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Proceedings

44th Annual New Mexico Water Conference

The Rio Grande Compact: It's the Law!

December 2-3, 1999
La Fonda on the Plaza, Santa Fe

New Mexico Water Resources Research Institute
New Mexico State University
Las Cruces, NM 88003

co-sponsored by
New Mexico Riparian Council

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44th Annual New Mexico Water Conference

The Rio Grande Compact:
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PROGRAM

Thursday Morning, December 2

History Behind the Rio Grande Compact

7:30 am	Registration, Mezzanine West, La Fonda on the Plaza
8:30	Opening Remarks **Bobby J. Creel**, Acting Director, Water Resources Research Institute **Ondrea Linderoth-Hummel**, President, New Mexico Riparian Council **Arthur Sanchez**, Santa Fe Mayor Pro-Tem
8:45	Keynote Address: History of the Rio Grande Compact of 1938 **Douglas R. Littlefield**, author of *Interstate water conflicts, compromises, and compacts: The Rio Grande, 1880-1938*
9:45	Other Historical Perspectives on the Rio Grande Compact: **Philip Mutz**, 34-year tenure with the Office of the State Engineer **Fred Allen**, 30-year tenure with the Office of the State Engineer **Jim Williams**, 30-year tenure with the Office of the State Engineer
10:30	Break

10:50	How We Dealt with the Drought of the '50s Moderated by **Gary Esslinger** **Ted Cox**, **John Clayshulte, Sr., Rudy Provencio**
11:30	Tribal Perspectives on the Rio Grande Compact **Blane Sanchez**, Sandia Pueblo **Peter Chestnut**, general counsel, Acoma and San Ildefonso pueblos

Thursday Afternoon

How the Rio Grande Compact Works

1:30 pm	How Colorado Meets Its Obligations Under the Rio Grande Compact **Steve Vandiver**, Colorado Division of Water Resources
2:15	Hydrology and Key Accounting Components of the Compact **Conrad Keyes**, Environmental and Water Resources Institute
2:30	Surface Water Hydrology of the Rio Grande Basin **Lee Wilson**, Lee Wilson & Associates
2:45	Overview of the Groundwater Hydrology of the Rio Grande Basin **John Hawley**, Emeritus Senior Geologist, NM Tech, Bureau of Mines **Mike Kernodle**, geohydrologist
3:00	Current Water Budget of the Middle Rio Grande Basin **Frank Titus**, hydrogeologist **Steve Hansen**, Bureau of Reclamation
3:20	Break
3:40	What is the Water Supply: Integrating Water Budget Studies **Debbie Hathaway**, Papadopulos & Associates
3:50	Basin Groundwater Criteria **John D'Antonio**, Office of the State Engineer
4:05	Paleohydrology of the Rio Grande **Neal Ackerly**, Dos Rios Consultants, Inc.
4:25	Current and Projected San Juan/Chama Water Use **Jaci Gould**, Bureau of Reclamation **John Stomp**, City of Albuquerque **Mike Hamman**, City of Santa Fe
5:00-6:45	Reception hosted by Hydrosphere Resource Consultants, Inc. Santa Fe Room
7:00 pm	Dinner Banquet - Ballroom New Mexico Riparian Council 1999 Awards First Albert E. Utton Memorial Water Lecture **Leon Metz**, Historian and Author

Friday Morning, December 3

Planning for the Future and Meeting Compact Obligations

8:00 am	New Mexico's Obligations and Compliance under the Rio Grande Compact **Norman Gaume**, Interstate Stream Commission
8:45	Consequences of Noncompliance **Charles DuMars**, University of New Mexico School of Law
9:00	Do We Need Water Markets? **John Hernández**, Professor Emeritus, New Mexico State University **Lee Brown**, Professor Emeritus, University of New Mexico
9:30	Upper Rio Grande Basin Water Operations Review and Environmental Impact Statement **Lt. Col. Thomas Fallin**, Corps of Engineers
9:50	History and Significance of the Low-Flow Conveyance Channel: What is its Future? **Chris Gorbach**, Bureau of Reclamation
10:10	Break
10:30	Domestic Well Depletions **John Shomaker**, John Shomaker & Associates
10:45	Demographics and Projected Demands on the System **Jim Peach**, New Mexico State University
10:55	Opportunities and Constraints for Environmental Enhancement and Recreation Along the Rio Grande **Brian Hanson**, US Fish and Wildlife Services **Steve Harris**, Rio Grande Restoration
11:25	Concluding Panel: Issues and Concerns **Hal Simpson,** Colorado Rio Grande Compact Commissioner **Tom Turney**, New Mexico Rio Grande Compact Commissioner **Joe Hanson**, Texas Rio Grande Compact Commissioner
12:00	Closing Remarks **Bobby J. Creel**, WRRI

RIO GRANDE COMPACT

The State of Colorado, the State of New Mexico, and the State of Texas, desiring to remove all causes of present and future controversy among these States and between citizens of one of these States and citizens of another State with respect to the use of the waters of the Rio Grande above Fort Quitman, Texas, and being moved by considerations of interstate comity, and for the purpose of effecting an equitable apportionment of such waters, have resolved to conclude a Compact for the attainment of these purposes, and to that end, through their respective Governors, have named as their respective Commissioners:

For the State of Colorado M.C. Hinderlider
For the State of New Mexico Thomas M. McClure
For the State of Texas Frank B. Clayton

who, after negotiations participated in by S.O. Harper, appointed by the President as the \representative of the United States of America, have agreed upon the following articles, to-wit:

ARTICLE I

(a) The State of Colorado, the State of New Mexico, the State of Texas, and the United States of America, are hereinafter designated "Colorado," "New Mexico," "Texas," and the "United States," respectively.

(b) "The Commission" means the agency created by this Compact for the administration thereof.

(c) The term "Rio Grande Basin" means all of the territory drained by the Rio Grande and its tributaries in Colorado, in New Mexico, and in Texas above Fort Quitman, including the Closed Basin in Colorado.

(d) The "Closed Basin" means that part of the Rio Grande Basin in Colorado where the streams drain into the San Luis Lakes and adjacent territory, and do not normally contribute to the flow of the Rio Grande.

(e) The term "tributary" means any stream which naturally contributes to the flow of the Rio Grande.

(f) "Transmountain Diversion" is water imported into the drainage basin of the Rio Grande from any stream system outside of the Rio Grande Basin, exclusive of the Closed Basin.

(g) "Annual Debits" are the amounts by which actual deliveries in any calendar year fall below scheduled deliveries.

(h) "Annual Credits" are the amounts by which actual deliveries in any calendar year exceed scheduled deliveries.

(i) "Accrued Debits" are the amounts by which the sum of all annual debits exceeds sum of all annual credits over any common period of time.

(j) "Accrued Credits" are the amounts by which the sum of all annual credits exceeds the sum of all annual debits over any common period of time.

(k) "Project Storage" is the combined capacity of Elephant Butte Reservoir and all other reservoirs actually available for the storage of usable water below Elephant Butte and above the first diversion to lands of the Rio Grande Project, but not more than a total of 2,638,860 acre feet.

(l) "Usable Water" is all water, exclusive of credit water, which is in project storage and which is available for release in accordance with irrigation demands, including deliveries to Mexico.

(m) "Credit Water" is that amount of water in project storage which is equal to the accrued credit of Colorado, or New Mexico, or both.

(n) "Unfilled Capacity" is the difference between the total physical capacity of project storage and the amount of usable water then in storage.

(o) "Actual Release" is the amount of usable water released in any calendar year from the lowest reservoir comprising project storage.

(p) "Actual Spill" is all water which is actually spilled from Elephant Butte Reservoir, or is released therefrom for flood control, in excess of the current demand on project storage and which does not become usable water by storage in another reservoir; provided, that actual spill of usable water cannot occur until all credit water shall have been spilled.

(q)"Hypothetical Spill" is the time in any year at which usable water would have spilled from project storage if 790,000 acre feet had been released therefrom at rates proportional to the actual release in every year from the starting date to the end of the year in which hypothetical spill occurs; in computing hypothetical spill the initial condition shall be the amount of usable water in project storage at the beginning of the calendar year following the effective date of this Compact, and thereafter the initial condition shall be the amount of usable water in project storage at the beginning of the calendar year following each actual spill.

ARTICLE II

The Commission shall cause to be maintained and operated a stream gaging station equipped with an automatic water stage recorder at each of the following points, to-wit:

(a) On the Rio Grande near Del Norte above the principal points of diversion to the San Luis Valley;
(b) On the Conejos River near Mogote;
(c) On the Los Pinos River near Ortiz;
(d) On the San Antonio River at Ortiz;
(e) On the Conejos River at its mouths near Los Sauces;
(f) On the Rio Grande near Lobatos;
(g) On the Rio Chama below El Vado Reservoir;
(h) On the Rio Grande at Otowi Bridge near San Ildefonso;
(i) On the Rio Grande near San Acacia;
(j) On the Rio Grande at San Marcial;
(k) On the Rio Grande below Elephant Butte Reservoir;
(l) On the Rio Grande below Caballo Reservoir.

Similar gaging stations shall be maintained and operated below any other reservoir constructed after 1929, and at such other points as may be necessary for the securing of records required for the carrying out of the Compact; and automatic water stage recorders shall be maintained and operated on each of the reservoirs mentioned, and on all others constructed after 1929.

Such gaging stations shall be equipped, maintained and operated by the Commission directly or in cooperation with an appropriate Federal or State agency, and the equipment, method and frequency of measurement at such stations shall be such as to produce reliable records at all times. (Note: See Resolution of Commission printed elsewhere in this report.)

ARTICLE III

The obligation of Colorado to deliver water in the Rio Grande at the Colorado-New Mexico State Line, measured at or near Lobatos, in each calendar year, shall be ten thousand acre feet less than the sum of those quantities set forth in the two following tabulations of relationship, which correspond to the quantities at the upper index stations:

DISCHARGE OF CONEJOS RIVER	
Quantities in thousands of acre feet	
Conejos Index Supply (1)	Conejos River at Mouths (2)
100	0
150	20
200	45
250	75
300	109
350	147
400	188
450	232
500	278
550	326
600	376
650	426
700	476

Intermediate quantities shall be computed by proportional parts.

(1) Conejos Index Supply is the natural flow of Conejos River at the U.S.G.S. gaging station near Mogote during the calendar year, plus the natural flow of Los Pinos River at the U.S.G.S. gaging station near Ortiz and the natural flow of San Antonio River at the U.S.G.S. gaging station at Ortiz, both during the months of April to October, inclusive.

(2) Conejos River at Mouths is the combined discharge of branches of this river at the U.S.G.S. gaging stations near Los Sauces during the calendar year.

DISCHARGE OF RIO GRANDE EXCLUSIVE OF CONEJOS RIVER	
Quantities in thousands of acre feet	
Rio Grande at Del Norte (3)	Rio Grande at Lobatos less Conejos at Mouths (4)
200	60
250	65
300	75
350	86
400	98
450	112
500	127
550	144
600	162
650	182
700	204
750	229
800	257
850	292
900	335
950	380
1,000	430
1,100	540
1,200	640
1,300	740
1,400	840

Intermediate quantities shall be computed by proportional parts.

(3) Rio Grande at Del Norte is the recorded flow of the Rio Grande at the U.S.G.S. gaging station near Del Norte during the calendar year (measured above all principal points of diversion to San Luis Valley) corrected for the operation of reservoirs constructed after 1937.

(4) Rio Grande at Lobatos less Conejos at Mouths is the total flow of the Rio Grande at the U.S.G.S. gaging station near Lobatos, less the discharge of Conejos River at its Mouths, during the calendar year.

The application of these schedules shall be subject to the provisions hereinafter set forth and appropriate adjustments shall be made for (a) any change in location of gaging stations; (b) any new or increased depletion of the runoff above inflow index gaging stations; and (c) any transmountain diversions into the drainage basin of the Rio Grande above Lobatos.

In event any works are constructed after 1937 for the purpose of delivering water into the Rio Grande from the Closed Basin, Colorado shall not be credited with the amount of such water delivered, unless the proportion of sodium ions shall be less than forty-five percent of the total positive ions in that water when the total dissolved solids in such water of exceeds three hundred fifty parts per million.

ARTICLE IV

The obligation of New Mexico to deliver water in the Rio Grande at San Marcial, during each calendar year, exclusive of the months of July, August, and September, shall be that quantity set forth in the following tabulation of relationship, which corresponds to the quantity at the upper index station:

DISCHARGE OF RIO GRANDE AT OTOWI BRIDGE AND AT SAN MARCIAL EXCLUSIVE OF JULY, AUGUST AND SEPTEMBER	
Quantities in thousands of acre feet	
Otowi Index Supply (5)	San Marcial Index Supply (6)
100	0
200	65
300	141
400	219
500	300
600	383
700	469
800	557
900	648
1,000	742
1,100	839
1,200	939
1,300	1,042
1,400	1,148
1,500	1,257
1,600	1,370
1,700	1,489
1,800	1,608
1,900	1,730
2,000	1,856
2,100	1,985
2,200	2,117
2,300	2,253

Intermediate quantities shall be computed by proportional parts.

(5) The Otowi Index Supply is the recorded flow of the Rio Grande at the U.S.G.S. gaging station at Otowi Bridge near San Ildefonso (formerly station near Buckman) during the calendar year, exclusive of the flow during the months of July, August and September, corrected for the operation of reservoirs constructed after 1929 in the drainage basin of the Rio Grande between Lobatos and Otowi Bridge.

6) San Marcial Index Supply is the recorded flow of the Rio Grande at the gaging station at San Marcial during the calendar year exclusive of the flow during the months of July, August and September.

The application of this schedule shall be subject to the provisions hereinafter set forth and appropriate adjustments shall be made for (a) any change in location of gaging stations; (b) depletion after 1929 in New Mexico at any time of the year of the natural runoff at Otowi Bridge; (c) depletion of the runoff during July, August and September of tributaries between Otowi Bridge and San Marcial, by works constructed after 1937; and (d) any transmountain diversions into the Rio Grande between Lobatos and San Marcial.

Concurrent records shall be kept of the flow of the Rio Grande at San Marcial, near San Acacia, and of the release from Elephant Butte Reservoir to the end that the records at these three stations may be correlated. (Note: See Resolution of Commission printed elsewhere in this report.)

ARTICLE V

If at any time it should be the unanimous finding and determination of the Commission that because of changed physical conditions, or for any other reason, reliable records are not obtainable, or cannot be obtained, at any of the stream gaging stations herein referred to, such stations may, with the unanimous approval of the Commission, be abandoned, and with such approval another station, or other stations, shall be established and new measurements shall be substituted which, in the unanimous opinion of the Commission, will result in substantially the same results so far as the rights and obligations to deliver water are concerned, as would have existed if such substitution of stations and measurements had not been so made. (Note: See Resolution of Commission printed elsewhere in this report.)

ARTICLE VI

Commencing with the year following the effective date of this Compact, all credits and debits of Colorado and New Mexico shall be computed for each calendar year; provided, that in a year of actual spill no annual credits nor annual debits shall be computed for that year.

In the case of Colorado, no annual debit nor accrued debit shall exceed 100,000 acre feet, except as either or both may be caused by holdover storage of water in reservoirs constructed after 1937 in the drainage basin of the Rio Grande above Lobatos. Within the physical limitations of storage capacity in such reservoirs, Colorado shall retain water in storage at all times to the extent of its accrued debit.

In the case of New Mexico, the accrued debit shall not exceed 200,000 acre feet at any time, except as such debit may be caused by holdover storage of water in reservoirs constructed after 1929 in the drainage basin of the Rio Grande between Lobatos and San Marcial. Within the physical limitations of storage capacity in such reservoirs, New Mexico shall retain water in storage at all times to the extent of its accrued debit. In computing the magnitude of accrued credits or debits, New Mexico shall not be charged with any greater debit in any one year than the sum of 150,000 acre-feet and all gains in the quantity of water in storage in such year.

The Commission by unanimous action may authorize the release from storage of any amount of water which is then being held in storage by reason of accrued debits of Colorado or New Mexico; provided, that such water shall be replaced at the first opportunity thereafter.

In computing the amount of accrued credits and accrued debits of Colorado or New Mexico, any annual credits in excess of 150,000 acre feet shall be taken as equal to that amount.

In any year in which actual spill occurs, the accrued credits of Colorado, or New Mexico, or both, at the beginning of the year shall be reduced in proportion to their respective credits by the amount of such actual spill; provided that the amount of actual spill shall be deemed to be increased by the aggregate gain in the amount of water in storage, prior to the time of spill, in reservoirs above San Marcial constructed after 1929; provided, further, that if the Commissioners for the States having accrued credits authorize the release of part, or all, of such credits in advance of spill, the amount so released shall be deemed to constitute actual spill.

In any year in which there is actual spill of usable water, or at the time of hypothetical spill thereof, all accrued debits of Colorado, or New Mexico, or both, at the beginning of the year shall be cancelled.

In any year in which the aggregate of accrued debits of Colorado and New Mexico exceeds the minimum unfilled capacity of project storage, such debits shall be reduced proportionally to an aggregate amount equal to such minimum unfilled capacity.

To the extent that accrued credits are impounded in reservoirs between San Marcial and Courchesne, and to the extent that accrued debits are impounded in reservoirs above San Marcial, such credits and debits shall be reduced annually to compensate for evaporation losses in the proportion that such credits or debits bore to the total amount of water in such reservoirs during the year.

ARTICLE VII

Neither Colorado nor New Mexico shall increase the amount of water in storage in reservoirs constructed after 1929 whenever there is less than 400,000 acre feet of usable water in project storage; provided, that if the actual releases of usable water from the beginning of the calendar year following the effective date of this Compact, or from the beginning of the calendar year following actual spill, have aggregated more than an average of 790,000 acre feet per annum, the time at which such minimum stage is reached shall be adjusted to compensate for the difference between the total actual release and releases at such average rate; provided, further, that Colorado, or New Mexico, or both, may relinquish accrued credits at any time, and Texas may accept such relinquished water, and in such event the state, or states, so relinquishing shall be entitled to store water in the amount of the water so relinquished.

ARTICLE VIII

During the month of January of any year the Commissioner for Texas may demand of Colorado and New Mexico, and the Commissioner for New Mexico may demand of Colorado, the release of water from storage reservoirs constructed after 1929 to the amount of the accrued debits of Colorado and New Mexico, respectively, and such releases shall be made by each at the greatest rate practicable under the conditions then prevailing, and in proportion to the total debit of each, and in amounts, limited by their accrued debits, sufficient to bring the quantity of usable water in project storage to 600,000 acre feet by March first and to maintain this quantity in storage until April thirtieth, to the end that a normal release of 790,000 acre feet may be made from project storage in that year.

ARTICLE IX

Colorado agrees with New Mexico that in event the United States or the State of New Mexico decides to construct the necessary works for diverting the waters of the San Juan River, or any of its tributaries, into the Rio Grande, Colorado hereby consents to the construction of said works and the diversion of waters from the San Juan River, or the tributaries thereof, into the Rio Grande in New Mexico, provided the present and prospective uses of water in Colorado by other diversions from the San Juan River, or its tributaries, are protected.

ARTICLE X

In the event water from another drainage basin shall be imported into the Rio Grande Basin by the United States or Colorado or New Mexico, or any of them jointly, the State having the right to the use of such water shall be given proper credit therefore in the application of the schedules.

ARTICLE XI

New Mexico and Texas agree that upon the effective date of this Compact all controversies between said States relative to the quantity or quality of the water of the Rio Grande are composed and settled; however, nothing herein shall be interpreted to prevent recourse by a signatory state to the Supreme Court of the United States for redress should the character or quality of the water, at the point of delivery, be changed hereafter by one signatory state to the injury of another. Nothing herein shall be construed as an admission by any signatory state that the use of water for irrigation causes increase of salinity for which the user is responsible in law.

ARTICLE XII

To administer the provisions of this Compact there shall be constituted a Commission composed of one representative from each state, to be known as the Rio Grande Compact Commission. The State Engineer of Colorado shall be ex-officio the Rio Grande Compact Commissioner for Colorado. The State Engineer of New Mexico shall be ex-officio the Rio Grande Compact Commissioner for New Mexico. The Rio Grande Compact Commissioner for Texas shall be appointed by the Governor of Texas. The President of the United States shall be requested to designate a representative of the United States to sit with such Commission, and such representative of the United States, if so designated by the President, shall act as Chairman of the Commission without vote.

The salaries and personal expenses of the Rio Grande Compact Commissioners for the three States shall be paid by their respective States, and all other expenses incident to the administration of this Compact, not borne by the United States, shall be borne equally by the three States.

In addition to the powers and duties hereinbefore specifically conferred upon such Commission, and the members thereof, the jurisdiction of such Commission shall extend only to the collection, correlation and presentation of factual data and the maintenance of records having a bearing upon the administration of this Compact, and, by unanimous action, to the making of recommendations to the respective States upon matters connected with the administration of this Compact. In connection therewith, the Commission may employ such engineering and clerical aid as may be reasonably necessary within the limit of funds provided for that purpose by the respective States. Annual reports compiled for each calendar year shall be made by the Commission and transmitted to the Governors of the signatory States on or before March first following the year covered by the report. The Commission may, by unanimous action, adopt rules and regulations consistent with the provisions of this Compact to govern their proceedings.

The findings of the Commission shall not be conclusive in any court or tribunal which may be called upon to interpret or enforce this Compact.

ARTICLE XIII

At the expiration of every five-year period after the effective date of this Compact, the Commission may, by unanimous consent, review any provisions hereof which are not substantive in character and which do not affect the basic principles upon which the Compact is founded, and shall meet for the consideration of such questions on the request of any member of the Commission; provided, however, that the provisions hereof shall remain in full force and effect until changed and amended within the intent of the Compact by unanimous action of the Commissioners, and until any changes in this Compact are ratified by the legislatures of the respective states and consented to by the Congress, in the same manner as this Compact is required to be ratified to become effective.

ARTICLE XIV

The schedules herein contained and the quantities of water herein allocated shall never be increased nor diminished by reason of any increase or diminution in the delivery or loss of water to Mexico.

ARTICLE XV

The physical and other conditions characteristic of the Rio Grande and peculiar to the territory drained and served thereby, and to the development thereof, have actuated this Compact and none of the signatory states admits that any provisions herein contained establishes any general principle or precedent applicable to other interstate streams.

ARTICLE XVI

Nothing in this Compact shall be construed as affecting the obligations of the United States of America to Mexico under existing treaties, or to the Indian Tribes, or as impairing the rights of the Indian Tribes.

ARTICLE XVII

This Compact shall become effective when ratified by the legislatures of each of the signatory states and consented to by the Congress of the United States. Notice of ratification shall be given by the Governor of each state to the Governors of the other states and to the President of the United States, and the President of the United States is requested to give notice to the Governors of each of the signatory states of the consent of the Congress of the United States.

IN WITNESS WHEREOF, the Commissioners have signed this Compact in quadruplicate original, one of which shall be deposited in the archives of the Department of State of the United States of America and shall be deemed the authoritative original, and of which a duly certified copy shall be forwarded to the Governor of each of the signatory States.

Done at the City of Santa Fe, in the State of New Mexico, on the 18th day of March, in the year of our Lord, One Thousand Nine Hundred and Thirty-eight.

(Sgd.) M. C. HINDERLIDER

(Sgd.) THOMAS M. McCLURE

(Sgd.) FRANK B. CLAYTON

APPROVED:
(Sgd.) S. O. HARPER

RATIFIED BY:

Colorado, February 21, 1939
New Mexico, March 1, 1939
Texas, March 1, 1939

Passed Congress as Public Act No. 96, 76th Congress,
Approved by the President May 31, 1939

RESOLUTION ADOPTED BY RIO GRANDE COMPACT COMMISSION AT THE ANNUAL MEETING HELD AT EL PASO, TEXAS, FEBRUARY 22-24, 1948, CHANGING GAGING STATIONS AND MEASUREMENTS OF DELIVERIES BY NEW MEXICO

RESOLUTION

Whereas, at the Annual Meeting of the Rio Grande Compact Commission in the year 1945, the question was raised as to whether or not a schedule for delivery of water by New Mexico during the entire year could be worked out, and

Whereas, at said meeting the question was referred to the Engineering Advisers for their study, recommendations and report, and

Whereas, said Engineering Advisers have met, studied the problems and under date of February 24, 1947, did submit their Report, which said Report contains the findings of said Engineering Advisers and their recommendations, and

Whereas, the Compact Commission has examined said Report and finds that the matters and things therein found and recommended are proper and within the terms of the Rio Grande Compact, and

Whereas, the Commission has considered said Engineering Advisers' Report and all available evidence, information and material and is fully advised:

Now, Therefore, Be it Resolved:

The Commission finds as follows:

(a) That because of change of physical conditions, reliable records of the amount of water passing San Marcial are no longer obtainable at the stream gaging station at San Marcial and that the same should be abandoned for Compact purposes.

(b) That the need for concurrent records at San Marcial and San Acacia no longer exists and that the gaging station at San Acacia should be abandoned for Compact purposes.

(c) That it is desirable and necessary that the obligations of New Mexico under the Compact to deliver water in the months of July, August, September, should be scheduled.

(d) That the change in gaging stations and substitution of the new measurements as hereinafter set forth will result in substantially the same results so far as the rights and obligations to deliver water are concerned, and would have existed if such substitution of stations and measurements had not been so made.

Be it Further Resolved:

That the following measurements and schedule thereof shall be substituted for the measurements and schedule thereof as now set forth in Article IV of the Compact:

"The obligation of New Mexico to deliver water in the Rio Grande into Elephant Butte Reservoir during each calendar year shall be measured by that quantity set forth in the following tabulation of relationship which corresponds to the quantity at the upper index station:

DISCHARGE OF RIO GRANDE AT OTOWI BRIDGE AND ELEPHANT BUTTE EFFECTIVE SUPPLY	
Quantities in thousands of acre-feet	
Otowi Index Supply (5)	Elephant Butte Effective Index Supply (6)
100	57
200	114
300	171
400	228
500	286
600	345
700	406
800	471
900	542
1,000	621
1,000	707
1,200	800
1,300	897
1,400	996
1,500	1,095
1,600	1,195
1,700	1,295
1,800	1,395
1,900	1,495
2,000	1,595
2,100	1,695
2,200	1,795
2,300	1,895
2,400	1,995
2,500	2,095
2,600	2,195
2,700	2,295
2,800	2,395
2,900	2,495
3,000	2,595

Intermediate quantities shall be computed by proportional parts.

(5) The Otowi Index Supply is the recorded flow of the Rio Grande at the U.S.G.S. gaging station at Otowi Bridge near San Ildefonso (formerly station near Buckman) during the calendar year, corrected for the operation of reservoirs constructed after 1929 in the drainage basin of the Rio Grande between Lobatos and Otowi Bridge.

(6) Elephant Butte Effective Index Supply is the recorded flow of the Rio Grande at the gaging station below Elephant Butte Dam during the calendar year plus the net gain in storage in Elephant Butte Reservoir during the same year or minus the net loss in storage in said reservoir, as the case may be.

The Rio Grande Compact

The application of this schedule shall be subject to the provisions hereinafter set forth and appropriate adjustments shall be made for (a) any change in location of gaging stations; (b) depletion after 1929 in New Mexico of the natural runoff at Otowi Bridge; and (c) any transmountain diversions into the Rio Grande between Lobatos and Elephant Butte Reservoir."

Be it Further Resolved:

That the gaging stations at San Acacia and San Marcial be, and the same are hereby abandoned for Compact purposes.

Be it Further Resolved:

That this Resolution has been passed unanimously and shall be effective January 1, 1949, if within 120 days from this date the Commissioner for each State shall have received from the Attorney General of the State represented by him, an opinion approving this Resolution, and shall have so advised the Chairman of the Commission, otherwise, to be of no force and effect.

(Note: The following paragraph appears in the Minutes of the Annual Meeting of the Commission held at Denver, Colorado, February 14-16, 1949.

"The Chairman announced that he had received, pursuant to the Resolution adopted by the Commission at the Ninth Annual Meeting on February 24, 1948, opinions from the Attorneys General of Colorado, New Mexico and Texas that the substitution of stations and measurements of deliveries by New Mexico set forth in said resolution was within the powers of the Commission").

RULES AND REGULATIONS FOR ADMINISTRATION OF THE RIO GRANDE COMPACT

A Compact, known as the Rio Grande Compact, between the States of Colorado, New Mexico and Texas, having become effective on May 31, 1939 by consent of the Congress of the United States, which equitably apportions the waters of the Rio Grande above Fort Quitman and permits each State to develop its water resources at will, subject only to its obligations to deliver water in accordance with the schedules set forth in the Compact, the following Rules and Regulations have been adopted for its administration by the Rio Grande Compact Commission; to be and remain in force and effect only so long as the same may be satisfactory to each and all members of the Commission, and provided always that on the objection of any member of the Commission, in writing, to the remaining two members of the Commission after a period of sixty days from the date of such objection, the sentence, paragraph or any portion or all of these rules to which any such objection shall be made, shall stand abrogated and shall thereafter have no further force and effect; it being the intent and purpose of the Commission to permit these rules to obtain and be effective only so long as the same may be satisfactory to each and all of the Commissioners.

GAGING STATIONS /1

Responsibility for the equipping, maintenance and operation of the stream gaging stations and reservoir gaging stations required by the provisions of Article II of the Compact shall be divided among the signatory States as follows:

(a) Gaging stations on streams and reservoirs in the Rio Grande Basin above the Colorado-New Mexico boundary shall be equipped, maintained, and operated by Colorado in cooperation with the U.S. Geological Survey.

(b) Gaging stations on streams and reservoirs in the Rio Grande Basin below Lobatos and above Caballo Reservoir shall be equipped, maintained and operated by New Mexico in cooperation with the U.S. Geological Survey to the extent that such stations are not maintained and operated by some other Federal agency.

(c) Gaging stations on Elephant Butte Reservoir and on Caballo Reservoir, and the stream gaging stations on the Rio Grande below those reservoirs shall be equipped, maintained and operated by or on behalf of Texas through the agency of the U.S. Bureau of Reclamation.

The equipment, method and frequency of measurements at each gaging station shall be sufficient to obtain records at least equal in accuracy to those classified as "good" by the U.S. Geological Survey. Water-stage recorders on the reservoirs specifically named Article II of the Compact shall have sufficient range below maximum reservoir level to record major fluctuations in storage. Staff gages may be used to determine fluctuations below the range of the water-stage recorders on these and other large reservoirs, and staff gages may be used upon approval of the Commission in lieu of water-stage recorders on small reservoirs, provided that the frequency of observation is sufficient in each case to establish any material changes in water levels in such reservoirs.

/1 Amended at Eleventh Annual Meeting, February 23, 1950.

RESERVOIR CAPACITIES /1

Colorado shall file with the Commission a table of areas and capacities for each reservoir in the Rio Grande Basin above Lobatos constructed after 1937; New Mexico shall file with the Commission a table of areas and capacities for each reservoir in the Rio Grande Basin between Lobatos and San Marcial constructed after 1929; and Texas shall file with the Commission tables of areas and capacities for Elephant Butte Reservoir and for all other reservoirs actually available for the storage of water between Elephant Butte and the first diversion to lands under the Rio Grande Project.

Whenever it shall appear that any table of areas and capacities is in error by more than five per cent, the Commission shall use its best efforts to have a re-survey made and a corrected table of areas and capacities to be substituted as soon as practicable. To the end that the Elephant Butte effective supply may be computed accurately, the Commission shall use its best efforts to have the rate of accumulation and the place of deposition of silt in Elephant Butte Reservoir checked at least every three years.

ACTUAL SPILL /2, /3

(a) Water released from Elephant Butte in excess of Project requirements, which is currently passed through Caballo Reservoir, prior to the time of spill, shall be deemed to have been Usable Water released in anticipation of spill, or Credit Water if such release shall have been authorized.

(b) Excess releases from Elephant Butte Reservoir, as defined in (a) above, shall be added to the quantity of water in storage in that reservoir, and Actual Spill shall be deemed to have commenced when this sum equals the total capacity of that reservoir to the level of the uncontrolled spillway less capacity reserved for flood control purposes, i.e., 2,040,000 acre-feet in the months of October through March, inclusive, and 2,015,000 acre-feet in the months of April through September, inclusive, as determined from the 1988 area-capacity table or successor area-capacity tables and flood control storage reservation of 50,000 acre-feet from April through September and 25,000 acre-feet from October through March.

(c) All water actually spilled at Elephant Butte Reservoir, or released therefrom, in excess of Project requirements, which is currently passed through Caballo Reservoir, after the time of spill, shall be considered as Actual Spill, provided that the total quantity of water then in storage in Elephant Butte Reservoir exceeds the physical capacity of that reservoir at the level of the sill of the spillway gates, i.e., -1,830,000 acre-ft in 1942.

(d) Water released from Caballo Reservoir in excess of Project requirements and in excess of water currently released from Elephant Butte Reservoir, shall be deemed Usable Water released, excepting only flood water entering Caballo Reservoir from tributaries below Elephant Butte Reservoir.

DEPARTURES FROM NORMAL RELEASES /4

For the purpose of computing the time of Hypothetical Spill required by Article VI , for the purpose of the adjustment set forth in Article VII, no allowance shall be made for the difference between Actual and Hypothetical Evaporation, and any under-release of usable water from Project Storage in excess of 150,000 acre-ft in any year shall be taken as equal to that amount.

/1 Amended at Eleventh Annual Meeting, February 23, 1950.

/2 Adopted at Fourth Annual Meeting, February 24, 1943.

/3 Amended September 9, 1998.

/4 Adopted June 2, 1959; made effective January 1, 1952.

EVAPORATION LOSSES /5, /6, /7

The Commission shall encourage the equipping, maintenance and operation, in cooperation with the U.S. Weather Bureau or other appropriate agency, of evaporation stations at Elephant Butte Reservoir and at or near each major reservoir in the Rio Grande Basin within Colorado constructed after 1937 and in New Mexico constructed after 1929. The net loss by evaporation from a reservoir surface shall be taken as the difference between the actual evaporation loss and the evapo-transpiration losses which would have occurred naturally, prior to the construction of such reservoir. Changes in evapo-transpiration losses along stream channels below reservoirs may be disregarded.

Net losses by evaporation, as defined above, shall be used in correcting Index Supplies for the operation of reservoirs upstream from Index Gaging Stations as required by the provisions of Article III and Article IV of the Compact.

In the application of the provisions of the last unnumbered paragraph of Article VI of the Compact:

(a) Evaporation losses for which accrued credits shall be reduced shall be taken as the difference between the gross evaporation from the water surface of Elephant Butte Reservoir and rainfall on the same surface.

(b) Evaporation losses for which accrued debits shall be reduced shall be taken as the net loss by evaporation as defined in the first paragraph.

ADJUSTMENT OF RECORDS

The Commission shall keep a record of the location, and description of each gaging station and evaporation station, and, in the event of change in location of any stream gaging station for any reason, it shall ascertain the increment in flow or decrease in flow between such locations for all stages. Wherever practicable, concurrent records shall be obtained for one year before abandonment of the previous station.

NEW OR INCREASED DEPLETIONS

In the event any works are constructed which alter or may be expected to alter the flow at any of the Index Gaging Stations mentioned in the Compact, or which may otherwise necessitate adjustments in the application of the schedules set forth in the Compact, it shall be the duty of the Commissioner specifically concerned to file with the Commission all available information pertaining thereto, and appropriate adjustments shall be made in accordance with the terms of the Compact; provided, however, that any such adjustments shall in no way increase the burden imposed upon Colorado or New Mexico under the schedules of deliveries established by the Compact.

TRANSMOUNTAIN DIVERSIONS

In the event any works are constructed for the delivery of waters into the drainage basin of the Rio Grande from any stream system outside of the Rio Grande Basin, such waters shall be measured at the point of delivery into the Rio Grande Basin and proper allowances shall be made for losses in transit from such points to the Index Gaging Station on the stream with which the imported waters are commingled.

/5 Amended at Tenth Annual Meeting, February 15, 1949.

/6 Amended at Twelfth Annual Meeting, February 24, 1951.

/7 Amended June 2, 1959.

QUALITY OF WATER

In the event that delivery of water is made from the Closed Basin into the Rio Grande, sufficient samples of such water shall be analyzed to ascertain whether the quality thereof is within the limits established by the Compact.

SECRETARY /8

The Commission, subject to the approval of the Director, U.S. Geological Survey, to a cooperative agreement for such purposes, shall employ the U.S. Geological Survey on a yearly basis, to render such engineering and clerical aid as may reasonably be necessary for administration of the Compact. Said agreement shall provide that the Geological Survey shall:

(1) Collect and correlate all factual data and other records having a material bearing on the administration of the Compact and keep each Commissioner adviser thereof.

(2) Inspect all gaging stations required for administration of the Compact and make recommendations to the Commission as to any changes or improvements in methods of measurement or facilities for measurement which may be needed to insure that reliable records be obtained.

(3) Report to each Commissioner by letter on or before the fifteenth day of each month, except January, a summary of all hydrographic data then available for the current year - on forms prescribed by the Commission - pertaining to:

(a) Deliveries by Colorado
(b) Deliveries by New Mexico
(c) Operation of Project Storage

(4) Make such investigations as may be requested by the Commission in aid of its administration of the Compact.

(5) Act as Secretary to the Commission and submit to the Commission at its regular meeting in February a report on its activities and a summary of all data needed for determination of debits and credits and other matters pertaining to administration of the Compact.

COSTS /1

In February of each year, the Commission shall adopt a budget for the ensuing fiscal year beginning July first.

Such budget shall set forth the total cost of maintenance and operating of gaging stations, of evaporation stations, the cost of engineering and clerical aid, and all other necessary expenses excepting the salaries and personal expenses of the Rio Grande Compact Commissioners.

Contributions made directly by the United States and the cost of services rendered by the United States without cost shall be deducted from the total budget amount; the remainder shall then be allocated equally to Colorado, New Mexico and Texas.

/8 The substitution of this section for the section titled "Reports to Commissioners" was adopted at Ninth Annual Meeting, February 22, 1948.

/1 Amended at Eleventh Annual Meeting, February 23, 1950.

Expenditures made directly by any State for purposes set forth in the budget shall be credited to that State; contributions in cash or in services by any State under a cooperative agreement with any federal agency shall be credited to such State, but the amount of the federal contribution shall not so be credited; in event any State, through contractual relationships, causes work to be done in the interest of the Commission, such State shall be credited with the cost thereof, unless such cost is borne by the United States.

Costs incurred by the Commission under any cooperative agreement between the Commission and any U.S. Government Agency, not borne by the United States, shall be apportioned equally to each State, and each Commissioner shall arrange for the prompt payment of one-third thereof by his State.

The Commissioner of each State shall report at the annual meeting each year the amount of money expended during the year by the State which he represents, as well as the portion thereof contributed by all cooperating federal agencies, and the Commission shall arrange for such proper reimbursement in cash or credits between States as may be necessary to equalize the contributions made by each State in the equipment, maintenance and operation of all gaging stations authorized by the Commission and established under the terms of the Compact.

It shall be the duty of each Commissioner to endeavor to secure from the Legislature of his State an appropriation of sufficient funds with which to meet the obligations of his State, as provided by the Compact.

MEETING OF COMMISSION /1, /9

The Commission shall meet in Santa Fe, New Mexico, on the third Thursday of February of each year for the consideration and adoption of the annual report for the calendar year preceding, and for the transaction of any other business consistent with its authority; provided that the Commission may agree to meet elsewhere. Other meetings as may be deemed necessary shall be held at any time and place set by mutual agreement, for the consideration of data collected and for the transaction of any business consistent with its authority.

No action of the Commission shall be effective until approved by the Commissioner from each of the three signatory States.

(Signed) M. C. HINDERLIDER
M.. C. Hinderlider
Commissioner for Colorado

(Signed) THOMAS M. McCLURE
Thomas M. McClure
Commissioner for New Mexico
(Signed) JULIAN P. HARRISON
Julian P. Harrison
Commissioner for Texas
Adopted December 19, 1939.

/1 Amended at Eleventh Annual Meeting, February 23, 1950.
/9 Amended at Thirteenth Annual Meeting, February 25, 1952.

Douglas R. Littlefield *received his bachelor's degree from Brown University, a master's degree from the University of Maryland and a Ph.D. from the University of California, Los Angeles in 1987. His doctoral dissertation was entitled, Interstate Water Conflicts, Compromises, and Compacts: The Rio Grande, 1880-1938. Doug heads Littlefield Historical Research in Oakland, California. He is a research historian and consultant for many projects throughout the nation. Currently he also is providing consulting services to the U.S. Department of Justice, Salt River Project in Arizona, Nebraska Department of Water Resources, and the City of Las Cruces. From 1984-1986, Doug consulted for the Legal Counsel, New Mexico Office of the State Engineer, on the history of Rio Grande water rights and interstate apportionment disputes between New Mexico and Texas for use in El Paso v. Reynolds.*

The History of the Rio Grande Compact of 1938

Good morning. I thought I'd start this off on an upbeat note with the following historical commentary:

"Mentally and morally depraved." "A cynical contempt for the canons of public and official decency." These were the angry words of Nathan E. Boyd, president of the Rio Grande Dam and Irrigation Company, shortly after the turn of the century when he discovered that Arthur Powell Davis, assistant chief engineer of the newly formed U.S. Reclamation Service, had issued a blunt report heavily critical of the company's plans to build a dam at Elephant Butte on the Rio Grande and to provide irrigation water to lands along that river, especially to New Mexico's fertile Mesilla Valley. "One is almost driven to account for its extraordinary irrelevancy," Boyd charged, "by concluding that it was written by a congenital idiot, borrowed for such purpose from the nearest asylum for the insane."

Boyd's remarks may have been intemperate, but nevertheless, they amply illustrate how heated the struggle for the river's water supplies had become even as early as the turn of the century. And Boyd's outrage stemmed only from battles over water on the limited reach of the Rio Grande extending just from southern New Mexico's Mesilla Valley to areas further downstream near El Paso, Texas, and Juarez, Mexico. Similar passions–although perhaps less colorful–three decades later underlay the broader conflicts among Colorado, New Mexico, and Texas that led up to the approval of the 1938 Rio Grande Compact.

Yet even that accord has not ended the controversies over the river's water supplies, and one of the reasons why, I believe, is a lack of knowledge about the Compact's history. It is this lack of understanding that has precipitated one of the enduring mysteries about the Compact. That puzzle is the question of why the 1938 Rio

Grande Compact's negotiators provided for deliveries of the river's waters by Colorado at the Colorado-New Mexico state line yet no similar delivery point was established at the New Mexico-Texas border. Instead, New Mexico's delivery obligation is made, according to the Rio Grande Compact, at San Marcial, New Mexico, just above Elephant Butte Reservoir. This delivery point is over a hundred miles upstream from Texas. Why, then, was this delivery point specified instead of some place nearer the New Mexico-Texas border?

The San Marcial delivery location has caused years of confusion (and, in fact, still perplexes some people). Moreover, at times the San Marcial delivery location has placed Texas authorities in the awkward position of aligning themselves with southern New Mexico water users against New Mexico water users above Elephant Butte in order to protect Texas's supplies of Rio Grande waters.

The reality of the matter, however, is that there **is** an allocation of Rio Grande waters at the New Mexico-Texas border. This apportionment was legislated by Congress in 1905 when federal lawmakers authorized the construction of the Rio Grande Project in southern New Mexico and western Texas by the U.S. Reclamation Service (today, the Bureau of Reclamation). The allocation mandated by Congress was that the Reclamation Service would divide the waters within the Rio Grande Project based on surveys of irrigable lands in New Mexico and Texas. Following those studies, the Reclamation Service established that the equitable apportionment of Rio Grande waters within the Rio Grande Project would be supplies sufficient for 88,000 acres in southern New Mexico and 67,000 acres in western Texas.

How that apportionment was intended to be incorporated into the broader allocation under the 1938 Rio Grande Compact is the focus of the remainder of my remarks today. To understand fully the relationship between the Rio Grande Project's allocations and those made under the 1938 Rio Grande Compact, one needs to delve into the histories of both the Project and the 1938 Compact.

First, a little of the history of the Rio Grande Project.

In November 1904, glowing accounts began to appear in newspaper articles in the western United States that an important compromise had been reached at the 1904 National Irrigation Congress–a meeting held annually for engineers, government officials, and parties prominent in the field of reclamation. This compromise, the press reported, would end a long and bitter dispute over the apportionment of the waters of the Rio Grande. The decade-long controversy at that point in time pitted irrigators in southern New Mexico's Mesilla Valley against those slightly downstream around El Paso, Texas, and Juarez, Mexico.

Typifying the enthusiastic accounts of the resolution of the strife, the *Houston Post* announced that after "fighting for the past ten years, El Paso, New Mexico and Mexico came together today, buried the hatchet and will pull as one man for a great storage dam across the Rio Grande for the reclamation of arid lands in this section." The *Post* added the further optimistic judgment that the success of this project meant "more for El Paso than can be told."

Closer to the struggle in western Texas and southern New Mexico, the newspaper reports were even more effusive about the successful end to the Rio Grande's conflicts. One of Las Cruces, New Mexico's newspapers, the *Rio Grande Republican*, for example, trumpeted that the National Irrigation Congress's effects would be long-lasting, especially in New Mexico. "All seemed to be working for the reclamation of the arid lands," the *Republican* gushed, "that our citizens might have palacial [sic] homes surrounded with life's comforts, instead of poverty."

Downstream in Texas, the *El Paso Herald*'s large headline boldly proclaimed "Unanimity," and the paper was filled with laudatory narratives of how a consensus, "absolute, firm as a rock," had been reached "in sentiment and purpose, among representatives from the Rio Grande valley of New Mexico, Texas, and Mexico, with reference to plans for reclaiming the valley."

The need to resolve how to allocate Rio Grande water supplies in southern New Mexico and around El Paso and Juarez had become increasingly important in the two decades preceding the 1904 National Irrigation Congress. During this period, water supplies had dwindled in the Mesilla and El Paso valleys as settlement had grown in the upper part of the basin in Colorado's San Luis Valley. The increased population in the San Luis Valley had resulted in a dramatic decline of the non-flood flows of the Rio Grande that formerly had reached the Mesilla and El Paso valleys. As the river had become drier and drier prior to 1904, residents of the two valleys had developed two ambitious but competing plans to compensate for the reduced flows.

Mesilla Valley residents had backed a solution to their water shortage problems by supporting the proposal by Nathan Boyd's Rio Grande Dam and Irrigation Company to build a reservoir at Elephant Butte, where the U.S. Bureau of Reclamation's Elephant Butte Reservoir presently exists. The company's planned Elephant Butte Reservoir was to store spring flood waters. The company would then supply irrigation water to several New Mexico valleys along the Rio Grande, including the Mesilla Valley. Of course, Boyd and his supporters hoped to benefit financially from the success of his company, and they also anticipated that the reservoir would increase settlement on the lower river and help win statehood for New Mexico, which remained a territory until 1912.

Simultaneous to the plans of the Rio Grande Dam and Irrigation Company, residents downstream around El Paso and Juarez endorsed a proposal for an international dam just above those two towns. Like the proposal for the Rio Grande Dam and Irrigation Company's Elephant Butte Dam, the international reservoir was to capture spring snowmelt flows for later use. The international reservoir idea, which had been developed by early prominent El Paso resident Colonel Anson Mills, would satisfy parched lands on both sides of the U.S. and Mexican border. Not by coincidence, a large body of these lands on both sides of the border were owned by Anson Mills and his brother, William, and thus, like Nathan Boyd in relation to the Elephant Butte plan, the two Mills brothers stood to benefit directly if the international dam were constructed.

Understandably, El Paso and Juarez settlers believed that the proposed Elephant Butte structure would interfere with spring flood flows that would be stored at the international dam, and claiming their water uses had prior rights to those of the Mesilla Valley, residents of El Paso and Juarez fiercely opposed the Rio Grande Dam and Irrigation Company's venture. Similarly, backers of the company strenuously fought the international dam scheme believing that there was insufficient water for both that reservoir and the one at Elephant Butte. In addition, proponents of the Elephant Butte plan resisted the international dam because they understood it would flood a large part of southern New Mexico.

The conflict over these opposing propositions had raged for many years by the time the 1904 National Irrigation Congress convened, and the struggle had become so fierce that it had involved the highest levels of the U.S. State Department after increasingly vehement demands by Mexico–which were supported by Texans–that Americans cease interfering with Rio Grande water destined for farms around Juarez and El Paso. Because of these diplomatic troubles, the contest between the Elephant Butte Dam and the reservoir just above El Paso also had included a nearly decade-long lawsuit by the United States Government to block the efforts of the Rio Grande Dam and Irrigation Company in order to find some means of satisfying Mexico's demands for water. The controversy over which dam would be built also had been the focus of intense debate in Congress, when Texas's Congressional delegation repeatedly introduced bills over several years to authorize the international dam at El Paso. Named the Culberson-Stevens bills after the Texas senator and El Paso-area congressman who introduced them year after year on both sides of Capitol Hill, these measures had the endorsement of Anson Mills, Texans, and the Mexicans, but they had been hotly contested by backers of the Rio Grande Dam and Irrigation Company.

The diplomatic squabbling, the lawsuit against the Rio Grande Dam and Irrigation Company, and the Culberson-Stevens bills indicated how difficult the struggle over Rio Grande waters had become in the Mesilla and El Paso valleys and how great the stakes were to both regions by the time of the 1904 National Irrigation Congress. It was at that gathering, which was held in El Paso, that the U.S. Reclamation Service, which had been formed only two years earlier, announced its studies of the river had resulted in a plan to end the water struggles. After hearing the details, delegates subsequently endorsed the Reclamation Service's plan as a satisfactory compromise to end the Rio Grande apportionment fight.

The Reclamation Service proposal involved the construction of a Government reservoir on the Rio Grande at Elephant Butte instead of the private structure proposed for that location by Nathan Boyd's company. Waters stored behind the Government Elephant Butte structure were to serve lands in New Mexico and Texas through a distribution system that would be known as the Rio Grande Project. The amount of acreage in New Mexico and Texas to receive project water supplies, according to the compromise approved by the delegates to the 1904 National Irrigation Congress, was to be determined by Reclamation Service surveys. Like the dam itself at Elephant Butte, the Rio Grande Project distribution system would be built and operated by the Reclamation Service, and the farmers who received water from the project were to repay the Government the cost of building the irrigation system. In addition to storing water for the Rio Grande Project, the Reclamation Service's compromise proposal called for Elephant Butte Reservoir to provide 60,000 acre-feet of water annually to Mexico to satisfy that country's demands, assuming a treaty could be negotiated covering this point. That figure had been determined by an earlier international commission to be the amount of water that had been denied Mexico due to increasing American diversions.

Ultimately, because of the endorsement of the Reclamation Service's plan by the 1904 National Irrigation Congress, the U.S. Congress enacted legislation in 1905 extending the 1902 Reclamation Act to the El Paso Valley in Texas. That state had not been covered by the original Reclamation Act because Texas, having been an independent nation before it joined the Union in 1845, had no federal public domain lands, the sale of which were to help offset the costs of Reclamation Service projects. Importantly, the 1905 law–as was clearly shown in Congressional debates before its enactment–also authorized the Reclamation Service to build Elephant Butte Dam and Reservoir and to apportion waters stored there among water users in the Rio Grande Project according to the Reclamation Service's surveys.

In effect, therefore, this 1905 law became the first Congressionally directed allocation of an interstate river. This was 23 years before the Boulder Canyon Act of 1928 apportioned the Colorado River–a law the U.S. Supreme Court in *Arizona v. California* (1963) mistakenly characterized as the first interstate river division accomplished by federal legislation.

Following the 1905 law, the international part of the 1904 National Irrigation Congress compromise was carried out when Congress ratified a treaty in 1906 providing for the delivery of 60,000 acre-feet of Rio Grande waters to Mexico each year. Thus, by 1906 the Rio Grande below Elephant Butte Dam was in the process of being apportioned among water users in New Mexico, Texas, and Mexico. Part of this allocation had been carried out through legislation and part of it by treaty with Mexico. The important point, however, is that this interstate and international division of the Rio Grande's waters was accomplished long before compact negotiations began on a broader allocation of the river's waters among Colorado, New Mexico, and Texas. How the Rio Grande Project's allocation made its way into the 1938 Compact in intent can be seen in the history of the Compact.

Over the years following the interstate apportionment within the Rio Grande Project, a variety of events took place that ultimately made an interstate compact among Colorado, New Mexico, and Texas necessary. First, Elephant Butte Dam was completed in 1916. Subsequently, the Reclamation Service finished studies of soils, drainage, and other factors and determined that the final Rio Grande Project would serve 88,000 acres in New Mexico and 67,000 acres in Texas. These allotments, which were subsequently endorsed twice by water users in both states, fulfilled the Congressional directive under the 1905 law extending the Reclamation Act to Texas that the Reclamation Service would apportion the river's waters based on the agency's studies.

While the allocations within the Rio Grande Project were being determined, water users under the project formed two organizations to work with the Government in operating the project and to coordinate payments for construction and operation and maintenance. Initially, these organizations were water users' associations, but the water users later formed irrigation districts to allow taxes to be levied for payments to the Government. The districts were the Elephant Butte Irrigation District in New Mexico and the El Paso County Water Improvement District No. 1 in Texas, and they signed contracts with the U.S. Government to pay expenses in the same 88/67 ratio as their respective acreage allocations.

As these events were transpiring, concern began growing by the early 1920s that the expansion of irrigation in the Middle Rio Grande Valley above Elephant Butte and in Colorado's San Luis Valley might undermine the apportionment within the Rio Grande Project by diminishing water supplies available to Elephant Butte Reservoir. It was partly this problem that prompted the beginning of compact discussions in order to protect the allocations within the project as well as to guard upstream uses from litigious assaults by Rio Grande Project water users.

The direct cause for beginning interstate compact talks centered on what was known as the Rio Grande "embargo." The embargo was a limitation on developing the river's water supplies anywhere on the public domain in New Mexico or Colorado that had been imposed in the late nineteenth century as the debate over whether the private Elephant Butte dam or the international dam would be built. First instituted in 1896 by Secretary of the Interior David R. Francis, the embargo had been left in place even after the 1904 National Irrigation Congress had endorsed the Reclamation Service's solution to the Rio Grande's problems to protect water supplies that eventually were to be stored at Elephant Butte Reservoir.

By the early 1920s, the embargo was still in effect, and regions above Elephant Butte chafed at the restriction. Residents of the Middle Rio Grande Valley near Albuquerque and in Colorado's San Luis Valley had tried in vain for years to have the embargo lifted, and when an interstate compact was proposed to settle allocations for the Colorado River, the suggestion was made that a similar negotiated compact could be used to apportion Rio Grande waters among Texas, New Mexico, and Colorado. With such an agreement in place, the theory went, the hated Rio Grande embargo could be lifted permanently.

With the successful signing of the Colorado River Compact in 1922, New Mexico and Colorado–both of which had taken part in the Colorado River's talks–quickly named commissioners to negotiate a similar agreement for the Rio Grande. Talks broke down, however, over a variety of issues including whether Texas should take part, and it was not until December 19, 1928, that compact deliberations got under way in earnest. As discussions began at the December 19th meeting, New Mexico's Compact Commissioner, Francis C. Wilson, defined his state's position first. Arguing that since neither New Mexico nor Texas asked for any new Rio Grande water supplies from Colorado but both sought to prevent further Colorado diversions, Wilson insisted on delivery of a specific amount of water at the Colorado-New Mexico state line. Wilson recognized Colorado's desire to increase development in the San Luis Valley, but he thought this could be accomplished by draining the waterlogged part of the valley that was commonly known as the "dead" or "sump" area and more formally termed the Closed Basin. This recovered water, Wilson believed, could be used elsewhere in Colorado with no detrimental effects below the state line. Wilson pointed out, however, that without such drainage any new dams in the Colorado part of the Rio Grande Basin would be a direct threat to Rio Grande Project water rights–which had been filed for by the Reclamation Service in 1906 and 1908–because those new structures in Colorado would impound existing flows coming out of the San Luis Valley.

Richard Burges, a highly respected water law attorney from El Paso who was attending the meeting as a Texas observer, spoke next on behalf of his state. Burges told the compact commissioners that Texas relied upon its rights as established by allocations within the Rio Grande Project. Moreover, Burges asserted that Texas held senior water rights for 20,000 acres under the ditch above Fort Quitman, Texas, but below the end of the Rio Grande Project. Most of this land, Burges pointed out, was being served by project return flows. In addition, Burges said he had been asked to "lay before the commission the claims of the City of El Paso to a municipal water supply from the waters of the Rio Grande," but he did not elaborate on this point.

With the New Mexico and Texas positions established, Colorado Lieutenant Governor George M. Corlett, who spoke for San Luis Valley irrigators, outlined the history of the Rio Grande embargo and described how that restriction had been a grave injustice to Colorado water users. Corlett offered two reasons why additional storage of Rio Grande waters in Colorado would not hurt water supplies downriver. First, he contended that return flows from San Luis Valley irrigation would offset any supplemental Colorado diversions. Second, Corlett asserted that any Rio Grande water flowing into New Mexico was wasted by evaporation in the desert heat long before it could reach Elephant Butte Reservoir.

For these reasons, Corlett stated that additional storage in Colorado would not adversely affect irrigators below the state line, and he suggested that such new reservoirs might even benefit farmers in northern New Mexico and in the Middle Rio Grande Valley by acting as storage for them as well as for Colorado interests. Corlett concluded that while he was unwilling to abandon plans for further Rio Grande reservoirs in Colorado, he was willing to work with New Mexico and Texas representatives to secure federal aid for drainage of the San Luis Valley Closed Basin and to provide related storage works on the upper Rio Grande and on the Conejos River, a tributary of the Rio Grande.

By mid-February 1929, the commissioners realized that no final agreement could be reached, and because the three states' legislatures met only once every two years and currently were in session, it became imperative that a temporary agreement be realized to avoid expensive litigation in the U.S. Supreme Court. With the desire to keep the Rio Grande issues out of a lawsuit, on February 12, 1929, the three states' commissioners signed a temporary compact that in essence established the status quo as a basis for apportioning the river's waters among Colorado, New Mexico, and Texas until a permanent accord could be achieved.

The temporary 1929 Rio Grande Compact requested that the United States construct a drain for the San Luis Valley's Closed Basin and a reservoir in Colorado near the state line to impound the increased river flow from the drainage works. These new reclamation features were to benefit all three states. Once the Closed Basin Drain and State Line Reservoir were completed, the 1929 Compact provided that the three states would meet again to work out a permanent agreement based on river flow measurements with these facilities in place.

Tied to the request that the federal government build the Closed Basin Drain and the reservoir at the Colorado-New Mexico state line was the central point of the temporary compact. Until the drain and reservoir were constructed, Colorado agreed not to increase diversions, build more storage facilities, or impair the flow of the Rio Grande as it then existed. The idea, of course, was to assure federal authorities that U.S. aid for the proposed projects could go forward unimpeded by the interstate quarrel.

The negotiators of the 1929 Rio Grande Compact could not have anticipated that less than nine months after they had signed the accord, the stock market crash of that year would trigger the worst economic crisis the United States had ever experienced. With the Great Depression making Congress and President Herbert Hoover reluctant to approve major expenditure bills, projects like the Closed Basin Drain and the State Line Reservoir were temporarily shelved. The Depression also delayed the resumption of Rio Grande Compact talks until December 1934 because authorities had other, bigger, problems to address due to the economic emergency.

When negotiations for a permanent Rio Grande Compact finally resumed, among the first to speak was George Corlett, who, as in 1929, once again represented San Luis Valley interests. Corlett demanded that Colorado be placed upon what he termed a "parity with New Mexico and Texas insofar as our present requirements are concerned." To Corlett and San Luis Valley water users, this meant having the right to build new storage reservoirs in Colorado's part of the Rio Grande Basin regardless of whether the Closed Basin Drain and the State Line Reservoir were constructed.

In response, Richard Burges, who had come to the meeting this time as a legal adviser to Texas's commissioner, T.H. McGregor, insisted that Texas was unwilling to allow Colorado to have more storage until the extent of flows from the Closed Basin Drain was known. New Mexico's representatives supported Burges's position, recognizing that without the Closed Basin Drain information, Colorado's upstream position could allow San Luis Valley water users to take ever-larger amounts of the Rio Grande's flow. With more debate amply demonstrating that none of the negotiators would retreat from their positions, the commissioners realized that no quick agreement was likely, and the session adjourned for the time being.

With negotiations at an impasse, in October 1935 Texas filed a lawsuit in the U.S. Supreme Court against New Mexico and the Middle Rio

Grande Conservancy District–which had been organized for lands near Albuquerque–to protect Rio Grande Project water supplies. Another purpose of the lawsuit also was to keep compact talks moving forward. Almost simultaneously, Franklin D. Roosevelt, who had been sworn in as President in 1933, directed the National Resources Committee, an agency created to coordinate resource development throughout the United States, to act as a clearinghouse on all Rio Grande water proposals and to help settle the river's apportionment dispute. The result was the creation of the Rio Grande Joint Investigation, a series of studies by state and federal authorities on water supplies, needs, and other information on which a compact could be based. In the meantime, *Texas v. New Mexico and the Middle Rio Grande Conservancy District* was postponed by Special Master Charles Warren, who had been appointed by the Supreme Court to hear the case.

By December 1937, with the fruit of the Rio Grande Joint Investigation in hand, the Rio Grande Compact Commission's engineering advisers developed a proposed schedule of deliveries to form the basis of a permanent compact. Deliveries were to be made by Colorado at the Colorado-New Mexico state line and by New Mexico at San Marcial, near the head of Elephant Butte Reservoir. No delivery schedule was called for at the Texas-New Mexico state line. The following March, the Rio Grande Compact Commission unanimously adopted schedules of delivery at those locations when they signed the Rio Grande Compact. Again, no schedule of deliveries was established at the New Mexico-Texas state line.

I do not plan to go into the details of the provisions of the 1938 Rio Grande Compact, because my purpose is to illustrate the relationship between the allocations within the Rio Grande Project made under the 1905 Congressional legislation and those made under the 1938 Compact. The history of the ratification struggles will make that connection between the two apportionments clear. In general, however, the 1938 Compact's provisions were:

1. The creation of a permanent compact commission to oversee the operations of the Compact.
2. The establishment of gaging stations along the river to ensure deliveries by Colorado at the Colorado-New Mexico state line and deliveries by New Mexico to Elephant Butte Reservoir.
3. The creation of a system of debits and credits to accommodate variations from agreed-upon schedules.

With the signing of the 1938 Rio Grande Compact, the commissioners returned to their home states to lobby for quick ratification by their respective state legislatures when they reconvened in early 1939. Having overcome such formidable disagreements to reach a final pact, however, little could the commissioners have imagined that ratification would become an almost insurmountable obstacle in Texas because of a major dispute about how the Compact's terms affected that state.

The 1938 Compact's lack of mention of specific deliveries at the New Mexico-Texas state line triggered the ratification problem in Texas. The Rio Grande Compact Commissioners' reasons for rejecting a schedule of deliveries at the New Mexico-Texas state line had never been made clear to Texans on the lower Rio Grande between Fort Quitman and the Gulf of Mexico. As a result, many of these water users thought that because the Compact only provided for water deliveries at Elephant Butte Reservoir and not at the New Mexico-Texas state line, Texas had no solid guarantee of **any** Rio Grande water.

To residents on the lower Rio Grande, the supposed lack of an apportionment at the New Mexico-Texas state line appeared to be a sell-out of the majority of Texas's interests in favor of a handful of Rio Grande Project farmers in the El Paso Valley–irrigators who already enjoyed the benefits of Elephant Butte Dam and federally constructed canals. Even more galling to lower Rio Grande water users, the abandonment of their needs had taken place during the severe drought of the 1930s.

Acting on these beliefs, water users in Texas below Fort Quitman demanded a guarantee of 200,000 acre-feet per year of Rio Grande waters. Threatening to go to the Texas legislature to fight against ratification of the Compact, these lower river water users also retained a law firm by the name of Smith and Hall to intervene in the still-pending Supreme Court case of *Texas v. New Mexico and the Middle Rio Grande Conservancy District*.

Before developing a legal strategy for the intervention, however, Sawnie Smith of Smith and Hall realized that he needed to know whether the Rio Grande Compact Commissioners deliberately had **not** provided for a specific amount of water to go to Texas, and if so, why. Writing to Frank Clayton (who had replaced T.H. McGregor as Texas's Rio Grande Compact Commissioner), Smith noted that there had been considerable comment on the fact that the new Rio Grande Compact made, as Smith wrote, "no provision for the division of waters below Elephant Butte between the States of New Mexico and Texas and makes no provision concerning the amount of water to which Texas is entitled." This apparent omission, to Smith, was puzzling, and he told Clayton it was "too obvious to have been inadvertent, and, therefore, unquestionably, the commissioners had what they considered valid reasons for it." Smith wanted an explanation, therefore, of "why the respective rights of Texas and New Mexico to those waters were not defined and provided for in the compact in express terms."

In reply, Clayton wrote that the negotiators of the new Rio Grande Compact had recognized an existing apportionment of the river's waters between New Mexico and Texas below Elephant Butte Dam through the allocations made by the Bureau of Reclamation and the operation of the Rio Grande Project. As Clayton explained, "the question of the division of the water released from Elephant Butte reservoir is taken care of by contracts between the districts under the Rio Grande Project and the Bureau of Reclamation." Observing that these contracts provided that the lands within the project would all have the same rights, Clayton confirmed that the water was allocated according to the respective areas involved in the two states–areas defined by the Bureau of Reclamation under the terms of the 1905 federal legislation sanctioning the 1904 apportionment compromise.

Clayton continued, "the total area is 'frozen' at the figure representing the acreage now actually in cultivation: approximately 88,000 acres for the Elephant Butte Irrigation District, and 67,000 for the El Paso County Water Improvement District No. 1, with a 'cushion' of three per cent for each figure." Adding that he believed "there will never be any difficulty about the allocation of this water,"–a perhaps overly optimistic assumption–Clayton told Smith he hoped his answer would satisfy lower Rio Grande water users.

Because of the evident misunderstanding about the Rio Grande Compact Commissioners' intentions, Clayton sent explanatory letters similar to his reply to Smith to all the incoming Texas state legislators. He also went in person to the lower Rio Grande Valley in early October 1938–armed with copies of the Compact and histories of the Rio Grande controversy–to explain the Rio Grande Compact Commissioners' aim. The campaign to clarify the Compact's intent quickly paid off, and Clayton won the support of lower Rio Grande water users for the Compact's ratification.

With most sources of controversy now resolved, the legislatures of Colorado, New Mexico, and Texas soon approved the Rio Grande Compact. On February 21, 1939, Colorado Governor Ralph L. Carr signed his state's ratification bill. Texas Governor W. Lee O'Daniel, also known as "Pappy" executed his state's approval measure on March 1, 1939. New Mexico Governor John E. Miles followed suit the next day. When President Roosevelt signed Congress's consent on May 31, 1939, the Rio Grande Compact took effect.

Thus, as this history of the Rio Grande Project and the 1938 Rio Grande Compact illustrates, there actually **is** an interstate apportionment of Rio Grande waters at the New Mexico-Texas border–one that was authorized by Congress in 1905 when the federal lawmakers approved the construction of the Rio Grande Project and directed the Reclamation Service to allocate waters within that project. That apportionment was then intended to be incorporated into the 1938 Rio Grande Compact, as Texas Compact Commissioner Clayton explained to lower Rio Grande water users and to the Texas legislators who ratified the accord.

***Philip Mutz** grew up on a ranch in Eagle Nest, New Mexico. He earned a B.S. in civil engineering from the University of New Mexico and then spent two years in the U.S. Army, including a tour in the Philippine Islands. From 1946-1954 Phil was employed as a hydrologic engineer with the Bureau of Reclamation in Albuquerque and Monte Vista, Colorado. For the next two years Phil worked for the Colorado Water Conservation Board focusing on water resources investigations of the San Luis Valley in relation to the requirements for the delivery of water under terms of the Rio Grande Compact. For the following 34 years he worked for the New Mexico Interstate Stream Commission. Included in his various duties over the years was the operation and development of the Ute Dam and Reservoir Project. In 1990 Phil began providing consulting services to the New Mexico Office of the State Engineer and Interstate Stream Commission. In 1991 he was appointed by the Governor as New Mexico's Commissioner on both the Upper Colorado River and the Canadian River commissions.*

POST COMPACT DELIVERY OF WATER BY NEW MEXICO

The Rio Grande Compact signed March 18, 1938, contains a schedule for delivery of water by New Mexico that uses the relationship of the recorded flow of the Rio Grande at the gaging station at Otowi Bridge near San Ildefonso to the recorded flow of the Rio Grande at the gaging station near San Marcial during the calendar year exclusive of the months of July, August and September. This "nine-month" schedule was adopted because the nine months that are included represented the best available relationship of the flows at the two gaging stations. Inclusion of the three other months, July, August and September, resulted in an erratic relation principally because of the wide variation in the discharge of the intervening tributary streams during summer thunderstorms.

The first year of Compact accounting was 1940 and both Colorado and New Mexico incurred under-deliveries. In the next two years, very large stream flow was predominant throughout the Rio Grande Basin and actual spill of water from Project Storage occurred in 1942. In accordance with provisions of the Compact, the debit/credit status as well as the accounting of releases from Project Storage began anew in 1943. Sufficient spill had occurred to spill all credit water in storage.

In 1943 and 1944, New Mexico accumulated substantial under-deliveries. As of January 1, 1945 the accrued status was a debit of 150,400 acre-feet.

On June 1, 1944, Commissioner McClure for New Mexico, requested a review of certain provisions of the Compact, pursuant to Article XIII, which provides for review of any provision that is not substantive in nature and which does not affect the basic principles upon which the Compact is founded. Commissioner McClure targeted review of the nine-month schedule stating that substantial quantities of water were being delivered past San Marcial during July, August and September.

The Rio Grande Compact Commission met on December 16, 1944 and adopted a resolution authorizing the Engineer Advisers to meet to consider all data available bearing on the subject and report their findings and recommendations to the Commission at a later date.

The Engineer Advisers found that the task assigned required much time and effort. Finally, the Engineer Advisers reached agreement on a 12-month schedule of deliveries for New Mexico, which was submitted to the Compact Commission on February 24, 1947.

The Commission did not formally act on the report until its annual meeting held a year later in February 1948 at which time the Commission adopted a resolution finding:

- That because of changing physical conditions, reliable records of the amount of water passing the San Marcial stream gage are no longer obtainable and that the gage should be abandoned for Compact purposes.
- That the need for concurrent records at the San Marcial and San Acacia stream gages no longer exists and the San Acacia gage should be abandoned for Compact purposes.
- That it is desirable and necessary that the obligation of New Mexico to deliver water in the months of July, August and September be scheduled.
- That the change in gaging station and substitution of the new measurements recommended will result in substantially the same results so far as the rights and obligations to deliver water are concerned, and would have existed if such substitution of stations and measurements had not been made.
- That the recommended measurements and schedule be substituted for the nine-month schedule set forth in Article IV of the Compact.
- That the resolution was passed unanimously and shall be effective January 1, 1949 if within 120 days the Commissioner from each state shall have received from the Attorney General of his state an opinion approving the resolution.

At its annual meeting held in February 1949, the Chairman of the Commission announced that he had received, pursuant to the resolution of the Commission at its meeting in February 1948, opinions from the attorney generala of Colorado, New Mexico and Texas that the substitution of stations and measurement of deliveries of water by New Mexico set forth in the resolution was within the powers of the Commission.

It should be noted that Article V of the Compact provides that with the unanimous approval of the Commission, the gaging stations referred to in the Compact may be abandoned and another station established and new measurements shall be substituted that will result in substantially the same results, so far as the rights and obligations to deliver water are concerned, as would have existed if such substitution of stations and measurements had not been made.

Post Compact Delivery of Water by New Mexico

It is ironic that Commissioner McClure for New Mexico during negotiation of the Compact, rejected a report by the Engineering Committee which recommended a schedule for New Mexico that was similar to the schedule substituted by the resolution of the Commission adopted in February 1948; Commissioner McClure cited the proposed 12-month schedule as well as other points in his rejection of the Committee's recommendation.

New Mexico continued to underdeliver water and when the 12-month schedule became effective on January 1, 1949, the accrued debit was 268,400 acre-feet. However, such accrued debit was within the limitations imposed by the Compact because sufficient 'debit water' was in storage in El Vado Reservoir.

The large, continuous flow in the Rio Grande resulting from the extensive precipitation that accrued through the watershed in 1941 and 1942 caused substantial damage to the channel of the river in the Middle Valley. The irrigation works of the Conservancy District, which were constructed in the early 1930s, were damaged, especially the outfalls for the drains that became clogged with sediment or were inoperative because the river aggraded due to sedimentation. Also an extensive delta area was created in the head of Elephant Butte Reservoir.

In 1942, the Bureau of Reclamation and the Corps of Engineers launched a program of coordinated studies of the problem area. Following the end of World War II, the joint studies were intensified and in November 1947 the Secretary of the Interior formally approved a detailed plan submitted by the two agencies. The plan included reconstruction of the irrigation works and financial reorganization of the Conservancy District, flood control reservoirs on the Rio Grande and Rio Chama, more drains in the Middle Valley and extensive rectification of the river channel between Velarde and Elephant Butte Reservoir. The joint

Middle Rio Grande Project was authorized by Congress in June 1948. This authorization was supplemented by a further act of Congress in 1950.

The authorization did not include a flood control reservoir on the Rio Grande as proposed in the 1947 plan. The authorization did include Jemez Canyon Reservoir and the Low Chamita Dam near the mouth of Rio Chama. Abiquiu Reservoir subsequently was constructed in lieu of the Low Chamita Dam. The authorization also included the low-flow channel from San Acacia to Elephant Butte Reservoir.

The Interstate Stream Commission cooperated closely with both federal agencies throughout the period of study and reviewed and commented on the several reports. Also, pending completion of the study and authorization of the Middle Rio Grande Project, the New Mexico Congressional delegation sponsored federal legislation providing funding to the Corps of Engineers to finance emergency flood control work on rivers in the state where conditions were critical. However, action on the legislation was delayed. Because some work on the Rio Grande was urgent, legislation was introduced in the 19th Legislature of New Mexico to expend moneys from the Improvement of the Rio Grande Income Fund, a state trust fund, to finance construction of acutely needed works. The legislature appropriated the funds to the Interstate Stream Commission in February 1949. The work was completed before the spring runoff of that year. In addition, the State Legislature in 1951 appropriated additional funds to finance construction of a pilot channel and drains in the flooded lands in the San Marcial area to partially drain these areas in advance of implementation of the authorized Federal Project. Both the Middle Rio Grande Conservancy District and Elephant Butte Irrigation District provided funds to supplement the state appropriations. Under this program, a small channel about 16 miles long was completed in early 1952.

During the period 1943-1950, inclusive, the flow of the Rio Grande was in the aggregate, below average. In 1950, at the request of the Conservancy District, an intricate arrangement was finally agreed upon to permit the District to release New Mexico debit water held in El Vado Reservoir to provide water to sustain at least the perennial crops in the Middle Valley. The arrangement included relinquishment to Texas of an equivalent amount of Colorado credit water being held in storage in Elephant Butte Reservoir. In exchange, Colorado was to be able to store water in Platoro Reservoir scheduled for completion in 1951.

Post Compact Delivery of Water by New Mexico

Runoff in 1950 was about 50 percent of normal. At the end of 1950, usable water in storage in Elephant Butte Reservoir was less than 400,000 acre-feet and storage in El Vado Reservoir was only about 29,000 acre-feet.

In 1949 and 1950, New Mexico accumulated small over-deliveries under the 12-month schedule, and as of January 1, 1951, the accrued debit was reduced to 263,100 acre-feet.

In 1951, the situation on the Rio Grande quickly became very serious for New Mexico. As of January 1, 1951, New Mexico was in its first violation of the Rio Grande Compact because the accrued debit exceeded the limitations of the Compact. Because there was less than 400,000 acre-feet of usable water in Elephant Butte and Caballo reservoirs, storage could not be made in El Vado Reservoir. Further, Texas demanded the release of the 29,000 acre-feet of debit water remaining in El Vado, which would drain the reservoir. The resulting releases from El Vado created much publicity in the newspapers. The Indian pueblos contended that their rights were superior to the Compact and, under their arrangement with the Conservancy District, water should be stored in El Vado for their use. The Department of Game and Fish took the position, supported by thousands of sportsman, that complete draining of El Vado could not be justified.

Releases of storage from El Vado were stopped by the Conservancy District before the reservoir drained completely because of threatened damage to the outlet works due to problems with ice. A request was made by Texas to release the remaining storage and the State Engineer was unable to enforce the request without Court action. Subsequently, storage was increased by the District during the spring runoff. Release of storage followed but only in quantities just sufficient to augment the flow of the Rio Grande to supply the demand in the Middle Valley.

In May 1951, the Conservancy District resolved that its policy is to take care of the needs of the farmers in the District insofar as possible.

Post Compact Delivery of Water by New Mexico

Storage in Elephant Butte Reservoir was reduced to its lowest level since initial filling and only contained 19,000 acre-feet on September 30, 1951.

Texas was not sympathetic and in October 1951 filed suit in the U.S. Supreme Court against the State of New Mexico and the Conservancy District alleging violations of the Rio Grande Compact citing accrued debit in excess of the limitations of the Compact and operation of reservoirs contrary to the Compact provisions.

Thereafter, the United States submitted a memorandum to the Court concluding that the United States was an indispensable party to the action.

In 1954, the Special Master appointed by the Court recommended that the suit be dismissed in the absence of the United States as an indispensable party because of the rights of the Indians.

Construction of the features of the Middle Rio Grande Project proceeded during the 1950s. In February 1957, the suit brought by Texas was dismissed by the Court because of the absence of the United States as an indispensable party.

The channel rectification and other works of the Middle Rio Grande Project began to show positive effects even prior to completion. New Mexico's delivery of water improved beginning about 1957 with over-delivery of the Compact obligations. New Mexico's accrued debit status, which aggregated 529,000 acre-feet at the end of 1956, was erased at the end of 1972. New Mexico was in Compact compliance in 1970 when the accrued debit was reduced to 182,000 acre-feet.

New Mexico has been in continuous compliance with its delivery obligation since 1969 and at the end of 1998 had an accrued credit of 153,000 acre-feet. Abundant precipitation in the watershed beginning in 1983 and continuing to date has contributed as well as other factors including improvement of water conveyance facilities in the Middle Valley under the cooperative program of the Interstate Stream Commission, the Conservancy District and the Bureau of Reclamation. Funding of a large portion of the work is from the Improvement of the Rio Grande Income Fund. Other contributing factors likely include a full supply of water for the Conservancy District and return flow from groundwater pumping.

__Fred Allen__ received a Bachelor of Science degree in Civil Engineering from the University of New Mexico. He spent 30 years with the State Engineer's Technical Division including thirteen years as Chief of the Hydrographic Survey Section and thirteen years as Chief of the Technical Division. After retirement from the Office of the State Engineer, Fred served with Plains Electric as a Water Resource Engineer. Currently, he is a contract hearing examiner with the Office of the State Engineer and a Water Resource Consultant. Fred is a registered New Mexico Professional Engineer and Surveyor.

Delivery of San Juan Water to the Otowi Gage

In the late 1950s, the State Engineer, in anticipation of the proposed San Juan/Chama Transmountain Diversion Project, was concerned that the San Juan water to be delivered to the Rio Chama would reach the Otowi Gage on the Rio Grande. The schedule set forth in the 1948 Resolution of the Rio Grande Compact Commission provides that the flow at the Otowi Gage shall be adjusted for any transmountain diversions into the Rio Grande between Lobatos, Colorado and the Otowi Gage. As the Rio Chama enters the Rio Grande above the Otowi Gage just north of Española, the discharges of the Rio Grande at the Otowi Gage would be adjusted for San Juan transmountain diversions.

The principal area of concern was the reach of the Rio Chama from Abiquiu Dam to its confluence with the Rio Grande. The State Engineer's objective was to be able to control diversions in this reach so that the acequias would not divert San Juan water during release of those waters into the Rio Chama unless they had made prior arrangements for San Juan water. A watermaster would be needed to accomplish this objective.

It became clear that an adjudication of Rio Chama water rights would be necessary in order to have a watermaster appointed by the court to supervise the apportionment of the Rio Chama water. Section 72-2-9 of the New Mexico statutes provides that "the state engineer shall have the supervision of the apportionment of water in this state according to the licenses issued by him and his predecessors and the adjudications of the courts."

The first step to an adjudication is a hydrographic survey. The hydrographic survey of the Rio Chama was initiated in September, 1957 and plane table surveys of isolated lands were completed by June, 1959. The main stem surveys were accomplished by photogrammetric methods. The survey of the Rio Chama reach from Abiquiu Dam to its confluence with the Rio Grande was virtually completed by the end of the State Engineer's twenty-seventh biennial period, which ended on June 30, 1966. We called this reach the Española to Abiquiu reach because we began the survey downstream and worked our way upstream. The survey was done piecemeal beginning with the most downstream acequia. Once the survey was completed, the hydrographic survey report and maps were turned over to the State Engineer legal staff for adjudication.

The adjudication suit on the Rio Chama stream system below El Vado Dam was initiated during the twenty-fifth biennial period, that is the period from July 1, 1960 to June 30, 1962.The State Engineer's biennial report for that period states that the adjudication suit was initiated in contemplation of construction of the San Juan Transmountain Diversion Project.

In addition, a court ordered hydrographic survey of the Rio Puerco de Chama was underway and it was accomplished by plane table method. The Rio Puerco de Chama is a south side tributary of the Rio Chama and empties into Abiquiu Reservoir. Most of the irrigated land is near the Village of Coyote. The survey was completed during the July 1, 1960 to June 30, 1962 period and the per-acre cost of that survey amounted to over $29. Now, in 1962 , $29 per acre in that rural community was just about what the land was worth. Steve Reynolds almost went into a state of shock when he found out what the cost of that survey was.

The Rio Chama Hydrographic Survey and the Rio Puerco de Chama Hydrographic Survey brought about a significant piece of legislation and that was the elimination of the Hydrographic Survey Fund. At the time these surveys were undertaken, the New Mexico statutes contained a section that established a Hydrographic Survey Fund for the purpose of financing surveys and water studies necessary in the adjudication of water rights. Once the water rights were adjudicated in a particular stream system, the costs of the hydrographic survey were assessed to the owners in proportion to the acres of water rights adjudicated to them. That is, the total cost of the survey was divided by the total acres of water rights adjudicated to obtain a per-acre cost.

The Rio Chama hydrographic survey was not so much for the benefit of the Rio Chama water right owners as for the beneficiaries of the San Juan imported water. The State Engineer was convinced that it was in the state's best interest that the state bear the cost of the hydrographic surveys.

State Senator Matt Chacon of Rio Arriba County represented many of the water right owners in both the Rio Puerco de Chama and Rio Chama adjudication suits. He was very receptive and supportive of legislation to eliminate the Hydrographic Survey Fund. He sponsored such legislation and the fund was eliminated by Chapter 124, Laws of 1965 and it provided that the costs of hydrographic surveys be borne by the state.

The San Juan/Chama Transmountain Diversion Project was initiated in late 1964 when excavation of the Azotea Tunnel was commenced. The contract for the Blanco Tunnel was awarded in May, 1965 and the contract for the Oso Tunnel was awarded in February 1966. The San Juan/Chama Diversion Project was completed in late 1970 when Heron Dam was constructed and the first water under the project was diverted in November 1970.

The adjudication of the Rio Chama mainstem reach from Espanola to Abiquiu was completed in 1971 and the court appointed George Shaw as watermaster on August 9, 1971. Measuring devices on the acequias in this reach were installed early in 1972, which allowed the watermaster to control diversions of Rio Chama water.

Delivery of San Juan Water to the Otowi Gage

The State Engineer's objective to control diversions of Rio Chama water during releases of San Juan water–so that the San Juan water reached Otowi Gage–was achieved in June 1972 when diversions of water from the Rio Chama in the Espanola to Abiquiu reach were administered by the Rio Chama Watermaster.

Jim Williams was employed by the New Mexico State Engineer from 1948-1978. He was assigned to the Roswell District of the Office of the State Engineer in August 1956 and later transferred to Albuquerque to establish the District 1 office which was scheduled to open on November 29, 1956, the same time the Rio Grande Underground Basin was to be declared by the State Engineer. Jim assisted in developing the administrative criteria for the Rio Grande Underground Water Basin. As District Supervisor in Albuquerque from 1956-1978, he was responsible for groundwater administration and to some extent, surface water administration, between Elephant Butte and the New Mexico-Colorado state line and between the Pecos Divide and the New Mexico-Arizona state line. Upon retiring from OSE, he became President and General Manager of a water and wastewater distribution system. Jim retired at the end of 1991 and served as a consultant until the fall of 1992.

Rio Grande Underground Water Basin Declared

From September 1956 to November 29, 1956, I worked with other staff members to develop administrative criteria for the declaration of the Rio Grande Underground Water Basin to be declared on November 29, 1956. On November 29, 1956, I was appointed supervisor of the newly declared basin, along with the supervision of the Estancia and Grants Bluewater Basins.

Steve Reynolds, the state engineer, had no alternative but to declare the basin for at least some of the following reasons:

1. New Mexico was not making its commitments under the Rio Grande Compact.
2. The Rio Grande was over appropriated and the relationship between the river and the groundwater reservoir indicated that groundwater development was contributing to the over-appropriation of the river.
3. Federal law suits filed by Texas against the state of New Mexico and the Middle Rio Grande Conservancy District as early as 1951, could at some point in time place a federal water master on the Rio Grande.
4. All but one municipality along the middle and upper Rio Grande was supplied by groundwater. Population projections indicated that more groundwater would be needed in order to meet future demands.
5. There was information that large groundwater diversions for farming operations were planned.

Steve knew that the declaration of the basin would be very controversial so he obtained the support of Governor Sims and incoming Governor Mechem before he declared the basin.

The administrative policy developed for the basin was different from those of other declared basins. The idea was to protect the river, but still permit mining of the groundwater reservoir as long as the effects on the river were offset by the retirement of valid existing water rights. In theory this was a good idea and it lessened some of the criticism directed toward the state engineer.

Based on information that I have received, some of the municipalities and others are now at the point where they need additional water rights in order to continue pumping. If these parties are unable to offset their effects on the river then lengthy litigation may follow during which time the river may be impaired and this could have an adverse impact on our compact commitments.

The following are examples of news reports during the period.

Rio Grande Underground Water Basin Declared

Portales Daily Tribune, Nov. 30, 1956
RIO GRANDE VALLEY DECLARED WATER BASIN

Albuquerque Journal, Nov. 30, 1956
DAM-COLORADO DISTRICT OF RIO SO DESIGNATED

Albuquerque Journal, Dec. 17, 1956
UNDERGROUND WATER PLAN ORDERED BY STATE ENGINEER DRAWS FIRE FROM SANCHEZ
City of Albuquerque City Commission Chairman Maurice Sanchez suggests that the City ignore the action of the State Engineer. The order is the most ill-advised and ill-conceived action possible. The chairman urged that the governor immediately direct the State Engineer to rescind the order.

Albuquerque Journal, Dec. 17, 1956
TAOS COUNTY COMMISSIONERS NIX UNDERGROUND WATER ORDER

Letters sent to Governor Mechem and to New Mexico Senators and Representatives:

Albuquerque Journal, Dec. 19, 1956
SANCHEZ URGES CITY TO REFUSE RIO RULES

Albuquerque Journal, Dec. 19, 1956
WATER EDICT TO END FARMING IN VALLEY BUREAU HEAD SAYS
Stated by Ernest Alary, President of the Bernalillo and Sandoval County Farm and Livestock Bureau

Albuquerque Journal, Dec. 23, 1956
WATER BASIN A NECESSITY, MECHEM THINKS

Albuquerque Tribune, Dec. 24, 1956
SANCHEZ SAYS EDICT TO HINDER INDUSTRY HERE

Albuquerque Journal, Jan. 4, 1957
MORE HEARINGS DUE ON WATER BASIN ORDER
Martin Threet, Middle Rio Grande Conservancy District attorney, questioned legal authority of Reynolds.

Albuquerque Journal, Jan. 4, 1957
UNDERGROUND WATER DISTRICT DRAWS FIRE
Martin Threet declares Reynolds exceeds statutory authority.

Taos News, Jan. 4, 1957
FARM BUREAU PLANS COURT ATTACK ON WATER BASIN ORDER

Albuquerque Tribune, Jan. 7, 1957
LAW TO KNOCK OUT RIO WATER BASIN IS SOUGHT
With heavy support, Legislature proposes to wipe out Rio Water Basin.

Albuquerque Tribune, Feb. 8, 1957
HEARING SCHEDULED ON BILL TO UPSET WATER BASIN ORDER

Albuquerque Journal, May 16, 1957
CITY TO FILE SUIT IN WATER RULING

Albuquerque Journal, May 22, 1957
COURT DECISION ON WATER BASIN TO BE APPEALED

Albuquerque Journal, May 24, 1957
DEFENDANTS FILE NEW COURT ACTION IN WATER CASE

Albuquerque Journal, May 30, 1957
JUDGE TURNS DOWN CITY'S PLEA IN CASE ON RIO GRANDE BASIN

Albuquerque Tribune, Nov. 5, 1957
COURT FIGHT PROMISED ON WELL ORDER

Albuquerque Journal, Nov. 5, 1957
SANCHEZ ACCUSED REYNOLDS OF SELLING CITY DOWN RIVER

Albuquerque Journal, May 7, 1958
STATE ENGINEER WINS LEGAL TEST ON WELL PERMITS

Albuquerque Tribune, Aug. 6, 1958
CITY LOSES WATER BASIN COURT FIGHT

Panelists from left: Ted Cox, John Clayshulte Sr. and Rudy Provencio

How We Dealt with the Drought of the '50s

Moderated by Gary Esslinger,
Manager, Elephant Butte Irrigation District

John Clayshulte, Sr. was born in Mesilla, New Mexico in 1920. After graduating from Las Cruces High School in 1938, he attended NM A&M where he graduated in 1942 with a degree in civil engineering. As an ROTC student, after graduation, he went directly into the Army Engineering Corp. He served in the European Theater and upon his return in 1945 he continued to enlarge the bee business started before he entered the service. He and his three sons have several small farms scattered throughout the Mesilla Valley. John served on the Elephant Butte Irrigation District Board from 1980-1999. His wife, Jeanne, also is a native of the Mesilla Valley.

Ted Cox was born in Canutillo, Texas, lives 4 miles west of Anthony, New Mexico and has been married to the same woman, and lived in the same house for 46 years. He is a fourth generation farmer in his family and currently farms 140 acres. In 1963 Ted bought a seed business, formerly known as Vinton Delinting Co., now known as Del Norte Seed and Feed, Inc. He graduated from Anthony Union High School in Gadsden. Ted studied agricultural engineering at New Mexico A&M. Ted and his wife, Patricia, have two children and one grandchild.

Rudy Provencio's family settled in the Mesilla Valley in the 1700s.Rudy studied agronomy and civil engineering at New Mexico State University and graduated with a degree in engineering. After graduation he worked for a construction firm in Houston, later returning to the Mesilla Valley in 1963 to farm. He and his two sons own and operate 3R Farms in Anthony. Rudy has served on the Elephant Butte Irrigation District Board since 1987.

Gary Essliner

Drought happens. It is something that we are all going to have to face. Today we have some panelists who have experienced drought, know something about it, and did something about it. They will share with you their recollections of their time in a drought.

When I picked up a dictionary to find out the definition of drought, I found that the word has a whole lot of different meanings. The American Heritage Dictionary defines drought as a long period with no rain, especially during the planting season. But here in the west where we do dry weather planting and we have an abundance of water in our storage, certainly this definition doesn't necessarily hold true. I came up with some other definitions including a few by the U.S. Geological Survey. One definition was for "agricultural drought," and that is a shortage of water in the root zone of plants such that the plant yield is reduced considerably. There also is "hydrologic drought," an extended period during which stream flow, lake and reservoir drought water levels are below normal. There is "meteorological drought," which is an extended period during which precipitation is below normal. And there is "sociological drought" that occurs when meteorological and hydrological conditions are such that less water is available than is anticipated and relied on for the normal level of social or economic activity in a region. Keep in mind that drought is cyclical and affects us all in different ways and we must all deal with it together.

Now I would like to introduce our distinguished panelists, first of whom is Ted Cox. Ted was born in Canutillo, Texas and now lives in New Mexico. He has been married to the same woman and has lived in the same house for 46 years. He is a fourth generation farmer and his family currently operates a 148-acre farm in the Mesilla Valley. Ted is also a successful businessman, and owns and operates a seed business in Anthony. He graduated from Anthony Union High and he studied agriculture and engineering at New Mexico A&M. Today Ted is going to talk to us about his experiences on the farm during the '50s. Second is John Clayshulte, also known as "Tuffy." As I recall my time with Tuffy over the last 21 years, I realize Tuffy is like E.F. Hutton, when he talks, everyone listens. Over the years, he has said so many things that have steered our board in the direction it is in right now. We give him a lot of credit for the philosophies behind the policies of the Elephant Butte Irrigation District's (EBID) board. He is a native of Mesilla. He was born in the Mesilla Valley in 1920 and graduated from Las Cruces High School in 1938 and went on to graduate from New Mexico A&M with a civil engineering degree. He was a member of ROTC, which lead him into the Army Engineering Corp. He served in Europe, returning in 1945. Tuffy is also a bee keeper in the Mesilla Valley and maybe he will share with you what a bee goes through during a drought. He also has a farm with his sons. Tuffy served on the EBID board from 1980 until 1999. His wife Jean is also a native of Mesilla Valley.

Our last panelist was to be Woodrow Gary, and if you have seen the movie, "Toy Story," you'll remember a character named Woody. EBID for many years had quite a character named Woody as well. I'm sorry he is not here today but there has been a death in his family just two days ago and I hope that you all keep him and his family in your prayers.

At the last minute we found a replacement for Woody, and again he is one of our board members, Rudy Provencio. Rudy's heritage in the Mesilla Valley goes back to the 1700s when his family settled there. He studied agronomy and civil engineering at New Mexico State University, graduating as an engineer. He worked for a construction firm in Houston for a while before coming back to the farm in 1963. He and his two sons own and operate a farm called 3R Farms in the Anthony area. Rudy has served on the EBID board since 1987, and is a 12-year veteran with the district. With that, I'll turn it over to Ted and allow him an opportunity to recollect his experiences with drought.

Ted Cox

Thank you Gary. After listening to the gentleman who spoke earlier today giving the releases of water from Elephant Butte over the years, I realized just how much foresight my father had at the time concerning the drilling of wells. We drilled our first irrigation well in 1949 to a depth of 145 feet. A second well was drilled in 1951 at 165 feet. As I recall, we pumped all our water for a five-year period during the '50s.

We were encouraged to transfer any river water that we might have received to our neighbors who weren't fortunate enough to have drilled wells. We had one well that could be pumped into the lateral and we were able to supply some of our neighbors with some of the water they needed.

I don't recall much land having been laid out at the time because the landowners did not have access to enough water. The crops we were growing during that five-year period did change somewhat. Alfalfa virtually disappeared, and I recall seeing quite a bit of barley, which is a very drought resistant crop if you starve it enough.

At the beginning of those pumping years, our static water level stood at 20 feet. After five years of steady pumping, the static water level dropped 12 feet and the drainage ditches in the area dried up. After we started getting river water again, it took three years of irrigation with river water to restore the static water level back to 20 feet, which is where it stands now.

I remember when Elephant Butte overflowed during the early '40s. It was a beautiful sight, but just ten or twelve years later, I visited again and it was just empty. There was so little water that they had moved the boat docks just about right under the dam and you could see the concrete houses that had been built earlier for the construction crews right near the dam. It was scary. My thought was, how long is this drought going to last? My thought ever since is, is this the beginning of another five-year drought? Could this possibly be a ten-year drought, or longer? Hopefully not.

My concern now is that with the increased need for water, groundwater levels could drop. We have shallow wells and as I understand it, El Paso has drilled some wells almost 2,000 feet deep that could pull water away from our wells. Not only that, if they dry up and the drain system stops flowing, you'll see the end of agriculture within the next few years. Another concern we've had is that we haven't drilled wells deep enough. If we run out of well water, we are virtually out of water to supplement surface water. My last comment would be that laser leveling has been a blessing to our area because it has saved us a lot of irrigation water. However, at the same time, we are not putting that much water on our crops so water isn't percolating back into the aquifer. It is a blessing on one hand but it is something we need to be concerned about.

Thank you.

John "Tuffy" Clayshulte

I have to agree with Ted that laser leveling in the valley has helped us cut back tremendously on the water we use.

When I look back, I can remember one year, I'm not sure just exactly what year it was, when we were allowed six inches of water. Pecan trees require 36 inches to four to five feet of water, depending on the kind of soil you have, if you want any quality at all in your crop. Six inches does not go very far.

We all went through quite a struggle in the '50s and each one of us had to do our best with our own problems. But since everybody had the same problems, everybody understood the problems and cooperated almost entirely as best they could–farmers with each other and with the EBID also.

In my case, I had a little farm down at the end of what we called Snake Ditch, about a two-mile ditch that passed 10 or 12 plots of land along that way. These were small plots that didn't have any other water. My brother had a pump right on the California Canal, and the California Canal is the one that terminates at Stahmann's Snow Ranch Farm. The Stahmann's farm is a big farm and they ran a lot of water. With my brother's permission and EBID's, I was able to pump into the California Canal, and run the water about a quarter to a half mile south to where the Snake Ditch began. When I started to irrigate my farm, the people living along the Snake Ditch all wanted some of that water. I cooperated as best I could. We were able to provide water to a lot of little pieces of land that couldn't get water before and I was able to water my 12-acre piece of land at the end of Snake Ditch.

One year I took all the money that I made from my bee business and used it for drilling a good well. The following year, I used that well on a lettuce crop and I had a wonderful field of lettuce. However, it cost $5 a crate to get the lettuce to market and I only got $5 a crate for it so I put a big sign up that said "Help Yourself." Some people did and some others wanted me to carry the lettuce to them!

The most important thing that I did during the time was to cooperate with EBID. With EBID's permission, I was able to put a pipe across the Mesilla Canal. EBID told me I had to go four feet below the canal with my pipe. That's fairly deep when you start to think about how deep the hole has to be to put a pipe in four feet below the canal. I didn't have very good equipment so it took me about two months of hard labor. I haven't used the pipe in 20 years but it is still available, and I could use it someday.

The way we solved problems in those days was strict cooperation among everybody concerned. Everybody was aware of everybody else's problems. We all tried to help each other, particularly the people that did have wells, and of course wells went in fast in those years. In the early '50s, there practically weren't any wells. I drilled my first well in 1954. The farms I bought after that had wells, thank goodness. Cooperation among people solved our problems back then. If we get into another drought situation, which I'm sure we will sometime, I hope we get the same cooperation among everyone. Thank you.

Rudy Provencio

What I remember most vividly about the drought years was the day and night pumping and the shock of receiving an annual water allotment of two inches when it takes at least 2.5- or 3-acre feet to grow a crop of cotton, which is one of our least water requiring crops. Perhaps most of all are the recollections of the unselfish cooperation that occurred among all of my neighbors. We all understood the importance, the urgency of growing a crop.

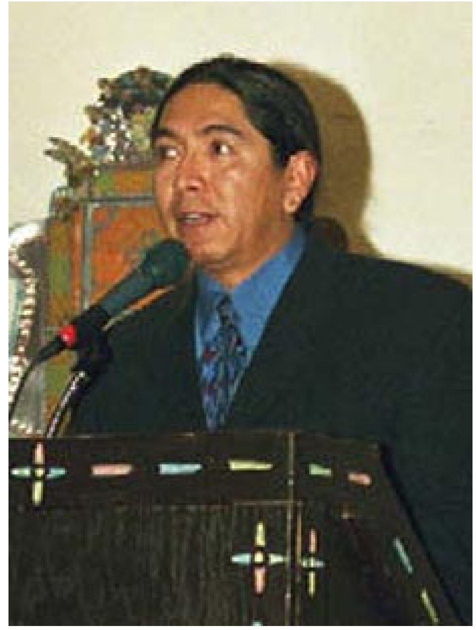
If you don't farm one year it's not like taking an unpaid vacation for that year. In the case of farmers, especially our irrigated farms down in southern New Mexico, it would put you out of business. That's because of our high capitalization costs. The land, even at that time was selling for $1,200 an acre. You had a lot of overhead costs that would continue whether you farmed or not. Irrigation water charges, for example, you had regardless of whether or not you received water. There also were property taxes, equipment costs, and so forth. The mortgage on your farm still had to be paid. Having to stay out for a year would put you out of business. We all realized this and the neighbors helped each other.

Not everybody could drill a well because it cost $5,000 at that time to drill a shallow well. Especially if you had a smaller farm, you just couldn't afford it. Neighbors went to ingenious lengths to help each other. You might have a farm or a field that didn't have a well and a neighbor a quarter mile away might have a well and be willing to pump for you. He might route the water into the EBID canal where it would travel a ways to a neighbors field and then that neighbor might make a ditch to cross his farm over to your field. Somehow everybody survived. I don't recall fields being idle either, every field at one time or another received groundwater.

If we come to another drought period, there will be some different conditions. In addition to the agricultural pumping, since the '50s, demands from other sources have grown. There's a lot of domestic pumping now. Cities are pumping a great deal of water that was not being pumped in the '50s. The demand on the groundwater is going to be much greater, draw downs are going to be quicker, shallow wells are going to be put out of business sooner and salts from the irrigation water are going to collect in our groundwater. Another big change is the cost of drilling a well. Even if you could get a permit, and you can only get a permit to replace an existing well, the price has jumped from $5,000, which is what it was in the '50s, to $45,000 for a shallow well and $145,000 for a deep well. That will not be an option for many farmers, especially in these days of low crop prices. I think it is well recognized that crop prices are at historic lows. All I can figure is that it's going to take even more cooperation and unselfishness to get through a drought. I suspect that when it happens, we'll find a way to cooperate.

Thank you.

Blane M. Sanchez is from both Acoma and Isleta Pueblos. Blane has a B.S. in agriculture from New Mexico State University and has completed graduate courses in the Water Resources Program at the University of New Mexico. He also has taken EPA technical training courses. Currently he is employed with the All Indian Council Pueblo. Previously, Blane worked for the Pueblo of Isleta and served as their environmental point of contact and Water Quality Officer. Prior to working in the water quality/environment area, Blane spent 12 years dedicated to natural resources and wildlife management with the BIA/Southern Pueblos Agency. Blane's background has provided him the opportunity to work on a number of Rio Grande related issues stemming from bosque management/restoration to silvery minnow recovery efforts.



The Rio Grande Compact: It's the Law - But What About Pueblo Water?

This presentation represents the speaker's opinions and thoughts and IN NO WAY represents in any form the views of the Pueblos/Tribes.

"The failure of the federal government to uphold it trust responsibility to Native Americans is clearly demonstrated in its deep-seated institutional ambivalence as guardian over Native American water resources."[1]

It is acknowledged that throughout U.S. history, the federal government has failed to protect and secure Indian land and water interests. The states' continuing commitment to extinguish Indian sovereignty and subsume Tribal governments under state law is a well documented fact.[2] One aspect of such history and fact is our topic of discussion today, the Rio Grande Compact.

In 1938, when the Rio Grande Compact was created, why were the Pueblos not present to participate? Was this a planned oversight to ignore the presence of Pueblos and their water interests? Could this oversight have been planned in order to make it so difficult or even impossible to amend the Compact and the Mexican Water Treaty years later to include Indian water? As we well know and for the most part, Tribal water rights have been determined through the court's interpretation of treaties, Executive Orders, and other agreements made between Indians and the federal government. Such interpretations have not been to the full enjoyment of Tribes. Though Article XVI of the Compact contains disclaimer language, this does nothing more than create more questions than answers.

<u>*Article XVI*</u>

> ***Nothing in this Compact shall be construed as affecting** the obligations of the United States of America to Mexico under existing treaties, or to **the Indian Tribes, or as impairing the rights of the Indian Tribes**.*

So what does this exactly mean? Let me point out some basic tenets.

> *"The 'law' of the Rio Grande is a composite of international treaty provisions, interstate compact commitments, federal reclamation laws, state laws, and **undefined Pueblo Indian water rights**. The Rio Grande originates in the mountains of southern Colorado and en route to the Gulf of Mexico passes through New Mexico, Texas, and by Mexico... because it cuts through three states, its flow is further apportioned by the Rio Grande Compact. Under this compact, a portion of its water is retained in Colorado, a portion retained in New Mexico, and the balance consumed in Texas and Mexico."*[3]

First, let's re-frame the geographic setting and the jurisdictional governments inadvertently left out from the above excerpt. Again, I must continue to remind audiences, there are not only three states found within the Rio Grande basin, but also 18 Pueblos[4] and three Tribes, each a recognized individual sovereign government.

Second, let me define the term "Compact" according to Webster's New World Dictionary:

> *(n) an agreement between two or more individuals, states, etc.; covenant*

Next, let me define the term "Covenant":

> *(n) Law - a formal sealed, contract*

Finally, let me define the term "Contract":

> *(n) an agreement between two or more people (or in this case states and possible tribes) to do something, especially one formally set forth in writing and enforceable by law*

Applying these definitions to the Rio Grande Compact, this "covenant,"or "contract," is an agreement entered into clearly by three states. Nowhere do we find a single Pueblo signature acknowledging this agreement. So how can we expect this Compact to apply to the Pueblos?

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> *"States and state institutions are bound by the provisions of the Rio Grande Compact. The federal government is likewise bound, as a matter of comity. In its capacity as trustee for the Indians, however, it is arguable that it is not bound. There is no indication in the compact that the Pueblos or Tribes of one state have agreed to the quantities pledged to a sister state."*[5]

Also, we find,

> *"These Indian pueblos hold water rights reserved under federal law and treaties which are not controlled by either interstate compacts or by state law."*[6]

But yet, Indian water was excluded when the Compact was devised in terms of delivery arrangements to Pueblos, with the exception of the disclaimer. Clearly, Pueblo water did not seem to be that important a factor. There were bigger issues.

> *"The Compact reflects the perception during negotiations that a guaranteed annual release of 790,000 af from Elephant Butte would protect existing downstream uses in Texas, New Mexico, and Mexico."*[7]

So what about the Pueblos and the fact that they have the highest priority water right? Should not the Compact reflect meeting those obligations first? If delivery schedules were created among the states, should not the same apply to Colorado and New Mexico to meet delivery obligations to the Pueblos, which would consequently affect Texas? Despite not containing delivery language, Article XVI of the Compact would be put to the test by six middle Rio Grande Pueblos.

I would like to acknowledge Diego Abeita, Pueblo of Isleta, Porfirio Montoya, Pueblo of Santa Ana, and Domingo Montoya, Pueblo of Sandia for their efforts to insure Pueblo water is not obligated to the Rio Grande Compact. Due to New Mexico's "debt" to Texas in 1951, the Compact Commission ordered that no water be stored in El Vado Dam. This directive would directly impact the six middle Rio Grande Pueblos' ability to irrigate. The six middle Rio Grande Pueblos met and appointed the Irrigation Committee comprising Diego Abeita, Porfirio Montoya, and Domingo Montoya to protect the Pueblos' water rights.[8]

After meeting with Bureau of Indian Affairs (BIA) attorney William Brophy and others, the Irrigation Committee made a request to the Secretary asking that the Compact Commission review its decision. When the Commission refused to change its decision, the Secretary directed the Middle Rio Grande Conservancy District (MRGCD) to store water for the six middle Rio Grande Pueblos at El Vado, even though no other storage was allowed that year. That action set a precedent allowing water to be stored in El Vado for the six middle Rio Grande Pueblos, which has continued ever since.

The Irrigation Committee continued to function apart from the Texas/New Mexico dispute of the Rio Grande Compact. When Texas sued New Mexico in the Supreme Court in 1951, the Committee urged the U.S. to file a brief asserting the water rights of the six Pueblos. The Special Master appointed to hear the case met with the Committee chairman to hear the Pueblos' concerns. In a report to the Court, the Special Master stated that "the U.S.'s duty to protect the Pueblo water rights in the Rio Grande made it an indispensable party to the case." As a result, the Court dismissed the action in 1957.[9]

As pointed out earlier, Article XVI of the Compact creates more questions than answers. Here are a few.

- In terms of the Agreement[10] for "Indian Water Storage in El Vado," what happens to the Pueblos' stored water if native water is sufficient to meet the irrigations needs of the Indians and there is no call? "Indian water" stored for Pueblo use should not be factored in as meeting downstream delivery obligations but should be available for Pueblos to market in any form they choose. How is this being addressed, and what are the Pueblos' options in using this unused stored water?
- How will future acknowledged Pueblo water rights be applied apart from the Compact? This applies to minimum instream flows that have already been recognized,[11] but not exercised readily by all the Pueblos. Minimum instream flows, if applied by the Pueblos, would support endangered species habitat, while not affecting their other uses.
- Where should the Pueblos' (and other Tribes) water come from? As stated before, the burden should not solely rest with New Mexico but be shared by all three states and maybe Mexico as well. Many claim it is impossible to renegotiate the terms of the Rio Grande Compact. Given that constraint, or inflexibility, choices are few for New Mexico.
- Ramifications of *Arizona v. California* could mean that New Mexico will have to relinquish Indian water to the Pueblos and Tribes. A recent *Albuquerque Tribune* article entitled, "Tribes could be big winners in Arizona water dispute," reported that "Arizona and federal negotiators are working on an agreement that could leave 10 Indian tribes in control of nearly half of the Colorado River water that flows through the Central Arizona Project."[12] What would be the result in New Mexico if a parallel determination were made, especially in light of the Rio Grande's meager supply of water?
- Who on the Rio Grande Compact Commission represents Pueblo water interests? The front cover of the "Report of the Rio Grande Compact Commission" every year states that the report is submitted to the governors of Colorado, New Mexico, and Texas. What about Pueblo governors?

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Other fundamental questions must be answered. A step forward in resolving our collective water issues would be to first recognize the Pueblos' sovereign status and truly give them the respect they deserve on a "government to government" basis. A positive move, in my opinion, would be to create an *ex officio* position on the Rio Grande Compact Commission and a similar position on the Interstate Stream Commission. So what if there are 18 Pueblos? Let the Pueblos and Tribes determine who would fill the seat.

Lastly, I would like to end my presentation with a suggestion to the Pueblos. It is my understanding that the All Indian Pueblo Council had an Irrigation Committee back in the 1940s. I would urge Pueblo leaders to revive this "water committee" and to take it several levels higher.

With this re-establishment, an "Inter-Pueblo Water Commission" could begin to work more directly with not only the Compact Commission, but with the Interstate Stream Commission as well. Moreover, such a move would augment individual Pueblos' efforts to take Commissions to task. Perhaps, together we can reach workable solutions.

Endnotes

[1]Unknown.

[2]Popularly cited as the "McCarran Amend-ment" to the Reclamation Act.

[3]Charles T. Dumars, Marilyn O'Leary, and Albert E. Utton, *Pueblo Indian Water Rights: Struggle for a Precious Resource*. Tucson: The University of Arizona Press, 1984, 2.

[4]There are 19 Pueblos recognized, but the Pueblo of Zuni is not included here because their reservation is outside the Rio Grande Basin. Also included here are the Jicarilla and Mescalero Apache Tribes and the Navajo Nation.

[5]See Footnote 3, p.5.

[6]*Institutional and Legal Responses to Global Climate Change in the Upper Rio Grande Basin, Proceedings of the First National Conference on Climate Change and Water Resources Management.* Charles T. Dumars.

[7]Steven J. Shupe and John Folk-Williams, *The Upper Rio Grande, A Guide to Decision Making*, Western Network, 1988.

[8]*Six Middle Rio Grande Pueblos Irrigation Committee Handbook*, Published by the Six Middle Rio Grande Pueblos Irrigation Com-mittee and the Southern Pueblos Governors Council, prepared by Richard Hughes, 1988.

[9]352 U.S. 991, 77 S.Ct. 552, 1 L.Ed.2d 540 (1957).

[10]*Agreement for Procedures for the Storage and Release of Indian Water Entitlements of the Six Middle Rio Grande Pueblos*, formal storage agreement with the Bureau of Reclamation, signed by Secretary Watt, December 28, 1981.

[11]See Footnote No. 3. p.45 note 13., "The Bureau of Reclamation releases water from Nambe Dam to ensure that 0.5 cfs flow is maintained over falls sacred to Indian religion and tradition."

[12]Shaun Mckinnon (The Arizona Republic), "Tribes could be big winners in Arizona water dispute," *Albuquerque Tribune*, October 16, 1999, p.3

Peter Chestnut began practicing law in 1975, after graduating from the University of New Mexico School of Law. His practice emphasizes Indian Affairs and water law, primarily representing and advising Pueblo Indian tribal governments. He is counsel of record for Pueblo of San Ildefonso in the leading case involving Pueblo Indian water rights, State of New Mexico v. Aamodt, still pending in the United States District Court. He also represents the Pueblo of Acoma in the Rio San Jose water rights adjudication. Peter is a member of the State Bar of New Mexico, U.S. District Court for New Mexico, the 10th Circuit Court of Appeals, the U.S. Court of Federal Claims, the U.S. Supreme Court, and has appeared in numerous Pueblo tribal courts. He is a member of the State Bar of the New Mexico Section of Indian Law and Natural Resources, and the American Bar Association. He graduated from Harvard College with honors.

A Pueblo Perspective on the Rio Grande Compact

Rio Grande Compact

1. The Compact allocates surface waters of the Rio Grande, first to Colorado, second to the Lower Rio Grande, below Elephant Butte Reservoir (San Marcial Gauge) based on flows at Otowi Gauge, located within the Pueblo of San Ildefonso. The Lower Rio Grande, commonly referred to as "Texas" for compact administration purposes, includes one irrigation district in New Mexico and one in Texas. Note that New Mexico's southern boundary for compact administration differs by 165 miles from the New Mexico state border with Texas. See El Paso v. Reynolds, 563 F.Supp. 379 (D.N.M. 1983)

2. The Middle Rio Grande (between Otowi and San Marcial Gauges) is entitled to native waters, according to Compact Article IV (4), plus storage from El Vado Dam. The Middle Rio Grande includes about 160 miles of the mainstem, beginning at San Ildefonso Pueblo (Otowi Gauge) and ending around Socorro (San Marcial Gauge). This is "New Mexico" for compact administration purposes.

3. New Mexico obligations under the Compact are described in Article IV. That article requires uses of flow measurements at the Otowi Gauge as the basis for determining the delivery requirements at Elephant Butte Reservoir, "except for July, August, and September." Groundwater is not mentioned in the Compact.

4. Article XVI (16) of the Compact states:

> Nothing in this compact shall be construed as affecting the obligations of the United States of America to Mexico under existing treaties, or to the Indian tribes, or as impairing the rights of the Indian tribes.

Indian Water Rights

1. "Indian tribes" referred to in the Rio Grande Compact include the Pueblos of New Mexico. These six Pueblos (Cochiti, Santo Domingo, San Felipe, Santa Ana, Sandia, and Isleta) are all on the

mainstem and within the Middle Rio Grande Conservancy District (MRGCD) service area.

2. Pueblo water law ("the ancient law of the Indians") is the basis for New Mexico's prior appropriation doctrine. See discussion in the State v. Red River Valley Co., 51 N. M. 207, 221;182 P.2d 421 (1947).

3. Congress recognized and protected Pueblo water rights in the Middle Rio Grande Conservancy District Act of March 13, 1928, Chapter 219, 45 Stat. 312. These include "prior and paramount" rights for irrigation and for domestic and livestock purposes. For irrigation, the six Pueblos have "prior and paramount" rights to irrigate 8, 847 acres, and co-equal priority with the MRGCD for "newly reclaimed" lands. These rights together total enough water to irrigate over 20,000 acres for the six pueblos.

4. Only the Pueblos have an entitlement to receive Rio Grande surface water. The State of New Mexico's share of the water under the Compact depends on the amount of flow in the river. See Article IV of the Compact.

- In dry or low-flow years, Pueblo water rights become a larger proportion of the total surface water available for irrigation in New Mexico.
- In 1980 surface water depletions in the Middle Rio Grande were 125,630 acre-feet.

5. Pueblo involvement with Middle Rio Grande Conservancy District includes having members of the MRGCD board of directors from Isleta and San Felipe Pueblos, at present and for recent decades.

Contract Rights

1. The contract between the federal Bureau of Reclamation (BOR) and the MRGCD for operation and maintenance (O & M contract) expires December 31, 1999.

2. The six Middle Rio Grande Pueblos Coalition has requested new terms in the O & M contract that will have the Pueblos, through the coalition, having a "seat at the table" with BOR and MRGCD for negotiating a new O & M contract.

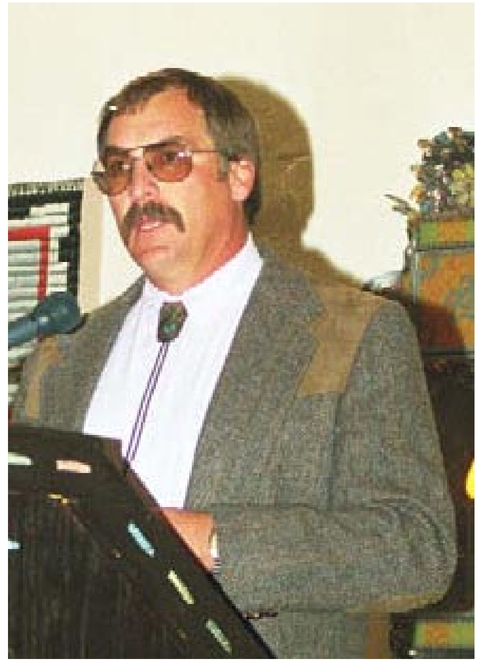
3. The six Pueblos Coalition has also asked BOR for a separate contract for administration of the storage water in El Vado Reservoir for the Pueblos' "prior and paramount" rights.

Twenty-First Century Water Law

1. Twenty-first century water administration of the Rio Grande Compact will see greater Pueblo involvement and attention to senior Pueblo priority and water delivery requirements.

2. Challenge for 21st century for lawyers and other water people to arrive at solutions that are fair and appropriately respectful of Indian Pueblo water rights and social needs.

Steven E. Vandiver *started with the Colorado Division of Water Resources in 1973 as a hydrographer-in-training in Denver. He came to Alamosa as a hydrographer shortly thereafter and continued to move up through the ranks as Lead Hydrographer, Dam Safety Engineer, and Assistant Division Engineer. In 1981, Steve assumed the responsibilities of the Division Engineer for Division 3, the Rio Grande basin in Colorado. Steve, as Engineer Adviser for Colorado, was involved in the administration of the Rio Grande Compact and the Costilla Creek Compact. He was also a member of the Rio Grande Silvery Minnow Recovery Team. Steve holds a bachelor's degree in civil engineering from the University of Colorado, Boulder and is a registered professional engineer.*



The Administration of the Rio Grande Compact in Colorado

INTRODUCTION

The Rio Grande Compact requires Colorado to deliver certain amounts of water annually to the stateline according to the delivery schedules in Article III. On any given year this can require from 25 to 50 percent of the water generated in the Rio Grande and Conejos River basins to arrive at the Lobatos gage just above the border with New Mexico. Since the diverters have the capability of diverting and using most of the water generated in both basins, it is necessary that a process be in place that enables Colorado to ensure that her obligation is met. One can imagine the turmoil that can be generated when water is bypassed to the stateline when there is a significant demand for that water in Colorado from the water rights owners on the rivers. A great amount of work was required by the State of Colorado and the water users in the San Luis Valley to reach an administrative scheme that allowed Colorado to use her entitlements under the Compact and still meet her obligations to the downstream states.

Since 1939, the administration of the Rio Grande Compact in Colorado has been an evolutionary process marked by three distinct periods. The first period from 1939-1967 was a time when Colorado officials made the decision to continue with the administration of water rights as they had during the study period of 1927 to 1936. This action worked well until 1952 when Colorado under-delivered approximately 154,000 acre-feet. The reasons for this under-delivery are largely unknown, but it began a period of under-deliveries and accrued debit that continued until 1967 when that accrued debit reached approximately 940,000 acre-feet. The year before, in 1966, the states of Texas and New Mexico had brought an action against Colorado in the U.S. Supreme Court to force Colorado to comply with the provisions of the Compact. In May of 1968, the Court granted the three states and the U.S. a stipulation for continuance of the case as long as Colorado met her Compact obligation until she was once again in compliance.

The second period, from 1968 to 1985, Colorado administered the Compact pursuant to the stipulation and was forced to determine a way to curtail water rights in a manner that would allow the appropriate delivery of water to the

Lobatos gage near the stateline. Since this administrative scenario had never been attempted, the Colorado State Engineer entered a very difficult time of working with the water users on both the Conejos River and the Rio Grande to determine how this issue might be resolved. In 1975, after several years of negotiated informal annual operative criteria, the State Engineer promulgated rules and regulations for the intrastate administration of the Compact on each river and between the two rivers. In 1979, the numerous protests to the proposed rules were heard in the local District Court in an eleven-week trial. The decision rendered by the Court upheld the State Engineer's Compact rules but the ruling was appealed to the Colorado Supreme Court. The Supreme Court decision upholding the State Engineer's rules was made in 1983. Therefore, from approximately 1968 to the present, the Colorado State Engineer has directed that the Compact be administered as a two-river system with each river responsible for its own delivery obligation dictated by Article III. The rules also provided that any curtailment of diversions would come from the junior water rights, which would have otherwise been in priority on any given day of administration. During this period of litigation over the rules, Colorado met or exceeded its obligation each year from 1968 through 1984 because of the incentive provided by the U.S. Supreme Court stipulation. In fact, because of the hydrologic and climatologic vagaries of the Upper Rio Grande Basin, coupled with the negative consequences of noncompliance with the stipulation, Colorado was forced to over-deliver to ensure that she met the obligation. This very conservative administration resulted in a reduction in the accrued debit of approximately 430,000 acre-feet in 17 years.

The third and current period began in June of 1985, when the Rio Grande Project in Southern New Mexico spilled and eliminated the debt of Colorado and New Mexico. This gave cause for the three states to recommend to the U.S. Supreme Court that the 1966 case be dismissed, which it was on December 9, 1985. Since 1985, Colorado has operated under the Compact as it was written and has met or exceeded its obligation since that time. What is required to accomplish this administration is the topic of this paper and will be described in detail below.

PERTINENT COLORADO WATER LAW

The Administration of the Rio Grande Compact in Colorado

When the State of Colorado achieved statehood in 1876, her corresponding constitution included and adopted the Doctrine of Prior Appropriation as the basis for the appropriation of the water. This was a matter of necessity due to the water-short characteristics of many of the streams in the State. It was recognized early on that because of the large numbers of competing appropriations that some judicial confirmation would be required to allow for the orderly distribution of the State's water. It was also authorized by the legislature in 1883 that a State Engineer would be given the responsibility to administer the water rights of the State.

As early as 1883, general adjudications were held on the Conejos River that confirmed and decreed water rights in relative priority based on the date of appropriation and the amount required to satisfy the irrigation requirements under each ditch. The first general adjudication that occurred on the Rio Grande mainstem was signed on May 1, 1896. These adjudicatory processes were widely noticed and all individuals who had completed their appropriations were allowed to come forward and provide proof of their claims. The date of appropriation, the legal description of the point of diversion, the flow rate of the appropriation, and the use to which the water right was to be placed was determined by the court and confirmed. The court referee investigated each claim for accuracy, ranked the water rights according to the appropriation dates, and recommended the court decree them accordingly. The State Engineer, through water commissioners, used these decrees to administer and deliver the available water to those who were entitled to it. Subsequent supplemental adjudications would include all new or existing claims not previously decreed and create additions to the water rights administrative list. All water rights in these subsequent adjudications were "junior" to all previously adjudicated rights regardless of their appropriation date. Therefore, a water right may have a very early appropriation date, but having failed to participate in the original adjudication, would end up junior to all others in the original adjudication.

The following table describes the adjudication dates and the amounts decreed in each on the two

Compact streams in Colorado. The Conejos adjudications include the Los Pinos and the San Antonio rivers because they are tributaries. It is readily apparent that the vast majority of the water available in both systems was decreed by around the turn of the century. The hydrology of the two basins described later in the text will show the grossly over-appropriated nature of the two streams.

Rio Grande and tributaries	Conejos River and tributaries
1896: 3209 cfs	1883: 1459 cfs
1903: 2501	1890: 1312
1916: 678	1914: 502
1934: 353	1915 to present: 375
1959: 765	
1960 to present: 140	
Total including instream flow:	
9139 cfs	4104 cfs

These adjudications established early on the system of administration that has followed for more than 100 years. Gaging stations were established on all streams that had become fully appropriated that allowed the water commissioners to determine the amount of water that was available for distribution. Recognition of return flows and tributary inflow to the stream make the task even more interesting. On the Rio Grande mainstem, gages were established routinely along the course of the river to help recognize the changes in the flow throughout the system. Through the years, the State Engineer has hired a staff of hydrographers to operate and maintain the gaging stations and to rate the measuring flumes on the ditches. The State Engineer is responsible for the distribution of water in the system to ensure the water is available at the time and place of demand by water right owners who are in priority. His staff is also responsible for ensuring that the ratings on the ditches are kept current to ensure the proper amount of water is delivered to each ditch. Headgates and measuring flumes are required by statute on each diversion and the State Engineer has the authority to refuse water to the owners who fail to maintain these structures in proper order. In recent developments, most of the larger diversions have installed satellite-monitoring equipment, which allows the user as well as the State to acquire real-time data in order to ensure better administration.

HYDROLOGY OF THE RIO GRANDE AND CONEJOS RIVER

The headwaters of the Rio Grande mainstem and the Conejos River are ringed by the Continental Divide. This area of southwestern Colorado normally receives a significant snowpack that provides the majority of the water that arrives at the upper index gages on the two rivers. These headwater areas are in relatively close proximity to the index gaging stations near Del Norte, Mogote, and Ortiz. Normally, the day's snowmelt or rain event runoff arrives at the gages during the next 12 to 24 hours, depending on what location in the basin one might consider. Since the operating reservoirs on both systems control only a fraction of the flow, the flows at the index gages are primarily a reflection of snowmelt and rainfall events. All these reservoirs hold relatively junior priorities and during the runoff, the reservoirs store under those decrees on a very limited basis when the flows at the index gages are very large. Therefore, during the irrigation season, the reservoirs bypass the inflow to them except for the highest portion of the runoff, if at all. Three ditches own the three irrigation reservoirs on the Rio Grande and the water from their decrees is not available to any other ditches on the river. The Conejos Water Conservancy District, on the other hand, operates Platoro Reservoir and the water from it is available to the member ditches. It is a commonly held belief that all the irrigation reservoirs on the Rio Grande are available to all the ditches, or to store water for other purposes. This is obviously not the case and only the owners of the reservoirs can use the water available to them. Since Platoro is a post-Compact reservoir, any water stored under its decree is accounted for as if it had passed the Mogote gage on a monthly basis. This stored water is then subtracted when it is released to ensure that the native water in the basin is properly accounted for and that the index supply and the corresponding obligation are not altered because of storage. The annual volumes of flow at the index stations are therefore relatively unaffected by the reservoirs on either of the Compact streams except on the occasion of a very wet year when some carryover can result.

The Adminis-tration of the Rio Grande Compact in Colorado

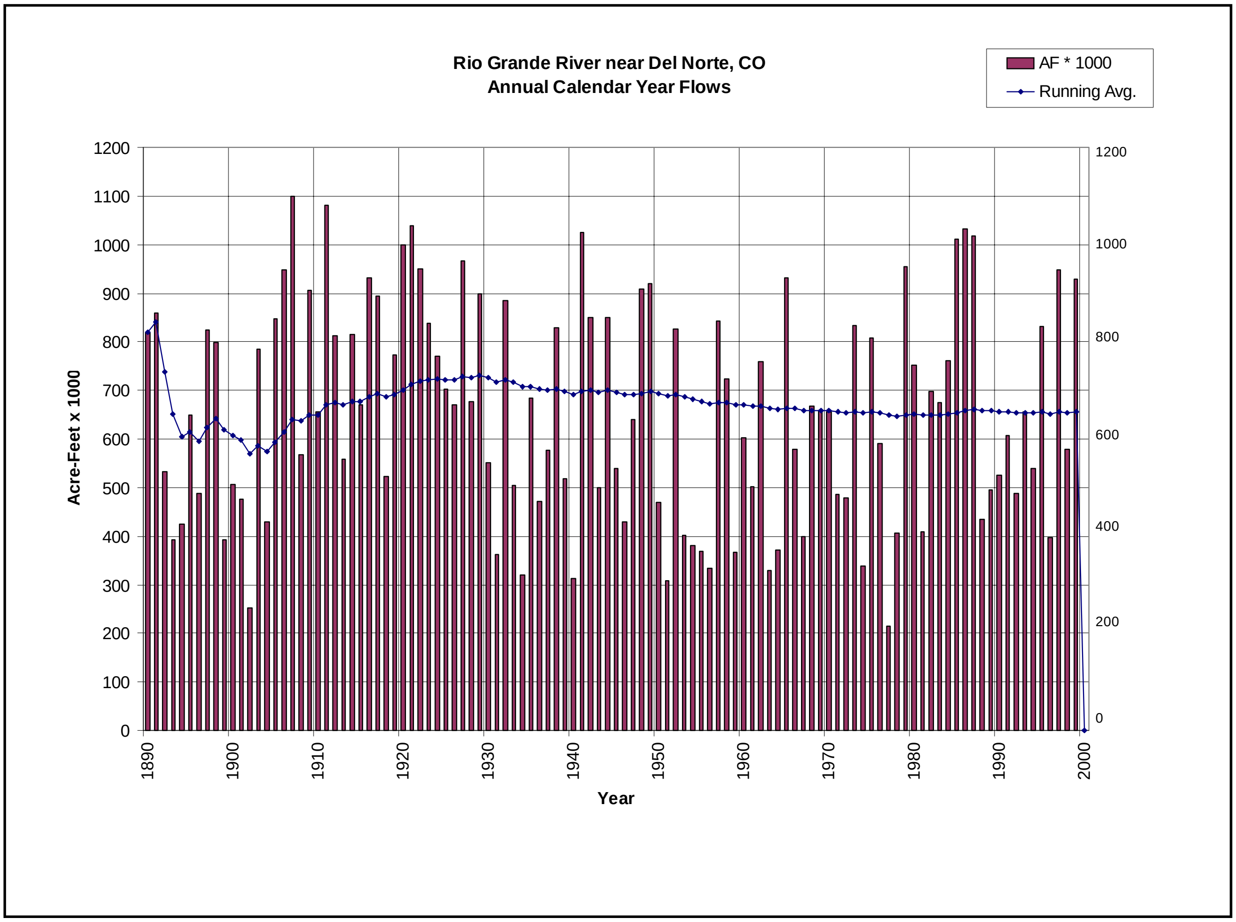


Figure 1. Rio Grande near Del Norte, CO, Annual Calendar Year Flows

The hourly, daily, seasonal and annual flows at the index stations are extremely variable. The daily diurnal effect during the runoff season as well as the variability of high altitude snowmelt can cause large changes within the day as well as from day to day. As is the situation with most western streams, the seasonal and annual flows are also highly variable. The past 25 years are a wonderful case study on variability of the water supply for the Rio Grande Basin. On the Rio Grande mainstem in Colorado, we have seen the historic low year in 1977 of 215,000 acre-feet and just a few years later saw three consecutive annual flows of more than 1,000,000 acre-feet, a volume which has been exceeded only in seven of the 110 years of recorded history. Figure 1 "Rio Grande River near Del Norte, CO – Annual Calendar Year Flows" shows the annual variability of streamflow at the Rio Grande near Del Norte gage. This gage is the upper index gage for the Rio Grande and is used to determine the amount of water owed to the downstream states as well as the water available for distribution in priority to water rights owners.

Peak flows on both systems are also reflective of the large variability of the low from year to year. On the Rio Grande near Del Norte gage, the peak averages around 5,400 cfs and varies over the history of the record from 1,730 cfs in 1977 to 18,000 cfs in 1912. The Conejos near Mogote gage shows a similar pattern with peak flows from 882 cfs in 1972 to 9,000 cfs in 1912 with the average around 2,000 cfs.

Average flows for the two rivers reflect that the historic mean flow is demonstrative of the fact that neither carries large flows on the average and that the large majority of the flows occur in the spring months of May through July. The rest of the year the flows are near base-flow conditions except for the runoff from the occasional rainfall event during the summer and fall. The mean flow for the Rio Grande near Del Norte gage is 907 cfs, for the Conejos near Mogote is 331 cfs, for the Los Pinos near Ortiz is 121 cfs, and for the San Antonio near Ortiz is 26 cfs. Base flows on the four rivers would be approximately 400 cfs, 150 cfs, 40 cfs, and 10 cfs, respectively.

The Adminis-tration of the Rio Grande Compact in Colorado

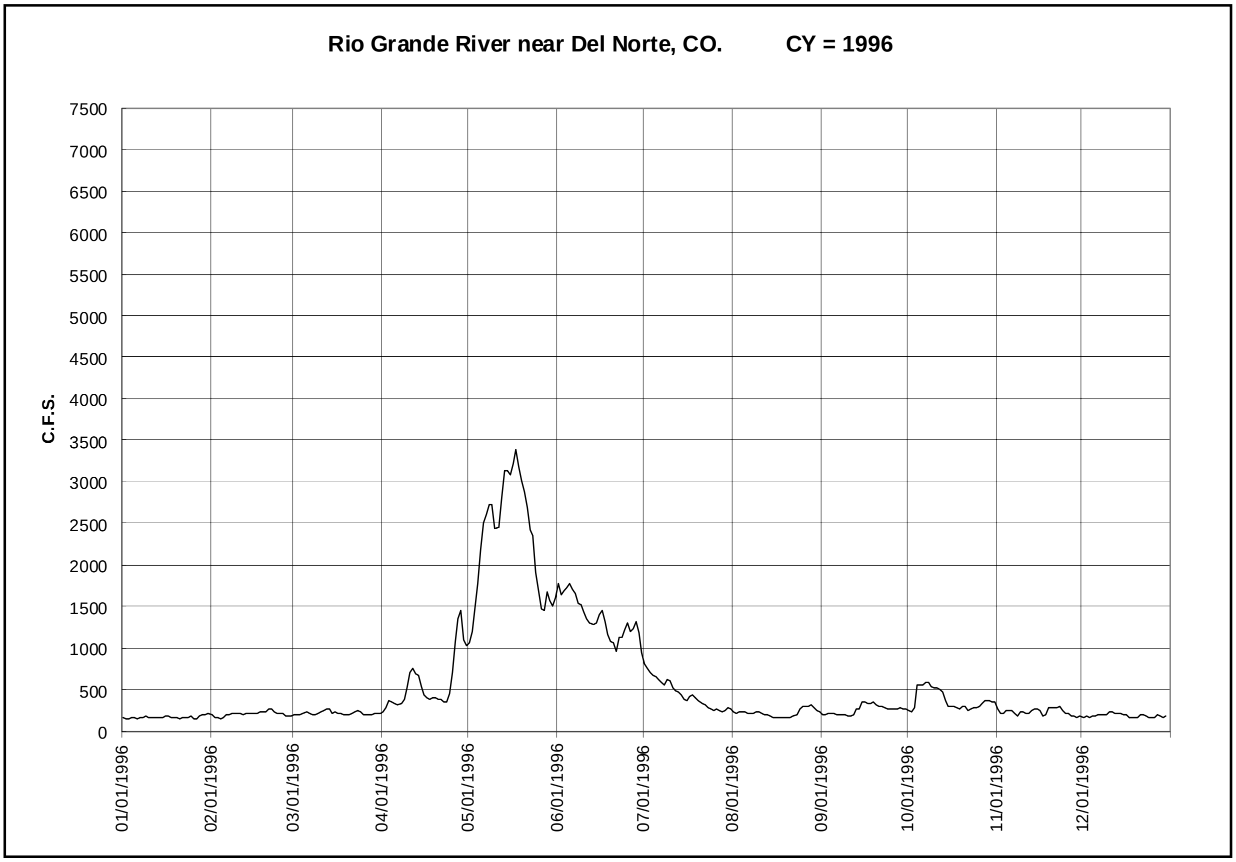


Figure 2. Rio Grande near Del Norte, CO for 1996

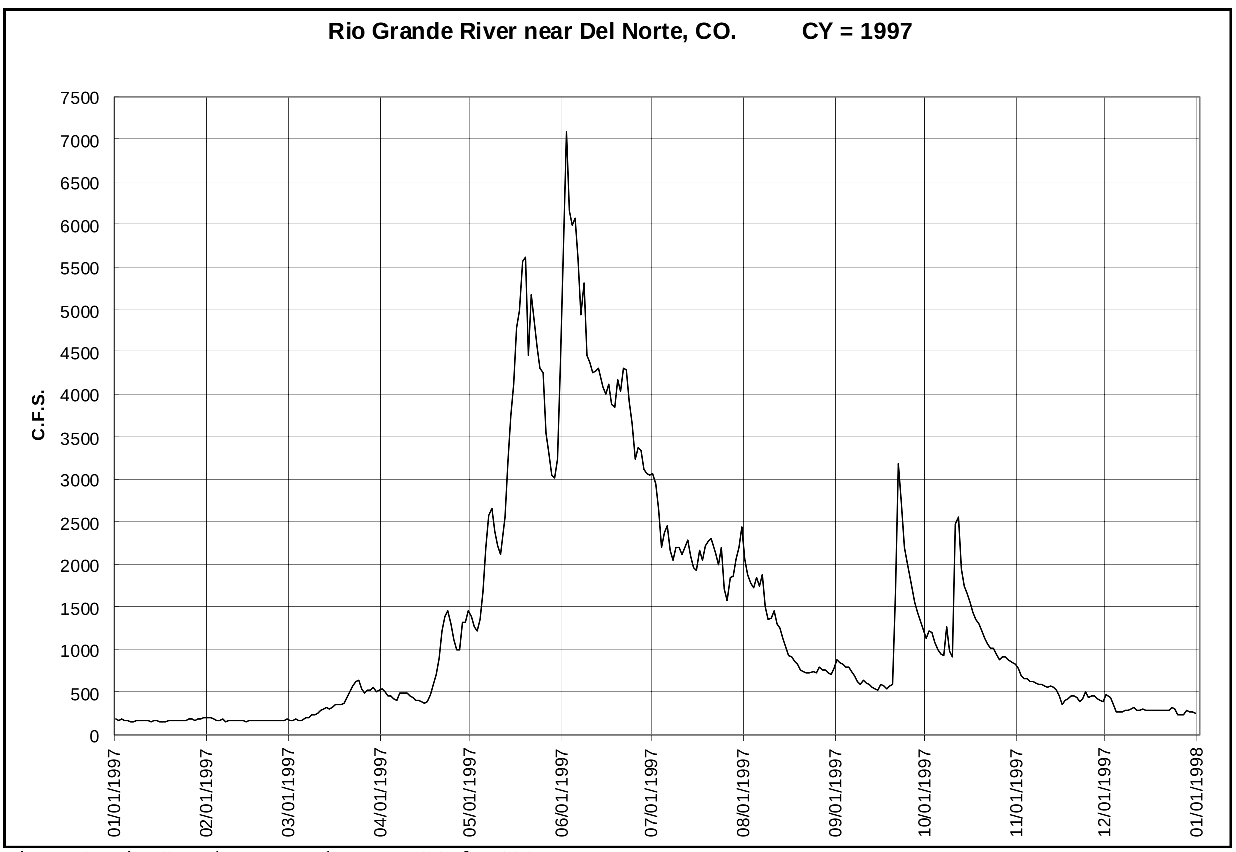


Figure 3. Rio Grande near Del Norte, CO for 1997

These statistics and Figures 2 and 3, "Rio Grande River near Del Norte, CO – CY=1996" and "Rio Grande River near Del Norte, CO – CY=1997" are provided to illustrate the large variability in the hydrology of the Upper Rio Grande Basin in Colorado and provide the setting in which the Compact in Colorado has to be administered. This variability creates a difficult challenge to the managers of the diversion systems and especially to those responsible for ensuring that Colorado meets her Compact obligation to deliver water to the downstream states. The constantly moving target demands that the Compact be administered on a daily basis. The staff involved in this effort must be able to readily analyze the past, current, and future conditions of streamflows of the calendar year. Real-time data, calendar year flows-to-date and good historic streamflow data are all required to calculate what must be done to stay current with deliveries. The challenge then is to use that knowledge to administer the priority system on both river systems while concurrently bypassing the proper amount of flow to the stateline to meet the required delivery for Compact purposes. It is imperative to water right owners as well as the water managers to ensure that Colorado is able to utilize her full entitlement allowed under the Compact while meeting her obligations. As conditions change during the year, they must be recognized in a timely manner and adjustments made to the administration of the river to accomplish those two goals.

TOOLS

There are a number of tools that the State of Colorado uses to administer effectively the Rio Grande Compact. These include legal, physical and political tools that are employed to determine the actions that must take place for Colorado to meet its obligation at the Lobatos gage.

Legal Tools:

- Doctrine of Prior Appropriation system contemplated by the Constitution;
- Case Law that reinforces and refines the Doctrine;
- Historic and current adjudication process;
- 1969 Water Right Determination and Administration Act;
- Rules and Regulations governing Rio Grande Compact administration

Physical Tools:

- Extensive stream-gage network;
- State Hydrographic Program;
- Satellite Monitoring System on stream gages and major diversions;
- Spreadsheets for water accounting;
- 10-day reporting;
- Natural Resources Conservation Service monthly forecasts;
- Communication protocol with National Weather Service;
- Closed Basin Project

Political Tools:

- Active water user associations;
- Water conservation and water conservancy districts;
- Continuing education programs to inform users and public;
- Media relationship to inform public of significant events;
- Strong relationship between the State Engineer staff and water user community

The Administration of the Rio Grande Compact in Colorado

CURRENT ADMINISTRATION

Since 1968, the Rio Grande Compact has had a significant impact on water rights administration in the Upper Rio Grande in Colorado. The State Engineer has administered the Compact on a two-river system since that time. Both the Rio Grande and the Conejos are administered independently according to their respective delivery obligations. Therefore, two separate accountings and administration schemes are used for day-to-day administration. The following administration process is used for both rivers and is linked only by certain adjustments to the deliveries that are explained later.

Article III of the Rio Grande Compact is the pertinent section that describes what administration of water rights is required to provide the appropriate flow to the stateline to meet Colorado's annual obligation. That article sets the annual delivery obligation for each river based upon the native water that flows past the index stations. The combination of the two separate delivery schedules determines Colorado's total obligation less the 10,000 acre-feet credit provided by the Compact. The delivery schedules are reflective of the inflow-outflow relationships developed during the Rio Grande Joint Investigation Study from 1927 to 1936. The delivery schedules set in place the amount of consumptive use that is allowed in each basin for given flows into that basin. The consumptive use that is allowed in each basin is reflected in their delivery schedules by subtracting the delivery obligation from the index flow. For each given annual flow, there is a theoretical consumptive use for each river and all additional flows must be passed through the system. The maximum consumptive uses are 570,000 acre-feet on the Rio Grande and 224,000 acre-feet on the Conejos system. These peak consumptive use amounts occur when the annual flow is quite large and considerably above the average flow. Figures 4 and 5, "Rio Grande Compact Delivery Requirements Verses Annual Index Flows" and "Rio Grande Compact Delivery Requirements As Percent of Annual Index Flows" graphically demonstrate the delivery schedules in Article III. They represent both the percentage of the index required as well as the numeric value of the obligation for the corresponding index supply.

The Administration of the Rio Grande Compact in Colorado

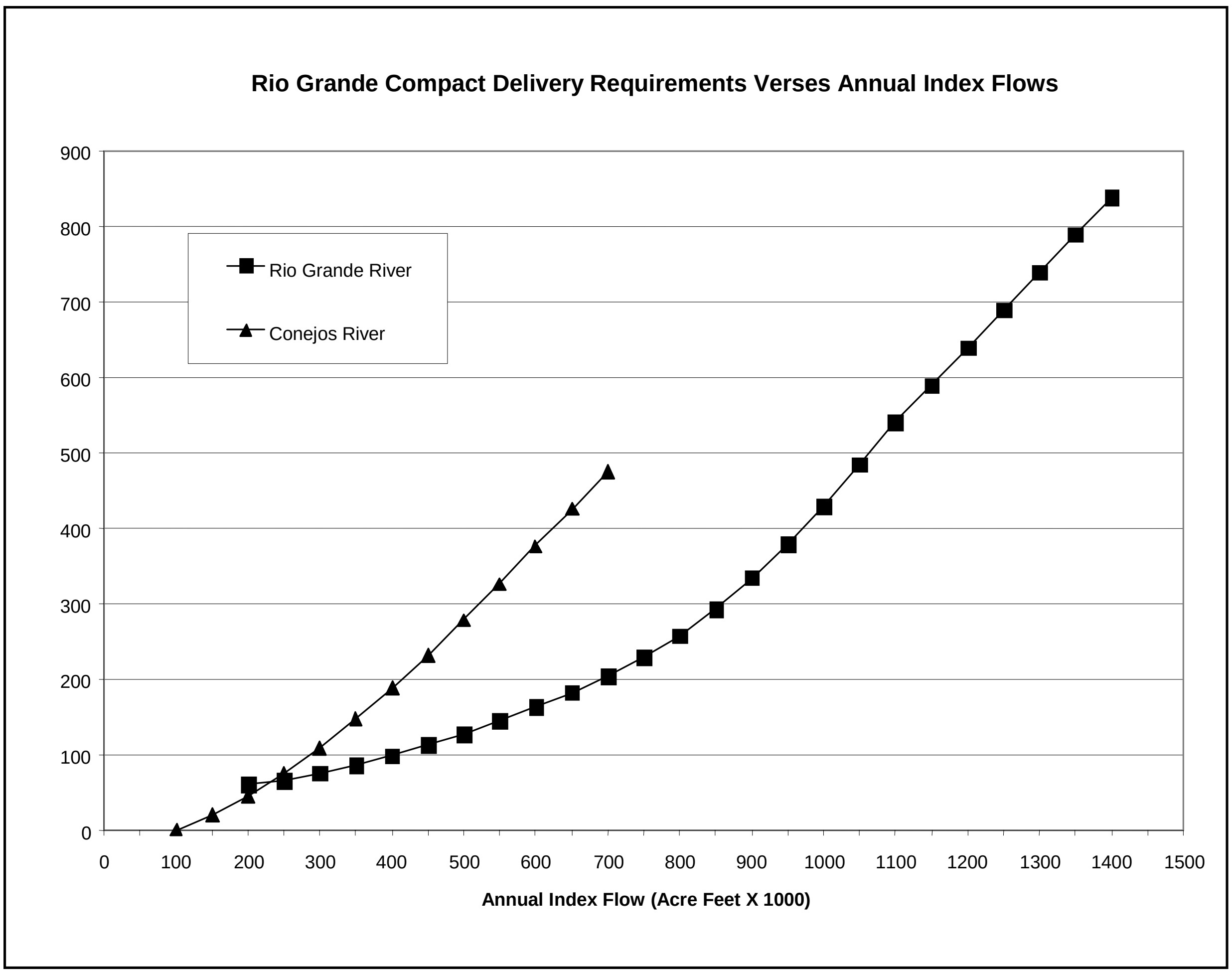


Figure 4. Rio Grande Compact Delivery requirements as percent of annual index flows

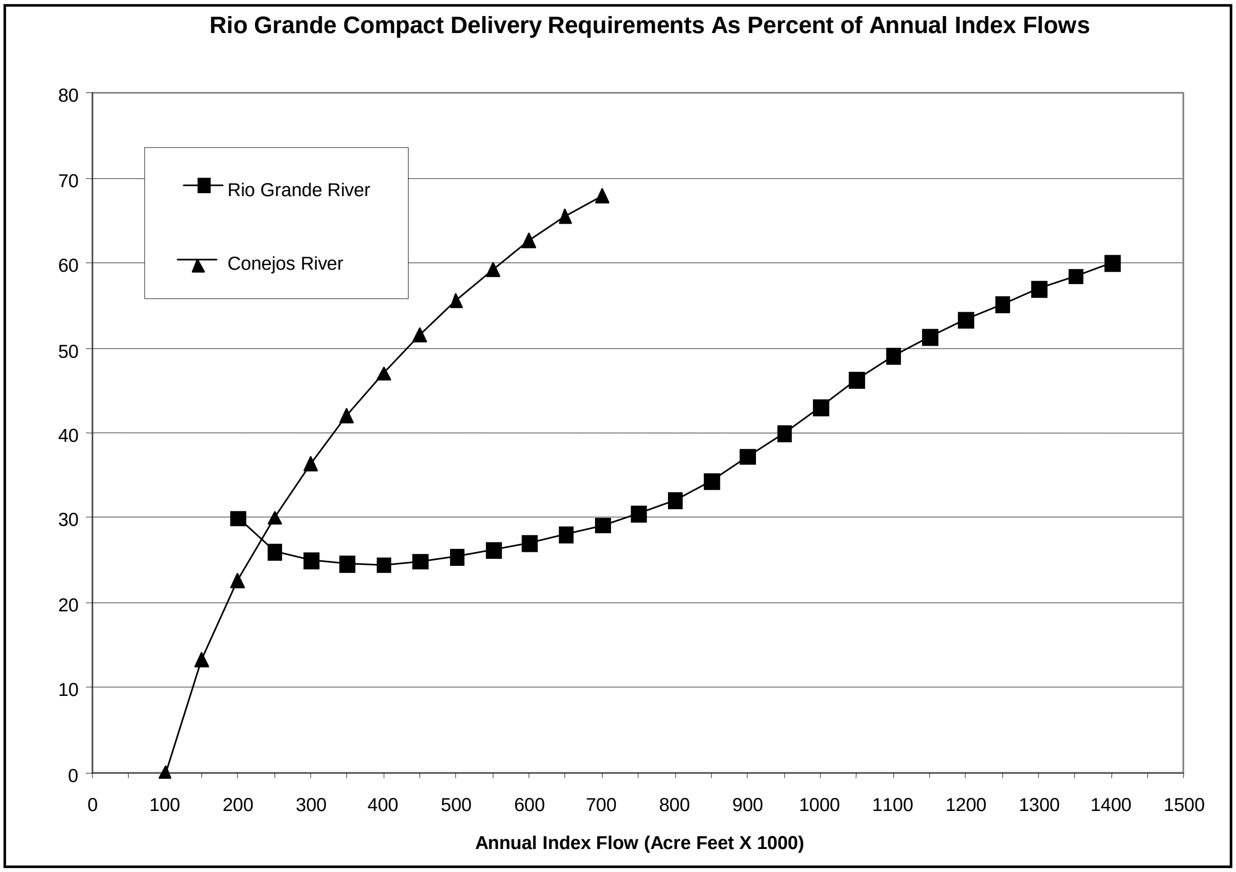


Figure 5. Rio Grande Compact delivery requirements as a percent of annual index flows

Deliveries to the stateline are not required to adhere strictly to the Compact's delivery schedules on an annual basis. The Compact in Article VI allows for the accrual of Compact credits and debits. Colorado may under-deliver by as much as 100,000 acre-feet in any particular year, and may accrue up to 100,000 acre-feet of annual debit over multiple years. Colorado may also receive up to 150,000 acre-feet of annual credit in any given year and may accrue an unlimited credit over multiple years. This credit and debit accounting provision of the Compact provides Colorado with some flexibility in managing water use from year to year, and allows the state to utilize the credit to enhance water supply in years when it will provide relief to a shortage in the system. The only downside to having credit water stored in Elephant Butte is that approximately 10 percent of the water is lost to evaporation each year. Current administration practices are to make deliveries that approximate the obligation on an annual basis. Because of the vagaries of the climate and hydrology, it is very difficult to forecast accurately enough during the runoff to exactly meet the delivery requirements.

SEASONAL ADMINISTRATION

Since 1968, Colorado has attempted several different scenarios to ensure that Colorado would meet her obligation. What has evolved over time is a very successful routine that guides administrators through the year. It provides a reasonably accurate method for meeting the obligation within a few percentage points, thus allowing Colorado to utilize fully her entitlements and at the same time meet her obligation to the downstream states. It requires recognizing the indexes and deliveries from the first of the year to the present, assuming deliveries for the early winter months and adjusting the forecast for the irrigation season as it progresses. After the annual index supply forecasts for both rivers are established, then water rights are curtailed as is necessary to ensure that the Compact delivery requirement is met. If the actual runoff and summer thunderstorm activity changes the forecasted index supply, adjustments are made to deliveries to account for those changes. Large late season increases in the indexes require significant changes in administration that can cause

The Adminis-tration of the Rio Grande Compact in Colorado

considerable hardship to very senior pre-Compact water rights.

As described above, day-to-day administration of the Rio Grande Compact for inter- and intrastate purposes involves a series of detailed calculations using historical, real-time, and forecasted streamflow information at all seven of the Compact gages as well as at the intermediate gages between them.

The upper index gages are:

- Rio Grande near Del Norte
- Conejos River near Mogote
- Los Pinos River near Ortiz (April – October)
- San Antonio River at Ortiz (April – October)

The lower index gages are:

- Rio Grande near Lobatos
- Conejos near La Sauses (two stations)

Flows at these locations are used to determine the total annual delivery obligation, to determine deliveries to date, and to establish a "curtailment" of water use if needed to meet the delivery obligation of the year. The State Engineer, through the Engineer Adviser and the staff in the Division of Water Resources office in Alamosa, makes these calculations every 10 days when diversions are being made, and monthly during the remainder of the year for both river systems. It is critical to remember that each river is analyzed separately and that each river has its own delivery obligation.

The general methodology for making these calculations is described in the four following steps. The dates are for illustrative purposes only and vary depending on the forecast and Compact status of the State of Colorado. Examples of the 10-day analysis sheets and report are attached.

January 1st through March 31st

Both the Rio Grande and the Conejos River diversions are curtailed 100 percent, that is, no diversions are allowed except for storage in pre-Compact reservoirs. Any storage in post-Compact reservoirs is accounted for and subject to Compact rules. An exception to the100 percent curtailment can occur if Colorado has a large accrued credit, a spill of Elephant Butte has or will occur, or if drought conditions prevail and thus the anticipated obligation is very low. This action will maximize deliveries to the stateline during this period and will allow for lower curtailment during the irrigation season. The Closed Basin Project is pumped at a prudent level considering the limitations of winter operations and well production. The March 1 forecast is used to make some of the initial analyses for how the Compact will be administered for the early part of the irrigation season. The Rio Grande headwater areas typically receive large accumulations of snow during this month and therefore it is normally assumed that significant changes will be made to the projected index supply when the April forecast is received.

April 1st through October 31st

Diversions are normally allowed to commence around April 1 but because of the normally cold springs and low demand, Compact obligations are usually made without any curtailment. As soon as the April forecast is received from the Natural Resources Conservation Service (NRCS) on or about the 7th of the month, the first comprehensive analysis is done to determine the projected index supply for the year. Upper index flows that have occurred through the end of March are added to the forecast (April–September) and to average flows for October through December. This will provide the first estimate of the annual index supply for each river.

From that estimate of the annual index, the obligation for each river is determined using the delivery schedules in Article III. Deliveries through the end of March are added to the normal (average) deliveries for November and December, the anticipated Closed Basin Project deliveries and the appropriate portion of the 10,000 acre-foot credit. The sum of those deliveries, subtracted from the projected obligation determines the amount of water needed at the stateline during the irrigation season (April–October). Adjustments to the amount needed are made for variables, which include Colorado's accrued credits or debits, return flows, tributary inflows or accretions to the rivers.

Once the amount to be delivered during the irrigation season is determined, it is necessary to determine how much of the available index supply must be delivered on a daily basis to achieve the

The Adminis-tration of the Rio Grande Compact in Colorado

desired delivery. This is accomplished by dividing the amount of delivery required by the amount of index supply available during the irrigation season. This quotient then represents the percentage of the daily available index supply that must bypass the Colorado diverters and be delivered to the stateline. Again, return flows, tributary inflows and groundwater accretions must be taken into consideration and the curtailment reduced accordingly or substantial over-deliveries can result. Weather conditions present of the greatest challenges for administrators as the weather can cause substantial changes to the index supply and the forecast, adding significantly to the delivery obligation. Late summer or early fall rainfall events can have very dramatic effects on administration and must be handled in a timely manner to prevent large under-deliveries. A study of delivery schedules shows that in higher years like 1999, the incremental amount of water that has to be delivered when an unexpected event occurs can reach as high as 90 percent of the increased amount of water indexed. Therefore, during the entire irrigation season it is imperative that a continual monitoring of daily administration occurs to ensure that the forecast is indeed tracking as was expected and that deliveries are being made accordingly.

November 1st through December 31st

Diversions on both the Rio Grande and the Conejos River are curtailed 100 percent if necessary to deliver water to the stateline to complete the remaining deliveries. Reservoirs are typically allowed to go into storage on November 1. Consultation with the water users on both rivers can result in some diversions extending into November if the Compact will be met with the remaining deliveries. In fact, six large ditches on the Rio Grande have obtained decrees to divert water to recharge the aquifers in the San Luis Valley to the extent the water is not needed to meet the Compact obligation. Typically, by no later than Thanksgiving, the winter weather has made diversions of water impossible and all diversions are concluded. Closed Basin Project deliveries are made to the river at the sustainable level necessary and in accordance with winter operations.

Because the Compact is river specific in Colorado, the process for determining curtailment percentages occurs independently for both the Rio Grande and the Conejos River and different curtailment percentages are applied to the two systems pursuant to the analysis described above. It is important to note this process relies heavily on forecasted inflows at least through the end of June. As the snowmelt runoff recedes, the summer thunderstorm activity or lack thereof begins to control the index supply for the remainder of the summer and fall seasons. The actual flows are not, and cannot be known until very late in the calendar year. While Colorado attempts to match the delivery requirement on an annual basis, over- and under-deliveries can and do result from inaccuracies associated with inflow forecasts and uncertainties associated with natural stream systems. These over- and under-deliveries are added or subtracted from the accrued debit or credit carried forward from previous years, and the resulting status as of January 1 of each year is considered in the following year's curtailment calculations.

The State of Colorado relies heavily on the coordinated forecast inflows to the basin that are developed and provided by the Natural Resources Conservation Service in cooperation with the National Weather Service. These forecasts are published monthly, typically beginning in January and ending in May or June. Since Colorado analyzes her Compact status and considers adjustments to the curtailment every 10 days, there is often a need for more up-to-date information, especially during periods of high runoff. Colorado has routine discussions with the Natural Resources Conservation Service and the National Weather Service concerning trends and intermediate forecasts prior to the release of updated monthly forecasts.

As previously discussed, the effect of applying a curtailment to the Rio Grande and the Conejos River is to make a percentage of the water flowing past the index gages unavailable for diversions such that it can be delivered at the stateline. As curtailment information is developed during the irrigation season, the calculated percentages are communicated to the appropriate water commissioners, who use this data in their water rights administration.

The Adminis-tration of the Rio Grande Compact in Colorado

RESERVOIR STORAGE, TRANS-BASIN DIVERSIONS, AND COMPACT ACCOUNTING

Most reservoirs within the Rio Grande Basin in Colorado were constructed prior to signing and ratification of the Rio Grande Compact. As such, storage and releases by these reservoirs are not reflected in the Compact accounting performed by the State of Colorado. By contrast, reservoirs constructed after 1939 ("post-Compact" reservoirs) are subject to special Compact restrictions concerning how and when they can store water and require adjustments to observed flows at index gages during the accounting procedures. For example, operations at Platoro Reservoir, which is the largest post-Compact reservoir in the Basin, affect the flows in the Conejos River at the Mogote Index Gage. Observed flows at the Mogote Gage must therefore be adjusted (upward when the reservoir is storing water, and downward when it is releasing) in order to calculate accurately the Compact delivery obligation for the Conejos River.

Similar adjustments are made to streamflow gages affected by trans-basin diversions into the Rio Grande Basin. Annual storage, releases and evaporative losses by post-Compact reservoirs and Basin inflows from trans-basin diversions are explicitly accounted for in the administration of the Compact.

DAILY ADMINISTRATION

Once the water commissioners for each river have received the curtailment percentage for the next period of the season, they incorporate that requirement into the delivery of water to ditches. After determining the amount of native flow at the upper index station each morning, they apply the curtailment percentage to that flow and thereby establish what water has to bypass the ditches and flow to the lower index delivery points. The remainder of the water is distributed to the ditches on their river in accordance with their relative priorities. Because of the distance involved between the index gages and the ditches and delivery points, the delivery to them is time-lagged. The intermediate gaging stations on the rivers help the water commissioners track the Compact water through the system. These gages also help establish return flows and tributary inflow that are available to help Colorado meet delivery requirements on both rivers.

Depending on the actual deliveries made during a 10-day period and considering what water is in transit, adjustments may be made to the curtailment. A monthly analysis of how the actual runoff compares to the forecast or how rainfall events may be affecting the annual index supply is also made. This continual updating and reevaluation provide Colorado administrators and water users the information to make informed decisions on if or how adjustments to the curtailment should be made. It also provides a process to assess the current conditions and if there have been changes from the assumptions used to establish the forecast. Extreme drought or flood conditions that change those assumptions are recognized and the administration varies accordingly. If normal summer and fall rainfall does not occur and lower than normal flows result, then the curtailment may be reduced. If the summer monsoon season provides vastly increased flows, then large increases in the curtailment may have to be made to remain current on deliveries. The 1999 season is a perfect example of how the curtailment must be increased due to significant changes in the river hydrology during the latter half of the year. As is very evident to the observer, the flows in the later summer months on the Upper Rio Grande were well above normal because of an unusual "monsoon" flow. This rainfall dramatically increased the index supply on the river and caused Colorado to increase the curtailment from 12 percent to more than 40 percent as the summer proceeded. The only way to compensate for the increased obligation from the increased index supply was to increase the curtailment. These types of unforeseen events show that without regular and routine monitoring and adjustment in operation, Colorado cannot expect to meet her obligation within reasonable tolerances. The vagaries in the hydrology and climate and the inability of man to predict weather in advance makes the administration of the Compact a dynamic and challenging process.

One of the goals of the State of Colorado is to try to determine the curtailment percentage that can be applied throughout the irrigation season so that the resulting effect of that curtailment is applied evenly across the priorities as the hydrograph rises and recedes. Large changes in the curtailment within the season can transfer the effect of the Compact and disproportionately affect the water rights in the system. This issue is extremely important to the water users on both rivers who decided long ago that the impact of the Compact should be shared as uniformly as possible by the water rights that were in priority in any given year.

REMARKS

Since 1968, the State of Colorado has worked diligently to develop a methodology that allows her to meet her Compact obligation. The ability to do so is hampered by a number of variables that are either unknown or subject to change without notice. Thus a system has been developed that recognizes and accounts for these variables. The system also is flexible enough that changes can be made to maintain deliveries that are required. The original curtailment and changes to it during the year directly affect the water supply for many water-right owners on the Conejos River and the Rio Grande. It is extremely important for Colorado to utilize fully the entitlements allowed under the Compact. Colorado's entitlements provide water to over one-half of the irrigated land on the Rio Grande above Fort Quitman, Texas. That system has to be run without large reservoirs and is primarily a run-of-the-river operation. For this reason, it is critical for Colorado to analyze continuously and improve her methodology of Compact administration. Improved snowmelt runoff forecasting as well as improved weather forecasting would greatly enhance the ability of Colorado to meet her obligations while reducing its impact on water users. It is, and always will be, the variability and the unknowns of the hydrologic system that provide the challenges to administrators and users on the system.

The Administration of the Rio Grande Compact in Colorado

RIO GRANDE COMPACT TEN DAY REPORT

PRELIMINARY DATA

DATE: November 22, 1999

Period Ending: November 20, 1999

CBP Allocation: 60% as of 1/1/99

RIO GRANDE

(Units in Thousands of Acre-Feet)

Projected Annual Index: 918,000   Obligation: 351,200   % of Index: 38%

MONTH	RIO GRANDE INDEX SUPPLY Recorded Flow near Del Norte	Accumulated Total		ADJUSTED DELIVERIES Rio Grande Lobatos less Conejos-La Sauses *	Accumulated Total
JAN	13.3	13.3		17.6	17.6
FEB	11.3	24.6		17.1	34.7
MAR	22.5	47.1		12.8	47.5
APR	41.9	89.0		4.2	51.7
MAY	170.0	259.0		27.2	78.9
JUN	245.3	504.3		63.3	142.2
JUL	147.1	651.4		34.4	176.6
AUG	110.7	762.1		66.2	242.8
SEP	84.9	847.0		52.7	295.5
OCT	39.0	886.0		26.0	321.5
NOV 1-10	8.4	894.4		6.6	328.1
NOV 11-20	5.7	900.1		8.1	336.2
Annual Credit					
APR-SEP	799.9				
TOTAL	900.1			338.2	

* Deliveries Include: Rio Grande Portion of Adjusted Closed Basin Project Production to Date   10,913 Acre-Feet.

Delivery Target	(% of Index)	Estimated Curtailment of Ditches	(% of Index)
January 1 - March 14	100%	January 1 - March 14	100%
March 15 - May 7	10%	March 15 - May 7	0%
May 8 - July 13	17%	May 8 - July 13	12%
July 14 - July 21	20%	July 14 - July 21	17%
July 22 - August 5	33%	July 22 - August 5	30%
August 6 - September 2	40%	August 6 - August 23	Vol. Bypass
September 3 - October 18	50%	August 24 -September 2	30%
October 19 -	40%	September 3 - October 18	40%
		October 19 - 31	30%
		November 1 -	0% (recharge)

Respectfully submitted,

Steven E. Vandiver, Division Engineer, Division III

cc:

Hal Simpson(3)
Steve Baer
Dale Pizel

Paul Clark
Ralph Curtis
Roy Helms

Dennis Felmlee
Bob Robins
John Allen Davey

Jim Horton
David Harrison
Mike Gabaldon

Bill Paddock
David Robbins
George Whitten

The Administration of the Rio Grande Compact in Colorado

RIO GRANDE COMPACT TEN DAY REPORT

PRELIMINARY DATA

DATE: November 22, 1999 Period Ending: November 20, 1999

CBP Allocation: 40% as of 1/1/99

CONEJOS RIVER

(Units in Thousands of Acre-Feet)

Projected Annual Index: 313,000 Obligation: 118,900 % of Index: 38%

MONTH	CONEJOS INDEX SUPPLY							ADJUSTED DELIVERIES	
	MEASURED FLOW			PLATORO SUPPLY					
	Conejos at Mogote	Los Pinos near Ortiz	San Antonio at Ortiz	Storage End of Month	Change In Storage	Supply in Month	Accum. Total	Conejos River at Mouths near La Sauses *	Accum. Total
JAN	2.7	—	—	21.7	0.2	2.9	2.9	5.6	5.6
FEB	3.1	—	—	21.9	0.2	3.3	6.2	5.5	11.1
MAR	5.9	—	—	22.8	0.9	6.8	13.0	7.2	18.3
APR	11.0	9.5	3.8	23.3	0.5	24.8	37.8	2.8	21.1
MAY	42.4	30.7	7.6	28.9	5.6	86.3	124.1	21.8	42.9
JUN	60.5	16.4	0.8	40.0	11.1	108.8	232.9	27.9	70.8
JUL	32.9	3.7	0.2	35.4	-4.6	32.2	265.1	8.9	79.7
AUG	18.7	4.6	0.4	38.1	2.7	26.4	291.5	12.6	92.3
SEP	13.7	1.9	0.1	33.5	-4.6	11.1	302.6	3.1	95.4
OCT	7.7	1.2	0.1	29.7	-3.8	5.2	307.8	2.1	97.5
NOV 1-10	1.0	—	—	29.7	0.0	1.0	308.8	0.7	98.2
NOV 11-20	0.9	—	—	29.6	-0.1	0.8	309.6	0.8	99.0
Annual Credit									
APR-SEP	199.2	66.8	12.9						
TOTAL	220.5	68.0	13.0		8.1	309.6		99.0	

* Deliveries Include: Conejos Portion of Adjusted Closed Basin Project Production to Date 7,277 Acre-Feet

Delivery Target	(% of Index)	Estimated Compact Curtailment	(% of Index)
January 1 - March 8	100%	January 1 - March 8	100%
March 9 - April 6	0%	March 9 - May 7	0%
April 7 - May 7	10%	May 8 - June 15	20%
May 8 - August 25	20%	June 16 - 30	0%
August 26 - October 4	28%	July 1 - August 5	35%
October 5 -	0%	August 6 - 25	0%
		August 26 - 31	30%
		September 1 -	0%

RIO GRANDE COMPACT
July 20, 1999 Analysis (Modified for Estimated Index)
Closed Basin Project Split: 60/40

RIO GRANDE BASIN

April - September Index

NRCS Forecast =	568,000
DWR Forecast =	668,000

Index Supply

January - February	24,600	*
March	22,500	*
April	41,900	*
May	170,000	*
June	245,300	*
July 1 - 20	97,300	*
July 21 - September	113,400	estimate
October	30,000	estimate
November - December	30,000	estimate
Total	775,000	

Index

In the bank:	Apr - pres	554,500
	YTD	601,600

Obligation = 243,000

Deliveries

January - February	34,800	*
March native	12,900	*
April	4,500	*
May	26,700	*
June	63,000	*
July 1 - 20	19,400	*
July 21 - Oct native	41,600	needed
Nov - Dec native	34,000	estimate
Total	236,900	
Paper Credit	5,000	
SC Norton Drain Flow	-5,500	estimate
Remaining CBP Share	6,600	estimate
Total Required Delivery	243,000	
Expected Overdelivery	0	

Delivery

In the bank:	Apr - pres	113,600
	YTD	161,300

Curtailment

Req Deliv	41,600	29.0%
Native Index	143,400	

* = Actual measured flows (Deliveries include Closed Basin Project share)
- All values in acre-feet
- Assumes 60% of the Closed Basin Project flows are creditable to the Rio Grande (Projected delivery of creditable CBP production to the Rio Grande is 24,000 acre-feet)
- Asssumes no recharge diversions after November 1, 1999
- Trinchera Creek flow to the Rio Grande will increase delivery

RIO GRANDE COMPACT
July 20, 1999 Analysis (Modified for Estimated Index)
Closed Basin Project Split: 60/40

CONEJOS RIVER BASIN

DWR Estimated
April - September Index

Flows =	287,000
Conejos =	209,000
Los Pinos =	65,000
San Ant. =	13,000

Index

In the bank:	Apr - pres	243,800
	YTD	256,800

Obligation = 116,600

Delivery

In the bank:	Apr - pres	58,700
	YTD	76,800

Curtailment

Req Deliv	7,400	17.1%
Native Index	43,200	

Index Supply

January - February	6,200	*
March	6,800	*
April	24,800	*
May	86,300	*
June	108,800	*
July 1 - 20	23,900	*
July 21 - September	33,200	estimate
October	10,000	estimate
November - December	10,000	estimate
Total	310,000	

Deliveries

January - February	11,000	*
March native	7,100	*
April	2,500	*
May	22,300	*
June	27,900	*
July 1 - 20	6,000	*
July 21 - Oct native	7,400	needed
Nov - Dec native	6,000	estimate
Total	90,200	
Paper Credit	5,000	
SC Norton Drain Flow	5,500	estimate
Carryover Credit in E.B.	11,500	
Remaining CBP Share	4,400	estimate
Total Expected Delivery	116,600	
Expected Overdelivery	0	

* = Actual measured flows (Deliveries include Closed Basin Project share)
- All values in acre-feet
- Assumes 40% of the Closed Basin Project flows are creditable to the Conejos
  (Projected delivery of creditable CBP production to the Rio Grande is 24,000 acre-feet)

Conrad G. Keyes Jr. *is president of ASCE's Environmental and Water Resources Institute. He received a B.S. in civil engineering from New Mexico A&MA; M.S. in civil engineering from New Mexico State University; and ScD also in civil engineering, water resources emphasis from NMSU in 1967. Conrad is a licensed professional engineer in Texas, Colorado and New Mexico. While a faculty member of NMSU, he served as department head of Civil, Agricultural, and Geological Engineering from 1979-1987. Conrad served as principal engineer for planning for the International Boundary and Water Commission from 1989-1994, branch manager of Boyle Engineering Corporation's El Paso Office from 1995-1997, and engineer advisor to the Texas Rio Grande Compact Commissioner from 1987-1989 and 1997-1999. Conrad was responsible for the annual evaluation of water deliveries from Colorado to New Mexico and from New Mexico to Texas at Elephant Butte Reservoir.*

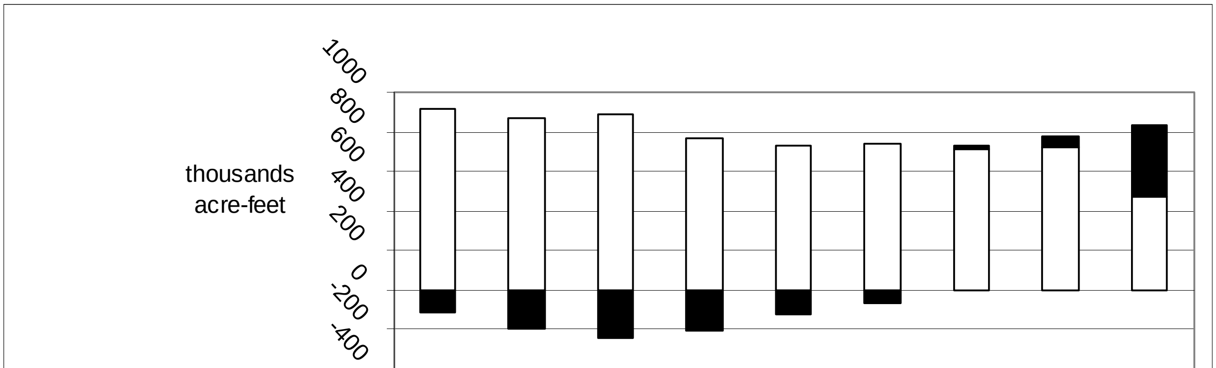
Hydrology and Key Accounting Components of the Compact

Thank you kindly for the introduction. The organizers of this conference have given me fifteen minutes to cover all the material in my topic. I'm glad that everybody before me has already covered the information. Now I can talk about some other things that I feel really need to be covered.

The first part of this presentation will be devoted to some hydrology issues of the Rio Grande Basin. I will present yearly flows at different locations, some key accounting components of the Compact, and summaries of water use by the states. Most of the information comes from past reports. Some of you will have seen the information before. Some have glanced at the data. However, most of you have not read the reports at all. My presentation will use a different type of visual aid to show the importance of information from previous reports.

The first data are from the Rio Grande Project during 1943 to 1951. Norman Gaume provided some of this information earlier in a different manner. I will also discuss the help that Reclamation requested in 1945. My presentation will discuss the Rio Grande Operation Re-evaluation Study in 1989 and highlight some interesting points from the final report. I will also look at 1998 Rio Grande Compact accounting, which Steve Vandiver and others have already talked about earlier. My comments on the accounting components of the Compact will lead into discussion of the next steps that are needed in the Basin.

Figure 1 summarizes water demands of the Rio Grande Project (waters below Elephant Butte) from 1943 to 1951. The total usable water released in those years is provided in the second row. According to the Rio Grande Compact, the "normal" Rio Grande Project water released is 790,000 acre-feet per year. The figure also shows the accrued departure from "normal" releases for those years provided. The total useable water releases ranged from a high of 913,000 acre-feet in 1943 to a low of 471,000 acre-feet in 1951. Again, the "normal" release is to be 790,000 acre-feet. In 1945, the accrued departure from "normal" was 247,000 acre-feet. Eventually the deficits, or the accrued departures from "normal," did in fact become positive from 1949 through during the 19-year period was 41% (or an average of 700,000 acre-feet). Colorado's use of the water during this period was around 38% (or an average of 667,000 acre-feet) and New Mexico's total use during these 19 years was 21% (or an average of 368,000 acre-feet). All these demands were made in accordance with the delivery rules of the Compact.



	1943	1944	1945	1946	1947	1948	1949	1950	1951
■ Accrued Departure from Normal	-116	-192	-247	-201	-123	-64	14	60	362
□ Total Useable Water Release	913	868	885	766	728	743	713	721	471

Figure 1. Water deliveries of the Rio Grande Project below Elephant Butte from 1943-1951.

1951.

On May 10, 1945, the Superintendent of the Rio Grande Project presented a publication to the public, in which he asked for help. Reclamation indicated there was a need to solve the serious water supply problem–accrued departure from "normal" was a large negative in Compact accounting for 1945. The Superintendent described the need to look toward the future security of the Project. Reclamation encouraged ways of using less water during the next few years. This meant using less than the "normal" release designed for the Project.

I'd like to discuss briefly the Rio Grande Basin Operation Re-evaluation in 1989. The Corps and others looked at flood control and optimum beneficial uses of waters in the basin. They also provided information about average water demands over a period of a few years and the storage capacity at Abiquiu, Cochiti, and Jemez Canyon reservoirs.

Figure 2 shows water deliveries for 1968 to 1986 in acre-feet. The pie chart shows that Texas's Compact water percentage of total use

Now, one can look at the states' deliveries associated with what was measured. Figure 3 shows the average percentage of returns to the river during the same period. Colorado returned an average of 18% of the 667,000 acre-feet (or 120,060 a-f) to the river from the usage in Colorado. New Mexico returned 34% of their delivered waters of 368,000 acre-feet (or 125,120 a-f) back to the river, and Texas returned 23% of the 700,000 acre-feet (or 161,000 a-f), which went out the bottom end of the Compact area.

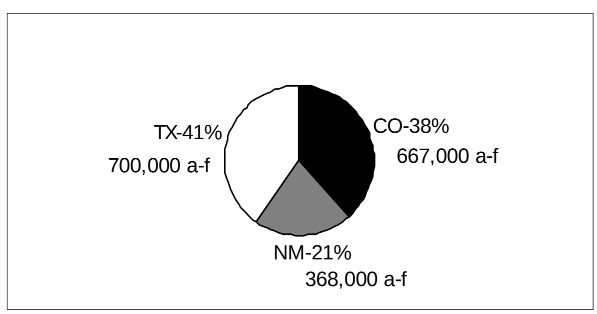


Figure 2. Water deliveries for 1968-1986 for Texas, Colorado and New Mexico.

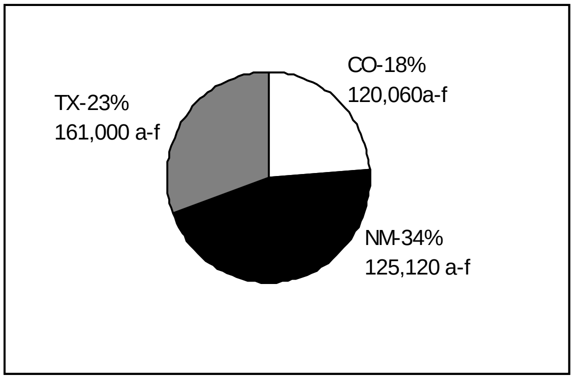


Figure 3. Average return flows by Colorado, Texas and New Mexico for the period 1968-1986.

Figure 4 comes from the same Corps of Engineers' studies in 1989. It shows the amount of reservoir storage in Colorado, New Mexico, and Texas. You will note that flood control in Colorado is minimal at about 6,000 acre-feet per year, and conservation space is about 54,000 acre-feet per year, for a total of 60,000 acre-feet per year. In New Mexico, there is about 1,874,000 acre-feet of total space and that includes flood, conservation, and other types of pools. Elephant Butte and Caballo reservoirs–the Texas reservoirs–provide the total space of 2.441 million acre-feet each year. The authorized storage is shown by percentages, which for Colorado with 1%, New Mexico with 43%, and Texas with 56% of the total available space.

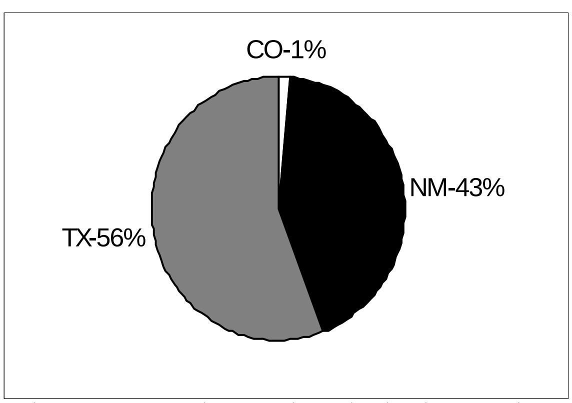


Figure 4. 1989 Rio Grande authorized reservoir storage in Colorado, New Mexico and Texas.

Reservoir	Flood	Conservation	Recreation	Sediment	Total
CO	6	54	-	-	60
NM	1,067	581	50	226	1,874
TX	100	2,341	50	-	2,441
Totals	1,173	2,976	100	226	4,375

(in thousands acre-feet)

Figure 5 provides us with the 1998 accounting of waters between the two portions of the basin in Colorado. The values come from the 1998 Annual Report of the Compact. Rio Grande waters are represented at the back of the figure in black. Conejos water is represented in the foreground by white bars. The supply out of the Conejos in 1998 was around 267,000 acre-feet. The Conejos delivery by Colorado at the New Mexico/Colorado state line was around 80,000 acre-feet. Usage in the Rio Grande portion of the Upper Basin, or the back bars, was about 578,000 acre-feet. The Rio Grande delivery to New Mexico was around 160,000 acre-feet. These amounts were in accordance to the rules of the Compact and, in fact, during 1998, Colorado accrued credits in Elephant Butte Reservoir.

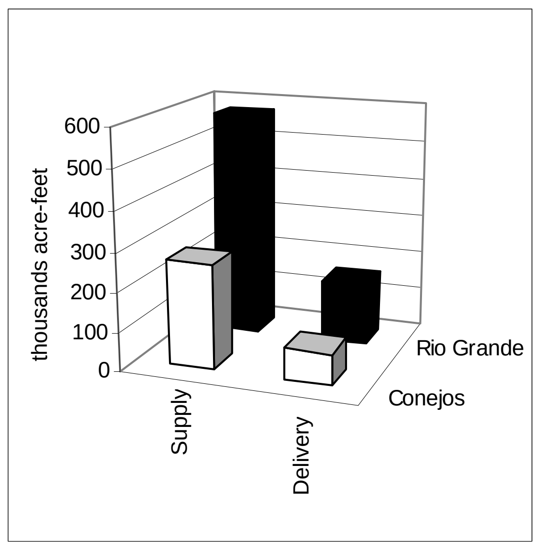
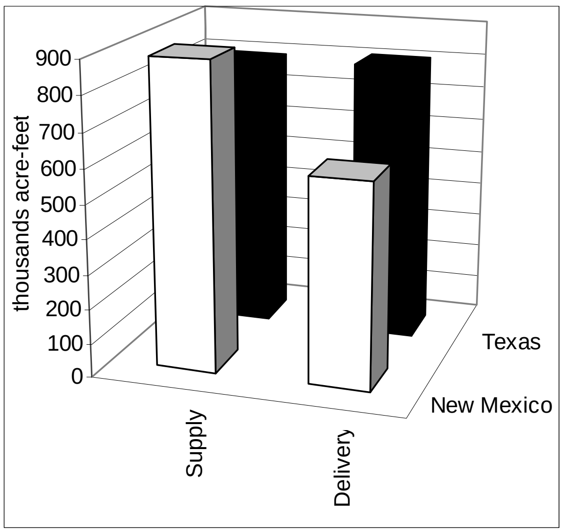


Figure 5. Accounting of Conejos River and the Rio Grande.

Figure 6 shows New Mexico and Texas supplies and deliveries. Texas values are represented by the black bars. The supply for Texas was to be 790,000 acre-feet, the normal release per year. However, the actual delivery in 1998 was 810,000 acre-feet. New Mexico had a supply of about 893,000 acre-feet, and the release from storage for Texas was about 597,000 acre-feet. In 1998, the rest, or about 296,000 acre-feet was used in New Mexico.



What does all this mean? If you compare the flood control space in New Mexico with the available conservation space, you find there definitely is adequate flood control space for most years. Reservoirs with adequate space, particularly at Abiquiu and Cochiti, were built after or during the 1950s. Many of the flooding problems occurred before that time. Likewise, Abiquiu Reservoir can be used for future water supplies if and when everyone agrees to such.

Furthermore, the Rio Grande Compact does not need to be changed to accommodate this use. The reservoir authorizations can be changed from time to time, if better water management is needed. In fact, the 1960 Flood Control Act created various ways to protect all Middle Rio Grande Project reservoirs. This Federal Act allows the reservoirs to be operated at all times in "conformity with the Rio Grande Compact." The Act also allows water management to be modified with the advise and consent of the Rio Grande Compact Commissioners.

The next step, in my opinion, is almost underway. An agreement is being considered in conjunction with the Upper Rio Grande Basin Water Operations Review and Environmental Impact Statement. Colonel Fallin will talk about this tomorrow. The work is scheduled to take place between 2000 to 2004. I believe we should consider the use of available flood control space for additional conservation space at all reservoirs. This can be done according to the Compact and its authorizations. However, some changes to one or two authorizations may be appropriate for a given space in one of the reservoirs in New Mexico.

***Lee Wilson** is President of Lee Wilson & Associates, a water resource consulting firm head-quartered in Santa Fe. A certified professional hydrogeologist, he earned his geology degrees at Yale (B.A.) and Columbia (Ph.D.). In his 35-year career, he has completed 300+ technical studies of surface and groundwater resources for government and industry; prepared more than 50 environmental impact statements and ecosystem reports for the U.S. Environmental Protection Agency; and provided expert witness services in some five dozen proceedings. Lee currently provides advice on water supply, water rights and water quality to more than a dozen municipalities and tribes along the Rio Grande, including Taos Pueblo, Santa Fe, Albuquerque, and Las Cruces.*

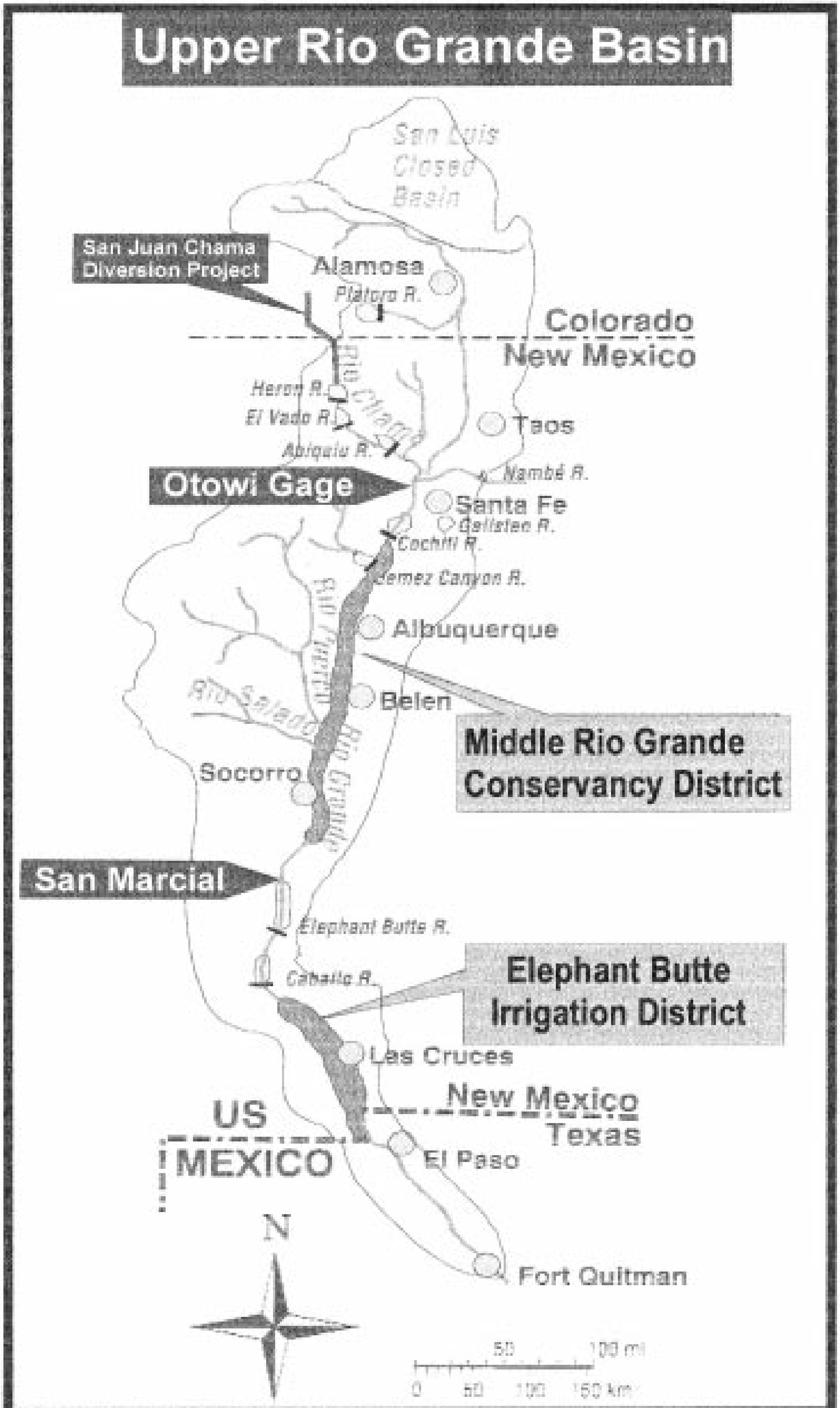
Surface Water Hydrology of the Rio Grande Basin

I have been asked to present everything I know about the surface water hydrology of the Rio Grande Basin in 15 minutes. That's no problem. To begin, we need to look at the location of the basin. Much of the world mistakenly believes the Rio Grande Basin includes all the area shown in Figure 1, and extends from the Colorado headwaters to the Gulf of Mexico. However, everyone at this conference knows the REAL Rio Grande Basin ends at Ft. Quitman.

Figure 2 shows some important features in the New Mexico part of the basin: two irrigation districts, the San Juan/Chama import project, Compact accounting points at Otowi and (formerly) San Marcial, reservoirs (the largest being Abiquiu, Cochiti and Elephant Butte), cities (the largest being Santa Fe, Albuquerque and Las Cruces, but these are small compared to downstream El Paso and Juarez) and more than a dozen tribes.

The renewable water supply for the Basin originates mainly from mountain snowmelt in Colorado and northern New Mexico (Figure 3),

Figure 1. The Rio Grande Drainage Basin



Courtesy NMOSE/ISC Waterline & Kenesson Design

Figure 2. Upper Rio Grande Basin

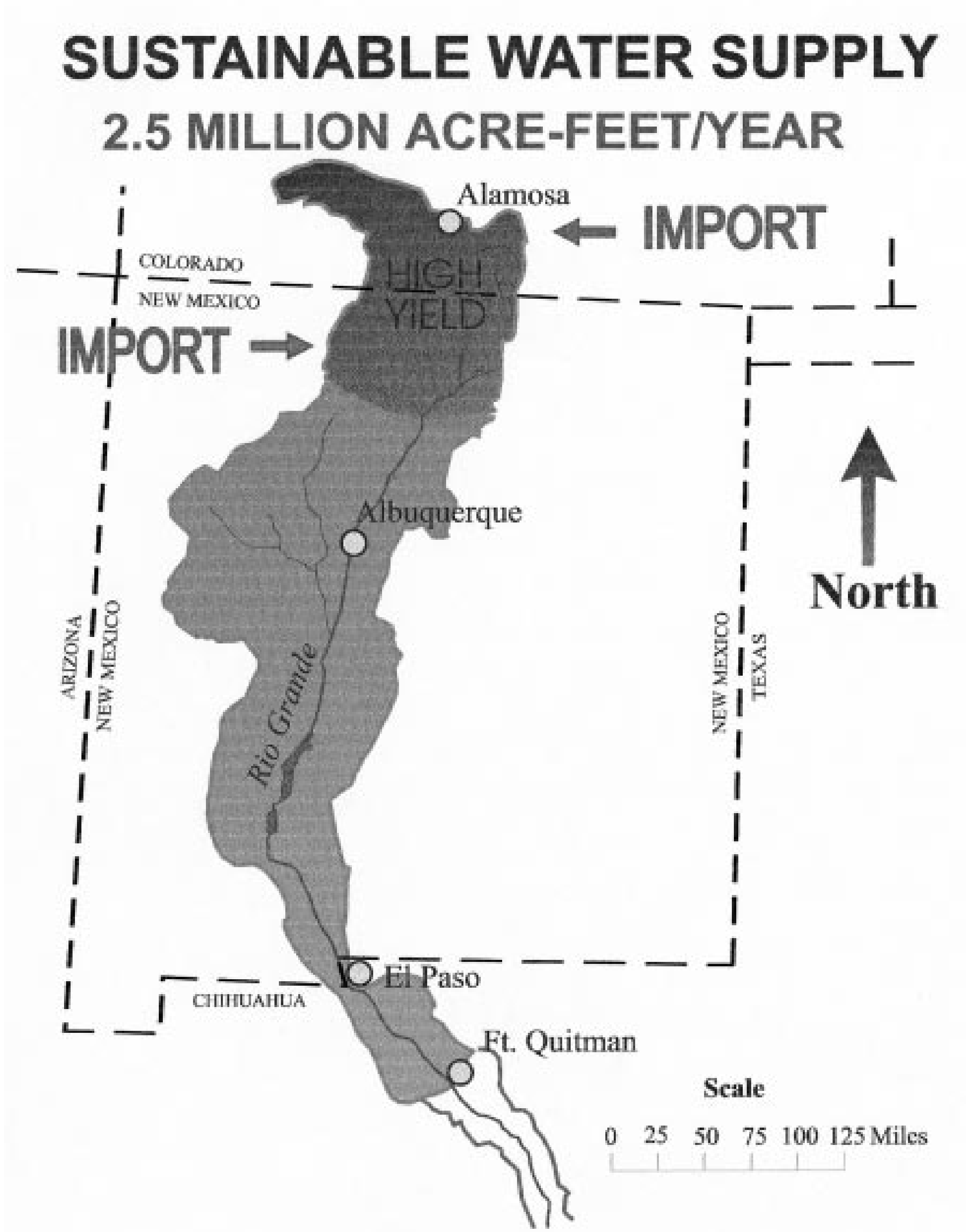


Figure 3. Sustainable water supply for the Rio Grande Basin (2.5 million acre-feet/year)

and averages about 2.5 million acre-feet (af) per year. There is an additional 5% supply provided by importation of San Juan/Chama water and the Closed Basin project in Colorado. The annual hydrograph reflects the snowmelt source with most of the natural flow occurring from April to July (Figure 4). For virgin flow conditions, I estimate the average May peak at more than 600,000 af. The virgin flow data also can be graphed on a flow-duration curve that shows

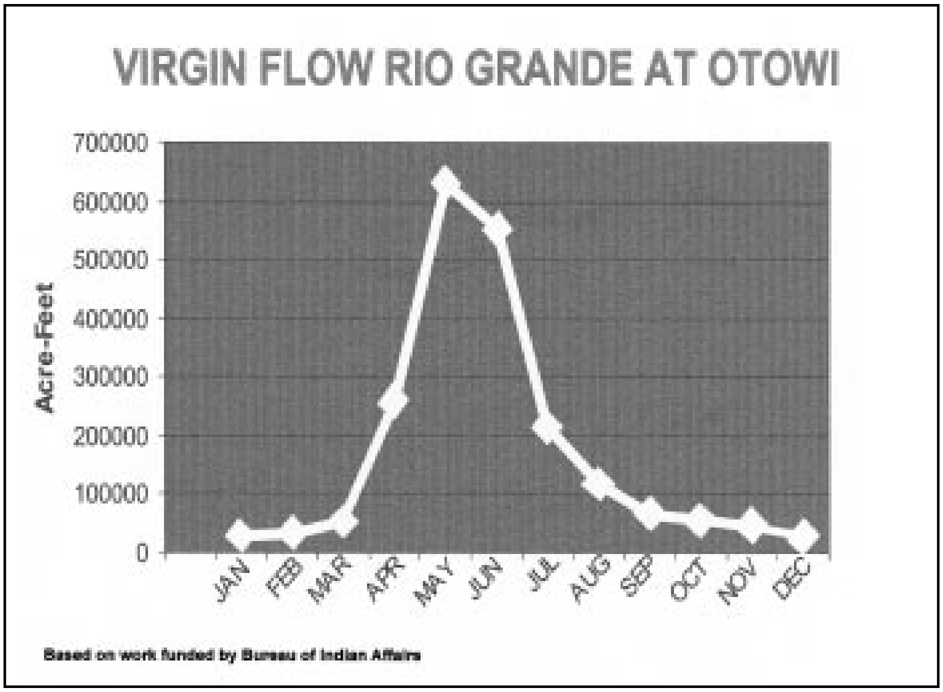


Figure 4. Rio Grande virgin flow at Otowi Gage

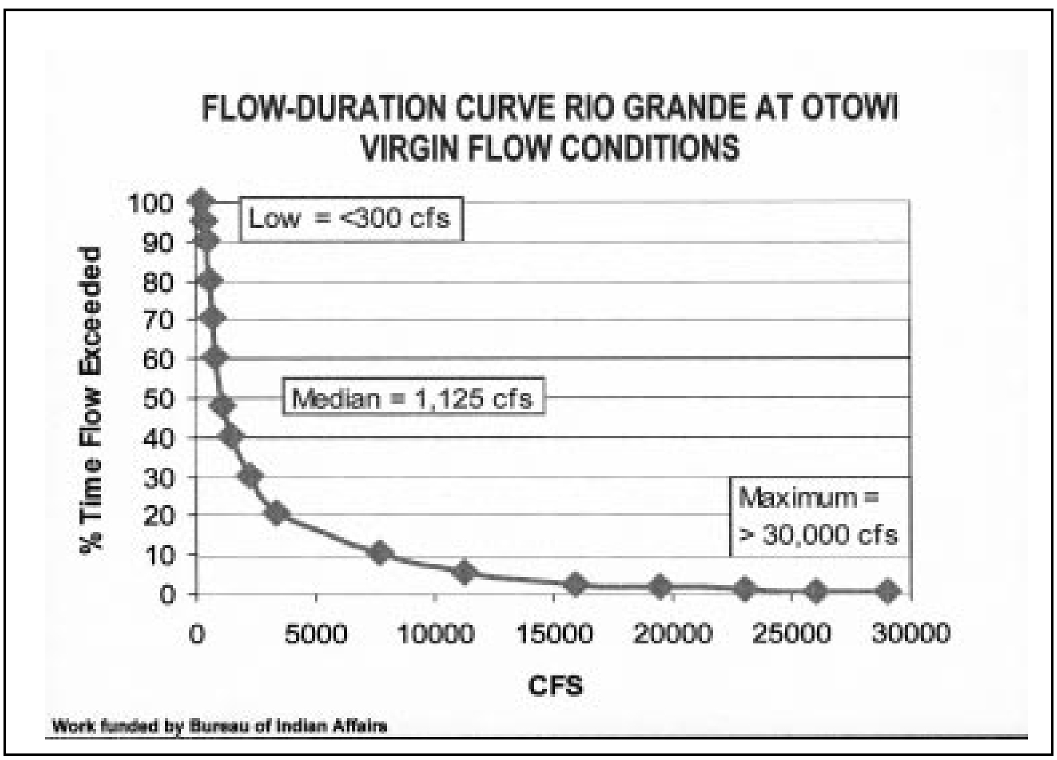


Figure 5. Rio Grande flow-duration curve at Otowi: Virgin flow conditons

more than a 100-fold range from the low of <300 cfs to the high >30,000 cfs, with a median above 1000 cfs (Figure 5).

As important as the overall supply is the great variability from year to year. Figure 6 shows runoff patterns in the Rio Pueblo de Taos for the last 1000 years, based on tree-ring records. Early this century when Rio Grande waters were being allocated, climate conditions were relatively wet and more water was available than normal. The '50s drought, in comparison, was severe–exceeded only by the one in the 1100s that was so disastrous to Pueblo Indians.

And also, the forest cover was in poor condition in the early part of the century, which meant that runoff was unusually large. Reforestation and watershed recovery promoted by the Forest Service and others has caused a net reduction in the runoff supply in recent decades. Figure 7 is typical; for the Taos area, it shows how much the runoff has declined even under relatively steady precipitation conditions.

Even with all the variability, 2.5 million acre-feet per year is quite a bit of water. Far and away the main use of this supply is for irrigation–a total of nearly one million acres, with the main areas as shown in Figure 8. Unfortunately for New Mexico, more than 600,000 of those acres are in the San Luis Valley of Colorado. I will comment on the three main areas of irrigation use.

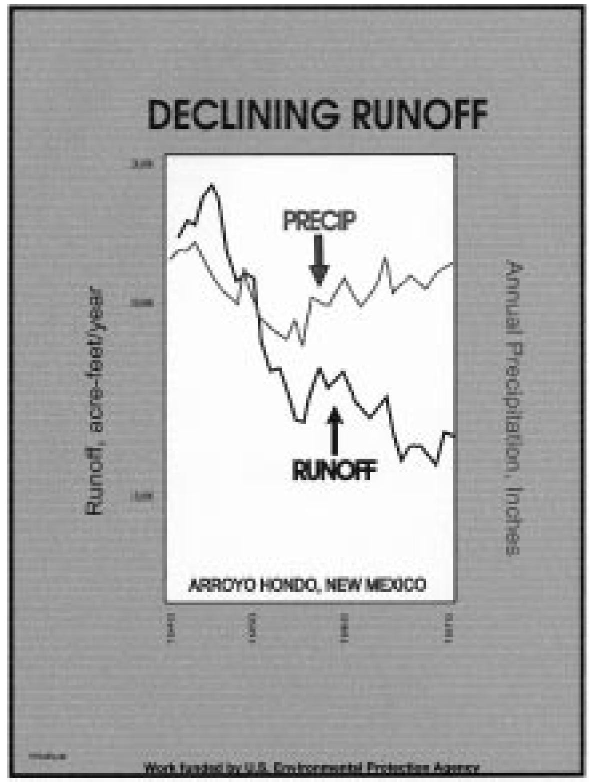


Figure 7. Declining runoff for the Taos area acre-feet/ year

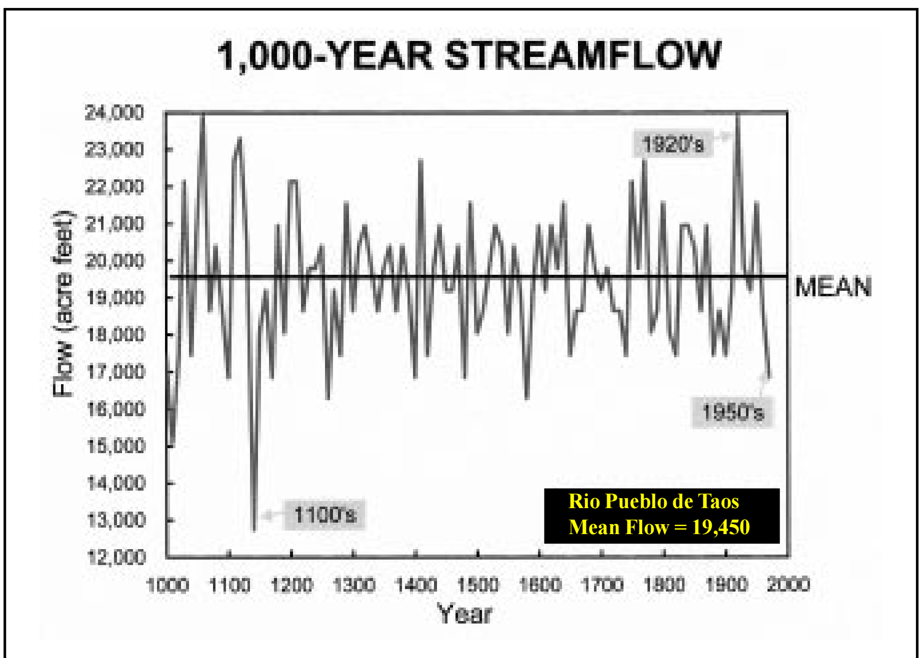


Figure 6. 1,000-year streamflow for Rio Pueblo de Taos

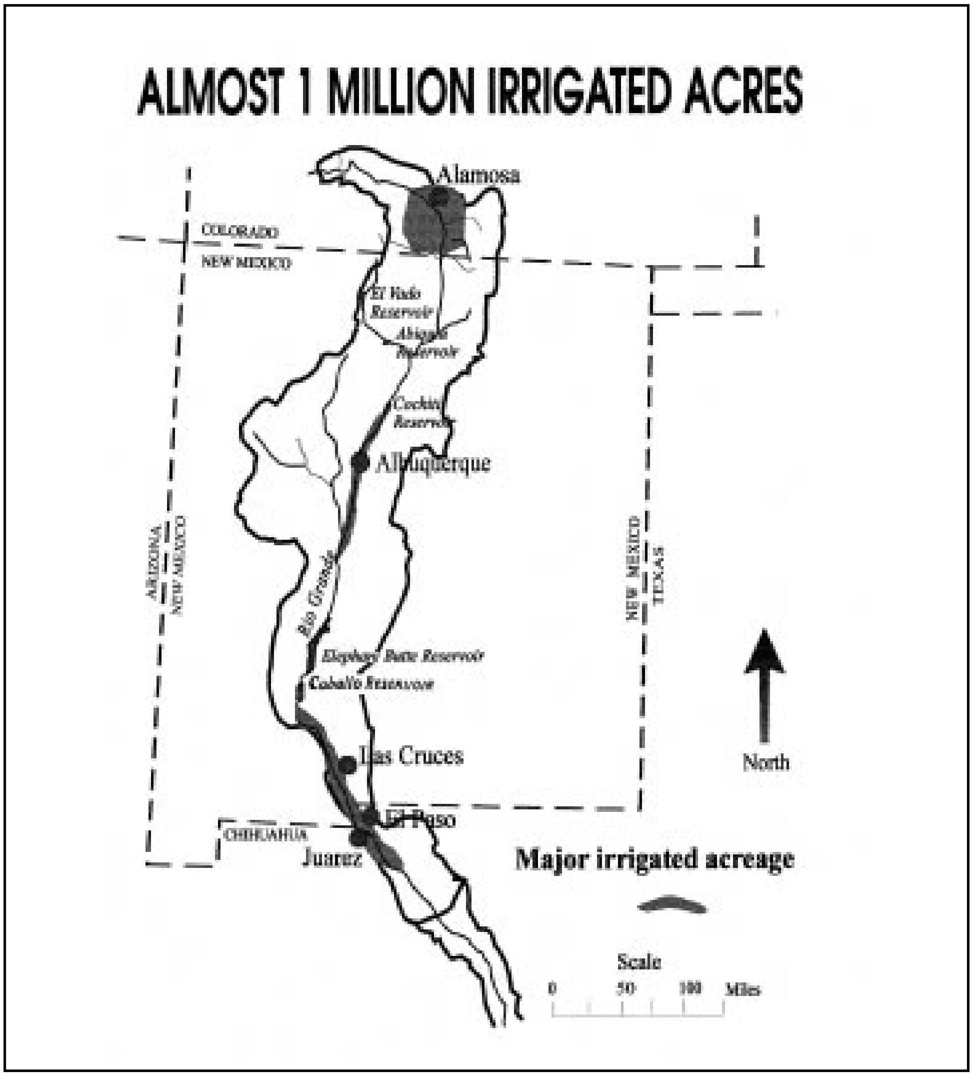


Figure 8. Major irrigated acreage in the Rio Grande Basin

The impact of Colorado is shown by comparing the virgin flow hydrograph at the Otowi gage, near Santa Fe, to the current flow (Figure 9). Of course the substantial reservoir storage upstream is partly responsible for the reduction in peak flow, but the overall reduced flow is mostly because of the use in Colorado. Winter flows are actually higher now than for virgin conditions, due to irrigation returns.

After Colorado, the next big straw in the system is the Middle Valley, where use is strictly controlled by the Compact. Figure 10 shows that roughly 60 to 80% of the Otowi flow must be bypassed down to Elephant Butte Reservoir. The Middle Valley is allocated about 300,000 AFY, which it fully uses, mostly through phreatophytes and irrigation. Because municipal wells tend to be far from the river, and wastewater discharges are direct to the river, you see little if any net use by the urban centers in this reach.

The final straw is the Rio Grande Project and the Treaty delivery to Mexico. Figure 11 shows how the Project supply was very short in the '50s-'70s, but has been full for two entire decades now. In dry years, nothing gets past Ft. Quitman. In wetter years, a little does. Every now and then we have a really wet year when the reservoir spills and water actually flows out of the basin. The long-term average flow at Ft. Quitman, which is mostly in a few wet years, is only about 140,000 AFY, or barely 5% of the total water supply. Steve Reynolds would be very proud: there is no question that in this basin, the users collectively do *use it*.

While some reservoirs have been built for flood control, the main factor has been that irrigation demand peaks in summer, after the runoff season, as shown in Figure 12. Shortages are a way of life on most tributaries, but they have been largely fixed on the mainstem.

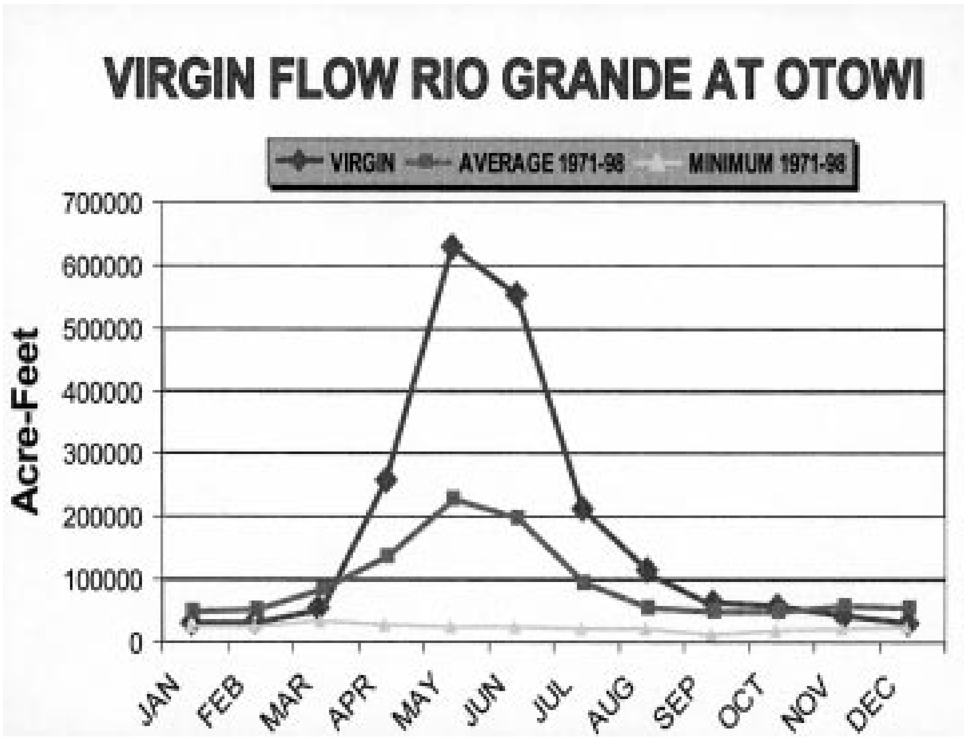


Figure 9. Virgin flow of the Rio Grande at the Otowi gage (acre-feet)

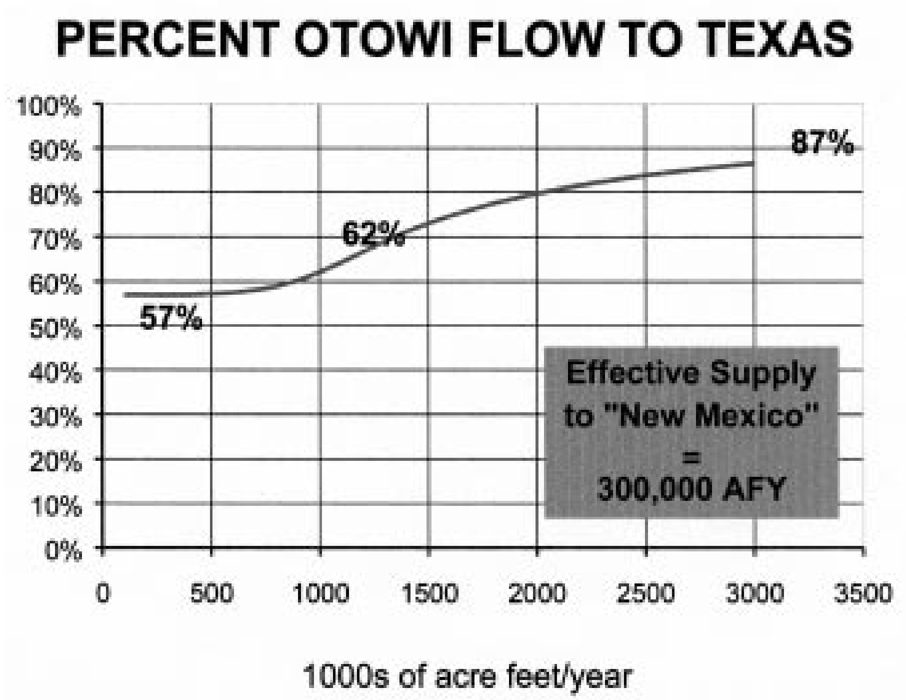


Figure 10. Percent of Otowi flow to Texas

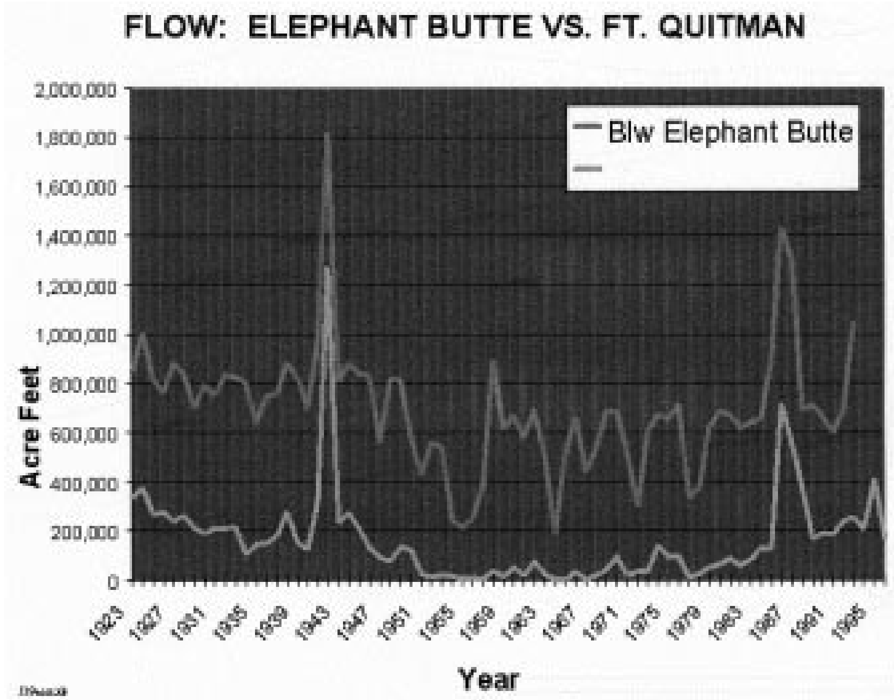


Figure 11. Rio Grande flow measured below Elephant Butte and at Ft. Quitman for 1923-1995

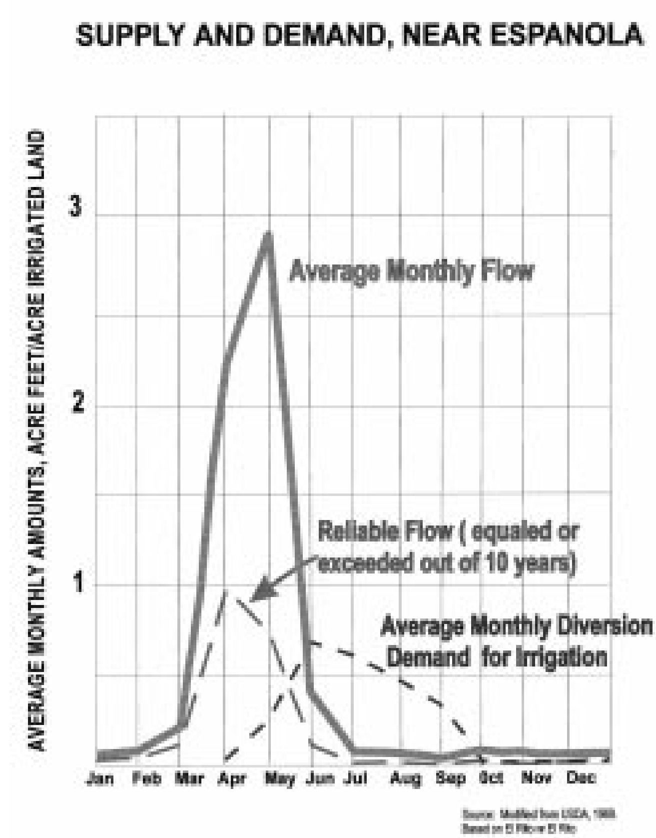


Figure 12. Supply and demand of Rio Grande water near Espanola

From a hydrologic perspective, the reservoirs have had lots of effects, such as evaporation. Figure 13 shows that evaporation rates are small in the northern reservoirs, but very large down south. Because Elephant Butte has a high rate and a huge area, it accounts for the bulk of the more than 340,000 af evaporated from the New Mexico reservoirs each year.

Another change has been to eliminate the highest runoff peaks (see Figure 14). It takes more than 11,000 cfs passing Albuquerque to really alter the channel and we haven't had a flow that large at Otowi since World War II. Since Cochiti was built, the actual flows at Albuquerque have been kept well below the 11,000 number.

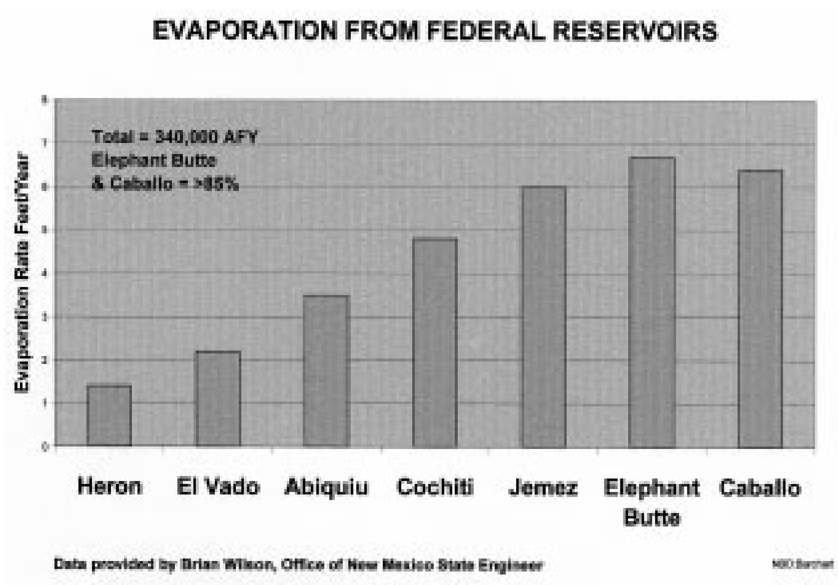


Figure 13. Evaporation rate for federal reservoirs in New Mexico

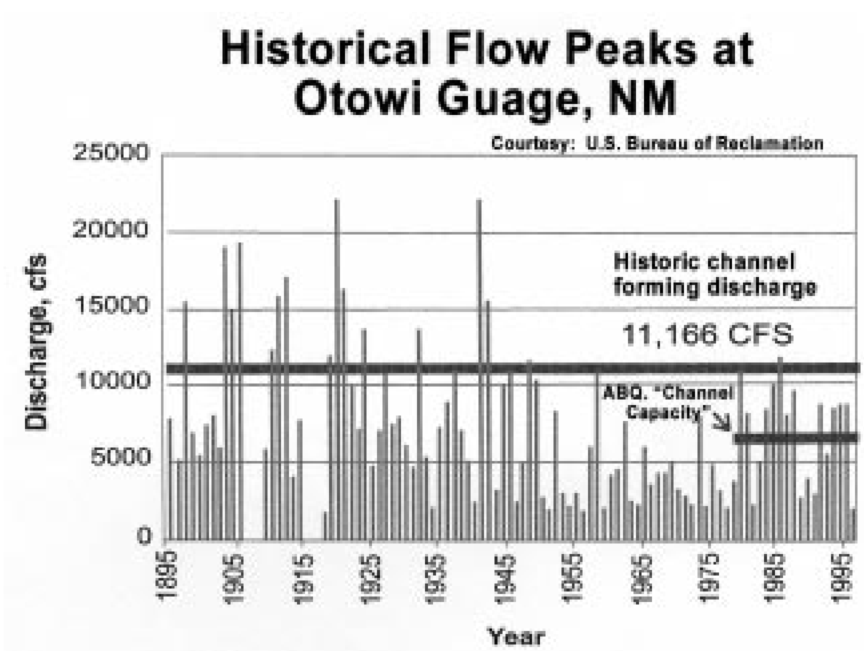


Figure 14. Historical flow peaks at Otowi gage for 1895-1995

With lower flood peaks, there has been a pronounced narrowing of the channel–below Albuquerque, the channel is only one-third or one-quarter its natural width (Figure 15). Levees and other structures have contributed to this effect, but the narrowing was inevitable once the dams were built and the flood peaks brought under control. Interestingly, if we draw a similar graph to show channel straightness, there isn't much change; the Rio Grande never did a whole lot of meandering.

Another important feature of the river has been its tendency to aggrade–to drop sediment, fill in the valley and get ever higher in elevation (Figure 16). The channel at San Marcial is 25 feet higher now than it was at the beginning of the century. This is largely a natural problem, as evidenced by the fact that thousands of feet of sediment have accumulated in the Rio Grande valley over the past few million years.

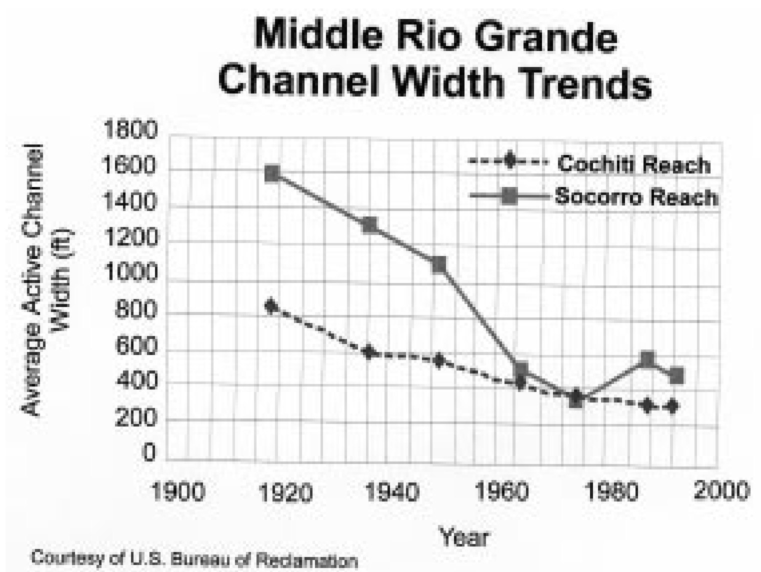


Figure 15. Middle Rio Grande channel width trends for Cochiti and Socorro reaches, 1920-1990

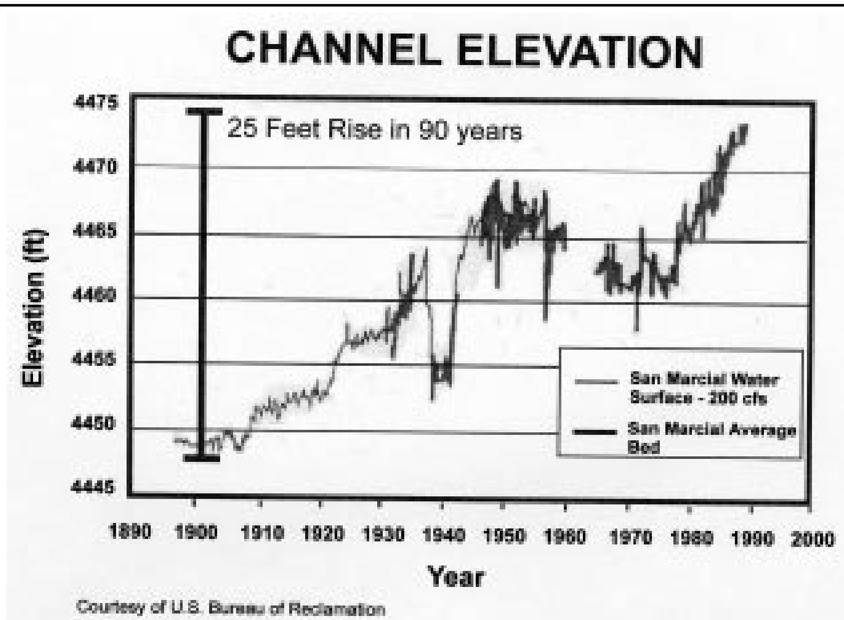


Figure 16. Change in San Marcial channel elevation over the past 100 years

Finally, I want to remind you all that most of my talk has been at the basin scale. But the hydrology of the real-world system has many localized components that can be critical in addressing specific issues (Figure 17). Most of the local effects reflect the diversion of water into canals and onto farms, or pumping effects by wells, along with the return of water through drains or wastewater effluent.

Much of our current research deals with studying the details of these more local relationships. Figure 18 is an example that comes from Bureau of Reclamation research. It shows how the tendency of the river to gain or lose water changes from one reach to another, and also over time.

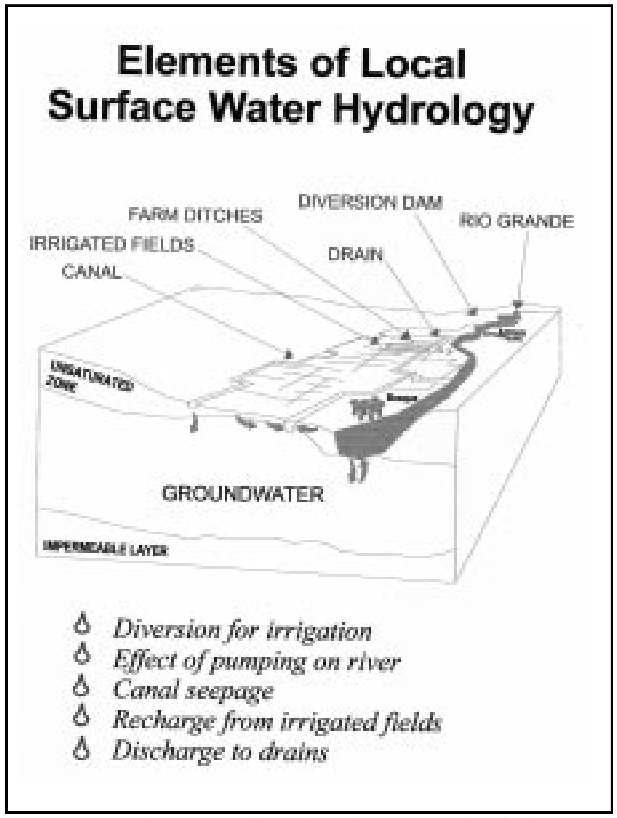


Figure 17. Elements of local surface water hydrology

Surface Water Hydrology of the Rio Grande Basin

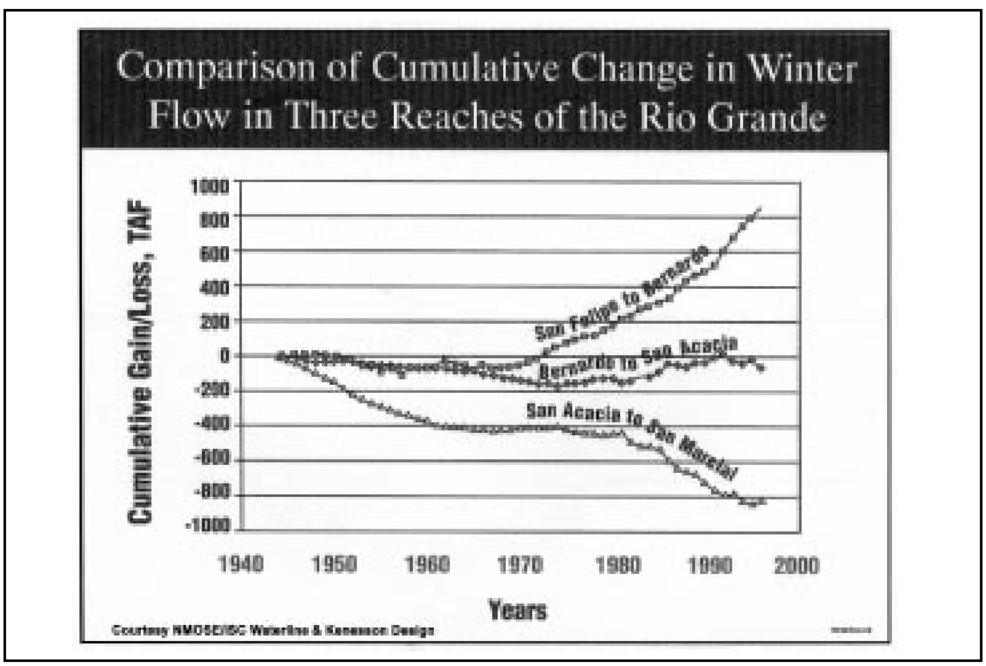


Figure 18. Comparison of cumulative change in winter flow in three reaches of the Rio Grande

It is worth remembering that water quantity isn't the only issue. Media coverage to the contrary, I don't view the Rio Grande as a "toxic sewer." One significant man-made problem is salinity build-up, mostly from irrigation return flow (Figure 19). The result is marginal quality water in the El Paso/Juarez area, especially in winter when the supply is not potable. This is a major consideration in the interstate negotiations over providing water to El Paso.

Finally, I'll close with a short list of what seems to be the biggest of the many, many issues that relate to surface water in the Rio Grande basin. Everyone here knows about these, so this is just a reminder:

- the possible need to provide instream flows for the Rio Grande silvery minnow;
- growing water demands in Albuquerque, Las Cruces, El Paso and Juarez, all of which are likely to be met in large part by surface water,
- Indian claims, which could easily account for 50% of the basin supply,
- and an expectation for all of these reasons–we could see a future in which the operations of reservoirs and water projects are quite different from today.

If changes in operations don't solve the problem, we look to the Compact. The Compact is always taken as a fact of life. This may not be so in the future, given all the pressures on the supply.

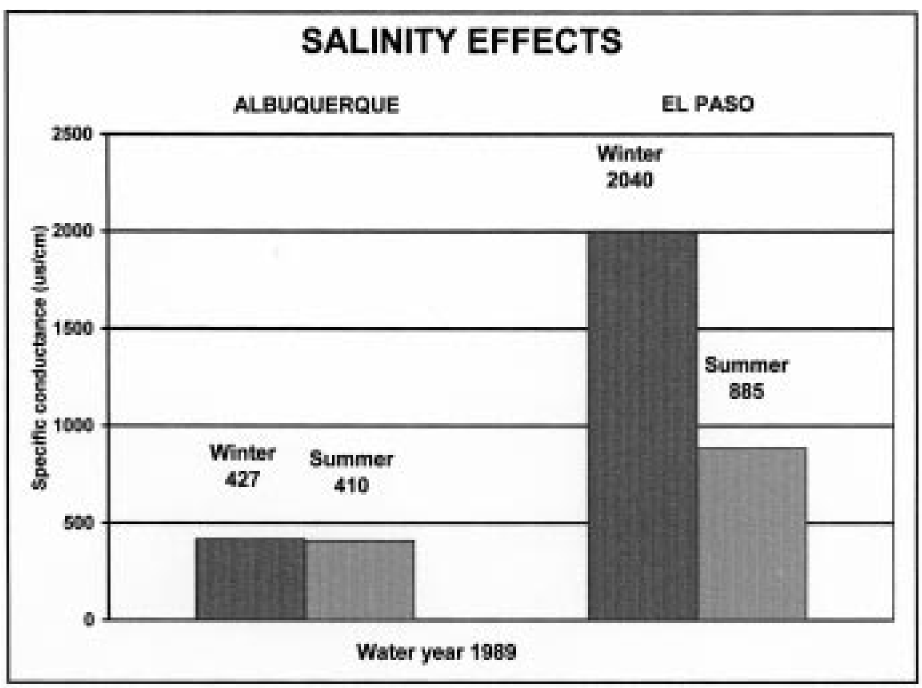
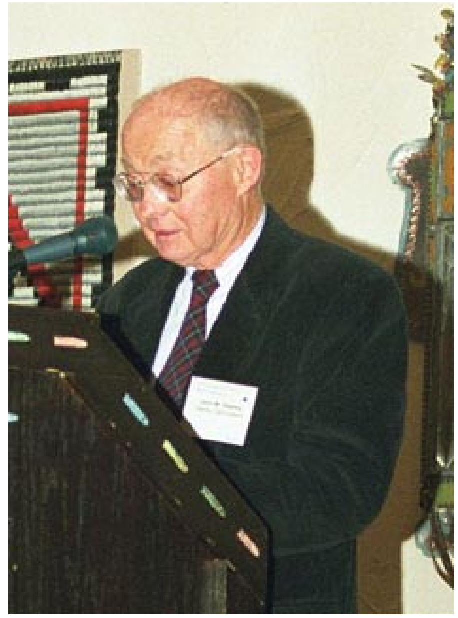


Figure 19. Salinity effect for Albuquerque and El Paso in 1989

John Hawley *has a Ph.D. in geology from the University of Illinois (1962), and has spent most of his 40-year professional career working on a variety of problems relating to the exploitation of natural resources and disposal of hazardous wastes in fragile desert environments. He was first employed by the U.S. Soil Conservation Service in Las Cruces and Lubbock, and between 1977 and 1997 headed the environmental geology program of the Office of State Geologist at New Mexico Tech, Bureau of Mines and Mineral Resources Division. John was awarded emeritus status from the NMTech Board of Regents on his retirement in 1997, and he now works part-time as a consultant and NMWRRI specialist on the hydrogeologic framework of Rio Grande Basin and other parts of the International Boundary region.*



Overview of the Hydrogeology and Geohydrology of the Northern Rio Grande Basin - Colorado, New Mexico, and Texas

Mike Kernodle *joined the U.S. Geological Survey in 1973 after serving with the State of Tennessee as a geologist for 5 years. He retired from the Survey in 1998, and now works as a part-time consultant and serves as a technical advisor to the Middle Rio Grande Water Assembly. Mike has over 25 years of experience in groundwater-flow modeling, with the last 18 years in New Mexico, and 14 years experience in hydrologic applications of geographic information systems. While in New Mexico, he has authored or co-authored 30 reports, atlases, and papers.*

INTRODUCTION

This brief overview of the hydrogeology and geohydrology of basin-fill aquifers in the northern Rio Grande Basin covers a large region that extends from the San Luis "Valley" of south-central Colorado to the Hueco Bolson southeast of El Paso and Ciudad Juarez (Figure 1). This is the general area covered by the Rio Grande Joint Investigation of 1938 (Natural Resources Committee 1938). Emphasis here is on three basin-fill aquifer systems that are representative of the most productive groundwater reservoirs in this part of the United States: The Alamosa subbasin of the San Luis "Valley," the central part of the Albuquerque Basin, and the southern Mesilla Basin between Las Cruces and El Paso. The complex geohydrologic system that exists in the region must be understood both in the context of events leading to enactment of the Rio Grande Compact, and to all subsequent issues relating to management of groundwater as well as surface-water resources.

A very important part of the Rio Grande Joint Investigation Report was the chapter by Kirk Bryan (1938) on the "Geology and ground-water conditions of the Rio Grande depression in

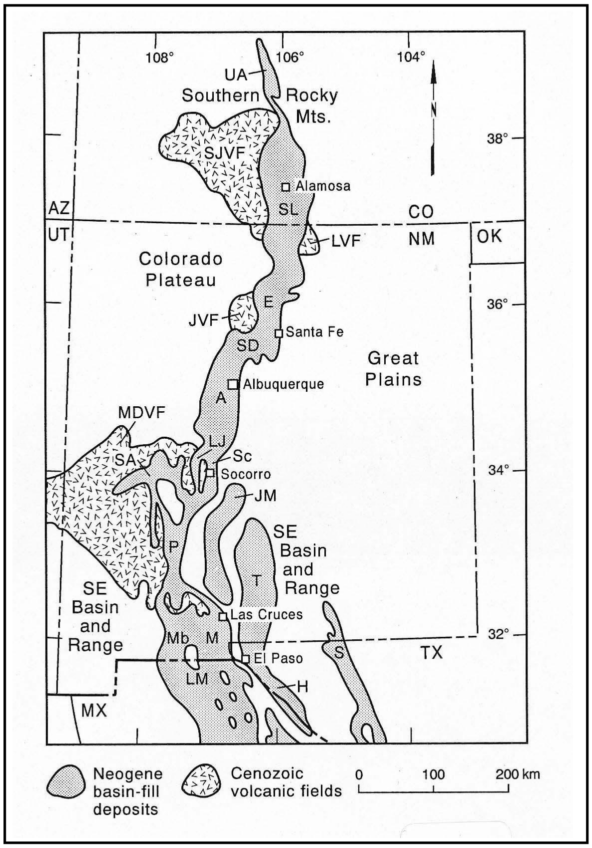


Figure 1. Index map showing major basins of the Rio Grande rift and contiguous volcanic fields. Modified from Keller and Cather (1994). Basins abbreviations from north to south: Upper Arkansas (UA), San Luis (SL), Española (E), Santo Domingo (SD), Albuquerque (A), Socorro (Sc), La Jencia (la), San Augustin (SA), Jornada del Muerto (JM), Palomas (P), Tularosa (T), Mimbres (Mb), Mesilla (M), Los Muertos (LM), Hueco (H), and Salt (S). Cenozoic volcanic fields: San Juan (SJVF), Latir (LVF), Jemez (JVF), and Mogollon-Datil (MDVF).

Colorado and New Mexico." Bryan was the first person to recognize the hydrogeologic importance of a series of deep structural basins that are the defining components of the Rio Grande rift (RGR) tectonic province (Hawley, 1978; Chapin and Cather, 1994). This area includes parts of the Southern Rocky Mountain, and Basin and Range physiographic provinces (Hawley 1986). From a hydrogeologic standpoint, Bryan's (1938) important contributions include his observations that:

> 1. The main body of sedimentary deposits of the Rio Grande depression, from the north end of the San Luis valley to and beyond El Paso, is considered to be the same general age and to belong to the Santa Fe formation (p. 205).
>
> 2. In general, the basins appear to have been elongated into ovals and to be divisible into two major types ... basins with a through-flowing river and basins with enclosed drainage (p. 205).
>
> 3. [Rio Grande depression basins] differ from other basins [in the Basin and Range province] principally in being strung like beads on a string along the line of the Rio Grande (p. 221).

Bryan's (1938) observations reflect not only his own work in the northern Rio Grande basin starting in 1909, but also the ongoing studies of his students (e.g., Bryan and McCann 1937, 1938; Denny 1940; Stearns 1953; Upson 1939; and Wright 1946) as well as previous hydrogeologic work in the region by Lee (1907); Siebenthal (1910); Meinzer (1911); Meinzer and Hare (1915); and Darton (1916). Reports by Lee (1907) and Siebenthal (1910), respectively, on water resources of the Rio Grande and San Luis "Valleys" cover much of the region described in this paper. Lee also presented an early conceptual model of the evolution of the Rio Grande fluvial system, and he emphasized the potential for building a large dam at the Elephant Butte site for irrigation water storage. Based on observations in Mexico and the American Southwest, Tolman (1909, 1937) also made a major contribution in better definition of the fundamental hydrogeologic distinction between depositional systems in aggrading intermontane basins with topographic closure (*bolsons*) and those that are open in terms of both surface and subsurface flow (*semi-bolsons*).

Figures 2 and 3 illustrate the basic conceptual models, which were initially developed by Bryan (1938) and Tolman (1937), for hydrogeologic systems and hydraulic regimes in groundwater reservoirs that occur in Upper Cenozoic basin (*bolson*) fills of western North America. Figure 2 is adapted from Bryan (1938, Figures 51 and 52), and it clearly demonstrates that a basic understanding of the integrated groundwater and surface-water flow system in basins of the "Rio Grande depression" already existed at the time (1937-1939) of final acceptance of Rio Grande Compact provisions.

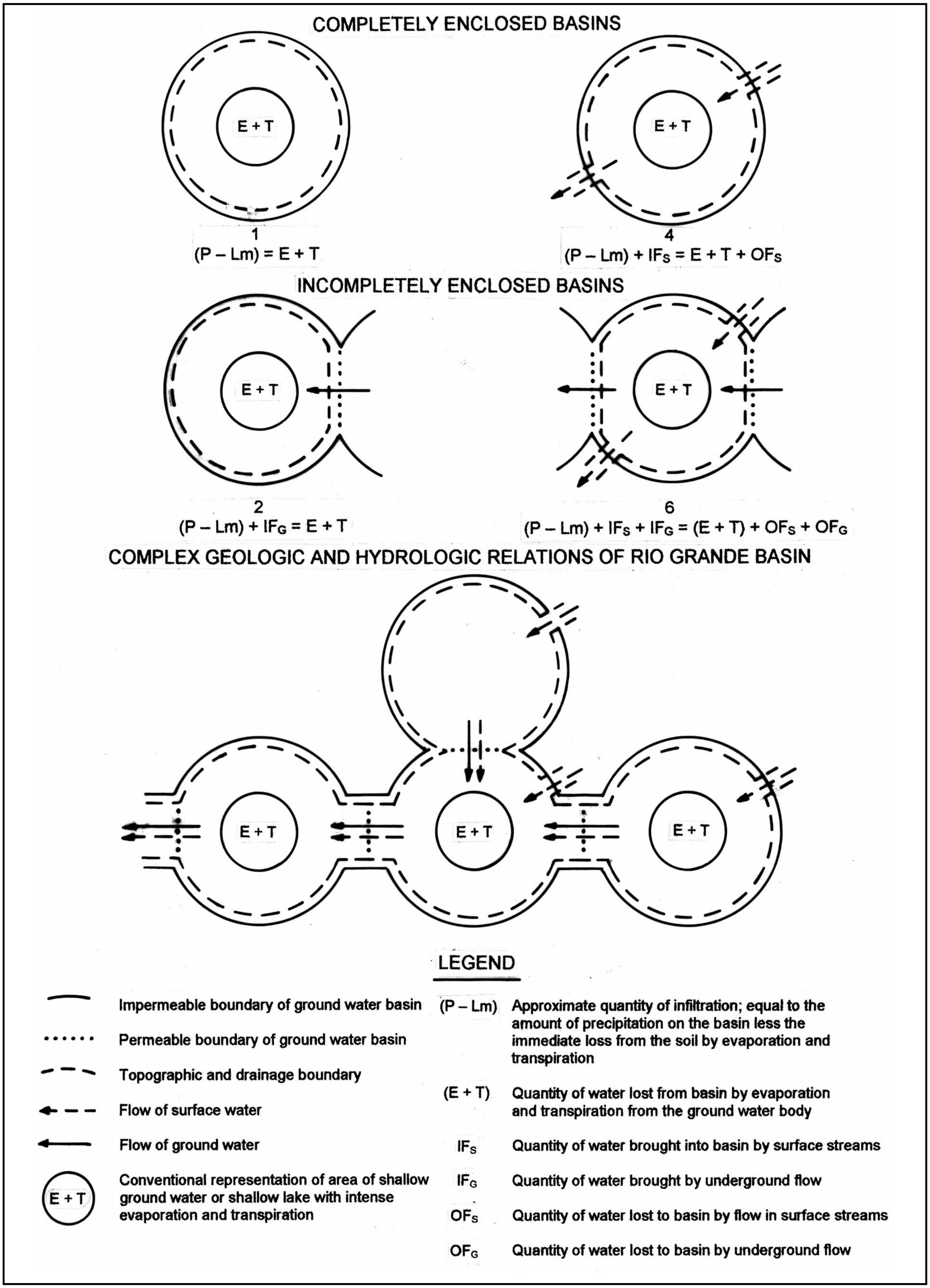


Figure 2. Kirk Bryan's conceptual models of hydraulic regimes in groundwater reservoirs of the "Rio Grande depression." Modified from Bryan (1938, Figures 51 and 52).

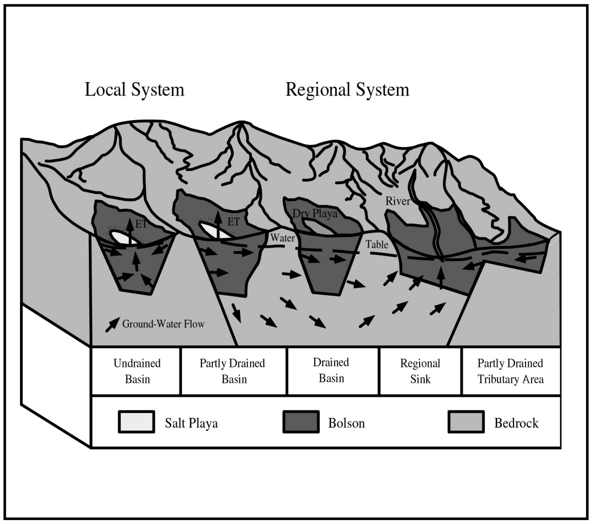


Figure 3. Conceptual hydrogeologic model showing *undrained* basins, *partly drained* basins, *drained* basins, and regional sinks (modified from Eakin et al. 1976; Hibbs et al. 1998). *Phreatic playas* are restricted to *undrained* and *partly drained* basins; and *vadose* conditions exist in "dry playa" areas.

Figure 3 illustrates the Bryan-Tolman conceptual model in a more general hydrogeologic sense for the entire Basin and Range province, and it incorporates subsequent work in the Great Basin section (e.g., Mifflin 1968, 1988; Eakin et al. 1976), and in the Trans-Pecos Texas and Chihuahua bolson region (Hibbs et al. 1998). The topographic terms *closed* and *open* are here used only in reference to the surface flow into, through, and from intermontane basins, whereas the terms *undrained*, *partly drained*, and *drained* designate classes of groundwater flow involving intrabasin and/or interbasin movement. *Phreatic* and *vadose*, respectively, indicate saturated and unsaturated subsurface conditions. *Phreatic playas* (with springs and seeps) are restricted to floors of *closed* basins (*bolsons*) that are *undrained* or *partly drained*, and *vadose playas* occur in both *closed* and *open*, *drained* basins. In the Rio Grande rift study region, as well as in most other desert basins of western North America, the intermediate basin class referred to as *partly drained* is probably the major groundwater-flow regime. Few intermontane basins (*bolsons* and *semibolsons*) are truly *undrained* in terms of groundwater discharge, whether or not they are *closed* or *open* in terms of surface flow.

Under predevelopment conditions, groundwater discharge in the region occurred mainly through subsurface leakage from one basin system into another, discharge into the gaining reaches of perennial or intermittent streams, discharge from springs, or by evapotranspiration from *phreatic playas* and cienegas (valley-floor wetlands). Most recharge to basin-fill aquifers occurs by two mechanisms, (1) "mountain front," where some precipitation falling on bedrock highlands contributes to the groundwater reservoir along basin margins (Figure 4); and (2) "tributary," where the reservoir is replenished and along losing reaches of larger intrabasin streams (Hearne and Dewey 1988; Anderholm 1994; Kernodle 1992; Wasiolek 1995). The upland networks of major stream valleys in the Sangre de Cristo, San Juan, and Jemez Mountains of southern Colorado and northern New Mexico are the primary source areas for recharge of basin-fill aquifers in the RGR region. Secondary contributors to these groundwater reservoirs are the few high and massive mountain ranges that form isolated highlands bordering individual basin units. Recharge estimates in this paper are based on the assumption that (1) less than 5% of average annual precipitation contributes to recharge, and (2) this contribution is distributed very unevenly over higher watersheds and in major stream valleys.

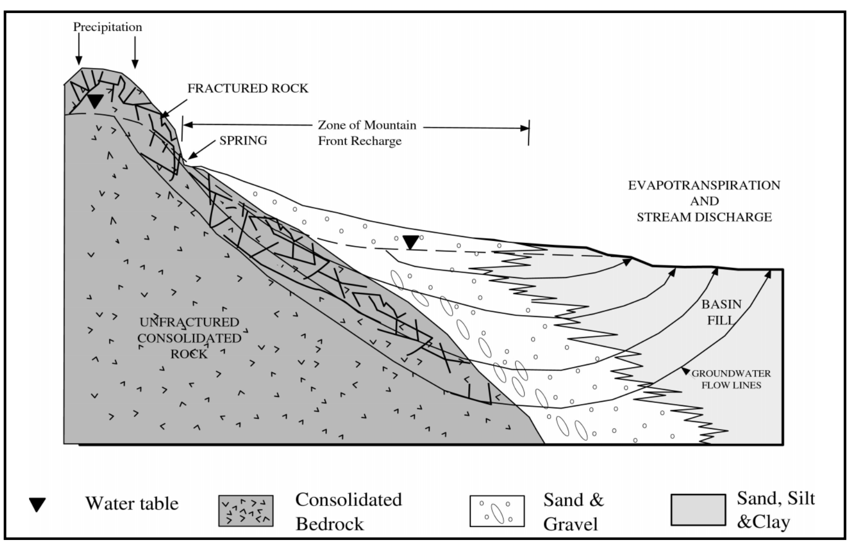


Figure 4. Two-dimensional conceptual model of a groundwater recharge system in a Basin and Range by hydrogeologic setting (from Wasiolek 1995, modified from Feth 1964, and Mifflin 1968).

DEVELOPMENT OF HYDROGEOLOGIC AND GEOHYDROLOGIC CONCEPTS SINCE 1945

The major scientific and technological breakthroughs during and immediately after World War II introduced a new era of hydrogeologic system characterization that continues today. These breakthroughs included development of modern geophysical-survey and deep drilling methods, and advances in geochemistry. Characterization of basin-fill aquifers in the San Luis Basin by Powell (1958) and Emery and others (1971) is representative of work in that area prior to 1975. Hydrogeologic mapping and related hydrologic and geologic investigations in basins of north-central RGR and central New Mexico is exemplified by the work of Bjorklund and Maxwell (1961), Titus (1961), Theis and Conover (1962), Spiegel (1962), Spiegel and Baldwin (1963), Griggs (1964), Cushman (1965), Weir (1965), Lambert, (1968), and Kelley (1977). Concurrent studies in the southern part of the region by the U.S. Geological Survey, Texas Water Commission, City of El Paso, U.S. Soil Conservation Service, and New Mexico State University combined detailed mapping and innovations in subsurface methods using borehole geophysics, standard sample logging, and aquifer geochemistry (e.g., Knowles and Kennedy 1958; Leggat et al. 1962; Cliett 1969; Hawley et al. 1969; King et al. 1971; Wilson et al. 1981).

Recent and future hydrogeologic mapping has been and will be characterized by the increased availability of high quality geophysical and geochemical data, and deep borehole sample and core logs. This era is dominated by the opportunities generated by the exponentially increasing power of computers, and evolution of numerical modeling and GIS technology. In the Rio Grande Basin region, as elsewhere, the bridge between the early 20th Century conceptual world and the present will continue to be *hydrogeologic ground truth*. Both surface and underground views of geohydrologic systems must now be expressed in units that modelers of groundwater-flow systems can understand and computers can process. Rapid improvements in the understanding of subsurface geophysical and geochemical systems, lithofacies assemblages, structural boundary conditions, and definition of hydrostratigraphic units (Seaber 1988) now allow modelers to join forces effectively with hydrogeologists, geophysicists and geochemists in meeting the incredible water-resource challenges that face Third Millennium society in this and other arid and semiarid regions.

Current investigations that directly relate to hydrogeologic characterization and groundwater-flow model development in the northern Rio Grande Basin are illustrated in the following sections. Recommended publications include: Balleau (1999), Bartolino (1999), Bedinger and others (1989), Hawley (1993), Haneberg (1995, 1998), Heywood (1995), Hansen and Gorbach (1997), Hibbs (1999), Hibbs and others (1997, 1998), Slate (1998), Lewis and West (1995), Tiedeman and others (1998), and West (1996).

CONCEPTUAL HYDROGEOLOGIC-FRAMEWORK MODEL

The hydrogeologic framework of basin-fill aquifers in the RGR region, with special emphasis on features related to environmental concerns, is described here in terms of three basic conceptual building blocks: lithofacies assemblages (LFAs), hydrostratigraphic units (HSUs), and structural-boundary conditions. A conceptual hydrogeologic model of an interconnected shallow valley-fill/basin-fill and deep-basin aquifer system was initially developed for use in groundwater-flow models of the Mesilla and Albuquerque basins (Peterson et al. 1984; Kernodle 1992, 1996, 1998; Hawley and Lozinsky 1992; Frenzel and Kaehler 1992; Hawley and Haase 1992; Thorn et al. 1993; Hawley et al. 1995; Kernodle et al. 1995). However, basic design of the conceptual model is flexible enough to allow it to be modified for use in other basins of the Rio Grande rift and adjacent parts of the southeastern Basin and Range province (Hawley et al. 2000).

The model is simply a qualitative description (graphical, numerical, and verbal) of how a given geohydrologic system is influenced by (1) bedrock-boundary conditions, (2) internal-basin structure, and (3) the lithofacies and mineralogical composition of various basin-fill stratigraphic units. It provides a mechanism for systematically organizing a large amount of relevant hydrogeologic information of widely varying quality and scale (from very general drillers observations to detailed bore-hole, geophysical and geochemical data). Model elements can then be graphically displayed in a combined map and cross-section GIS format so that basic information and inferences on geohydrologic attributes (e.g., hydraulic conductivity, transmissivity, anisotropy, and general spatial distribution patterns) may be transferred to basin-scale, three-dimensional numerical models of groundwater-flow systems. As emphasized by McCord and Stephens (1999), this scheme of data presentation and interpretation is generally not designed for groundwater-flow models at a site-specific scale.

Lithofacies Assemblages

Lithofacies assemblages (LFAs) are the basic building blocks of the hydrogeologic model (Figure 5, Table 1), and they are the primary components of the hydrostratigraphic units (HSUs) discussed below. These sedimentary facies classes are defined primarily on the basis of grain-size distribution, mineralogy, sedimentary structures and degree of post-depositional alteration, and they are grouped according to inferred environments of deposition. LFAs have distinctive geophysical, geochemical and hydrologic attributes, and they provide a mechanism for showing distribution patterns of major aquifers and confining units in hydrogeologic cross sections. Basin and valley fills are here subdivided into thirteen major assemblages that are ranked in decreasing order of aquifer potential (Tables 1 to 3; LFAs ***1-10***, ***a-c***). Figure 5 is a schematic illustration of the distribution pattern LFAs observed in the Rio Grande rift and southeastern Basin and Range Region. Lithofacies properties that influence groundwater flow and production potential in this region are summarized in Tables 2 and 3. Note that *Roman numeral* notations (I-X) originally used in previous hydrogeologic framework models (Hawley et al. 1995) have been changed to *Arabic* style in order to facilitate the development of alpha-numeric attribute codes that can be used in both conceptual and numerical models of basin-fill aquifer systems.

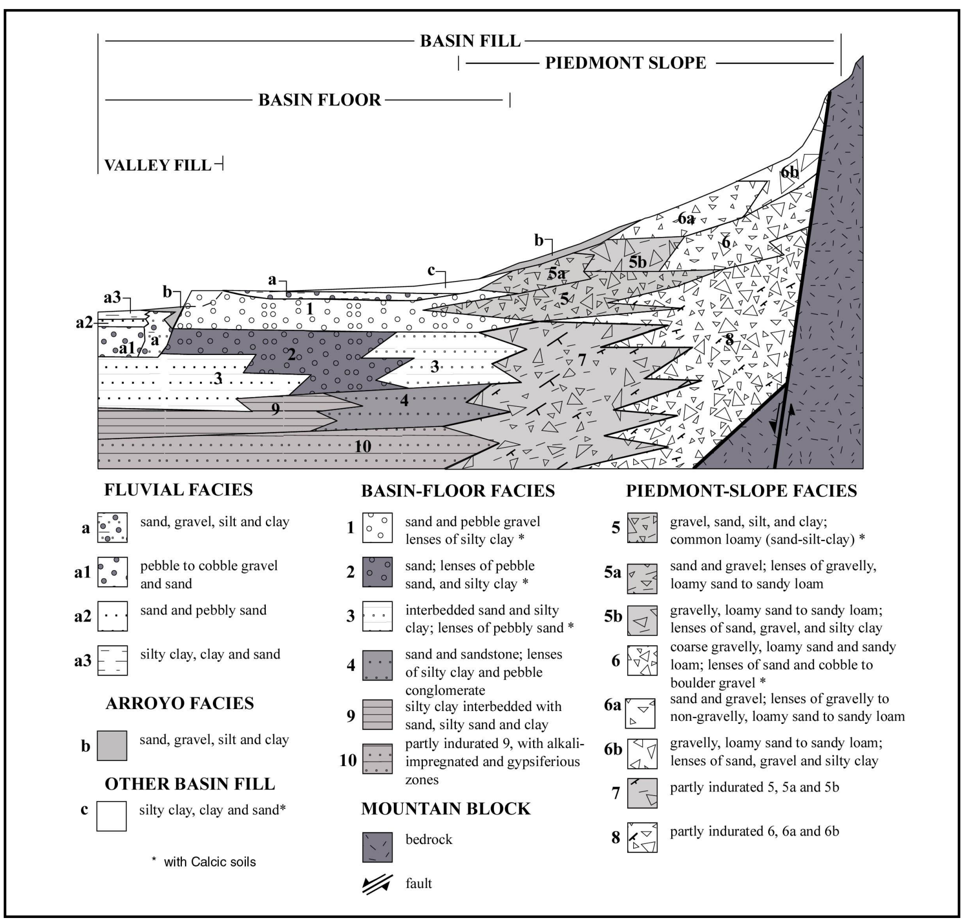


Figure 5. Schematic distribution pattern of major lithofacies assemblages (Tables 1-3) in basin-fill deposits of the Rio Grande rift region (from Hawley et al. 2000).

Table 1. Summary of lithofacies-assemblage depositional settings and dominant textures for Santa Fe Group (***1-10***) and Post-Santa Fe (***a,b,c***) basin and valley fills (modified from Hawley and Haase 1992, Table III-2)

Lithofacies		Dominant depositional settings and process	Dominant textural classes
1		Basin-floor fluvial plain	Sand and pebble gravel, lenses of silty clay
2		Basin-floor fluvial, locally eolian	Sand; lenses of pebble sand, and silty clay
3		Basin-floor, fluvial-overbank, fluvial-deltaic and playa-lake; eolian	Interbedded sand and silty clay; lenses of pebbly sand
4		Eolian, basin-floor alluvial	Sand and sandstone; lenses of silty sand to clay
5		Distal to medial piedmont-slope, alluvial fan	Gravel, sand, silt, and clay; common loamy (sand-silt-clay)
	5a	Distal to medial piedmont-slope, alluvial fan; associated with large watersheds; alluvial-fan distributary-channel primary, sheet-flood and debris-flow, secondary	Sand and gravel; lenses of gravelly, loamy sand to sandy loam
	5b	Distal to medial piedmont-slope, alluvial-fan; associated with small steep watersheds; debris-flow sheet-flood, and distributary-channel	Gravelly, loamy sand to sandy loam; lenses of sand, gravel, and silty clay
6		Proximal to medial piedmont-slope, alluvial-fan	Coarse gravelly, loamy sand and sandy loam; lenses of sand and cobble to boulder gravel
	6a	Like *5a*	Sand and gravel; lenses of gravelly to non-gravelly, loamy sand to sandy loam
	6b	Like *5b*	Gravelly, loamy sand to sandy loam; lenses of sand, gravel, and silty clay
7		Like *5*	Partly indurated *5*
8		Like *6*	Partly indurated *6*
9		Basin-floor—alluvial flat, playa, lake, and fluvial-lacustrine; distal-piedmont alluvial	Silty clay interbedded with sand, silty sand and clay
10		Like *9*, with evaporite processes (paleophreatic)	Partly indurated *9*, with gypsiferous and alkali-impregnated zones
a		River-valley, fluvial	Sand, gravel, silt and clay
	a1	Basal channel	Pebble to cobble gravel and sand (like *1*)
	a2	Braided plain, channel	Sand and pebbly sand (like *2*)
	a3	Overbank, meander- belt oxbow	Silty clay, clay, and sand (like *3*)
b		Arroyo channel, and valley-border alluvial-fan	Sand, gravel, silt, and clay (like *5*)
c		Basin floor, alluvial flat, cienega, playa, and fluvial-fan to lacustrine plain	Silty clay, clay and sand (like *3,5,* and *9*)

Table 2. Summary of properties that influence groundwater production potential of Santa Fe Group lithofacies assemblages (modified from Haase and Lozinsky 1992) [>, greater than; <, less than]

Lithofacies	Ratio of sand plus gravel to silt plus clay[1]	Bedding thickness (meters)	Bedding configuration[2]	Bedding continuity (meters)[3]	Bedding connectivity[4]	Hydraulic conductivity (K)[5]	Groundwater production potential
1	High	> 1.5	Elongate to planar	> 300	High	High	High
2	High to moderate	> 1.5	Elongate to planar	> 300	High to moderate	High to moderate	High to moderate
3	Moderate	> 1.5	Planar	150 to 300	Moderate to high	Moderate	Moderate
4	Moderate to low*	> 1.5	Planar to elongate	30 to 150	Moderate to high	Moderate	Moderate
5	Moderate to high	0.3 to 1.5	Elongate to lobate	30 to 150	Moderate	Moderate to low	Moderate to low
5a	High to moderate	0.3 to 1.5	Elongate to lobate	30 to 150	Moderate	Moderate	Moderate
5b	Moderate	0.3 to 1.5	Lobate	30 to 150	Moderate to low	Moderate to low	Moderate to low
6	Moderate to low	0.3 to 1.5	Lobate to elongate	30 to 150	Moderate to low	Moderate to low	Low to moderate
6a	Moderate	0.3 to 1.5	Lobate to elongate	30 to 150	Moderate	Moderate to low	Moderate to low
6b	Moderate to low	0.3 to 1.5	Lobate	< 30	Low to moderate	Low to moderate	Low
7	Moderate *	0.3 to 1.5	Elongate to lobate	30 to 150	Moderate	Low	Low
8	Moderate to low *	> 1.5	Lobate	< 30	Low to moderate	Low	Low
9	Low	> 3.0	Planar	> 150	Low	Very low	Very low
10	Low*	> 3.0	Planar	> 150	Low	Very low	Very low

[1] High >2; moderate 0.5-2; low < 0.5
[2] Elongate (length to width ratios > 5); planar (length to width ratios 1-5); lobate (asymmetrical or incomplete planar beds).
[3] Measure of the lateral extent of an individual bed of given thickness and configuration.
[4] Estimate of the ease with which groundwater can flow between individual beds within a particular lithofacies. Generally, high sand + gravel/silt + clay ratios, thick beds, and high bedding continuity favor high bedding connectivity. All other parameters being held equal, the greater the bedding connectivity, the greater the groundwater production potential of a sedimentary unit (Hawley and Haase 1992, VI).
[5] High 10 to 30 m/day; moderate, 1 to 10 m/day; low, < 1 m/day; very low, < 0.1 m/day.

Table 3. Summary of properties that influence groundwater production potential of Post - Santa Fe Group lithofacies assemblages [>, greater than; <, less than]

Lithofacies	Ratio of sand plus gravel to silt plus clay[1]	Bedding thickness (meters)[3]	Bedding configuration[2]	Bedding continuity (meters)[3]	Bedding connectivity[4]	Hydraulic conductivity (K)[5]	Groundwater production potential
a	High to moderate	> 1.5	Elongate to planar	> 300	High to moderate	High to moderate	High to moderate
a1	High	> 1.5	Elongate to planar	> 300	High	High	High
a2	High to moderate	> 1.5	Planar to elongate	150 to 300	Moderate to high	Moderate	Moderate
a3	Moderate to low	> 1.5	Planar to elongate	30 to 150	Moderate to high	Moderate to low	Moderate to low
b	Moderate to low	0.3 to 1.5	Elongate to lobate	<100	Moderate	Moderate to low	Moderate to low
c	Low to moderate	0.3 to 1.5	Elongate to lobate	30 to 150	Low	Low	Low

[1] High >2; moderate 0.5-2; low < 0.5
[2] Elongate (length to width ratios > 5); planar (length to width ratios 1-5); lobate (asymmetrical or incomplete planar beds).
[3] Measure of the lateral extent of an individual bed of given thickness and configuration.
[4] Estimate of the ease with which groundwater can flow between individual beds within a particular lithofacies. Generally, high sand + gravel/silt + clay ratios, thick beds, and high bedding continuity favor high bedding connectivity. All other parameters being held equal, the greater the bedding connectivity, the greater the groundwater production potential of a sedimentary unit (Hawley and Haase 1992, VI).
[5] High 10 to 30 m/day; moderate, 1 to 10 m/day; low, < 1 m/day; very low, < 0.1 m/day.

Hydrostratigraphic Units

Most intermontane-basin fills in the New Mexico region have been subdivided into two major lithostratigraphic units (Figure 6), the Santa Fe Group in Rio Grande rift basins (e.g., Hawley 1978; Chapin and Cather 1994) and the Gila Group in basins of the Mexican Highland and Datil-Mogollon sections to the west (Hawley et al. 2000). In addition, a clear distinction has rarely been made between deposits simply classed as "bolson" or "basin" fill and contiguous (formal and informal) subdivisions of the Santa Fe and Gila groups. As a first step in organizing available information on basin fill stratigraphy that has a close relationship with aquifer characteristics, a provisional hydrostratigraphic classification system (Seaber 1988) has been developed. It follows guidelines used successfully in the Albuquerque and Mesilla basins (Hawley and Lozinsky 1992; Hawley et al. 1995) and in adjacent "Southwest Alluvial Basins" as defined by Wilkins (1986, 1998).

Hydrostratigraphic units defined in the RGR region are mappable bodies of basin fill and valley fill that are grouped on the basis of origin and position in both lithostratigraphic and chronostratigraphic sequences. The informal ***upper***, ***middle***, and ***lower Santa Fe*** hydrostratigraphic units (HSUs: ***USF, MSF, LSF***) comprise the major basin-fill aquifer zones, and they correspond roughly to the (formal and informal) upper, middle, and lower lithostratigraphic subdivisions of the Santa Fe Groups used in local and regional geologic mapping (Figure 6). Dominant lithofacies assemblages in the ***upper Santa Fe*** HSU are *LFAs* ***1-3, 5 and 6***. The ***middle Santa Fe*** HSU is characterized by *LFAs* ***3, 4, 7-9***, and the ***lower Santa Fe*** commonly comprises *LFAs* ***9, 7-10***. Basin-floor facies assemblages ***3*** and ***9*** are commonly present throughout the Santa Fe Group section in closed-basin (bolson) areas.

The other major hydrostratigraphic units comprise channel and floodplain deposits of the Rio Grande (***RG***) and its major tributaries such as the Rio Chama and Rio Puerco. These valley fills of Late Quaternary age form the upper part of the region's most productive shallow-aquifer system (*LFA**a***). Surficial lake and playa deposits, fills of larger arroyo valleys, and piedmont-slope alluvium are primarily in the *vadose* zone. However, they locally form important groundwater discharge and recharge sites. Historical *phreatic* conditions exist, or have recently existed, in a few playa remnants of large pluvial lakes of Late Quaternary age (Hawley 1993). Notable examples are "gypsum or alkali flats" in the Tularosa, Jornada del Muerto and Los Muertos basins, which are contiguous to, but outside the area discussed in this paper.

Bedrock and Structural Boundary Components

Structural and bedrock features that influence aquifer composition and behavior include basin-boundary mountain uplifts, bedrock units beneath the basin-fill, fault zones and flexures within and at the edges of basins, and igneous-intrusive and extrusive rocks that penetrate or are interbedded with basin fill. Tectonic evolution of the fault-block basins and ranges of the study area (many with a half-graben structure and accommodation-zone terminations) has had a profound effect on the distribution of lithofacies assemblages and the timing and style of emplacement of all major hydrostratigraphic units (Figs. 5 and 6). Discussion of this topic is beyond the scope of this paper, however, the reader is referred to pertinent reviews in Collins and Raney (1991), Keller and Cather (1994), Hawley and others (1995), Bauer and others (1995), Goff and others (1996), Mack and others (1997, 1998), Faulds and Varga (1998), Haneberg (1998), and Pazzaglia and Lucas (1999).

HYDROGEOLOGIC FRAMEWORK OF REPRESENTATIVE RGR BASINS

Figures 7, 8, and 9 are schematic hydrogeologic cross-sections that illustrate the basic structural framework and distribution patterns of major hydrostratigraphic units, respectively, in the central parts of the San Luis, Albuquerque, and Mesilla basins of the Rio Grande rift structural province. In addition to parts of the Española Basin near Los Alamos and the Hueco Bolson near El Paso (Purtymun 1995; Cliett and Hawley 1996), these are the only areas where high-quality borehole geophysical and sample logs, and a variety of other geophysical and geochemical survey data are available. It is important to note that much of this information is related to deep-

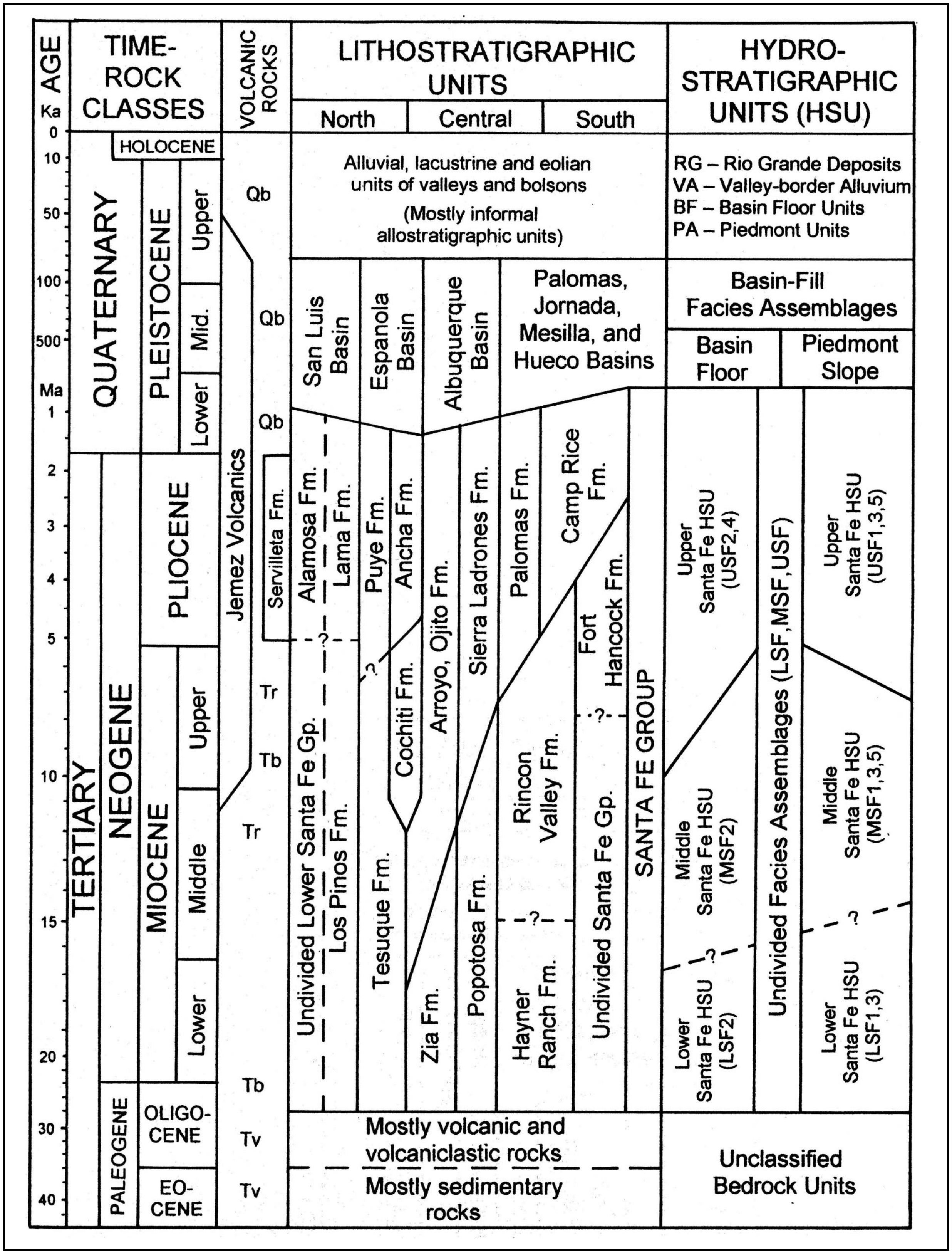


Figure 6. Regional summary and correlation of major lithostratigraphic and basin-fill hydrostratigraphic units (HSUs) in the Rio Grande rift region. Volcanic-rock symbols: Qb-Quaternary basalt; Tb and Tr- Tertiary mafic and silicic volcanics, respectively; Tv-primarily intermediate and silicic volcanics.

basin exploration for hydrocarbon and geothermal resources. Geologic mapping and geochronologic studies throughout the RGR region demonstrate the continuity and correlation of major lithostratigraphic and informal hydrostratigraphic units (Figure 6) that were originally recognized by Kirk Bryan (cf. Hawley 1978; Chapin and Cather 1994).

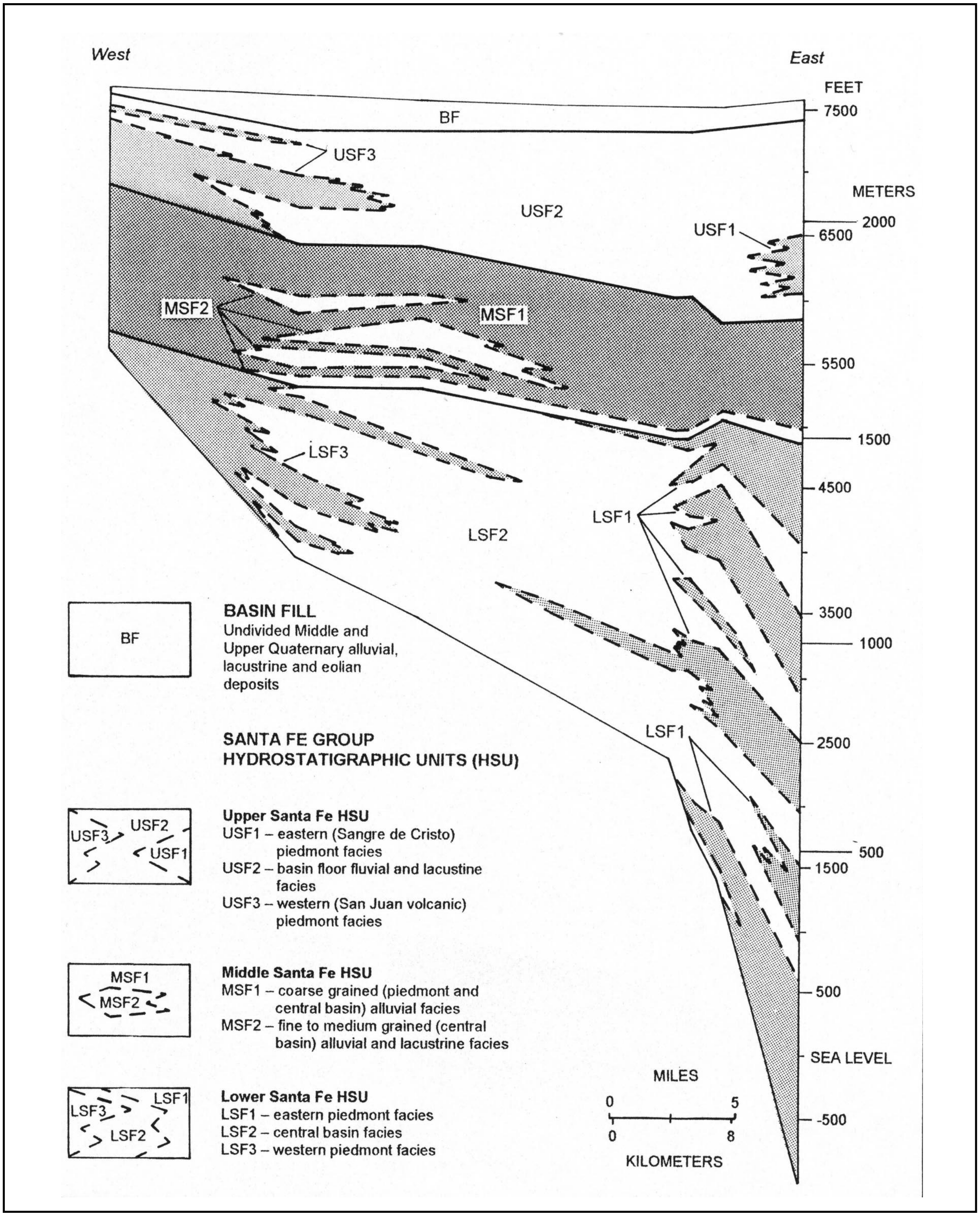


Figure 7. Schematic hydrogeologic cross section of the Alamosa subbasin of the San Luis structural basin near the Alamosa-Saguache County Line. Modified from Brister and Gries (1994, Figure 3). The base of the section is the top of an ash-flow tuff unit of late Oligocene age.

Figure 7 is a hydrogeologic section, adapted from Brister and Gries, 1994, that documents the half-graben structure and relatively narrow width of the Alamosa subbasin of the San Luis Valley in the area west of Great Sand Dunes National Monument. It is the only RGR basin discussed in this paper that is both topographically *closed* and internally *drained* (cf. Figures 2 and 3). Brister and Gries (1994) include the Alamosa Formation of Siebenthal (1910) in their Upper Santa Fe Group lithostratigraphic unit, and their "Lower" Santa Fe Group correlates with the Santa Fe Formation of previous workers (Powell 1958; Emery et al. 1971). In this paper the gravelly upper part of the "lower" Santa Fe section is informally defined as the ***middle Santa Fe*** HSU, which comprises two major facies groups, piedmont slope (**MSF1** and **3**) and basin floor (**MSF2**). Note that the Hearne and Dewey (1988) model of the San Luis Basin only covers the upper 3,200 feet of saturated basin fill, and it, therefore, is primarily restricted to the ***upper*** and ***middle Santa Fe*** HSUs.

The Brister-Gries study utilized information from cross-basin seismic-survey lines as well as sample and geophysical logs from deep boreholes. As shown in Figure 7, the Santa Fe Group is locally as much as 9,500 ft. thick near the eastern edge of the half-graben (hanging-wall) block. This study also demonstrates that Santa Fe Group basin fill is relatively thin in the western half of the Alamosa subbasin, and that most basin deposits heretofore correlated with the Santa Fe Group by hydrogeologists are actually Lower to Middle Cenozoic sedimentary and volcanic rocks that predate RGR development. This suggests that model estimates of "Santa Fe Formation" hydraulic conductivity made by Hearne and Dewey (1988) may be much too high in large parts of the western Alamosa subbasin (cf. Table 4).

The east-central part of the Albuquerque Basin includes the deepest known segment of the RGR structural depression. Basin fill in the area near Isleta Pueblo locally exceeds 14,500 ft. (Lozinsky 1994; Hawley et al. 1995, Fig. 3). Figure 8 is a schematic hydrogeologic section of

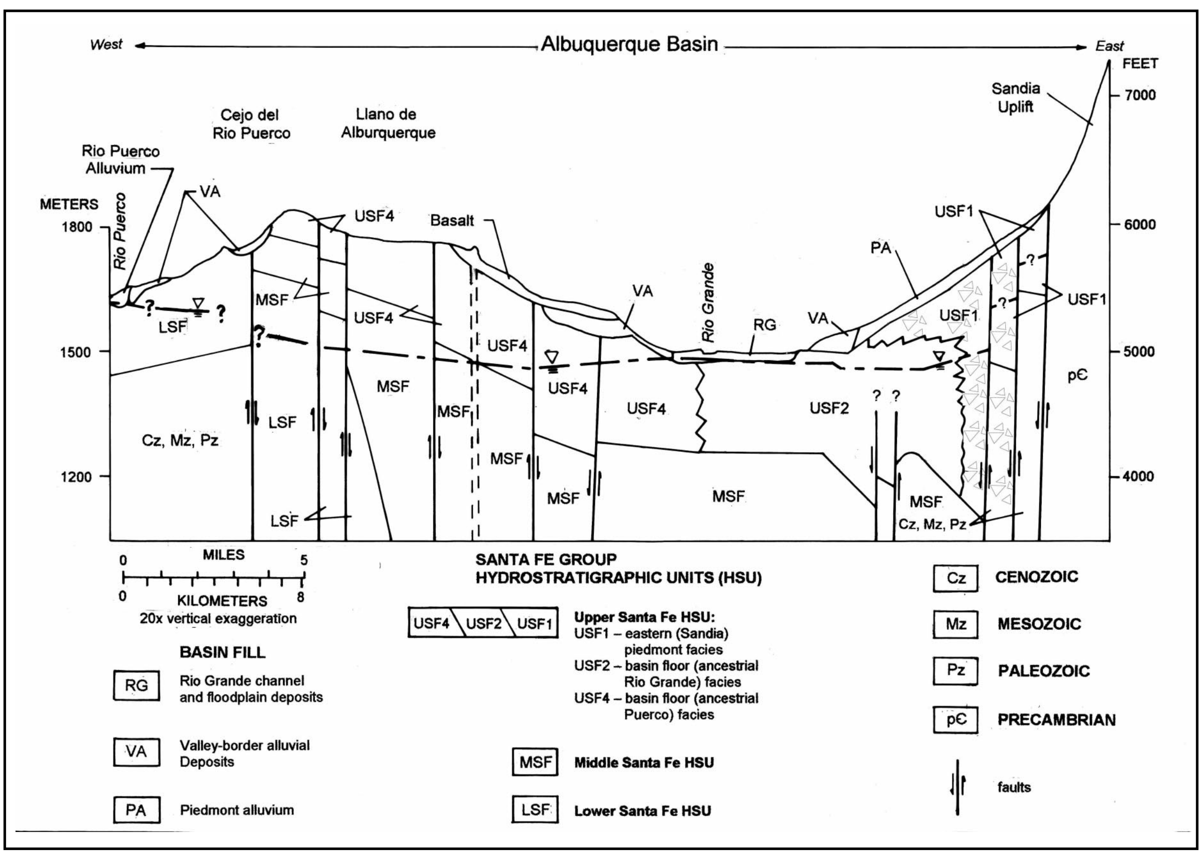


Figure 8. Schematic hydrogeologic cross section of the northern Albuquerque Basin about 3 miles south of the Bernalillo-Sandoval County Line. Modified from Hawley and others (1995, Fig. 4).

the central basin area between Albuquerque and Rio Rancho. Its base is at mean sea level, which is about 3,200 feet below the active layers of the groundwater-flow model discussed in the concluding section of this report. As in the Alamosa subbasin, the major aquifer system utilized in the Albuquerque-Rio Rancho metropolitan area comprises the ***upper*** and ***middle Santa Fe*** Hydrostratigraphic Units (HSUs: ***USF*** and ***MSF***) as originally defined in Hawley and Haase (1992) and Hawley and others (1995). However, the Albuquerque Basin is typical of all RGR basins in New Mexico in that the Rio Grande Valley system is (1) deeply entrenched and (2) contains a hydrologically very significant inner valley fill of Late Quaternary River deposits (HSU-***RG***). The major aquifer is the ancestral Rio Grande (fluvial) facies in the ***upper*** and *upper part of the* ***middle Santa Fe*** HSUs (primary LFAs ***1-3***). The trough in the water table, schematically shown beneath the Llano de Alburquerque on Figure 8, is here interpreted as a feature bounded by major fault zones that restrict groundwater inflow from adjacent parts of the Rio Grande and Rio Puerco Valleys.

The Middle Rio Grande Basin between Cochiti Dam and Elephant Butte Reservoir is the major area of ongoing geologic, geophysical, hydrologic, and hydrogeochemical investigations in the entire RGR region (Haneberg 1995, 1998; Hansen and Gorbach 1997; Slate 1998; Bartolino 1999; Pazzaglia and Lucas 1999). There will clearly be some revisions in the conceptual hydrogeologic models of this complex basin system as the result of this work. Basic model interpretations (Hawley et al. 1995, and Kernodle et al. 1995), however, still appear to be validated by current investigations.

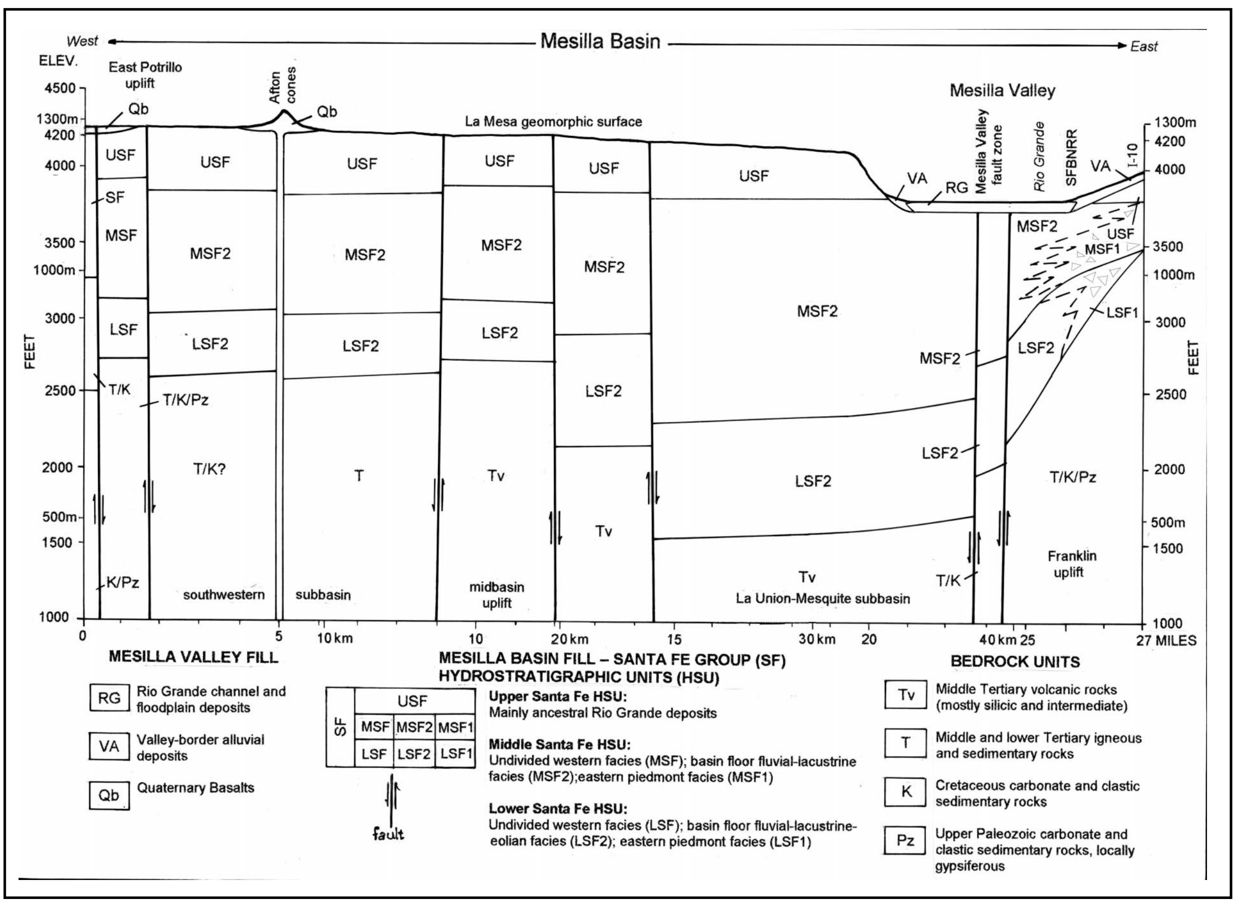


Figure 9. Schematic hydrogeologic cross section of the central Mesilla Basin (Bolson) near the 32nd Parallel in Dona Aña County, New Mexico and northwestern El Paso County, Texas. Modified from Hawley and Lozinsky (1992, Plate 16C).

Figure 9 is a schematic hydrogeologic cross-section of the south-central Mesilla Basin, which is approximately aligned along the 32nd Parallel. The section is based on (1) geologic mapping, primarily by Seager and others (1987), and (2) subsurface geophysical, hydrogeologic, and water-quality information collected by Hawley and Lozinsky (1992). Major contributors to the hydrogeologic interpretations shown in Figure 9 include Leggat and others (1962), Cliett (1969), Hawley and others (1969), King and others (1971), Gile and others (1981), Wilson and others (1981), Peterson and others (1984), Seager and others (1987), and Ken Stevens (USGS-WRD unpublished).

The distinctive feature of the rift-basin-fill sequence in the Mesilla Basin is that it is relatively thin in comparison to the Albuquerque and San Luis basins, with a saturated thickness of no more than 3,000 ft. As in basin areas to the north and the Hueco Bolson to the southeast, the most productive and thickest aquifers are ancestral Rio Grande fluvial deposits (LFAs ***1*** and ***2***) of the ***upper Santa Fe*** HSU (***USF2***). However, these units are only saturated in the northeastern part of the basin near Las Cruces (Hawley and Lozinsky 1992). In the southern and western part of the basin the ***upper Santa Fe*** HSU is entirely in the vadose zone, and the most productive aquifers comprise the ***middle*** and ***lower Santa Fe*** HSUs (***MSF2/LSF2****: LFAs* ***3*** and ***4***). A particularly productive aquifer is the "deep aquifer"of Leggat and others (1962), which underlies the southern Mesilla Valley in the Anthony-Canutillo area (HSU ***LSF 2***, Figure 9). This unit includes a distinctive eolian sand facies (*LFA* ***4***) that intertongues mountainward with piedmont fanglomerates (*LFAs* ***7-8)***, and basinward with basin-floor facies assemblages *LFAs* (***3, 9*** and ***10***?). The latter facies are here interpreted as fluvial-deltaic-playa/lake deposits (Table 1, Figure 5).

GROUNDWATER FLOW MODELS

Introduction

Groundwater-flow models are a numerical way (just one) to merge hydrogeology and geohydrology to produce a link between cause, process, and effect. The intention is an attempt to predict the future or to test the validity of the conceptual model of the groundwater system. In so doing, the usual approach is to replicate as closely as possible every internal condition and outside influence that can affect groundwater flow levels (heads). Even so, the title of Knoikow and Bredehoeft's 1992 article says it all: "Ground-water models cannot be validated." Modeling is an ever-evolving and ever-learning iterative process as more knowledge of the system is gained and incorporated. Improvements in science and technology will always be necessary for proper utilization of this new knowledge base.

Models of groundwater flow in the Rio Grande Basin aquifer system first need to be examined in terms of the hydrogeologic constraints placed on flow regimes by structural-boundary, lithofacies, and hydrostratigraphic conditions that are either well documented or reasonably inferred (Table 4). Kernodle's (1992) critique of "U.S. Geological Survey Ground-Water-Flow Models of Basin-Fill Aquifers in the Southwestern Alluvial basins region" sets the tone for this paper. "As a rule identifiable geologic features that affect groundwater-flow paths, including geologic structure and lithology of beds, need to be represented in the model (p.65)"; and major categories of geohydrologic boundaries in alluvial basins include: "1) internal boundaries that alter flow paths, including small-permeability beds, fissure-flow volcanics and faults; 2) recharge boundaries, primarily around the perimeter of basins (mountain-front recharge), and along the channels of intermittent streams, arroyos, and washes (tributary recharge); [and] 3) recharge and discharge boundaries associated with semipermanent surface-water systems in the flood plains of major streams ... (p. 66)". Finally, "although two-dimensional models may successfully reproduce selected responses of the aquifer, they fail to accurately mimic the function of the system (p. 59)". In comparison ... three-dimensional models more accurately portray the flow system in basin-fill [aquifers] by simulating the vertical component of flow. However, the worth of the model is still a function of the accuracy of the hydrologist's concept of the workings of the aquifer system (p. 59)."

Table 4.--Summary of modeled aquifer properties for documented U.S. Geological Survey three-dimensional groundwater-flow models in the Rio Grande basin region of Colorado, New Mexico and West Texas (modified from Kernodle, 1992)

Basin	San Luis[1]	Española[2]	Albuquerque[3]	Mesilla[4]	Hueco[5]
Layers in model	7	22	11	5	2
Total depth (ft.) in model	3,200	4,000±	1,730	3,450	3,000±
Thickness of top layer (ft)	0-150	300±	20	200±	200
Horizontal hydraulic conductivity					
Alluvium	NA	NA	40	70/140	20
Santa Fe Group		1.0		3-22	17/134
Upper	25-450		10-70		
Middle/Lower	30-40		2-10		
Simulated fines	10	NA	0.5	NA	NA
Anisotropy ratio	670/2,300	330	200	200	0.0035-33,000
Specific yield	0.20	0.15	0.15	0.20	0.1-0.3
Specific storage (storage coefficient)	$5X10^{-6}$	$2X10^{-6}$	$2X10^{-6}$	$1X10^{-6}$	($1X10^{-4}$ to $4X10^{-4}$)
Boundaries					
River, canals, and drains	L	C,L	L	R	L
Other	MRF, ET	MFR	MFR, ET	MFR, ET	MFR
Primary properties altered during calibration	Q	Q	NA	K, VK, R	VK, S
Major sources of water to wells	ET	S	S, R	R, S	S

1. Hearne and Dewey, 1988 **2.** Hearne, 1988 **3.** Kernodle, 1998; Kernodle et al., 1995 **4.** Frenzel and Kaehler, 1992 **5.** Meyer, 1976
Abbreviations: NA, not applicable; **L,** head-dependent flux (leaky); **C,** specified-head cell (constant head); **R,** head-dependent flux (w/flow-routing river and drains); **ET,** evaportranspiration (or salvaged ET); **MRF,** mountain-front and tributary recharge; **Q,** groundwater withdrawal amount and location; **K,** horizontal hydraulic conductivity; **B,** boundary conditions; **VK,** vertical conductivity; **I,** irrigation-return flow; **S,** aquifer storage (specific yield and/or specific storage)

Geohydrologic Setting

The "string of pearls", the string of groundwater basins in the Northern Rio Grande Basin, primarily are interconnected by surface waters of the Rio Grande and not so much by groundwater underflow. Estimates of groundwater rates of downstream interbasin flow are generally in the range of 10 to 20 cubic feet per second (Kernodle and Scott 1986; Kernodle et al. 1987; McAda and Wasiolek 1988).

Typically, each basin has an upper and lower constriction consisting of low hydraulic conductivity prebasin-fill deposits, or has a structural barrier such as the La Bajada-Pajarito fault complex which partially separates the Albuquerque Basin from the Santa Fe/Española basin to the north. Another example is the Franklin - Sierra Juarez uplift between the Hueco Bolson and the Mesilla Basin. All of the basins discharge groundwater, to some degree, to the next one downstream. In most instances the constrictions or structural obstacles cause an upward discharge of old and, frequently, reduced-quality water. Examples include La Cienega (valley-floor wetland) and lower Santa Fe River areas in the Santa Fe/Española Basin, the La Joya to San Acacia reach in the Albuquerque Basin, and the lower reaches of the Mesilla Valley above the El Paso narrows.

As previously mentioned, a major source of recharge to the basins is mountain-front and tributary recharge. Another major source of recharge is the Rio Grande, the string that connects the "pearls." A less significant source of recharge is from adjacent basins that do not contain segments of the Rio Grande Valley system. For example, a significant amount of underflow comes from the San Juan Mountains into the Alamosa subbasin of the San Luis Valley (Hearne and Dewey, 1988); and modest amounts of underflow occur from the Colorado Plateau to the Albuquerque Basin (Frenzel and Lyford 1982; Kernodle and Scott 1986), and from the Jornada del Muerto Basin to the Mesilla Basin (Frenzel and Kaehler 1992). It is important to note that other basins not covered in this discussion also have interconnections (Figure 1). For example, the San Agustin Basin contributes to the Socorro

Basin (Kernodle et al. 1987) and the Tularosa Basin contributes underflow to the Hueco Bolson (Bedinger et al. 1989; Hibbs et al. 1997).

Even before 20th-Century exploitation of major groundwater resources, every intra-basin source of water plus a portion of flow in the Rio Grande went to evaporation from open water or to transpiration. Each basin along the "string of pearls" with the possible exception of the Alamosa and Sunshine Valley subbasins of the San Luis Basin, caused a diminished flow in the river except during periodic local flood events. After groundwater development began, more water was lost from the surface-water system (a gain to groundwater) and less was lost to evapotranspiration. No efforts have yet been made to augment other sources of recharge to the basins' aquifers.

Models – Past, Present, and Future

The earliest model of a northern Rio Grande Basin was the one by Reeder and others (1967) of a portion of the Albuquerque Basin. It was based on some still valid concepts and others that are obsolete; but they made it work with a hand-cranked calculator. Over the following years, many government-financed and private models were completed of this and other basins in the rift. Each progressive step took advantage of technological improvements in computing power and collective improvements in the overall understanding of Rio Grande rift-basin flow systems.

The SWAB RASA (Southwest Alluvial Basins Regional Aquifer-Systems Analysis program–Wilkins 1986; 1998) addressed the geohydrology of 22 basin-fill aquifers in the Rio Grande rift and adjacent parts of the southeastern Basin and Range province in New Mexico, western Texas, and southern Colorado. As part of that study, four models were commissioned to explore the practical and economic feasibility of different approaches to modeling rift basins.

A model of the Alamosa subbasin of the "Valley" tested a superposition approach (Hearne and Dewey 1988) as well as a two-dimensional vertical cross-section model to determine the necessary depth of simulation of the subsequent areal three-dimensional model. A model of the "Albuquerque-Belen Basins" (Kernodle and Scott 1986; Kernodle et al. 1987) tested the feasibility of using a deep (200 feet) constant hear boundary throughout the 2- to 5-mile wide flood plain to represent the Rio Grande. A third model was contracted to the New Mexico Bureau of Mines and Mineral Resources (O'Brien and Stone 1983) to use flow-net analysis to guide transmissivity estimates for a two-dimensional model. The fourth SWAB model to be formally documented was of the Mesilla Basin (Frenzel and Kaehler 1992). That model aspired to include every hydrologic detail of even the remotest importance.

An early objective of the SWAB RASA was to construct a groundwater-flow model of the entire rift system. As the study progressed, it became very clear that the "string of pearls" could not be simulated from a groundwater perspective. Hence, a different approach was taken: to evaluate all existing public-domain (e.g., USGS or government contract) models in an attempt to analyze the assets, flaws, common attributes, and various calibration approaches (Kernodle 1992). Altogether, 14 models were evaluated, with selected information on five of them included in Table 4. The critique resulted in a set of nine guidelines that were tested in new models for a basin with an already existing model (Albuquerque) and for joined basins (San Agustin-Socorro), which had not previously been modeled. A third model of the Palomas-Engle Basin was left incomplete. Each model was allocated approximately three weeks for completion. The experimental model of the Albuquerque Basin was, statistically, an improvement over its predecessor even though the first took years to complete and the other, only weeks. Still, both are seriously outdated in their portrayal of the current understanding of the hydrogeologic framework of the basin.

The nine guidelines (Kernodle 1992) are listed below, but, be aware that technological improvements and recent data acquisition have expanded the envelope on some of them (cf. Tables 2-4):

1. Perform a literature search to determine basin geometry, geologic structure, and lithology.
2. Use a three-dimensional model to simulate the aquifer to a depth of approximately 4,000 feet or to the total depth of the basin fill if less than 4,000 feet. Use at least five model layers, the top layer being 200 feet or less in thickness.
3. Simulate the basin-fill aquifer system as having a horizontal hydraulic conductivity of 20 to 45 feet per day in the open-drainage

basins and 2 to 10 feet per day in the closed drainage basins, except where field data indicate otherwise. Simulate fine-grained playa or lake deposits as having a hydraulic conductivity of 0.25 to 10 feet per day and flood-plain alluvial deposits as having a hydraulic conductivity of 50 to 70 feet per day.

4. Do not vary horizontal hydraulic conductivity as a function of depth unless specific lithologies are being simulated. Compaction of the aquifer and increases in temperature with depth need not be simulated as affecting the apparent hydraulic conductivity (or flow paths), except where these specific problems are being addressed. The two factors have opposite, and potentially offsetting, effects.
5. Use a horizontal to vertical hydraulic-conductivity ratio of from 200:1 to 1,000:1 except where geologic features such as faults, clay sequences, or steeply dipping beds exist.
6. Simulate aquifer specific storage to be in the range of 2×10^{-6} to $5 \text{ X } 10^{-6}$ per foot, and specific yield in the range of 0.10 to 0.20.
7. Include rivers and drains, if present, in the simulations as head-dependent-flux boundaries, preferably with flow routing to allow the location of the boundary to change with time.
8. Include estimated mountain-front and tributary recharge, evapotranspiration, and net irrigation flux.
9. Include historical groundwater withdrawals.

To this list we might add that short- and long-term climatic changes can have significant impacts on all water resources (Hawley 1993; Hawley et al. 2000). The region has experienced a prolonged drought from the early 1950s until the late 1970s. The following two decades were very abnormally wet. During those two decades the population and dependence on groundwater has grown enormously. The laissez faire attitude of the 1950s must, and will, be replaced by a pro-active approach to overall water resources management.

We have learned a lot about the geology and hydrology of the Rio Grande Rift during the last decade. But, we cannot take too much pride in our recent accomplishments or our modeling prowess. We are busy building the knowledge base, but the solid foundation was laid many years ago by true pioneers in science.

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Frank Titus became a New Mexico water user in 1956, when, just out of graduate school, he joined the U.S. Geological Survey as a hydrogeologist in Albuquerque. Nine years later he moved to Socorro to teach geology and groundwater at New Mexico Tech (1965-1973). During this 17-year period, his major reports were on geology and water resources in the Sandia and northern Manzano Mountains, in Valencia County, and in the Estancia Valley. From 1973-1987, Frank managed Environmental Impact Statements and waste-management studies coast to coast, including Canada and Alaska. In 1987 he returned to Albuquerque to manage DOE's Uranium Mill Tailings Remedial Action Project. In 1995 Frank became state engineer Tom Turney's Science Advisor and also chairman of the Technical Advisory Committee for Middle Rio Grande water resources. He is now active in the Middle Rio Grande Water Assembly and its Action Committee. His Ph.D. in geology is from the University of New Mexico.

Current Water Budget of the Middle Rio Grande Basin

Note: Frank Titus distributed copies of the "Current Water Budget of the Middle Rio Grande Basin," which was prepared by the Middle Rio Grande Water Assembly, Inc. The following is the summary from that report. Those interested in obtaining a copy of the Budget should contact the Assembly at (505) 247-1750.

Middle Rio Grande Water Budget Summary Text

This simple water budget and the material accompanying it are designed for a broad audience of people who have an interest in the region's water resources. This summary provides context for understanding the information in the tables and graphs on the following pages. An audience with good understanding will, we hope, improve public input and also multiply the public's influence over water stewardship.

The water budget addresses wet water in both the surface water and the groundwater parts of the regional hydrologic system. Many water budgets have been created over the past three decades by knowledgeable professionals. The numbers we use here differ little from those earlier presentations. Most of those water budgets however were embedded in lengthy technical documents not at all designed for non-hydrologist audiences.

Both tabular and graphic formats are used in this pamphlet to present the hydrologic picture, and the numbers in the two formats are the same. Some people like numbers, some like pictures. In addition to the annual averages, an *actual* one-year water budget, for 1993, a near-typical year, is also provided.

1. The **Middle Rio Grande Valley** addressed in this water budget extends from the Otowi gage on the north (where the Los Alamos highway crosses the Rio Grande) to Elephant Butte Dam on the south, a distance of about 200 miles. These are the two index" points, or water-accounting points, in New Mexico that are specified by the Rio Grande Compact.

2. Groundwater and surface water are but parts of a single hydrologic system. Throughout the river's floodplain (the inner valley" of the Rio Grande) the water table in most places (though not at Albuquerque) is only 10 feet or so below land surface. The uppermost groundwater in the shallow aquifer, which underlies the floodplain, is in direct contact in most places with the surface water in the river and with water in the many drainage ditches throughout the valley. It is here that all exchanges between groundwater and surface water occur.

3. All municipal water systems pump groundwater to supply their customers, and the larger systems—principally Albuquerque and Rio Rancho—pump at rates we now know significantly exceed the ability of the Rio Grande to replenish (ie., recharge) the aquifer. This is called **"mining" groundwater.**

* Groundwater currently is being mined at a rate of about 70,000 acre-feet per year (af/y). An effect of the overdraft is that the water table beneath Albuquerque has been seriously lowered—locally beneath the northeast heights by amounts approaching 200 feet.
* Both specialists and non-specialists are aware that this rate of exploitation is unsustainable, and alternative plans are under serious discussion by many parties and concerned specialists.

4. This is an **annual water budget.** It gives annual averages for nearly all inflows, outflows and changes in storage in the system, and it identifies the pathways on which these occur. Information presented herein conforms generally with definitions and parameters used in the Rio Grande Compact.

* Natural variability is high for nearly all the numbers in the budget. The variability range is shown for some, but not all, parameters. (The high variability in flow of the Rio Grande is shown graphically in the histogram on page 3.)
* The data for river flows at Otowi gage and Elephant Butte Dam, the data for major-tributary inflows, and the data for most of the aquifer pumping and municipal wastewater are direct measurements of surface-water flows or pumping. Most other numbers are from complex analyses, and/or from analytical or computer modeling.
* Rio Grande flow gaging data have officially reported uncertainties of the order of 10%. Groundwater and other calculated data have uncertainties at least this large. Hence, the accuracy of data in this water budget is affected by this reality.

5. The water budget is for the **26-year period of 1972-1997**, inclusive.

* Flow records at the Otowi gage go back more than 100 years, but in 1971 the San Juan-Chama diversion project began importing water from the Colorado River system into the Rio Grande.

6. The **Otowi gage**, located as it is downstream from the confluence of the Rio Chama and the Rio Grande at Española, measures the combined flow of native water in the Rio Grande system and the imported water from the San Juan-Chama diversion system.

* The 1972-1997 average flow of *native* water at Otowi is approximately 1,100,000 acre-feet/year.
* The 1910-1993 average of all flows past the gage is also about 1,100,000 acre-feet (af).

7. **The San Juan-Chama diversion project** delivers an average of 96,000 af/y to Heron Reservoir. Evaporation and water used to increase reservoir storage reduces the amount reaching the Rio Grande. That reaching the Rio Grande has augmented the flow at Otowi gage by about 55,000 af/y since 1971.

* This is part of New Mexico's Colorado River share; it is picked up from tributaries of the San Juan River, conveyed through a tunnel under the continental divide to Heron Lake, then to the Rio Chama.
* The San Juan-Chama water is not subject to Rio Grande Compact control.

Current Water Budget of the Middle Rio Grande Basin

8. The **Rio Grande Compact** specifies the annual amount of surface water to be provided to downstream users from Elephant Butte Reservoir based on "native" Rio Grande inflow at Otowi. Four values that relate to Elephant Butte outflow are given in the accompanying table and flow diagram. These are, (a) the delivery that would be required it the averages in the table were the actual flow fro a single year; (b) The average of **actual wet-water flows** past the dam; (c) the average of the **Elephant Butte Effective Supply** (which combines actual deliveries and change in lake storage). Note: given 10% or larger error for data, the Elephant Butte Effective Supply and the deliveries mandated by compact are statistically the same.

9. "Depletion" is calculated by subtracting the outflow at Elephant Butte Dam from the native-water inflow at Otowi. (Note that this calculation ignores all other inflows and outflows that originate *within* the Middle Rio Grande.)

* Under the compact, the *maximum* that the Middle Rio Grande is allowed to deplete from any and all Otowi *native inflows exceeding 1,500,000 af/y* is a fixed 405,000 af/y. At lesser inflows, the depletable amount decreases progressively (down to 47,000 at inflows of 100,000 af/y).
* *Evaporation from Elephant Butte Reservoir* must be included as part of the Middle Rio Grande's permissible depletion.

10. Direct **evaporation from Elephant Butte Reservoir** is commonly the largest single depletion loss from the system. The amount varies widely from year to year, being controlled by both weather and size of the lake surface through the year.

* Note: The outflow called "Recharge to shallow aquifer" above San Acacia, while a larger number, is mostly offset by nearby shallow-aquifer returns to the surface-water part of the system.

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The Middle Rio Grande Water Supply Study:

Summary of Work-in-Progress to Provide a Quantitative and Probabilistic Description of the Groundwater and Surface Water Supply of the Middle Rio Grande Region

Introduction

The Middle Rio Grande Water Supply Study, currently in progress, is developing a quantitative and probabilistic description of the conjunctive-use groundwater and surface water supply available to the Middle Rio Grande region. The study area extends from Cochiti Reservoir to Elephant Butte Reservoir. This water supply study will provide a framework to support regional water planning efforts for the Middle Rio Grande and will describe conditions relevant to maintaining compliance with the Rio Grande Compact. This study is being conducted for the Army Corps of Engineers and the New Mexico Interstate Stream Commission. An Executive Steering Committee has been convened to meet periodically with the study team to review progress and results. This Committee includes technical representatives of a diverse group of stakeholders and agencies within the planning region.

The regional water planning process focuses on five questions:

- What is the water supply?
- What is the water demand?
- What alternatives exist to meet demand with available supply, including water conservation?
- What are the advantages and disadvantages to these alternatives?
- What is the best plan and how will it be implemented?

This study will address the first of these questions concerning characterization of the water supply. Other studies are anticipated by the contracting agencies to address the remaining water planning questions.

Specific products that will be generated from this study that will be available to planners and investigators include:

- A metadata database that identifies and describes available data in the Middle Rio Grande Basin;
- A document database of water-resource reference material;
- Groundwater modeling results characterizing the expected depletions to the Rio Grande from present and future groundwater pumping;
- Probabilistic characterization of Middle Rio Grande water budget components, including inflows and depletions;
- A risk analysis model evaluation of the water supply, incorporating the climatic-dependent variability in individual water budget components;
- A data needs assessment; and,
- An illustrated report describing the water supply.

These products will provide an up-to-date integration of past and on-going technical studies that can be considered by regional water planning entities as they frame water plans.

Study Approach

The Middle Rio Grande water supply includes four components: the native (non-San Juan/ Chama Project) flow of the Rio Grande at the Otowi gage, inflow from tributaries between Otowi and Elephant Butte Dam, imported (San Juan-Chama Project) water, and groundwater. Variability is an inseparable characteristic of this water supply. Therefore, quantification of the variability in the supply will be fundamental for the quantification of the water supply. The scope of work includes procedures for characterizing the variability in the native and tributary inflow supply components and in selected depletion components; and, for tracking this variability through the water budget for the study region.

The water supply to be quantified is conceptualized as the amount of water potentially available for use, or depletion, within the study area. This conceptualization represents both the hydrologic supply and the legal limitations imposed by the Rio Grande Compact. The supply is the difference between the basin inflow and the downstream flow obligation determined by the Compact.

The supply will be quantified as a set of probability distribution functions, taking into account the historical variability of inflow components. To relate this supply to reach-specific demands, the available supply will be compared to depletions under current river and development conditions. Identification of depletions will draw from past and in-progress water budget and depletion studies by other investigators. The probabilistic quantification of the water supply will utilize risk analysis tools to track probability distributions and correlation structures within the river system.

Observations Concerning the Water Supply

Preliminary results of the study support the following observations:

- Variability is a defining characteristic of the Middle Rio Grande water supply;
- The major component of the water supply available to this region is the highly variable mainstem inflow at Otowi (the gaged inflow at Otowi, adjusted for transmountain diversions and upstream storage effects, is the Otowi Index Supply of the Rio Grande Compact);
- The water supply is supplemented with (a) transmountain diversions of the San Juan/ Chama Project, and, (b) highly variable quantities of tributary inflow to the region;
- The supply to the Middle Rio Grande region is significantly reduced by evaporation from Elephant Butte Reservoir (the Middle Rio Grande supply is largely a function of the difference between the inflow at Otowi and the Compact-based obligation at Elephant Butte Reservoir);
- Evaporation from the Elephant Butte Reservoir, dependent in large part on reservoir surface area, is highly variable; years with large evaporation depletions do not always coincide with years of high supply;
- Groundwater pumping from the alluvial aquifer or Santa Fe Formation eventually results in reduction of the flow in the Rio Grande, regardless of the location of the pumping;
- The current level of groundwater pumping has not reached a "steady-state condition"; depletions to the river from current levels of

pumping will continue to increase for many years, even if pumping rates are not increased beyond current levels;

- The groundwater "supply" is limited by the availability of offsets for river impacts; as opposed to the storage capacity of the aquifer;
- Wastewater returns from extracted groundwater offer a partial credit to offset groundwater impacts; the relative benefit of this offset decreases with time as lagged effects reach the river; and,
- Risk analysis modeling of the basin water budget under present development conditions indicates that, absent intervention, both credit and debit conditions under the Rio Grande Compact are probable outcomes.

Supporting data, metadata, analysis procedures and quantitative results will be provided in the final report to be released in August 2000. The report and related material will be available through the State Engineer Office/Interstate Stream Commission website, at www.ose.state.nm.us.

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Proposed Middle Rio Grande Guidelines for Review of Water Rights Applications

Note: The information contained in this paper is still considered in DRAFT form and is the collaborative effort of the following Office of the State Engineer staff members: Paul Saavedra, Chief of Water Rights Division; Tom Morrison, Chief of Hydrology Section; D.L. Sanders, Legal Services Division; Jess Ward, Water Rights Division, MRG Basin Supervisor; and John D'Antonio Jr., District I Supervisor.

In New Mexico, the surface water of the Rio Grande has been considered fully appropriated since the Rio Grande Compact was consummated. Accordingly, the state engineer does not allow new Rio Grande surface water appropriations. Since groundwater diversions from aquifers hydrologically connected to the Rio Grande impact the fully appropriated surface flow, the state engineer conjunctively manages the water resources within the Rio Grande Basin to protect existing water rights and to ensure New Mexico's compliance with the Rio Grande Compact. Accordingly, to protect prior stream appropriators, the state engineer requires Rio Grande Basin appropriators to obtain valid water rights to offset the effects on the flow of the Rio Grande resulting from their groundwater diversions.

When finalized, the guidelines will embody the Water Rights Division's current practice for evaluating pending and future applications for permits in the Middle Rio Grande Administrative Area (MRGAA, shown in Figure 1), to ensure compliance with the Rio Grande Compact, to prevent impairment to existing rights, to limit groundwater level decline rates so the life of the aquifer is extended, and to minimize land subsidence. The stream system within the MRGAA includes the Rio Grande stream system between Cochiti Dam and San Acacia Dam, its irrigation canals and laterals, its drains and wasteways, the underlying aquifers, and the tributaries to the Rio Grande.

Since the declaration of the Rio Grande Underground Water Basin, which includes the area now designated as the MRGAA, groundwater permittees have been required to obtain valid water rights in an amount sufficient to offset the effects of their diversions on the surface flows of the Rio Grande stream system. This requirement protects the surface flows of the Rio Grande stream system from being depleted or reduced by groundwater diversions.

Proposed Middle Rio Grande Guidelines for Review of Water Rights Applications

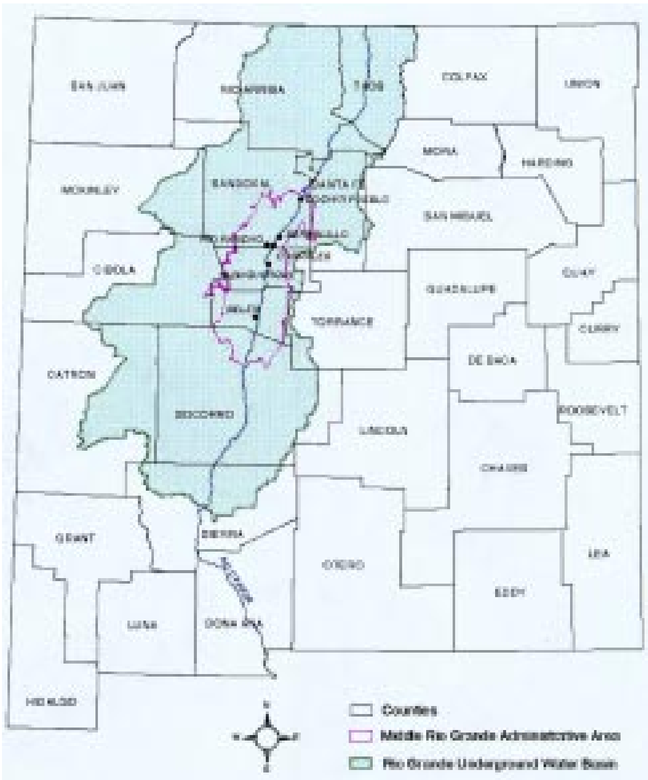


Figure 1. Rio Grande Basin and Middle Rio Grande Administrative Area

Offsetting the effects of groundwater diversions is critical to the conjunctive management of the water resources within the MRGAA. Any existing permittee requiring surface water rights for offset purposes is confronted with finding a seller of valid surface water rights and obtaining a permit from the state engineer to transfer the surface water rights. The transfer of surface water rights within the MRGAA is a complicated and often lengthy process due to the complex interrelationship between the surface and groundwaters, the numerous existing appropriations to be protected, and the diversity of the numerous interests having standing to participate in the administrative process for an application for permit. Because a transfer application can be denied or approved and the decision appealed to the district court, the court of appeals and the state supreme court, the final decision may be far removed from the time the application was filed.

The public welfare of the state is protected only if there is certainty that a permittee will be able to obtain and transfer all necessary valid surface water rights to prevent adverse effects upon the flow of the Rio Grande. Accordingly, the public welfare is best served by limiting actual diversion to the amount of valid surface water rights transferred or otherwise held by the permittee.

APPLICATIONS TO APPROPRIATE UNAPPROPRIATED WATER

No new applications to appropriate unappropriated water within the MRGAA, other than those permitted under NMSA 72-12.1, will be accepted.

PERMIT LIMIT ON ACTUAL DIVERSION[1]

The actual amount of the groundwater diversion will be limited to the valid surface water rights held by the permittee to offset the greater of either:

- total well diversions less any approved offset flow returned directly to the Rio Grande; or
- the net surface water depletion associated with past and present use including

consideration of residual effects of past diversions.

Return flow credits are permitted only upon the state engineer's approval of a permittee's return flow plan.

SURFACE WATER RIGHTS REQUIRED TO OFFSET GROUNDWATER WITHDRAWALS

Any permit approved to appropriate ground-water shall be conditioned to limit the actual diversion of water to the valid surface water rights held as defined below:

- surface water rights water rights transferred by State Engineer permit to groundwater;
- water recovered under an approved Aquifer Storage and Recovery (ASR) Program;
- San Juan Chama project water held by a perpetual contract between the permittee and the Secretary of the Interior[2]

MRGAA RESTRICTIONS

Applications for wells, other than those under Section 72-12-1, shall be evaluated using the interim MRGAA model to ensure resulting groundwater level decline rates do not exceed 2.75 feet per year in non-critical areas. Such applications may be approved unless:

- The state engineer finds that the granting of the application will impair existing water rights, be contrary to water conservation within the state, or be detrimental to the public welfare of the state; or
- The proposed appropriation combined with the exercise of existing water rights will cause total water level declines in any Critical Management Area model cell to exceed 250 feet from predevelopment conditions to the year 2040.

CRITICAL MANAGEMENT AREAS

An area with excessive water level decline rates shall be closed to additional appropriations and shall be defined as a Critical Management Area (CMA). A CMA shall generally include those model cells in which the predicted water level declines exceed an average rate of 2.50 feet per year through the year 2040 and those cells in which the current observed rate of water level declines exceeds an average of 2.50 feet per year. The current CMA boundary is shown in figures 2 and 3. The boundaries will be modified as the CMA expands due to hydrologic stresses.

Non-Critical Areas are defined as those model cells that do not fall within any CMA.

CRITICAL MANAGEMENT AREA RESTRICTIONS

No applications will be accepted in a CMA except for applications to replace, repair, deepen, or supplement an original well or for wells under Section 72-12-1 (NMSA). The amount of water previously placed to beneficial use under an existing given permit will be the limit for any new permits to replace, repair, or deepen wells within the CMA. Supplemental wells may be considered if the combined diversion from the supplemental well and primary well does not exceed the maximum amount of water previously placed to beneficial use from the primary well. No alternate points of diversion (i.e., additional or new wells) necessary to appropriate the maximum permitted amount of water may be permitted in the CMA. Owners of declared water rights within a CMA will not be granted any permits to increase their diversion beyond the amount of groundwater already placed to beneficial use.

CALCULATION OF WATER LEVEL DECLINE RATES

Decline rate calculations shall be made by simulating full production of proposed wells beginning in the year the application was filed, through the beginning of year 2040, unless the application includes a pumping schedule. If a schedule has been provided, simulations will be performed in accordance with the schedule. The proposed stresses and full exercise of existing permits will be assumed, including reasonable use of 72-12-1 wells, through the year 2040. Computed decline rates through the year 2040, from existing and proposed uses, shall be divided by the number of years used in the predictive scenario to obtain the average decline rate. If a pumping schedule has been provided, the permit shall be conditioned to limit pumpages in accordance with the schedule. The interim model will be updated to include the new permits so that the cumulative effects are considered in the evaluation of subsequent applications. Any model cell which reaches a predicted average decline of 2.50 feet per year or more due to existing and

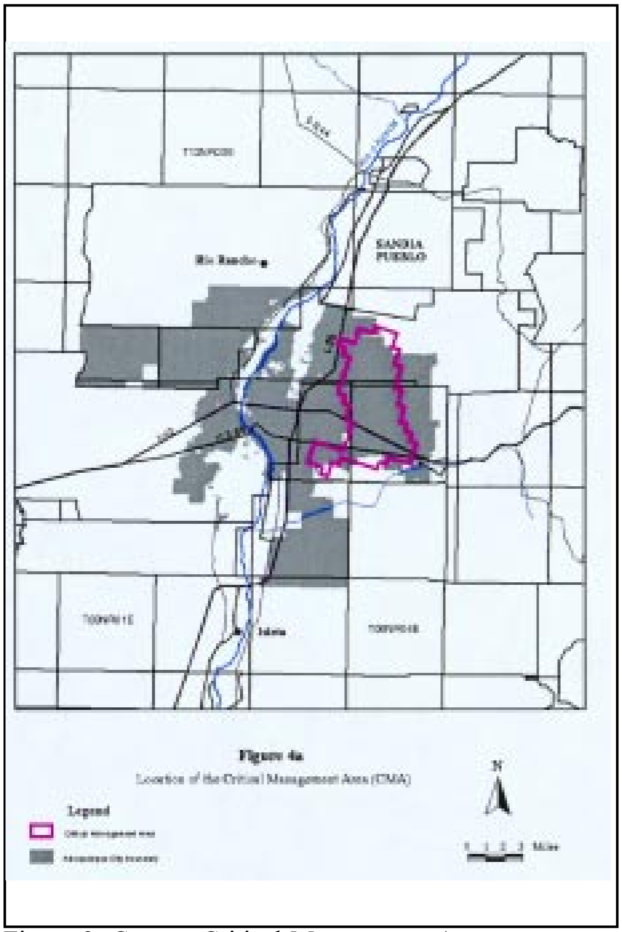


Figure 2. Current Critical Management Area

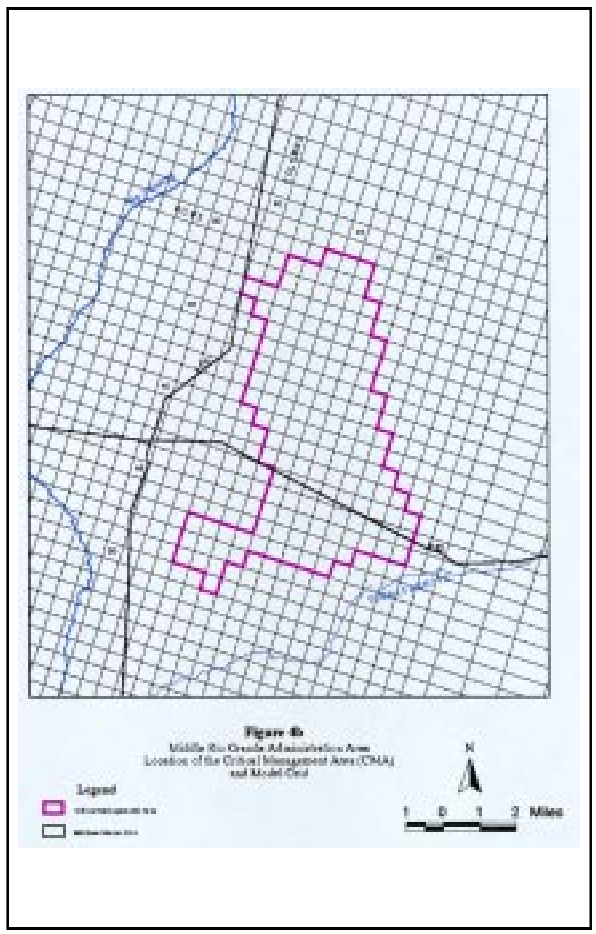


Figure 3. Middle Rio Grande Administration Area.

subsequent permits, and all cells directly above and below that cell, will be designated as a CMA.

SECTION 72-12-1 WELL RESTRICTIONS

New wells within a CMA permitted under Section 72-12-1 (NMSA) may be limited to a total diversion amount of less than the currently designated 3 acre-feet per year. Permits for these wells will most likely be conditioned to require metering.

OTHER CONSIDERATIONS

Permits may be conditioned to require monitoring as deemed necessary by the state engineer. The state engineer will deny any application if he finds that the granting of the application would be contrary to statute and may cancel any permit if the conditions of approval are not met or if the actions of the permittee are not in accordance with the permit.

TRANSFER OF VALID GROUNDWATER RIGHTS

With respect to protecting the flows of the Rio Grande, the transfer of groundwater rights will be processed on a case-by-case basis. **The above discussion is applicable to the transfer of groundwater rights only within the MRGAA.**

[1]Pre-basin groundwater right diversions shall be limited by the conditions set forth in permits previously approved by the state engineer.

[2]The guidelines are not intended to apply to permits for groundwater within the MRGAA, which are in existence at the time of adoption of the proposed guidelines (hereinafter referred to as existing permits); that is, the effects of the groundwater diversion pursuant to an existing permit may continue to be offset with short-term contracts for San Juan/Chama project water. Short-term San Juan/Chama contract water may be used for offset purposes only in the year which the effects occur. Any state engineer action requested by an existing permittee will invoke the application of final guidelines to the existing permit.

Neal W. Ackerly *received his doctorate in anthropology from Arizona State University in 1986. In the mid-1980s, he directed a number of projects focusing on the dynamics of prehistoric irrigation systems in central Arizona. Working in New Mexico over the past ten years, he has documented historical interactions between small- and large-scale irrigators and the rivers on which they depend. His studies encompass large federal irrigation projects (EBID, MRGCD) as well as smaller community acequia systems in the Mimbres, Ruidoso, Peñasco, and Velarde areas. Among other efforts, he recently prepared an overview of the historical development of irrigation systems across New Mexico, and currently is working on a pilot project for the U.S. Army Corps of Engineers to develop a GIS of acequia systems on the Rio Chama.*

PALEOHYDROLOGY OF THE RIO GRANDE: A FIRST APPROXIMATION

The issue I would like me to address today revolves around long-term discharge characteristics of the Rio Grande. Discharge fluctuations affected the people of New Mexico in the past and will certainly affect us in the future. To address this global issue, I want to focus on three interrelated subissues including:

1. What are historical trends in the flow of the Rio Grande based on gauging station data?
2. What proxy data might be used to extend our understanding of the Rio Grande's flow beyond the period for which gauging station data are available?
3. What do proxy data indicate about long-term variability in the Rio Grande's flow?

For reasons that will become clearer, I am going to touch only briefly on the issue of average long-term flow. Rather, what I want to focus more on here today is the issue of **variability** in the potential discharge of the Rio Grande.

First, then, what are the general trends in water availability during the past century? I have arbitrarily selected discharge data from the San Marcial gauging station, mostly because it is located in the center of the state. Further, San Marcial is above Elephant Butte Reservoir and is less affected by water storage than gauging stations situated further downstream. Data cover the period 1896–1964 when the station was removed. Annual discharge is aggregated into "water years" extending from October of year *n* to September of year *n+1*. Water year data for San Marcial were extracted from U.S.G.S. *Water Supply Papers* 1312 (1960), 1732 (1964), 1923 (1970), and 2123 (1974).

The general trend between 1896 and 1964 shows a downward progression over the 68 years for which gauging station data are available (Figure 1). Some might argue that this simply reflects progressively larger water diversions over the past century. However, a comparable analysis of gauging station data from Otowi station, situated between Santa Fe and Taos above any significant water diversions, shows a similar decline. Considered jointly, this trend indicates declining water availability during the past

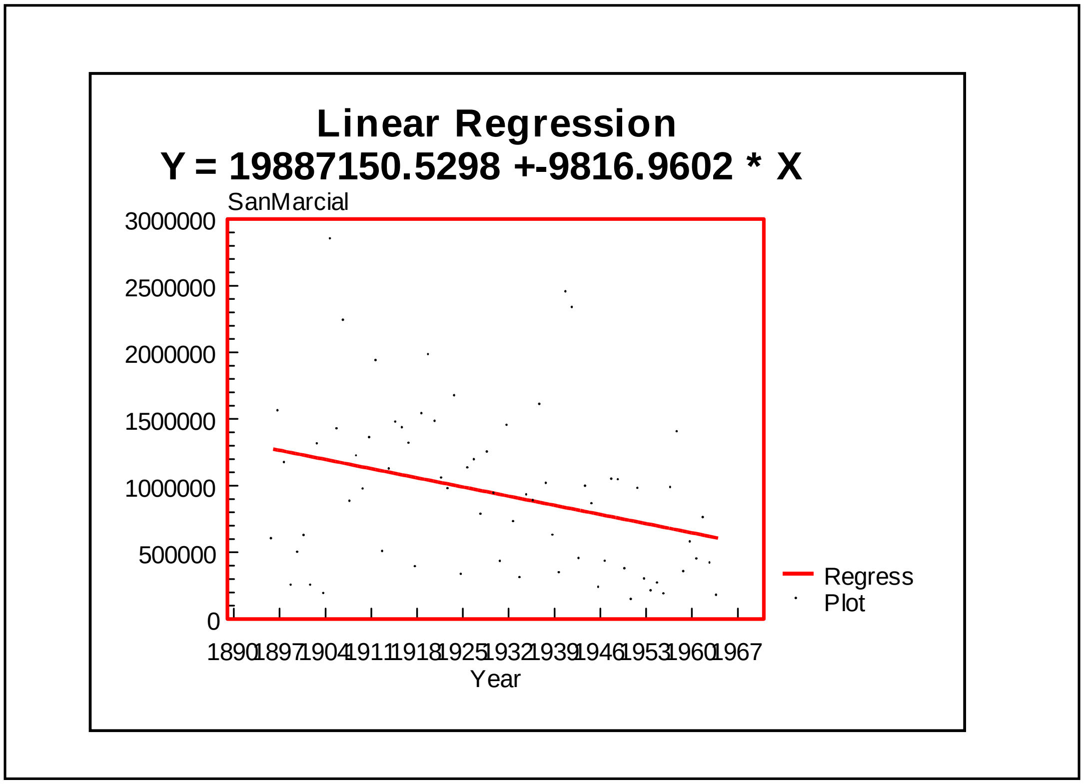


Figure 1. Simple linear regression of discharge against water year at San Marcial: 1896-1964.

century or so. At the same time, Figure 1 underscores the fact that there is a remarkable degree of variability associated with discharge during this period. Indeed the coefficient of variation is a very high 0.64 (= 940417.4, STD = 604819.5).

However, gauging station data do not tell us very much about longer-term trends in the Rio Grande's flow and long-term trends that are more worrisome. Fortunately, some relatively simple statistical procedures linking gauging station data with proxy indicators of longer-term variability in discharge offer the potential to extend these analyses further back in time. I would like to suggest that long-term fluctuations in tree-rings provide a reasonable basis for modeling the flow attributes of the Rio Grande for periods with much greater time depth than gauging station records (Stockton and Boggess 1980). As most are aware, tree ring thickness varies with precipitation and, ultimately, discharge.

The first issue to be dispensed with, of course, is whether there is any correlation between discharge and tree ring widths. To begin this process, I arbitrarily selected gauging station data from San Marcial, if for no other reason that it was located (more-or-less) in the middle of the state. Annual water year discharge data from the San Marcial gauging station were then correlated with 20 corresponding annual tree-ring chronologies distributed across New Mexico (Dean and Robinson 1978, Drew 1972). A series of bivariate and multivariate analyses were employed to screen potential correlations between tree-rings and historic gauging station data.

Focusing first on a simple bivariate approach, I screened 20 ring series from around New Mexico and found a 484 year-long chronology from Ft. Wingate (Robinson 1970) to be most closely correlated with annual gauged discharge from San Marcial ($n = 69$, $r = +.75$, $r^2 = .55$). The equation of this relationship is:

(San Marcial a.f. Discharge) = 1032.658137(Ft. Wingate ring width) - 177188.102408

A scatterplot showing the interrelationship between gauging station data and Ft. Wingate tree-rings is shown in Figure 2.

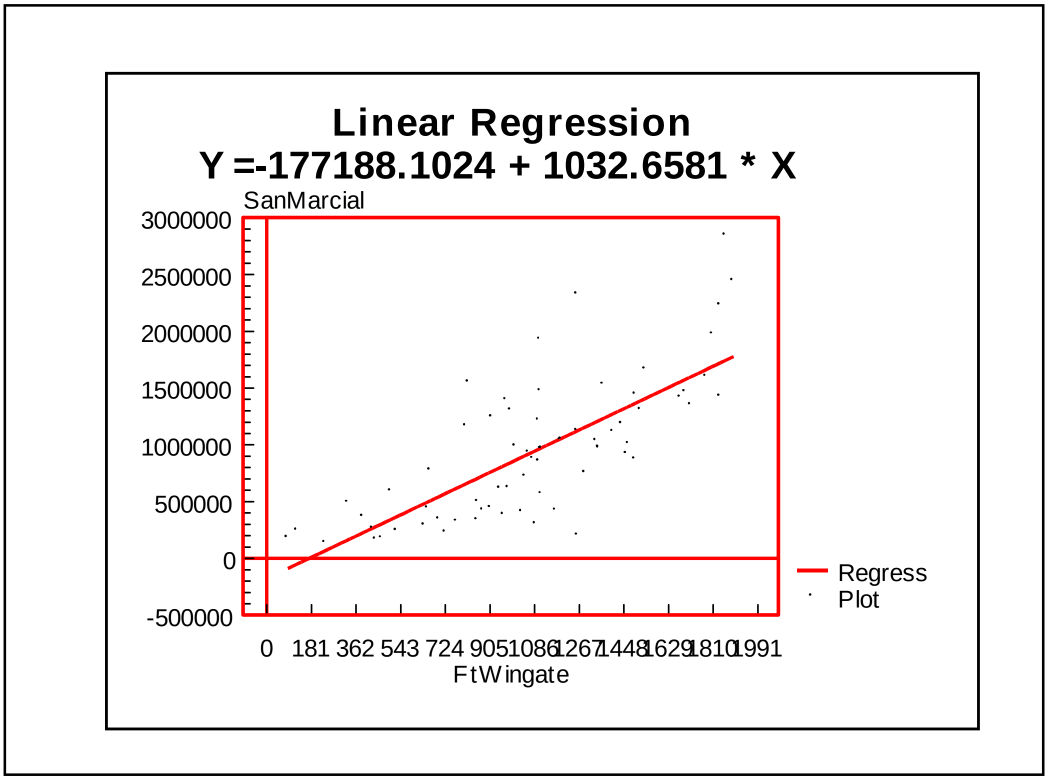


Figure 2. Linear correlation between Ft. Wingate TR and San Narcial water year discharge

Using this equation, predicted discharge values were then computed and plotted against actual discharge values at San Marcial for the period 1896-1964 when the gauge was removed. It may be seen that this equation generates a reasonably accurate correspondence between the two time series (Figure 3).

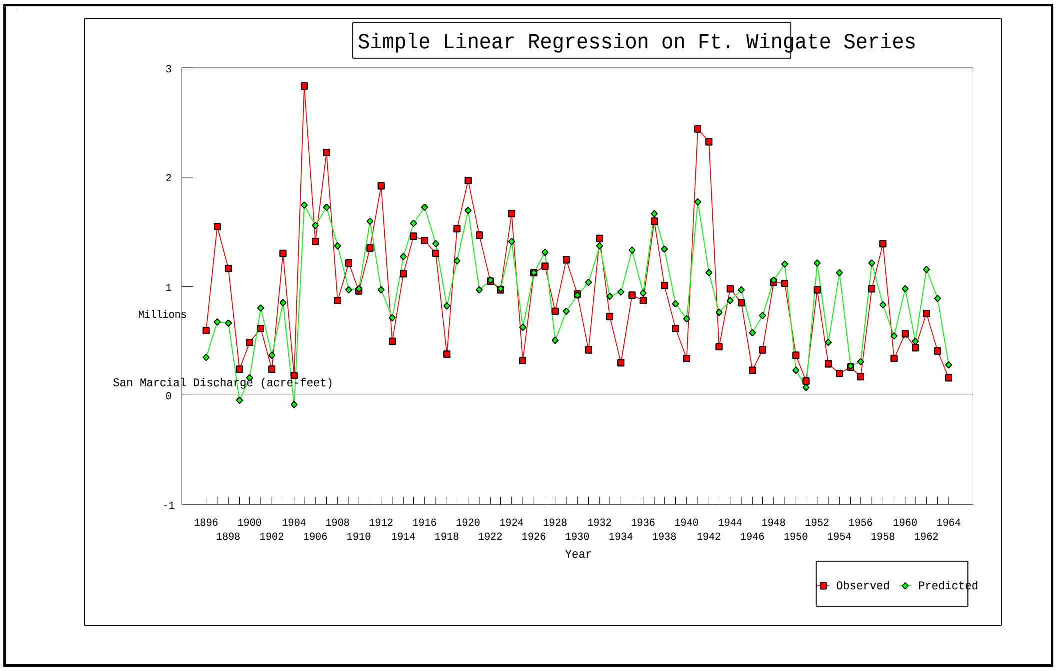


Figure 3. Correspondence between observed and predicted discharge estimates at San Marcial using Ft. Wingate Series: 1896-1964.

I should mention that relatively sophisticated analyses involving regression on principal components were performed under the assumption that perhaps principal components analyses using data from all 20 tree-ring stations across New Mexico might generate even better correlations with discharge. This more complex analysis did not, in fact, provide correlations substantially better than simple bivariate regression analyses using the Ft. Wingate sequence. This simply underscores the need to collect data from more tree-ring stations across the state to begin to adequately model paleodischarge of the Rio Grande.

For purposes of this discussion, I will simply invoke the KISS principle and focus for the remainder of my discussion on the more simple bivariate model involving regression of the Ft. Wingate ring series on San Marcial discharge. The availability of a 484-year long tree-ring sequence from Ft. Wingate allows us to begin to explore potential variability in longer-term discharge in the Rio Grande between A.D. 1480 and today. Figure 4 shows annual discharge of the Rio Grande at San Marcial estimated by rearranging the terms of the bivariate regression equation shown above. The estimated annual acre-foot discharge over this 484 year period is 847,269.88 (STD = 425430.58). A 95 percent confidence interval on the estimated mean annual discharge is 847,269.88 ± 37,669.5 acre-feet.

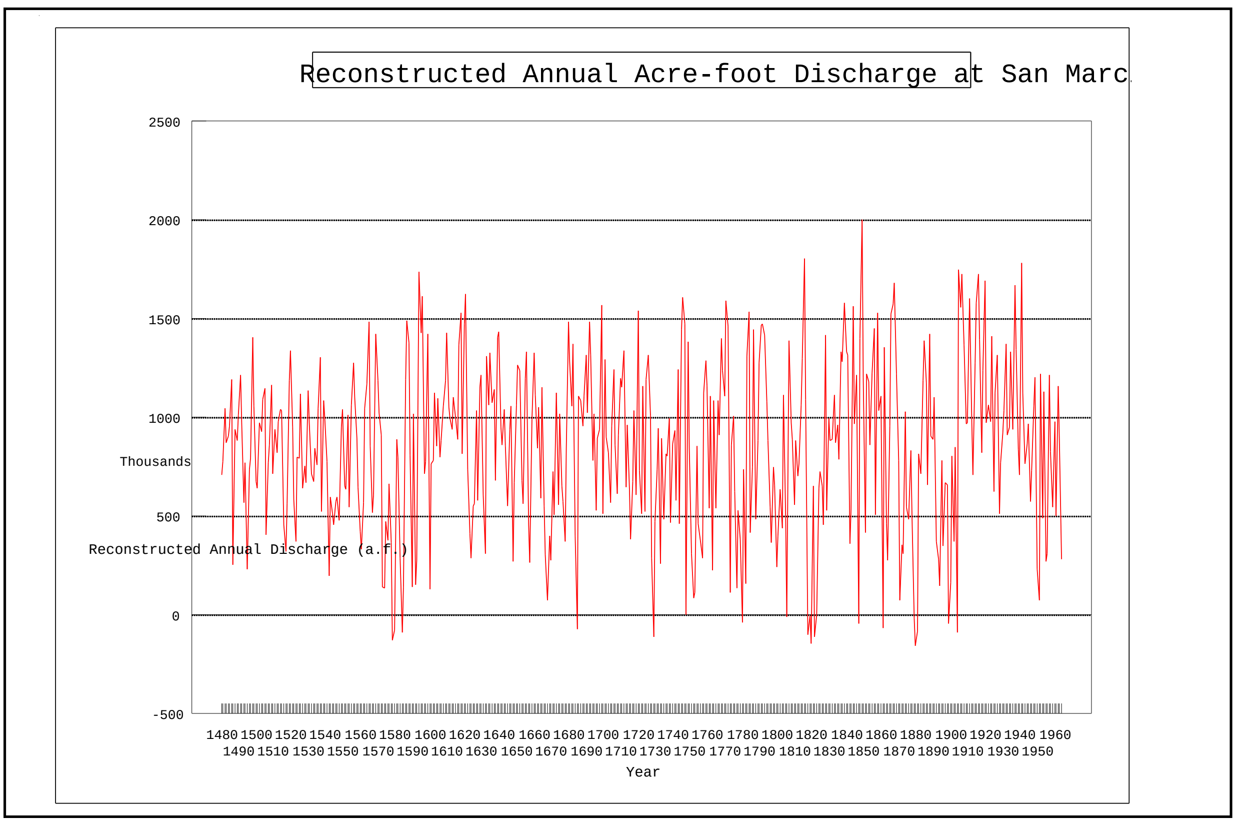


Figure 4. Reconstructed Annual A.F. Discharge at San Marcial: 1480-1964.

What is most important about this reconstruction is that it illustrates *relative* fluctuations in the Rio Grande's discharge over a long period. Whether it is absolutely correct is not crucial. Second, it demonstrates that the drought of the 1950s–a period that is perhaps our psychological touchstone for adverse drought effects–pales to insignificance compared to the number, magnitude, and periodicity of drought periods in the past.

Comparison of reconstructed annual acre-foot discharge using tree ring proxy data for the interval A.D. 1480-1895–prior to installation of a gauging station at San Marcial–with reconstructed acre-foot discharge after 1895 suggests that annual flow of the Rio Grande at San Marcial after 1895 was higher than that observed during the previous 415 years. Indeed, post–1895 discharge appears to be higher by about 13 percent than pre–1895 reconstructions (i.e., 940,417.4 acre-feet vs. 832,193 acre-feet).

Since post-1895 gauging station data are the basis for water allocations under the Rio Grande Compact, this recent period seems to reflect higher–than–average flows relative to the preceding 415 years. In short, Rio Grande water may be oversubscribed to a substantial degree relative to the long-term hydrology of the basin. Similar findings from the Colorado River lend support to the notion that water throughout the West is oversubscribed (Meko 1990:124, Stockton 1990:43). This suggests that water allocations under the Rio Grande Compact, not to mention the 1906 treaty between the United States and Mexico, may, during periods of low discharge, become highly problematic. Further, it suggests that we have not experienced the kinds of low-flow periods common in the past.

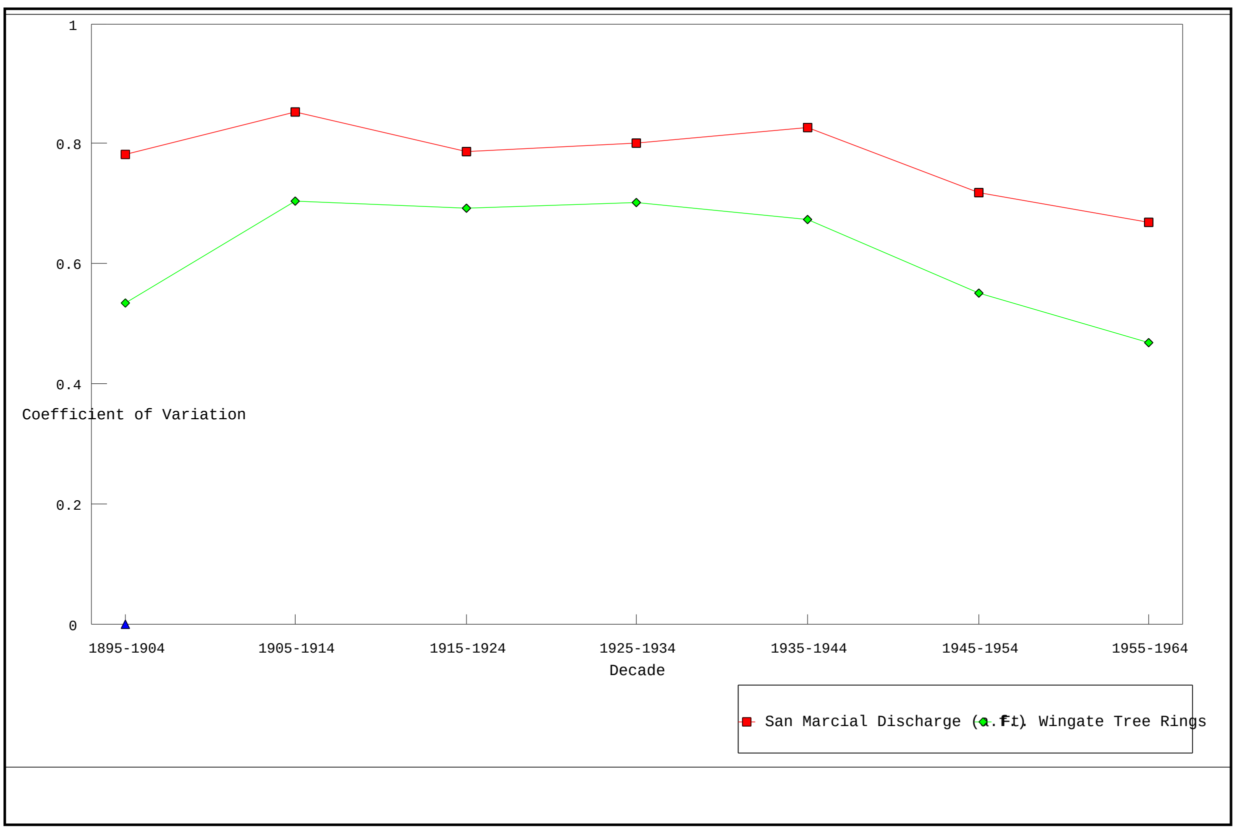
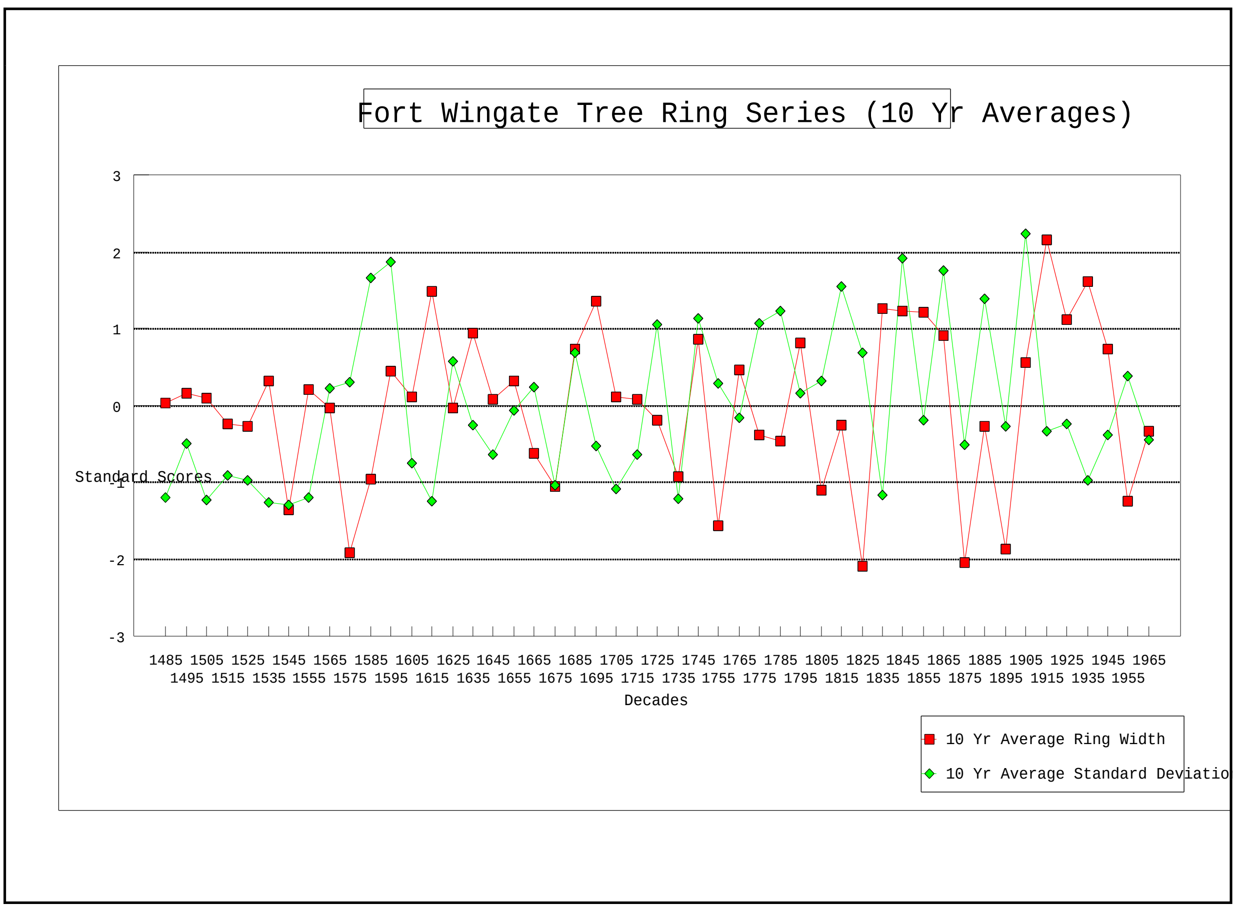


Figure 5. Comparison of Decadal coefficients of variation between San Marcial Discharge and Ft. Wingate Tree Ring Widths.

I now want to shift the focus from annual discharge reconstructions to decadal reconstructions. What is interesting about the interrelationship between the San Marcial gauging station data and the Ft. Wingate tree ring sequence is that they also exhibit a close correspondence in terms of variability estimates. As shown in Figure 5, decadal variability in gauged discharge is closely paralleled by decadal variability in the tree ring series from Ft. Wingate. This, in turn, suggests that long-term variability in the Ft. Wingate tree ring series can provide reasonable first approximations about variability in the paleo-discharge of the Rio Grande. As Figure 5 illustrates, reliance on the ring series will *underestimate* the actual magnitudes of discharge variation by an average of 25.2 percent (range=13.4–42.8 percent).

By shifting to decadal analyses, it is possible to systematically compare interactions in reconstructed decadal discharge and decadal variability. Figure 6 shows a time-sequent plot of fluctuations in decadal average ring widths, as well as decadal average standard deviations in ring widths over the period A.D. 1480-1964. Both have been standardized to facilitate presentation on a single plot.



Figures 6. Decadal variations in standardized ring widths and standardized standard deviations: Ft. Wingate.

This plot shows that there are periods of relatively low variability (e.g., A.D. 1480-1560) followed by intervals characterized by relatively high variability (e.g., A.D. 1570-1590). Even more interesting are the decades that alternate as follows:

1. High width, low standard deviations (i.e., higher discharge with less variability, e.g. A.D. 1620-1629, 1690-1699)
2. High widths, high standard deviations (i.e., higher discharge with more variability, e.g. A.D. 1740-1749, 1830-1839)
3. Low widths, low standard deviations (i.e., lower discharge with low variability, e.g. A.D. 1540-1549, 1730-1739), and
4. Low widths, high standard deviations (i.e., lower discharge with higher variability, e.g. A.D. 1580-1589, 1820-1829, 1950-1959)

Equally important, the period A.D. 1920-1964 exhibits relatively low variability relative to the entire 484 year sequence.

The issue I am concerned with revolves around the relative predictability of river discharge. Accordingly, this sequence allows us to begin to examine variability in the Rio Grande's discharge over a much longer period than what gauging station data can provide. To begin this analysis, the ring series was then divided into 50-year intervals and the occurrence of decades exhibiting standardized standard deviations greater than or equal to +1.0 and less than or equal to -1.0 were tallied (Table 1). I arbitrarily selected a cutoff of $\pm$ 1.0 simply because the evidence indicated that the bivariate regression model underestimated actual highs and lows, and underestimates actual variability.

An examination of Table 1 shows there has been a general shift from decades with low variability early in the 484-year sequence toward decades with progressively greater variability in later decades. A systematic comparison of the 249-year period prior to 1730 with the following 234-year period confirms that the variances between these two periods are significantly different ($F_{234,249} = 1.627$, $p = .0003$).

Second, our contemporary perceptions of the Rio Grande's character may be flawed as a result of our inability to remember (or even know) its history. In other words, our collective memory regarding the river's character may be erroneous since, as Table 1 shows, there have been **no** decades since the 1930s when there were large departures, either positive or negative, in decadal standard deviations so that we may think that the Rio Grande does not fluctuate wildly when, in point of fact, longer-term data suggests that this 1930-1970 period represents a short-lived anomaly.

Table 1
Frequency of Large Positive or Negative Standard Deviations by Time Period: Ft. Wingate.

Period	STD GE +1.0	STD LE -1.0	% of Decades Affected	Conclude
A.D. 1480-1520	0	2	.40	Less Variability Common
A.D. 1530-1570	0	3	.60	Less Variability Common
A.D. 1580-1620	2	1	.60	More Variability Common
A.D. 1630-1670	0	1	.20	Negligible difference
A.D. 1680-1720	1	1	.40	Equiprobable
A.D. 1730-1770	2	1	.60	More Variability Common
A.D. 1780-1820	2	0	.40	More Variability Common
A.D. 1830-1870	2	1	.60	More Variability Common
A.D. 1880-1920	2	0	.40	More Variability Common
A.D. 1930-1964	0	1	.20	Negligible Difference

To better underscore the shift that transpired over this period, the entire sequence was divided into two 250-year time periods and the occurrence of decades showing large positive or negative standard deviations were then tallied (Table 2). Table 2 shows clearly that there has been a shift since about 1729 from decades with relatively low variability to decades with much higher variability. This is what my old statistics professor, Dr. Dennis Young, used to call the inter-ocular impact finding; you don't need to run a statistic to appreciate that this is a significant difference (Fisher's Exact p = 0.02). In short, the river's discharge has been more variable over the past two centuries or so compared with the preceding two centuries.

Table 2

Period	No. of decades where STD is GE +1.0	No. of decades where STD is LE -1.0
A.D. 1480–1720	3	8
A.D. 1730-1970	8	3

On a similar note, we may not fully appreciate how different the average annual discharge of Rio Grande has been over the past few centuries. For example, based on the demonstrated correlation between ring widths and discharge presented here, fluctuations in either (a) the *relative proportions* or (b) *absolute numbers* of decades exhibiting large deviations from the long term average provides information about the river's flow.

To evaluate such fluctuations, the number of decades where the average annual ring width fluctuated above +1.0 or below -1.0 were tallied (Table 3).

Table 3

Period	No. of decades where AVG is GE +1.0	No. of decades where AVG is LE -1.0
A.D. 1480–1720	2	3
A.D. 1730-1970	6	5

Two facts emerge from this analysis. First, the **relative proportions** of decades exhibiting large positive or negative deviations in annual ring width–and, by extension, annual discharge–do not appear to have changed substantially over these two broad time periods. However, what is notable is that the **absolute number of decades** exhibiting significant deviations has increased dramatically since 1730. During the 249 years prior to 1730, there were only 5 decades where the average tree ring widths exceeded $\pm$ 1.0–only 20% of the time series. In contrast, during the 245 years *since* 1730, there have been a total of 11 decades where average tree ring widths exceeded $\pm$ 1.0; a more than doubling in the frequency to 44% of this subset of the time series. This coincides well with the rather high frequency variations indicated by analyses of coefficients of variation.

This second finding is important to us here today. The fact that a larger number of decades fluctuate well above or well below the long term average confirms that the annual discharge of the Rio Grande has been more variable, and, by extension, less predictable, since 1730. Moreover, the fact that there has been only a single large *negative* deviation (i.e., the drought of the 1950s) since 1930 may be lulling us into a false sense of security regarding the Rio Grande's predictability with respect to average annual discharge.

To briefly summarize, what I have tried to present today is a simple model of long-term variability in the flow of the Rio Grande. What I have shown that there is a significant correlation between tree-ring fluctuations and gauged river discharge during the period A.D. 1896-1964. Using a statistical model based on this correlation, I have then retrodicted variations in the Rio Grande's discharge extending back in time to A.D. 1480.

Analyses of fluctuations over this 484 year period suggest that the Rio Grande has been much more variable since A.D. 1730, both in terms of average discharge and decadal variability in average discharge. Since 1930, the Rio Grande has exhibited relatively little variability compared to the entire 484-year period for which discharge can be modeled. This suggests that our contemporary perceptions of the Rio Grande's characteristics, particularly with regard to its inherent variability in annual discharge, may be skewed. The seeming lull since 1930 may presage a return to relatively less variable conditions that, for example, typified the period between 1480-1730. If so, then it is also likely that we face the prospect of receiving average annual flows that may be as much as 10–15 percent *below* estimates based on gauging station data. On the other hand, this seemingly less variable period since 1930 may simply be a pause before the river returns to the extreme variability of the past 250 years (Stockton et al. 1983:315).

In the absence of additional information, we should plan our water use based on far more conservative estimates. Gauging station data from San Marcial between 1896-1964 indicate that "long-term" discharge averaged 940,417.4 acre-feet. In contrast, the far more long-term average estimated using proxy data from 1480-1895 indicate that the long-term average may be more on the order of 832,193 acre-feet, a difference of 13 percent *below* the nominal gauged annual flow of the Rio Grande at San Marcial. If we want to undertake planning on the basis of gauging station data that are 13 percent *above* the much longer term estimated average discharge, then, to borrow a turn of phrase from Charles Dickens' Tiny Tim, "God bless us, every one." Quite frankly, I don't think we can afford that luxury. A probability density histogram based on reconstructed annual discharge between A.D. 1480 and 1964 suggests that we should be planning our water use on higher–probability values of between 550,000 and 750,000 acre-feet (Figure 7).

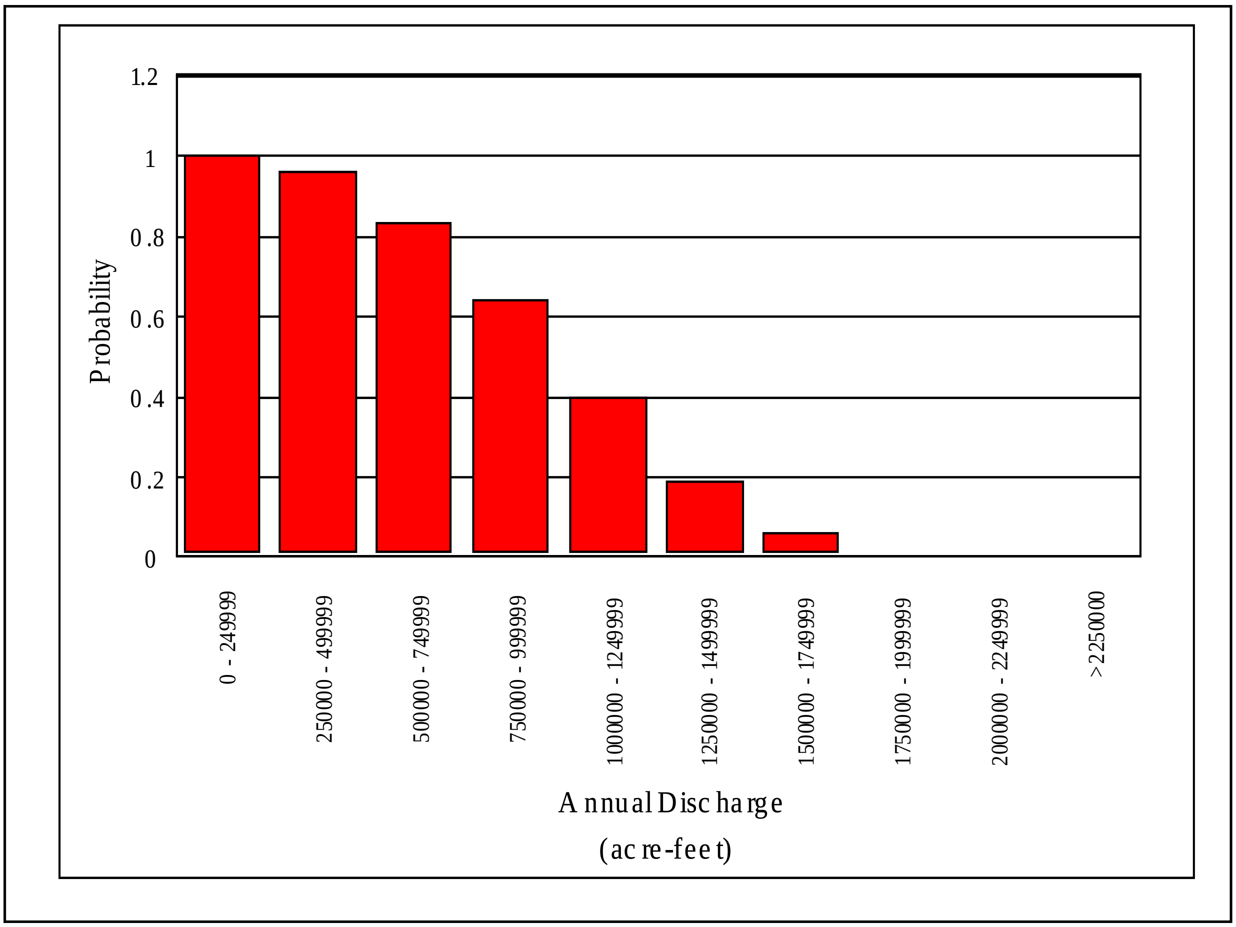


Figure 7. Probability density histogram of acre-foot discharge at San Marical based on Reconstructed discharge between A.D. 1480 and 1964.

As an anthropologist, I have spent considerable time studying past civilizations in arid lands that relied on surface water. Most of these societies failed. Analyses suggest that they failed for three reasons:

1. They overestimated the amount of water available in the rivers on which they depended;
2. They underestimated annual variability in discharge, and
3. They underestimated the frequency, persistence, and recurrence intervals of extreme low-flow events

Unlike earlier societies, we have employed two pieces of technology that buffer annual discharge fluctuations: storage dams and groundwater pumping. However, storage dams are not necessarily effective and, as the 1950s drought so amply demonstrated when Elephant Butte Reservoir was virtually dry, this technology has already failed once in our lifetime. What saved us during the 1950s drought was our ability to pump groundwater. Thanks to this technology, what should have been a wake-up call turned into a moderate inconvenience.

Today, we find ourselves not only relying on surface water to meet our water needs, but, as well, pumping groundwater to meet these needs. It is not hard to envision a scenario, perhaps unfolding sometime between A.D. 2010 or 2020, when drought once again dramatically reduces surface water supplies. Unlike the 1950s, however, our continued withdrawals during the intervening years will have significantly depleted groundwater reserves and we will then find out, in spades, whether we should have used water in the fashion to which we are now accustomed. When–not if–this does happen, it may come as a shock to find that we, too, have repeated the mistakes of past civilizations and, like them, are faced with a water crisis..

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San Juan/Chama Project Water Use

PROJECT AUTHORIZATION

The San Juan/Chama (SJ/C) Project was authorized by Congress in 1962 through Public Law (P.L.) 87-483, which amended the Colorado River Storage (CRS) Act of 1956 (P.L. 84-485) to allow diversion of Colorado River Basin water into the Rio Grande Basin, New Mexico. The original planning projections for the SJ/C Project contemplated an ultimate diversion of 235,000 acre-feet (ac-ft) per year, with an initial phase development of 110,000 ac-ft. The initial phase is all that was authorized (by P.L. 87-483) and subsequently constructed. The project takes water from the Navajo, Little Navajo, and Blanco rivers, which are upper tributaries of the San Juan River, itself a tributary of the Colorado River, for use in the Rio Grande Basin, New Mexico. The New Mexico Interstate Stream Commission is responsible for prioritizing which entities can contract for the water and what their allocation will be.

PROJECT FEATURES

Only Phase One of the SJ/C Project was authorized and built. Full development of the project included an additional thirty miles of tunnels, and three regulating reservoirs in the San Juan Basin. The complete project could have made year-round deliveries possible with a legislated allowable maximum annual diversion of 270,000 ac-ft, that included three units, the Cerro, Taos, and Llano.

The SJ/C Project that was built includes three diversion dams in the San Juan Basin of Colorado–the Blanco, Little Oso, and Oso, and includes three tunnels totaling 27 miles. The project included Heron Dam, modification to El Vado outlet works, and the Pojoaque Unit, which includes Nambe Falls Dam.

Project Diversion Dams and Tunnels

The northern most facility is Blanco Diversion Dam on the Rio Blanco. It diverts water to Blanco Tunnel, with a capacity of 520 cubic feet per second (cfs), and transports water 8.6 miles from the Rio Blanco southward to the Little Navajo River. There the Little Oso Diversion Dam diverts flows up to 150 cfs, from the Little Navajo River to the Oso Tunnel, and joins with flows from Blanco Tunnel. Oso Tunnel is a concrete lined structure with a capacity of 650 cfs, is 5.1 miles long and transports water from the Little Navajo River to the Navajo River. The southern most facility is Oso Diversion Dam, which can divert up to 650 cfs from the Navajo River to Azotea Tunnel to join with flows from Oso Tunnel. The 12.9 miles of concrete lined Azotea Tunnel has a capacity of 950 cfs and transports water from the Navajo River, under the

Continental Divide to Azotea Creek in the Rio Grande Basin.

Minimum bypass requirements were established in PL 87-483 8(f). This provides monthly minimum amounts of water, as defined in acre-feet, to be left in the Rio Blanco, Little Navajo River, and Navajo River. The amount of water diverted into Heron Reservoir is a function of water availability on each of these three tributaries to the Colorado River. While there are upper limits to the amount of water that can be diverted into Heron Reservoir, sometimes the limiting factor to these diversions is the amount of water that must be left, or bypassed, in each of these three water courses.

SJ/C annual diversions legislated limits include a total diversion ten-year moving average that cannot exceed 1,350,000 ac-ft, and diversions per year cannot exceed a maximum of 270,000 ac-ft. The majority of project diversions occur during April, May, and June, which coincide with spring runoff.

Heron Dam and Reservoir

From the Azotea tunnel outfall on Willow Creek, this water flows downstream to Heron Reservoir, which is the primary regulating and storage reservoir for the project. Heron Dam is located on Willow Creek just upstream of the confluence with the Rio Chama. The dam is an earth fill structure, 269 feet high, which forms a reservoir with a conservation capacity of 401,320 ac-ft, and a surface area of 5,950 acres. The spillway has a capacity of 660 cfs, and the outlet works has a capacity of 4,160 cfs. The operation and maintenance of the facility are performed by Reclamation.

Heron Reservoir is operated in compliance with the Rio Grande Compact. There are no provisions for storage of Rio Grande water, also referred to as natural or native water, in Heron Reservoir. Flows from Willow Creek that are not SJ/C or transmountain water, and inflows to the reservoir from the Rio Chama upstream of the dam, as measured at La Puente, are bypassed through the reservoir. SJ/C water must have a downstream destination, and is beneficially and consumptively used in New Mexico. Reclamation will not contract for more than the firm yield of 96,200 ac-ft.

San Juan/
Chama
Project Water
Use

Two basic principles control the water released from Heron Reservoir. The first concerns depletions to the river from groundwater pumping. These depletions are offset by releases of SJ/C water from Heron Reservoir. The New Mexico Interstate Stream Commission determines the amount of water needed to be released to offset these depletions, and recommends when to make the release.

Releases are then coordinated through the SJ/C contractors for release of this offset water. Secondly, SJ/C project water is delivered to contractors downstream of Otowi. Some of these releases include project water delivered to the City of Albuquerque to maintain a 50,000 ac-ft permanent recreation pool in Elephant Butte Reservoir, and the City's agreement with the Interstate Stream Commission for up to 5,500 ac-ft, with an option for 1,500 ac-ft, to maintain the sediment pool at Jemez Canyon Reservoir, (the Jemez exchange contract expires in the year 2000), and the Middle Rio Grande Conservancy District (MRGCD) for supplemental irrigation water. SJ/C water is also released to maintain a 1,200 surface acre permanent pool for recreation and fish and wildlife purposes at Cochiti Reservoir, 5,000 ac-ft is delivered to Cochiti to offset evaporative losses associated with maintenance of this pool.

Under the contracts, there is no carry-over provision for SJ/C project water in Heron Reservoir. Contractors must take delivery of their water from Heron by December 31. The no carry-over requirement often results in contractors seeking storage for their unused water in reservoirs downstream of Heron. El Vado, Abiquiu, Jemez Canyon (by exchange), and Elephant Butte Reservoirs have all been used for storage of SJ/C project water.

El Vado Dam Outlet Work Modification

Construction of El Vado Dam and Reservoir was completed in 1935. It was originally constructed to provide conservation storage (currently 186,250 ac-ft) for MRGCD to provide water for irrigation. The operation and maintenance of the facility are performed by Reclamation, under an agreement with MRGCD.

Native Rio Grande water stored in El Vado is subject to the terms of the Rio Grande Compact. The two main compact restrictions on native water in El Vado are that Rio Grande water cannot be stored when Elephant Butte usable water is less than 400 ac-ft, and Rio Grande water will be held in storage to the extent of New Mexico's accrued debit. There is storage provided at El Vado for Indian Prior and Paramount water rights. The Rio Chama diverters have senior direct flow rights, which are bypassed through the dam.

Water imported into the Rio Grande namely SJ/C project water can be stored in El Vado but is not subject to provisions of the Rio Grande Compact. As part of the SJ/C Project, the outlet works at El Vado Dam were enlarged so that Project releases from Heron Reservoir could pass unimpeded through the dam. The outlet works capacity was enlarged to pass 6,600 cfs. Construction on the modification began in 1965 and was completed in 1966.

Nambe Falls Dam, Pojoaque Unit

The Pojoaque Tributary Unit provides 1,030 ac-ft of supplemental water for approximately 2,768 acres of irrigated land. The storage feature for the Unit is Nambe Falls Dam and Reservoir located on the Rio Nambe. The dam is a concrete and earth embankment structure 150 feet high, which forms a reservoir with a capacity of 2,020 ac-ft. Construction of Nambe Falls Dam began in June 1974 and the dam was completed June 1976. Reclamation is responsible for operation and maintenance of Nambe Falls Dam, however, this function is performed by the Pojoaque Valley Irrigation District under an agreement with Reclamation.

The water stored in Nambe Falls Reservoir is natural to the Rio Grande Basin, but the reservoir is operated as if it were SJ/C water. SJ/C Project water is released from Heron Reservoir to offset depletions of natural water as a result of reservoir operations at Nambe Falls Dam. With this operation objective, the flows at the Otowi river gage are not impacted by the Unit.

Nambe Falls Reservoir fills and spills every year usually in the spring. The distribution of project water is shared among the Indian Pueblos of Nambe, Pojoaque and San Ildefonso who jointly get 33.92%, and the non-Indian users served by Pojoaque Valley Irrigation District, who receive 66.08%.

San Juan/ Chama Project Water Use

San Juan /Chama Project Allocation of Water Supply for a Total Firm Yield of 96,200 ac-ft
(category of use shown in parentheses)

48,200 ac-ft	City of Albuquerque, (M&I)
20,900 ac-ft	MRGCD, (irrigation)
6,500 ac-ft	Jicarilla Apache Tribe (M&I)
5,605 ac-ft	City of Santa Fe, (M&I)
5,000 ac-ft	Cochiti Reservoir Recreation Pool, (recreation)
1,200 ac-ft	Los Alamos County, (M&I)
1,030 ac-ft	Pojoaque Valley Irrigation District, (irrigation)
1,000 ac-ft	City of Espanola, (M&I)
500 ac-ft	City of Belen, (M&I)
400 ac-ft	Town of Taos, (M&I)
400 ac-ft	Village of Los Lunas, (M&I)
400 ac-ft	Town of Bernalillo, (M&I)
60 ac-ft	Village of Red River, (M&I)
15 ac-ft	Twining Water and Sanitation District, (M&I)
4,990 ac-ft	Contracts under consideration with:
2,000 ac-ft	San Juan Pueblo
2,990 ac-ft	Taos Area

Possible Impacts from Future Changes to SJ/C Water Operations

These impacts arise from changes in water operations due to water users developing diversions for taking delivery of their water for municipal and industrial uses. In the past these SJ/C water contractors have entered into third party contracts for delivery and use of SJ/C water. Most of these contracts are expiring soon, which will change how SJ/C water is moved through the system. Following is a summary of some of these possible changes. The intent of the author is to list the possible changes, but keep in mind that the impact of these changes has not been fully analyzed. Some changes may enhance and some may reduce the amounts of actual wet water in the river. Both quantity and timing of releases are also critical to overall water management in the basin.

Releases to Enhance Rafting and Fish between El Vado and Abiquiu Reservoirs

In 1988, PL 100-633 was passed to designate approximately 4.6 miles of the Rio Chama between El Vado and Abiquiu as a Wild and

Scenic River. After this designation, a group of people came together to identify management strategies and developed the Rio Chama Instream Flow Assessment. One strategy adopted was to manage the timing and magnitude of SJ/C releases to provide instream benefits for the Rio Chama. Effective and efficient management of deliveries of project water provides conjunctive benefits for fisheries and recreation. During the non-irrigation season deliveries downstream of El Vado Dam enhance winter brown trout spawning, and fish habitat in general. In addition, for an eight-week period each summer, movements of large flows on weekends and lower flows during the week from El Vado to Abiquiu Reservoir provide enhanced boating and rafting experiences through the designated Wild and Scenic reach of the Rio Chama. This flexibility in water deliveries is made possible by an agreement between the City of Albuquerque and MRGCD, where water is borrowed from the City pool at Abiquiu, and paid back to MRGCD pool in El Vado with deliveries from Heron.

First, releases from El Vado support rafting. These releases are often available during spring runoff with native flows, and from mid-July to the end of August with a borrow-payback scheme between the City of Albuquerque and MRGCD with SJ/C water. In April, May, and June, MRGCD uses native water in the main stem of the Rio Grande, and borrows SJ/C water from the City pool in Abiquiu Reservoir to meet irrigation demands in the middle valley. The water borrowed from Abiquiu is returned by MRGCD from El Vado Reservoir on weekends to help provide flows to enhance rafting.

Second, releases from El Vado provide fishery flows from the end of October through March. These releases are made possible through the movement of SJ/C water from Heron and El Vado to make various deliveries during the winter months. Recommended flows range from 150 to 400 cfs. Once the release is set for the winter, it is maintained from the beginning of October through the end of March. This provides a steady-flow condition that enhances fish reproduction, and early development.

Jemez Reservoir Sediment Pool

A sediment control pool at Jemez Reservoir, a Corps of Engineers facility, is maintained by the New Mexico Interstate Stream Commission to enhance the sediment-trap efficiency of the reservoir. This pool is maintained by exchanging SJ/C water to replace evaporation, and is usually topped off once a year. The ISC has been leasing 5,500 ac-ft of SJ/C water, with an additional option of 1,500 ac-ft, from the City of Albuquerque SJ/C for this purpose. This agreement expires in 2000.

San Juan/ Chama Project Water Use

Elephant Butte Recreation Pool

Under agreement between the City of Albuquerque and the New Mexico Department of Natural Resources, up to 50,000 ac-ft is available to maintain the recreation pool in Elephant Butte Reservoir through the year 2010. City of Albuquerque has an additional storage agreement to store up to 50,000 ac-ft of their SJ/C to maintain the federal recreation pool in Elephant Butte.

Power Generation

Los Alamos County has an annual allocation of 1,200 ac-ft of SJ/C water. This allocation was originally obtained by the Department of Energy, but in 1998 these rights were transferred to the County. Los Alamos County has two power generation plants, one located at the outfall of El Vado Reservoir, with a capacity of 8 megawatts, and the other located at the outfall of Abiquiu Reservoir, with a capacity of 12.6 megawatts. Both can handle 900 cfs, while the minimum amount of water needed for power generation is approximately 140 to 200 cfs. Both generators are operated from run of the river and do not impound, restrict flow, or use SJ/C directly for power generation. However, the SJ/C borrowing and payback scheme currently going on greatly enhances the County's ability to generate power.

MRGCD Minimum Flow Agreement with the City of Albuquerque

This agreement expires at the end of 2000, and has provided a minimum flow of 250 cfs at Central Street Bridge during the irrigation season. This agreement was made prior to the City's Southside Water Reclamation Plant upgrade to improve water quality. The purpose for providing a minimum flow was to furnish water for dilution of the treatment plant effluent to meet water quality permit requirements. Currently the City provides MRGCD with 20,000 ac-ft of SJ/C water to maintain these flows.

Reservoir Fluctuations

With the development of both the City of Santa Fe and the City of Albuquerque water diversion projects putting their SJ/C water to municipal and industrial (M&I) use, there will be greater reservoir fluctuations at Heron, El Vado and Abiquiu.

Endangered Species Operations, Supplemental Water Contracts

Many SJ/C contractors are leasing the use of their water to Reclamation which in turn, gives it to MRGCD to use for irrigation. MRGCD then allows their native water to flow in the river to support the Rio Grande silvery minnow. The two largest contractors for this supplemental water have been the cities of Santa Fe and Albuquerque. When the cities start taking delivery of their SJ/C water for municipal and industrial use, there will be less water for Reclamation to contract for to support silvery minnow flows.

Rio Chama Acequias

Rio Chama Acequia Association has senior native water rights on the Rio Chama. The New Mexico Interstate Stream Commission administers these water rights. El Vado may not operate to the detriment of the senior water right holders below Abiquiu Dam whose rights have a total diversion requirement of 140 cfs. Natural flow is bypassed under these conditions and Rio Grande storage in El Vado is reduced. Releases from Abiquiu Reservoir have been averaging approximately 75 to 100 cfs of native water daily during the irrigation season.

El Vado Storage of Native American Prior and Paramount Water

There are storage rights at El Vado Reservoir for Six Southern Indian Pueblos of the Middle Rio Grande: the Pueblos of Cochiti, Santo Domingo, San Felipe, Santa Ana, Sandia, and Isleta. Storage and release of Rio Grande water for these Indian Pueblos are not subject to the terms of the Rio Grande Compact. While the upper limit of Pueblo needs is reasonably predictable and controls the determination of storage, the actual amount released for Indian needs varies and is normally much less than the amount stored for the Indians. The release of Indian water is predicated on the prior and paramount water right land needs without constraint of the Rio Grande Compact.

San Juan/ Chama Project Water Use

Summary of Authorizations and Legislation Impacting or Associated with the San Juan/Chama Project

1908	*Winters Doctrine* decision is important for SJ/C Project approval; no State enforcement on Indian Reservations.
1928	Colorado River Compact is ratified, establishing allowable depletions for the Upper Colorado River Basin states.
1928	Indian Pueblo prior and paramount rights provides for a series of later statutes and operation and maintenance on reclaimed acreage and extends the agreement for delivery of prior and paramount rights in the operation of the MRGCD.
1933-34	Bunger Survey identifies SJ/C as a viable means of delivering water to Albuquerque.
1939	Rio Grande Compact, establishes compact delivery obligations for Colorado, New Mexico and Texas, and recognizes transmountain diversions.
1946	Reclamation performs a study that establishes New Mexico's Upper Colorado River Basin water right at 800,000 ac-ft.
1949	Upper Colorado River Basin Compact is ratified, setting New Mexico's share of Upper Colorado river water to 11.25%.
1950	Secretary of Interior asks San Juan Technical Committee to find ways for New Mexico to use its Upper Colorado River Basin allotment.
1956	Colorado River Storage Act, provides for a non-power generating storage facility on the Rio Chama.
1962	PL 87-483, Navajo Indian Irrigation Project (NIIP), and SJ/C Project are authorized jointly, limiting diversions for the SJ/C to 110,000 ac-ft, down from the original 235,000 ac-ft. Project water uses were identified for municipal, domestic, industrial, recreation and fish and wildlife. The Navajo Council agreed to both projects, reducing their claims in exchange for NIIP. One big unknown for future water management is how water shortages will be shared.
1964	PL 88-293 establishes a permanent pool in Cochiti Reservoir for recreation, fish and wildlife purposes.
1974	PL 93-493 authorizes Elephant Butte Recreation Pool, (Jicarilla Apaches file suit after BOR contracts for storage of SJ/C at Elephant Butte. Albuquerque is prohibited from storing SJ/C).
1981	New authorization allows the Secretary of Interior to contract with others to store their SJ/C water in Elephant Butte and Abiquiu reservoirs.
1981	PL 97-140 provides authorization for storage of SJ/C water in Abiquiu (200,000 ac-ft), and Elephant Butte reservoirs.
1988	PL 100-522 provides authorization for storage of Rio Grande (200,000 ac-ft) water in lieu of SJ/C water in Abiquiu.

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Current and Projected San Juan/Chama Water Use for the City of Santa Fe

Given what we have heard today, Y2K looks like a walk in the park. You all look like you're ready for some refreshments and one of the advantages of speaking last is that you get to keep your presentation very brief.

I'll start today with the City of Santa Fe's historical uses of San Juan/Chama water. Our contracted amount of San Juan/Chama water is 5,605 acre-feet, and as you saw during Jaci Gould's presentation, we have a small piece of the pie. We have some "have to" requirements like 2,000 acre-feet per year that are dedicated to our Buckman Well Field offset. The Buckman wells supply roughly 50% of the city's annual and peak demand. The Buckman Well Field is a post-1956 water right requiring any impacts to the Rio Grande or any of its tributaries be offset as calculated by models for particular basins by the Office of the State Engineer. Our impact to the Rio Grande, as we speak today, is about a third of our pumping at Buckman. We pump 6,000 acre-feet on average requiring us to offset about 2,000 acre-feet per year. However, that offset requirement increases over time and it will approach a one-for-one ratio, instead of the current situation where we're pumping three and offsetting one. The other "have to" that is absolutely required is the transportation costs associated with releasing water from Heron and getting it to the point of diversion, which in our case, is near the Otowi Gauge. It has been determined that there is about a 2% loss rate that must be applied to San Juan/ Chama water. That represents another "have to" as far as our consumption uses go right now.

There were some issues that occurred during the 1970s during a period when New Mexico was in a debt situation. The City of Santa Fe has two reservoirs located above town that supply, in a good year, about 40% of the city's water supply. Roughly two-thirds of the water in those post-compact reservoirs are considered storage capacity, and one-third is considered to be pre-compact. When we are in a debit situation, in theory, we are not supposed to use any of our water that is locked in storage in those two reservoirs. Given that we had excess water in the system up in the San Juan/Chama Project, we were able to work with the state engineer and the Middle Rio Grande Conservancy District (MRGCD), and others, on methods for offsetting impacts to the water stored in our compact space. In essence, it was a one-for-one exchange. We were able to use our surface water from the Santa Fe River in exchange for running San Juan/Chama water down the Rio Grande to offset any compact implications.

Other things we have done in the past and will continue to do, in the near future anyway, include our option of offsetting our storage payments to the MRGCD, with whom we have a contract to store our excess supply at El Vado, and our option of using some of our San Juan/Chama water to pay for our storage costs, or of paying $2.50 per acre-foot per year, which is an alternative.

We've entered into agreements on occasion when MRGCD needed supplemental irrigation water in low years. They would borrow from us and we have been paid back as of this date. There also are evaporative losses associated with these transfers and those constitute "have to" requirements. We store water in Heron and have it released on an "on-call" basis, so to speak. It is highly unlikely that we will completely eliminate the need to store San Juan/Chama water in El Vado and Abiquiu, but over time the need to store excess water diminishes as we consume our full amount.

Concerning operational uses for minimum flows and boating on the Chama, we've essentially provided operational flexibility to the Bureau of Reclamation to use our contracted water to enhance flows both above and below Abiquiu Dam for minimum flows and boating opportunities. More recently, we have leased water to the Bureau of Reclamation for supplemental Middle Rio Grande operations and silvery minnow minimum flow requirements. Oops, I blew it, that is not the way I'm supposed to describe it. For you Compact people in the room, we will actually be releasing San Juan/Chama water for irrigation diversion so that MRGCD can use natural water to supplement the Rio Grande for silvery minnow habitat.

Concerning future uses of San Juan/Chama water, we are implementing the 40-year water plan that we developed, which calls for us to exercise our contract rights to the fullest extent. What that entails is putting together an infrastructure system that allows us to consume the imported water that we have been contracted and paying for since the mid 1970s. Currently, in a good year, we use 60% groundwater and 40% surface water to meet our demands. In a dry year, that can drop down to an 80:20 ratio, like we experienced in 1996. To enhance our ability to meet existing demands and diminish our reliance on groundwater, we want to flip that ratio. In a normal year, we only want to consume about 20% from groundwater in our well fields and meet demands by using 80% surface water. That would allow us to bank our groundwater for the possibility of an 80:20 future scenario if indeed the drought predictions prove correct.

Current and Projected San Juan/ Chama Water Use for the City of Santa Fe

The whole purpose of the San Juan/Chama Project that Steve Reynolds, Stewart Udall, Presidents Kennedy and Johnson and everyone else who was involved in the original authorization of the project was to provide imported water to be consumed 100%. Through direct diversion on our part, less our transportation losses, we would be able to obtain full use of our return flow. The implementation of our program allows us to maximize our return flow options and shifts existing non-potable demands from potable to treated effluent. For example, right now we have a couple of large golf courses and facilities using potable groundwater for irrigation and it would be easy to convert those to treated effluent. Another method for full utilization, with the right infrastructure, would be some kind of method to enhance our return flow credit opportunities by figuring out a way to get the return flow back to as close to the point of diversion as possible. By doing so, you get a one-for-one return and then you can take your original diversion over time so in essence you are able to triple it. If we have the appropriate infrastructure, we can take our original diversion and consume about 40% of it on the first-time through, and return 60%, which then allows us an additional diversion. That is important because we are dealing with a closed system that allows you to consume fully the San Juan/Chama water within the municipality.

We also are looking toward using the Santa Fe River to recharge treated wastewater and consider whether there would be effective groundwater recharge if we were to put it into the stream channel of the river. Discharging effluent into the river upstream from the downtown area would also have a secondary benefit of aesthetics and recreation.

What are the implications of our implementation plan? What we are really saying is that in Santa Fe, if we're allowed to fully implement the program we are proposing, we can virtually eliminate ourselves from markets for native water on the Rio Grande. If we are not able to implement our plan or to take full advantage of our San Juan/Chama water, we are back in the business of trying to find native flows. It is critical that we implement this program. We have been able to convince our congressional delegation of how critical the situation is and they have been very helpful in assisting us.

This situation has presented us with opportunities to develop some focus for minimum flow and stream-bank improvement programs on some of the degraded reaches of the Santa Fe River. We believe that if we combine our treated effluent efforts with some of the stream-bank enhancements, we can actually improve riparian conditions and degraded river situations.

Another implementation aspect is that if we take our San Juan/Chama allocation in a more uniform manner, our operations could actually enhance the base flows of the Rio Chama, primarily below Abiquiu Dam to Otowi bridge–our point of diversion. But this could all lead, however, to problems with flood water recreation. However, I think over time if all the San Juan Chama contractors begin doing exactly what we are proposing, flat water recreation in the Rio Chama is going to become somewhat nonexistent in the future as I see it, unless we do some other water banking and native flow storage up there. But that's kind of a sleeping giant politically.

By removing ourselves from the native flow situation and by giving ourselves the flexibility to move back and forth between groundwater and surface water, I think that on at least an incremental basis, we can enhance the minimum flows on the Rio Grande during critical periods. However, it is going to take an awful lot of infrastructure, planning, and cooperation with all the municipalities in the district as well as some other folks who are involved. There are times when I say that we can squeeze that turnip Steve Hansen was talking about a little bit tighter during critical low-flow periods and keep some of those riparian habitats on the Rio Grande in good shape.

Thank you again for bearing with us this afternoon and I'll see you at the bar.

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New Mexico's Obligations and Compliance under the Rio Grande Compact

The Rio Grande Compact was signed in Santa Fe, New Mexico in 1938 following more than a decade of negotiations and four decades of controversy regarding the relative shares of this desert river by three states and two countries. The controversies regarding use of water from the Rio Grande prior to the Compact resulted in the "Rio Grande Embargo" by the Secretary of the Interior in 1896, a treaty with Mexico requiring delivery of 60,000 acre-feet annually at Juarez signed in 1906, an interim compact which froze water development in 1929, and a United States Supreme Court lawsuit by the State of Texas against New Mexico and the Middle Rio Grande Conservancy District in 1935. The Rio Grande Compact became law in 1939 when it was approved by the legislatures of the three signatory states and the United States Congress.

The Compact was developed for the purposes described in its introduction:

- "to remove all causes of present and future controversy among these States and between the citizens of one of these States and citizens of another State with respect to the use of the waters of the Rio Grande above Ft. Quitman, Texas"
- "for the purpose of effecting an equitable apportionment of such waters"
- "for interstate comity"

The Rio Grande Compact apportionment of water reflects uses at the time it was being negotiated. Large-scale irrigation systems were developed in the San Luis Valley in Colorado in the late 1800s. By 1890, most large canal and ditch systems now in use had been constructed. Colorado lands irrigated from the Rio Grande totaled more than 600,000 acres prior to the Rio Grande Compact. The Rio Grande Project–including Elephant Butte Reservoir, which was completed in 1916–was developed by the Bureau of Reclamation to serve more than 155,000 acres of irrigated land in New Mexico and Texas. (The majority of this irrigated land–57percent–is in New Mexico.)

In contrast, acequias in the Middle Rio Grande in New Mexico were irrigating approximately 40,000 acres, far less than Colorado and the Rio Grande Project. The Middle Rio Grande Conservancy District began construction in 1930 to consolidate most of the acequia systems and provide flood control and drainage services. At the time the Rio Grande

Compact was being negotiated, much of the formerly irrigated land had been abandoned due to water-logging. Subsequent reclamation and irrigation system development activities in the Middle Rio Grande between Cochiti Dam and Elephant Butte Reservoir irrigated a maximum of perhaps 80,000 to 90,000 acres of the approximately 123,000 acres that were permitted by the State Engineer. Middle Rio Grande total irrigated land today may be about 60,000 acres.

Major features of the Rio Grande Compact include the following:

- Colorado is required to deliver water to New Mexico at the state line. Colorado's annual delivery obligation is based on the annual flow of the Rio Grande at Del Norte and the flow of three tributaries. New Mexico's annual water allocation reaches a maximum of 405,000 acre-feet of the flow of the Rio Grande measured at the Otowi index gage plus the inflow to the Rio Grande between the Otowi gage and Elephant Butte Dam.
- New Mexico is obligated to deliver the remaining portion of the annual Otowi gage inflow to below Elephant Butte Dam. In an average year, when 1.1 million acre-feet of Rio Grande water flows past the Otowi gage, New Mexico is entitled to consume 393,000 acre-feet of that amount (see Figure 1).

New Mexico's Obligations and Compliance under the Rio Grande Compact

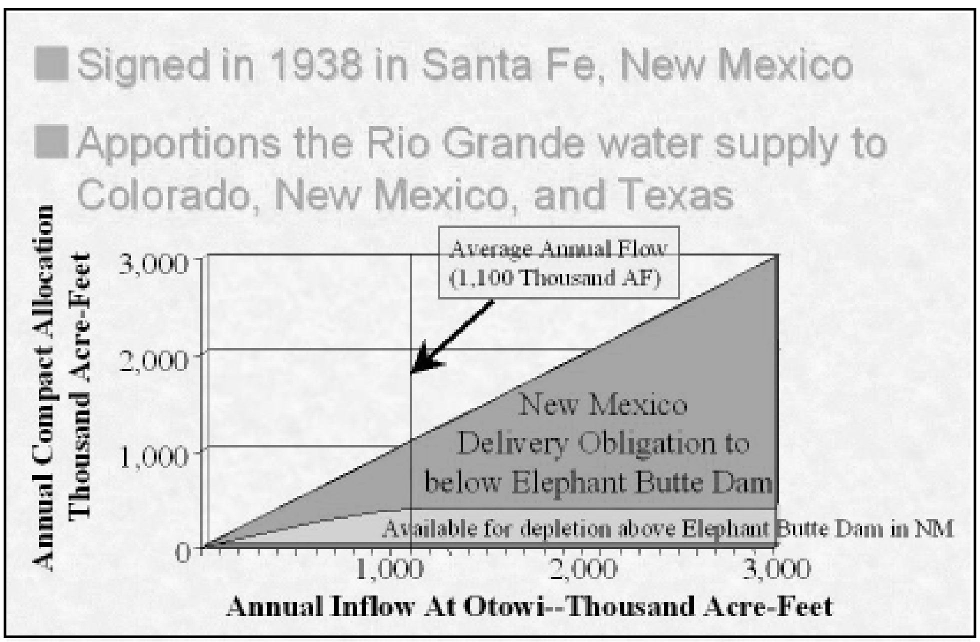


Figure 1. In an average year, when 1.1 million acre-feet of Rio Grande water flows past the Otowi gage, New Mexico is entitled to consume 393,000 acre-feet of that amount.

New Mexico's Obligations and Compliance under the Rio Grande Compact

- When the annual flow of the Rio Grande at the Otowi gage is very low, New Mexico may consume 43% of that water and must deliver the remaining 57% to below Elephant Butte Dam.
- When the annual flow of the Rio Grande at the Otowi gage is very high, New Mexico may consume only 13% of that water and must deliver the remaining 87% to below Elephant Butte Dam.
- New Mexico's deliveries are measured as the releases from Elephant Butte Dam plus the change in storage in Elephant Butte Reservoir.
- Evaporation from Elephant Butte Reservoir is accounted against New Mexico's Compact allocation of Rio Grande water.
- New Mexico is also allowed to consume all of the highly variable tributary inflows to the Rio Grande between the Otowi gage and Elephant Butte Dam. This includes flows from the Rio Jemez, the Rio Salado, the Rio Puerco, Galisteo Creek, and the Santa Fe River. In an average year, tributary inflows total about 100,000 acre-feet plus an unknown and small amount from minor ungaged tributaries.
- If depletion of Rio Grande flows in New Mexico above the Otowi gage change, the Otowi "index" flow is adjusted accordingly. No adjustments of this nature have been needed.
- The Compact requires annual water accounting and provides for a system of annual debits and credits.
- Colorado may accumulate up to 100,000 acre-feet of debits in its deliveries to New Mexico. New Mexico may accumulate up to 200,000 acre-feet of debits in its deliveries below Elephant Butte Dam.
- Water must be retained in storage in reservoirs constructed after 1929 to the extent of each state's respective debits and cannot be used. It must be released upon demand by the downstream states under conditions specified in the Compact. Reservoirs constructed after 1929 in New Mexico include El Vado Reservoir, owned by the Middle Rio Grande Conservancy District, and Nichols and McClure reservoirs, which provide a large portion of the Santa Fe municipal water supply.
- If storage in Elephant Butte Reservoir is less 400,000 acre-feet, neither Colorado nor New Mexico may increase the amount of water stored in reservoirs constructed after 1929.
- Spills from Elephant Butte and Caballo reservoirs are an important element of the Compact. Credit water spills first. Debits are reduced as the reservoirs approach full capacity to the point of elimination when the reservoirs are completely full.
- Normal total releases from Elephant Butte Dam and Caballo Dam are defined as 790,000 acre-feet per year. Releases in excess of that amount affect the calculation of spills.
- Water imported from the Colorado River Basin, including the San Juan-Chama Project supply, is not subject to Rio Grande Compact apportionment.
- The Rio Grande Compact does not affect the obligations of the United States to Indian Tribes or impair their rights.

Figures 2 and 3 illustrate New Mexico's historical annual water supply under the Rio Grande Compact. Figure 2 shows the variability in the amount of the flow of the Rio Grande at the Otowi index gage that New Mexico has been entitled to deplete. Figure 3 adds two other sources of water—that yielded by the tributaries between Otowi and Elephant Butte and the San Juan-Chama Project deliveries past the Otowi gage.

It should be emphasized that the Rio Grande Compact, and the State Engineer's duty to see that New Mexico complies with it, not only is an interstate commitment but also a commitment by New Mexico to see that New Mexicans living below Elephant Butte Dam receive their apportioned share of the river. The Compact provides an allocation of Rio Grande water inflows to New Mexico, not between New Mexico and Texas, but among water users in New Mexico above Elephant Butte Dam and water users in New Mexico and Texas downstream from the dam. However, it is the Texas Compact Commissioner who will see that the Compact is enforced if New Mexico does not comply with its obligations. That was the case when the State of Texas sued the State of New Mexico in the United States Supreme Court in 1951.

Figure 4 illustrates New Mexico's historical compliance with its Rio Grande Compact delivery

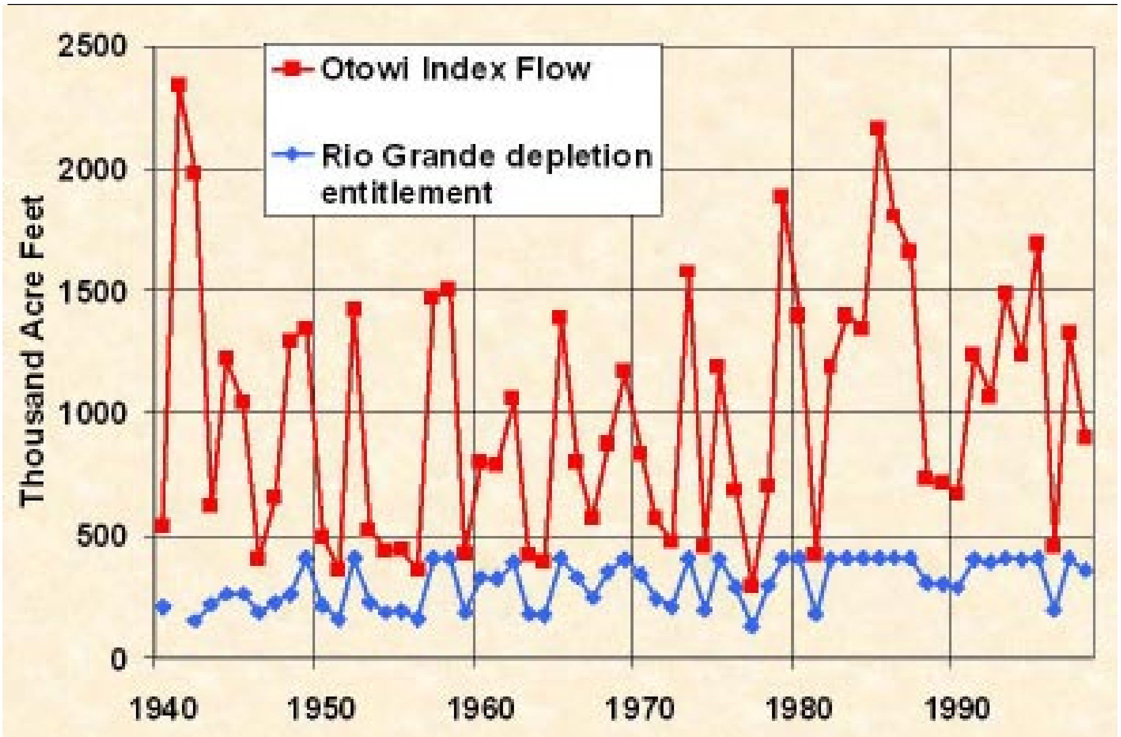


Figure 2. New Mexico's Share of the Rio Grande at Otowi

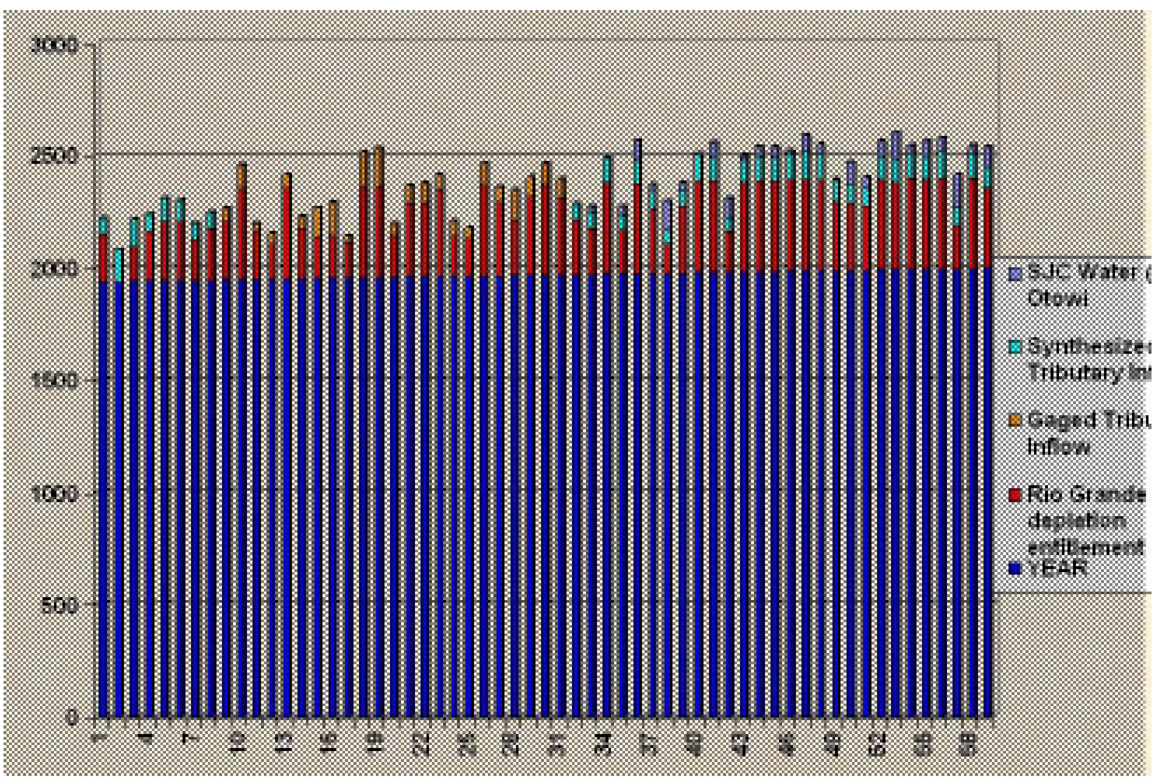


Figure 3. Rio Grande plus Tributaries and San Juan/Chama

New Mexico's Obligations and Compliance under the Rio Grande Compact

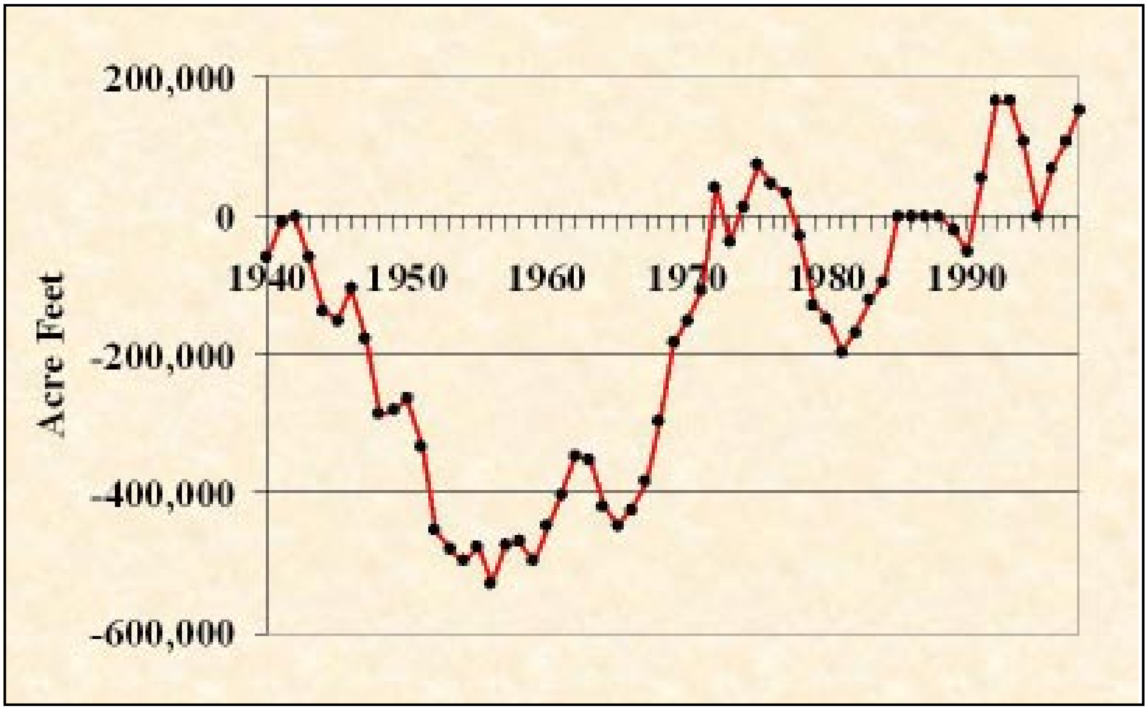


Figure 4. New Mexico's Rio Grande cumulative compact delivery

obligations expressed as cumulative debits and credits. New Mexico is currently in a net credit situation, but that is not the usual historical condition. The largest single factor in New Mexico's compliance has been the control of "natural" depletions. This has involved control of evapotranspiration from riparian vegetation, construction and maintenance of drains to "salvage" water that otherwise would be lost to evapotranspiration, maintenance of the river channel, and construction and use of man-made channels to deliver water downstream with fewer losses and depletions than transmission via the natural river channel. Conveyance of water via these more efficient channels has been an essential component of New Mexico's compact compliance.

Casual observers may think that New Mexico's compliance with the Compact is seemingly unmanaged and without effort. Nothing could be further from the truth. Major federal projects, including the Joint Middle Rio Grande Project and the Low Flow Conveyance Channel, have been and continue to be essential to New Mexico's recent and contemporaneous compliance. The Interstate Stream Commission has sponsored and provided funding for major water salvage and drainage projects that have contributed substantial amounts of water for beneficial uses and Compact deliveries. Ongoing river channel maintenance activities are essential to water delivery downstream and to reduce depletions of that water.

New Mexico's activities associated with its compliance of the Rio Grande Compact deliver obligations also have been highly controversial. Major litigation and legislative initiatives resulted from State Engineer Reynold's decision in 1956 that the effect of groundwater pumping on the river must be offset by the retirement of equivalent surface water uses. Supreme Court litigation brought by Texas during the drought of the 1950s and the associated Texas demand for release of water from the post-Compact El Vado Reservoir was complicated by Middle Rio Grande Pueblo water rights and issues and ultimately was resolved by the federal projects cited above.

"Natural" evapotranspiration of water dominates the depletions in the Middle Valley supplied from New Mexico's Compact share of the Rio Grande. In 1947, the Bureau of Reclamation concluded that riparian vegetation, wetted sands, and the river were losing more than 300,000 acre-feet annually to evapotranspiration. Water budget information from a 1992 Reclamation study indicates non-crop evapotranspiration, including evaporation from the river and the associated irrigation infrastructure, was about 250,000 acre-feet per year, compared to crop water depletions of about 130,000 acre-feet per year. "Natural" depletions charged against New Mexico's apportioned share of the Rio Grande also include evaporation from Elephant Butte Reservoir, which has averaged about 100,000 acre-feet per year over its history but has been much higher recently, about 180,000 acre-feet per year over the past 15 years.

This is very different from the situation in Colorado and the Rio Grande Project area below Elephant Butte Dam. Irrigated crop water depletions are predominant in those areas and reservoir evaporation is much lower.

Two factors in New Mexico's recent history of annual Compact delivery credits include augmentation of the river flows from (1) municipal pumping of groundwater and discharge of some of that mined groundwater to the Rio Grande as treated wastewater effluent, and (2) increased return flows from irrigation diversions that have been substantially augmented by San Juan-Chama project supplies. Neither of these will continue indefinitely into the future. Figure 5 shows cumulative losses and gains in three reaches of the Middle Rio Grande during the winter season when neither irrigation diversions nor riparian evapotranspiration is taking water from the river. The San Felipe to Bernardo reach shows significant changes from the pre-1972 flow regime that may be associated with return flows from municipal and industrial groundwater pumping in the metropolitan Albuquerque area and from return flows associated with irrigation applications of San Juan-Chama Project water. The San Acacia to San Marcial reach shows reduced depletions over the 1960s and 1970s that are associated with the full operation of the Low Flow Conveyance Channel in comparison with the earlier and later periods before the channel was constructed and diversions to the channel ceased in the mid-1980s.

New Mexico's Obligations and Compliance under the Rio Grande Compact

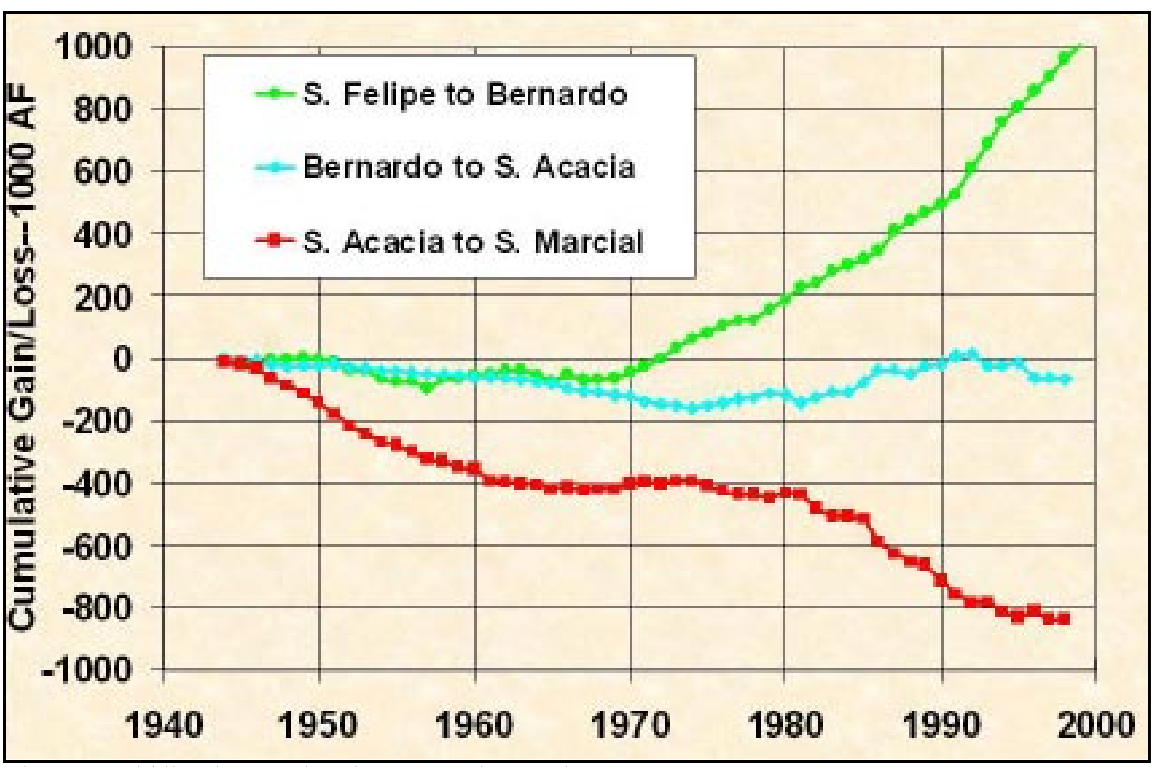


Figure 5. Middle Rio Grande Winter Accretions and Losses

Albuquerque and Santa Fe originally intended complete consumptive use of their allocations of San Juan Chama water associated with pumping groundwater interconnected with the Rio Grande. Both cities now plan to construct facilities for direct diversions of their allocations associated with the recent scientific conclusions regarding the ability of their wells to divert river water that can be offset with release of San Juan-Chama Project water.

New Mexico's contemporaneous compliance with its Rio Grande Compact delivery obligations will be challenged by drought, planned municipal direct use of San Juan-Chama water, or the water demands of the Rio Grande silvery minnow and avoidance of adverse impacts to its declared critical habitat. If silvery minnow demands are satisfied by conservation of existing irrigation losses and use of that conserved water in a manner that converts existing losses, which remain in the hydrologic system, to new depletions, New Mexico may not remain in compliance.

Non-compliance is an outcome that New Mexico must strive to avoid. Under-delivery resulting in net debits as allowed by the Compact will lock-up water in reservoirs constructed after 1929 upon which the Middle Valley and the City of Santa Fe depend. Debits exceeding the 200,000 acre-feet cumulative amount allowed by the Compact will land New Mexico in the United States Supreme Court. Texas officials in recent conversations with the State Engineer and with me have made that very clear.

"Active River Management" is the term State Engineer Turney has used to describe the general system of water use measurement and controls that New Mexico must define and implement. This system must:

- recognize the limits and variability of New Mexico's Compact-apportioned share of the river;
- effectively utilize the system of debits and credits the Compact provides; and
- maximize average water supply through conjunctive use of ground and surface water and the continued control of natural depletions.

As I see it, Active River Management has three main components:

- measurement and forecasting of annual river flows, New Mexico's depletion entitlement that can be taken from those river flows, and the portion of those river flows that must be delivered through New Mexico to downstream water users
- management and control of depletions, including the depletion of river flows caused by pumping groundwater that is hydrologically connected to the river and the depletions of river flows due to natural causes
- markets that work to transfer New Mexico's finite supply of water to new uses

The first two components require metering of water. River-flow forecasting is dependent upon measurement of river flows. The State of New Mexico's current 50 percent cooperative funding program for essential New Mexico stream gaging is not achieving as much actual measurement due to federal expense increases and federal funding curtailment. Some gages that would have provided needed information today have been abandoned. For example, tributary inflows to the Middle Rio Grande are much less thoroughly measured now than they were 30 years ago, even though our need for water and dependence on those tributary inflows is increasing.

Management of water depletions is essential. In the Middle Rio Grande, natural depletions are predominant. The State of New Mexico has controlled water depletions through water drainage, salvage, and construction, operation and maintenance of "efficient" water conveyance facilities. Continued control of natural depletions with these or other equivalently effective tools is imperative to New Mexico's compliance with its Compact obligations.

In her opening remarks for this conference, New Mexico Riparian Council President Andrea Linderoth-Hummel said that "riparian equals water." That is certainly true. Actually, to be more precise, riparian equals depletion of water. Andrea said, "we need to know how much water is being used where" and we need to know "how much is needed for this habitat which is so near and dear," referring to the Middle Valley's bosque. I couldn't agree more. Additionally, we need to determine how we will allocate New Mexico's limited Compact share of water between natural depletions and beneficial uses.

New Mexico must also manage and limit depletions for human uses, both in the Middle Rio Grande and in the Lower Rio Grande. This will require metering of diversions of water, deliveries to farms, and return flows. I know this is controversial in areas where metering has not been required. However, in river basins such as the Pecos and with users including Carlsbad Irrigation District and the Pecos Valley Artesian Conservancy District, metering is accepted completely and viewed as necessary to ensure that users of a common but limited water supply receive their due share.

Another element of Active River Management to limit total uses of water to New Mexico's allocation is, by law, priority administration. The priority system requires junior users to be cut off when the supply is insufficient to meet senior water rights. An effective system of enforcement will be required, at least initially.

Several speakers at this conference have described how Middle Rio Grande water supplies are highly variable. Contemporaneous supplies are higher than historical averages. The Rio Grande is visited routinely by severe drought. Planning is needed to determine the most effective conjunctive use of groundwater and New Mexico's Compact allocation of surface water, along with San Juan-Chama water, to meet water demand in years when the supply is limited.

Finally, an effective market is essential for transfer of water from water right owners who forego their use of water to those who have insufficient, junior, or no water rights but need water. Water user categories requiring additional water might include farms with high water-use crops requiring more water than available water rights will allow; growing municipalities; new industries contributing to economic development; and environmental users. However, markets cannot supply new uses of water without foregoing an equivalent amount of water use elsewhere. The capital of these markets must be wet water and specifically must not be dormant and unused water rights.

I was directed by the Interstate Stream Commission at its last meeting to prepare a plan for the Commission's use of accumulated balances in the two permanent income funds that it controls, subject to appropriations by the Legislature, to improve stream gaging and diversion and return-flow metering throughout the state over the next few years. The plan will be presented to the Legislature at its next session. The Interstate Stream Commission has requested substantial appropriations to address inadequate flow measurement in the Middle Rio Grande and to perform a detailed evaluation of current water depletions associated with beneficial uses and natural causes.

Thank you for the opportunity to speak to you regarding these critically important matters.

Charles T. DuMars is a professor of law at the University of New Mexico School of Law. Currently, he also is Acting Director of the Transboundary Resource Center at UNM's School of Law. He has taught courses in water law, constitutional law, comparative Mexican and United States law, and also Indian water rights law. He has served on committees for the National Research Council of the National Academy of Sciences related to water, including a study of protection of the Mexico City water supply in which he served as co-chair. He is the author of numerous articles in both English and Spanish relating to water law and Mexican environmental law. Chuck has worked on cases involving equitable apportionment of waters between states in the United States Supreme Court, interstate compacts, and currently is a Special Assistant Attorney General to the State of Georgia, where he was one of the principal draftsmen of the proposed Interstate Compact between Georgia, Alabama and Florida.

Consequences of Rio Grande Compact Noncompliance

What is an interstate compact? It is a federal law that preempts state law. It also is a contract enforceable in the U.S. Supreme Court by specific performance and by damage awards. These are very important facts we need to know when evaluating the possible remedies under the Rio Grande Compact.

The obvious purpose of an interstate compact is to allocate some quantity of water to each state that reflects their equitable share. The allocation mechanism that accomplishes that purpose is important, and there are essentially three, maybe four options.

One option is to decide that the upstream state will deliver a certain quantity of water every year–a certain number of acre-feet no matter what–at a delivery point. Another option is to apportion the total yield of the basin by percentage. A third option is to place a cap on consumption by the upstream states. Yet another option is to allocate a particular delivery requirement between one point and another, as was done in the Rio Grande Compact. To illustrate, I thought it would be interesting to look at the New Mexico compact allocations that reflect this point:

Discharge of Rio Trande at Otowi Bridge and Elephant Butte Effective Supply
(quantities in thousands of acre-feet)

Otowi Index Supply	Elephant Butte Effective Index Supply
100	57
200	114
300	171
400	228
500	286
600	345
700	406
800	471
900	542

(continued)

Otowi Index Supply	Elephant Butte Effective Index Supply
1,000	621
1,100	707
1,200	800
1,300	897
1,400	996
1,500	1,095
1,600	1,195
1,700	1,295
1,800	1,395
1,900	1,495
2,000	1,595
2,100	1,695
2,200	1,795
2,300	1,895
2,400	1,995
2,500	2,095
2,600	2,195
2,700	2,295
2,800	2,395
2,900	2,495
3,000	2,595

Figure 1 contains relevant language of the Upper Colorado River Compact. When possible, this is the preferred allocation method. The unknown factor, of course, is the total yield of the basin. At a minimum, everyone gets its share by percentage. Since everyone is involved in negotiating and working on the percentage allocations, you are not in a situation where people are going to go to court to fight over whether they are in compliance with the Compact. As a result, there has been no litigation of the Upper Colorado River Compact. I would not expect there to be because the Compact uses a percentage allocation system.

But now consider Figure 2, which is part of the Colorado River Compact. The top provision indicates a delivery requirement of around 7.5 million acre-feet a year. That provision has not been to court yet because, although there are a number of ambiguities elsewhere in the Compact, the lower basin states have been successful in foreclosing projects in the upper basin states so that the upper basin states cannot use their share of water. Hence, the upper basin states have naturally delivered the required quantities at the

UPPER COLORADO
RIVER BASIN COMPACT
ARTICLE III

(a) Subject to the provisions and limitations contained in the Colroado River Compact and in this compact, there is hereby apportioned from the upper Colorado river system in perpetuity to the states of Arizona, Colorado, New Mexico, Utah and Wyoming, respectively, the consumptive use of water as follows:

(2) to the states of Colorado, New Mexico, Utah and Wyoming, respectively, the consumptive use per annum of the quantities resulting from the application of the following percentages to the total quantity of consumptive use per annum apportioned in perpetuity to and available for use each year by upper basin under the Colorado River Compact and remaining after the deduction of the use, not to excee 50,000 acre-feet per annum, made in the state of Arizona.

state of Colorado....................51.75 percent
state of New Mexico..............11.25 percent
state of Utah...........................23.00 percent
state of Wyoming...................14.00 percent

Figure 1. Upper Colorado River Basin Compact, Article III.

Colorado River Compact
Article III

(a) There is hereby apportioned from the Colorado river system in perpetuity to the upper basin and to the lower basin, respectively, the exclusive beneficial consumptive use of 7,500,000 acre-feet of water per annum, which shall include all water necessary for the supply of any rights which may now exist.

Figure 2. Colorado River Compact delivery requirement as per Article III

delivery point. But again, the Compact is clear that you must deliver a specific amount of water over a specific period of time at a particular point.

This option is a very interesting way to do things because it gives complete and total flexibility to the upper basin states–as long as they deliver *X* amount at point *X*, how they get it there is their business.

Another option is one that seems like it would generally work but it has, in fact, generated the most litigation, not only in New Mexico but also between Kansas and Colorado, for example. This option limits the amount of water the upper states can consume by putting a cap on man-made depletions.

The Pecos River Compact, Article 3A states, "New Mexico shall not deplete by man's activities the flow of the Pecos River at the New Mexico - Texas line below an amount which will give to Texas a quantity of water equivalent to that available to Texas under the 1947 condition." Now that provision makes a lawyer's heart warm. The statement contains ambiguities fraught with the potential for litigation. What was the 1947 condition exactly? What did it mean? Was it referring to the beginning of the year or to the end of the year? What about growth in water wells? What constitutes "man's activities"? And so on. The result of that provision's interpretation–and I'm sorry to confess that partly due to my own efforts–is that it is now possible for downstream states to sue upstream states for non-delivery and get damage awards.

In the Pecos litigation, after a great deal of negotiation, Special Master Myers came up with a draconian decision that would require the retirement of large amounts of water to meet delivery requirements and make up for past under-deliveries under the Compact. The decision also included the concept of water interest. The result of this decision was very bad for New Mexico. Steve Reynolds, Peter White, and I worked with others to determine whether or not it would be possible to simply pay off the damages in dollars, rather than water. That issue went to the United States Supreme Court where it was ruled that because the Compact is essentially a contract, we might have the option of paying damages in dollars. When that decision came out, Texas argued that there should be close to a billion dollars in past damages for opportunities lost. One of the arguments I made was that because of the inefficiencies associated in raising crops in Texas, and because of the opportunity cost of labor, Texas should actually pay New Mexico for not allowing Texas farmers to farm and instead letting Texans work the oil fields!

Somewhere between those two extremes came out a fair compromise, I think. The parties negotiated with the excellent lawyers and hydrologists for Texas, and on the other side, New Mexico received some very good private counsel. Given what we learned from the Pecos litigation, let's look at the Rio Grande Compact.

Consequences of Rio Grande Compact Noncompliance

The good news on the Rio Grande Compact is that it is simple, that is to say, the delivery requirement is simple: if X amount of water passes a particular point, Y amount of water must arrive at another point. The amount is a ratio which is balanced 43 percent at the low end and 13-14 percent at the high end. That way, New Mexico gets the benefit of low flows. Thus, if X amount passes Otowi gauge, and Y arrives at Elephant Butte, the difference is the amount of water the middle valley gets to keep. If we don't get the required amount to the downstream point, then we are in violation of the Compact, which is something I will talk about momentarily.

We looked closely at the Pecos type of compact in our work designing compacts in the southeastern United States and rejected it, because the problem with this kind of compact is that it presumes constancy and an understanding of the operation of surface-river systems. There are a host of things that the upstream states cannot control, that nevertheless dramatically affect their ability to deliver water under the Compact. On the Pecos River, not only is New Mexico responsible for man's activities, but it is responsible for God's activities, and that is a pretty substantial task. Turning back to the Rio Grande Compact, what if New Mexico under-delivers? Is there a possibility that in the future there could be an action for damages against New Mexico? Look at the provision in Article 6:

"...in a year in which there is an actual spill of useable water or at the time of hypothetical spill, all accrued debits of New Mexico or Colorado or both, at the beginning of the year shall be canceled."

What does "all accrued debits" mean? If you look at another section of the Compact, it says,

"...accrued debits shall not exceed 200,000 acre-feet at anytime" along with some modifying language about reservoir levels, and so on. If an accrued debit means all under-deliveries are forgiven upon a spill, then there would be no actual damages because all the debits are wiped out. If it means all legal debits under the Compact are wiped out, but not excessive debits, then a different result might be obtained.

If you will recall, historically, there have been substantial under-deliveries over the amount authorized by the Compact. Litigation resulted, but the litigation in the 1950s was dismissed for lack of an indispensable party. The same result might not be obtained today. And so it is in my view, an open question remains: What does the *Texas v. New Mexico* damages ruling mean in the future for New Mexico Rio if there are under-deliveries under the Rio Grande Compact?

Suppose you are on the Interstate Stream Commission, or supposed you are the Governor of New Mexico, or you are the New Mexico State Engineer, and you read a Compact provision that says, "...accrued debits shall not exceed 200,000 acre-feet at any time." Suppose you have someone else saying that if you do exceed 200,000 acre-feet and you cause damage in Texas, you are subject to substantial damages? And suppose a federal agency is telling you that you are obligated to adjust the hydrograph on the river to protect endangered species and the adjustment may cause you to accrue debits that violate the Compact? You would be between a rock and a hard place certainly, because on one hand if you violate the Endangered Species Act, you can be fined or jailed, and on the other hand, if you follow the ESA, you will subject NM to damages under the Compact for under delivery to Texas. This would be an interesting exercise of choices assuming Mother Nature plays the cards that she has played historically, such choices may face New Mexico in the near future.

In addition to the remedies of damages, there are related issues. It is possible to obtain injunctive relief under a compact. Ideally, the downstream state in the lower Rio Grande would seek injunctive relief if there were any kind of accrued departures in excess of what is allowed. With respect to water quality, downstream states will maintain their rights to seek some kind of equitable proportional relief in the Supreme Court–assuming that such relief exists, I'm not sure that it does in the area of water quality.

Consequences of Rio Grande Compact Noncompliance

However, such relief is outside the Compact and is beyond the scope of this discussion. With respect to damages, a number of cases are pending before the Special Master. These cases ask the following interesting legal questions, the answers to which could substantially limit the right to damages. One very intriguing question involves the 11th Amendment of the U.S. Constitution, which precludes citizens of one state from suing citizens of another state. If the theory of damages is that the State–in the Pecos case we are referring to Texas–represents the citizens of the State as *Parens Patriae*, and it wants money for the damages, can one state require the other state to pay damages to them as trustee for its citizens? Would such an action violate the 11th Amendment? Can you make a state pay damages to individuals if the 11th Amendment would have precluded the individuals from suing the state in the first place? What about the situation where a state intentionally delays because it wants money rather than water? Can you get prejudgment interest if you are the downstream state? Can you consider secondary losses? To what degree might laches play a roll?

Finally and most significantly, one question that will be answered by the Supreme Court is whether the upstream state will have the option to choose to deliver water for damages or will that be a choice for the downstream state to make? How will that issue actually unpackage when it gets to the U.S. Supreme Court?

The point I want to stress here is that the Rio Grande Compact means what it says. The Compact specifies that if a particular amount of water passes a gage at one point, a certain amount of water must arrive at another point. The good news is that when it rains between the two gages or other nice things happen, a state is able to deliver water that wasn't anticipated. The bad news is that Mother Nature can change her mind–we have our knowledge of the historic hydrograph and the relationship between the river and its tributary inflows between those two points to remind us of that. And trouble may, not necessarily will, mean damages and that is a very significant fact about which we should all be concerned.

***John Hernandez** is a well known expert in the field of environmental engineering and water resources management. He has had administrative responsibilities at both state and national levels, has served as a consultant to industry and government, and he has been an expert witness in water pollution cases. Prior to obtaining his doctorate from Harvard Uni-versity in 1965, he worked for the Office of the State Engineer in the Dam Design Section (1954-57), and then for the New Mexico Department of Public Health as head of the water pollution control program. John taught engineering at New Mexico State University from 1965 to 1999, and in the mid-1970s he served for five years as NMSU's Dean of the College of Engineering. John retired from NMSU in 1999 and was named emeritus professor. His federal government service was in the early 1980s when he served as the Deputy Administrator for the U.S. Environmental Protection Agency, responsible for EPA's water pollution control legislation and regulatory program. From 1991-1995 John was an advisor to the New Mexico Office of the State Engineer and was assigned the task of developing a plan to ensure water deliveries to Texas on the Pecos River and the development of a five-year, $40 million technical assessment program for the Middle Rio Grande Basin.*

Do We Need Water Markets?

The title of my talk, and that of Lee Brown who follows me, is "Do We Need Water Markets?". The answer is, absolutely yes. Water is a scarce commodity. The rules that we have inherited for managing water resources in New Mexico are those that have come down from Hispanic and territorial years. The administrative procedures provided, particularly those related to the doctrine of prior appropriation, and the superior right of senior water-right holders, clearly show that water has always been a limiting factor to growth. Anytime you have a scarcity in an essential product, you're going to need some kind of market. And the reality is that we already have an active market in water rights. Lee Brown wrote, in a paper he prepared for the Middle Rio Grande Conservancy, that "when water becomes scarce, it acquires economic value often reflected in price, but always reflected in trade-offs in that one use must be given up in order to gain another." That's a simple, but powerful statement. Water transfers are worse than a zero-sum game as there are built-in inefficiencies that result in water losses that take place when you transfer water from one place or one use to another. There's even one other thing that's inherent in Lee's statement– through any type of a transfer process whether through a water bank or the purchase of an irrigated farm, one or more current uses must be forgone to make water available to the new user. I emphasize the fact that one or more existing uses will have to be forgone, because in all water transfers, water losses to some uses are very likely to be encountered.

If at least one or more uses have to be forgone, you can provide compensation for the principle economic use of the water that's going to be transferred to a new use. But there will be trade-offs that take place with respect to other water uses that are lost in this process. The State Engineer has a set of rules for administering water transfers that are complex. Any process designed to compensate for the other losses in water use that occur will be far more complex than the process used currently by the State Engineers Office.

Let me describe some of the inefficiencies in water transfers and talk about some of the associated losses in water uses that may occur. Steve Hansen of the Bureau of Reclamation talked about this yesterday afternoon. He said, "continued irrigation is an essential element to the Middle Rio Grande Valley" and "you have to continue irrigation for a number of reasons." He said in essence, if farms are abandoned, non-beneficial uses of groundwater to phreatophytes will occur anyway. The system of native vegetation will continue to use water even though you cease to farm a piece of land. Evapotransporation will continue. A second issue is that if irrigation is discontinued, recharge of the groundwater system will be reduced. That recharge is essential to the maintenance of flows in the river during periods of the year. If irrigation is discontinued in the Middle Rio Grande Valley, irrigation return flows will not be returned to the river to keep it alive. I don't know how many of you understand how important those irrigation return flows and the waste-ways leading back to the river are to keeping the river alive from place to place. They are a fundamental part of maintaining the endangered species from Isleta Dam on down to Elephant Butte.

Trying to find a means of compensation for discontinued water uses due to water transfers is going to be difficult. How do you do it? I'm going to suggest one of those ways. I believe it is the responsibility of the State Engineer, in hearing water transfer cases, to assure that the public interest in these other uses is somehow protected.

Water banking may include two processes. Professor Al Utton discussed two of these processes in the paper titled, *Alternatives and Uncertainties in Interstate Groundwater Law*. He identified two processes that are in conflict with each other. The first one is based on the commerce clause, which is really a statement of a free market and provides for free market applications. The other process he talked about in his paper was equitable apportionment. Equitable apportionment deals with how you take into account competition between water uses and the judicial or quasi-judicial process needed to provide equitable distribution between uses. In processing a water transfer, there must be some kind of equitable apportionment–equitable sharing of public interests in water with other uses is part of the responsibility of the State Engineer and his administration. Professor Utton said, "There will always be a conflict between equity and efficiency arguments that will lead to disputes and uncertainties."

Steve Reynolds believed in the free market approach with oversight of water transfers by "Steve Reynolds." That was probably a pretty good process. I don't think any of us have an argument with that. In the 1950s I worked for Steve Reynolds and during that period he was subject to criticism and to lawsuits that occurred as a result of the closing the Middle Rio Grande Basin to further appropriation. His action in the mid-1950s allowed for a free market operation in the basin that still continue to function.

I did some research into the interstate stream compacts and how they might affect water markets. The most interesting article I found was a defense of Steve's closing the Middle Rio Grande Basin. The article was about the Rio Grande Compact and was written by Dee Lynford. I don't know how many of you knew or remember him, but Dee was a remarkable historian. He worked for Steve as head of his report section and he was a class act–what a marvelous person. Dee was a good writer too, but I'm sure Steve rewrote parts of whatever Dee wrote simply because whenever Steve took out his pen, he would rewrite stuff whether the author liked it or not, or whether it needed it or not. He rewrote some of my text way back when. Dee Lynford defended Steve's action in declaring the Basin in order to preserve the Rio Grande Compact. Dee was right.

Steve Reynolds talked about free markets and free market transfers of water. In today's more complex world, can water transfers be accomplished in the Middle Rio Grande Valley? Yes. I'm going to refer you to an unpublished paper prepared through the New Mexico Water Resources Research Institute for the Bureau of Reclamation on forbearance; that is, how the farming community of the Middle Rio Grande would forbear using their water. I'm sure that there are farmers who would forgo their use of water for transfer to instream flows for the Rio Grande Silvery Minnow.

My paper lists eight different ways to proceed with forbearance transfers. I'll just give you one of those eight different ways. One way is for the U.S. Fish and Wildlife Service to buy water rights on the open market. Water rights could be bought from farmers on certain ditches, or from a district water bank.

There are a couple distinctions made in that paper you should know about. There is a difference between "native Rio Grande water" and "contract water," that is, San Juan/Chama water. You must have different rules for dealing with each of these. The other one is that 'wet water" is the only water you can really transfer. These two concerns must be recognized in water transfer processes.

Reclamation has provided a wonderful guide for representing their interest in water rights on the Rio Grande. It is a contract between the Bureau of Reclamation and El Paso Water Improvement District #1. It is based on a 1920 law. I'll read one provision to you from that contract: "Project water, subject to contract, may be used to supply miscellaneous uses, and other uses than irrigation subject to certain conditions. Project water for these other uses may come from a number of different sources. Project water may be attached to the land, or a land owner may wish to change the use of their land from irrigation to a purpose other than irrigation. Project water may be assigned to the irrigated lands where the land owner is willing to forbear the use of their water so that the water may be supplied to a third party. Other project water that has been used in the past for irrigation, or beneficially used in making irrigation deliveries may be available for other uses through conservation, recovery and improved efficiency measures." In effect, the Reclamation contract states that El Paso farmers can buy and sell their water. I think this is terrific.

There are some proposed water banking acts that have been discussed. I have some criteria that may not meet all those proposed acts. The purpose of a water banking act is to provide a mechanism for buying, selling or leasing water rights and to provide a means for being assigned to a qualified water bank. A water banking law should specify the criteria for qualification, and qualification requests would have to be approved by some state agency, perhaps the Interstate Stream Commission. A water bank should be a quasi-governmental entity similar to acequia associations, irrigation districts, and universities. Approval for a one-year water transfer from one water user to another could be made by a qualified water bank, with notice to, but without permission from, the Office of the State Engineer. That is, you could transfer the water for one year to any other user after providing notice. The State Engineer could not halt the transfer during the one-year period, except with a court injunction.

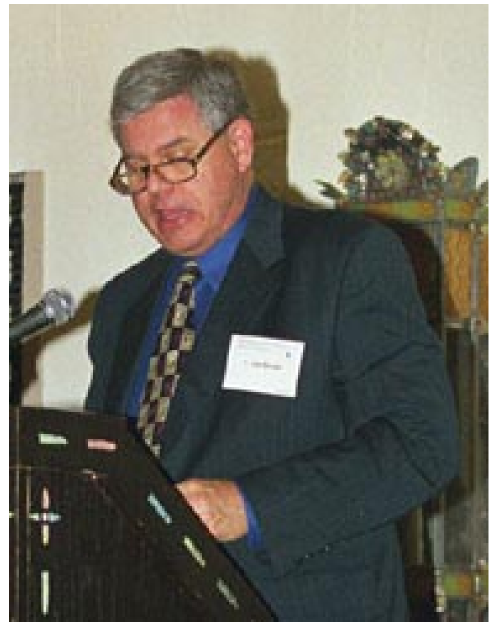
A transfer for more than a one-year period would require meeting all the current state law criteria for a water transfer. Public notice and hearings should be a part of that criteria. All economic interests in water must be allowed to have a significant voice in the process. That includes farmers, Pueblos, irrigation districts, federal interests like the Bureau of Reclamation, and the environmental community.

I'll close by saying that water banking is less than a zero-sum game. There is only so much water out there and anytime you take it and change it from one place to another, it's got to be a zero-sum game where one or more existing uses will be lost, and that "more" has to be taken into account.

Transfer processes are inefficient, trade-offs are complex, and the mechanistic administration followed by the Office of the State Engineer in the past may not produce equity in future water transfers. All parties having economic interests in the transfer of water in the Middle Rio Grande must have an opportunity to be heard. Public interests must also be heard. In considering water transfers, the State Engineer should accept his responsibility to protect both the private and the public interests in water.

Thanks very much.

***Lee Brown** is Professor Emeritus of Economics and Public Administration at the University of New Mexico where he also served administratively as Director of the Bureau of Business and Economic Research, the School of Public Administration, and the International Water Resources Association. Lee served as co-director of the Natural Resources Center in the School of Law with the late Al Utton. Publications include "The Southwest Under Stress" with Allen Kneese, "New Courses for the Colorado River" with Gary Weatherford, and "Water and Poverty in the Southwest" with Helen Ingram. He is now an economic consultant on water economics in Corrales, New Mexico.*



Do We Need Water Markets? YES, BUT...

Do we need water markets? When I mentioned the topic of this session to a resource economist from another state recently, he responded, "Why are you talking about that subject now? You already have active water markets in New Mexico." And, indeed, he is right. Sales of water rights occur quite frequently in most basins in our state. Some states, California and Arizona most prominently, have instead experienced major public debate and even turmoil in the last decade or two associated with the creation of water markets that had not previously existed, and with their operation when they do. In quiet contrast, water markets in New Mexico seemingly have evolved without effort and certainly without much public debate until recently. To those economists who are evangelic proponents for water markets, New Mexico is even frequently cited when they are asked to name a place where water markets work well. Why, then, if we already have working water markets, are we finally discussing this topic here in New Mexico?

At one level of meaning, of course, the answer to this last question is simple. While we do have active markets **for water rights** in New Mexico, we don't truly have markets **for water itself**, and the water banking proposals before us focus on sales of "wet water." While the sale of a water right conveys legal title to use water from a stream or groundwater basin, that right does not necessarily produce "wet water" as the colloquial phrase "paper water" aptly connotes. It is the capacity to move "wet water" that is the target of the current legislation. But there is also a second, possibly heretical, level of meaning at which the topical question for this session can be interpreted. Should we be buying and selling water in the marketplace *in any form*? I suspect that at least some of the current resistance to water banking is associated with basic misgivings or even outright hostility to the notion of marketing water as a commodity in any fashion whatsoever. The quiet evolution of markets for water rights has obscured this underlying distrust of the marketplace's treatment of water purely as a commodity like any other and may have lulled some of us into the presumption that water itself could also be as readily bought and sold as are water rights.

I submit that New Mexicans are not of one mind about the pros and cons of markets for either water or water rights. For many, the monetization of water is a comfortable concept which is readily assimilated, while for some others it is even so unpalatable as to be sacrilegious from religious, cultural or naturalistic perspectives. And, even many of those who willingly accept water as essentially just another commodity are still alarmed at what existing markets for water rights are doing to the pattern of water use in our state as rights move from irrigated agriculture to municipal ownership and from rural regions to urban areas. New Mexico has never explicitly adopted a clear public policy about the desirable institutional role for water markets in our state or even truly had a vigorous public debate on the subject. Although this underlying disagreement has surfaced intermittently in administrative hearings by the state engineer, occasionally in the courts, and indirectly in the legislature under the rubric of "public welfare," none of these venues have adequately grappled with the subject from a policy perspective. In fact, I think it is fair to say that we have been avoiding that debate.

While I personally endorse the general concept of water banking and believe that productive discussion on specific bills to enable it is important, I believe that a more valuable and fundamental dialogue about markets and the public welfare needs to focus on the water reallocation process in our state and the institutional role of markets in accomplishing that reallocation. My comments, then, address this more basic form of our question rather than the proposed water banking legislation specifically.

As an economist who has studied the emergence of water markets in the western U.S. for many years, I have developed a qualified answer to our question which is "YES, BUT..." Although I dislike qualified answers, I also generally subscribe to the view of the late Steve Reynolds who said, and I paraphrase, "For every complex question, there is a simple answer... and it is wrong." Let me briefly step back from the particular debate of the current day and share with you a few of the reasons underlying the positive cast to my answer along with the qualifications that I place upon it. Let's begin with the YES portion of my answer, that is, the positive functions and features of markets. I will only highlight two of those functions, though there are others we could easily come up with if we worked on it.

<u>YES</u>. The most obvious function provided by water markets is their ***capacity to accommodate change***. In a simpler society, as a wise man once said, "If one neighbor needed more water and a second neighbor could get by with less, the two could go sit under an apple tree and work out a mutually agreeable solution." Water markets were unnecessary. In today's complex society and economy, we should still strive for more neighborliness in our approach to water issues. But, practically speaking, water markets allow the development of specialists (realtors, lawyers, hydrologists, appraisers and others) who have detailed knowledge to which one individual cannot generally aspire.

Water markets also ***establish an explicit price reflecting the relative scarcity of water.*** For example, this first figure is the historical pattern of prices for water rights reported by Phil Soice for the Middle Rio Grande region while the second figure is a similar pattern of prices for the Santa Fe region, also reported by Phil. Note the differences over time and across regions. It is this variation in the price of water rights, or for water itself, that provides an important signal that water is becoming relatively more scarce over time and among basins as the economic demand for water grows at different rates and the available supply differs among basins. This price signal encourages conservation on the demand side and the offer of new water on the supply side. Parenthetically, I would note that the prices paid for water rights in New Mexico are generally not a part of the public record as are virtually all other dimensions of a water rights transfer, including its quantum, its ownership, the place and use *from* which it is being transferred and the place and use *to* which it is being transferred.

In my opinion, these two functions of water markets alone justify their institutional existence and provide the principal reasons that I believe they are a valuable social tool when they work well. Certainly, as with all human institutions, they are never perfect, have flaws and usually can stand significant improvement. Across the West in particular, there are differences from basin to basin and state to state as to how well individual marketplaces for water and water rights fulfil these two functions. For reasons of time, I won't go into specific examples of market failures or imperfections. But, to my point of view, market flaws are reasons for improving the marketplace through such devices as water banks rather than limiting the applicability of water markets.

<u>BUT</u>. To move to the qualifications in my YES, BUT answer, in my view, we must look instead to competing values rather than imperfections in the marketplace, and here I speak more as a New Mexican than as an economist. Markets are one of the principal engines of economic growth and

Figure 1. Middle Rio Grande Basin Water Right Purchase Prices. Reprinted by Permission of V. Phillip Soice, President, Southwest Water Consultants, Inc., Santa Fe, NM

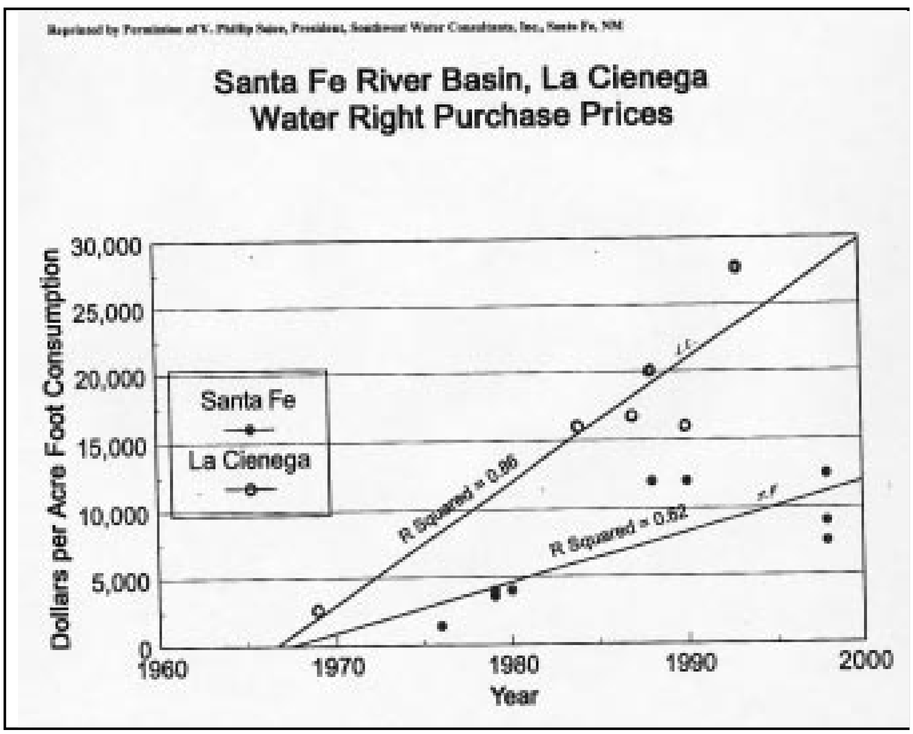


Figure 2. Santa Fe River Basin, La Cienega Water Right Purchase Prices. Reprinted by Permission of V. Phillip Soice, President, Southwest Water Consultants, Inc., Santa Fe, NM

improvement. By moving water from uses which have lower economic value to those which have higher economic value, markets increase the material well-being of society and send us price signals at the same time. But material improvement is but one social goal among many. There are other essential values in life besides material improvement whether they be found in the market defying sweep of Central Park in the heart of New York City, the family ties poignantly captured in the movie "Straight Story," the beauty of a Puccini aria or the compassion of a Mother Teresa. Even MasterCard recognizes that reality if you've been watching their current advertising campaign.

Markets have limited utility in the face of such competing values and can even destroy such values through greed and excessive competition. Just as the Constitution uses checks and balances to prevent too much concentration of power in one branch of government, so too must society use alternative institutions to check and balance the role of the marketplace. The institutions of education, religion, culture, family, neighborhood, community, place and government, to name a few, have each lined up at one time or another in successful opposition to the force of the marketplace and will do so again. I don't share the lament of some that the power of the marketplace in water affairs is overwhelming and inevitable. California and Arizona would not have had such great difficulty creating markets for water if they were inevitable.

The marketplace is only dominant to the extent that we collectively wish and allow it to be so. Markets are in the ascendancy now globally precisely because collectively we have chosen to accept its consequences due to our current preoccupation with material improvement. If we want to create alternative outcomes to what the market would create, we can do it. Perhaps, we are painfully beginning to do just that at the World Trade Organization conference in Seattle. Time will tell. The task of defining and implementing non-market outcomes may not be easy, but why should it be? As I have said, markets are engines of economic growth and relinquishing any degree of economic improvement in the short-run, or even long-run if necessary, should not be done without careful consideration.

So, how does this discussion bear upon water institutions in New Mexico? To the extent we want water to be used to accommodate change and improve our material well being, I have already indicated that I believe markets are a fundamentally necessary institution in helping us reach that goal. To the extent that we wish to balance and check material goals, other institutional vehicles are available to us whether they be water trusts, county zoning and regulation, implementable public welfare criteria or even more fundamental shifts in our collective valuation of water outcomes. Determination of when, where and how we draw lines between market facilitated outcomes and non-market preservation or enhancement of other goals is not an easy task. And, it is compounded by the fact that interstate markets for water are now upon us and will likely become stronger. By dictum of the U.S. Supreme Court, we can only limit **inter**state water transactions to the extent we apply the same limitations **intra**state in the interest of public welfare and the conservation of water. And, public policy in New Mexico, locally and statewide, remains ill-defined with respect to the location of these lines of demarcation between market determined and non-market determined outcomes.

YES, I think we need water markets, BUT I also think we need a much broader vision of New Mexico's future and numerous other institutions to help realize that vision. I hope we will begin to accelerate the public discussion about how to merge the various institutions that govern our water affairs so that we can more effectively move ahead of the curve of events and shape those events rather than simply responding to them as they arise. It is past time to do so.

***Maj. David Guzman** is Deputy District Engineer, U.S. Army Corps of Engineers, Albuquerque District. He is a 1983 graduate of Texas A&M University, with a B.S. degree in civil construction eingineering. He earned an M.A. degree in business management from Webster University in 1997. Major Guzman was commissioned a second lieutenant in 1983 and is a graduate of the Engineer Basic and Advanced Courses at Fort Belvoir, Virginia. He is a native of San Antonio, Texas.*

The Upper Rio Grande Basin Water Operations Review and Environmental Impact Statement

A word to my fellow Texans who are here right now: As soon as Norm Gaume isn't looking, I'm coming home for Christmas and I'll try to carry over as much water as I can.

As Dick mentioned, I am the Deputy District Engineer and it's not often that I get the opportunity to speak to such forums as this. That privilege is usually reserved for the District Engineer, who in this case is Colonel Thomas Fallin. Unfortunately, his presence was required elsewhere, so I took his speech. I took his presentation; stayed in his comfy hotel room–this gorgeous, historical hotel. I ate his banquet dinner last night. I've enjoyed the conversation with the people who have been here during this conference. I'm starting to feel a little guilty here, though. I'll tell you what I'm going to do at the end of this presentation. I don't want to make Colonel Fallin feel left out, so what I'll do at the end of this presentation is put his e-mail address up on the screen. If you have any questions whatsoever, send them to him and he'll take care of them for you.

The Upper Rio Grande Basin Water Operations Review and Environmental Impact Statement is a cooperative effort led by the Bureau of Reclamation(Reclamation), the New Mexico Interstate Stream Commission(NMISC), and the U.S. Army Corps of Engineers(Corps). The goal is to develop an integrated plan that changes, within existing authorities, the operations of the river and reservoir system to increase efficiency and accommodate new requirements.

The success of this review will culminate with the continued use of our water resources for the purposes that we use them today, whether it's agriculture, recreation, environmental, emergencies, and so on. That's the goal.

Why do this review? It's very simple. The demand for water has increased through the years. It impacts on users as well as wildlife and our environment.

Why are we concerned? Because water is a limited resource, but most importantly, because it's our responsibility. It's our responsibility to leave this world in better condition than we found it when we first got here.

If we do things right, we'll succeed in improving system efficiency, improving flood control, enhancing conditions and accommodating our future diverse needs.

As I mentioned, there are three lead agencies, but each agency is responsible for different aspects of water management. The primary areas of responsibility for the Corps is flood loss reduction and sediment control (Figure 1), primarily at Abiquiu, Cochiti, and Jemez Canyon reservoirs. At Platoro, only flood control will be reviewed. Reclamation will focus on irrigation, municipal and industrial use, recreational use, and fish and wildlife (Figure 2). The NMISC will concentrate on Rio Grande Compact deliveries and the timing of San Juan/Chama releases (Figure 3).

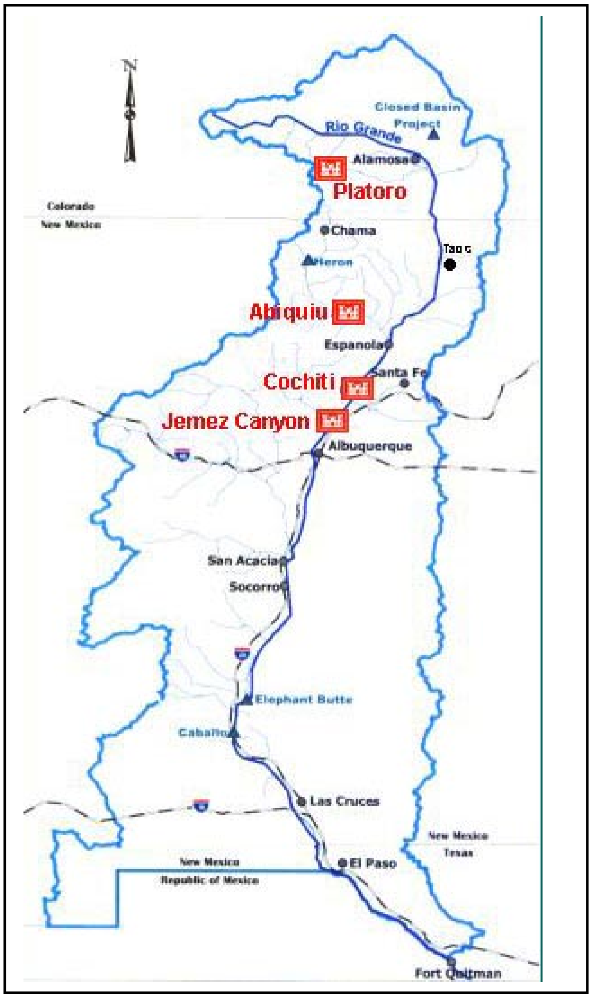


Figure 1. Responsibilities of the Corps of Engineers.

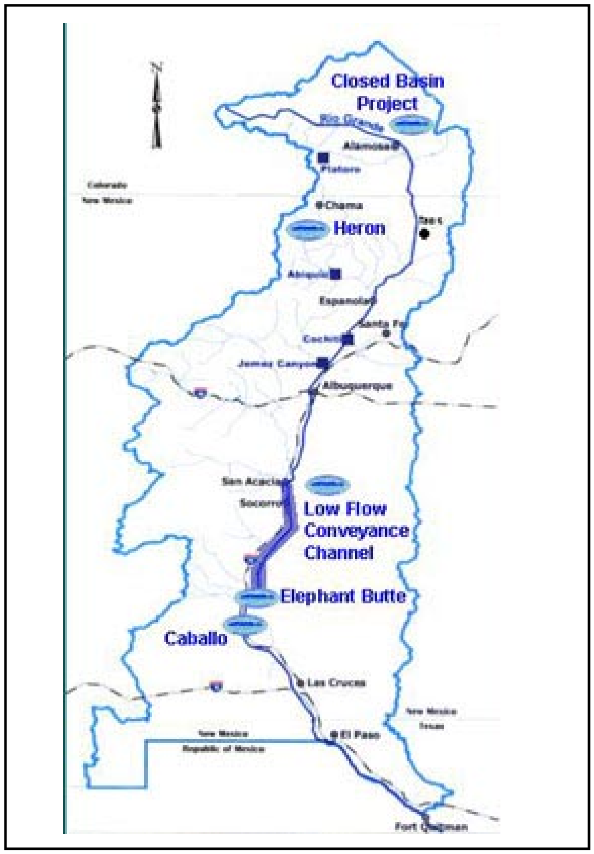


Figure 2. Responsibilities of the Bureau of Reclamation.

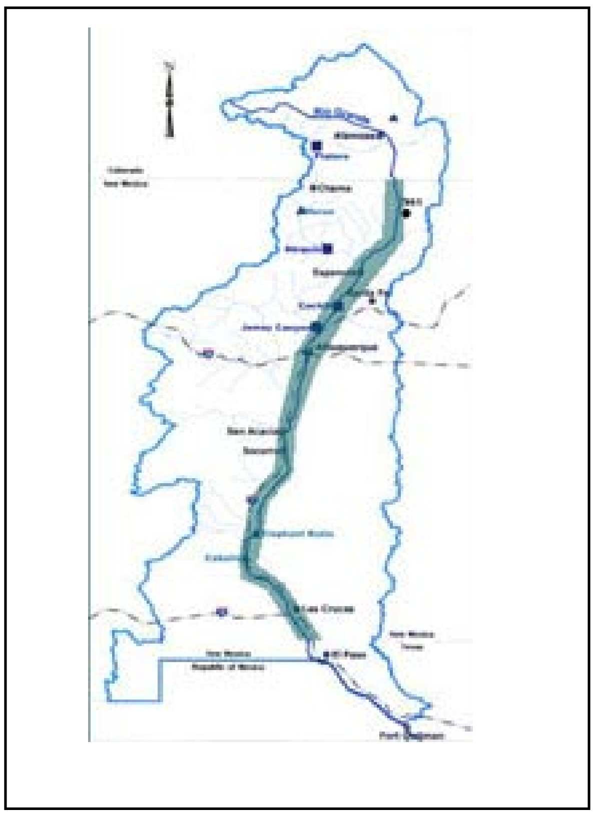


Figure 3. Responsibilities of the Interstate Stream Commission.

We need to keep in mind that this basin is an interconnected unit and as we work through this process, one part can affect another part. We know it won't be easy. Differences in laws, standards, and special interests will all present formidable challenges as we move through this review. As the Sci-Fi movie saying goes "we are not alone."

The review will take all this into consideration and develop alternate water operations or options, and evaluate them. In conjunction with the review, we will prepare an Environmental Impact Statement (EIS), which I'll discuss later.

One tool utilized to develop the review is URGWOM, a model that will track flow at any point on the river or volume in the reservoirs. The hydraulic model(s) will translate flow into depth and velocity. These will be used in the aquatic and riparian models to determine effects or changes due to variations in operation. Geographical Information System (GIS) tools will also be used for analysis and to provide illustrations to detect effects.

Alternative operations have been discussed earlier in this conference. They include developing safe channel capacity to determine releases from Cochiti and Jemez Canyon dams; looking at storage at Abiquiu; and improving flood protection below Caballo Dam. It is possible that other options may come out of the scoping process.

Each option, obviously, will have its own unique issues that must be addressed individually as they pertain to that option. It's not a stand-alone process. You heard Lee Wilson yesterday mention one reach of the Rio Grande where there's been 25 feet of sediment accumulated in the last nine years. Figure 4 is a picture of the San Marcial Rail Road Bridge. Figure 5 depicts a healthy riparian area that thrives on substantial flow. Currently, the San Marcial Railroad Bridge limits the ability to increase the flow. As you can see, the water is almost up to the bridge.

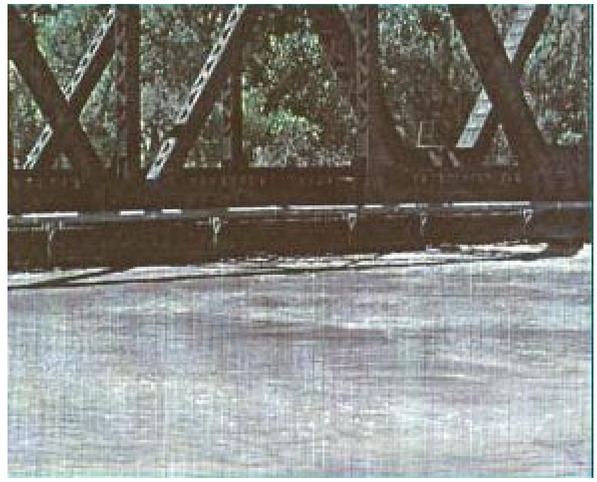


Figure 4. San Marcial Railroad Bridge.

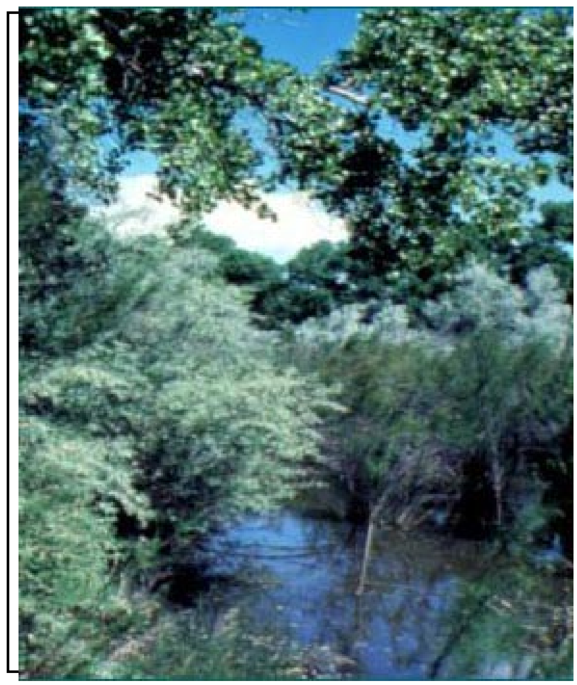


Figure 5. Riparian area

The review will also seek balance. As I mentioned before, what happens in one specific area may impact negatively or positively in another. All of that must be taken into consideration. A thorough analysis of the whole basin is necessary.

Most importantly, working in a vacuum must be avoided. Public participation is key. Input from everyone–agencies, pueblos and tribes, water organizations, users, special interest groups, and the general public–is vital. Throughout the review, cultural and tribal considerations must be respected. Public meetings for the last half of 2000 are as follows:

July 26, 2000	Espanola, NM
August 9, 2000	Chama, NM
August 17, 2000	Albuquerque, NM
September 20, 2000	Santa Fe, NM
September 27, 2000	El Paso, TX
October 17, 2000	Las Cruces, NM
October 18, 2000	Socorro, NM

Figure 6 shows the general organization for conducting the review. The Executive Steering Committee will focus on bringing various groups together for communicating and exchanging information and concerns. The timeline for the project is shown on Figure 7.

The Notice of Intent to prepare the EIS will be published soon. We'll follow through with public scoping meetings, develop the alternatives, collect data, draft and revise the EIS, finalize the EIS, and record the decision by the end of 2004.

How are we planning to keep everyone informed? We will do so through mailings, public meetings, newsletters, fact sheets, web page, and so on. This is not an exhaustive list. There will be other areas added as we proceed with the review.

I've noticed that we have some pretty smart folks attending this conference. I'm sure some of you have been watching that show "Who Wants

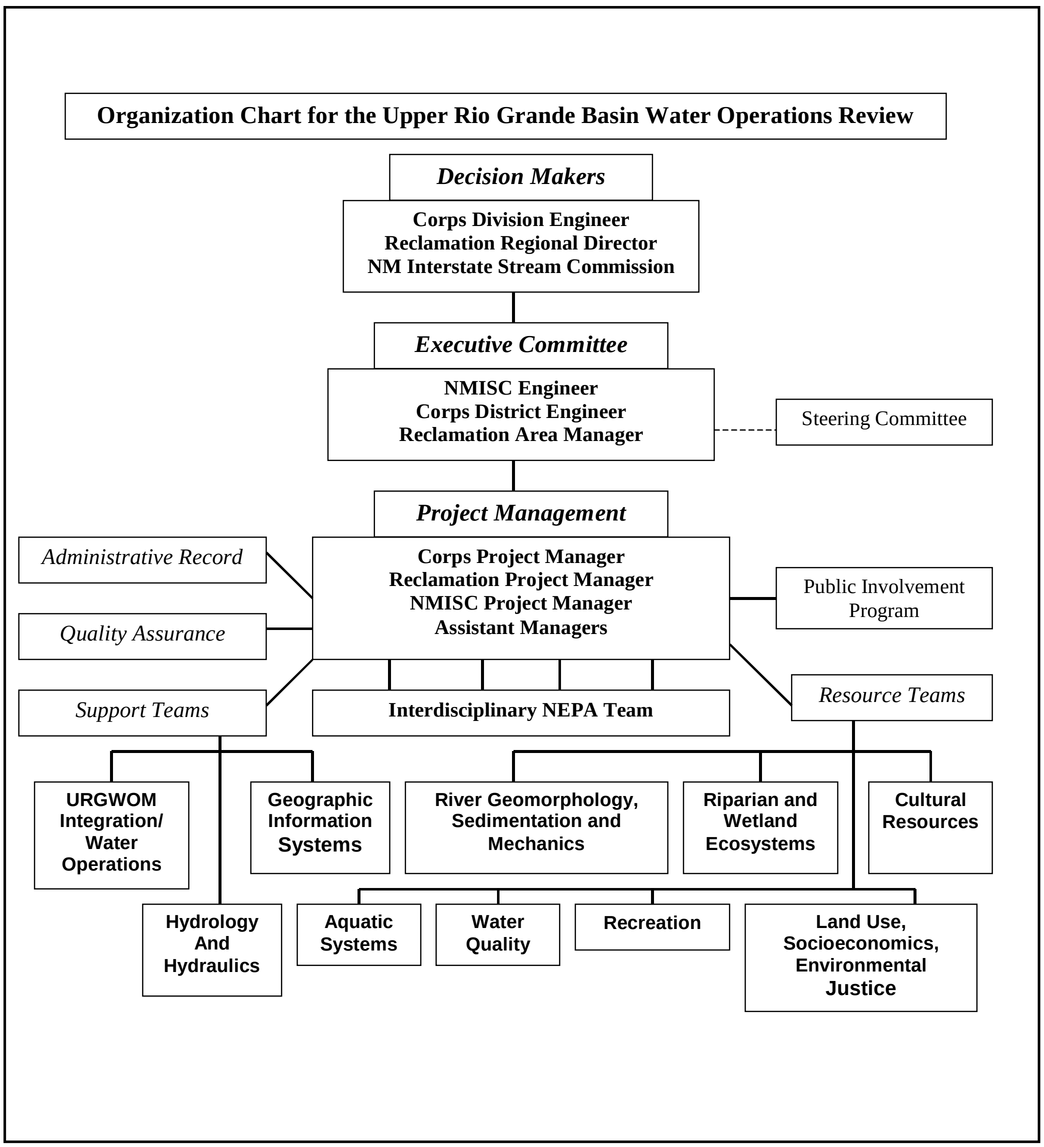


Figure 6. Water Operations Review Organizational Chart

Overview of Master Schedule

	Task Name	Duration	Start	Finish
1.0	Internal Scoping	590d	7/1/98	9/30/00
2.0	Executive Committee	1307d	1/1/00	12/31/04
3.0	Steering Committee	1307d	1/1/00	12/31/04
4.0	Public Involvement	1647d	9/15/98	12/31/04
5.0	NOI and Public Scoping	197d	1/31/00	10/31/00
6.0	ID NEPA Team and Technical Team Development	482d	8/1/99	6/1/01
7.0	Develop Alternatives	458d	11/1/99	7/31/01
8.0	Implement Coordination & Consultation Protocol	1263d	3/1/00	12/30/04
9.0	Finalize Integrated Plan of Study	175d	1/1/01	8/31/01
10.0	Data Assessment and Collection	1155d	8/1/99	12/31/03
11.0	Impact Assessment	413d	10/1/01	4/30/03
12.0	Select Prefered Alternative	132d	5/1/03	10/31/03
13.0	Write Draft EIS	217d	5/1/03	2/28/04
14.0	Public Review of DEIS and Documentation	45d	3/1/04	4/30/04
15.0	Final EIS	153d	5/1/04	11/30/04
16.0	Records of Decision	23d	12/1/04	12/31/04
17.0	Prepare Action Plan	174d	4/1/04	11/29/04

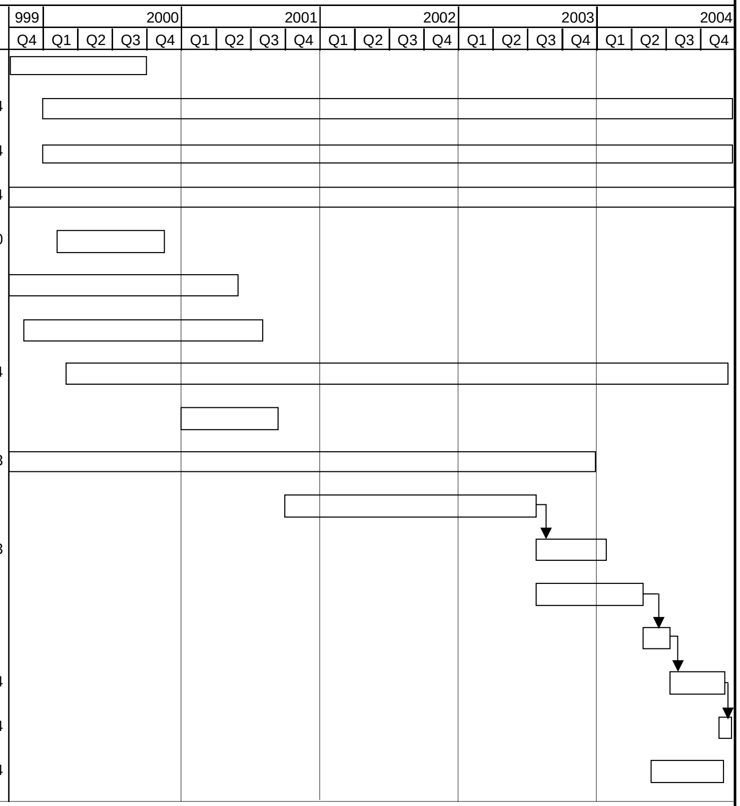


Figure 7. Timeline.

to be a Millionaire ?" and they have a lot of smart folks that appear on that show, too. As smart as they are, they all still get three lifelines. I'm not the smartest guy in the world, but I'm smart enough to know that if I'm going to come here to speak to you, I'm going to come with my own three lifelines as well. If you need technical information, or have any questions about the review, these are the folks to call:

Gail Stockton, Corps of Engineers, 505-342-3348
Chris Gorbach, Reclamation, 505-248-5379
Rhea Graham, NM Interstate Stream Commission, 505-841-9480

I know a lot of difficult challenges will come up during this review and there will be frustrations. I want to leave you with a short story:

In a small town one day, there was an old donkey walking around. The donkey falls into a dry, old well. Folks gathered around and looked down in the well and said, "You know, this donkey's dumb enough to fall in there. Why go to the effort to save him ?" They decide, "Let's just bury him in place."

The old donkey is down at the bottom of the well when all of a sudden he feels this "thump-thump" of dirt hitting him on his back. He starts freaking out. He starts shaking off the dirt and stamping on it. Dirt continues to "thump" and continues to fall. The donkey continues to shake it off and steps up, shakes it off, and steps up again. The donkey soon realizes that the more he shakes off the dirt, the more he can step up. The more he steps up, the closer he gets to coming out of the well. Finally, the donkey was able to shake it off, step up, and step out.

Now a pessimist would just say that that was just dumb luck, but the optimist will say that was a story of determination, perseverance, and the essence of survival. The reason I brought up this story is because I want to challenge all the participants who will be working on this review. When the regulations, the conflicts, the special interests, and everything else starts "thumping" you on your back, don't throw your arms up in frustration. I challenge you to shake it off and step up.

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History and Significance of the Low-Flow Conveyance Channel: What is its Future?

Introduction

The Low-Flow Conveyance Channel, also known simply as the low-flow channel or conveyance channel, is an artificial channel that runs alongside the Rio Grande between San Acacia, New Mexico and Elephant Butte Reservoir. The Bureau of Reclamation built the low-flow channel as part of the Middle Rio Grande Project's river channelization program for the purpose of reducing consumption of water, providing more effective sediment transport, and improving valley drainage. Operation and maintenance of the low-flow channel are continuing Reclamation responsibilities.

The basic concept behind the low-flow channel is that depletion of water can be reduced by diverting some or all of the river's flow into a narrower, deeper, and more hydraulically efficient channel. The low-flow channel exposes relatively

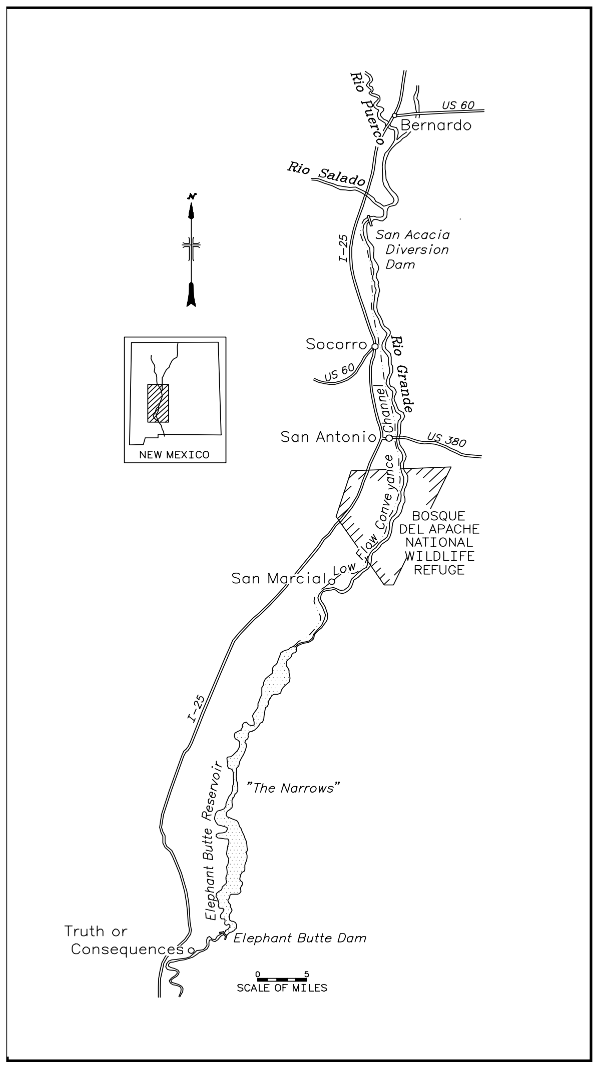

Figure 1. Location Map

less water surface area to evaporation and is less prone to loss of water by seepage than the natural river channel. The higher flow velocities in the low-flow channel can also move more sediment than the river, especially at lower discharges. The low-flow channel has a nominal capacity of 2,000 cfs but, in practice, diversions greater than 1,800 cfs have rarely occurred. The maximum recorded mean daily discharge of the low-flow channel at San Acacia is 1,950 cfs.

Historical Context

During the first half of this century the habitability and agricultural productivity of the Middle Rio Grande Valley declined because of inefficient water delivery, poor drainage, and frequent floods. The first attempt to address these problems in a comprehensive manner was the organization of the Middle Rio Grande Conservancy District (MRGCD) in the 1920s. At about the same time the states of New Mexico, Texas, and Colorado began negotiating the Rio Grande Compact to apportion the flow of the river among themselves. The final Compact, which took effect in 1939, requires the State of New Mexico to deliver at Elephant Butte Dam, a scheduled portion of the Rio Grande flow that passes the river gauging station at Otowi. In effect, the Compact allocates a limited share of the river's flow for depletion in the Middle Valley.

The MRGCD struggled through the depression years of the 1930s to dig drains, consolidate the irrigation system, and build El Vado Dam on the Rio Chama. Calls for federal assistance increased when a damaging flood occurred on the Rio Grande in 1941. The origins of the Middle Rio Grande Project and the Low-Flow Conveyance Channel lie in the damages caused by this flood, another high-flow year in 1942, and subsequent beginning of a drier period in the mid-'40s.

The floods of the early '40s completely filled Elephant Butte Reservoir. As the reservoir filled, channels into the reservoir were inundated and filled with sediment. Even above the reservoir itself, large quantities of sediment brought with the floods deposited and plugged the river channel. An infestation of salt cedar on the floodplain helped to trap sediment and compounded the problem.

With the onset of drier conditions in the mid- and late '40s, the reservoir dropped, and the distance between San Marcial and the reservoir increased. Because the clogged river could not move sediment, deposits continued to accumulate above the reservoir. Eventually, by the record dry year of 1951, the head of the reservoir had receded to about 40 miles below San Marcial and the river below Bosque del Apache had become a series of disconnected segments separated by sediment plugs and delta deposits.

Figure 2. Aerial view looking downstream from the southern boundary of the Bosque del Apache in January 1952. At this time there was no river channel from this point downstream for about 2½ miles.

Because there was no channel into the reservoir, water spread widely over the floodplain and reservoir delta, even at low flows. Depletions due to evaporation and use by growing vegetation increased. Estimates made at the time put the depletion of water between San Marcial and the reservoir at more than 140,000 acre-feet annually. By comparison, total valley depletions in the 50-mile reach between San Acacia and San Marcial currently average around 100,000 acre-feet per year. Large streamflow depletions below San Marcial were a big factor in the difficulties that New Mexico had in meeting its Compact delivery obligations beginning in the mid-'40s. New Mexico's difficulties in delivering water to Elephant Butte resulted in the application of Compact provisions that limited the storage of water at

El Vado for use in the Middle Valley. Excess depletions also contributed to water shortages for the Rio Grande Project, which provides water to lands below Elephant Butte in New Mexico and Texas as well as in the Republic of Mexico.

In 1947, the Bureau of Reclamation and the Corps of Engineers completed a comprehensive plan for assisting the Middle Rio Grande valley in addressing its water and sediment management problems. This plan included dams for flood and sediment control, rehabilitation of the Middle Valley's irrigation and drainage system, and extensive river channelization works. Congress authorized the recommended plan, with the notable exception of the proposed Chiflo Dam, in the Flood Control Acts of 1948 and 1950.

Opening channels into Elephant Butte Reservoir to increase efficiency of conveying water and sediment was the highest priority when work on the Middle Rio Grande Project began. In 1951, President Truman gave Reclamation special authority to start channel construction immediately. Work on the low-flow channel and clearing a floodway for passage of higher flows began in October of that year.

Construction on the low-flow channel continued throughout the '50s. A first phase, the so-called San Marcial Channel, was completed at the end of 1953. Diversions through a heading near the southern end of the Bosque del Apache began in November of that year. Extension of the low-flow channel upstream to San Acacia was completed in 1959. When completed, the low-flow channel extended some 70 miles from San Acacia to a point just above the narrows of Elephant Butte Reservoir.

Diversions from the river to the low-flow channel began at San Acacia in 1959. During the '60s and '70s, the entire river flow was carried in the low-flow channel most of the time. In general, flow was routed to the river below San Acacia only during periods of high flow in the spring and occasionally during the summer rainy season.

While the low-flow channel conveyed the great majority of river flow in the '60s and '70s, the average annual depletion of water between San Acacia and San Marcial–as measured by total flow through the respective valley cross sections–was reduced by about 40,000 acre-feet annually. Extrapolating to the Narrows, some estimates of water savings attributed to conveyance of water in the low-flow channel are as high as 60,000 acre-feet a year. The effects of the reduced depletions on deliveries to Elephant Butte Reservoir are reflected in the record of New Mexico's Compact delivery status. As shown in Figure 3, a debit of more than 500,000 acre-feet that had accrued between 1943 and 1956 was entirely eliminated by 1972.

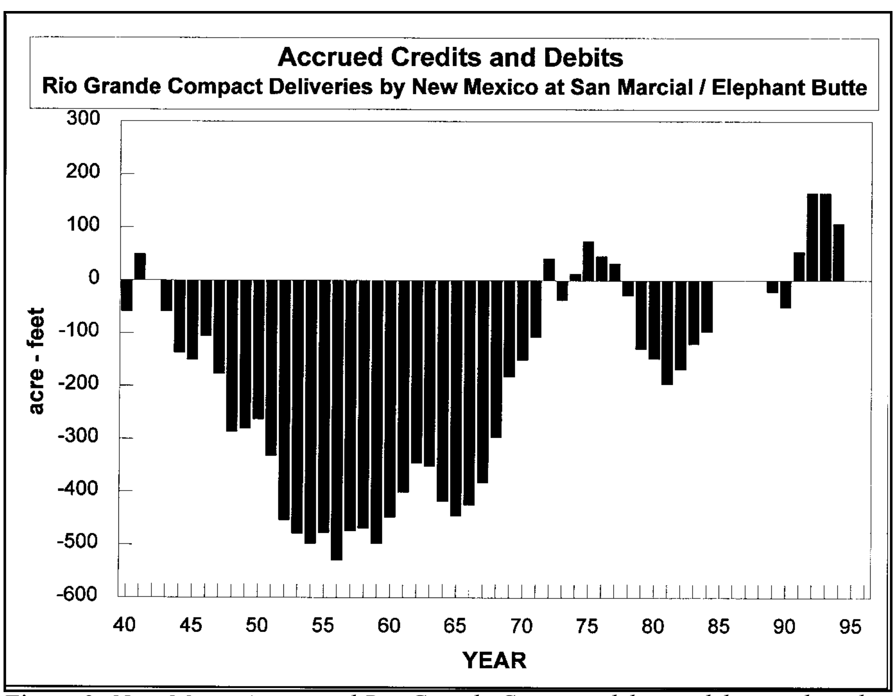

Figure 3. *New Mexico's accrued Rio Grande Compact delivery debits and credits, 1939-1996*

Current Conditions

The period of low-average streamflow that began in the mid 1940s persisted through the '70s. During this time the average flow of the Rio Grande at San Marcial was only about two-thirds of the average flow for the entire period of record, which goes back before 1900. There was an especially severe drought between 1950 and 1956 when the average flow of the river was only about 40 percent of the long-term average.

Beginning in 1979, the average flow of the Rio Grande increased markedly compared to the low streamflows of the '50s, '60s and '70s. By 1985, the higher flows had filled Elephant Butte Reservoir for the first time since 1942. The spill cancelled all accrued Compact delivery debits, but the high flow and high reservoir created some new management problems.

An episode of heavy sediment deposition began that affected a reach of the river extending for some distance above the reservoir. At the San Marcial railway bridge, which is about 8 miles above the reservoir's high-water pool, some 15 feet of sediment have deposited since 1979. While sedimentation at San Marcial has been quite rapid over the past several years, it must be noted that this is an episode overlaying a continuing long-term sedimentation trend. Records going back to before 1900 indicate that fairly rapid sedimentation has been occurring over at least the past century. Destruction of the town of San Marcial by floods in 1929 can be directly attributed to sedimentation of the river channel.

A brief history of the railway crossing illustrates some of the effects of sedimentation at San Marcial. Before 1920, the railway crossed the river on a steel bridge about a half mile upstream from where the present bridge now stands. During a flood in 1920, the river shifted to a new channel, breaching the railway embankment at the site of the present bridge. A wooden trestle was built to carry trains across the new channel. Because of sediment deposition, the railroad company raised the tracks nine feet when they built the present steel bridge to replace the trestle in 1930. Deposition of sediment from the floods in 1941 and '42 necessitated raising the bridge an additional 12 feet in 1943. So the railroad tracks at San Marcial are now more than 20 feet higher than they were in the 1920s. Continuing sedimentation has again reduced clearance under the bridge to a degree that flow capacity is significantly reduced. Limited channel capacity under the bridge and through the San Marcial reach have become the main factors controlling flood releases from Cochiti Dam. The lower releases from Cochiti have had significant impacts throughout the Middle Valley.

Aggradation of the Rio Grande channel above Elephant Butte Reservoir in the 1980s resulted in loss of channel capacity and some shifting of the channel alignment. While peak discharges were not remarkably high, unusually long-flow durations compounded problems caused by high-river stages as water stored upstream was delivered to Elephant Butte throughout the year.

The lower 15 miles of the Low-Flow Conveyance Channel were inundated and filled with sediment as the reservoir filled in the early '80s. In 1983, the outlet of the Low-Flow Conveyance Channel was moved to a location near the top of the reservoir pool, but diversion of water and sediment at San Acacia could not be continued because rapid deposition of sediment prevented maintenance of a suitable outfall. Diversions at San Acacia were suspended in March 1985.

During the late 1980s, extensive rehabilitation and improvement work was done on the low-flow channel in anticipation of future operations. With diversions suspended, the low-flow channel continues to serve as the valley's main drainage outlet, carrying seepage flows and irrigation returns to the reservoir. The low-flow channel also serves as the Bosque del Apache National Wildlife Refuge's main water supply and provides supplemental water to the MRGCD. Water flowing out of the low-flow channel also sustains highly productive marshes and wetlands below San Marcial

Because the river has been confined to the eastern side of the floodplain by the levee that protects the low-flow channel, the aggradation of the river bed in the San Marcial area has caused it to become perched in a narrow strip along the eastern side of the floodplain. Head difference between the river on one side of the levee and the low-flow channel on the other is now as much as 10 to 15 feet. Severe stress on the levee has been manifest in cracking and occasional incidents of river water piping through the embankment.

Future of the Low Flow Conveyance Channel

The need for efficient conveyance of water to Elephant Butte Reservoir to meet Rio Grande Compact delivery obligations remains. In the inevitable drought, the need will be even more critical.

Reclamation's Albuquerque Area Office has managed the river and maintained the levee to protect and preserve as much of the low-flow channel as possible so that full operation can be resumed in the future under suitable conditions. Raising and reinforcing the levee in the San Marcial area has prevented further breaching and consequent damage to the low-flow channel. However, as aggradation of the river has continued, it has become increasingly doubtful that containing the river on the east side of the levee is a practical long-term strategy. Consequently, Reclamation is now completing an Environmental Impact Statement to evaluate proposed modifications to the channel system. The proposed modification involves moving the low-flow channel and the river below San Marcial into new alignments westward of their current locations. The realigned river would be on the lower section of the floodplain west of the levee and the low-flow channel would be near the western edge of the floodplain.

Realignment of the river would relieve pressure on the levee and reduce potential for an uncontrolled breach. In addition to damaging the low-flow channel, an uncontrolled breach of the levee would cause substantial loss of high quality riparian wildlife habitat and could result in a disconnected river channel. Realignment would also expand the active floodplain with benefits to wildlife as well as sediment management.

Future options for operation of the low-flow channel will be evaluated as part of the Upper Rio Grande Basin Water Operations Review. The range of possible operating options ranges from continuing a no-diversion operation or resuming diversions when conditions permit or require.

Concerns over the environmental effects of low-flow channel operations have arisen in recent years that are expected to impose limitations on future operations. Most prominent among these are endangered species considerations, particularly associated with habitat needs of the Rio Grande silvery minnow and the southwestern willow flycatcher. Future diversion of the entire river flow, as was typical in the 1960s, will probably not be possible. It is reasonable to expect that the quantities of water that can be saved by more limited low-flow channel operations may not compare with the 1960s. Studies are continuing to determine the effectiveness of partial diversion strategies.

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DOMESTIC WELL DEPLETIONS IN THE RIO GRANDE BASIN

Section 72-12-1 of the 1978 Compilation of New Mexico Statutes tells us that:

> "…[b]y reason of the varying amounts and time such water is used and the relatively small amounts of water consumed in the watering of livestock, in irrigation of not to exceed one acre of noncommercial trees, lawn or garden; in household or other domestic use, and in prospecting, mining or construction of public works, highways and roads or drilling operations designed to discover or develop the natural resources of the state of New Mexico, application for any such use shall be governed by the following provisions:
>
> Any person, firm or corporation desiring to use any of the waters described in this act for watering livestock, for irrigation of not to exceed one acre of noncommercial trees, lawn, or garden; or for household or other domestic use shall make application or applications from time to time to the state engineer on a form to be prescribed by him. Upon the filing of each such application, describing the use applied for, the state engineer shall issue a permit to the applicant to so use the waters applied for.

"The State Engineer shall issue a permit..." There is no provision for public notice or hearing, or for any investigation on the subject of impairment of existing rights. Diversion from the wells is not measured, in most cases, and is not subject to New Mexico's prior-appropriation system. The depletion of the flow of rivers that results from the pumping is not the responsibility of the owners of the wells. The cost in terms of streamflow depletion is borne by the holders of surface-water rights, which may be senior to the domestic-well right by 100 years or more. For administrative purposes, the annual diversion from one of these wells is limited to 3 acre-feet, which, in most of New Mexico, is enough to irrigate a one-acre garden. Nobody really knows how many of these wells for domestic supply have been drilled. Earlier hydrographic surveys, in preparation for stream adjudication, did not take these wells into account.

This feature of the groundwater law has been with us from the beginning. The original attempt to bring groundwater under the State's water-rights administration was in 1927, in a law that declared the waters in "underground streams…" to be public, and subject to appropriation (Laws 1927, chap. 182). The 1927 law explicitly exempted water for domestic and stock-watering use from its provisions. When the 1927 law was repealed and replaced in 1931 (Laws 1931, chap. 130), there was no explicit exemption for water for domestic use, but the 1931 groundwater law applied only to "irrigation or industrial uses," and therefore left domestic and stock-watering uses unregulated. The current language in §72-12-1, affirmatively exempting small-scale domestic use, and many other uses besides, was added in 1953 (Laws 1953, chap. 61).

It accords with our ideal of Western self-reliance that each householder is guaranteed the right to develop his own water supply on his own land, without any interference by the state government. On the other hand, in providing the guarantee, we simultaneously take away much of the state's obligation to protect the right: another householder can come along and drill a well on his land, even if it happens to be just across the fence.

Is the aggregate pumping of "relatively small amounts of water" from domestic wells properly considered a *de minimis* water use, "trifling; minimal; so insignificant that a court may overlook it in deciding an issue or case," to use the definition from Black's Law Dictionary? The §72-12-1 permits limit diversion from each well to 3 acre-feet (977,553 gallons) per year, equivalent to a constant pumping rate of 1.86 gallons per minute. Although the actual average use is surely much less than even that tiny rate, the aggregate pumping still represents a significant amount of water.

DOMESTIC WELL DEPLETIONS IN THE RIO GRANDE BASIN

Wilson and Lucero (1997, Table 5) estimate that total diversion from the §72-12-1 wells in the Rio Grande drainage basin (the Rio Grande and Lower Rio Grande Underground Water Basins combined) during 1995 was 19,318 acre-feet.This is equivalent to 2.9 percent of all groundwater diversions in the river basin, and about 0.9 percent of groundwater and surface-water diversions combined. The diversion from §72-12-1 wells in New Mexico's part of the Rio Grande drainage basin was about equivalent to the combined 1995 diversions by Santa Fe (12,560 acre-feet), Española (1,102 acre-feet), and Los Alamos (5,836 acre-feet). It was about the same as Las Cruces' diversion (19,071 acre-feet). In New Mexico as a whole, Wilson and Lucero estimate that domestic self-supplied water use (diversion) was 29,732 acre-feet in 1995, 0.67 percent of all withdrawals.

The population supplied by §72-12-1 wells (rural and urban self-supplied) was estimated at 192,028, or about 16.3 percent of the population of the Rio Grande basin. Wilson and Lucero (p. 13) based their estimates of water use on population data, assuming diversion of 70 to 100 gallons per capita per day (gpcd), depending on climate and the prevalence of indoor running water, for the segment of the total population that is not served by public systems. At the nationwide average rate of occupancy of 2.7 people per dwelling unit (p. 12), these diversion rates represent a range of 0.21 to 0.30 acre-feet/year per dwelling. The overall average rate of water use implicit in Wilson and Lucero's estimates is 0.27 acre-feet/year per dwelling.

It is difficult to quantify depletion, the water actually lost to evaporation, and therefore the return flow that would be available to other users. Wilson and Lucero (1997, p. 13) assumed a uniform rate of 45 percent depletion, implying that 55 percent of the water produced from the domestic wells can be considered return flow. The disposition of wastewater in areas served by these domestic wells is commonly to septic tanks. In some settings, particularly where the water table is very shallow, the return flow can be more than 90 percent of the amount diverted, but in many places in New Mexico the return flow from septic tanks serves only to increase the moisture content of the soil and does not reach the water table. The water "returns to the groundwater system," to borrow the language of the condition in some groundwater permits, but it will not be available to other appropriators. It seems likely that the actual average rate of return flow is less than 55 percent, and that the depletion is more than 45 percent of 19,318 acre-feet/year, or 8,693 acre-feet/year.

Because the return flow related to domestic wells usually consists of septic-tank effluent, a high rate of real return flow, which looks good from a water-rights perspective, may simply mean that well-owners are pumping each others' wastewater.

The negative aspects of the §72-12-1 wells are most evident where they are most concentrated. Peterson (1999, p. 66) estimates that there have been 2,000 permits issued in the Sandia Underground Water Basin; annual diversions from them may constitute some 28 to 34 percent of the total water produced in the basin, but nobody knows for sure. Many of the wells predate the declaration of the basin (in 1966), and permits are still being issued. It seems probable that many of these wells interfere with each other, but there is no priority administration and the senior domestic rights are protected only from the effects of larger withdrawals that are subject to the State Engineer process, not from the combined effects of other §72-12-1 wells. The task of protecting the senior domestic rights has generally fallen to the counties; they have done it by regulating the sizes of lots in new developments.

In Placitas, a recent study by Peggy Johnson of the State Bureau of Mines and Mineral Resources shows that in some relatively small areas, where there is a relatively high density of wells and the aquifer system is made up of low-permeability rocks, water levels have declined several tens of feet over the years. In a part of southern Santa Fe County in which the supply is largely from §72-12-1 wells, water levels have declined in many individual wells.

Aside from water-rights questions, the individual wells pose some danger to their users, in that they are more likely than public-supply wells to capture septic-tank return or other contaminated water. State and county environmental regulations are an effort to avoid this problem, but they cannot be as effective as the well-siting studies, the required regular sampling and analysis, and the wellhead-protection programs that go along with public-supply wells.

The number of §72-12-1 wells must be prodigious. If the estimates of 19,318 acre-feet/year diversion, and 0.27 acre-feet/year diversion per dwelling, are more-or-less correct, then there would be about 72,000 wells in the Rio Grande basin. This number seems very high, until one reflects on the rough inventories that have been made. Just in the semi-urban area southeast of Santa Fe, for example, the State Engineer records show about 1,500 wells; there are estimated to be 3,100 wells in the Santa Fe River basin itself; and there are about 650 wells in the Pojoaque area. The sequential numbering of files in the Rio Grande Basin reached RG-72800 this past September, and that represents only the transactions since the basin was declared in 1956. In the Lower Rio Grande Basin, which was not declared until 1980, the file numbers have reached LRG-10600. Of course these file numbers include all kinds of wells and water rights, and permits for wells that have never been drilled, but perhaps 60 to 70 percent of them represent §72-12-1 wells.

DOMESTIC WELL DEPLETIONS IN THE RIO GRANDE BASIN

If all of the wells did actually produce the full 3 acre-feet/year available to them, then the total would amount to something like 216,000 acre-feet/year–a very significant part of the total water resource of the basin. Everyone seems to agree that the average actual use now is far less than 3 acre-feet/year, probably something close to the 0.27 acre-feet/year implied in Wilson and Lucero's study, but the potential is there for a lot of expansion of gardening, and of water use. It seems absurd, in this time of peace and prosperity, to bring up the subjects of victory gardens and economic distress sufficient to cause a large increase in garden acreage, but both of those conditions have existed within living memory; if they happen again, there will be a significant increase in depletions by domestic wells.

In percentage terms, the §72-12-1 wells may seem to be of minor importance. On the other hand, a consumptive use of even as little as 3 acre-feet/year is surely not *de minimis* in the Gila-San Francisco Underground Water Basin, where a U.S. Supreme Court decree (in Arizona v. California) requires that there be no new depletions. Here, the §72-12-1 permit is for "inside use" only, and transfer of an existing water right is a prerequisite for irrigation of any garden. The aggregate annual diversion of 19,318 acre-feet/year from the Rio Grande Basin would certainly not be considered *de minimis* by anyone if it all happened in one place on the Rio Grande, rather than being broadly dispersed. Withdrawals from §72-12-1 wells would perhaps not be *de minimis* where there are enough of them in one area to cause rapid water-level declines and mutual impairment, as seems to be happening in some parts of New Mexico that are popular for semi-rural development.

Although we do not subject ourselves, at least as rural and semi-rural dwellers, to much meddling in our water supplies by state government, we self-reliant westerners insist on great care in the administration of the prior-appropriation system when it comes to water use on even a slightly larger scale. Applications for as little as a few acre-feet per year have been protested.

It's easy to imagine a situation in which a group of people own all of the surface-water rights in an area, including the water available in the irrigation system, but not all of the land that lies above the irrigation ditches. If land above the ditches is subdivided, and dotted with §72-12-1 wells, then the resulting depletion of surface water will be a loss to the surface-water owners. Indeed, this situation has developed in many places in New Mexico. Strictly speaking, it more resembles theft than western self-reliance. Perhaps it would be more equitable for the subdivider to acquire water rights to offset the surface-water depletion.

The State Engineer allows the estimated in-house use of water from §72-12-1 wells, usually at the rate of 0.067 acre-feet/year per person (0.18 acre-feet/year for the typical 2.7-person household), to be pooled to provide water rights for the formation of mutual-domestic central systems, while the wells themselves may continue in use for irrigation of the gardens. In theory, no more water-use will result, but in this subtle process a new water right, in an already fully appropriated stream, springs into being.

Some attempts to regulate domestic wells seem oriented toward controlling development itself, rather than remedying a perceived inequity in terms of water rights. A proposed ordinance in Sandoval County, which reflects the intensity of development based on individual §72-12-1 wells in and near Placitas, would generally limit new wells to "sustainable" or "impact-free" categories. A sustainable well is one for which diversion-less-return-flow would not exceed the recharge to the aquifer within the tract being supplied; an impact-free well would have "negligible impact" on all existing wells, springs, and creeks within a mile of the well and all properties served by it. Neither of these standards, while they may seem rather strict, addresses the fundamental water-rights issue. The hydrologic reality, of course, is that a "sustainable" well or a well that has "negligible impact" still represents a net loss of water from the basin, a loss for which there is no water-right accounting. The word "negligible" in this context remains to be defined.

In most places in New Mexico, and setting aside the question of strict adherence to the principal of prior appropriation, perhaps the water-rights effect of a §72-12-1 well really is *de minimis*. Where the aquifer is not stream-connected, or wells are distant from a river, and especially where the aquifer is relatively permeable and the number of wells per square mile is small, the influence in terms of drawdown in other wells, and depletion of streamflow, may well not be worth the State Engineer's effort to regulate.

It can certainly be argued that the same people would need about the same amounts of water, whether they are connected to a regulated system or have their own domestic wells, and the larger number of domestic wells spreads the drawdown effect over more area and thereby lessens the drawdown near larger production wells by some increment. If there are uncomfortably large water-level declines here and there, because some wells are tapping aquifers with very meager yield, this may simply be the price of independence.

The domestic-well exemption has some practical advantages: the permits are not much trouble for the State Engineer to issue, requiring no investigation, notice, or hearing, and therefore can be issued quickly and at low unit cost. The homeowner can proceed without the unpredictable delay and cost associated with the State Engineer process. Proliferation of shallow, private wells has another marginal advantage in some areas, particularly in the developing world: pumping of water from shallow wells tapping the aquifer near the water table, which in semi-urban and urban areas is often contaminated, helps to protect–at least for a while–the deeper part of the aquifer, which is tapped by the public-supply systems.

It would be a fairly simple matter to define large areas of the state in which the present rules might continue to work well enough. For most of New Mexico, perhaps the only practical change needed is a strengthening of the well-construction and well-record requirements, as will be discussed below. It may also make sense to set the face-value of these *de minimis* domestic permits at some amount closer to the actual household water requirement, rather than the 3 acre-feet/year, not offering each applicant the right to irrigate a one-acre garden. The proposed Sandoval County ordinance would set the amount at one-quarter of an acre-foot per year.

Some more effort toward education of the drilling contractors licensed by the State Engineer would probably be helpful. One difficulty with the §72-12-1 wells is that their characteristics, and particularly the amounts of water pumped from them, are only very poorly known. It is these wells, of course, that would provide broad geographic coverage of geologic and groundwater information, if the information were reliable. The State Engineer requires a well record for each new well, but the lack of accuracy of these records is legendary.

Well locations are customarily given with a precision no better than the nearest 10 acres, and the space for reporting the land-surface elevation is almost always left blank, so that the water-level information has limited usefulness.

Just a little more information about each well would be of great value. For example, instead of guessing at the well location, or giving a lot number in a subdivision (so that it will be necessary to go to the court house and look at the subdivision plat in order to find out where the well is), an investment of a few hundred dollars in a pocket GPS receiver would enable the driller to report an acceptably accurate location. A good elevation is harder to come by, but with a sound GPS map location, either the drilling contractor, or someone coming along later to use the data, can interpolate the elevation reasonably well from the topographic map.

The well record includes a blank in which to report the capacity of the well, but one never knows whether this estimate is based on actual pumping, or is simply a guess; or, if the well was indeed pumped, whether the capacity was limited by the aquifer's characteristics, the well's construction, or the choice of pump. There is almost never any indication of the drawdown required in order to produce water at the estimated rate. Only a little information about the aquifer can be deduced.

It would be easy to dramatically increase the usefulness of all this domestic-well drilling for our understanding of the resource, and the extra cost would be almost nothing in most cases. A few words in the well-record about how long the well had been pumped, and how the pumping rate was measured, together with a measurement of the depth to water at the end of the period of pumping, would make all the difference.

It's hard to think of a reason why we are better off not knowing these things, except that a little more effort on the part of drilling contractors and rural and semi-rural homeowners would be required. The water-well industry would be capable of these improvements.

It has also been proposed that pumping from the domestic wells be metered. This would be of much value in understanding the patterns of water use in a basin, but would be very expensive to institute and administer.

A great many of the §72-12-1 wells present problems related to their construction. A weakness in the traditional way that domestic wells were, and sometimes still are, constructed is that the annulus between the borehole and the casing is left open. Often there is only a short cement seal around the casing at ground level. This configuration allows contaminated water from the surface, or from septic tank leach fields, to move down the well and sully the water in the aquifer. This can be avoided in new wells by installing a clay or cement seal around the casing, above the water table or above the uppermost casing perforations. I expect that this situation will be addressed in amended State Engineer regulations.

When a domestic well is abandoned, often the only ceremony attending the abandonment is filing of an application for a permit for a new well. Many §72-12-1 wells have been abandoned, and it can be assumed that many or most of these have not been plugged and will continue to serve as potential conduits for the movement of contaminated water, especially after the casing rusts away or collapses. The current State Engineer regulations require only that "[w]ells from which all water rights have been removed shall be plugged in accordance with Article 4-14 and 4-19.1 (OSE, 1995, §2-13)." Article 4-14, as it happens, does not really require plugging at all; abandonment of a non-artesian well is considered satisfactory if no more is done than simply capping the casing. I expect that the State Engineer will also strengthen this provision.

A problem for the operators of public-supply systems, if §72-12-1 wells are permitted in their service areas, is that people have the option of choosing to ignore the conservation efforts of the public system, while depleting the same water source by drilling their own wells. This is thought to have happened to some extent in Santa Fe during the drought of 1996, when the City's efforts to control water use through rate increases led to some new wells (Craig O'Hare, Sangre de Cristo Water Co.).

New domestic withdrawals don't fit very well with the efforts being made by some communities, particularly Santa Fe and Albuquerque, to reduce reliance on groundwater mining, and move toward sustainable supply based on diversion of surface water. The New Mexico Municipal League (1998) studied the issue in depth, and has put forward draft legislation several times since the 1970s to give control of new §72-12-1 permits to the municipalities that own their water systems. This effort has not been successful so far, but the Interim Water and Natural Resources Committee has recommended "do pass" for the 2000 session. This proposed local-option law would apply only within the municipal boundary, and only to new wells within 300 feet of the nearest water line.

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Demographic Trends and Water Demand: New Mexico, El Paso, and Ciudad Juárez

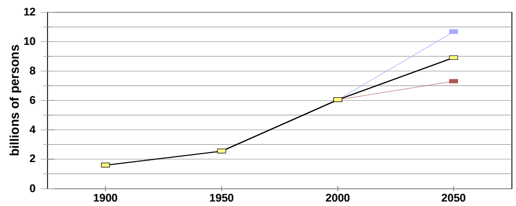
Most of the issues addressed at this conference would either disappear completely or be much easier to solve if the populations of New Mexico, El Paso, and Ciudad Juárez were declining rapidly rather than growing rapidly. Many variables (including the structure of industry, general economic conditions, and housing characteristics) affect the demand for water, but the size, growth, and other characteristics of the population set the context in which nearly all discussions of water demand (water problems, if you like) take place. This brief presentation will focus mainly on regional population trends and projections. The place to begin is with some demographic fundamentals and a review of some world and national demographic issues.

For the last fifty years, most popular and many professional discussions of demographic trends have centered on the "explosive" growth of the world's population. We are all familiar with the story. Rapidly declining mortality in much of the world was not immediately accompanied by corresponding declines in fertility. Under these conditions, the powerful force of compound annual growth rates suggests a world population size that would inevitably collide with the planet's allegedly finite resource base. This basic population scenario, widely believed by many people, is at least as old as Malthus' (1798) rather gloomy predictions of economic stagnation brought about by rapid population growth and a finite resource base.

But a funny thing happened on the way to the Malthusian disaster. In the last few years, a great deal of interest has been expressed in academic and non-academic circles alike concerning the implications of an absolutely declining world population within the next few decades. Much of this discussion has been prompted by the aging of the world population and the population projections of the United Nations.

Beginning in 1996, the UN projections include a scenario in which the world's population would begin to decline in absolute terms within the next few decades. The latest (1998) UN projections (Chart 1) show a range of world population in the year 2050 of 7.3 billion to 10.7 billion persons. Both the low and high UN scenarios are plausible given historical trends in mortality and fertility. Nearly half of the world's population now lives in nations in which the total fertility rate is below the replacement level. Unlike population projections of smaller geographic areas such as nations or states, the UN projections do not suffer from highly uncertain migration assumptions. Given current technology, net world population migration is zero. Yet, even without the volatility of migration assumptions, the UN projections exhibit a range of 3.4 billion persons–roughly half of the low-scenario population in 2050 and somewhat more than half of the world's current population.

Chart 1
World Population: 1900-2050



Similar uncertainty is apparent in national population projections for the U.S. and Mexico. UN (1998) projections of the U.S. population to the year 2050 (Chart 2) range from a low of 292 million persons to a high of 419 million persons. The difference between the high and low projections of 127 million persons is nearly half (46 percent) of the current U.S. population. Although there are differences in fertility and mortality assumptions between the high and low projections, the critical assumption leading to these very different projections is net international migration. The UN projections of Mexico's population (Chart 3) exhibit a similarly wide range with a high population of 223 million persons to a low population estimate of approximately 119 million persons in the year 2050. The difference between the high and low projections of 104 million persons is greater than Mexico's current population.

Chart 2
U.S. Population Projections

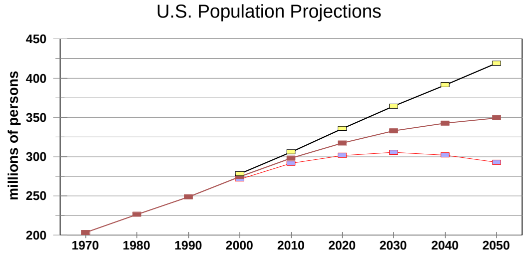
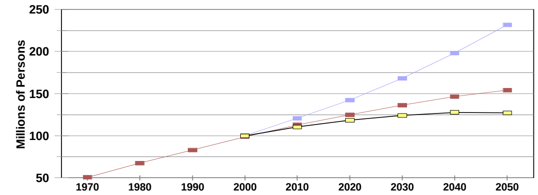


Chart 3
Mexico Population Projections



What do these trends have to do with the dynamics of population growth in New Mexico, El Paso and Juárez? First, the global and national level projections illustrate the inherent difficulties of projecting the future size of any population. Reasonable demographic assumptions lead to widely varying future scenarios of growth or decline. Second, it is in general a much easier and safer proposition to project large populations than small ones. Migration, for example, tends to be much more volatile at the state and local level than at the national level. To the extent that migration is associated with economic conditions in the sending and receiving areas, an accurate migration forecast must depend on forecasts of local economic conditions well into the future. Third, the national level projections of population in the U.S. and Mexico suggest that population growth rates in the two nations are not independent. Large numbers of out-migrants from Mexico, for example, could reduce population growth rates in Mexico while increasing population growth rates in the U.S. In turn, population growth rates in the region under consideration are powerfully influenced by national trends. In short, if there is great uncertainty about population growth at the national level, there is even greater uncertainty at the state and local level.

THE REGIONAL POPULATION

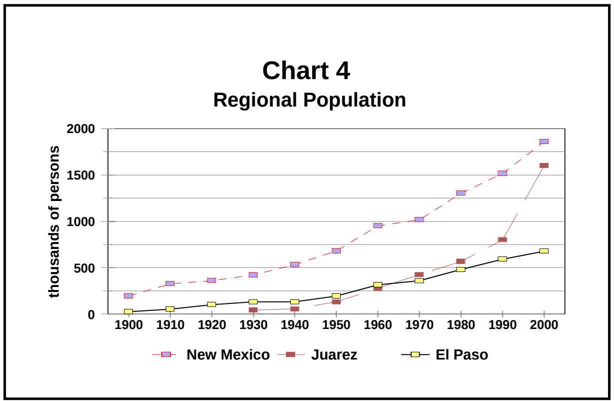
Recent population data for the region are presented in Table 1. By comparison, the U.S. population grew by 8.5 percent during the 1990 to 1998 time period. The 1990s are not a particularly unusual time period for the region when examining population growth rates, which are typically higher in the region than at the national level.

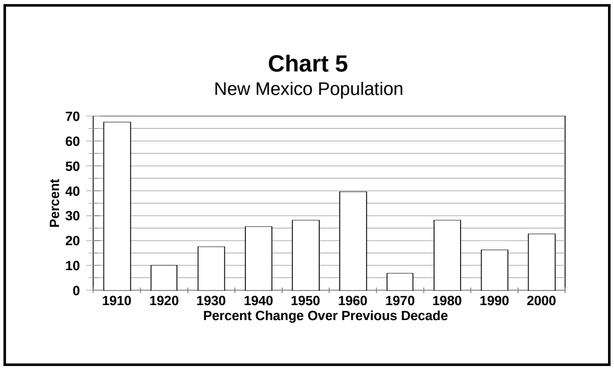
Table 1
Regional Population in 1990 and 1998

Area	1998 Population (millions of persons)	Percent Change 1990 to 1998
New Mexico	1.737	14.6
El Paso	0.703	18.8
Ciudad Juárez	1.167	42.7
Total	3.607	24.2

Source: New Mexico and El Paso data are U.S. Bureau of the Census estimates available on the internet at: www.census.gov. The figure for Juárez is interpolated from Mexican census data and projections in Peach and Williams, 1999.

A longer term perspective on regional population growth may be obtained by examining Chart 4 which displays total population in the three areas during the 20th century except for Juárez for which consistent data extend back only to 1930. As indicated in the chart, the population of New Mexico increased about eight-fold over the century from about 200,000 persons in 1900 to 1.7 million (estimate) in 2000. This is about the same rate of growth as the population of Mexico during the century and more than double the U.S. growth rate. Nevertheless, New Mexico's population growth rate has been highly variable from decade to decade as indicated in Chart 5. Despite a relatively rapid growth in population for the state as a whole, population growth rates by county within the state vary considerably. Indeed, five New Mexico counties lost population in every decade since the 1930s.

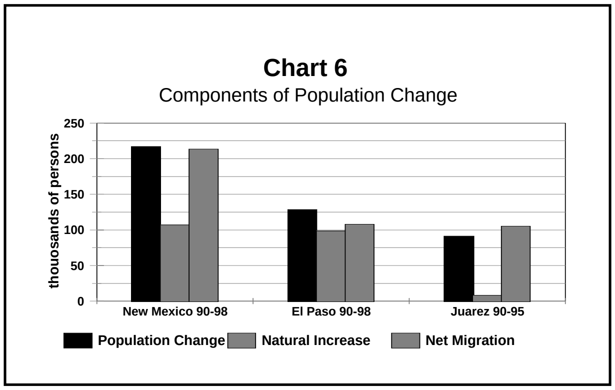




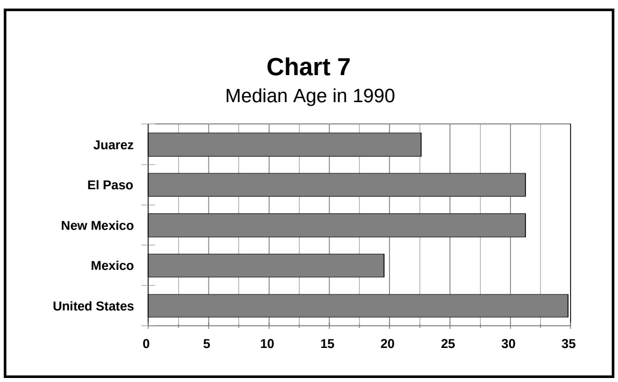
El Paso county's population has grown from only a few thousand in 1900 to more than 600,000 in 1998. Most of El Paso's population growth occurred in the last fifty years. And, as with New Mexico, El Paso county population growth rates varied considerably by decade.

The population of Cd. Juárez grew from 43 thousand in 1930 to just over 1.0 million in the 1995 Mexican Census and may reach 1.5 million by the time the 2000 census figures are available. There has been a noticeable acceleration of growth rates along the Mexican border–including Juárez–during the 1990s. Some of this acceleration in growth rates may be due to an undercount in the 1990 Mexican Census. Yet, migration to Juárez probably has accelerated in the 1990s, especially after the 1994-96 economic crisis in Mexico. Juárez population growth rates, like those in many other Mexican border cities, have been high for more than fifty years. At current growth rates (1990-95), the population of Juárez will be larger than New Mexico's total population early in the 21st century. Whether or not Juárez's population continues to grow at current rates is an open question.

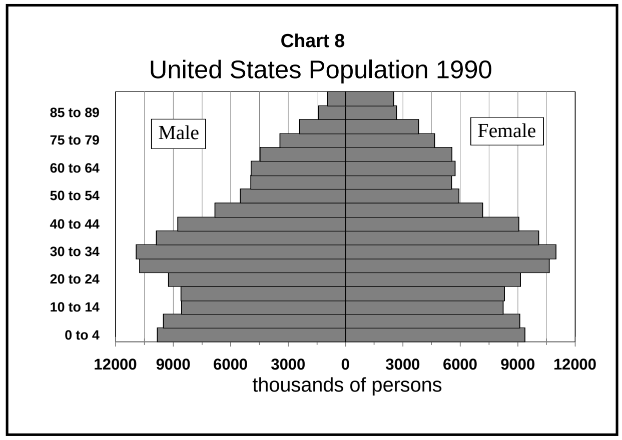
To better understand the future population dynamics of the region, it is necessary to examine the components of population change: births, deaths and net migration. Chart 6 displays the components of population change for New Mexico and El Paso from 1990 to 1998 and Juárez for 1990-1995. In all three areas, the importance of natural increase (the excess of births over deaths) should not be underestimated. Between 1990 and 1998, natural increase accounted for 59.3 percent of New Mexico's population increase and 91.8 percent of El Paso's population increase. In Juárez, natural increase accounted for 50.6 percent of population change between 1990 and 1995.

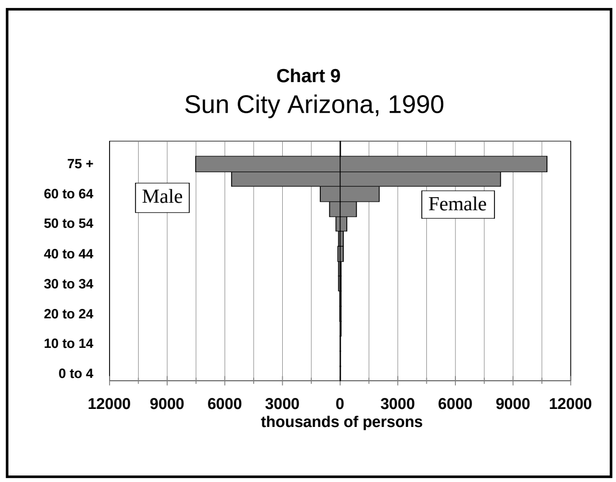


The natural increase data cited above point to the importance of what demographers refer to as demographic momentum, the tendency of a population to increase due to its age and sex distribution, even when fertility rates might be stable or declining. In other words, a population with a large portion of its population in the child-bearing years can expect to see a lot of births even if birth rates are stable or falling. Conversely, a population with a high proportion of older people is likely to have fewer births. In general, the regional population is younger than the U.S. population, but older than the population of Mexico. Selected median ages of the regional population in 1990 are displayed in Chart 7. The relatively young regional age distributions suggest continued population growth, even if fertility rates were to decline.



Even so, we need to realize that the regional population, like that of the U.S. and much of the world is an aging population. Although median ages in the region are lower than in the U.S. as a whole, median ages in the area are increasing and will continue to do so. The implications of an aging population are profound and include direct effects on labor force participation, productivity per worker, population growth, patterns of public expenditures, crime rates and yes, of course, water demand. Such implications can be illustrated very simply. Charts 8 and 9 are population pyramids of the U.S. and Sun City, Arizona in 1990. There is no need for graduate work in economics or demography to draw reasonable conclusions from these charts.

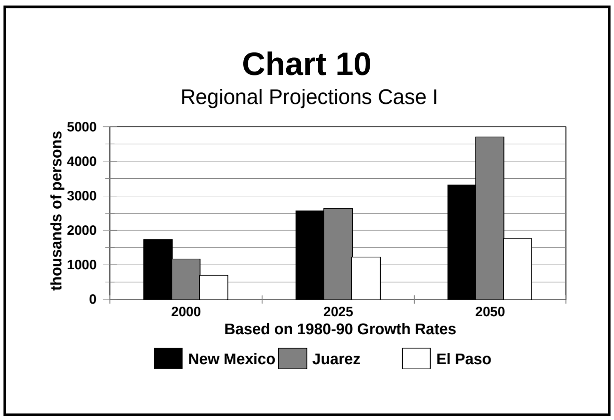


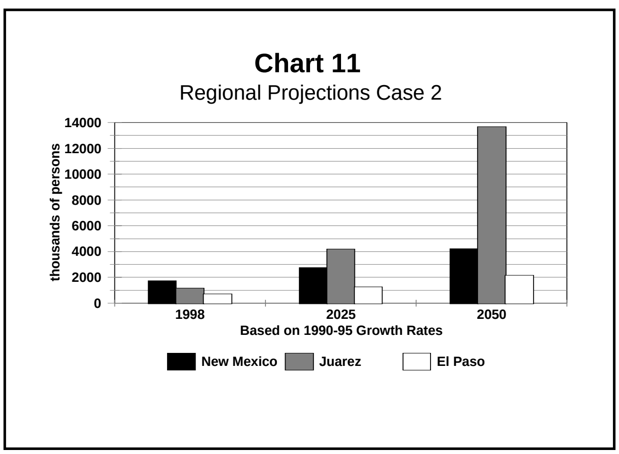


SOME SIMPLE REGIONAL PROJECTS

While a variety of more sophisticated and more intellectually satisfying population projection techniques are available, it is sometimes a useful exercise to simply extrapolate current trends. Despite some significant shortcomings, simple trend projections offer a number of advantages. Trend projections are computationally efficient. This means that simple trend projections can be done by almost anyone using a variety of different growth rate assumptions. Further, the number of underlying assumptions used in simple trend projections is very small. Using simple trend projections does not require accurate assumptions concerning the future course of fertility, mortality, migration, or economic conditions. Finally, simple trend projections are easy to understand–an important consideration in many contexts.

Simple trend projections of the regional population are presented in Charts 10 and 11. Two scenarios are presented here, but others can be easily computed using nothing more than a hand-held calculator. The first scenario uses compound annual growth rates from U.S. and Mexican decennial census data for 1980 and 1990. The second scenario is based on compound annual growth rates from 1990 to 1995 for Juárez and 1990 to 1998 for New Mexico and El Paso, Texas. The 1995 ending period for Juárez was selected because Mexico conducted a mid-decade census, but does not publish annual population estimates. On the U.S. side, the 1990 figures are from the decennial census while the 1998 figures are U.S. Census Bureau estimates (www.census.gov). Projections are presented for both scenarios for the years 2025 and 2050.





Using the first scenario, the regional population more than doubles from a 1998 population of 3.7 million to 9.8 million in 2050. Under this scenario, the population of Juárez exceeds that of New Mexico by the year 2025 and is 43 percent larger than New Mexico's population by 2050. Still referring to the first scenario, the population of both New Mexico and El Paso increase by 65 percent by 2025 and more than double by 2050.

The second scenario, based on growth rates of the 1990s rather than the 1980s, implies even more dramatic changes in the regional population. Under this scenario, Juárez would be one of the world's larger metropolitan areas with a population approaching fourteen million people–or more than double the combined populations of New Mexico and El Paso. This scenario is not a likely one even given the historically high rates of population growth in Juárez.

CONCLUSIONS

Even a brief tour of the population dynamics of the New Mexico, El Paso and Juárez region suggests that water experts and water users alike face some interesting issues in the coming decades. But that is not news to the participants at this conference. What we should all keep in mind as we plan for future water demands and debate water issues is that there is a great deal of uncertainty about regional population growth. Reasonable demographic assumptions lead to widely varying future population scenarios. Combining future demographic uncertainty with rapidly changing global, U.S. and regional economic conditions leads to a very simple conclusion: regional water demand in a decade or two will probably not be what we currently project it to be.

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Habitat Restoration and Enhancement of the Middle Rio Grande Basin

Habitat restoration and enhancement are becoming more and more popular in New Mexico as demonstrated by Senator Pete Domenici's support for the Middle Rio Grande Bosque Initiative. The Initiative was begun as a multiagency initiative to describe the Middle Rio Grande ecosystem. As a consequence of the coordination, a report was completed entitled, *Middle Rio Grande Ecosystem: Bosque Biological Management Plan*. The goal of the Initiative is to sustain and enhance the biological quality and ecosystem integrity of the Middle Rio Grande bosque. To achieve this goal, a full-time coordinator is in place with the Fish and Wildlife Service. In addition, as recently as 1999, Pete Domenici also obtained funding in the amount of $2,000,000 for restoration in the Middle Rio Grande.

The priority for the Fish and Wildlife Service for habitat restoration is a ecosystem approach so that habitat for many species can be restored and a functioning, self-sustaining environment can be achieved. Beyond that, our priorities are endangered species, and restoration of wetland and riparian habitats. These habitats have decreased significantly–over a 90 percent loss in the Southwest.

In some cases, restoration requires the removal of exotic vegetation before desirable vegetation can be established. A root rake can be dragged through the soil to remove the roots of undesirable vegetation (Figure 1). To plant vegetation, such as cottonwood poles, holes can be drilled in the soil, with screw-type augers or water-pressure hoses. In soils that are free of large rocks, hand augers can be used to drill holes (Figure 2). Planting trees using cottonwood poles is a good method of stabilizing stream banks (Figure 3). Pole planting accelerates revegetation because the plants are large from the beginning. Planted vegetation should be protected with wire to prevent damage from rabbits, rodents and livestock.


Figure 1. Vegetation can be removed with a rootrake.


Figure 2. An auger creates a hole for a cottonwood pole.

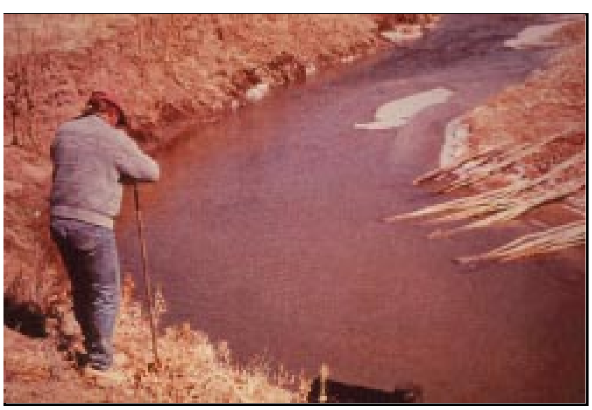
Figure 3. Cottonwood poles can stabilize stream

The Fish and Wildlife Service, Ecological Services, has two restoration programs. One program is limited to the Middle Rio Grande under the Middle Rio Grande Initiative. The Service administers contracts for habitat creation, such as development of wetlands. The second program is called the Partners for Fish and Wildlife Program. This program is a cost share program with nonfederal entities and can occur anywhere in New Mexico.

Wetlands are very desirable for restoration or creation because they support a unique assemblage of species not found in other habitats and because wetlands are scarce in the Southwest (Figure 4). Wetlands can be created through proper landscaping and hydrology using heavy equipment. Wetlands can often be created near water courses. One simple method of restoring wetlands and riparian habitats, is to reduce grazing or exclude livestock. For example, livestock have been excluded at one location for seven years in the San Francisco River in New Mexico with dramatic results (Figures 5 and 6). The project was very simple, it only involved construction of fences. To ensure higher wildlife values near water courses, upland areas should also be properly managed. At successful restoration sites, we encourage field trips to demonstrate restoration and at the same time educate others concerning the environment.

Currently, there are many lawsuits in New Mexico concerning endangered species. The water management community is protecting their existing uses, and other agencies are attempting to recover endangered species. For example, there are at least four potential lawsuits concerning the Rio Grande silvery minnow. Lawsuits require an enormous amount of time and funding. Instead of devoting valuable, scarce resources to this activity, the citizens of New Mexico would be better served by a cooperative approach to environmental issues. Let's use these resources for habitat restoration, because it will benefit all components of the ecosystem, including the human population.

Figure 4. Wetlands support an abundance of wildlife.

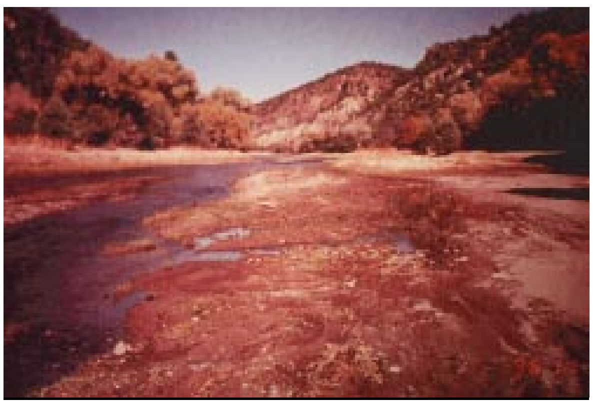

Figure 5. The San Francisco River in poor condition.

Figure 6. The San Francisco River after livestock exclosure.

__Steve Harris__ received his baptism in the Rio Grande at Boquillas, Coahuila, Mexico in 1964, and has been a student of the river's history and natural history since 1975. He is president of a river outfitting business, Far-Flung Adventures, and executive director of the basin-wide streamflow advocacy group, Rio Grande Restoration.

The Rio Grande Compact: It's A Law

Let me begin by expressing my thanks to Cathy Ortega Klett and WRRI for inviting me to speak today. I really appreciate this opportunity to present my views of the Rio Grande Compact what it does do, what it doesn't do, and what it **could** do, from the perspective of a river outfitter and guide.

Whitewater recreation is a beneficial use of water. Recreation may not be **as beneficial** a use of water as agriculture (you can't eat fun), but it IS beneficial nevertheless. Far-Flung Adventures' files contain 25 years of letters attesting to the benefits our guests receive by connecting with the great and turbulent "something other," which is the living pulse of our planet.

More prosaically, river recreation is an economic engine, though it's more like a two-stoke than a V-10. The dollar economic value of river-oriented recreation is measured in the tens of millions of dollars, compared with well over $1 billion in farm income in our fair basin. But, tourism is the number one industry in Colorado, New Mexico and Texas.

Moreover, the largest part of the value of a river like the Rio Grande doesn't even show up on the spreadsheet: there are orchids and eagles and wolves and bears still afoot in isolated corners of our basin and fluttering great cottonwoods.

The knowledge of the existence of creatures that make our hearts soar and the possibility of glimpsing some source of nature's wonder around the next bend are a big part of the attraction to my guests and most of what motivates me to try and protect the river. Farmers and recreationists and managers and paisanos, geeks and day traders– we're bound up in the processes of the planet and we ignore this fact at our own peril.

To go rafting, one needs a certain flow of water, though any outfitter in the Southwest will tell you that you don't need as much as you might think. Since the Compact has something to do with the flow of water in the Rio Grande, along with the fickle climate, agricultural economics, state water law, case law, common law, the Clean Water and Endangered Species acts, contrary administrative rules, international treaties, reclamation contracts, relationships of power, and the irresistible momentum of history and custom, the Rio Grande outfitter is acutely aware of the water management prescriptions of the Rio Grande Compact.

My own close personal relationship with the Rio Grande Compact began in April of 1985 when I saw a photograph, on the front page of the *Albuquerque Journal,* of some farmers with big grins standing on the spillway at Elephant Butte Reservoir. The caption said they were from the

San Luis Valley and that they were celebrating the fact that, for the first time since 1942, "The Butte" had overflowed.

With a little digging, I learned that the folks in the picture were rejoicing because they'd suddenly just emerged from 18 years of figuring out how to comply with a Supreme Court decree that said that they not only had to do something that had seemed impossible in 1967–that is to get their scheduled deliveries of water to Lobatos Bridge–but also, even more impossibly, to whittle away at a nearly ONE MILLION acre-foot water debt. The spill at Elephant Butte, I learned, was a watershed historical event delivering Colorado agriculturalists and water technicians from, to borrow a John Hawley phrase, "the end of the world as they knew it."

The decade of the 1980s was a great time to be a Rio Grande boater. Except for 1981, there was a ton of snow, and fantastic runoffs. But no matter how much snow the Soil Conservation Service said was up there, by July 10 the river took a precipitous drop and in about a week would become unnavigable. In 1986, boaters were able to run the Taos Box throughout July, unaccountably, unprecedentedly, despite one of the drier years of the "glorious eighties." The reason, I discovered, was that the Butte hadn't quite spilled and the Conejos River irrigators were being curtailed in order to assure Colorado's delivery obligations were met.

In 1988, despite a normal or better snowpack, we had a drastically reduced season, and had to send back customer deposits that had already been spent. An early melt had allowed Colorado to deliver their obligation before the rafting/irrigation season even started. Rafters realize, as do farmers, that each season is a new shuffle and a new challenge to which to adapt and you can't count the money 'til the hay is loaded.

Also, in 1988, the river outfitters' industry "discovered" the Rio Chama. When there's just a trickle of native Rio Grande water coming through Otowi, we found out that Albuquerque area irrigators move lots of water through the Chama.

By 1991, Gary Daves, Mike Hamman (then with Reclamation), Brian Hanson, New Mexico State Parks' Bob Findling, and Bureau of Land Management's Tom Mottl, the river runners, Chama Valley, and Middle Rio Grande Conservancy District representatives collaboratively advanced the concept of the "Recreational Dam Release." Suddenly hundreds of whitewater boaters were able to ply the lively waters of the Chama throughout the summer season. With recreational releases, the germ of an idea of modifying water operations to create secondary benefits, was planted in New Mexico. I mean, if you can float on a bolt of water one Saturday and irrigate with the same molecules on the following Thursday, why not double the benefits you get from the water? Why not?

The Rio Grande Compact: It's A Law

In 1996, the inevitable drought occurred. An historic *Albuquerque Journal* photo appeared depicting the river in the Middle Rio Grande as dry as the Sahara. **The last minnow that had survived the "Big Barbecue," the rush to develop every source of water we could find, the Rio Grande silvery minnow very nearly winked out and another historic line had been crossed**. Henceforth, the endangered condition of an aquatic species would command our official, if often grudging, consideration. Later that same summer, the Closed Basin Project Operating Committee released water into the river "for ecosystem purposes in Colorado," in response to a Rio Grande running a scant six cubic feet per second.

Looking back over these and other experiences, I see that a lot of harbingers of the future of the Rio Grande in the changes I have witnessed:

- A farming valley can make huge operational changes and not only survive, but actually thrive.
- Consumptive and non-consumptive beneficial uses can coexist. Winners and losers are not necessarily necessary.
- Altruism is a possible response to great threatening challenges. An institutional water user can behave in ways that are not strictly concerned with gaining or maintaining hegemony, but rather address issues at large in the greater society.
- Water operations can be as flexible as we want them to be.
- Social institutions can just as easily be our masters as our servants.
- Even mountains and rivers sometimes find relief in Federal Court.
- Our great thirsts now exceed the available water supply.

Denial is a pathological psychological condition and my EMT textbook mentions it as one of the frequent symptoms of a heart attack. An older friend of mine quite recently went through a triple bypass heart operation, and as he was recovering and feeling well enough to go home, he got into a conversation with the technician who'd been taking his vital signs during his stay in the hospital.

"Fred," he asked, "what do you think of me as a patient?"

"Well, Andy," replied the orderly, "I think you're smart and I think you're lucky."

"Okay," said my friend, "I think I understand the lucky part. I've had the best care known to medical science. What I don't get is why you would think I'm smart."

"Andy, you're smarter than most because you admitted there was a problem before it was too late to do anything about it." This is my theme for my last five minutes: "We're lucky because we still have a river, and everything the river supports, compromised though it may be. **But are we smart enough to realize the depth and imminence of the problem we have?"**

The framers of the Compact knew they had a problem. For more than forty years the downstream users had been telling the upstream users: "Hey, we're dying down here." In 1895, the Republic of Mexico even claimed that the Juarez Valley was going to be abandoned, because they could no longer count on enough water to farm; in fact, the wine and brandy industry did die on the vine, so to speak. There's this wonderful saying in the irrigation world: "I'd rather have a junior right at the top of the ditch than a senior right at the bottom,"–that is what was happening. Colorado even righteously claimed they owned the water that originated in the snowfields of their state, until the U.S. Supreme Court told them otherwise, in 1907. *(Kansas v. Colorado.)*

The Rio Grande problem was a regional problem; it was a tough, and contentious problem in interstate relationships. There was a lot of saber-rattling and wagon-circling when the Secretary of Interior declared a moratorium on dam building.

Ironically, the catalyst for change was federal intervention. The "Joint Investigations" cost nearly half a million, mostly federal depression-era dollars and was a thorough, scientific view of the scant and variable supply, as well as an inventory of both the actual agricultural uses and the development potential of the river above Ft. Quitman.

Here was a difficult question of equity, with the future of the whole upper basin at stake, and it was ultimately solved by cooperation. The four commissioners, four consulting engineers, and seven lawyers who drafted the final Compact convened six times over five years to finally hammer out the details, concluding with one incredible 16-day marathon. Finally in 1940, for the first time, an elegant system of inflow-outflow relationships was codified and applied to the river.

The Rio Grande Compact: It's A Law

The Compact is designed to do one big thing: ensure the "equitable apportionment of the waters of the Rio Grande for agricultural purposes." In 1939, that was enough. Irrigated agriculture was not simply the most important thing, it was the only thing that had to be considered.

It was the 1930s, the whole West had just come through a 90-year "orgy of development" and we didn't have Steve Vandiver's crystal ball to help us. We knew a lot less about nature and natural processes than we do now, and we thought about nature in a radically different way than we do today. For a good many reasons, the "water rights" of nature were not mentioned in the Rio Grande Compact or the original state water codes....and it still isn't.

This was not an unforgivable oversight and it is, I contend, an error that can still be corrected. And if the Rio Grande itself, which gives us so much, is to ever gain its due from a belatedly grateful humanity, the time to do so is right now. The river at Albuquerque is at a decision point. It is very likely that, unless some ways are sought to rectify the disregard in which our water policies hold nature, the Middle Rio Grande is going to end up looking like the Los Angeles River or the Salt River at Phoenix or the Lower Gila. Our own children may be the last generation with the opportunity to really know a river at the center of the landscape in their lives. The silvery minnow is telling us something: **we are well along in the process of killing the river.**

What this has to do with the Rio Grande Compact is this: there are those who say that, because of one provision or another in this suite of laws that govern our use of the river, we cannot really change things. Yes, they use the Compact and the beneficial use requirement of state law to justify their own fear of change.

Preparing to speak with you today, I carefully reread this document and I couldn't find any articles or clauses that said we couldn't protect the river. I find the "barriers" to including nature in our water administration arrangements to be purely conceptual and arguments to the contrary to be products, in the words of Wallace Stegner, of "the still unlovely human mind."

So I ask the question: "If, becoming cognizant of the ecological destruction we have visited on the river, we changed our minds, would the Compact prevent our accommodating nature?" I think not. Personally, I'm damn glad that the Compact demands that we share the water with our human neighbors, because it means that volumes of water will continue to flow downstream, albeit on human, rather than nature's, time schedule.

However, there are certain incongruities:

- Releases from storage – Steve Vandiver pointed out that the Compact sometimes directs this process. Conrad Keyes countered that Congress could change reservoir authorizations. Changing the **timing** of deliveries to better accommodate the original environmental uses is possible, and desirable.
- Municipal allocations – In the tumultuous year of 1996, I heard a lawyer for the state of Colorado advance the argument before the Commission that the Compact prevented reallocation of Project water to municipalities. There's an interesting suit that the El Paso Water Board must be thankful has not yet been filed, though the contracts must still be bollixed up in the quiet-title mediation. (I wouldn't know.)
- Indian water rights – Article 16 is a thoughtful throw-in, but doesn't offer any guidance for integrating the long awaited settlement, or judgment, of *Winters* rights into Compact administration. It's not inconceivable that we will live to see the Pueblos express their vision of **homelands** (as opposed to farms) as the purpose of their reservations and claim water for the nonconsumptive purposes which they still cherish.
- Spill provisions – The theory behind the very creative spill provision is: "if the Butte spills, then there's full supply for Mesilla and El Paso/Juarez." So what's to fight over? We can't reclaim the past. Again, in that "drought rehearsal" year of 1996 (the 53rd year of Compact administration), the unforeseen combination of drought plus a spill very nearly occurred. Had a spill occurred, the Compact would have justified Colorado's keeping every precious drop and an ecological emergency might well have ensued.

One way of dealing with such an eventuality might be for the Commission to resolve to create an environmental side accounting within Article 6. Our objective should be to optimize supplies for all users. And in any case, the true occurrence of the havoc such an eventuality would play with the environment cannot safely be ignored.

Finally, there's Article 13, the right to review proposed "non-substantive" changes to the Compact. My reading, and the view I would commend to all the lawyers who may be rendering their opinions to the Commissioners, is that Article 13 actually intends to permit them, if unanimous consent can be obtained, the flexibility to make resolutions in response to changing conditions, so long as they do not pretend to abrogate existing provisions.

I've been gratified by the tone of this conference–the implicit recognition by many of the presenters that this is not 1939, and the clear identification of the challenges we continue to face. Social changes external to the Compact are accelerating and cannot be ignored. The pressure on us to respond is building. Eventually, we will be forced to confront the water needs of the river as the support system for lives other than our own.

Intentional change is always risky, requiring courage and conviction we may have to dig deep to find. It must be of some comfort to know that our forefathers who wrote this document faced these same personal challenges and met them. Article 13 says they were wise enough not to pretend that the document they created was etched in stone. We ought not argue that it was.

The question we are left with is this: Are we to be the masters of our institutions or shall we be their slaves?

Thank you.

The Rio Grande Compact: It's A Law

River Recreation and the Economy of Northern New Mexico
April 1994
Department of Agricultural and Resource Economics
The University of Arizona
Tucson, Arizona
by Bonnie Colby, Liz Ryan, and Julie Leones

Conclusion

Flow levels on the Upper Rio Grande in northern New Mexico are subject to wide variations from year to year, impacting whitewater rafting opportunities and the local economy. Flow levels in the later summer months are not sufficient to support a full summer rafting season on the Taos Box and this limits the contributions of rafting to the northern New Mexico economy.

In 1992, visitor expenditures directly linked to rafting contributed $4.6 million in total industry output, $1.8 million in employee compensation and accounted for 142 jobs for the 1992 season in the four county region. These are significant economic inflows, even though most activity on the Taos Box ended half way through the summer due to inadequate flows. The economic impacts in the region would increase by approximately 17% if flows were maintained at 592 cfs through Labor Day weekend. If cfs was maintained at 1,083 cfs, the economic impacts would increase by about 73%.

Visitors engaging in Rio Grande rafting are diverse, representing a variety of ages, incomes, types of employment and levels of education. The average visitor had approximately 16 years of education, was 40 years old, and had a household income of $53,200 a year. Primarily people from the western United States engaged in Rio Grande rafting, with the majority of visitors coming from Texas, California and other parts of New Mexico.

The economy of northern New Mexico depends heavily on tourism. Whitewater rafting is a nonconsumptive use of water that provides jobs and income in a region with low wages and high unemployment. If the region is to realize the full economic potential from this use of the Rio Grande, adequate flows need to be assured for the full summer season each year. Economic stimulation through whitewater rafting is only one small part of the overall benefits of improved stream flows. High flows also would have significant environmental benefits, improving fish and wildlife habitat and water quality. These benefits can only be realized through a cooperative and concerted effort of Rio Grande water users, resource managers, and federal, state and local officials, to determine the fairest and most cost-effective method for improving flow levels on the Upper Rio Grande in northern New Mexico.

Panelists from left: Tom Turney, Joe Hanson, moderator Tom Bahr, Robert Armstrong, and Steve Vandiver (sitting in for Hal Simpson)

Issues and Concerns of the Rio Grande Compact Commissioners

Moderated by Tom Bahr,
Former Director, WRRI

Bob Armstrong is the newly appointed Federal Rio Grande Compact Commissioner. In 1993, he was confirmed by the U.S. Senate to serve as Assistant Secretary for Land and Minerals Management with the Department of the Interior. Bob has served as a member of the Texas House of Representatives and for 12 years during the 1970s and early 1980s, he was elected to manage 22 1/2 million acres of public land and mineral ownership in Texas. In 1985 he was appointed to the Texas Parks and Wildlife Commission. His experience with conservation organizations includes: The Sierra Club Austin Chapter, which he founded in 1968; the Western States Land Commissioners Association; the Texas Nature Conservancy; a founding board member of the Texas Parks and Wildlife Foundation; and the board of the Trust for Public Land. He is a recipient of the Field and Stream Conservation Award, the Nature Conservancy President's Public Service Award, the Chevron Conservation Award, and the Nature Conservancy's Lifetime Achievement Award for 1997. Bob was born and raised in Austin, Texas. He received a bachelor's degree in 1958 and L.L.B in 1959 from the University of Texas.

Tom Turney is the New Mexico Rio Grande Compact Commissioner and has served as New Mexico State Engineer since 1994. A professional engineer for over 29 years, Tom is licensed in the fields of civil, electrical, sanitary and architectural engineering, and is registered in New Mexico, Colorado and Arizona. Before becoming state engineer, he worked for a number of cities in northwest, central and northeast New Mexico as well as with the Mescalero and Apache tribes. Tom earned both bachelor's and master's degrees in civil engineering from New Mexico State University. He is a native New Mexican, his grandfather having settled in Jornada, New Mexico in the 1880s.

Hal D. Simpson is the Colorado Rio Grande Commissioner and was appointed Colorado's State Engineer in 1992. As State Engineer, Hal is responsible for the direction and management of the Division of Water Resources, which has a staff of 230 and a budget of about $14 million. The State Engineer is Colorado's commissioner on five interstate compacts and is responsible for

assuring compliance with these compacts. Hal served as Deputy State Engineer from 1984 to 1992. He received both B.S. and M.S. degrees in civil engineering from Colorado State University. His master's degree specialized in water resources and groundwater hydrology. He has done post-graduate work in water resources at the University of Colorado. Hal is a registered professional engineer in Colorado, and is a second generation native from the Greeley area where he grew up on a dryland wheat farm with a small dairy.
Note: Commissioner Simpson was unable to attend due to an unanticipated change in scheduling. Steve Vandiver, of the Colorado Division of Water Resources, spoke for Commissioner Simpson. Steve also presented a paper earlier in the conference.

Joe G . Hanson received a bachelor's degree in geology from the University of Texas at El Paso. In 1962 he started his own business, Hanson Farms, and in 1968 he added Hanson Homes. From 1985 to the present, he has been Chairman of the Board for Hanson Development Corporation. Joe has been involved in a number of business and civic organizations and currently is Vice Chairman, Board of Fellows at UTEP, Board Member, Bank of the West; and Member, Chancellors Council, University of Texas System. In January 1999, Joe became the Rio Grande Compact Commissioner for Texas.

Bob Armstrong

Good morning. My e-mail address is "landmanbob" and as that name would indicate, I have not had much to do with water, but in the last couple of years, I have been gravitating more toward water issues. Recently I headed a presidential commission that looked at recreational lakes. Federal lakes were once primarily used for storage for irrigation purposes. Now we have more than 1.5 billion visits to federal facilities including the national parks and 900 million of those visits are to lakes for recreational purposes. That number surpasses national park visits by 15 million. With work on recreational lakes, I developed a good rapport with the Senate and hopefully they will enact into law some good suggestions.

Perhaps the man who has influenced me more about water is Wayne Elmore. He just looks at how we can slow the water down. I was delighted to see that Bill Zedick got his award because he, like Elmore, starts at the headwaters to see how we can slow it down.

I consider myself a very lucky person because just a week after I am appointed to the Rio Grande Compact Commission, I'm invited to this gathering of people ready to teach me about what they are doing regarding the Compact. I would say we have the best minds that you could get for this kind of event. There are going to be problems and we recognize those problems, particularly concerning growth issues. But if we can bring these peoples' minds to bear on these problems, we will prevail.

At this time, I don't have any pontifical statements to make, but I will when we have another meeting like this. I am delighted to be here and I want to thank Bob Creel for putting on a good show.

Steve Vandiver (Standing in for Colorado Commissioner Hal Simpson)

I'm obviously not Hal Simpson–he was detained by our governor. There is a drought and flood conference put on by the Department of Natural Resources in Denver, Colorado yesterday and today and Hal is there with the governor. He expressed his apologies for not being able to be here and certainly I know he would have enjoyed what has transpired. I did ask him what he wanted me to say though and I will try to express his thoughts on pressing issues and concerns.

As you heard yesterday, one of Colorado's biggest concerns is water supply. Without reservoirs and without the ability to control our water, we are pretty much at the mercy of what runs off the mountains. The average annual rainfall where I live at Alamosa is 6.9 inches and we are partially surrounded by 14,000 foot mountains on three sides. It doesn't allow for a lot of precipitation to help augment our water supply. We dodged a bullet last year. We were looking at about a 40% of normal snowpack the first week of last April, which would have resulted in much less than that in runoff. The good Lord saw to it that we got two snowstorms and a whole summer's worth of rain. We ended up with almost a million acre-feet from what would have been probably 300,000 acre-feet. We can't depend upon last year's good fortune every year. This year we have started with the same minimal snowpack. It is easy to see why one of our biggest concerns is our water supply and how we deal with it.

Secondly, Colorado is extremely concerned with the preservation of benefits under the Rio Grande Compact. Through negotiations, Colorado was afforded certain benefits under the Compact. We received allocations just as New Mexico and Texas did. However, circumstances like a spill at Elephant Butte, minimum unfilled capacity provisions, and issues of proposed Compact reservoirs–all those events play a role in determining the usable water supply in Colorado. We are very much interested in making sure that Colorado's benefits are preserved. An issue that would force potential changes to Colorado's benefits includes changes in the operation of the Rio Grande Project. That is a terribly difficult subject that we are involved in right now. Colorado wants to stay out of that fight very badly, but at the same time wants to make sure that whatever changes occur, they do not change the benefits that we were provided in the Rio Grande Compact. We have expressed to the downstream districts and to the other two states that we support and acknowledge the fact that changes are needed to respond to demands. All we ask is that the other interests in the basin are considered in what is done, and if there are simple solutions to preserving benefits to the upstream states, that we do that. Growth issues are certainly a part of that and I will leave those issues to the other commissioners to discuss.

Endangered species issues are a concern. We have many endangered species of our own in Colorado and for many years, we wished them away. Finally our wishes couldn't hold up any more and we have learned some very difficult lessons on how to handle endangered species issues. The Colorado River is a good example of changes in operations and the use of existing facilities to accommodate issues involving endangered species. The challenge to all of us is to accommodate those new demands, and it is our belief that you can do that with existing facilities, with changes in operations, and with re-regulation in some cases. The problem is that solutions are often site specific and species specific much of the time. You cannot necessarily take one basin's solution and apply it directly to another, unfortunately. You can certainly use the good ideas that are developed. We also feel that given the tremendous facilities that exist in New Mexico, there are facilities in place that can help with their efforts. Colorado has tried to be helpful in identifying solutions that could help other states.

Lastly, we hope that everyone uses the best management practices available. In my presentation yesterday, I tried to explain what Colorado is doing regarding its use of best management practices in order to meet our obligation as well as to be able to best use our entitlements under the Compact. A tremendous amount of work and resources are needed to do that, but it can be done. It requires a lot of money and human resources, and state legislators must understand its importance. The only way that legislators can grasp its importance is if the people in this room make sure they understand. Those are the major issues that concern Colorado and look forward to working with the other Compact commissioners and all of you in this room to address the challenges of using a very limited resource for an ever-changing and ever-increasing demand.

Thank you.

Tom Turney

This is probably the best attended water conference I have ever attended. I think it is great, and I want to thank Tom Bahr, Bob Creel and the WRRI staff for all the effort that they have put into this conference. I don't think I've ever seen this room so crowded with people.

New Mexico does have issues and concerns regarding the Rio Grande Compact and I am going to guess at what we may see over the next ten years. One of the issues that will definitely be at the forefront, at least in the next two or three years and maybe even five to ten years, concerns endangered species. How are we going to get the silvery minnow from being placed in jeopardy? If there are depletions associated with re-operation of the river for the silvery minnow, where are those depletions going to come from? Where will the flows that will be necessary to offset those depletions come from? Where will those water rights come from? It is very, very important that New Mexico be able to meet its interstate compact obligations. This is a major question for us. I was pleased to hear this morning that the United States Fish and Wildlife Services was not necessarily against the reconstruction of the low-flow channel. The low-flow channel is important to the state of New Mexico's ability to meet its compact obligations. New Mexico is definitely going to have to become involved in the operation of the Rio Grande. For the first time, the state will be participating in a joint effort in preparing the final assessment dealing with this issue.

In the next few years, you are going to be hearing from me a lot about something called "active river management." This is something in which the state of New Mexico must become a major player. A key part of active river management concerns measuring flows. Irrigation districts along the river have already become leaders in measuring diversions and return flows. Next year, with some money that has been set aside, we will be continuing to measure and perhaps expand that program. Yesterday, during Steve Vandiver's talk, I was reminded that it will become increasingly more important that the state actively participate in adjudication of the water along the Rio Grande. We already have a number of ongoing adjudications on tributaries to the Rio Grande, like on the Lower Rio Grande where we are using GPS-GIS technologies. We are completing hydrographic surveys in record time, hoping they can be finished in 36 months. That 36-month timetable will probably be reduced to 12 to18 months as we move up the river. I am also dealing with the San Juan River, although I have not yet made a priority judgement between the Upper Rio Grande and the San Juan River yet. I believe education is a key element in managing the state's water resources.

Growth issues along the river are going to become more and more important. Albuquerque has been mining groundwater for quite awhile, but they want to change that strategy by moving toward surface water usage, while preserving groundwater for drought periods. For the past few decades, Albuquerque has been augmenting the Rio Grande flow by discharges through their wastewater treatment facilities. Ultimately, as Albuquerque moves toward more reliance on surface water and less on mining groundwater, this augmentation may decrease. One big question that remains is what will happen when this augmentation begins to decrease–what will be the impact on meeting our compact obligations?

The issue of domestic wells was brought up this morning and it's an issue states are going to have to face. We heard numbers tossed around this morning of an estimated 19,000 acre-feet of diversions from domestic wells just along the Rio Grande. We are issuing new permits out of the Albuquerque office at the rate of about 3,000 a year, and this number will probably increase. People like our current system–they come in and pay us five dollars and we issue a domestic well permit. However, the challenge we will face is how to continue having a process where it is very easy for people to obtain a domestic well permit from my office and at the same time, the existing senior water rights are protected and we continue to meet our compact delivery obligations. I think there will be a lot of discussion over the next few years on domestic wells in the Rio Grande Valley and the type of policies we want to adopt with respect to domestic wells.

New Mexico is faced with pressures from many different stakeholders: Rio Grande rafters out of Pilar and similar places, those who fish along the river, acequias, municipalities, traditional agriculture interests like the Middle Rio Grande Conservancy District, and the Endangered Species Act. All these stakeholders are going to be putting enormous pressure on the state and certainly I can see that our future is going to be very, very challenging.

Thank you.

Joe Hanson

As I was visiting with Herman Settemeyer, the Texas Compact Coordinator about what I was going to say today, Herman said "Don't worry about it too much because by the time they get to you, about half the audience will have left, half of the rest will be asleep, and most of the rest are going to wish that you would hurry up and finish what you have to say so they can go to lunch." So with that in mind, I'll keep my remarks very brief.

It goes without saying I think, that the primary concern for the state of Texas is that the upstream states comply with the terms and conditions of the Rio Grande Compact. That is primary and goes without saying. Everything that has been discussed here for the last day-and-a-half is of concern to all of us–upstream, downstream, Texas, New Mexico, and Colorado, because it shows us the increased demands on the system. El Paso, Albuquerque, Las Cruces and all the metropolitan areas are going to have to rely on the Rio Grande for their primary source of water. And others like the environmentalists, the Native Americans, and recreational water users also will put demands on the system. I wish I could tell you that I see a time of dialog and harmony, and of peace and goodwill on the river, but unfortunately I do not see that. I think we are going to spend a tremendous amount of human and financial assets on attorneys, engineers, and hydrologists over the next number of years until we can finally sit down with each other and learn to cooperate and use every drop of water to its maximum and most beneficial use.

Thank you.