THE COLORADO SATELLITE-LINKED WATER RESOURCES MONITORING SYSTEM

ANNUAL STATUS REPORT
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4TH EDITION

EDITED BY: JOHN R. KALISZEWSKI
PROJECT MANAGER

OFFICE OF THE STATE ENGINEER
DIVISION OF WATER RESOURCES

Jeris A. Danielson
State Engineer

ROY ROMER
Governor

JERIS A. DANIELSON
State Engineer

OFFICE OF THE STATE ENGINEER
DIVISION OF WATER RESOURCES

1313 Sherman Street-Room 818
Denver, Colorado 80203
(303) 866-3581

I am pleased to release the FY 1988-89 Annual Status Report of the Colorado Satellite-Linked Water Resources Monitoring System. The report addresses all aspects of the monitoring system including examples of system utilization for all seven major drainage basins in the state of Colorado. The system has proven to be a highly effective tool in the management of our precious water resources. This has become especially apparent with the drought conditions that have prevailed in the state since 1988.

There are several key aspects of the system that I would like to point out:

- The system provides cost benefits estimated to be $1.5 million annually. Benefits-to-cost-ratio is approximately 6 to 1.
- The system is a public system with access available to all Colorado water users.
- The system can be easily expanded with additional monitoring stations and additional sensor types.
- The system has received national merit awards from the Council of State Governments and the National Society of Professional Engineers for innovation and design. The state of Colorado remains on the leading edge of technology in this area.

One critical area of concern that needs to be addressed is funding. The State Legislature provided $93,109 from the General Fund for operation of the system in FY 1988-89. The remainder of the $248,649 budget was to be collected from user fees. Insufficient user fees were collected resulting in a $17,059 underfunding. This had an impact on the operation of the system. Senate Bill 148, requesting that the General Fund appropriation be increased to $253,021.00 for FY 1989-90 was tabled. A General Fund appropriation of $100,000 was approved. The spending Authority was limited to $228,000.

It is the consensus of this office and the water user community statewide that water rights administration is the responsibility of the State and should be funded accordingly. Efforts will continue to reach this goal.

Jeris A. Danielson
State Engineer

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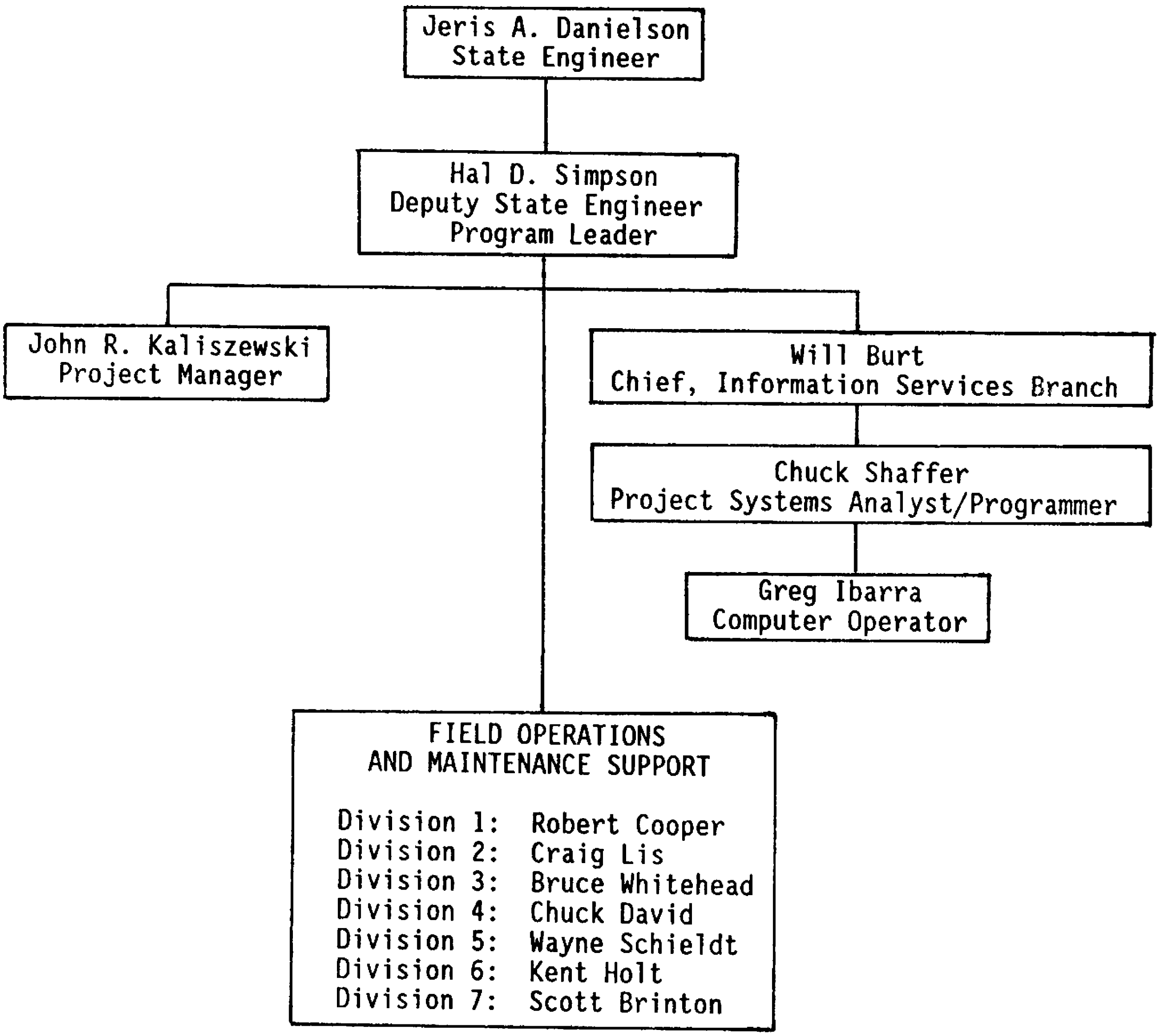


INTRODUCTION

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 or by phone 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 pursuant to Section 37-95-107(5), C.R.S. (1983), by enactment of Senate Joint Resolution No. 20. 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 (FY 84-85) 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, New Mexico, and Hawaii.

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.

PROJECT MANAGER'S REPORT

The Colorado satellite-linked monitoring system, providing real-time water resources data on a continuous basis from key gaging stations across the state of Colorado, remains an integral tool in the hands of the State Engineer, Division Engineers, and Water Commissioners in its primary utility, water rights administration. The system represents an important technological advance in the state's ability to monitor and evaluate current hydrologic conditions in order to effectively carry out the statutory responsibilities of water rights administration.

The following goals and objectives set for FY 88-89 were achieved to a satisfactory degree:

- Assimilate the system into a broader range of the user community.
- Increase valid data capture in excess of 98%
- Evaluate quality assurance criteria for real-time data collection.
- Increase cooperation with other operators of satellite-linked data collection hardware in Colorado.
- Increase system utility to facilitate data editing and the development of the final hydrologic record.
- Control operations and maintenance costs.

The following goals and objectives set for FY 88-89 were not achieved to satisfaction:

- Obtain increased General Fund support.

  SB148, requesting that the General Fund appropriation for FY 89-90 be increased to cover all operational expenses, was tabled. The General Fund appropriation was increased from $89,539 to $100,000.

- Assimilate the monitoring system operationally into other Colorado state agencies.

  Two cooperative projects are in the process of being initiated; with the Colorado Department of Health in water quality monitoring and with the Colorado Department of Highways in flood monitoring relative to bridge construction.

- Increase the network by 5%.

  The network was increased by 3% from 153 to 158 stations. Insufficient funds held back desired network expansion.

- Increase the system capabilities by 10%

  The Colorado Water Resources and Power Development Authority provided $68,048 for system enhancement that included air temperature sensors, dam safety monitoring sensors, water quality monitors, precipitation sensors, evaporation monitors, and snowpack monitoring hardware. These sensors were installed at a select number of stations. The ability to expand system capabilities at this point is limited by operations and maintenance field support.

The goals and objectives for FY 89-90 are:

- Obtain full General Funding for FY 90-91.
- Assimilate the monitoring system operationally into other Colorado state agencies.
- Increase the network by 5%.
- Increase central system capabilities to meet growing system demands.
- Provide technical assistance to various water resources management entities in the state to encourage the purchase, installation, and operation of satellite-linked data collection hardware.
- Develop and implement standard operating procedures relative to data quality assurance.

The multitude of court approved administration plans involving water exchanges, augmentation, and changes in points-of-diversion, inject levels of complexity that typically cannot be effectively administered without the availability of real-time data. Despite the fact that the number of adjudicated water rights increased 23% from 1982-1988, the number of water commissioners actually decreased from 94 to 93. These statistics indicate that based strictly on an increase in water rights, the number of water commissioners should have increased by twenty-two. If we consider the increased workload due to the growing complexity being incorporated recently into water rights administration, it is estimated that the number of water commissioners should have increased by thirty. The monitoring system cannot be expected to replace the need for thirty additional water commissioners but can compliment a moderate increase in the number of water commissioners.

A budget proposal has been submitted to the Joint Budget Committee of the State Legislature requesting that in FY 90-91 the General Fund appropriation be increased from $89,539 to $128,124. The cost benefits realized by the operation of the system are an estimated $1.5 million annually. This is a ratio of nearly 6 to 1 over operating costs. Aside from cost-benefits, we need to evaluate potential cost-avoidance. If the system can potentially eliminate the need for ten additional water commissioners, savings may be an estimated $350,000 to $400,000 annually. The step to full General Funding is critical to the continued operation and development of the system and in making the system accessible to all Colorado water users. This office contends that the system operates for the benefit of all Colorado water users and, as such, should be funded completely from the General Fund.

An additional FTE should be seriously considered and possibly incorporated into the FY 90-91 budget. The position, System Maintenance Manager, would be responsible for both coordinating and carrying out the sustained operation and maintenance of the remote data collection hardware. As the system becomes more integrated into real-time water rights administration, there develops a greater need to maintain the operation of the monitoring network on a continuous and consistent basis. This requires a full-time position. A summer intern was hired June-August 1989, to assist in overall system operations and maintenance. This worked very well and will be requested again in FY 89-90 if funds are available.

Expenditures for the operation of the monitoring system for FY 88-89 amounted to $219,779. The projected budget was $248,649. Cost reductions of $28,870 were primarily the result of balancing expenditures to meet available funds. Total funding available was $231,637 including $26,331 in a reserve fund balance. User fees collected were $103,350 in FY 88-89, up from $93,400 collected in FY 87-88. A fund balance of $11,858, was carried over for emergency expenditures. The FY 89-90 operating budget is projected to be $227,515.

Excessive failures experienced with the remote data collection hardware continues to be an area of concern. Failures fall into two categories; unit failures requiring manufacturer repair and unit failures that could be repaired or corrected in the field. In FY 88-89, nineteen (19) Data Collection Platforms (DCPs) were returned to the manufacturer for repair. This represents 12% of the DCPs operated by the state. The majority of the failures involved the voltage control oscillator, frequency oscillator, or an analog-to-digital chip. Nearly twice as many units failed but were made operable in the field. These intermittent failures were generally related to scrambling of operating software due to lightning strikes or other forms of static electricity, deficiency in the on-site power supply, moisture in the antenna/antenna cable, or vandalism. The annual cost of these failures is conserva- tively estimated to be between $30,000 to $40,000. This includes repair costs, travel costs, staff time to visit these stations and repair or exchange malfunctioning hardware, and the cost to edit invalid or lost data.

Non-state entities continue to increase their involvement in operating satellite-linked data collection stations in Colorado. These include the Northern Colorado Water Conservancy District, City of Aurora, City of Colorado Springs, Bureau of Reclamation, and the National Weather Service. The number of DCPs operated by these entities and monitored by the state's receive site totals over 150 stations.

The National Oceanic and Atmospheric Administration - National Environmental Satellite Data Information Service (NOAA-NESDIS) continues to hold quarterly meetings for users of the Geostationary Operational Environmental Satellite (GOES). Two of these meetings were attended by the system Project Manager during this last year.

A consortium of federal agencies, the Satellite Telemetry Interagency Working Group (STIWG), continues to promote the advancement of GOES Data Collection System (DCS) technology and ensure its continuation for environmental data collection. This is important for two reasons. First, the GOES DCS is being redesigned with implementation to occur in 1990. Second, GOES DCS has secondary priority relative to the operation of the GOES spacecraft. Weather imaging has the highest priority, resulting in frequent repositioning of the spacecraft for optimization of imaging at the cost of effective DCS.

GOES-WEST (GOES-6) underwent a final stabilization maneuver in May, 1988. The inclination (measure of orbital stability) will deteriorate at a rate of 1° per year. An inclination in excess of 1.9° results in signal loss. By mid-1990, a loss of two to three transmissions will occur. It is likely that NESDIS will activate the DCS on GOES Central (GOES-7) located at 98°W, that would temporarily alleviate this problem. The new GOES series prototype, scheduled for launch in December 1990, may have narrower band widths to accommodate additional channels and increased transmission rates to handle increased data volume. Minor modifications to existing DCPs may be required at that time. NESDIS is considering modifying the DCS specifications for GOES-NEXT, such that transponder signal strength would be decreased by 60%, effectively making the state's receive site obsolete. Efforts by NESDIS to establish a Standard Hydrological Exchange Format (SHEF) were completed. Sutron has implemented SHEF into the DCP software as an option. NESDIS advised that SHEF format will not be obligatory. NESDIS announced plans for an improved DCS ground system to be operational by late 1989. System capacity will be increased to 100,000 DCPs and 5,000 users. Data transfers, aside from privately operated GOES receive sites, will be accomplished through the NOAA-PORT system utilizing the DOMSAT communications system and low-cost Direct Readout Terminals (DROTS). This office remains concerned with possible future policy change by NESDIS that may require user fees to be paid to NESDIS for GOES DCS usage. The use of GOES DCS has been free of charge to the state.

A major thrust in FY 89-90 will be in increasing the utility of the monitoring system for enhanced drought management. This would include network expansion and relocation of monitoring hardware to meet short-term needs.

The state of Colorado is in the process of developing a Geographic Information System (GIS). Data acquired by the satellite-linked monitoring system would be placed in a common data base with other types of geographic-based data. The GIS would allow for the extraction of multi-characteristic information onto a common map base.

The NOAA Environmental Research Laboratory, Boulder, Colorado, is evaluating flood forecasting capabilities utilizing real-time data. Access was provided to the satellite-linked monitoring system data base. The Program for Regional Observing and Forecasting (PROFS) is headed up by Dr. Lynn Johnson, University of Colorado (Denver).

I. PROGRAM DESCRIPTION

The monitoring system represents state-of-the-art technology in real-time data collection. Although the system utilizes space age technology, it is relatively simple. Conventional data collection hardware and data processing techniques have been incorporated into the system configuration.

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 data base access
7. Satellite communications link

The remote data collection hardware is generally installed at pre-existing stream, diversion, 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, 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 shaft encoders were modified with digital displays/data resets. This provides for easy sensor calibration and data display for station operators. 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 4.6 operating system. The system is designed to handle in excess of 350 DCPs. 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 DCPs via an RS-232 port and, being equipped with acoustic couplers, can provide for system access via phone communications. The DWR has tied into the state of Colorado microwave telecommunications system. A line has been provided to each Division office to provide for unlimited access to the system's central computer.

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 series of federal communications satellites 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 223 transmission slots allowing for 223 DCPs 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. Currently, no fees for the use of the GOES Data Collection System (DCS) are charged to the State.

NOAA-NESDIS launched its last available GOES spacecraft (GOES-7) on February 26, 1987. It was located in the GOES-EAST position at 75°W equatorial. GOES-CENTRAL (GOES-6) was relocated to the WEST position at 136°W equatorial. The new GOES series prototype, scheduled for operation in 1990, may have narrower band widths to accommodate additional channels, and increased transmission rates to handle increased data volume. Minor modifications to existing DCPs may be required at that time. NESDIS established a Standard Hydrological Exchange Format (SHEF). Sutron implemented SHEF into the DCP software. At the end of FY 88-89, NESDIS reported that there were 8,950 transmission assignments with 6,730 scheduled for transmission with

5,560 active. The difference in number between scheduled and active DCPs is due to seasonally operated DCPs. NESDIS activated an improved DCS ground system. System capacity improved to 100,000 DCPs. The orbit of GOES-WEST (6) is deteriorating at a rate of 1 degree per year. As of June 19, 1989, it had an inclination of 1.25 degrees and was having no impact on reception at the DWR receive site. Problems with reception are not expected until May 1990. The launch of GOES-NEXT is scheduled for December 1990. NOAA-NESDIS advised that GOES-NEXT will have a -3.5 db margin relative to relayed signal strength. This represents approximately a 10% loss. NOAA-NESDIS further advised that increased power consumption on GOES-NEXT as a result of significantly higher data collection system utilization, will lower signal strength even more, possibly below the 35 db threshold receive sensitivity of the Sutron Direct Readout Ground Station (DRGS). NOAA-NESDIS has offered a solution to this potential problem, the DOMSAT Receive Only Terminal (DROT). All transmissions would be received by NOAA-NESDIS at the Wallops Island (Virginia) Command and Data Acquisition station, and relayed to the user community via a DOMSAT communications link at a rate of 56 KB. Data would be received by a 1.8m dish and DROT. Data of interest would be filtered out of the data stream and sent to the central computer (DEC VAX 11/750). There are two significant benefits to this proposal over operating a DRGS. The cost is projected to be less than $10,000. The ground stations operated by NOAA-NESDIS are capable of receiving the weaker signals that may result with GOES-NEXT, and are able to track a wandering spacecraft. NOAA-NESDIS has arranged to operate demonstration DROTs at Wallops Island and at the Denver Federal Center beginning in September 1989. A question remains as to the future costs of utilizing a private communications satellite, DOMSAT.

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 by NOAA-NESDIS and the Federal Communications Commission to transmit on GOES-WEST, 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 16 modems, enabling the handling of 16 users simultaneously. The Division of Water Resources reached an agreement with the Northern Colorado Water Conservancy

District (Loveland) to utilize their downlink as a backup. Each downlink is programmed to receive and process the other's data transmissions. The real-time data is stored on-line for a minimum of five days. After five days, the data are dumped unless requested to be stored longer. In the case of a failure in either the Direct Readout Ground Station or the central computer, the data are not lost, but are available on the backup system. A modem-linked computer port allows direct access by the DWR to the data. As the two systems are identical, there are no problems with data format. The data are transferred by computer-to-computer dump.

GOES-WEST (GOES-6) underwent a final stabilization manuever in May, 1988. The inclination (measure of orbital stability) will deteriorate at a rate of 1° per year. An inclination in excess of 1.9° results in signal loss. By mid-1990, a loss of two to three transmission periods daily can be expected. Launch of GOES-NEXT is scheduled for December, 1990. NOAA-NESDIS is considering making GOES Central (GOES-7) available for DCS. The spacecraft is located at 98°W but would be relocated to 108°W. The current inclination is 0.27°.

DCS operation has secondary priority according to NOAA-NESDIS operating guidelines for GOES. The GOES weather imaging system has the priority. As a consequence, the spacecraft are frequently moved to facilitate the monitoring of major weather events, e.g. hurricanes.

The GOES spacecraft undergo an eclipse period each spring and fall, where the on-board solar panels are not able to function. For a period up to two hours per day, NOAA-NESDIS deactivates the DCS due to insufficient power. The periods run February 26 to April 12 and August 31 to October 15, occurring between 2330-0130 MST. There is minimal impact on DWR DCP transmissions as less than 20% of the DCP's are scheduled to transmit in the self-timed mode during this period. To compensate, redundant data sets (current 4 hours and previous 4 hours of data) are transmitted at each self-timed transmission. If the weather imaging instrumentation is either not functioning or is not being used, power consumption is not a problem and no eclipse problems occur.

NOAA-NESDIS runs tests on all DCS channels to check the integrity of the system. Test address 15C94F4E is utilized. This transmits over regularly scheduled transmissions and causes loss of such transmissions. It is not a significant problem as it affects less than 1% of the transmissions on a given day.

Data transmissions are processed on a real-time basis. Raw data are converted into engineering units and time stamped. Discharge and contents values are computed from stage data utilizing stage-discharge and stage-contents table conversions. Shifts are automatically applied to account for changes in the stream channel characteristics affecting stage-discharge relationships as identified from actual on-site measurements. Other computations are made as necessary including stage-discharge conversions utilizing Parshall flume equations, incremental precipitation, and temperature. At the end of each 24-hour period, mean daily values are computed and archived in a separate data base file.

Maintaining data base integrity is a primary operations goal. 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 nearly 65% of the stations in the state's monitoring network are operated by other entities that generally are not utilizing the data to make real-time decisions. Stations are typically visited by a hydrographer on a 2 to 4 week interval. On-site measurements are made along with any necessary calibrations. Normal data ranges for each station are entered into the central computer. If data values fall outside of the expected range, they are flagged accordingly. Flagged values are not utilized in computing mean daily values. Each day the computer reports the number of "data quality" flags for each station.

Data editing may be done to either 15-minute resolution data or the mean daily values. Editing is done on a separate working file duplicated from the original data base. In this fashion, the integrity of the real-time data is maintained. Data editing privileges, along with the ability to input data processing/data conversion commands, are restricted to authorized users. User name/password combinations carry limited privileges as determined by the system's data base manager.

At the request of the DWR, additional transmission slots were provided by NESDIS on channel 062W. The City of Colorado Springs was reassigned to channel 034W releasing 19 slots, the Northern Colorado Water Conservancy District was reassigned to channel 034W releasing 18 slots, and the City of Aurora was reassigned to channel 034W releasing 15 slots.

Seven transmission slots were set aside for test purposes:

Address	Reporting Time (GMT)	Division
514AD174	0246	1
514AB492	0244	2
514A718C	0240	3
514A21F0	0235	4
514A8108	0241	5
514AE4EE	0247	6
514A927E	0242	7

A number of gaging stations not incorporated into the GOES-linked monitoring network are having their respective hydrologic data entered manually into the central data base. This allows for the data to be further processed and edited for the final record utilizing the records development software. The data can be easily retrieved utilizing the Hydromet reports and graphics output programs.

The Division of Water Resources is responsible for system maintenance. Field personnel from each Division received training from Sutron technicians in the operations and maintenance of the system hardware. Selected staff engineers receive a week of follow-up training at Sutron's facilities in Herndon, Virginia each year. Training is directed at system diagnostics, hardware calibration, and basic repairs. Each Division is supplied with a minimum of two sets of replacement hardware. If a component malfunctions and cannot be repaired in the field, that component is replaced and returned to the manufacturer for repair.

Computer generated system diagnostics reports assist in monitoring the operating qualities of the remote data collection hardware. The report tabulates the operations characteristics for each station for the previous day. The report lists the number of received, scheduled, and missed transmissions, any message length errors, transmission time errors, errors in transmission quality including power (EIRP) and frequency, any deficiency in remote power supplies, and the number of missing values and parity errors for each station. Frequently, hardware operating problems can be detected before reaching a critical (non-operative) stage.

A program is being developed that will provide for input of information relative to stations operations status. This will provide the user with information on such things as current operating conditions, data validity, and the next scheduled station maintenance.

Excessive failures experienced with the remote data collection hardware continue to be an area of concern. Failures fall into two categories; unit failures requiring manufacturer repair and unit failures that could be repaired or corrected in the field. In FY 88-89, 19 DCPs were returned to the manufacturer for repair. This represents 12% of the DCPs operated by the state. The majority of these involved the voltage control oscillator, frequency oscillator, or analog-to-digital chip. Nearly twice as many units failed but were made operable in the field. These intermittent failures were generally related to scrambling of operating software due to lightning strikes or other forms of static electricity, deficiency in the on-site power supply, moisture in the antenna/antenna cable, or vandalism. It is hoped that the majority of component failures have surfaced and been repaired. Steps are being taken to alleviate the intermittent failures. Advanced grounding techniques are being evaluated to curtail problems associated with scrambling of operating software due to power surges. A case study on this problem showed that in a six-week period in the Arkansas River basin (Division 2), a total of twelve DCPs and shaft encoders developed the effects of scrambled operating programming requiring a station visit and reprogramming. The problem was apparently exasperated by numerous electrical storms occurring in the basin during this period.

The cost of these failures is conservatively estimated to be between $30,000 to $40,000. This includes repair costs, travel costs, and staff time to visit these stations and repair or exchange malfunctioning hardware, and the cost to edit invalid or lost data.

Failures in the Direct Readout Ground Station occurred six times during FY 88-89. These were generally related to power surges or power failures. Except for one occurrence which happened on a weekend, the failures had insignificant impact. The clock on the VAX 11/750 central computer continues to lose 20 to 25 seconds per week. This does not raise a critical problem but does require that the clock be reset every two to three days. The exact time is found by contacting the National Bureau of Standards facility located in Boulder, Colorado. Clocks in the DCPs are calibrated in the same fashion. However, those clocks are more stable, losing no more than 10 to 20 seconds annually.

Poor quality phone lines in several areas of the state are responsible for problems in accessing the system's central computer remotely. Simple log-on becomes quite difficult. Future plans by Mountain Bell to improve these lines will resolve the problem.

Communications with NOAA-NESDIS, other GOES DCS users, and the Colorado user community is essential. NOAA-NESDIS coordinates the activities of two national GOES DCS user groups, the Technical Working Group and the Direct Readout Ground Station Working Group. Meetings are held quarterly to discuss GOES DCS operations, future system improvements, system utility, and to facilitate communications between users. These meetings have proven to be beneficial. The Project Manager attends two of the four meetings annually. Within the state of Colorado, a consortium of governmental agencies (federal, state, and municipal) have formed a committee to coordinate activities within the state related to hydrology-meteorology. The Hydromet Committee has been instrumental in promoting real-time data collection in Colorado.

The monitoring system continues to operate with only two full-time employees, the Project Manager and the Systems Analyst/Programmer. The Project Manager's responsibilities include the coordination of daily operations, network development, system enhancement, maintaining communications with the user community, interagency/intra-agency coordination, user fee development, budget management, and the coordination of the development of system applications and utilization. The Systems Analyst/Programmer's responsibilities include the operation of the receive site and central computer, data base management, control and management of system access by the user community, software modification and development, and ADP training. A third position, Systems Maintenance Manager, remains unfilled due to budgetary constraints. However, with future additions to the network, sensor add-ons, and increasing primary duties of field staff, this position will become necessary. Essential support is provided from other staff. Program direction is provided by the State Engineer and Deputy State Engineer. The Chief of the Division's Branch of Information Services provides technical support and provides the part-time services of a computer operator. Systems operations and maintenance support is provided by each of the seven Division offices. Each Division has assigned a hydrographer in charge of maintenance of the remote data collection hardware in his Division.

C. System Software

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 applications 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.

Additional programs have been developed internally to supplement the Hydromet software. SMSEQPT provides for a computerized inventory and tracking system for the remote data collection hardware, primarily 166 DCP's and 166 shaft encoders with a replacement cost of $650,000.00. RECORD was developed to facilitate the development of the hydrologic records. It modifies the Hydromet records development programs to better meet the needs and requirements of the Division of Water Resources. Data editing can be performed on either the 15-minute resolution data or the mean daily values. Editing is done on a separate working file duplicated from the original data base. In this fashion, the integrity of the real-time data is maintained. This is necessary since administrative decisions are based on the evaluation of real-time data. LOG was developed to monitor transmission activity on a specified demodulator. This includes scheduled and unscheduled transmissions making it possible to identify unauthorized transmissions that could cause interference problems. Sutron has released a new version of the Hydromet software that the DWR will install by late 1989.

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 at the remote site are surpassed. The remote data collection hardware is easily installed and can be operated in remote locations utilizing portable power packs and solar panels. The hardware can be operated in a wide environmental range from -40°C to +55°C. The DCPs are user programmable in the field. The units are capable of interfacing with up to 16 sensors simultaneously in either analog or digital mode. Very few locations in Colorado do not have a line-of-sight with either GOES-CENTRAL or GOES-WEST. As the GOES spacecraft are in a geostationary orbit, continuous communications can be maintained. The Direct Readout Ground Station can operate in an urban environment with negligible radio frequency interference. The receive site is equipped with eight demodulators allowing the monitoring of eight GOES channels simultaneously. A Sutron developed program was installed in FY 87-88 that allows for programmable operation of the demodulators. Operator input directs the demodulators to switch channels by time. All transmissions through GOES are in the public domain. The state's receive site is thus capable of monitoring all transmissions of interest through either GOES-CENTRAL or GOES-WEST. The system is capable of handling a minimum of 350 DCPs. Data storage capacity is 912 MBytes. Up to 16 users can access the system simultaneously. The system evaluates incoming transmissions and prepare a detailed summary of pertinent operating characteristics.

The Office of the State Engineer operates a computer accessory unit, WATERTALK, that allows data to be output to the user by phone using computer-generated voice-synthesis. The user can dial the WATERTALK unit, located in Denver, and receive up-to-date flow conditions at key gaging stations across the state by input of commands utilizing the keypad of a touch-tone phone. Flow information is automatically up-dated by the central computer in communicating with WATERTALK. Four phone lines are dedicated for WATERTALK user access such that four users can access the unit simultaneously.

Data transmissions are processed in an automated fashion on a real-time basis. Data conversions including analog-to-digital, stage-to-discharge, and mean daily values computations are performed in an automated fashion based on user input. Data are automatically screened and appropriately flagged if they fall outside of a user defined normal range, thus providing a basis for data quality assurance. Data editing routines, with access controlled by user name/password, allow for data base modification in both the real-time data and the archival data base. Data for stations not in the monitoring network may be entered manually, from computer-to-computer transfer, or by computer tape.

The data can be retrieved and output in various reports and graphics formats. The most fundamental output format for the evaluation of flow data is the hydrograph. Data from up to four stations or from four periods of record for a single station can be plotted on a single hydrograph.

The system is capable of providing flood warnings. If river conditions surpass user identified high water levels, the system automatically sends out warning messages to designated personnel by either computer-to-computer communications or by delivering a voice-synthesized message over the phone.

E. Future System Developments

The satellite-linked monitoring system can be both expanded and enhanced to increase its capabilities and effectiveness. The expansion of the state's monitoring network and the enhancement of the system by the addition of other sensor types will be limited by the availability of funds. The cost to purchase and install GOES-linked data collection hardware at an existing shelter is approximately $6,000 per station. Refer to Appendix A. Current funding levels do not provide for capital expenditure beyond hardware replacement costs. There is a large variety of sensor types available over a wide cost range. Sensors are available that can interface with the Sutron DCP and provide valuable data on a real-time basis. These include precipitation, air temperature, water temperature, soil moisture, snow depth, solar radiation, pH, dissolved oxygen, conductivity, wind direction and speed, humidity, and soil temperature. Costs for specific sensors range from $300 to $4,500. Refer to Appendix B. The need for additional data must be coupled with funds from the state of Colorado and from various user groups to cover the costs. System enhancement cannot become a reality without additional operations and maintenance field support staff.

The Office of the State Engineer, Division of Water Resources, can justify the need for an additional 25 to 30 satellite-linked monitoring stations to assist in water rights administration. This office is also interested in real-time data that can assist in runoff forecasting and in dam safety monitoring. Other state agencies including the Division of Wildlife and the Department of Health identified the need for an additional 20 to 25 stations. The Division of Wildlife is interested in monitoring minimum streamflows and water quality relative to fisheries management. The Department of Health is interested in monitoring basic water quality parameters. The Office of the State Engineer has made the receive site and central computer facilities available to any state agency desiring to get involved in GOES-linked data collection. Technical expertise will also be provided on a cooperative basis.

Numerous non-state water resources management entities are planning on installing and operating additional satellite-linked stations statewide. These include the National Weather Service, Bureau of Reclamation, Northern Colorado Water Conservancy District, City of Colorado Springs, and the City of Aurora. The National Weather Service (NWS) has installed sensors measuring air temperature and precipitation along with stage at 38 stations in the Colorado River basin in Colorado. Through a cooperative agreement, the NWS installed precipitation and air temperature sensors at two state operated stations, Colorado River near Dotsero and the Blue River below Green Mountain Reservoir. The Northern Colorado Water Conservancy District is planning on installing additional GOES-linked meteorological stations for use in runoff forecasting and irrigation planning. The Bureau of Reclamation and the City of Colorado Springs are planning on the installation and operation of real-time monitoring stations for reservoir management and dam safety. The City of Aurora will be increasing its network of stations in South Park for water resources accounting. The stations that are of interest to the user community will be monitored by the state's system.

The input of historic flow data into the system's data base for key gaging stations in Colorado is expected to be completed by early 1990. This will allow for comparisons of recent data with data covering in some cases 100 years of record. Current flow conditions can be compared with normal, wet, and dry periods. Examples of historic flow records available are:

Station	Initial Date of Record
Arkansas River at La Junta	1889
Arkansas River at Pueblo	1885
Big Thompson River at Mouth of Canyon near Drake	1887
Cache La Poudre at Mouth of Canyon near Fort Collins	1881
South Platte River at Denver	1889

Dolores River at Dolores	1895
Gunnison River near Grand Junction	1894
Rio Grande near Del Norte	1889

It has become evident that there are situations where short-term real-time data collection is necessary. This could include stations for flood warning, dam safety, or for specific water rights administration such as water exchanges. An example of one of these uses took place in May, 1987, when the Cucharas Reservoir (Division 2, Arkansas River basin) showed signs of possible dam failure. The reservoir was at near capacity with 51,000 acre-feet of water. A monitoring station was installed the next day at the reservoir utilizing a pressure transducer to monitor stage elevation. Another station was installed upstream on the Cucharas River to monitor inflow. Both stations remained operational until August 1, 1987. Four sets of remote data collection hardware, portable shelters, and sensors are being pre-packaged to assist in meeting future needs.

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 runoff forecasting and automated river call determination are of special interest. Program development will come slow over the next two years but will gradually increase momentum as the monitoring system becomes more integrated into daily water rights administration.

The Colorado Water Resources and Power Development Authority provided $68,048 for the purchase of sensor hardware to enhance the capabilities of the monitoring system. This hardware was installed in FY 88-89 and General assessments of utility to date are:.

Dam Safety Monitoring Hardware Package

This hardware was initially utilized to develop a mobile real-time dam safety monitoring package at Cucharas Reservoir in southeastern Colorado. The four stations provide for monitoring of reservoir inflow, reservoir contents, reservoir outflow, reservoir seepage, and piezometers (2) within the dam. Retrofit costs can be high. This type of monitoring shows promise where a reservoir's safe operating level has been lowered.

Air Temperature Monitoring Sensors

Twenty-eight stream gaging stations were instrumented with air temperature sensors. The data were utilized to correlate discharge when the hydrologic record is ice effected and to forecast runoff. This has proven to be cost-effective and easy to maintain.

Water Quality Monitoring Hardware Package

This hardware was utilized at the gaging stations, Clear Creek at Lawson and the South Platte River at Henderson to monitor conductivity, water temperature, dissolved oxygen, and pH. The long-term needs of the data are apparent. However, necessary operations and maintenance costs, and data processing and evaluation procedures are extreme.

Precipitation Monitoring Sensors

Seven gaging stations were instrumented with automated precipitation monitoring sensors. The sensors are of the weighing bucket type capable of measuring both liquid (rain) and frozen (snow) precipitation. These sensors require limited operations and maintenance and can provide valuable data especially during drought periods.

Snowpack Monitoring and Runoff Forecasting

The package consists of a precipitation sensor, snowpillow, air temperature sensor, snow temperature sensor, and solar radiation sensor. Not enough data have been collected and evaluated to make a determination of utility. Data processing and evaluation is apparently significant.

Evaporation Monitoring Sensors

Two gaging stations were instrumented with automated evaporation sensors. The sensors are not as dependable or as accurate as is required.

F. Monitoring System Network

The real-time hydrologic data collection network operated by the state of Colorado is comprised of 158 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, 37 stations
Division 2 / Arkansas River Basin, 48 stations
Division 3 / Rio Grande Basin, 18 stations
Division 4 / Gunnison River Basin, 11 stations
Division 5 / Colorado River Basin, 22 stations
Division 6 / White/Yampa River Basin, 7 stations
Division 7 / Dolores/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 is 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 at the discretion of the State Engineer or one of the Division Engineers. Six stations were substituted for in the last 12 months as a result of an evaluation of the utility of real-time data 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. One hundred-one (101) of the 158 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	32
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
Metropolitan Denver Sewaage Disposal District #1	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 July 1, 1988, there were 150 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.

Twenty-three satellite-linked monitoring stations operated by the state of Colorado are done so on a seasonal basis only. These stations are primarily gages at transmountain diversions and irrigation diversions where actual diversions are not made during the winter months, and at high elevation sites where ice-effects negate a valid record.

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

DIVISION 1 (South Platte River Basin)	Data Type
1. South Platte River at Waterton	S
2. South Platte River near Kersey	S
3. South Platte River at Balzac	S
4. Boulder Creek near Eldorado Springs	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 in the Canyon	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. Cherry Creek Meteorological Station	P,E
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

	Data Type
DIVISION 1 (South Platte River Basin) cont.	
32. Hansen Feeder Canal	S
33. Cheesman Reservoir	SE
34. South Boulder Creek below Gross Reservoir	S
35. Big Thompson River below Lake Estes	S
36. Clear Creek at Lawson	C,WT,DO,pH
37. South Platte River at Henderson	C,WT,DO,pH
Division 2 (Arkansas River Basin)	
1. Arkansas River at Portland	S
2. Arkansas River above Pueblo	S
3. Arkansas River near Nepesta	S
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,WT,C
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

44.	Horse Creek at Highway 194	S, WT, C
45.	Cucharas River above Cucharas Reservoir	S
46.	Cucharas Reservoir	SE,pz(2)
47.	Cucharas River below Cucharas Reservoir	S
48.	Cucharas Reservoir Seepage Flume	S

Division 3 (Rio Grande Basin)

		Data Type
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
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
18.	Rio Grande River near Monte Vista	S

Division 4 (Gunnison River Basin)

1.	Surface Creek near Cedaredge	S
2.	Gunnison River below the East Portal of the Gunnison Tunnel	S
3.	Surface Creek at Cedaredge	S
4.	Muddy Creek above Paonia Reservoir	S
5.	Muddy Creek below Paonia Reservoir	S
6.	Cimarron River near Cimarron	S
7.	South Canal	S
8.	Uncompaghre River near Ridgway	S
9.	Dallas Creek near Ridgway	S
10.	Redlands Canal near Grand Junction	S
11.	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

<u>Division 5</u> (Colorado River Basin) cont.

		Data Type
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

<u>Division 6</u> (White/Yampa River Basin)

1.	Yamcola Reservoir	SE
2.	Illinois River near Rand	S
3.	Yampa River above Stagecoach Reservoir	S
5.	Michigan River near Gould below the Confluence of the North and South Forks	S
6.	Little Snake River near Slater	S
7.	Bear Creek near Toponas	S
8.	Elk River near Milner at the Mouth	S

<u>Division 7</u> (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,P,E

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

Division 1 (South Platte River Basin)	Data Type
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
19. Cherry Creek Reservoir	SE,P

<u>Division 2</u> (Arkansas River Basin)

1. Purgatoire River at Trinidad	S

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

<u>Division 3</u> (Rio Grande Basin)

1. Rio Grande Reservoir	P,AT

<u>Division 4</u> (Gunnison River Basin)

1. Blue Mesa Reservoir	P,AT,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)	Data Type
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
13. Eagle River at Redcliff	AT,P,S
14. Piney River near State Bridge	AT,P,S
15. Crystal River near Avalanche Creek	AT,P,S
16. Eagle River near Redcliff	AT,P,S

Division 6 (White/Yampa 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

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
National Weather Service, Central Forecast Office
(Denver)

Division 1 (South Platte River Basin)

1. Clear Creek at Lawson	S, P
2. Big Thompson River North Fork near Drake	S,AT

Division 6 (White/Yampa Basin)

1. North Platte River near Northgate	S

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

	Data Type
Division 1 (South Platte River Basin)	
1. Boulder Creek at Boulder	S
2. Cache La Poudre at Fort Collins	S
3. Clear Creek at Golden	C,WT
Division 2 (Arkansas River Basin)	
1. Arkansas River near Coolidge, KS	S
2. Frontier Ditch near Coolidge, KS	S
3. Trinidad Reservoir	SE
4. Fort Lyon Canal near Cornelia	S
5. Fort Lyon Canal near Big Bend	S
6. Arkansas River near Nathrop	S
7. Arkansas River near Parkdale	S
8. Monument Creek at Pikeview	S,P
9. St. Charles River at Vineland	S
Division 6 (White/Yampa River Basin)	
1. Yampa River near Oak Creek	S,WT,C
2. Yampa River near Deer Lodge	S,WT,C
3. White River below Boise Creek near Rangley	S
4. Yampa River at Steamboat	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
3. Lemon Reservoir	SE

Stations Operated by the U. S. Bureau of Reclamation

Division 3 (Rio Grande Basin)	
1. Platoro Reservoir	SE,P
Division 4 (Gunnison River Basin)	
1. Silverjack Reservoir	SE
2. Paonia Reservoir	SE
3. Ridgway Reservoir	SE
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

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
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
15.	Fraser River near Windy Gap	S
16.	Upper Blue River	S

Stations Operated by the City of Aurora

Division 1 (South Platte River Basin)

		Data Type
1.	Michigan River near Jefferson	S
2.	South Platte River above Spinney	S
3.	Fourmile Creek near Hartsel	S
4.	Middle Fork at Santa Maria	S
5.	Fourmile Creek at Highcreek	S
6.	Middle Fork at Prince	S
7.	South Fork above Antero	S
8.	Jefferson Creek above Jefferson	S
9.	Ohler Gulch above Jefferson	S
10.	Tarryall Creek near Como	S

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
4.	Lake Creek above Twin Lakes	S
5.	Bob Creek at Colorado Canal	S,AT,P, BPE,H, WS,WD
6.	Fountain Creek at Colorado Springs	S
7.	Fountain Creek at Monument	S
8.	Lake Henry Reservoir and Outflow Gage	SE,S

9.	Merridith Reservoir	SE
10.	Merridith Reservoir Inflow	S
11.	Sugar City Flume	S

Station Operated by the
Santa Maria Reservoir Company

<u>Division 3</u> (Rio Grande Basin)

1.	Continental Reservoir	SE

Station Operated by the
Rio Grande Reservoir Company

<u>Division 3</u> (Rio Grande Basin)

1.	Rio Grande Reservoir	SE

Station Operated by the
Rio Grande Water Users Association

<u>Division 3</u> (Rio Grande Basin)

1.	Rio Grande Canal	S

Station Operated by the
Division of Wildlife

<u>Division 3</u> (Rio Grande Basin)

1.	Tabor Transmountain Diversion	S

Stations Operated by the
Colorado-Ute Electric Association, Inc.

<u>Division 4</u> (Gunnison River Basin)

1.	Trout Lake	SE
2.	Trout Lake Outflow	S

<u>Division 7</u> (Dolores and San Juan River Basins)

1.	Electra Lake Outflow	S
2.	Electra Lake Diversion	S
3.	Electra Lake	SE

Station Operated by the
Aspen Consolidated Sanitation District

<u>Division 5</u> (Colorado River Basin)

1.	Roaring Fork River below Maroon Creek near Aspen	S

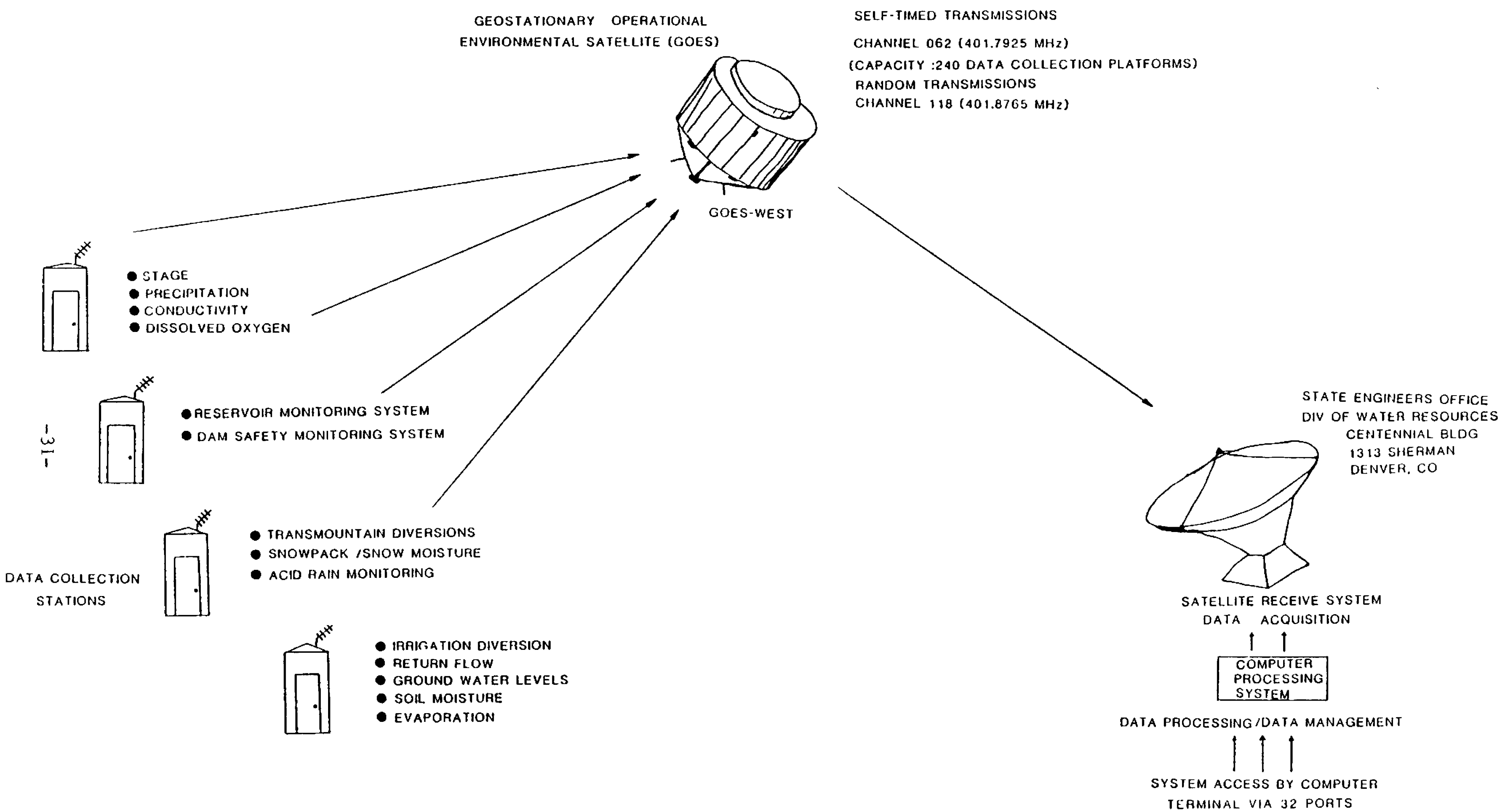
Stations Operated by the Southwestern Water Conservation District

Division 7 (Dolores and San Juan River Basins)

1.	Cherry Creek near Red Mesa	S
2.	Long Hollow Creek at the Mouth Near Red Mesa	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
V	Voltage Metering
C	Conductivity
WT	Water Temperature
E	Evaporation
PZ	Piezometer
DO	Dissolved Oxygen
pH	pH
WS	Wind Speed
BP	Barometric Pressure
WD	Wind Direction
H	Humidity



MONITORING SYSTEM CONFIGURATION

Figure 1

GOES SATELLITE RECEIVE SITE ELECTRONICS

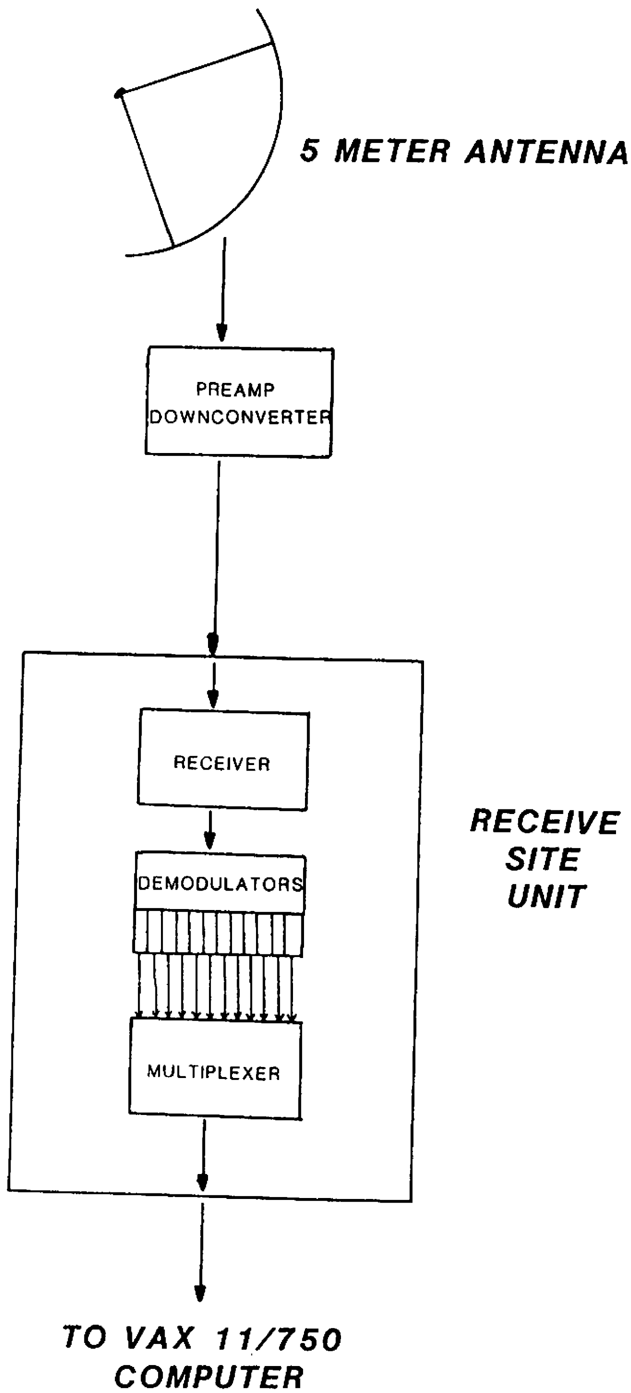


Figure 2

VAX 11/750 COMPUTER AND COMMUNICATIONS HARDWARE

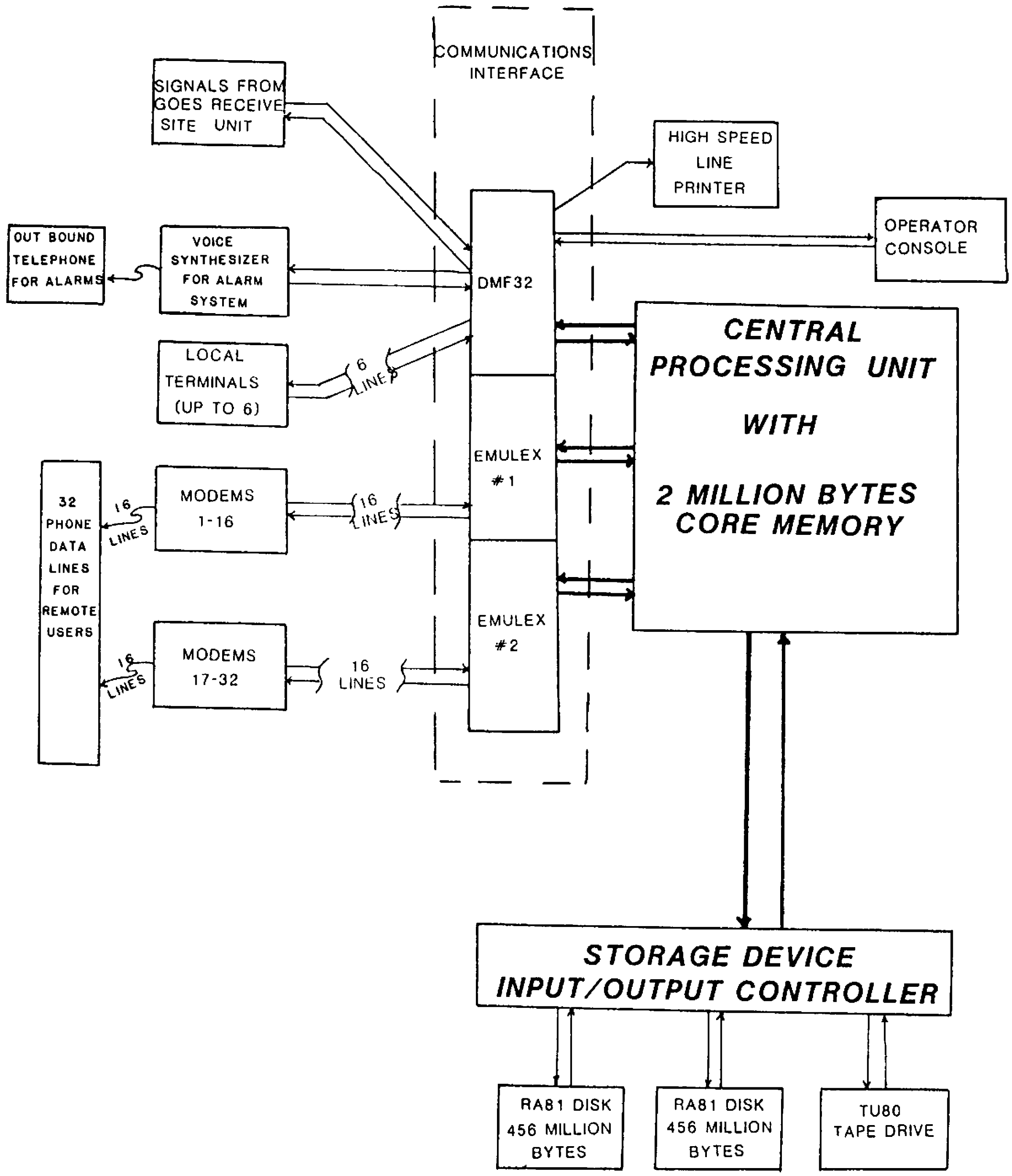
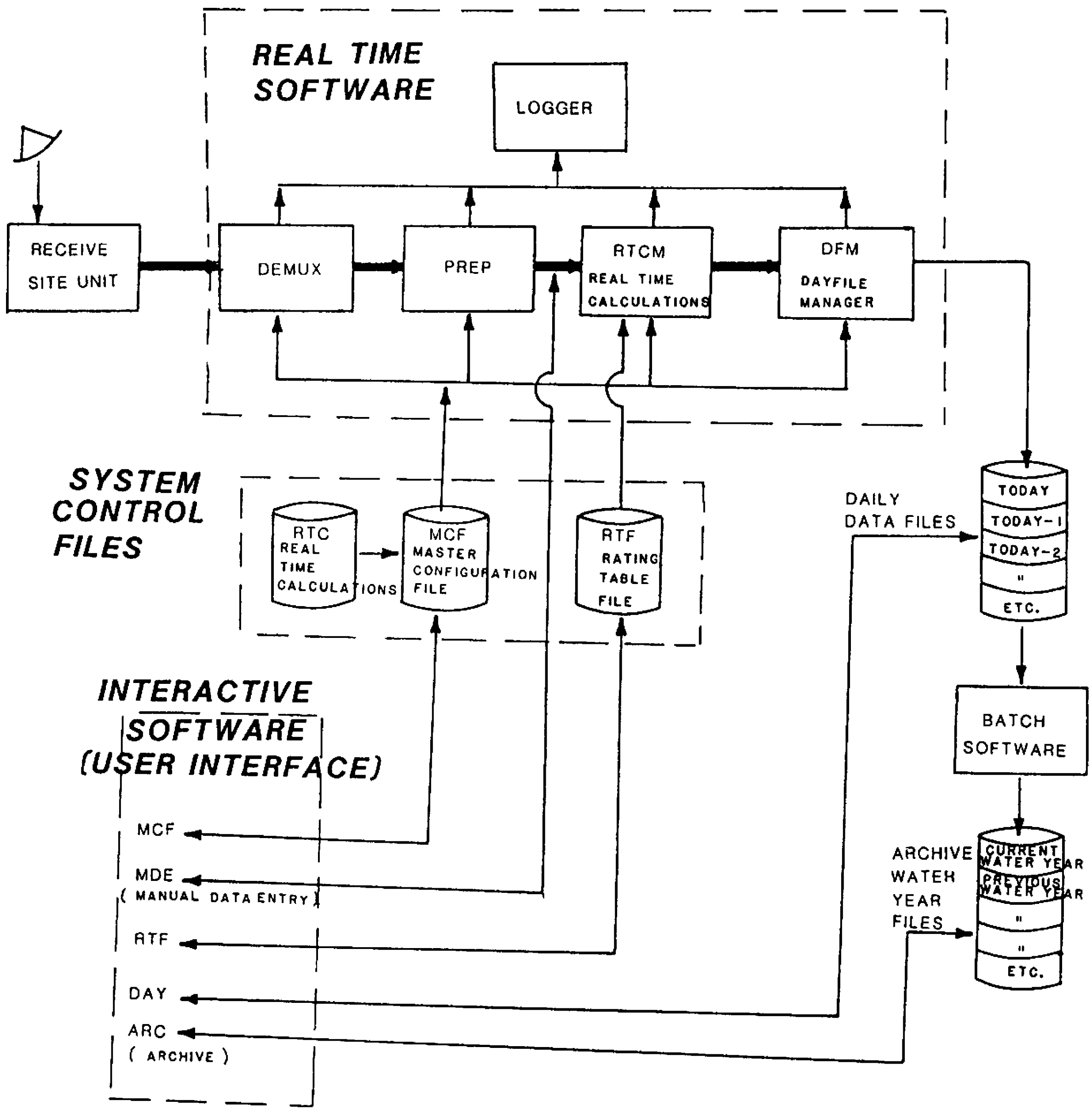


Figure 3

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

XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX

WATER YEAR 1986

** JUN **

COLUTACO

XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX

	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					

XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX

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

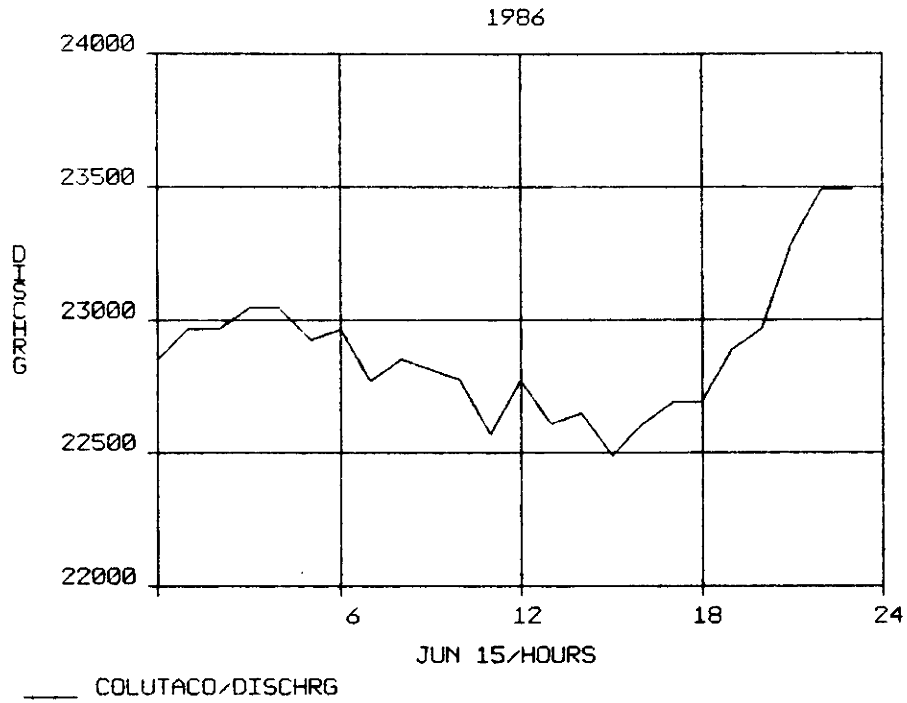


Figure 8
DAYFILES PLOT

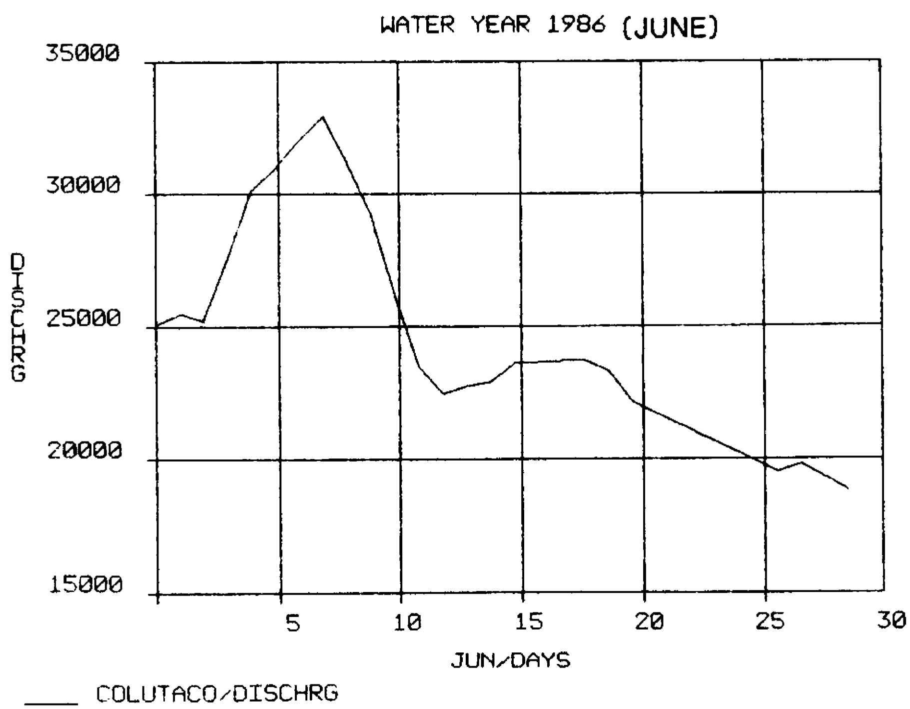
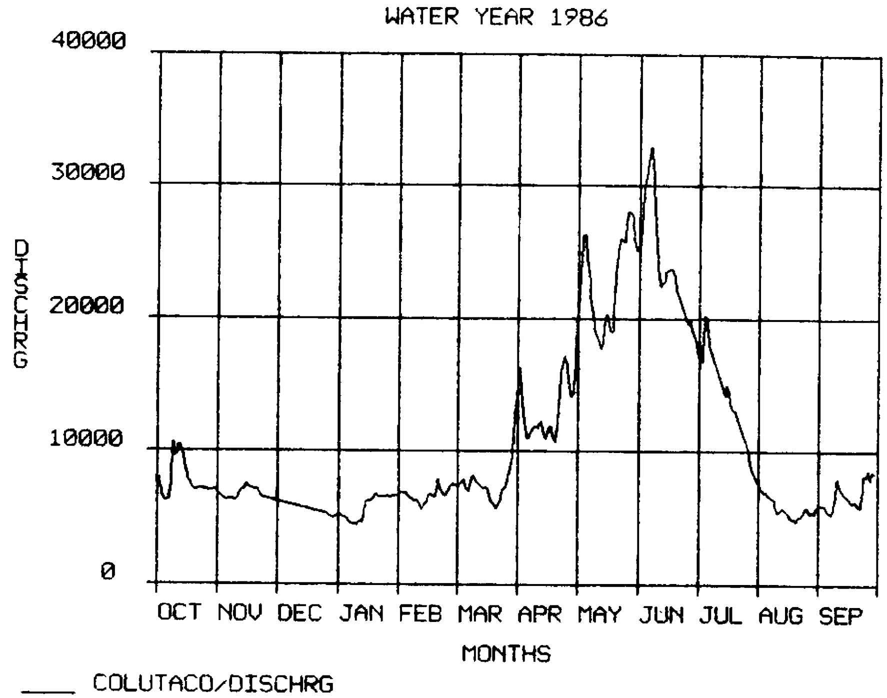


Figure 9
ARCHIVES PLOT

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. Access to real-time data makes it possible to adjust the "river call" to match dynamic hydrologic conditions. If additional water supplies are available, more junior rights can be satisfied. On the other hand, if water supplies decrease, then water use can be curtailed to protect senior rights.

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. The number of water rights increased by 23% from 1982 to 1988, from 102,028 to 124,994. Plans for water rights transfers approved by the water courts are becoming increasingly complex. This is especially evident where agricultural water rights are transferred to municipal use. One point that must not be overlooked is that Colorado is coming out of a wet cycle. Histor- ical 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 ensure 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 affect significantly the hydrology of the river. Twenty-one major irrigation diversions are monitored by the system.

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 ensuring 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. Data values that fall outside of user defined normal or expected ranges are flagged appropriately. Flagged data values are not utilized in computing mean daily values. Missing values can be added and invalid data values corrected by the respective hydrographer for that station using data editing functions. The records development software was significantly modified to allow for progressive records development. Computations are carried out by the computer alleviating the chance for human error.

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.

It is essential to understand that real-time records can be different from the final record for a given station. This can be the result of editing raw data values because of sensor calibration errors, sensor malfunctions, analog-to-digital conversion errors, or parity errors. Discharge conversions can be modified by the entering of more current rating tables and shifts. Corrections to the data are sometimes necessary to compensate for hydrologic effects such as icing. Human error can also result in invalid data. The final record for those gaging stations operated by non-state entities, such as the U. S. Geological Survey-Water Resources Division, is the responsibility of that entity. Modifications to the real-time records for these stations are accepted by the state of Colorado.

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 lists the incorporated stream gaging stations with the designated alert levels used to flag high water conditions. 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.

It is important to comprehend inherent limitations of the satellite monitoring system relative to its utilization as a warning system. There are no absolute safeguards against false alarms. Sensor malfunctions are an obvious cause for such false alarms. However, the computer can be programmed to ignore data values that are not plausible. For example, stage values greater than 10 to 15 feet are not physically possible at most stream gaging stations. In the event of a flash flood in a narrow, confined canyon, the remote data collection hardware would be washed away. This is especially the case for a station operating downstream of a failed dam. Ice jams on a river can cause the upstream stage to increase and consequently provide invalid discharge conversions. There is always a time lapse from the time a hydrologic event occurs to when the system identifies that it has occurred and when a random (emergency) transmission is sent. If an event occurs at 1410 hours, the system is not aware of the condition until 1415 hours since the DCP is programmed to activate at even 15-minute intervals to record a data measurement. The DCP then computes a transmit interval utilizing a random number generator. This interval is between 2 and 10 minutes. If a 6-minute interval is utilized, the random transmission will be made at 1421 hours. The elapsed time from event occurrence to transmission of data is 13 minutes. Scenarios could be given which would give a minimum elapse time of two minutes or a maximum elapse time of 24 minutes. In addition, a random transmission occurring on channel 118W has approximately a 20% chance (with current channel load levels) of not being received due to interference with another random transmission being sent at the same time.

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.

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
13. Rio Grande near Monte Vista	7.50	5,000

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

	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

III. OPERATING BUDGET

A. FY 87-88 Operating Costs

The actual operating cost of the satellite-linked monitoring system for FY 88-89 was $219,779. The projected budget was $248,649. Available funds amounted to $225,866. A detailed breakdown of expenditures is given in Table 3. $19,720 of the $25,807 of the emergency fund balance was utilized to balance deficit spending. A summary of the major spending variances is as follows:

UNDER VARIANCES

ITEM	UNDER EXPENDITURES
FIXED EXPENSES	
II-D. Scheduled Maintenance	$4,120
This basically involves preventive maintenance and calibration of remote data collection hardware and sensors.	
II-B. Telecommunications	$16,591
Long-distance phone access by water commissioners was restrained.	
III. Indirect Cost Assessment	$ 8,372
The Department of Natural Resources applies an assessment against cash funds to cover administrative overhead.	
II-C Computer Operations $4,609	
Sufficient computer operations supplies were carried over from the previous year.	
VARIABLE EXPENSES	
II-B Hardware Replacement	$6,196
Hardware replacement as a result of natural damage and vandalism was limited to availability of funds.	
I-C Hardware Service	$2,198
Increased scheduled maintenance reduced this amount.	

OVER VARIANCES

ITEM	OVER EXPENDITURES
VARIABLE EXPENSES	
I-A Traveland Per Diem	$3,691
Increased costs were related to additional station calibration visits.	
II-B System Enhancement	$6,146
Personal computers utilized for access to the system's data base were provided to seven key water commissioners.	

It is necessary to point out that certain indirect costs in operating the system are also realized. These indirect costs are absorbed by the Division of Water Resources. These indirect costs, amounting to an estimated $86,240 per year, are as follows:

1.	Manpower to maintain the monitoring network 7 divisions/30 hours per month @ $12 per hour	$30,240
2.	Travel costs to maintain remote data collection hardware	$14,000
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

B. FY 89-90 and FY 90-91 Budgets

The projected operating cost of the system for FY 89-90 is $227,515. The projected operating cost of the system for FY 90-91 is $243,635. A detailed breakdown of these costs is given in Table 4.

C. Future Budget Considerations

There are indications that in the future user fees will be charged by NOAA-NESDIS to offset the costs of operating the GOES DCS. These user fees may be assessed as early as 1990, coinciding with the launch of the next generation of GOES spacecraft and the activation of the NOAA-NESDIS Automatic Data Processing System. There is no estimate as to the possible range of user fees.

The new generation of GOES spacecraft may utilize transmission relay rates of 300 bits per second (bps) over the present rate of 100 bps. This would require modifications to the existing DCP transmitters. If the modification cost were to range from an estimated $200 to $400 per unit, the total cost to modify the 166 units operated by the state of Colorado would amount to $33,200-$66,400.

There is a concern over short-term and long-term hardware replacement costs. On the short term (24 to 48 months), replacement will be primarily due to damaged/vandalized hardware. Current replacement cost for the GOES-linked data collection hardware installed at a single station is approximately $5,500. If 5% of the hardware had to be replaced in a given year, the cost would be $41,500. This exceeds budgeted amounts by $28,000. On the long-term (48 to 72 months), consideration must be given to blanket replacement of hardware. The effective lifetime of a DCP is expected to be between 6 to 8 years (as per the manufacturer, the Sutron Corporation). DCPs operated by the state of Colorado will reach this in the 1990 to 1992 period. The cost to replace 166 DCPs is currently $481,400.

An additional FTE should be seriously considered to work on the program. The position, System Maintenance Manager, would be responsible for both coordinating and carrying-out the sustained operation and maintenance of the remote data collection network. As the system becomes more integrated into real-time water rights administration, there develops a greater need to maintain the operation of the monitoring network on a continuous and consistent basis. Demands on designated Division staff to maintain the remote data collection hardware have become a burden as their primary hydrographic duties have increased dramatically. This position would add an estimated $40,000 to the budget.

TABLE 3

SATELLITE MONITORING SYSTEM
FY 88-89 BUDGET

ITEM		FY 88-89 (projected)		FY 88-89 (actual)	
FIXED EXPENSES					
I.	PERSONNEL COSTS	$98,251		$100,301	
II.	OPERATING COSTS	100,901		77,482	
	A. Hardware Maintenance Contracts	19,834		22,735	
	B. Telecommunications	52,596		36,005	
	C. Computer Operations	6,173		1,564	
	D. Scheduled Maintenance	22,298		17,178	
III.	INDIRECT COST ASSESSMENT	12,243		3,871	
		$211,395	(85%)	$181,654	(83%)
VARIABLE EXPENSES					
I.	OPERATING COSTS	$15,996		$16,911	
	A. Travel and Per Diem	3,858		7,549	
	B. Training	4,492		4,057	
	C. Hardware Service	4,133		1,935	
	D. Other Operating Costs	3,513		3,370	
II.	CAPITAL OUTLAY	21,258		21,214	
	A. Hardware Replacement	11,246		5,056	
	B. System Enhancement	10,012		16,158	
		$37,254	(15%)	$33,125	(17%)
TOTALS		**$248,649**		**$219,779**	

TABLE 4

SATELLITE MONITORING SYSTEM
FY 89-90 AND FY 90-91 BUDGET

ITEM		FY 89-90 (projected)		FY 90-91 (projected)	
FIXED EXPENSES					
I.	PERSONNEL COSTS	$105,316		$110,582	
II.	OPERATING COSTS	83,628		91,833	
	A. Hardware Maintenance Contracts	22,735		23,872	
	B. Telecommunications	38,697		43,566	
	C. Computer Operations	2,200		2,400	
	D. Scheduled Maintenance	19,996		21,995	
III.	INDIRECT COST ASSESSMENT	8,429		8,429	
		$197,373	(87%)	$210,844	(87%)
VARIABLE EXPENSES					
I.	OPERATING COSTS	$17,575		$19,511	
	A. Travel and Per Diem	7,626		8,322	
	B. Training	4,060		4,473	
	C. Hardware Service	2,350		3,000	
	D. Other Operating Costs	3,539		3,716	
II.	CAPITAL OUTLAY	12,567		13,280	
	A. Hardware Replacement	6,067		7,280	
	B. System Enhancement	6,500		6,000	
		$30,142	(13%)	$32,791	(13%)
TOTALS		**$227,515**		**$243,635**	

IV. FUNDING SOURCES

A. FY 88-89 Funding

Ninety-one thousand one hundred nine dollars ($93,109) was appropriated from the General Fund for the operation of the satellite-linked monitoring system in FY 88-89. A total of $248,649 was approved for total program expenditures. The remaining $122,540 was to be collected from user fees, pursuant to Section 37-80-111.5(c), C.R.S. (1985 Supplement).

In FY 88-89, fees amounting to $103,350 were collected as compared to $93,400 in FY 87-88, and $94,800 in FY 86-87. The following is a summary of the fees collected in FY 88-89:

Southeastern Colorado Water Conservancy District	$35,000
Colorado River Water Conservation District	7,500
Northern Colorado Water Conservancy District	7,500
Southwestern Water Conservation District	7,200
Arkansas River Compact Commission	7,000
Dolores Water Conservancy District	6,500
Aspen Consolidated Sanitation District	3,200
City of Aurora	2,950
Colorado Division of Wildlife	2,500
City of Denver	2,400
Animas-La Plata Water Conservancy District	1,800
Colorado-Ute Electric Association	1,600
Urban Drainage District	1,200
Central Colorado Water Conservancy District	1,200
City of Thornton	1,200
Bureau of Reclamation (San Juan Chama Project)	1,200
Farmers Reservoir and Irrigation Company	1,200
Denver Metropolitan Sewage Disposal District #1	1,200
City of Westminster	1,200
Rio Grande Canal Water Users Association	1,200
Lower South Platte Water Conservancy District	1,200
1210 Grande Reservoir Company	1,200
Henrylyn Irrigation District	1,000
Conejos Water Conservancy District	1,000
Santa Maria Reservoir Company	700
Florida Water Conservancy District	600
Mancos Water Conservancy District	600
City of Durango	600
Pine River Irrigation District	600
Uncompaghre Valley Water Users Association	600
West Divide Water Conservancy District	500
TOTAL	$103,350

Total funds available for FY 88-89 was $225,866. A summary of the funding is as follows:

Fund balance from FY 85-86 through FY 88-89	$25,807
General Fund with POTS	93,109
User Fees	103,350
Surplus hardware refund	3,600
TOTAL	$225,866

Actual expenditures for FY 88-89 amounted to $219,779 leaving a fund balance of $6,087. The fund balance is an accumulation of unspent year-end funds going back to FY 85-86. The amount of fees that are collected in any given year varies. Fees are also received throughout the year rather than at the beginning of the year. Efforts are maintained so as not to overspend against available funds. In addition, a fund of $25,000 to $35,000 is considered necessary to handle possible emergency expenditures.

B. FY 89-90 Funding

One hundred thousand dollars ($100,000) was appropriated from the General Fund for the operation of the satellite-linked monitoring system for FY 89-90. A total of $228,000 was approved for FY 89-90 program expenditures. A total of $128,000 in user fees will be required to meet the projected budget. This excludes use of the existing fund balance of $6,087. Fee collections are projected to be $98,000 in FY 89-90. This would result in a deficit of $18,147.

C. FY 90-91 Funding

A budget request was submitted to the Joint Budget Committee of the General Assembly to increase the General Fund appropriation for the operation of the monitoring system to $128,124 in FY 90-91.

D. User Fee Requirements by Division

Based on an operating budget of $228,000 for FY 89-90, and a network of 158 stations, the cost to operate and maintain a single satellite-linked gaging station is $1,425 per year. The costs to operate the seven subnetworks, identified by river basin/division, are as follows:

Basin	Water Division	Number of Stations	Cost to Operate
South Platte	1	37	$52,725
Arkansas	2	48	68,400
Rio Grande	3	18	25,650
Gunnison	4	11	15,675
Colorado	5	22	31,350
White/Yampa	6	7	9,975
Dolores/San Juan	7	15	21,375

Based on user fee requirements of $128,000, the relative user fee requirements by basin/division and the net differences based on projected fee collections are as follows:

Basin	Water Division	User Fee Requirements	Projected Fee Collection	Net Difference
South Platte	1	$ 29,975	$ 13,550	-$16,425
Arkansas	2	38,886	45,000	+ 6,114
Rio Grande	3	14,582	3,100	- 11,482
Gunnison	4	8,911	4,950	- 3,961
Colorado	5	17,823	8,900	- 8,923
White/Yampa	6	5,671	2,200	- 3,471
Dolores/San Juan	7	12,152	20,300	+ 8,148
TOTALS		$128,000	$ 98,000	-$30,000

E. Future Funding Considerations

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. It is important to understand that approximately 70% of cash funds are contributions rather than user access fees or service fees.

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.

A major thrust in marketing the satellite-linked monitoring system is in the integration of the system into the operations of other state agencies. Discussions have been held with the Division of Wildlife, Department of Health, and the Water Conservation Board, to determine what needs can be met through the utilization of the monitoring system. Increased General Fund appropriations can be more easily obtained if more broad based, interagency utilization can be achieved.

V. COST-BENEFIT CRITERIA

It is estimated that the Colorado satellite-linked water resources moni- toring system provides benefits to the state of Colorado amounting to between $1,337,000 and $1,505,000 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 in FY 88-89 was $306,019 ($219,779) in direct costs and $86,240 in indirect costs), the net benefit to the state of Colorado is between an estimated $1,031,000 and $1,199,000. 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 an estimated $731,000 and $899,000 per year.

Direct and indirect benefits are calculated as follows:

1. Approximately $5,300,000 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 $530,000 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.

   Despite the fact that the number of water rights increased from 102,028 in 1982 to 124,994 in 1988 (increase of 23%), the number of water commissioners decreased from 94 to 93. These statistics indicate that based strictly on the number of water rights, the number of water commissioners should have increased by twenty-three. We must also consider the increased workload due to the growing complexity being incorporated recently into water rights administration. The monitoring system cannot be expected to replace the need for twenty-three additional water commissioners, but can compliment a moderate increase in water commissioners. If the system can potentially eliminate the need for ten additional water commissioners, savings may be an estimated $350,000 to $400,000 annually. The responsibility of water rights administration is a statutory responsibility given to the State Engineer. The necessary personnel and tools to carry out this responsibility must also be provided.

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 vary but the value of the water 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

VI. EFFECTS OF LOSS OF FUNDING FOR FY 89-90

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 $1.5 million investment by the state of Colorado.

The FY 89-90 budget of $227,515 is broken down into two categories; fixed expenses amounting to $197,323, and variable expenses amounting to $30,142. The variable expense items are 13% 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 intra-agency 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. There would be a deliberate effort to maintain subnetworks that have received operations and maintenance subsidies (user fees).

2. As a result of the above, the state of Colorado would have thirty transmission slots on GOES revoked by the NOAA-NESDIS 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/Irrigation 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
11. Central Colorado Water Conservancy District
12. Henrylyn Irrigation District
13. Mancos Water Conservancy District
14. Pine River Irrigation District
15. Aspen Consolidated Sanitation District

C. Municipalities

1. Denver Board of Water Commissioners
2. Pueblo
3. Colorado Springs
4. Durango
5. Alamosa
6. Westminster
7. Aurora
8. Thornton
9. Metropolitan Denver Sewage Disposal District #1

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

5. Department of Health
6. Division of Parks
7. Department of Highways

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
      c. Washington, D.C.
   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
   4. Trout Unlimited

G. Private Entities
   1. Fort Lyon Canal Company
   2. Santa Maria Reservoir Company
   3. Mutual Reservoir and Irrigation Company
   4. Farmers Reservoir and Irrigation Company
   5. Colorado-Ute Electric Association
   6. Rio Grande Reservoir Company

H. WATERTALK

   Users estimated at 500-600.

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, streamflow data 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 ensure 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.

The Denver Water Board (DWB) and the City of Aurora use the satellite system for real-time operation of complex reservoir systems. This requires the use of reservoir levels and reservoir releases. The DWR also uses the satellite system to verify the DWB and Aurora reservoir operations for daily administration. In addition to having numbers near real time for reservoir accounting, everyone involved with the accounting uses the same numbers.

To properly perform reservoir accounting, total water balance is needed real time. In addition to releases and storage change, evaporation and seepage are needed to complete the accounting. If we compute inflow based on release and change in storage, the measurable unknown is evaporation. Presently, the only real or actual evaporation data we get is from the Cherry Creek pan. This data can only be obtained weekly and the data is massaged by the Corps before we see it. Therefore, the inclusion of real-time evaporation on the satellite system, to the accuracy required by the accounting, would be of interest to reservoir operators and DWR water administration.

The addition of weather station parameters to the satellite system could be utilized to confirm or compute crop evapotranspiration. This data could be used to trend crop water needs and forecast diversion needs for better river administration. A precipitation network would also help water commissioners determine the approximate time water would arrive at certain locations within the river system rather than waiting for river gages to react.

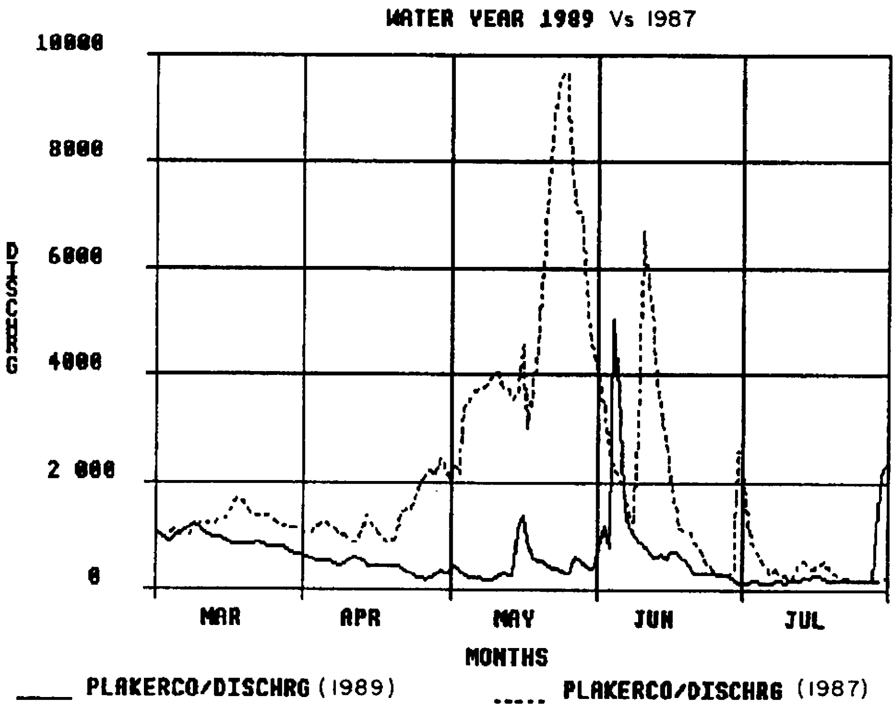
The addition of water quality parameters, both surface and sub-surface, should be considered to develop base line trends. The potential for quantity and quality considerations in water rights administration could be a fact of life someday, and would require not only base-line data but real-time data for daily administration. One example could be the quality effects on the existing ground water due to artificial recharge.

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.

ASSESSING DROUGHT CONDITIONS
IN THE SOUTH PLATTE RIVER BASIN

The South Platte River basin had above average runoff from 1982-1988. Drought conditions began to affect the basin beginning in late 1988. The basin benefits from significant water storage capacity. However, demand is extremely high in the basin generating concern over the availability of future water supplies.

The hydrograph shown plots mean daily discharge values for the gaging station, South Platte River near Kersey (PLAKERCO), for the March-July period for both 1989 and 1987. The mean daily flow for this station in 1987 was 1346 cfs. The mean daily flow for this station for the period 1976-1988 was 1383 cfs. The flow for 1989 was significantly below normal.

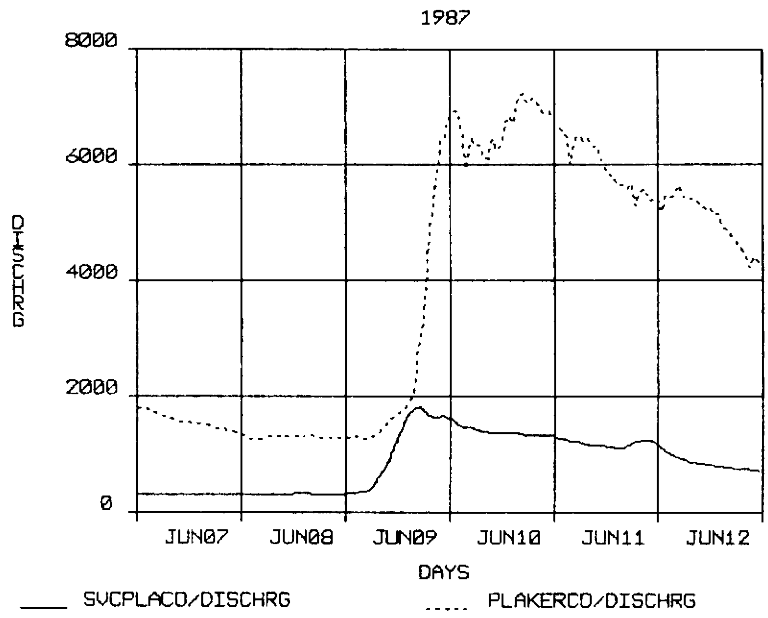


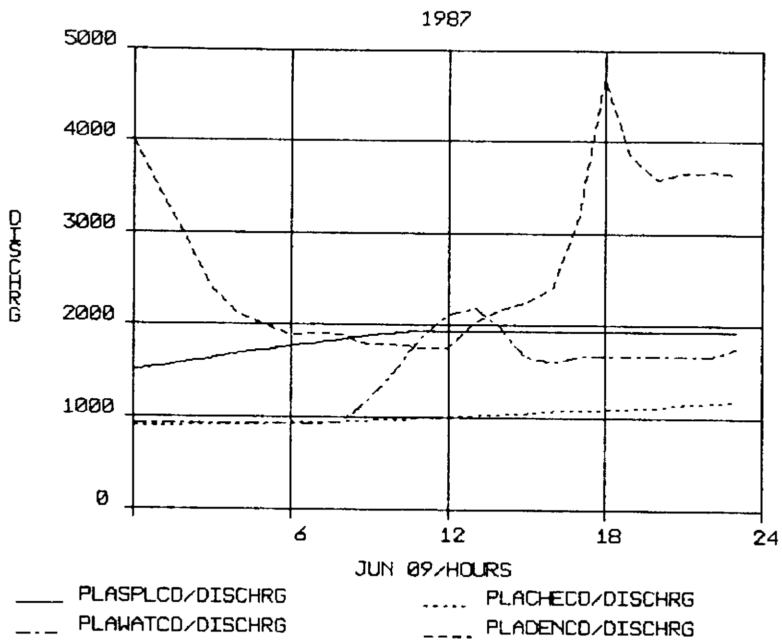
**ADMINISTRATION OF THE SOUTH PLATTE RIVER,
DISTRICT 2 - MONITORING TRIBUTARY INFLOW
UTILIZING REAL-TIME DATA**

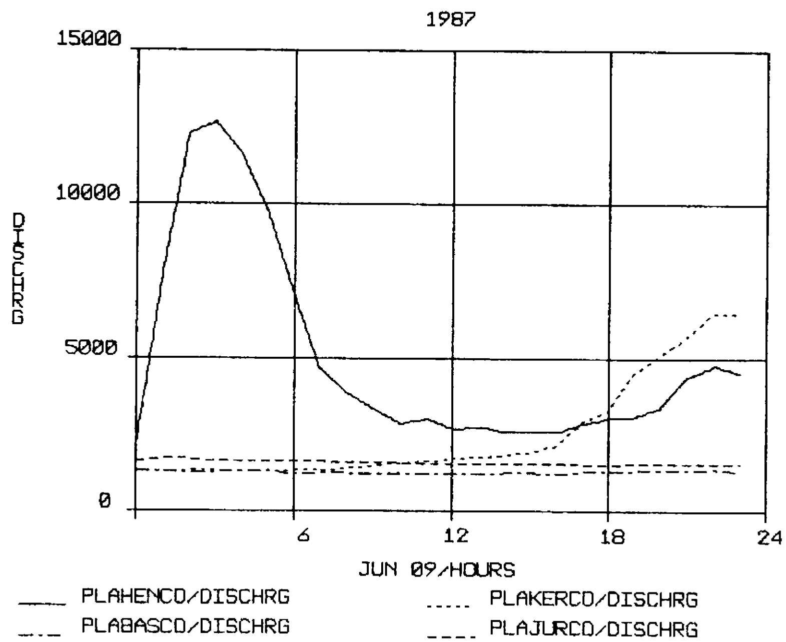
The ability to monitor flow conditions of major tributaries to the South Platte River on a real-time basis is essential to effective administration of downstream water rights. Three major tributaries enter the South Platte River in the reach between Fort Lupton and Kersey (District 2). These tributaries 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) and the South Platte River near Kersey (PLAKERCO) for the period June 7-12, 1987. SVCPLACO supplies approximately 20% of the flow measured at PLAKERCO. A significant hydrologic event on June 9, 1987, increased flow at both stations by over 400%.

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







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 ensure 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 9, 1987. The flow at PLASPLCO (upstream station) increased steadily from about 1500 cfs to 1900 cfs during the 24-hour period while the flow at PLAWATCO increased from about 1000 cfs to 2200 cfs between 0800 to 1300 hours. This indicates that an additional 800 cfs came from releases from Strontia Springs Reservoir, curtailment of diversions by Denver through the Highline Canal and Denver Pipeline, or both. Flow at PLADENCO was unsteady ranging from 1800 cfs to 4600 cfs. As the release from Chatfield Reservoir, measured at PLACHECO, amounted to approximately 1000 cfs, flow at PLADENCO was primarily the result of unsteady flow from Cherry Creek and urban runoff.

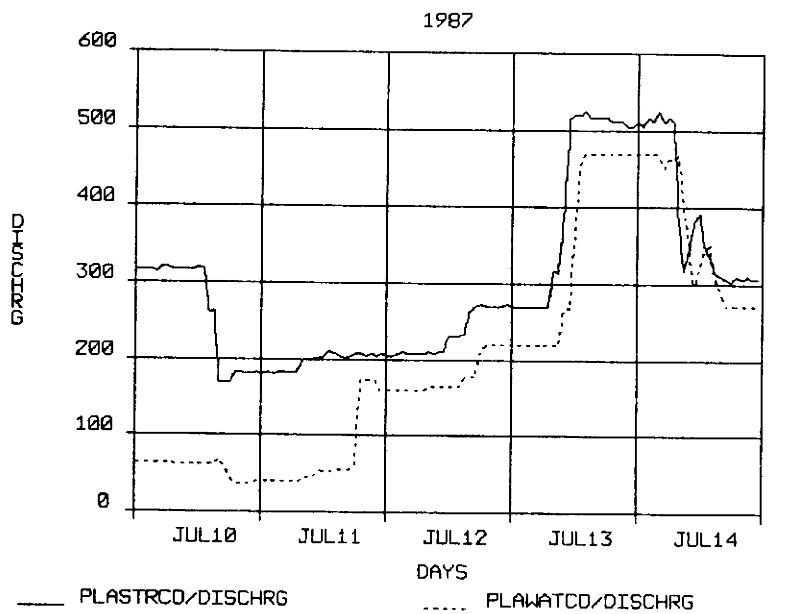
The hydrograph shown in the lower left plots real-time discharge data for four lower South Platte River basin stations, South Platte River at Henderson (PLAHENCO), South Platte River near Kersey (PLAKERCO), South Platte River near Weldona (PLAWELCO), and South Platte River at Julesburg (PLAJURCO), for June 9, 1987. The flow at PLAHENCO increased from approximately 2500 cfs to 12,500 cfs between 0000 to 0300 hours. The hydrograph shows that this water began to reach the downstream station PLAKERCO at about 1600 hours.

Alan Berryman, Division 1 Engineer

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 July 10-14, 1987. 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.



WY	STATION	CODE	HR	JUL10	JUL11	JUL12	JUL13	JUL14
==	=========	=======	==	=========	=========	=========	=========	=========
87	PLASTRCO	DISCHRG	00	262.23	197.43	233.60	414.47	382.54
87	PLAWATCO	DISCHRG	00	56.34	76.00	178.25	347.48	359.64
	DENVER	DIVERSION		206.	121.	55.	67.	23.

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

B. Division 2, Pueblo, Colorado, Arkansas River Basin
Steve Witte, 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 an integral factor in the management program 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.

During the 1987 water year, releases were made from the flood pool in John Martin Reservoir from March 24 to July 7, 1987. The Corps of Engineers determined that the safe channel capacity below the reservoir was 3,000 cfs.

The monitoring system was used successfully to control releases in order to avoid exceeding channel capacity. The inflow stations above John Martin Reservoir are all incorporated into the system's monitoring network. In addition, the major irrigation diversions are in the network. Similar operating procedures were utilized for Pueblo Reservoir. This capability gives valuable lead time in order to make administrative decisions concerning streamflow routing through the reservoirs relative to standard operating procedures, which in turn affects the operation of the entire basin.

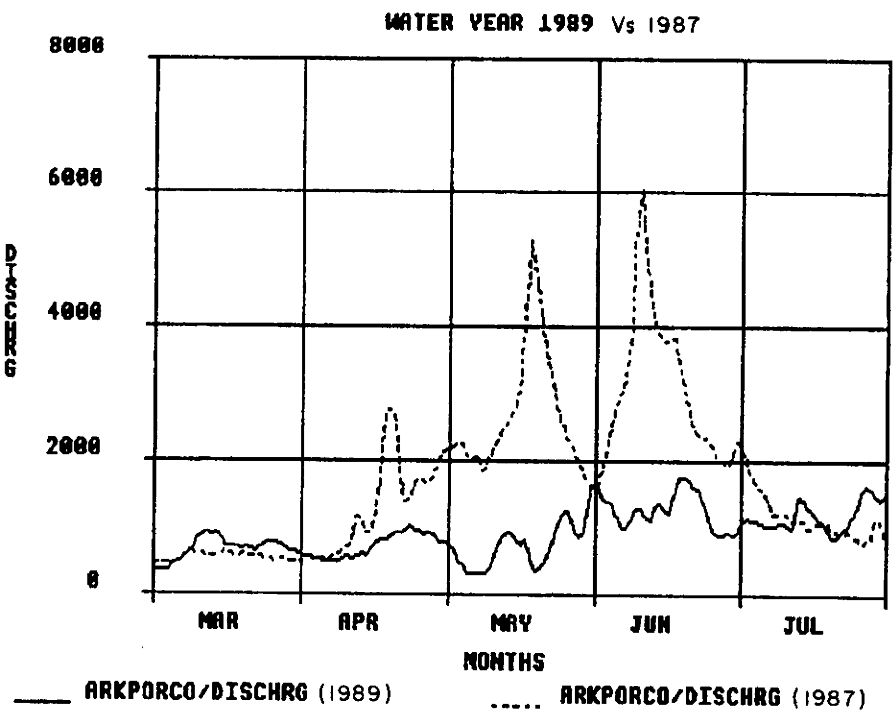
Growing concern with the quality of water as well as the quantity has created a need for data collection of parameters in addition to stream stage. The USGS has a number of stations with water quality monitors which are already in the satellite system's network. These have been interfaced with the DCPs to provide data on water temperature and total dissolved solids (TDS).

New equipment for monitoring air temperature, precipitation, snowfall, and solar radiation has been acquired to assist in improving water rights administration. Precipitation gages will give advance warning of rain peaks, snow pillows will determine snowpack, and pyranometers will provide information pertinent to calculating snowmelt.

ASSESSING DROUGHT CONDITIONS
IN THE ARKANSAS RIVER BASIN

The Arkansas River basin had above average runoff from 1982-1987. Drought conditions began to affect the basin beginning in late 1988. Although there is adequate storage capacity as a result of Pueblo Reservoir and John Martin Reservoir, irrigation demand is extremely high.

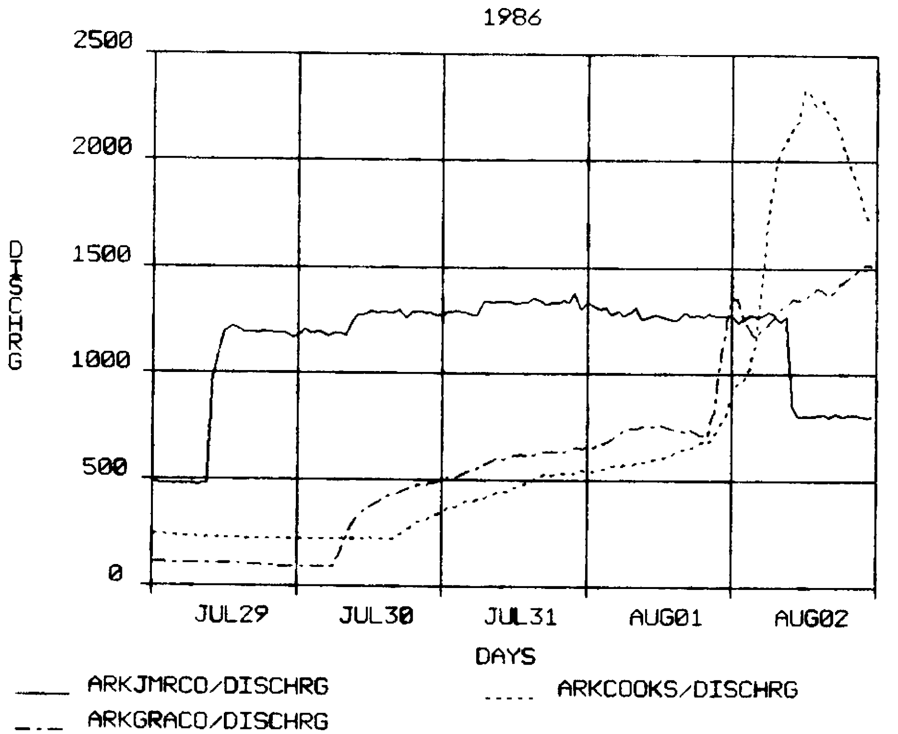
The hydrograph shown plots mean daily discharge values for the gaging station, Arkansas River at Portland (ARKPORCO), for the March-July period for both 1989 and 1987. The mean daily flow for this station in 1987 was 1,039 cfs. The mean daily flow for this station for the period 1940-1952, 1975-1987, was 809 cfs. It would not appear that the flow was much below normal, however, the flow at this station during the June-July period in 1989 was supplemented with release of 350 cfs from Twin Lakes Reservoir.



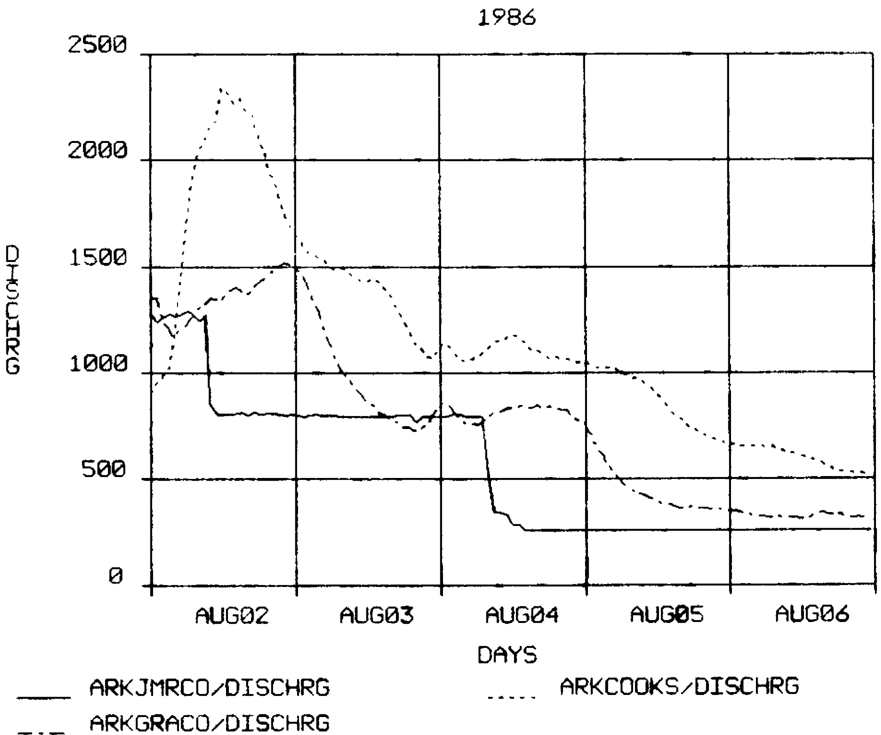
ADMINISTRATION OF THE ARKANSAS RIVER COMPACT UTILIZING REAL-TIME DATA

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 underdeliver.

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



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.

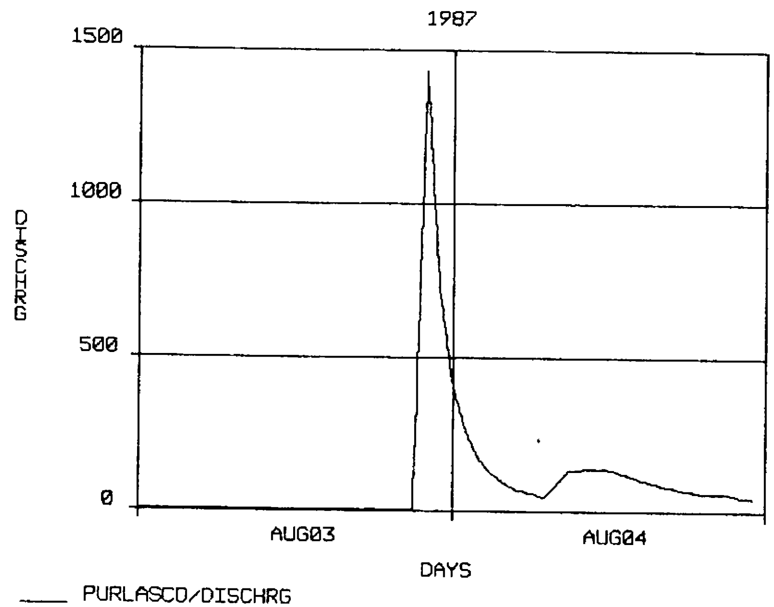
Robert Jesse, Division 2 Engineer

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.

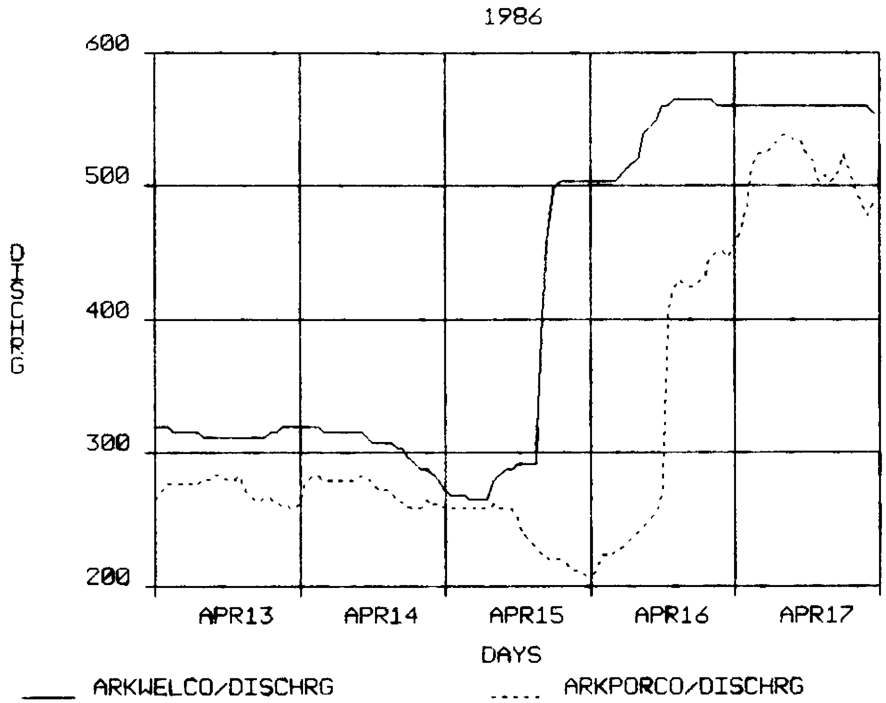
The hydrograph shown plots real-time discharge data for the gaging station, PURLASCO, for the period August 3-4, 1987. Flows on August 3, 1987 were less than 5 cfs. A precipitation event resulted in a rapid increase in discharge beginning at 2115 hours, August 3, 1987. The tabulation of hourly discharge values indicates that flow increased from 5 cfs at 2100 hours to 1670 cfs by 2130 hours. The discharge decreased steadily.

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 August 3, 1987), to a "river call" of July 22, 1948, going into effect on August 4, 1987.



PURLASCO	AUG	03	21:00	DISCHRG	5.04
PURLASCO	AUG	03	21:15	DISCHRG	625.00
PURLASCO	AUG	03	21:30	DISCHRG	1670.00
PURLASCO	AUG	03	21:45	DISCHRG	1640.00
PURLASCO	AUG	03	22:00	DISCHRG	1430.00
PURLASCO	AUG	03	22:15	DISCHRG	1240.00
PURLASCO	AUG	03	22:30	DISCHRG	1040.00
PURLASCO	AUG	03	22:45	DISCHRG	864.00
PURLASCO	AUG	03	23:00	DISCHRG	732.00
PURLASCO	AUG	03	23:15	DISCHRG	615.00
PURLASCO	AUG	03	23:30	DISCHRG	550.00
PURLASCO	AUG	03	23:45	DISCHRG	466.00
PURLASCO	AUG	04	00:00	DISCHRG	414.00
PURLASCO	AUG	04	01:15	DISCHRG	267.00
PURLASCO	AUG	04	01:30	DISCHRG	172.00
PURLASCO	AUG	04	01:45	DISCHRG	124.00
PURLASCO	AUG	04	02:00	DISCHRG	90.30

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



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 #

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

Due to drought conditions in the Rio Grande Basin, and a return to administration of the Rio Grand Compact during the 1989 irrigation season, the satellite monitoring system once again proved to be an invaluable tool for water rights administration on a real-time basis. The system was also used extensively for hydrologic streamflow records development, with most of our records for published gaging stations being worked using the computer. Other uses of the system included snowmelt and streamflow forecasting, dam safety, and reservoir and transmountain diversion accounting.

Administration and accounting of the Rio Grande compact was the primary use of the satellite monitoring system this year. This was the first year since 1985 that it was necessary to deliver a specific percentage of flow recorded at the upper index gages on the Rio Grande and Conejos Rivers to the New Mexico/Colorado stateline. The system enabled us to track the flows and diversions on a daily basis, which kept the amount delivered to the stateline near the minimum required under the restrictions of the compact. The Data Collection Platform installed at the Bureau of Reclamation's closed basin project last year was very useful during this irrigation season since both the Rio Grande and Conejos systems receive credit for a portion of the flows delivered by the project. The satellite-linked station installed during FY 1986-87 at Platoro Reservoir by the Bureau of Reclamation was extremely useful in accounting for water purchased by the Conejos water users from the Bureau of Reclamation. The delineation fo the natural flow component of the Conejos River from storage releases out of Platoro Reservoir is a prime example of the utility of the monitoring system.

The smaller drainages in the San Luis Valley also suffered from low flow conditions during the 1989 water year, so the satellite monitoring system was very critical for administration of water rights on these drainages. With the monitoring system in place, our water commissioners are able to access flow values from their offices or homes, which saves many man hours which can be used for administration of water rights instead.

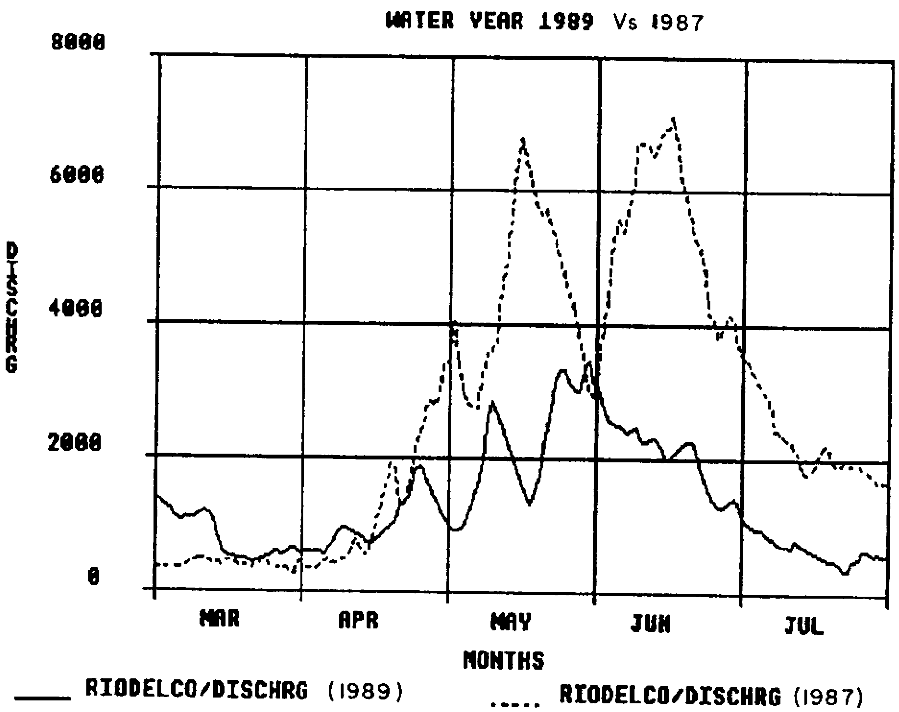
The record development system was used extensively by our hydrographic unit during the 1989 water year. The records for all of the compact gaging stations are worked on a monthly basis to monitor compliance of the Rio Grande Compact. The record development system has been a more efficient and timely means of computing these flows. All of the annual streamflow records for the gaging stations with satellite monitoring equipment in place were worked using the record development system. We have been very pleased with the quality of these records.

The system as a whole has been a very valuable tool for administration of water rights and development of flow records in Division 3. We are hopeful that there will be funding available to install at least two more sites in the San Luis Valley to complete the network on the Rio Grande and Conejos Rivers. We have also been approached by a conservancy district and a private irrigation company that may be willing to install some additional sites on the east side of the valley to monitor drainages out of the Sangre De Cristo Mountains. The addition of the air temperature probes this year on selected sites have been very useful for estimating winter flows at gaging stations, and predicting snowmelt and increases in surface runoff.

ASSESSING DROUGHT CONDITIONS IN
THE RIO GRANDE BASIN

The Rio Grande basin had above average runoff from 1982-1987. Drought conditions began to affect the basin beginning in late 1988. As storage in the basin is extremely limited, declining stream flows at key index gaging stations are of concern.

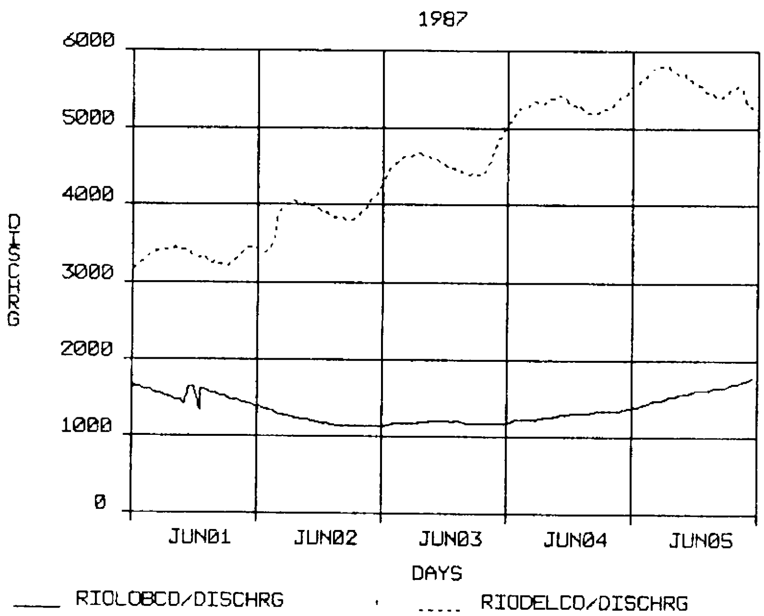
The hydrograph shown plots mean daily discharge values for the gaging station, Rio Grande near Del Norte (RIODELCO), for the March-July period for both 1989 and 1987. The mean daily flow for this station for 1987 was 1482 cfs. The mean daily flow for this station during the period 1889-1987 was 913 cfs. The flow at this station for 1989 was approximately 30% below normal.



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.

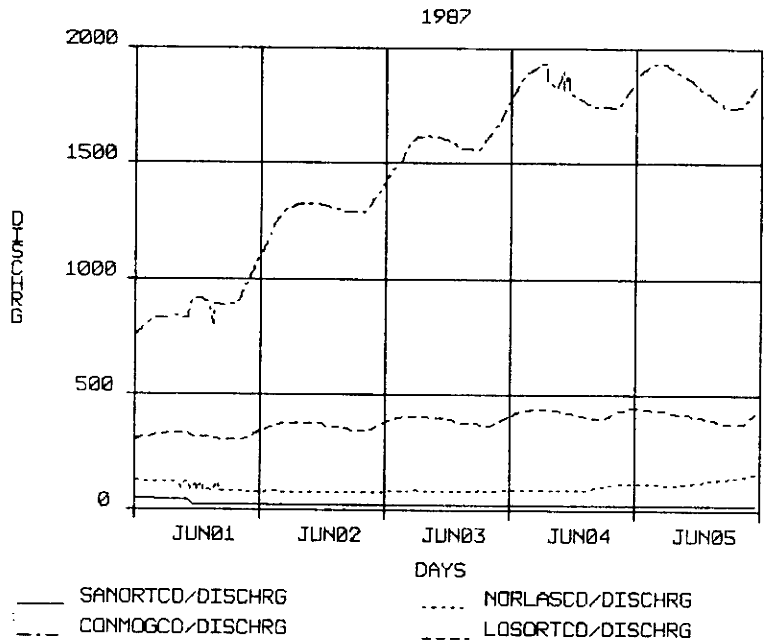
The first hydrograph shown plots real-time discharge data for the gaging stations, Rio Grande near Del Norte (RIODELCO) and the Rio Grande near Lobatos (RIOLOBCO), for the period June 1-5, 1987. During this period, the flow at RIODELCO increased steadily from 3000 cfs to almost 6000 cfs. This represents significantly high flow conditions. Flow conditions during this period at the stateline gaging station, RIOLOBCO, averaged about 1500 cfs. This indicates that diversions below RIODELCO and above RIOLOBCO increased from 1500 cfs on June 1, 1987 to 4000 cfs on June 5, 1987. 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 1	JUN 2	JUN 3	JUN 4	JUN 5
87	RIODELCO	DISCHRG	00	3344.95	3879.35	4555.74	5293.66	5562.31
87	RIOLOBCO	DISCHRG	00	1522.86	1203.24	1180.51	1288.60	1581.09

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 1-5, 1987. Significantly high flow conditions existed at CONMOGCO during this period. The runoff was 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



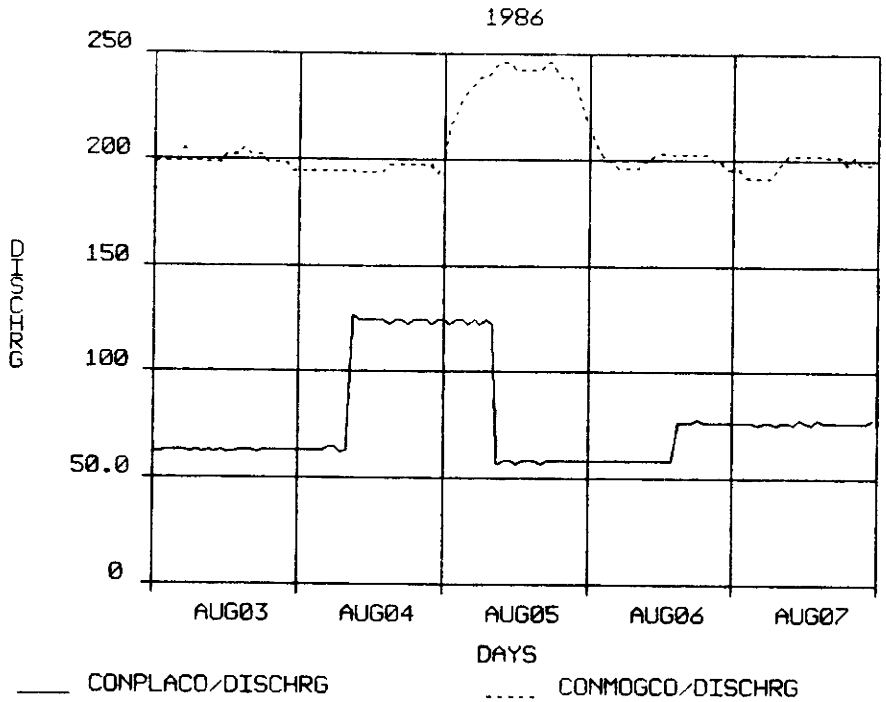
WY	STATION	CODE	HR	JUN 1	JUN 2	JUN 3	JUN 4	JUN 5
==	=========	=======	==	=========	=========	=========	=========	=========
87	SANORTCO	DISCHRG	00	31.84	20.65	19.17	19.93	20.21
87	NORLASCO	DISCHRG	00	104.89	78.82	84.58	96.71	129.12

WY	STATION	CODE	HR	JUN 1	JUN 2	JUN 3	JUN 4	JUN 5
==	=========	=======	==	=========	=========	=========	=========	=========
87	CONMOGCO	DISCHRG	00	879.73	1294.58	1591.70	1823.56	1840.26
87	LOSORTCO	DISCHRG	00	318.85	366.30	393.25	425.48	411.16

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



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

D. Division 4, Montrose, Colorado, Gunnison River Basin
Keith Kepler, Acting Division Engineer

The satellite monitoring system has become an extremely useful tool in the daily administration of water rights in Division 4. The water supply for the past irrigation season was extremely short, making 1989 the second dry year in a row. Flows in the various drainages were from 47% to 70% of average. The system provides the real-time data necessary for meaningful water resources accounting, flood monitoring, dam safety and hydrologic records development.

The availability of real-time data provides for administering direct flows to maximize beneficial use. This is critical in Division 4 where the senior water rights are generally downstream of junior water rights. A timely knowledge of the amount of water available allows delivery to junior water rights while assuring senior users of their entitlement. During the runoff season with large diurnal variations in flow, real-time knowlege of the water supply allows serving a maximum number of users.

The real-time data are useful in separating natural flow from reservoir releases at a point in the stream system. Examples of this application exist at the reservoirs on Muddy Creek and the Uncompahgre River. Satellite-linked gaging stations above and below each reservoir monitor inflows, storage and outflows. This information allows the Division Engineer and his staff to regulate the operation of the reservoirs and differentiate reservoir water from direct flow for proper deliveries.

Division 4 enjoyed an adequate supply of water for the first three years of operation of the satellite monitoring system; thus, the utilization of the data was minimal. The below average water supply of the past two irrigation seasons has demonstrated the necessity of real-time data allowing the Division Engineeer, division staff and water commissioners to be more effective under these conditions. Additional stations monitoring the storage and outflows of Ridgway Reservoir were installed by the Bureau of Reclamation at the request of the Division Engineer. The data are being used by many different entitites, government and private, to facilitate planning and for accounting and administration of our water resources. Division 4 has requested satellite equipment for three additional stations to further exploit the utility of this new technology.

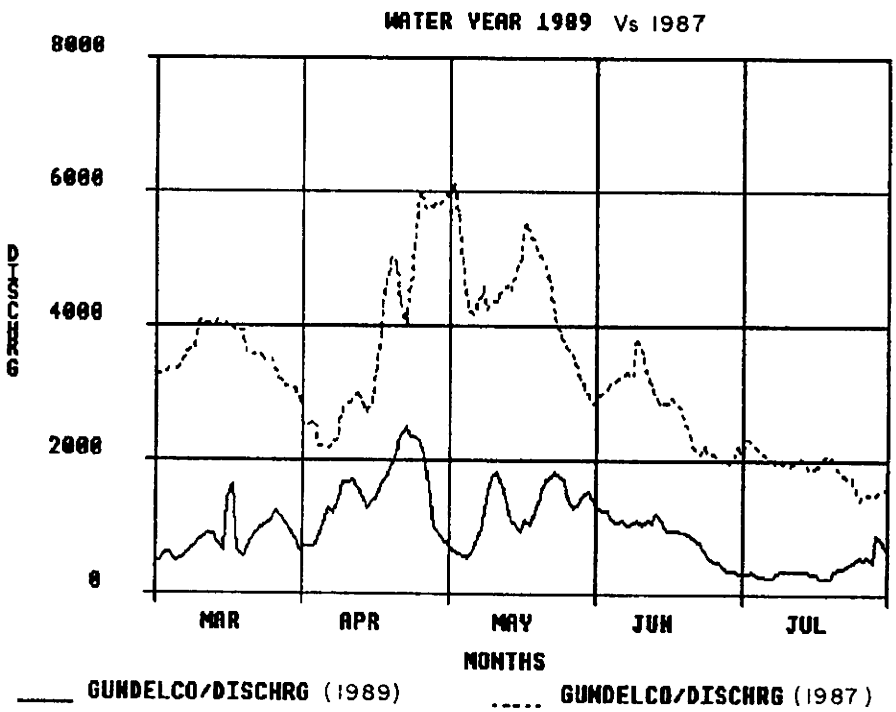
A benefit of the satellite monitoring system is in operations cost reduction. Like water, operating funds are in short supply. The real-time data provided by the satellite system has served to hold down man hours and travel costs associated with the administration of a growing and complex set of water rights.

The flood warning capability of the satellite network is an untried but potential benefit to Division 4. While flooding has not been a major concern the past several years, the possibility exits. Any early warning of a flood event would have great value.

ASSESSING DROUGHT CONDITIONS IN THE GUNNISON RIVER BASIN

The Gunnison River basin had above average runoff from 1982-1987. Drought conditions began to affect the basin beginning in 1988. There is significant storage capacity in Blue Mesa Reservoir but limited capacity beyond that.

The hydrogaph shown plots mean daily discharge values for the gaging station, Gunnison River at Delta (GUNDELCO), for the March-July period for both 1989 and 1987. The mean daily flow for this station for 1987 was 2858 cfs. The mean daily flow for this station for the period 1976-1987 was 2,584 cfs. The flow was only an estimated 50% of normal.

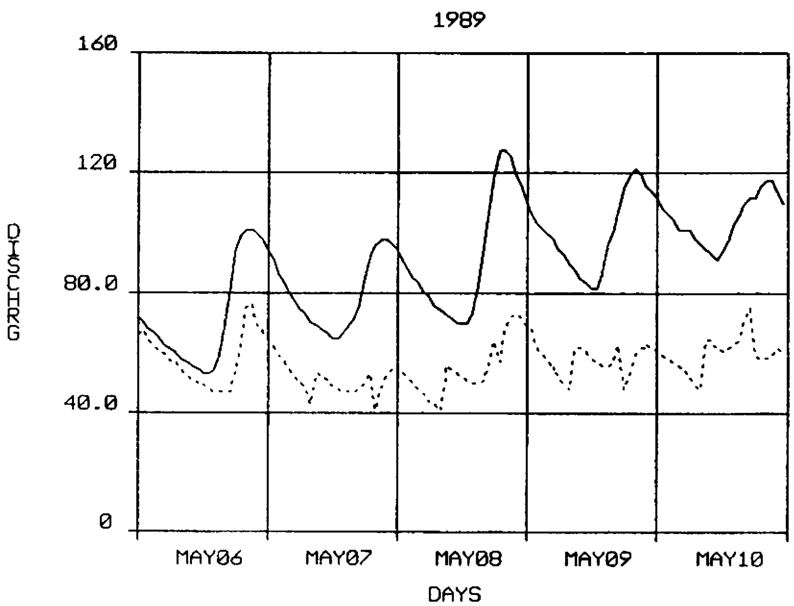


ADMINISTRATION OF SURFACE CREEK UTILIZING REAL-TIME DATA

The administration of Surface Creek is complicated by having to satisfy all natural flow rights while also delivering storage water from the Grand Mesa reservoirs and transbasin diversions. Surface Creek is a highly over-appropriated system with the majority of senior rights located below numerous junior rights.

The availability of real-time flow data has become an essential tool in administering water rights in Surface Creek. 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 May 6 - May 10, 1989. Diurnal peak flows were diverted into lower priority ditches while satisfying senior downstream diverters. The system provides a way to estimate peak flows and downstream arrival times of deliveries to maximize the beneficial use of the water. Manpower and travel are reduced in not having to visit each station several times a day to take a reading.

Keith Kepler, Acting Division 4 Engineer
Richard Drexel, Water Commissioner, District 40



____ SURCEDCO/DISCHRG ..... SATCEDCO/DISCHRG

WY	STATION	CODE	HR	SAT MAY 6	SUN MAY 7	MON MAY 8	TUE MAY 9	WED MAY10
89	SURCEDCO	DISCHRG	00	71.55	79.20	91.53	100.06	104.53
89	SATCEDCO	DISCHRG	00	57.97	51.34	54.75	58.32	60.27

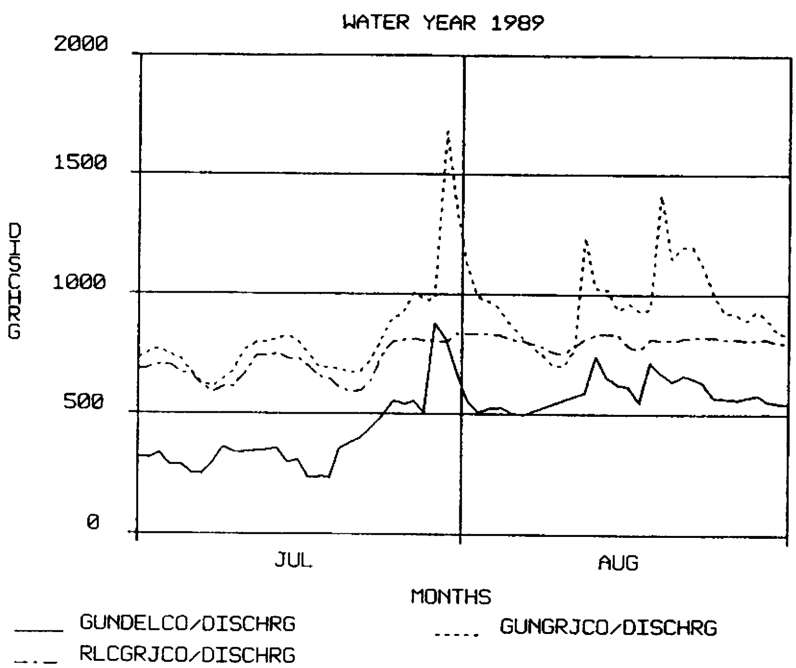
ARCHIVES >

ADMINISTRATION OF THE GUNNISON RIVER AND THE REDLANDS CANAL UTILIZING REAL-TIME DATA

Flow at the Gunnison River at Grand Junction is largely composed of waters from the Gunnison River at Delta, inflows from the Uncompahgre River at Delta plus irrigation return flows at several points. Only minor diversions and returns exist between the gaging station, Gunnison River near Grand Junction (GUNGRJCO) and the point of diversion for the Redlands Canal (RLCGRJCO). The RLCGRJCO has a relatively senior right of 670 cfs from the Gunnison River for power generation and irrigation. Low river flows in early July resulted in a call being placed by the RLCGRJCO on July 10. The River recovered naturally during this period and administration was avoided until July 20 when the flows dropped again. On July 23-24, rains in the upper basin increased flows in the Gunnison eliminating the shortage.

The hydrograph shown plots mean daily flows for the gaging stations Gunnison River at Delta (GUNDELCO), GUNGRJCO and RLCGRJCO for July and August 1989. The flow at GUNGRJCO dropped below 670 cfs on July 7-8, 1989, and approached that level again on July 21-22, 1989. Administration of the river for the Redlands Canal call only lasted three days before rains provided relief.

Keith Kepler, Acting Division 4 Engineer

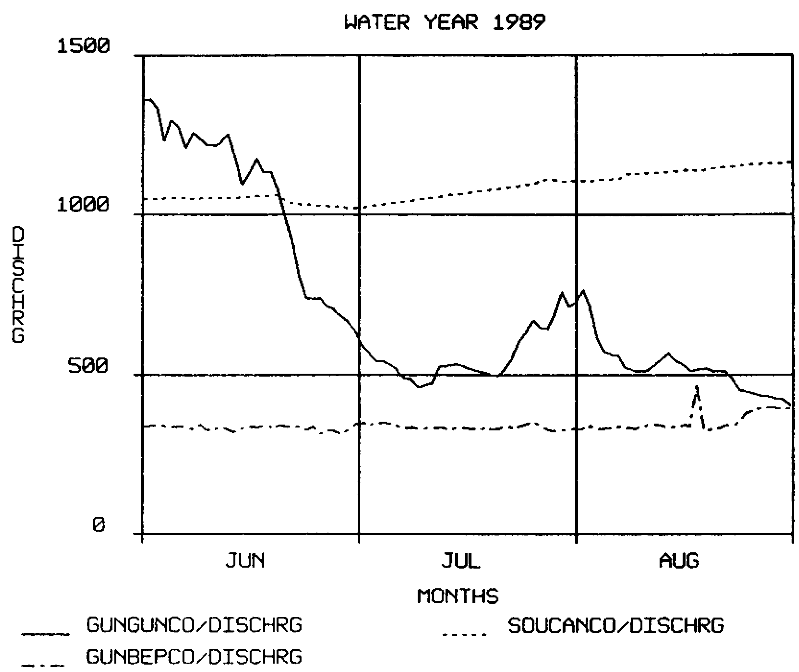


ADMINISTRATION OF THE GUNNISON RIVER AND BUREAU OF RECLAMATION RESERVOIRS UTILIZING REAL-TIME DATA

Flows in the lower Gunnison River are controlled by three Bureau of Reclamation Reservoirs; Blue Mesa, Morrow Point and Crystal. The major inflow into the reservoirs is monitored by the gaging station, Gunnison River near Gunnison (GUNGUNCO). The inflow is primarily the result of snowmelt runoff and return flow from extensive mountain meadow irrigation. Releases from the reservoir system, primarily for power generation, were relatively constant during the summer months at 1450 cfs. The releases greatly exceeded the inflow during the irrigation season. Immediately below these reservoirs, the Gunnison Tunnel diverted 1100-1200 cfs as monitored by the gaging station, South Canal near Montrose (SOUCANCO), 300+ cfs was kept in the river to flow through the Black Canyon as monitored by the gaging station Gunnison River below East Portal (GUNBEPCO).The 1100+ cfs diverted through the Gunnison Tunnel by the Uncompahgre Valley Water Users Association is delivered to the Uncompahgre River system and used to irrigate 80,000+ acres of farmland between Colona and Delta.

The hydrograph shown plots the mean daily inflow to the Currecanti Reservoirs (GUNGUNCO) and the releaes (SOUCANCO & GUNBEPCO). Although the Currecanti Reservoirs are operated for power generation, the hydrograph illustrates how the irrigation users benefit from their presence.

Keith Kepler, Acting Division 4 Engineer

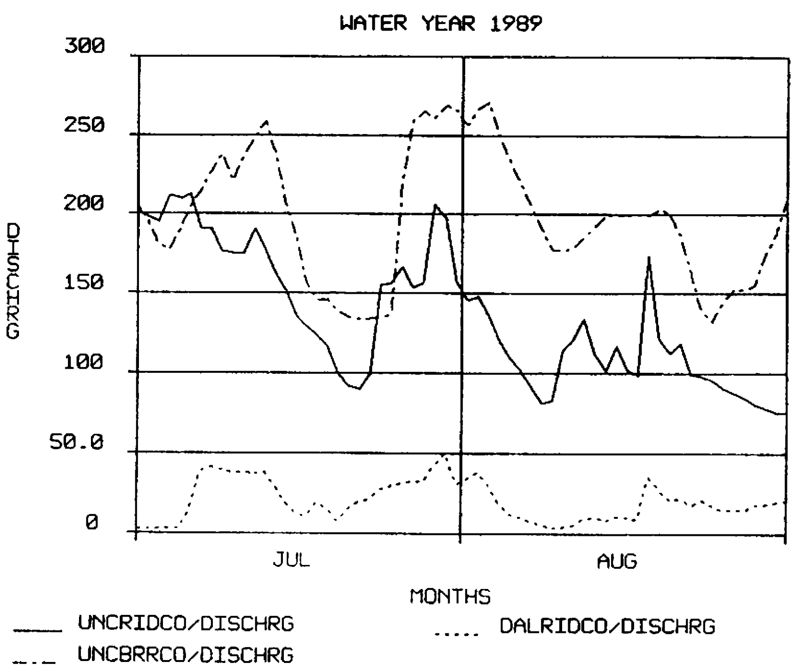


ADMINISTERING THE OPERATION OF RIDGWAY RESERVOIR UTILIZING REAL-TIME DATA

The water rights for Ridgway Reservoir are relatively junior and must be closely administered to avoid injury to downstream senior rights. Two gaging stations, Uncompahgre River near Ridgway (UNCRIDCO) and Dallas Creek near Ridgway (DALRIDCO), monitor inflows to the reservoir and two stations, Ridgway Reservoir (RIDRESCO) and Uncompahgre River below Ridgway Reservoir (UNCBRRCO), monitor storage and releases respectively. Real-time data from the satellite monitoring system provides accounting information adequate to allow the reservoir to operate with negligible impact on senior rights.

This hydrograph shown plots the inflows at DALRIDCO and UNCRIDCO against the outflow at UNCBRRCO for the period of July and August, 1989.

Keith Kepler, Acting Division 4 Engineer



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.

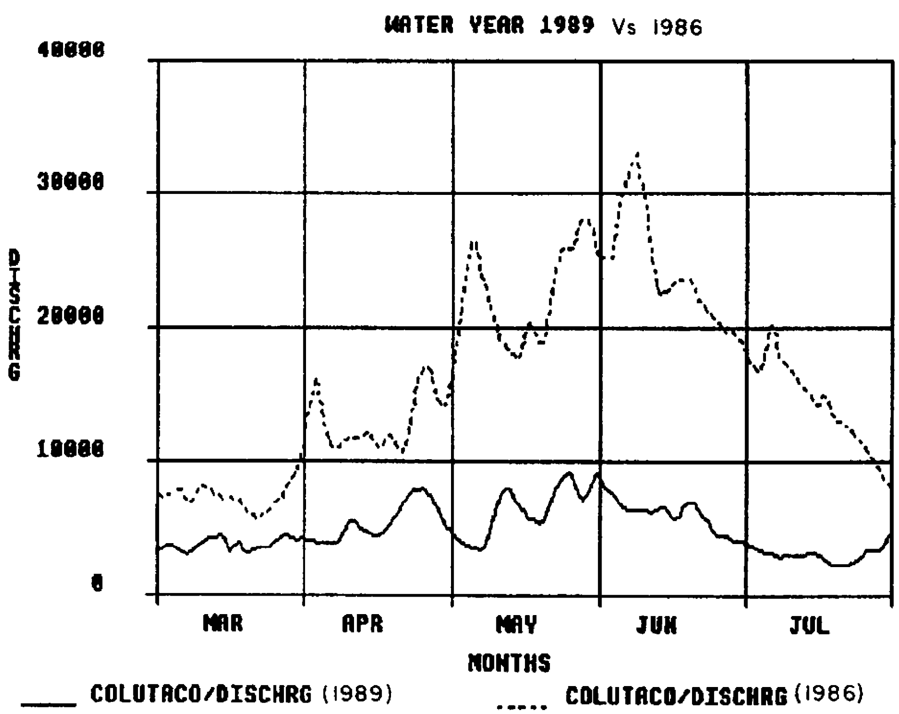
The initial step in this process is the assimilation of data for direct diversions, streamflows, reservoir contents, evaporation, and precipitation. Once the data are entered into a spread sheet, needed diversion or storage adjustments can be made. Some of the data are obtained from the water commissioners on site checks and phone calls. The remainder are 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 saves 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, 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.

ASSESSING DROUGHT CONDITIONS
IN THE COLORADO RIVER BASIN

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 beneficial use all of its entitlement under the Compact. Compact administration has been relatively uncomplicated in this decade due to abundant water supplies. However, this may not be the case if drought conditions continue in western Colorado.

The hydrograph shown plots mean daily discharge values for the gaging station, Colorado River near the Colorado-Utah Stateline (COLUTACO) for the March-July period for both 1986 and 1989. The mean daily flow for this station in 1986 was greater than 11,000 cfs. The mean daily flow for this station for the period 1950-1987 was 5,736 cfs. The flow for 1989 was below normal.

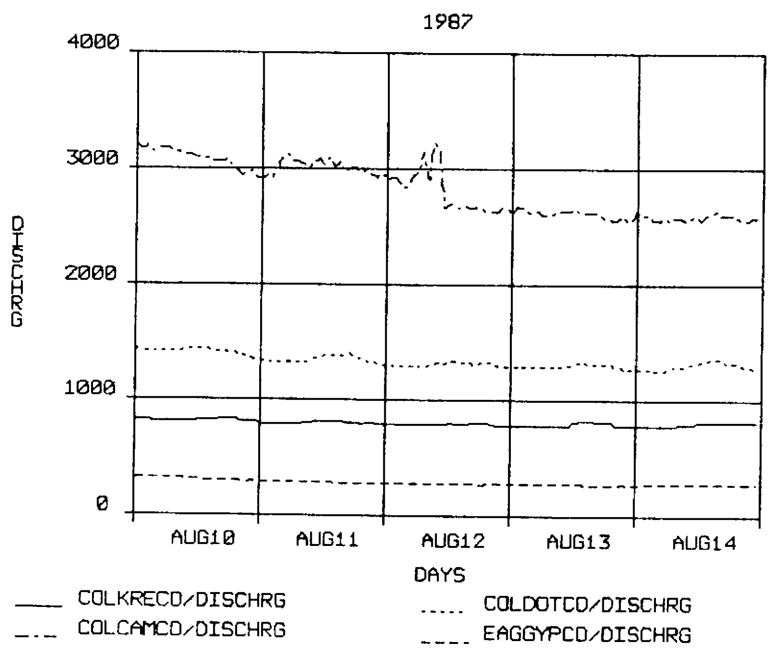


ADMINISTRATION OF THE COLORADO RIVER FROM KREMMLING TO CAMEO UTILIZING REAL-TIME DATA

The 1987 water year was one of above average water supply for the Colorado River basin. However, conditions were such that a "river call" still had to be implemented for part of the year. 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 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 August 10-14, 1987. The discharge measured at COLDOTCO, above the Glenwood Shoshone Power Plant, ranges from 1250 cfs to 1400 cfs. 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 on August 12, 1987, to ensure that the senior right for the Glenwood Shoshone Power Plant would not be injured. Flow at COLCAMCO dropped to approximately 2,600 cfs but above the 2,260 cfs level that prompts a river call.

Orlyn Bell, Division 5 Engineer

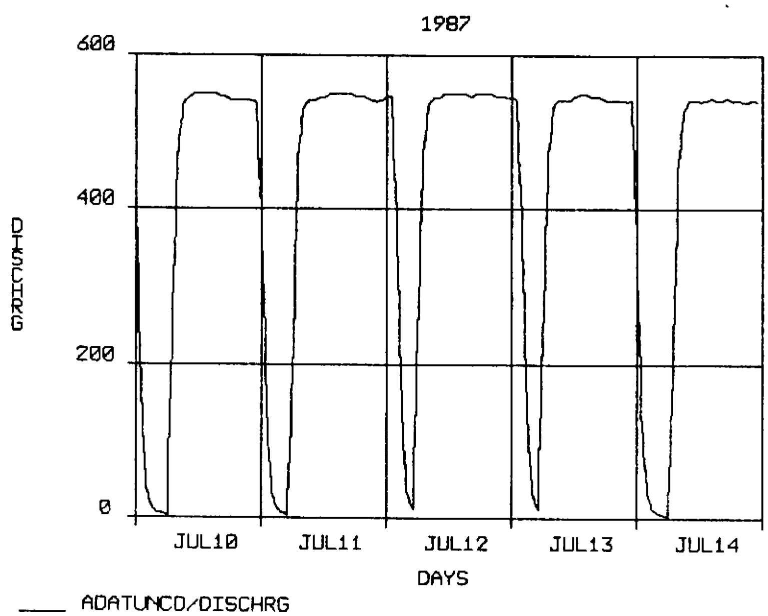


MONITORING TRANSMOUNTAIN DIVERSION FLOWS THROUGH THE ADAMS TUNNEL UTILIZING REAL-TIME DATA

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 July 10-14, 1987. 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	JUL10	JUL11	JUL12	JUL13	JUL14
87	ADATUNCO	DISCHRG	00	395.45	415.75	460.11	455.18	388.78

F. **Division 6, Steamboat Springs, Colorado, White/Yampa River Basin**
Ed Blank, 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, a DCP has been installed by this office on the gaging station on the upper reaches of the Little Snake River.

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 which would result in an incremental cost of approximately $2,884 per year. 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 North Platte River and its tributaries are the most consistently administered streams in Division 6. Two water commissioners are responsible for the administration of approximately 435 structures. Historically, the water commissioners have 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 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. These stations were accessed daily by the water commissioners during water administration periods. The Michigan River Water Conservancy District and the Jackson County Water Conservancy District enjoy the benefits of these two stations.

A network of four DCPs 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 Coal Creek at Mouth near Yampa (COAYAMCO), are maintained primarily for administrative efficiency. By maintaining the BEATOPCO station, which measures the inflow to Yamcolo Reservoir, and COAYAMCO, I have been able to reallocate manpower resources to allow one water commissioner to perform the same work formerly accomplished by two in this area. This year, satellite-linked monitoring hardware was installed at Yamcola Reservoir and the Yampa River above Stagecoach Reservoir. These stations provide essential data relative to reservoir operations.

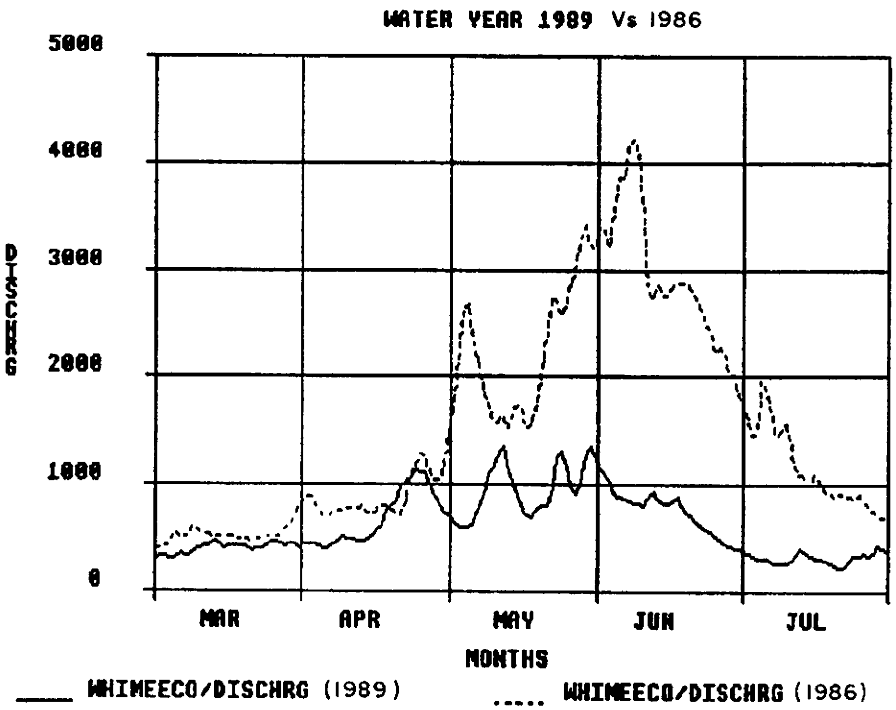
The monitoring hardware operating at the Elk River at Clark was moved downstream to the mouth at Milner. This was necessary to ensure that senior rights were being satisfied during low flow periods.

The gaging station, Yampa River near Maybell (YAMAYCO), 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 USGS installed monitoring hardware at the gaging station, Yampa River at Steamboat Springs (YAMSTECO) that assists in tracking upstream reservoir releases.

ASSESSING DROUGHT CONDITIONS IN
THE WHITE RIVER BASIN

The White River basin had above average runoff conditions from 1982-1986. Drought conditions began to affect the basin beginning in 1987. Very limited storage capacity has exasperated the effect of the drought.

The hydrograph shown plots mean daily discharge values for the gaging station, White River near Meeker (WHIMEECO), for the March-July period for both 1989 and 1986. The mean daily flow for this station for the period 1902-1986 was 633 cfs. The flow was only an estimated 50% of normal.

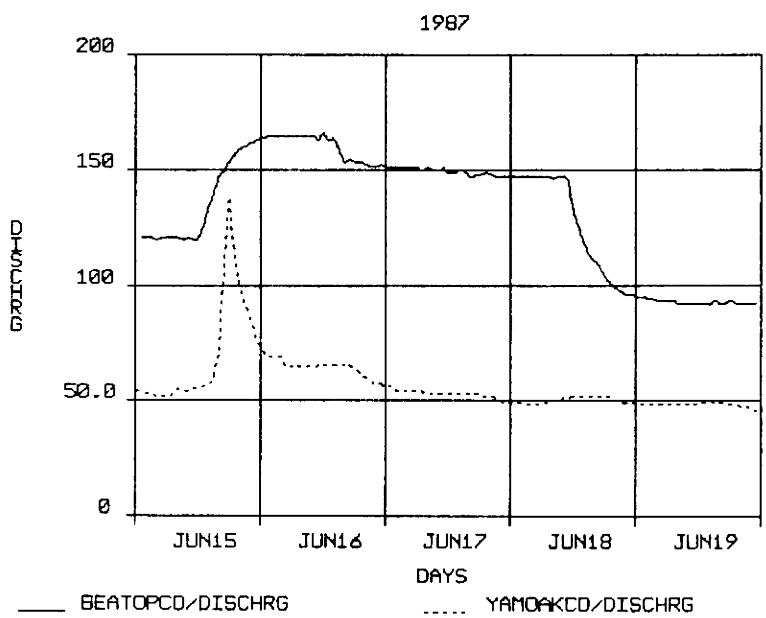


ADMINISTRATION OF THE BEAR-YAMPA RIVER - DISTRICT 58 UTILIZING REAL-TIME DATA

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, 1987. Flow at BEATOPCO, regulated by releases from Still-water Reservoir, fluctuated between 90 cfs to 165 cfs over the 5-day period. Flow at the downstream station, YAMOAKCO, was steady at 50 cfs over the 5-day period except for a precipitation related peak on June 15, 1987.

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. Our monitoring network is unique in that the stations are located in a stream drainage which consists of separate and individual but large streams which exit the state without becoming a single administrative unit as in the other divisions.

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 adjust reservoir releases.

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. Early morning flows can be used to predict anticipated daily flows. Diversions are adjusted to allow for maximum daily usage yet meeting compact requirements. Dry conditions experienced in late summer and early fall required precise and prompt delivery of irrigation water to Colorado users. 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.

We were able to utilize the historic data records to make tabular and graphical presentations to public groups showing effects of various water right's demands on the La Plata and Florida Rivers. These data were assembled using the Hydromet applications software.

In June, the plotted flows of the Hesperus and Stateline gages were compared using software developed for the VAX. With this we were able to see significant losses through the system where the stream channel was affecting the flow. We were able to respond by June 19 and 20 to get the Compact back into an administration credit situation.

Based on the predicted runoff from the Colorado Water Supply Outlook of 46,000 A.F. and 160,000 A.F. inflow on the Florida and Pine Rivers, we were able to look at storage capacity and the predicted use to determine that nearly 80% of our storage would be required. This information was then passed along to various ditch companies to alert them of the potential draft of their supplies. Thus warned, they were able to closely monitor their Project users.

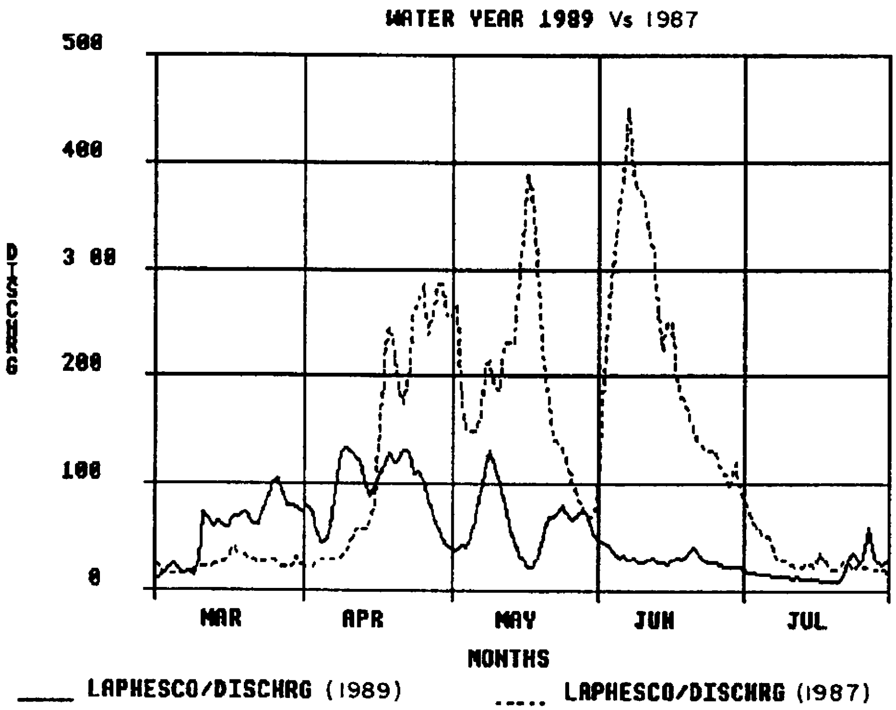
System improvements have been made at several locations with the installation of air temperature gages and three precipitation gages. An evaporation pan was installed below Vallecito Reservoir. It has functioned well; however, the data generated is showing marked discrepancies with a nearby check station, and is leading to questions about the reliability of the depth monitoring sensor on the pan, as well as our confidence in evaporation data from any source. It is recommended that we not rely upon evaporation pan data until calibration and accuracy evaluations are made.

Additional stations were added on the system within Divisin 7 on the La Plata River at Cherry Creek and Long Hollow. They enable us to develop a historical record of return flows on the La Plata River as well as to determine real time stream flow characteristics in situations such as described above.

ASSESSING DROUGHT CONDITIONS
IN THE LA PLATA RIVER BASIN

The La Plata River basin had above average runoff from 1982-1987. Drought conditions began to affect the basin beginning in late 1987. Conditions reached a point in 1989 where deliveries to New Mexico did not satisfy the La Plata River Compact.

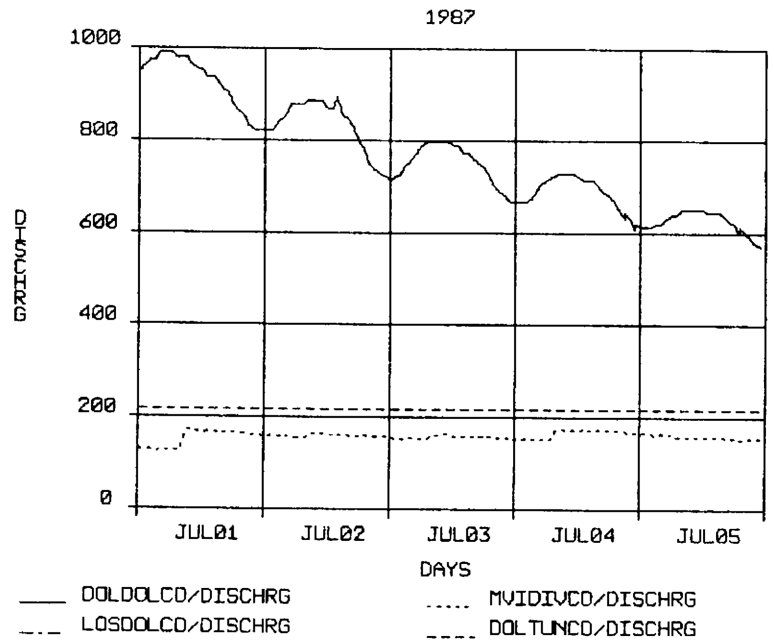
The hydrograph shown plots mean daily discharge values for the gaging station, La Plata River at Hesperus (LAPHESCO), for the March-July period for both 1987 and 1989. The mean daily flow for this station for 1987 was 63 cfs. The mean daily flow for this station for the period 1918-1987 was 46 cfs. After an early runoff in 1989, the flows became critically low during the summer months.



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 July 1-5, 1987. Inflow into McPhee Reservoir steadily decreased from 1000 to 600 cfs with outflow remaining steady at about 375 cfs. There is no inflow from LOSDOLCO. The table lists mean daily discharge values for the period.



WY	STATION	CODE	HR	JUL 1	JUL 2	JUL 3	JUL 4	JUL 5
87	DOLDOLCO	DISCHRG	00	927.91	831.72	752.38	689.47	624.60
87	LOSDOLCO	DISCHRG	00	0.01	0.00	0.00	0.00	0.00

WY	STATION	CODE	HR	JUL 1	JUL 2	JUL 3	JUL 4	JUL 5
87	MVIDIVCO	DISCHRG	00	150.74	160.61	158.11	164.73	159.49
87	DOLTUNCO	DISCHRG	00	217.70	217.97	217.87	218.07	217.96

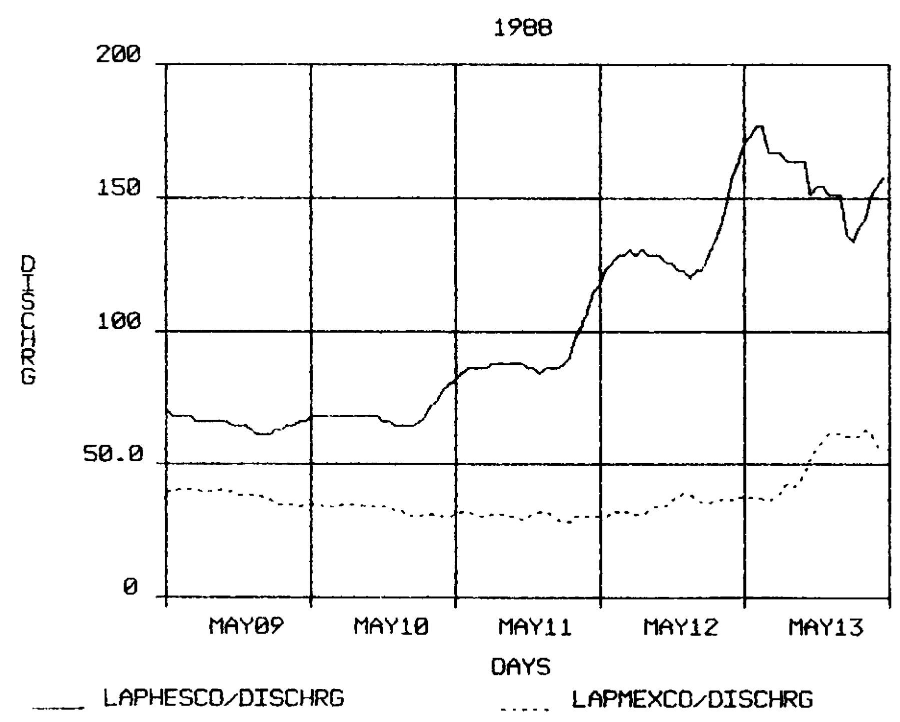
Chuck Lile, Division 7 Engineer
John Porter, Dolores Project Manager

THE ADMINISTRATION 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 50% of the flow at the Hesperus index gage, to the Colorado-New Mexico stateline on a daily basis. Decreased flow conditions prompted administration of the La Plata River system in May 1988, when New Mexico requested up to 90 cfs of its entitlement.

The hydrograph shown 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), for the period May 9-13, 1988. The hydrograph shows that flow increases significantly at LAPHESCO beginning on May 11, 1988. The water commissioner continuously adjusted the system to provide New Mexico with its proper entitlement but no more than that.

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



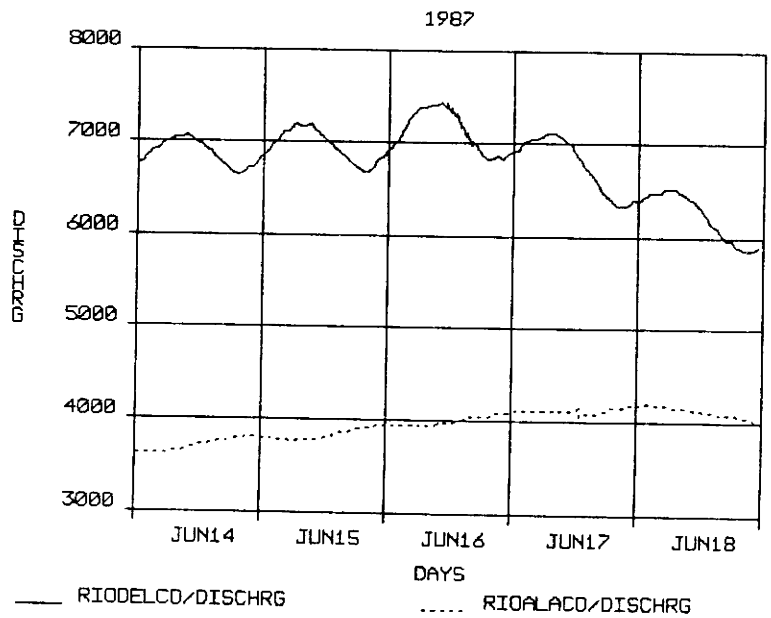
H. Flood Monitoring Utilizing Real-Time Data

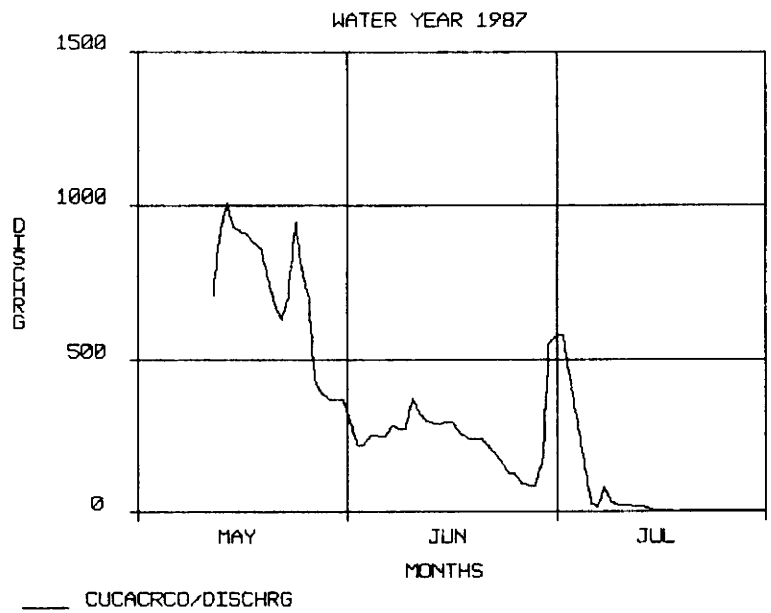
The ability to obtain real-time river data through the state computer during the recent runoff season was enormously useful in aiding the National Weather Service (NWS) to satisfy the requirement put upon it by Congress to furnish flood watch and warning information to the public. There were at least 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.

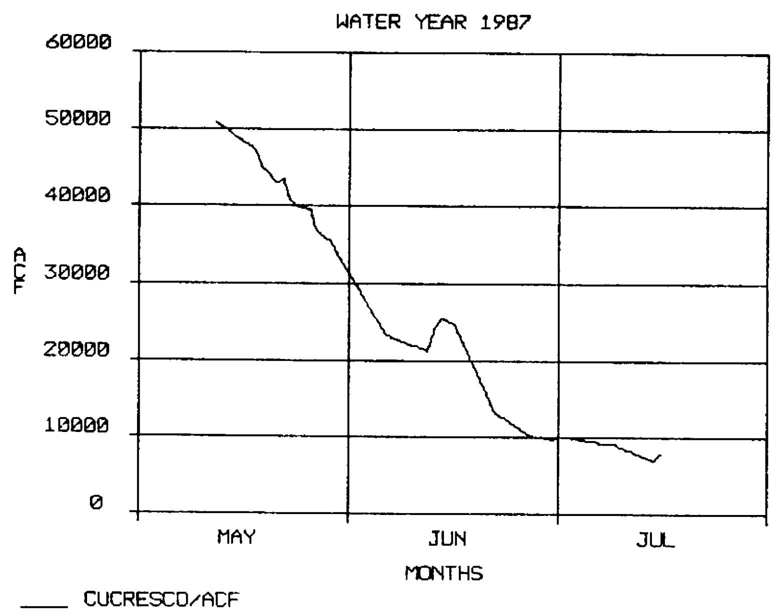
The Rio Grande in the vicinity of Alamosa reached the alarm level on June 14, 1987, triggering a computer generated call to the NWS Central Forecast Office (NWS-CFO). Since the NWS-CFO was able to monitor the river levels continuously through the system's computer, the NWS-CFO was able to ascertain that 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 14-18, 1987. Flow at the upper station, RIODELCO, reached an alert level of 7,060 cfs at 0800 hours on June 15, 1987. Flow at the lower station, RIOALACO, reached an alert level of 3,000 cfs at 0000 hours on June 14, 1987. Evaluation of upstream conditions at RIODELCO, utilizing real-time data, indicated that on June 17, 1987, the flow was decreasing.

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







I. Dam Safety Monitoring Utilizing Real-Time Data

On May 10, 1987, the earthen dam at Cucharas Reservoir, located approximately 40 miles south of Pueblo in the Cucharas River basin, showed evidence of structural deformation. The reservoir, at near capacity of 51,000 acre-feet of water, was instrumented the next day with satellite-linked data collection hardware to monitor reservoir capacity and inflow on a real-time basis.

The reservoir outlet was capable of releasing only 500 cfs. An emergency outlet completed on May 15, 1987, provided for the release of an additional 500 cfs. The hydrograph located in the upper left hand corner plots mean daily discharge values for the gaging station, Cucharas River above Cucharas Reservoir (CUCACRCO), for the period May-July, 1987. During the month of May, inflow averaged approximately 700 cfs with peaks up to 1,000 cfs. Precipitation in late June and early July accounted for an apparent increase in runoff and subsequent inflow. The hydrograph located in the lower left hand corner plots mean daily content values for Cucharas Reservoir (CUCRESCO) for the same period. Evacuation of the reservoir was steady with an apparent slow down by late June. Reservoir capacity reached a safe level of less than 10,000 acre-feet by mid-July.

Robert Jesse, Division 2 Engineer

J. Historic Flow Data

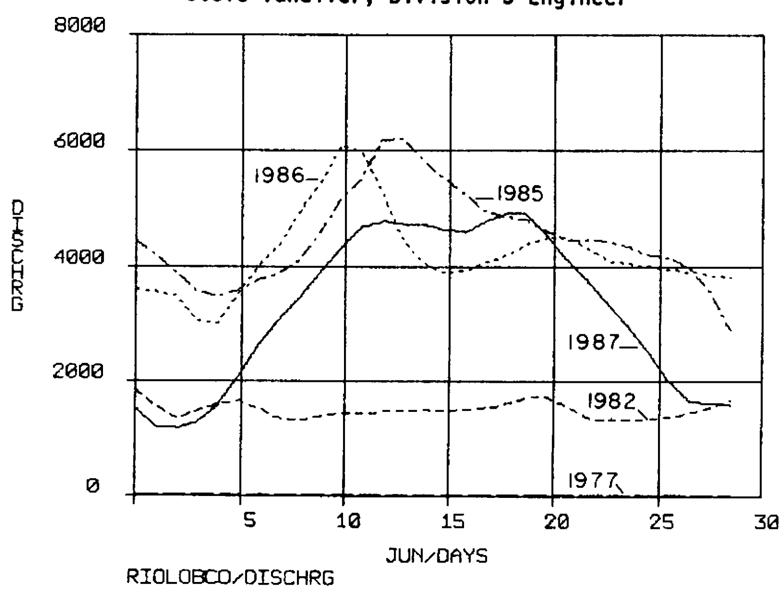
By mid-1988, historic flow data will be archived in the satellite monitoring system data base for key gaging stations in Colorado. These data, representing mean daily discharge, will go back as far as 80 to 90 years for some stations. The data will be on-line and accessible through the HYDROMET ARCHIVES 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, 1986, and 1987. 1977 represents a period of record low flows; 1982 represents an average flow period based on a twenty-year average; and 1985-1987 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 1985-1987. 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
Steve Witte, Division Engineer

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

Division 4, Montrose, Colorado, Gunnison River Basin
Keith Kepler, Acting Division Engineer

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

Division 6, Steamboat Springs, Colorado, White/Yampa River Basin
Ed Blank, 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.

APPENDIX A

GOES-LINKED REMOTE DATA COLLECTION HARDWARE AND ACCESSORIES

Data Collection Platform	$3,500 - $4,000
Incremental Shaft Encoder	450 - 1,100
Yagi antenna	200 - 250
Antenna cable	50 - 75
12-volt power supply	50 - 175
Power supply cable	25 - 50
Environmental enclosure	200 - 300
Solar panel	250 - 350
Solar panel cable	25 - 50
Programming terminal	750 - 1,250
Grounding package	50 - 75
Float/tape/counterweight	100 - 200

Installation costs (pre-existing structure) range from $200 - $700.

VENDORS

Handar, Inc.
1380 Borregas Avenue
Sunnyvale, CA 94089
Telephone: (408) 734-9640

Sutron, Inc.
2190 Fox Mill Road
Herndon, VA 22071
Telephone: (703) 471-0810

Synergetics, Inc.
P. O. Box E
Boulder, CO 80306-1236
Telephone: (303) 530-2020

APPENDIX B

SENSORS THAT CAN BE UTILIZED IN GOES-LINKED REMOTE DATA COLLECTION

Water Level Measurement Sensors

Type:	Shaft encoder/float
Cost:	$500 - $1,200
Output:	Analog-to-digital
Requirements:	Stilling Well
Advantages:	Accurate to ±.01 foot; easy to install and operate
Limitations:	Requires a stilling well, difficult to operate with ranges greater than 10 feet; ice effected

Type:	Acoustic echo-ranging
Cost:	$650 - $850
Output:	0-5 VDC or 4-20 mA
Requirements:	Stable platform installation
Advantages:	Non-contact sensor; not effected by water conditions
Limitations:	Accuracy ±.05% of range; range 2-14 feet

Type:	Pressure transducer (strain gauge)
Cost:	$700 - $1,500
Output:	0-5 VDC or 4-20 mA; can be converted to BCD to allow for analog-to-digital output
Requirements:	Stable sensor position
Advantages:	No stilling well required; easy to install and operate; wide range available; portable; can position sensor at considerable distance from transmitter
Limitations:	Accuracy ±0.1% of range; power consumption 175 mA from 12 VDC

Precipitation Measurement Sensors

Type:	Tipping bucket
Cost:	$500 - $700
Output:	Analog incremental counter
Requirements:	Unimpeded rain catchment
Advantages:	Easy to install and operate
Limitations:	Liquid precipitation only

Type:	Weighing bucket
Cost:	$1,600 - $2,200
Output:	0-5 VDC or 4-20 mA
Requirements:	Unimpeded rain catchment
Advantages:	Both liquid and frozen precipitation
Limitations:	Scheduled maintenance necessary; measures cumulative precipitation minus evaporation

APPENDIX B (cont.)

Water Quality Sensors

Type:	Multipurpose including water temperature, conductivity, pH, redox, and dissolved oxygen
Cost:	$4,500 - $5,000
Output:	Digital
Requirements:	Proper site selection and data analyses
Advantages:	Portable, multipurpose unit
Limitations:	Scheduled maintenance necessary

Temperature Measurement Sensors

Type:	Air
Cost:	$200 - $300
Output:	0-5 VDC or 4-20 mA
Requirements:	Shield from solar radiation effects
Advantages:	Easy to install and operate
Limitations:	None

Type:	Water
Cost:	$200 - $300
Output:	0-5 VDC or 4-20 mA
Requirements:	Stable position in water
Advantages:	Easy to install and operate
Limitations:	Water temperature varies with depth

Snow Depth Measurement Sensors

Type:	Snow pillow
Cost:	$1,500 - $2,000
Output:	0-5 VDC or 4-20 mA
Requirements:	Controlled snowcourse
Advantages:	Delineates current snowpack water equivalence
Limitations:	Installation must be protected from rodents