the real-time flow conditions at RIOLOBCO during May and June, 1985, were significantly high. At that time, the State of Colorado had built up a debit of approximately 800,000 acre-feet owed to the river. However, a clause in the interstate compact stated that if Elephant Butte Reservoir (located in New Mexico) ever spilled, all debits would be erased. Due to high flow conditions in 1983 and 1984, Elephant Butte Reservoir had reached near capacity. The Division 3 Engineer, utilizing the satellite monitoring system, was able to persuade the Colorado water users in the Rio Grande basin to curtail water use so as to enhance the opportunity to spill Elephant Butte Reservoir. The spill took place on June 13, 1985.

The hydrograph shown plots mean daily discharge values for RIOLOBCO for June 1977, June 1982, and for June 1985. The difference in flow between June 1977 and June 1985 is dramatic. It helps to remind us that the current wet cycle that we are in can change at any time.

Steve Vandiver, Division 3 Engineer

IX. DEFINITION OF TERMS

NOMENCLATURE FOR STATION NAMES

Station names have been abbreviated to eight characters. The first three characters identify the river basin, the second three characters identify the station location, the last two characters identify the state. Example: The monitoring station, Colorado River near Dotsero, Colorado, is abbreviated COLDOTCO.

DIVISIONS

The Office of the Colorado State Engineer, Division of Water Resources, is divided statutorily into seven divisions for purposes of water rights administration. The seven divisions coincide with the seven major drainage basins in Colorado. Each division has a central office administered by a Division Engineer.

Division 1, Greeley, Colorado, South Platte River Basin
Alan Berryman, Division Engineer

Division 2, Pueblo, Colorado, Arkansas River Basin
Robert Jesse, Division Engineer

Division 3, Alamosa, Colorado, Rio Grande Basin
Steven Vandiver, Division Engineer

Division 4, Montrose, Colorado, Gunnison River Basin
Thomas Kelly, Division Engineer

Division 5, Glenwood Springs, Colorado, Colorado River Basin
Orlyn Bell, Division Engineer

Division 6, Steamboat Springs, Colorado, Green River Basin
Steven Witte, Division Engineer

Division 7, Durango, Colorado, Dolores and San Juan River Basins
Daries Lile, Division Engineer

DISTRICTS

The Office of the State Engineer, Division of Water Resources, divided the State of Colorado into eighty districts for purposes of water rights administration on a smaller geographic area than a division. District administration is carried out directly by the designated Water Commissioner.

RIVER CALL

The "river call refers to a date in the water rights appropriation records where water rights senior to that date may be exercised. Water rights junior to that date may not be exercised. The "river call" reflects the availability of water to satisfy those senior water rights for a district or districts. A call is placed by a water right owner when his or her right is not receiving the water to which they are entitled.

FREE RIVER

A "free river" designation exists when the availability of water exceeds the demand of active water rights.

INDEX STATION

A key gaging station that determines the availability of water for establishing the "river call" or determines the water to be delivered under a compact agreement.

FLOW AND VOLUME CONVERSIONS

Real-time discharge values, as listed in DAYFILES, are instantaneous values in cubic feet per second (cfs).

Daily discharge values, as listed in ARCHIVES, are mean values computed from 96 real-time measurements, and are in cubic feet per second (cfs).

Daily content values, as listed in ARCHIVES, are mean values computed from 96 real-time measurements, and are in acre-feet.

COMMON WATER CONVERSION FACTORS

1 cubic foot-per-second equals 1 cubic foot of water passing a point in one second of time.

1 acre-foot equals the quantity of water required to cover 1 acre of land 1 foot deep.

VOLUME

1 acre-foot = 325,851 gallons

1 acre foot = 43,560 cubic feet

1 cubic foot = 7.4805 gallons

1 cubic foot/second = 448.8 gallons/minute

1 cubic foot/second = 646,317 gallons/day

1 cubic foot/second = 86,400 cubic feet/day

1 cubic foot/second = 1.9835 acre-feet/day

1 cubic foot/second = 723.96 acre-feet/year

1 million gallons/day = 1.547 cubic feet/second

1 million gallons/day = 3.07 acre-feet/day

TIMES

Times given are local time based on a 24-hour clock.