SAN JUAN-CHAMA PROJECT

WATER SUPPLY

Part I: Report and Appendices A-C

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EXECUTIVE SUMMARY

The Interstate Stream Commission staff evaluated the San Juan-Chama Project water supply in light of recent hydrologic modeling activities for the San Juan River Basin. The Commission staff determined that no change is warranted to the Bureau of Reclamation's official firm annual yield estimate for the project of 96,200 acre-feet at Heron Dam. The Commission's hydrologic investigation also found that based on the hydrologic data available for the period 1936-2005, the long-term average annual diversion from the San Juan River Basin by the San Juan-Chama Project can be anticipated to average about 105,200 acre-feet per year in the future. Therefore, Reclamation's San Juan River Basin Hydrology Model should include a baseline depletion amount of about 105,200 acre-feet per year, on average, for the project. The baseline depletion amount for the San Juan-Chama Project suggested herein is for planning purposes only, and it should not be used for regulatory purposes because the project diversions in the future will be driven by actual future hydrology, not estimated or modeled hydrology for some defined past period of time.

INTRODUCTION

The Bureau of Reclamation since 1995 has been preparing and performing hydrologic modeling of the San Juan River Basin for use in water planning studies in this basin, including studies relating to environmental compliance activities for federal water projects in the basin. Reclamation's San Juan River Basin Hydrology Model has been used to assist the San Juan River Basin Recovery Implementation Program in developing its 1999 Flow Recommendations for the San Juan River and to develop operating criteria for Navajo Reservoir to meet the needs of water users in New Mexico and the habitat needs of populations of endangered fish species in the river.[1] Reclamation recently proposed revisions to the model that include, among other things, changes to the hydrology above the San Juan-Chama Project points of diversion and consequent decreases in anticipated diversions by the project to the Rio Grande Basin that might suggest a decrease in the firm yield of the project at Heron Dam.[2] The Bureau of Reclamation's February 1989 Addendum to Hydrology Report, San Juan-Chama Project Yield Update, concluded that the firm annual yield of the San Juan-Chama Project at Heron Dam is 96,200 acre-feet per year. Of this amount, 88,210 acre-feet has been contracted, 5,000 acre-feet is reserved to offset evaporation losses from the Cochiti Lake recreation pool pursuant to Public Law 88-293, and 2,990 acre-feet is reserved for settlement of Indian water rights claims in the Rio Grande Basin.

Sections 1 and 2 of this report review past water supply and hydrologic modeling studies, respectively, relating to the availability of water for or from the San Juan-Chama Project. Section 3 of this report presents the Interstate Stream Commission staff's analysis of San Juan-Chama Project diversions. A comparison of annual project diversions between past hydrology studies and the Commission staff's investigation is presented in table 1 attached hereto. Section 3 of this report also discusses the implications of the Commission staff's analysis on water available from the project in the Rio Grande Basin and on hydrologic modeling and Endangered Species Act section 7 consultations in the San Juan River Basin. The two Heron Reservoir operations studies that were conducted by the Commission staff and that are presented and discussed in section 3 of this report

[1] The operation of Navajo Reservoir to meet the San Juan River Basin Recovery Implementation Program's flow recommendations, or a reasonable alternative, provides Endangered Species Act compliance for water projects and water management activities throughout the San Juan River Basin, including in Colorado and New Mexico.

[2] New Mexico has agreed to the use of previous versions of the San Juan River Basin Hydrology Model only for the purpose of evaluating flow recommendations for the San Juan River and possible impacts of water development projects measured against the flow recommendations. When the San Juan River Basin Recovery Implementation Program in 2003 organized a Hydrology Committee charged with the task of reviewing Reclamation's modeling activities as well as other responsibilities, the program also adopted the following model disclaimer: "While every effort will be made to incorporate the best data and modeling available into the San Juan River Basin Hydrology Model, use of the hydrologic model in the work of the Hydrology Committee and the San Juan River Basin Recovery Implementation Program does not necessarily constitute agreement or approval by individual program participants with the model data, methodologies or assumptions. The model data, methodologies and assumptions do not under any circumstances constitute evidence of actual water use, water rights or water availability under compact apportionments and should not be construed as binding on any party. Furthermore, use of the model, model data, methodologies and assumptions does not change the responsibilities of the respective States to maintain records of water rights and water use. Official records of water rights and water use are maintained by the State agencies statutorily charged with that responsibility." New Mexico does not agree with the use of the model to determine the yield available to the San Juan-Chama Project; however, it is not clear as to how other parties might interpret the applicability of the model data to determine the amount of water available from the project for uses in the Rio Grande Basin, or how the Fish and Wildlife Service might use the model data in Endangered Species Act section 7 consultations for water development and management activities in the San Juan River Basin.

for the purpose of evaluating the water supply available to and from the San Juan-Chama Project both used historic hydrology for the period 1936-2005 that also reflects average depletions upstream from the project diversion sites since 1970, potential project diversions under current operating criteria and under operating practices that reflect physical and administrative operational constraints and reasonably attainable diversion efficiencies, and an annual demand on the project measured at Heron Dam of 96,200 acre-feet per year. One Heron Reservoir operation study used the reservoir storage capacity condition existing as of 1984, and the other reservoir operation study used the storage capacity condition projected to occur about 2070 after additional sediment deposition within the reservoir pool.

Section 1:

PAST SAN JUAN-CHAMA PROJECT WATER SUPPLY STUDIES

WATER SUPPLY STUDIES FOR SAN JUAN-CHAMA PROJECT AUTHORIZATION

A. Background

In support of the 1962 authorizing legislation for the Navajo Indian Irrigation and San Juan-Chama projects, the Bureau of Reclamation and the State of New Mexico during the mid to late 1950s and early 1960s prepared various water supply studies for the San Juan River Basin. The water supply studies included anticipated San Juan-Chama Project diversions for the period 1928-1960 in Reclamation's Navajo Reservoir Operation Study and for the period 1928-1959 in New Mexico's Navajo Reservoir Operation Study No. 8.[3] The annual project diversions in both studies are similar; except, that New Mexico's study shorted the divertible flows at the points of diversion by a cumulative amount of 25,000 acre-feet in 1947, 1951 and 1956 due to sharing of shortages in the Navajo Reservoir water supply, and that New Mexico estimated and used slightly smaller divertible flows than did Reclamation for 1956-1959. Both studies assumed diversion demands of 508,000 acre-feet per year for the Navajo Indian Irrigation Project, and New Mexico's study also assumed a diversion demand of 224,000 acre-feet per year on Navajo Reservoir for future municipal and industrial uses.[4] Reclamation's study assumed, in the absence of records, that the project diversion for 1960 hydrology would be 110,000 acre-feet. Reclamation at that time considered the extended drought from 1953-1956 to be unprecedented and not representative of future conditions; therefore, the long-term average diversion was assumed to be 110,000 acre-feet per year considering the data available through only 1952 even though Reclamation's annual project diversion estimates for the 1928-1959 period averaged about 104,700 acre-feet per year.

B. Project Diversions

The annual San Juan-Chama Project diversions for both studies as reported in the Congressional record are shown in table 1 attached hereto, columns 1 and 2, respectively. To estimate the monthly flows available for diversion by the project beginning May 1935, Reclamation and New Mexico apparently used the following general procedure.[5] For the Rio Blanco diversion, monthly flows at the diversion site were estimated as the monthly flow measured at the Rio Blanco near Pagosa Springs gage prorated on the basis of drainage area ratio to the Rio Blanco dam site upstream from the diversion site. For the Navajo River diversion, monthly flows at the diversion site were estimated as the monthly flow measured at the Navajo River at Banded Peak Ranch gage

[3] See San Juan-Chama Reclamation Project and Navajo Indian Irrigation Project, Hearings before the Subcommittee on Irrigation and Reclamation of the Committee on Interior and Insular Affairs, House of Representatives, Eighty-Seventh Congress, First Session on H.R. 2552, H.R. 6541, and S. 107, April 24, 25, 26, and June 1, 1961, pages 116 and 144.

[4] Under the April 2005 San Juan River Basin in New Mexico Navajo Nation Water Rights Settlement Agreement, it is anticipated that Navajo Indian Irrigation Project diversions from Navajo Reservoir will average up to 353,000 acre-feet per year, and the Interstate Stream Commission today estimates that future municipal and industrial demands from the reservoir will total about 62,800 acre-feet per year (about 30,300 acre-feet for the proposed Navajo-Gallup Water Supply Project excluding the City of Gallup's project uses, plus about 32,500 acre-feet of contracted diversion by the Jicarilla Apache Nation including water subcontracted to the City of Gallup and the Public Service Company of New Mexico). The Hammond Irrigation Project under permit also receives about 23,000 acre-feet per year of water from the Navajo Reservoir water supply.

[5] See San Juan-Chama Project, Colorado-New Mexico, Recommended as a Participating Project in the Colorado River Storage Project, Appendix D – Hydrology, Chapters 1, 2 and 3, Volume II of VI, US Bureau of Reclamation, Region 5, Amarillo, Texas, November 1955, pages D2-1 through D2-8.

plus 50 percent of the tributary inflow occurring between the Navajo River at Banded Peak Ranch, the Little Navajo River at Chromo, and the Navajo River at Edith gages. For the Little Navajo River diversion, monthly flows at the diversion site prior to 1953 were estimated as the monthly flow measured at the Little Navajo River at Chromo gage, assuming that depletions from the reach between the diversion site and the Chromo gage equally balance tributary inflow to the reach. For the period 1928-April 1935, flows at each diversion site were estimated by Reclamation using an undisclosed procedure.

The monthly flows available for diversion were then determined based on the monthly flows at the points of diversion less monthly diversion bypass requirements; except, that for September 1953-1959, monthly flows at the Little Navajo River diversion site were not so estimated due to lack of gage data, and diversions by the project at this site apparently were instead estimated directly from estimates of the combined project diversions at the other two diversion sites.[6] The New Mexico State Engineer in cooperation with the Colorado Water Conservation Board had developed the following monthly diversion bypass quantities in acre-feet for each stream that were considered adequate to meet requirements of all water rights having a prior right over San Juan-Chama Project diversions and to maintain live streams for sanitary and domestic purposes, including to provide flushing water in May on the Rio Blanco and the Navajo River and to sustain a minimum flow for fish and stock:

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rio Blanco	900	800	1,200	1,200	2,400	1,200	1,200	1,200	1,200	1,200	1,200	900
Navajo River	1,800	1,900	2,200	2,200	5,300	3,300	3,300	3,300	3,300	2,200	2,200	2,200
Little Navajo River	0	0	0	0	1,600	1,600	1,600	1,600	1,600	0	0	0

A bypass flow at the Little Navajo River diversion site was explicitly not required during the non-irrigation season.[7] Diversions by the project from each of the three streams were limited based on the following San Juan-Chama Project initial stage design criteria (in cubic-feet-per-second):[8]

Diversion Feeder Capacities:		Conduit Capacities:	
Rio Blanco Diversion	460 cfs	Blanco Tunnel	520 cfs
Little Navajo River Diversion	100 cfs	Oso Tunnel	550 cfs
Navajo River Diversion	700 cfs	Azotea Tunnel	850 cfs

However, the original project design included a combination of open-channel canals and tunnels that would have permitted interception of water at additional minor drainage inlets.[9]

[6] See letter from J.R. Riter, Bureau of Reclamation, to Steve Reynolds, New Mexico State Engineer, dated April 17, 1961.

[7] See San Juan-Chama Project, Colorado-New Mexico, US Bureau of Reclamation, November 1955, Appendix D, page D2-7.

[8] See Supplemental Report on San Juan-Chama Project, Colorado-New Mexico, Recommended as a Participating Project in the Colorado River Storage Project, Bureau of Reclamation, Amarillo, Texas, May 1957, page 7, table 3.

[9] See Supplemental Report on San Juan-Chama Project, Colorado-New Mexico, Recommended as a Participating Project in the Colorado River Storage Project, Volume VII of VIII, Bureau of Reclamation, Amarillo, Texas, May 1957, Appendix K, page K-4.

C. Project Yield

At the time of Congressional authorization, the firm yield of the initial stage of the San Juan-Chama Project at Heron Dam, given the requirements of project operation specified by Public Law 87-483, appears to have not been determined. However, Heron Reservoir operation studies that had been performed using estimates of project diversions and a demand for releases from the reservoir averaging 102,100 acre-feet per year had showed the onset of shortages to the demand beginning in 1955, although the reservoir had not been filled prior to entering the critical period.[10] Heron Reservoir evaporation was anticipated to average about 7,800 acre-feet per year through 1955, but filling the reservoir prior to the critical period drawdown would have resulted in a greater average annual evaporation loss.

[10] See House Document No. 424, 86th Congress, 2d Session, San Juan-Chama and Navajo Indian Projects, Letter from Secretary of the Interior transmitting A Coordinated Report on the San Juan-Chama Project, Colorado-New Mexico, and the Navajo Indian Irrigation Project, New Mexico, pursuant to Section 9(a) of the Reclamation Project Act of 1939 (53 Stat. 1187), June 20, 1960, page 5. Of the total demand, 52,900 acre-feet was anticipated to be used for municipal and industrial purposes and the remainder was anticipated to be used for supplemental irrigation.

SAN JUAN-CHAMA PROJECT DEFINITE PLAN REPORT

A. Background

After Public Law 87-483 authorized the initial stage of the San Juan-Chama Project, the Bureau of Reclamation in 1964 prepared a Definite Plan Report for the project.[11] The Definite Plan Report re-evaluated the project water supply for the purpose of designing project facilities to divert and deliver water consistent with the authorizing legislation.

B. Project Diversions

The annual San Juan-Chama Project diversions used in the Definite Plan Report are shown in table 1 attached hereto, column 3. To estimate the monthly flows available for diversion by the project for calendar years 1935-1957, Reclamation used the following general procedure.[12] For the Rio Blanco diversion, monthly flows at the diversion site were estimated consistent with the earlier water supply studies as the monthly flow measured at the Rio Blanco near Pagosa Springs gage prorated on the basis of drainage area ratio to the Rio Blanco dam site upstream from the diversion site. For the Navajo River diversion, monthly flows at the diversion site beginning water year 1957 were estimated as the gaged flow of the Navajo River above Chromo, and prior to water 1957 were estimated from the monthly flows measured at the Navajo River at Banded Peak Ranch and a single log-log regression equation for all months combined relating monthly flow of the Navajo River above Chromo to monthly flow at Banded Peak Ranch that was derived from data available for water years 1957-1961. For the Little Navajo River diversion, monthly flows at the diversion site were estimated as 63 percent of the monthly flows at the diversion site that were used in Reclamation's earlier water supply studies to reflect relocation of the Little Oso diversion dam farther upstream than originally planned. Consistent with Reclamation's earlier water supply studies, the monthly flows available for diversion were then determined based on the monthly flows at the points of diversion less the monthly diversion bypass requirements on the Rio Blanco and the Navajo River specified by Public Law 87-483 and the monthly diversion bypass amounts for downstream water rights on the Little Navajo River described in the Bureau of Reclamation's November 1955 San Juan-Chama Project planning report at page D2-7; except, that the bypass amounts for the Little Navajo River were first met by inflow to the river below the Little Oso diversion dam to the extent of its availability before bypassing any flow originating above the diversion dam. Diversions by the project from each of the three streams were limited based on the following San Juan-Chama Project initial stage adopted design criteria (in cubic-feet-per-second):

Diversion Feeder Capacities:		Conduit Capacities:	
Rio Blanco Diversion	520 cfs	Blanco Tunnel	520 cfs
Little Navajo River Diversion	150 cfs	Oso Tunnel	550 cfs
Navajo River Diversion	650 cfs	Azotea Tunnel	950 cfs

[11] See Definite Plan Report, San Juan-Chama Project, Colorado-New Mexico, Volume I, US Department of the Interior, Bureau of Reclamation, Region 5, May 1963, Revised June 1964.

[12] See Definite Plan Report, San Juan-Chama Project, Colorado-New Mexico, Volume I, US Department of the Interior, Bureau of Reclamation, Region 5, May 1963, Revised June 1964, Appendix B, pages B-1 through B-4. The Definite Plan Report adjusted the flows at the project diversion dams for published corrections to stream discharge records.

A modified project design adopted a three-tunnel plan instead of the original conduit system considered in the earlier project planning reports.

The period of record used for the Bureau of Reclamation's San Juan-Chama Project Definite Plan Report and Reclamation's earlier water supply studies overlapped for only the years 1935-1957. For the overlapping period 1935-1957, the average annual diversion from the San Juan River Basin by the project was approximately 2,000 acre-feet per year greater in the Definite Plan Report as compared to that indicated by Reclamation's earlier water supply studies (see table 1). The San Juan-Chama Project annual diversions in the Definite Plan Report averaged about 110,500 acre-feet per year for the period 1935-1957.[13]

C. Project Yield

The Bureau of Reclamation in the 1964 Definite Plan Report for the San Juan-Chama Project evaluated the yield of the project at Heron Dam based on the monthly flows estimated to be available for diversion by the project for calendar years 1935-1957, the operational constraints for the project established by Public Law 87-483, and Heron Reservoir net evaporation losses estimated using available weather data collected at El Vado Dam.[14] The Definite Plan Report did not bypass any flow that was estimated to be available for diversion by the project and that might be subject to bypass by reason of sharing of available water supplies with Navajo Reservoir water supply contractors in years of shortage pursuant to section 11(a) of Public Law 87-483. The Heron Reservoir operation study contained in the Definite Plan Report used a demand for releases from the reservoir averaging 103,600 acre-feet per year, and indicated shortages in deliveries from Heron Reservoir in up to five years such that the amount of water that could be supplied for calendar years 1935-1957 would average 99,700 acre-feet per year. Heron Reservoir was not filled prior to the critical period as a consequence of assuming that reservoir storage would be empty at the beginning of the study period in March 1935, and thus the operation study showed significant shortages to the demand during the last three years of the study period 1955-1957. The yield of the project at Heron Dam was estimated to average between 99,700 acre-feet and 101,800 acre-feet per year for the period 1935-1957 after shortages.[15] The Definite Plan Report also includes a then-final allocation of water from the project totaling 101,800 acre-feet per year delivered at Heron Dam.[16]

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[13] A long-term average diversion for the San Juan-Chama Project of 110,000 acre-feet per year was used in several subsequent water planning and modeling studies, including for the Secretary of the Interior's 1988 Hydrologic Determination and the 1991 Biological Opinion for the Animas-La Plata Project. The 1991 Biological Opinion provided the impetus for the formation of the San Juan River Basin Recovery Implementation Program.

[14] See Definite Plan Report, San Juan-Chama Project, Colorado-New Mexico, Volume I, US Department of the Interior, Bureau of Reclamation, Region 5, May 1963, Revised June 1964, Appendix B, pages B-3 through B-11. Missing El Vado Dam monthly pan evaporation data were estimated using the monthly percentage distribution of evaporation determined for Santa Fe in a publication entitled: "Evaporation – New Mexico and Contiguous Areas." The monthly gross lake water surface evaporation rates were reduced for effective precipitation, which was estimated monthly as the sum of: 90 percent of the first inch of precipitation measured at El Vado Dam, plus 85 percent of the second inch, plus 75 percent of the third inch, plus 50 percent of the fourth inch, plus 30 percent of the fifth inch.

[15] See also Hydrology Report, San Juan-Chama Project Yield Update, US Department of the Interior, Bureau of Reclamation, Southwest Region, Amarillo, Texas, April 1986, page 28; and Draft Hydrology Report, Revised San Juan-Chama Firm Yield, US Department of the Interior, Bureau of Reclamation, Albuquerque Area Office, Albuquerque, New Mexico, October 1999,

page 2. The Definite Plan Report also assumed implementation of Heron Reservoir operations rule curves to begin allocation of shortages to demands if the modeled or projected reservoir storage on July 1 in a given year was less than 68,700 acre-feet, which was deemed insufficient to be relied upon for meeting all demands through the year following, depending upon runoff conditions the next spring (see Definite Plan Report, San Juan-Chama Project, Colorado-New Mexico, Volume I, US Department of the Interior, Bureau of Reclamation, Region 5, May 1963, Revised June 1964, Appendix B, pages B-9 and B-10). The Definite Plan Report to equitably apportion the San Juan-Chama Project supply between project contractors in years of short supply also incorporated a complete set of rule curves for each month of the year from which to determine the percent of the demand that can be supplied in a given month based on the water in storage in Heron Reservoir at the beginning of the month (see Definite Plan Report, San Juan-Chama Project, Colorado-New Mexico, Volume I, US Department of the Interior, Bureau of Reclamation, Region 5, May 1963, Revised June 1964, pages 19-20).

[16] Of the total project water allocation at Heron Dam, 48,200 acre-feet was allocated for municipal and industrial uses by Albuquerque, 5,000 acre-feet was allocated for replacing evaporation losses from the Cochiti Lake recreation pool, 20,900 acre-feet was allocated for the Middle Rio Grande Conservancy District irrigation uses, and the remainder was allocated for tributary units.

BUREAU OF RECLAMATION SAN JUAN-CHAMA PROJECT YIELD STUDIES

A. Background

In the 1980s, the United States, the State of New Mexico and the Jicarilla Apache Nation entered negotiations to attempt a settlement of the water rights claims of the Jicarilla Apache Nation in the San Juan River Basin and the Rio Grande Basin. One element of the negotiations was whether the yield of the San Juan-Chama Project estimated in the 1964 Definite Plan Report remained valid. To support the settlement negotiations, the Bureau of Reclamation in 1986 prepared a yield study for the project.[17] Reclamation in 1989 prepared an addendum to the 1986 yield study that extended the hydrology for an additional three years of record. The critical period of July 1945-March 1978 and the critical period hydrology were the same for both studies, but Heron Reservoir operations differed between them due to a change in Heron Reservoir accounting procedures approved by the Rio Grande Compact engineering advisory committee in 1988.[18] In 1999, Reclamation prepared a draft revised firm yield study that corrected the three years of hydrology added in the 1989 addendum and further extended the hydrology through 1997.[19]

B. Project Diversions

The annual San Juan-Chama Project diversions for the period 1935-1984 used in the 1986 yield study, for the period 1935-1987 used for the 1989 addendum, and for the period 1935-1997 used for the 1999 draft revision are shown in table 1 attached hereto, columns 4, 5 and 6, respectively. To estimate daily flows available for diversion by the project, Reclamation used the following general procedure.[20] For the Rio Blanco diversion, flows at the diversion site prior to March 1971 were estimated based on flows measured at the Rio Blanco near Pagosa Springs gage. For the Navajo River diversion, flows at the diversion site prior to 1971 were estimated from the gaged flows at nearby gaging stations (the basic method was to take flows measured at the Navajo River at Banded Peak Ranch gage and add an estimate of the runoff occurring between this gage and the diversion site as calculated from downstream gages). For the Little Navajo River diversion, flows at the diversion site prior to October 1952 were estimated based on the flow measured at the Little Navajo River at Chromo gage, and from October 1952 through March 1971 were estimated based on flow correlations with the Rio Blanco near Pagosa Springs and Navajo River at Banded Peak Ranch gages. Beginning April 1971, flows at each diversion site were estimated based on the stream flow gage record at the diversion site and project operation records, including pro-rata adjustments to the daily gaged diversion records at each site each month to obtain a water balance

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[17] See Hydrology Report, San Juan-Chama Project Yield Update, US Department of the Interior, Bureau of Reclamation, Southwest Region, Amarillo, Texas, April 1986.

[18] See Addendum to Hydrology Report, San Juan-Chama Project Yield Update, US Department of the Interior, Bureau of Reclamation, Upper Colorado Region, Albuquerque, New Mexico, February 1989, pages 1-2.

[19] See Draft Hydrology Report, Revised San Juan-Chama Firm Yield, US Department of the Interior, Bureau of Reclamation, Albuquerque Area Office, Albuquerque, New Mexico, October 1999.

[20] See Hydrology Report, San Juan-Chama Project Yield Update, Bureau of Reclamation, April 1986, pages 3-11, and Draft Hydrology Report, Revised San Juan-Chama Firm Yield, Bureau of Reclamation, October 1999, pages 2-5.

monthly with the measured flow at the Azotea Tunnel outlet.[21] The 1986 yield study cites unspecified previous project planning documents as providing the detailed computations of daily flows available for diversion and daily diversions at each diversion site.

The daily flows available for diversion were then determined based on the daily flows at the points of diversion less daily diversion bypass requirements. Reclamation established the following daily diversion bypass requirements in cubic-feet-per-second (cfs) by converting the monthly diversion bypass quantities in acre-feet for each stream set forth at page D2-7 of Appendix D of the Bureau of Reclamation's November 1955 report entitled "San Juan-Chama Project, Colorado-New Mexico" to a constant daily average bypass flow for each month:

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rio Blanco	15	15	20	20	40	20	20	20	20	20	20	15
Navajo River	30	34	37	37	88	55	55	55	55	37	37	37
Little Navajo River	0	0	0	0	27	27	27	27	27	0	0	0

Although section 8(f) of Public Law 87-483 requires only that Reclamation bypass the monthly diversion bypass quantities in acre-feet for the Rio Blanco and the Navajo River set forth at page D2-7 of Appendix D of the Bureau of Reclamation's November 1955 report, the US District Court for the District of Colorado in *Schutz v. Stamm, et al.*, in 1977 ruled that Reclamation's construction which was adopted to establish daily flow bypasses for the Rio Blanco and the Navajo River diversion sites is a reasonable application of the operation requirements for the San Juan-Chama Project set forth in section 8(f).[22] Section 8(f) of Public Law 87-483 does not require a specific

[21] For water years 1971-2005, the outflow from the Azotea Tunnel measured at the tunnel outlet every year has exceeded the sum of the diversions measured at the three San Juan-Chama Project diversion sites by amounts ranging from 1 percent to 13 percent annually, and volumetrically averaging about 5 percent over the period, of the sum of the three diversions measured in the San Juan River Basin (see Appendix A, table A-7). The annual difference between the data sets is consistently in the range of 4 percent to 7 percent, and does not appreciably vary with flow or over time. Reclamation for the 1986 yield study considered the flow measurements made at the Azotea Tunnel outlet to be more accurate than those made at each of the project diversion sites because the measurement flumes at the diversion sites are subject to operational problems related to small debris, sediment and small gravel gathering in the approach section of the flumes, and because the flume at the tunnel outlet is not subjected to as many of these problems (see Hydrology Report, San Juan-Chama Project Yield Update, Bureau of Reclamation, April 1986, page 9). Trash racks at the diversion sites are cleaned regularly, sediment and gravel are removed in the fall, and gage station shifts are significant during periods of runoff (Bureau of Reclamation, Chama Field Office staff, oral communication, September 2006). The Rio Grande Compact Commission for its official records uses the measured outflow from the Azotea Tunnel to account and administer Rio Grande and San Juan River water under the compact (see the Bureau of Reclamation's Annual Water Accounting Reports to the Rio Grande Compact Commission Engineer Advisers). The states of Colorado, New Mexico and Texas are party to the Rio Grande Compact and represented on the compact commission. For the period 1971-2005, the average annual difference between measured Azotea Tunnel outflow and the sum of the diversions as measured at the project diversion sites amounted to about 4,660 acre-feet per year.

[22] See *Schutz v. Stamm, et al.*, Civil Action No. 74-M-318, Order and Judgment, US District Court for the District of Colorado, November 17, 1977. Also, the Colorado Water Conservation Board in 1974 obtained under Colorado state law instream flow rights for maintenance of fish and wildlife habitat in the Rio Blanco and the Navajo River. The Board's monthly instream flow rights on the two streams are as follows (values that differ from the daily diversion bypass requirements established by Reclamation pursuant to section 8(f) of Public Law 87-483 are italicized):

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rio Blanco	*20*	*20*	20	20	*29*	*29*	*29*	*29*	*29*	20	20	*20*
Navajo River	*37*	*37*	37	37	*55*	55	55	55	55	37	37	37

bypass at the Little Navajo River diversion site; nonetheless, Reclamation has set daily bypass flows for the Little Navajo River of 27 cfs for the irrigation season based on the information at page D2-7 of Reclamation's 1955 report.[23] However, while the 1986 yield study met the bypass requirements at the Rio Blanco and Navajo River diversion structures from only the natural flow originating above the diversion sites, the study met the set bypass flows for the Little Navajo River at its mouth by first using inflow to the river below the diversion structure and then using flow originating above the diversion site when necessary.[24] To estimate the amount of inflow to the Little Navajo River between the diversion structure and the mouth, the natural flow at the mouth was estimated as the natural flow at the point of diversion increased in direct proportion to the respective drainage areas.[25] Reclamation also has set daily bypass flows for the Little Navajo River of 4 cfs for the non-irrigation season until further notice, which bypasses apparently were not considered in the 1986 yield study but were considered in the 1999 draft revised yield study.[26]

Diversions by the project from each of the three streams were limited based on the following San Juan-Chama Project diversion feeder capacities and tunnel operational criteria:[27]

Diversion Feeder Capacities:		Conduit Capacities:	
Rio Blanco Diversion	520 cfs	Blanco Tunnel	520 cfs
Little Navajo River Diversion	150 cfs	Oso Tunnel	550 cfs
Navajo River Diversion	650 cfs	Azotea Tunnel	950 cfs

The project as built consists of tunnels only with no capabilities to intercept water from additional drainages.

The Colorado Water Conservation Board has not obtained such instream flow rights for the Little Navajo River. In *Schutz v. Stamm, et al.*, the US District Court found that Public Law 87-483 requires the Secretary of the Interior to bypass the specific flows designated by section 8(f) and not to maintain fish and wildlife habitat, and the Court did not rule on the validity of the instream flow rights (see Order and Judgment, November 17, 1977, pages 10-13).

[23] See Memorandum of the Upper Colorado Regional Director, Bureau of Reclamation, dated January 7, 1977.

[24] See the 1964 Definite Project Report.

[25] See Draft Hydrology Report, Revised San Juan-Chama Firm Yield, Bureau of Reclamation, October 1999, page 4.

[26] See Memorandum of the Upper Colorado Regional Director, Bureau of Reclamation, dated January 7, 1977; and see Draft Hydrology Report, Revised San Juan-Chama Firm Yield, Bureau of Reclamation, October 1999, pages 1 and 8. The non-irrigation season bypass flows at the Little Navajo River diversion are made at the request of the State of Colorado for downstream stock and domestic water uses. The Interstate Stream Commission staff did not disagree with a 4 cfs bypass at the Little Oso diversion dam during the period October through April (see Interstate Stream Commission Staff's Memorandum to File on Hydrology Report – San Juan-Chama Project Yield Update, Bureau of Reclamation, April 1986, dated December 17, 1986, pages 2-3).

[27] See Hydrology Report, San Juan-Chama Project Yield Update, US Department of the Interior, Bureau of Reclamation, Southwest Region, Amarillo, Texas, April 1986, figure 2 following page 4. The gates at the three project diversion sites are operated to attempt to maintain flows in the Azotea Tunnel at or below a target maximum flow of 950 cfs, but flows through the tunnel historically have exceeded 950 cfs at times due to large flow diurnals at the project diversion sites (Bureau of Reclamation, Chama Field Office staff, oral communication, October 2006). The physical capacity of the Azotea Tunnel is greater than 950 cfs.

The periods of record used for the Bureau of Reclamation's San Juan-Chama Project yield studies and the San Juan River water supply studies of the 1960s overlapped for only the years 1935-1959. For the overlapping period 1935-1959, the average annual diversion from the San Juan River Basin by the project was approximately 3,000 acre-feet per year greater in the yield studies as compared to that indicated by the 1960s water supply studies (see table 1). The average annual theoretical diversion for the San Juan-Chama Project estimated by Reclamation's yield studies ranged from about 108,800 acre-feet per year for the period 1935-1984 used in the 1986 yield study to about 114,900 acre-feet per year for the period 1935-1997 used in the 1999 draft yield study.

C. Project Yield

To determine the yield of the San Juan-Chama Project at Heron Dam, the 1986 yield study operated Heron Reservoir monthly for the period of record using the following criteria.[28] The original area-capacity table for Heron Reservoir representing 1971 conditions was adjusted throughout for distribution within the reservoir pool area of 100 years of estimated sediment deposition, resulting in the revised reservoir capacity of about 390,700 acre-feet that was used in the study. In accordance with San Juan-Chama Project water accounting methods developed for Rio Grande Compact accounting, gross lake evaporation rates for April-October were estimated as pan evaporation times a pan coefficient of 0.7 and for November-March were estimated as monthly functions of mean air temperature developed by Reclamation. Net lake evaporation rates were estimated as gross lake evaporation minus US Bureau of Reclamation effective precipitation to reflect the difference between post-reservoir and pre-reservoir losses within the reservoir pool area. Monthly pan evaporation and precipitation measurements available at Heron Dam beginning 1976 and at El Vado Dam prior to 1976 were used to compute monthly lake evaporation, and correlations with nearby weather stations were used to fill in data when data at the dam sites were missing. A comparative analysis for the period 1971-1984 of resultant Heron Reservoir net evaporation losses and total reservoir losses estimated using then-current Rio Grande Compact water accounting and project operations criteria, and using monthly water budget calculations that reflect lake evaporation, dam seepage and other factors, indicated that total reservoir losses, including lake evaporation, dam seepage and reservoir releases from storage that are accounted as Rio Grande water and as not being available for San Juan-Chama Project contractors, were estimated to average about 30 percent greater than net evaporation losses alone. Based on the comparative analysis, reservoir losses were estimated monthly by multiplying the monthly net evaporation rates times 1.303.[29] For the monthly demands of contractors on Heron Reservoir, it was assumed that the municipal and industrial demands were uniform throughout the year, the Middle Rio Grande Conservancy District demand occurs in December, the demands for releases to replace evaporative losses from the Cochiti Lake recreation pool are distributed in accordance with said evaporative losses, the Pojoaque Valley Irrigation District demand for exchange water occurs during the spring runoff, and the San Juan Pueblo allocation demand occurs during the irrigation season.

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[28] See Hydrology Report, San Juan-Chama Project Yield Update, Bureau of Reclamation, April 1986, pages 19-28.

[29] The Interstate Stream Commission staff questioned increasing the computed Heron Reservoir net evaporation rates by a factor of 1.303 to account reservoir losses in the Bureau of Reclamation's 1986 San Juan-Chama Project yield study, citing differences between historic and anticipated future reservoir operations and citing also adjustments to the procedure for accounting natural flows at Heron Dam (see Interstate Stream Commission Staff's Memorandum to File on Hydrology Report – San Juan-Chama Project Yield Update, Bureau of Reclamation, April 1986, dated December 17, 1986, pages 1-2).

The 1986 yield study selected a beginning Heron Reservoir content of 75,000 acre-feet on the basis that Heron Reservoir would essentially fill without spilling in July 1945 at this storage level, but would fill and spill at a beginning content of 100,000 acre-feet.[30] The alternative of using a greater beginning content and reducing project diversions from the San Juan River Basin in 1945 to avoid spill was not considered. The results of the 1986 yield study indicate that the firm annual yield of the San Juan-Chama Project at Heron Dam is 94,200 acre-feet per year. The 1986 yield study also estimated that with an annual demand at the dam of 96,000 acre-feet, there would be shortages totaling about 42,800 acre-feet over the 1935-1984 period of record, including annual shortages to the demand of about 8,700 acre-feet (9 percent of the demand) in 1964, about 16,200 acre-feet (17 percent of the demand) in 1965, about 3,300 acre-feet (3 percent of the demand) in 1977 and about 14,600 acre-feet (15 percent of the demand) in 1978. However, these shortage amounts assume the beginning Heron Reservoir content of 75,000 acre-feet and a maximum end-of-month reservoir storage in 1945 of only about 372,650 acre-feet. If the beginning reservoir content were increased by about 20,000 acre-feet to about 95,000 acre-feet, then the reservoir study could have filled the reservoir to the assumed capacity of about 390,700 acre-feet, which would have resulted in only three years of shortage totaling about 25,000 acre-feet.

The 1989 addendum to the 1986 yield study changed only the process for calculating Heron Reservoir losses.[31] In March 1988, the Rio Grande Compact accounting procedures for Heron Reservoir were changed to eliminate the water budget method that resulted in reservoir losses in excess of evaporation losses.[32] Neither the revised Rio Grande Compact accounting procedures nor the 1964 Definite Plan Report require adjusting the computed net reservoir evaporation loss by an operational accounting factor of 1.303; and consequently, the 1989 addendum did not continue the adjustment to the reservoir evaporation losses that was used in the 1986 yield study. The 1989 addendum selected a beginning Heron Reservoir content of only 59,000 acre-feet, again so as to avoid Heron Reservoir spills or project diversion curtailments in the early years of the study period while also essentially filling the reservoir without spill in July 1945. With these changes to the 1986 yield study, the 1989 addendum recommended adoption of a firm annual yield at Heron Dam of 96,200 acre-feet.

In 1999, Reclamation prepared a draft revised San Juan-Chama Project yield study to update the hydrology and determine if the yield recommended by the 1989 addendum remained valid. The 1999 draft revision to the 1986 yield study reportedly required that project diversion bypasses be used to maintain a 4 cfs minimum flow at the mouth of the Little Navajo River during the non-irrigation season, which only had a minor effect on the assumed project diversions from the San Juan River Basin from 1972-1984 and consequently reduced the average annual project

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[30] See Hydrology Report, San Juan-Chama Project Yield Update, Bureau of Reclamation, April 1986, page 28.

[31] See Addendum to Hydrology Report, San Juan-Chama Project Yield Update, US Department of the Interior, Bureau of Reclamation, Upper Colorado Region, Albuquerque, New Mexico, February 1989.

[32] The water budget or mass balance method for computing and accounting native Rio Grande water inflow to Heron Reservoir, separate and apart from imported San Juan-Chama Project water, often resulted in the calculation of negative Rio Grande inflow, suggesting losses greater than those associated with reservoir evaporation computations alone. Consequently, other methods were developed to determine Rio Grande inflow to the reservoir (see Draft Upper Rio Grande Water Operations Model, Physical Accounting Model Documentation, June 2005, pages 3-4).

diversion for the critical period 1945-1978 by about 100 acre-feet per year (see table 1).[33] Also, although the 1999 draft revision reduced the maximum Heron Reservoir capacity for 100 years of sediment to a capacity of 390,560 acre-feet, it used a 1986 revised area-capacity table for the reservoir without adjusting the table for distribution of the sediment within the reservoir pool area. In addition, the 1999 draft revision, by arbitrarily keeping the beginning Heron Reservoir content of 59,000 acre-feet from the 1989 addendum, came about 4,600 acre-feet short of filling the reservoir completely in 1945 prior to entering the critical period, thus decreasing the available storage in an amount equivalent to a loss of about 100 acre-feet of yield over the 1945-1978 critical period. A combination of these factors contributed to a reduction in the computed net lake evaporation losses by about 300 acre-feet per year, on average for the 1945-1978 critical period, in the 1999 draft revision as compared to the 1989 addendum.[34] The evaporation reduction would have been larger in the 1999 draft revision had the demand on Heron Reservoir not been reduced from the 1989 addendum, such that lower lake levels would have been maintained, on average. The 1999 draft revision to the 1986 yield study concluded that the firm annual yield of the San Juan-Chama Project at Heron Dam is about 95,800 acre-feet, which is 400 acre-feet, or about 0.4 percent, less than the 96,200 acre-feet firm annual yield determined by the 1989 addendum to the 1986 yield study. Nevertheless, the 1999 draft revision recommended that because the difference between the revised estimated firm yield and the 1989 addendum firm yield estimate is within the range of data and computational error, the official firm yield of the project should not be changed. The 1999 draft revised yield study for the San Juan-Chama Project was not released as a final document.

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[33] Although Reclamation in the 1999 draft revised San Juan-Chama Project firm yield report believed that the 400 acre-feet difference between the 96,200 acre-feet firm yield estimated by the 1989 addendum to the 1986 yield study and the 95,800 acre-feet firm yield estimated by the 1999 draft revised firm yield is largely due to the inclusion of a 4 cfs minimum non-irrigation season bypass flow for the Little Navajo River, the data included in the yield studies suggest that only 100 acre-feet per year, or 25 percent, of the estimated decrease in yield was due to this factor.

[34] See Addendum to Hydrology Report, San Juan-Chama Project Yield Update, Bureau of Reclamation, February 1989, Table A, and Draft Hydrology Report, Revised San Juan-Chama Firm Yield, Bureau of Reclamation, October 1999, Table 15.

Section 2:

INCORPORATION OF PROJECT IN HYDROLOGIC MODELS

SAN JUAN RIVER BASIN HYDROLOGIC MODELING STUDIES

A. Background

The Bureau of Reclamation, with assistance from the Bureau of Indian Affairs, in 1995 began a coordinated effort to construct an integrated hydrologic model of the San Juan River Basin for use in water planning activities in the basin, including for use in water project operations and environmental compliance activities such as evaluating Navajo Reservoir operations to meet the needs of water users and benefit populations of endangered fish species in the San Juan River. The model was used by the San Juan River Basin Recovery Implementation Program to assist in the development of its 1999 Flow Recommendations for the San Juan River, including to develop criteria for the operation of Navajo Reservoir to meet recommended spring peak flow statistics and target base flows in the reach of critical habitat below the confluence of the San Juan and Animas rivers. The model subsequently was revised and used for environmental compliance activities for the Animas-La Plata Project, the Navajo Indian Irrigation Project, the proposed Navajo-Gallup Water Supply Project, and Navajo Reservoir operations. The version of the model commonly referred to by Reclamation as the Generation 2 model was used in hydrologic studies to support the Final Environmental Impact Statement on Navajo Reservoir Operations completed in April 2006, and to prepare the Planning Report and Draft Environmental Impact Statement for the Navajo-Gallup Water Supply Project dated March 2007.[35]

In the meantime, Reclamation in cooperation with the San Juan River Basin Recovery Implementation Program has been working on a revision to the Generation 2 model, commonly referred to as the Generation 3 model, that would extend the hydrologic record used in the model through 2004 and simulate the hydrology of the San Juan River below Navajo Dam and the lower Animas River on a daily time step with improved capabilities, including both look-back analysis and forecast capabilities, with the hope of using the model to explore possibilities for optimizing Navajo Reservoir daily and seasonal operating criteria or rules to better provide for meeting water use demands and downstream endangered fish habitat needs. The proposed Generation 3 model also is being used now by the San Juan River Basin Recovery Implementation Program's Biology Committee for the preliminary evaluation of possible revisions to the program's 1999 Flow Recommendations for the San Juan River. Results of the preliminary Generation 3 model were presented to the Recovery Implementation Program's Hydrology Committee for discussion and feedback in June 2006 and again in September 2006. Both the Generation 2 and Generation 3 models include San Juan-Chama Project diversion and operations assumptions from which a yield for the project might be estimated or inferred. San Juan-Chama Project diversions are derived by Reclamation using a separate RiverWare module that simulates diversions as a function of hydrology at the diversion points, required bypass flows, project diversion and tunnel capacities, the project diversion quantity limits set forth by section 8 of Public Law 87-483, and storage space available at Heron Reservoir after consideration of reservoir capacity, reservoir evaporation and a project demand on that reservoir of 96,200 acre-feet annually. The critical period for the project is July 1945-April 1978 in both versions of the model, but the annual diversions during the critical

[35] Versions of hydrologic models for the San Juan River Basin used prior to the Generation 2 model are not reviewed in this report. Such models include the model used for the 1991 Biological Opinion for the Animas-La Plata Project and the model used in 1998-1999 for the hydrologic evaluation of flow recommendations for the San Juan River by the San Juan River Basin Recovery Implementation Program.

period vary significantly between the Generation 3 and Generation 2 models for a variety of reasons. Reclamation's presentation of the proposed Generation 3 model provided the impetus for this detailed review of modeling assumptions at and above the San Juan-Chama Project diversion sites because of possible negative ramifications of the model results on environmental baseline depletions for the project and the estimated project yield.

B. Project Diversions

Unlike the San Juan-Chama Project yield studies that rely on historic flows available at the points of diversion, the San Juan River Basin Hydrology Model relies on modeled flows at the points of diversion that are somewhat less than historic flows assuming that the upstream depletions are greater in the future than they have been historically. The annual San Juan-Chama Project diversions for the period 1929-1993 used in the Generation 2 model and for the period 1929-2004 used in the June 2006 and September 2006 versions of the Generation 3 model are shown in table 1 attached hereto, columns 7, 8 and 9, respectively. The periods of record used for the modeling, the San Juan-Chama Project yield studies and the San Juan River water supply studies of the 1960s overlap for the years 1935-1959 only. For the overlapping period, the average annual diversion from the San Juan River Basin by the project in the Generation 2 model was about the same as in the 1960s water supply studies and about 3,000 acre-feet per year less than in the yield studies, and the average annual diversion by the project in the proposed Generation 3 model is about 4,000 acre-feet less than that in the Generation 2 model. For the critical period 1945-1978, the average annual diversion from the San Juan River Basin by the project in the Generation 2 model was about 2,000 acre-feet per year greater than that in Reclamation's yield studies, and the average annual diversion by the project in the September 2006 version of the proposed Generation 3 model, after revisions to the June 2006 version, is about 5,000 acre-feet per year less than that in the yield studies (see table 1). The possible reduction in San Juan-Chama Project diversions indicated by the proposed Generation 3 model hydrology has raised concerns regarding the proposed model revisions, particularly as to how the proposed revisions might relate to a determination of the yield of the project available for uses in the Rio Grande Basin or to any consultations on water project development or operations in the San Juan River Basin under section 7 of the Endangered Species Act.

To estimate daily flows available for diversion by the project for the Generation 2 model, Reclamation used the following general procedure.[36] Historic daily flows beginning October 1971 at each project diversion site were estimated based on the historic gaged flows and diversions measured at the site, without the adjustments to the three project diversions to match measured Azotea Tunnel outflow that were made for the yield studies.[37] Monthly natural flows at the

[36] See Draft San Juan River Basin Recovery Implementation Program Hydrology Model, Hydrologic Model and Data Development, Keller-Bliesner Engineering and Bureau of Reclamation, October 2000, chapter 4; and see Documentation, Naturalized Flows Development, San Juan River Basin, Department of the Interior, Bureau of Reclamation, Western Colorado Area Office, Durango, Colorado, October 2002, chapters 1-3 and pages A-1 through A-2 and E-5 through E-14.

[37] See footnote 21. An increase in estimated historic San Juan-Chama Project diversion amounts to reflect the Azotea Tunnel at outlet gage records would result in increased computed historic and natural flows at the project diversion sites since 1971, and the increased flows would be reflected in revised correlations of the flows at each diversion site to either gaged or natural flows at the key gaging stations used to determine by regression the monthly natural flow values for the diversion sites prior to 1972. Consequently, computed natural flows at the project diversion sites and project diversions would be increased over the

diversion sites beginning October 1971 were estimated based on the historic flows plus monthly estimates of historic irrigation depletions above the diversion sites computed using the modified Blaney-Criddle method, annual Colorado Agricultural Statistics crop acreage data for Archuleta County adjusted yearly based on 1993 actual crop survey data for the county (except, that 1993 developed pasture acres, which constituted about 90 percent of the crop acreage in the county and about 95 percent of the crop acreage in the hydrologic unit that year, were used for each year), the proportion of county crop acres within the tributary drainages upstream of the diversion sites in 1993, average monthly temperature and precipitation data from the Pagosa Springs weather station, no physical water supply shortages based on Type I study methods, and an incidental depletion factor for the county obtained from the 1965 Comprehensive Framework Study and subsequent Bureau of Reclamation Colorado River System Consumptive Uses and Losses reports. Monthly natural flows similarly computed for the Rio Blanco near Pagosa Springs gage were used as representative of natural flows at the Rio Blanco diversion site for water years 1970-1971, and monthly natural flows for the Navajo River and Little Navajo River for water years 1970-1971 were estimated using monthly linear regression equations to natural flows similarly computed at the Navajo River at Banded Peak Ranch gaging station.[38] Extension of the monthly natural flows at the project diversion sites prior to 1970 was accomplished by statistically relating monthly natural flows at the sites for 1972-1993 to concurrent gaged flow records for the key stations Animas River at Durango (which was used to generate natural flows at the diversions for 1929-1930), San Juan River near Blanco (which was used to generate natural flows at the diversions for 1931-1935), and San Juan River at Pagosa Springs (which was used to generate natural flows at the diversions for 1936-

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hydrologic period of record. The correlations used to extend natural flows prior to 1971 are sensitive to errors in natural flow computations for the post-1971 period (see footnote 44).

Also, the US Geological Survey for several years in the 1990s published and rated the daily flow data for the Rio Blanco below Blanco Diversion Dam, the Little Navajo River below Little Oso Diversion Dam, and the Navajo River below Oso Diversion Dam gaging stations as good, fair or poor for different periods of time depending upon the conditions at the stations. For example, the daily flow records below the Rio Blanco diversion for water year 1994 were generally rated as fair (except that estimated daily discharges for several weeks in December, January, May and July were rated poor), for water year 1995 were rated as good (except that estimated daily discharges for much of October-January and June-September were rated poor), and for water year 1996 were generally rated as good (except that estimated daily discharges for much of October-December were rated poor due to unstable approach conditions at the flume). The volume of water associated with estimated discharges below the Rio Blanco diversion in water year 1995 amounted to about 54,280 acre-feet, or about 75 percent of the 72,740 acre-feet of annual runoff at that site in 1995. The daily flow records below the Navajo River diversion were generally rated as good for water years 1994-1996 (except that estimated daily discharges for a few weeks each winter were rated poor). Below the Little Navajo River diversion, a constant flow of 2 cfs was estimated for nine months of water year 1994. Flow records rated as good means that about 95 percent of the daily discharges are within 10 percent of their true value, fair means that about 95 percent of the daily discharges are within 15 percent of their true value, and poor means that the records do not meet the "fair" rating criteria. The ratings provide an indication of random error in daily flow values, not systematic error or bias. The US Geological Survey did not rate the diversion records collected for the project either at the three project diversion sites or the Azotea Tunnel outlet.

[38] The monthly correlations between natural flows at the Navajo River diversion site and the Navajo River at Banded Peak Ranch gaging station for the period 1972-1993 had r-squared values ranging from 0.83-0.99, including about 0.98 for May-June. The monthly correlations between natural flows at the Little Navajo River diversion site and the Navajo River at Banded Peak Ranch gaging station for the period 1972-1993 had r-squared values ranging from 0.44-0.90, including about 0.82 for May-June. The monthly correlations used for the Generation 2 model flows were linear regression equations (see Documentation, Naturalized Flows Development, San Juan River Basin, Department of the Interior, Bureau of Reclamation, Western Colorado Area Office, Durango, Colorado, October 2002, pages E-11 through E-14).

1969).[39] Reclamation in the Generation 2 model used the resultant estimated monthly natural flow at each project diversion site for 1929-1993 as the flow available for diversion at each site.[40] The monthly natural flows at each diversion site were disaggregated to daily flows available at each site using the daily distribution for the month exhibited by the sum of the historic gaged stream flow plus gaged diversion at the site after 1971, and using the daily gaged stream flow pattern for the month exhibited at the gaging station used in the regression to obtain the natural flow at the site for the month prior to 1971.[41]

The proposed Generation 3 model essentially consists of two separate and distinct models: (1) the State of Colorado's StateMod model for the San Juan River Basin that simulates flows and uses throughout the basin in Colorado and New Mexico; and (2) the Bureau of Reclamation's RiverWare model for the San Juan River that simulates only the operation of Navajo Reservoir and daily flows in the mainstream of the San Juan River below Navajo Dam and in the Animas River below Durango. Results from Colorado's StateMod model are used as input data to Reclamation's RiverWare model.[42] Reclamation also adjusts StateMod computed inflows to Navajo Reservoir for

[39] The Generation 2 model documentation indicates that the flows at the San Juan-Chama Project points of diversion were adjusted for depletions above the diversion sites, but the documentation does not indicate whether the gaged flows for the key stations used to develop and to apply the statistical correlations were adjusted for depletions and changes in reservoir storage above the stations. For example, the flow of the San Juan River near Blanco after 1940 was affected by river regulation and changes in depletions associated with development of the Pine River Project (see footnote 71), but the flow records for the Blanco gage were not adjusted for Pine River Project operations or depletions over time (Keller-Bliesner Engineering staff, oral communication, May 2007). The San Juan River near Blanco gage was discontinued in January 1955, and flow records are available for the San Juan River near Archuleta gage beginning December 1954. However, the stream flow measured at the San Juan River near Archuleta gaging station is not equivalent to the stream flow at the Blanco gaging station site, primarily due to diversions from the Archuleta to Blanco reach by the Citizens Ditch. Thus, it is not clear how regressions of monthly flows at the San Juan-Chama Project points of diversion to concurrent monthly flows at the Blanco gage were developed, or that the application of such regressions is technically valid. The goodness of fit of the statistical relationships used to generate the natural flows at the project diversions is not presented in the model documentation.

[40] The average annual flow modeled as available at the San Juan-Chama Project diversion sites for 1929-1993 by the Generation 2 model was more than the average annual historic flow at the sites. Reclamation in implementing the Generation 2 model mistakenly did not deduct either historic or baseline depletions above the diversion sites from the natural flows to determine flows available for diversion by the project (see Draft San Juan River Basin Recovery Implementation Program Hydrology Model, Hydrologic Model and Data Development, Keller-Bliesner Engineering and Bureau of Reclamation, October 2000; Bureau of Reclamation, Denver Technical Center staff, oral communication at meeting of San Juan River Basin Recovery Implementation Program Hydrology Committee, September 12, 2006).

[41] The process of disaggregating monthly natural flows to daily flows using gaged flow records implicitly assumes that historic irrigation depletions above the project diversion sites are temporally distributed in the same pattern as stream flow (that is, that irrigation depletions on a daily basis increase and decrease with stream flow). However, the opposite relationship between flow and irrigation depletions typically exists during June-July as stream flow from snowmelt recedes and crop consumptive use and irrigation demands increase, and irrigation demands during the summer may be reduced due to rainfall on fields when stream flow is concurrently increasing due to local rains. Also, monthly crop consumptive irrigation demands computed for the Pagosa Springs weather station may not reflect differences in monthly and daily precipitation and temperature between Pagosa Springs and the irrigated areas above each of the San Juan-Chama Project diversion sites. In addition, daily stream flow records for the gages used to determine and disaggregate daily flows are typically rated as either good or fair by the US Geological Survey, except that discharges estimated from time to time are rated poor. Thus, daily gaged stream flows used to determine flows available at the diversion sites typically are within no less than about 10 percent to 15 percent of their true values due to random error (see footnote 37).

[42] The Bureau of Reclamation for reasons of expediency decided to rely on Colorado's StateMod model, rather than update its Generation 2 model, to extend the hydrology for the San Juan River Basin through 2004 because StateMod has the capability to

Reclamation's estimated San Juan-Chama Project operations. For the Generation 3 model, Reclamation used monthly flows available for diversion by the project estimated by the State of Colorado using the StateMod model that incorporates the following general procedure.[43] Historic daily flows beginning October 1971 at each project diversion site were estimated based on the historic gaged flows and diversions measured at the site, again without the adjustments to the three project diversions to match measured Azotea Tunnel outflow that were made for the yield studies.[44] Monthly natural flows at the diversion sites beginning October 1974 were estimated based on the historic flows plus monthly estimates of historic irrigation depletions above the diversion sites computed using the original Blaney-Criddle method with high altitude crop coefficients, annual Colorado Agricultural Statistics crop acreage data for Archuleta County adjusted yearly based on revised 1993 and 2000 actual crop survey data for the county (except, that the larger of the revised 1993 and 2000 developed pasture acres were used for each year), the proportion of county crop acres within the tributary drainages upstream of the diversion sites in 1993 and 2000, average monthly temperature and precipitation data from the Pagosa Springs weather station, shortages to crop consumptive use demands computed based on Colorado diversion records and water budget techniques, and incidental depletions computed as a function of return flow.[45] For water years

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generate updated natural flows estimates for extending the hydrologic period of record throughout the basin. In accepting the StateMod model hydrology as input to Reclamation's RiverWare model for the San Juan River mainstream, Reclamation gave deference to the State of Colorado's determinations of hydrology and of historic and baseline depletions by Colorado water users in the San Juan River Basin.

[43] See San Juan/Dolores River Basin Water Resources Planning Model User's Manual, Colorado's Decision Support Systems, Colorado Division of Water Resources and Colorado Water Conservation Board, November 2005.

[44] The June 2006 version of the Generation 3 model used historic gaged San Juan-Chama Project diversions from Colorado's HydroBase plus measured stream flow to determine historic flows at the diversion sites beginning water year 1972. The September 2006 version of the Generation 3 model incorporates revised gaged project diversions for water years 1972-1974 that were corrected to match diversion records of the Colorado State Engineer Office. The data correction also affected the regressions of computed natural flows at the diversion sites to gaged flows at key gaging stations used to derive estimates of natural flows at each diversion site prior to 1972 (Bureau of Reclamation, Denver Technical Center staff, oral communication), thus significantly affecting annual project diversions in the Generation 3 model for 1929-1974 as indicated by comparison of the initial June 2006 Generation 3 model results and the revised September 2006 Generation 3 model results (see table 1 attached, columns 8 and 9). Also, see footnote 37.

[45] To estimate historic monthly net irrigation depletions, the water budget included estimating irrigation diversions and lagging of irrigation return flows in the StateMod calibration using historic conditions (see San Juan/Dolores River Basin Water Resources Planning Model User's Manual, Colorado Water Conservation Board, November 2005, chapter 4; and Colorado River Decision Support System, San Juan River Basin Water Resources Planning Model, Final Report, Boyle Engineering Corporation and Riverside Technology, Colorado Water Conservation Board, November 1999, pages 4-7 to 4-11). The algorithm within StateMod to include in the water budget an accounting of soil moisture availability for meeting crop consumptive use demands was not utilized (see Draft San Juan Recovery Implementation Program Hydrology Documentation, Hydrology Data and Models, Bureau of Reclamation, September 2004, pages 89-90). StateMod computed historic irrigation shortages because it did not consider that portions of the crop consumptive use were met from available soil moisture as opposed to irrigation applications, particularly early in the year (see footnote 49).

The StateMod model uses the original Blaney-Criddle method with high altitude crop coefficients to compute crop consumptive use on pasture lands situated above 6,500 feet elevation, and uses the modified Blaney-Criddle method to compute crop consumptive use on lands below 6,500 feet elevation (see San Juan/Dolores River Basin Water Resources Planning Model User's Manual, Colorado Water Conservation Board, November 2005, page 5-32). Irrigated lands upstream from the San Juan-Chama Project points of diversion are above 7,600 feet elevation. The Bureau of Reclamation pursuant to section 601(b) of the Colorado River Basin Project Act, Public Law 90-537, prepares and submits to Congress periodic reports for periods of five

1972-1974, historic upstream irrigation diversions were estimated based on wet/dry/average year hydrology and variable efficiency methodology that takes into account possible shortage avoidance strategies.[46] Monthly natural flows at the project diversion sites prior to 1971 were estimated using monthly log-log correlations of natural flows at each site to historic flows at key pattern gages that were developed from the post-1971 data. At the Rio Blanco diversion site, natural flows prior to 1971 were estimated by regression from historic flows of the East Fork San Juan River above Sand Creek, which historic flows were gaged for 1957-1971 and filled by regression with monthly flows gaged on the San Juan River at Pagosa Springs for 1936-1956. At the Navajo River and Little Navajo River diversion sites, natural flows prior to 1971 were estimated by regression from historic flows of the Navajo River at Banded Peak Ranch, which historic flows were gaged for 1937-1971 and filled by regression with monthly flows gaged on the Navajo River at Edith for 1936.[47] The procedure for generating natural flows at the diversion sites in the Generation 3 model for water years 1929-1935 is not documented.[48] The monthly flow modeled as available at each project diversion site for 1929-2004 was then computed as the monthly natural flow at each site minus upstream baseline depletions, which in the Generation 3 model were greater than the average of the historic upstream depletions used to calculate natural flows, thus resulting in modeled monthly

years on Colorado River System Consumptive Uses and Losses. The Consumptive Uses and Losses reports include irrigation consumptive uses in Colorado, including above the project diversion sites, computed using the modified Blaney-Criddle method without return flow lagging and with 1965 Comprehensive Framework Study incidental depletions and Type I shortages (see, for example, Colorado River System Consumptive Uses and Losses Report, 1996-2000, US Department of the Interior, Bureau of Reclamation, Revised December 2004, page 10). Reclamation's Colorado River Simulation System (CRSS) model used for Colorado River system modeling activities in support of mainstream reservoir operations and water supply studies uses natural monthly flows for the San Juan River at Archuleta that are computed using historic gaged flows, changes in upstream reservoir storage and upstream depletions, including the irrigation depletions from Reclamation's Consumptive Uses and Losses reports and backup appendices.

[46] To use historic stream flow for estimating historic irrigation diversions prior to 1975 and consumptive irrigation requirements prior to 1950, the State of Colorado relates irrigation demands to the average demands occurring in dry years of low supply (less than 25 percent non-exceedence flows), in years of average supply (between 25 percent and 75 percent non-exceedence flows) and in wet years of high supply (greater than 75 percent non-exceedence flows) (see San Juan/Dolores River Basin Water Resources Planning Model User's Manual, Colorado Water Conservation Board, November 2005, pages 4-10 to 4-12). To generate pre-1975 data for input to Reclamation's RiverWare model of the San Juan River, the time series for diversions and consumptive irrigation requirements above the San Juan-Chama Project diversion sites are based on dry/average/wet month categorizations of the historic monthly flows of the San Juan River at Pagosa Springs, 1975-2004 average monthly historic diversions for the corresponding dry/average/wet month ranges, and 1950-2004 average consumptive irrigation requirements for the corresponding dry/average/wet month ranges.

[47] See San Juan/Dolores River Basin Water Resources Planning Model User's Manual, Colorado Water Conservation Board, November 2005, pages 4-11 to 4-12 and C-1 to C-11. The goodness of fit of the statistical relationships of natural flows at the San Juan-Chama Project diversion sites to the historic flows at the key pattern gages is not presented in the StateMod documentation. The historic flows at the key pattern gaging stations were not adjusted for depletions above the gages. The monthly correlations between historic flows at the East Fork San Juan River above Sand Creek gage and the San Juan River at Pagosa Springs gage for the period 1975-2003 had r-squared values ranging from 0.70-0.98, and the monthly correlations between historic flows at the Navajo River at Banded Peak Ranch gage and the Navajo River at Edith gage for the period 1975-2003 had r-squared values ranging from 0.33-0.94. Also, see footnote 41.

[48] The period of record used in StateMod simulations is documented as 1936-2003 (see San Juan/Dolores River Basin Water Resources Planning Model User's Manual, Colorado Water Conservation Board, November 2005, page C-8). The Generation 3 model generated natural flows at the project diversion sites for water years 1929-1935 using flows of the San Juan River at Pagosa Springs, the Navajo River at Edith or other stations that were either gaged or filled by regression with flows gaged at other stations.

flows available at the points of diversion that are generally less than monthly historic flows at the diversion sites.[49] Reclamation then disaggregated the monthly flows modeled at each diversion site to daily flows available at each site using the daily distribution for the month exhibited by the sum of the historic gaged stream flow plus gaged diversion at the site after 1971, and using the daily flow distribution for the month from the Generation 2 model prior to 1971.[50]

The daily flows available for diversion were then determined based on the daily flows at the points of diversion less daily diversion bypass requirements. For both the Generation 2 model and the Generation 3 model, Reclamation used the following daily diversion bypass requirements in cfs pursuant to section 8(f) of Public Law 87-483 and the Upper Colorado Regional Director's January 7, 1977, memorandum:

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rio Blanco	15	15	20	20	40	20	20	20	20	20	20	15
Navajo River	30	34	37	37	88	55	55	55	55	37	37	37
Little Navajo River	4	4	4	4	27	27	27	27	4	4	4	4

Reclamation meant to use the Regional Director's bypass flow of 27 cfs for the Little Navajo River for the month of September, but mistakenly used the wintertime value of 4 cfs in September for that

49 Based on an accumulation for water years 1971-1993 of the difference between the Generation 3 flows modeled to be available at the diversion sites and the historic gaged stream flows plus diversions at the diversion sites, the total baseline depletion of about 5,020 acre-feet per year above the project diversion sites exceeds historic depletions above the diversion sites by an average of about 1,300 acre-feet per year or 35 percent (Presentation to the San Juan River Basin Recovery Implementation Program Hydrology Committee, Bureau of Reclamation, September 12, 2006). Therefore, the flow available for diversion by the project in the Generation 3 model is reduced accordingly as compared to historic conditions.

The baseline condition in the StateMod model includes all existing irrigation systems on line with calculated demands under full water supply conditions (see San Juan/Dolores River Basin Water Resources Planning Model User's Manual, Colorado Water Conservation Board, November 2005, page 1-2). Historic irrigation depletions include the occurrence of historic fallowed acreage within at least some of the developed agricultural lands, but baseline conditions assume none of the developed lands are fallowed (see Documentation, Naturalized Flow Development, San Juan River Basin, Bureau of Reclamation, October 2002, page F-30). Historic irrigation depletions also inherently consider that irrigation diversions have not always been used to meet the full computed crop consumptive use demand on pasture due to crop use of soil moisture replenished by snowmelt in the spring, rainfall on fields not incorporated into the consumptive use calculations made using Pagosa Springs weather data, debris in flood water, ditch maintenance or operation, down time for cutting and drying hay, foregoing irrigation in the fall because of insufficient growing season remaining to get another cutting of hay, or other factors. The calculations of historic irrigation depletions short the consumptive uses based on historic diversions and assumed irrigation efficiencies. Conditions causing irrigators to not fully irrigate in accordance with the computed consumptive use demand likely will exist in the future as they have occurred for decades in the past. The State of Colorado through its model is administratively reserving rights of water users to fully divert water to deplete the entire computed crop consumptive use demand, regardless of the users' actual beneficial irrigation use demand (Colorado Water Conservation Board staff, oral communication, September 12, 2006; see San Juan/Dolores River Basin Water Resources Planning Model User's Manual, Colorado Water Conservation Board, November 2005, page D-7).

50 See Draft San Juan Recovery Implementation Program Hydrology Documentation, Hydrology Data and Models, Bureau of Reclamation, September 2004, pages 54-55 and 62-63. In the Generation 3 model, the gaging stations upon which daily disaggregation of modeled flow is based prior to 1971 thus differ from the gaging stations used in the regression analyses to extend the natural flow data prior to 1971. Also, the process of disaggregating monthly modeled flows to daily flows using gaged flow records assumes that historic and baseline irrigation depletions above the project diversion sites, and the differences between them, are temporally distributed in the same pattern as stream flow (see footnote 41).

stream.[51] Reclamation met the bypass requirements at each of the diversion sites from only the natural flow originating above the sites. Unlike the 1964 Definite Plan Report and the 1986 yield study, Reclamation did not consider first using inflow to the Little Navajo River below the diversion structure to meet the bypass flows designated for that stream. The bypass parameters used by Reclamation to derive San Juan-Chama Project diversion data for use in its RiverWare model overrides Colorado's use in StateMod of different monthly bypass flow requirements.[52]

Using the Generation 2 model, the average annual diversion by the San Juan-Chama Project from the San Juan River Basin would amount to about 107,500 acre-feet per year based on hydrology for the period 1929-1993. This amount of long-term average depletion for the project was used in the hydrologic modeling evaluations performed for development of the San Juan River Basin Recovery Implementation Program's 1999 Flow Recommendations for the San Juan River, the 1999 Biological Assessment for the Navajo Indian Irrigation Project, the 2005 Biological Assessment for the Navajo-Gallup Water Supply Project, and the 2006 Final Environmental Impact Statement for Navajo Reservoir Operations. Using the September 2006 version of the Generation 3 model, the average annual diversion by the project would amount to about 104,000 acre-feet per year for the period 1929-1993 and about 101,900 acre-feet per year for the period 1929-2004 which reflects the effect of drought during the years 2000-2004 (see table 1). Both the Generation 2 and Generation 3 models reduced project diversions when Heron Reservoir was full and would otherwise spill.[53] Also, the Generation 3 model respected the diversion capacities at each of the three project diversions in addition to the Azotea Tunnel capacity, which the Generation 2 model mistakenly did not.[54] The Interstate Stream Commission's revised schedules of anticipated depletions from the Upper Basin in New Mexico dated April 2005 and May 2006 include a long-term average annual diversion by the project from the San Juan River Basin of 105,200 acre-feet

[51] Bureau of Reclamation, Denver Technical Center staff, oral communication, September 2006.

[52] Colorado's StateMod model computes San Juan-Chama Project diversions at the Rio Blanco and Navajo River diversion sites from the daily flows available at each diversion site each month using the maximum of: (1) the daily bypass requirements for the month for the Rio Blanco and Navajo River diversions adopted pursuant to Public Law 87-483; and (2) the Colorado Water Conservation Board's instream flow right values for the Rio Blanco and the Navajo River (see footnote 22). However, the Bureau of Reclamation takes the monthly flows available at the project diversion sites that are computed in StateMod, disaggregates them to daily flows, and to determine the bypass flows does not consider the Board's instream flow rights. Thus, the project diversions computed by Reclamation are greater than those computed by StateMod. In addition to implementing the annual and ten-year diversion limitations on the project specified by Public Law 87-483, Reclamation also performs a monthly water budget operation for Heron Reservoir to determine when project diversions would be curtailed to prevent a spill at Heron Reservoir. Reclamation then adjusts the monthly inflows to Navajo Reservoir computed by StateMod to reflect Reclamation's estimated San Juan-Chama Project diversions, with the adjustment determined by adding the project diversions computed by StateMod and subtracting the project diversions computed by Reclamation. The adjusted monthly inflows to Navajo Reservoir are input to the San Juan River RiverWare model (see Draft San Juan Recovery Implementation Program Hydrology Documentation, Hydrology Data and Models, Bureau of Reclamation, September 2004, pages 62-63).

[53] Colorado's StateMod model does not operate Heron Reservoir (see Draft San Juan Recovery Implementation Program Hydrology Documentation, Hydrology Data and Models, Bureau of Reclamation, September 2004, pages 62-63).

[54] Bureau of Reclamation, Denver Technical Center staff, oral communication, September 12, 2006. The San Juan-Chama Project diversion feeder capacities and tunnel operational criteria are the same as those used by the Bureau of Reclamation San Juan-Chama Project yield studies of the late 1980s.

per year, which was determined by Reclamation in 2004 based on its preliminary extension of the Generation 2 hydrology data through 2000.[55]

C. Project Yield

Both the Generation 2 and Generation 3 versions of the San Juan River Basin Hydrology Model used a monthly water budget operation study for Heron Reservoir to determine when Heron Reservoir would be full and San Juan-Chama Project diversions from the basin would be curtailed to avoid spill. In association with the models, the Bureau of Reclamation operated Heron Reservoir monthly for the period of record using the following criteria.[56] Reclamation used the revised area-capacity table for Heron Reservoir developed from a resurvey of the reservoir area in 1984 and dated 1986, which provides a reservoir capacity of about 401,300 acre-feet at spillway crest elevation 7186.1 feet, and did not adjust the reservoir capacity or capacity table for future sediment deposition. To compute Heron Reservoir evaporation, Reclamation for average monthly net evaporation rates for Heron Reservoir for each year 1929-2004 used the long-term average monthly net evaporation rates for Navajo Reservoir obtained from Reclamation's HydroMet database. Monthly pan evaporation and precipitation measurements available at Heron Dam and at El Vado Dam were not used, and neither were Rio Grande Compact water accounting and operations criteria (natural inflow to Heron Reservoir was simply assumed to be directly bypassed through the dam without storage effect). The beginning Heron Reservoir content was 300,000 acre-feet, and the reservoir was operated to release 96,200 acre-feet each year to meet the annual demand of contractors at Heron Dam so long as water was available. For the monthly demands of contractors on Heron Reservoir, it was assumed for the Generation 3 modeling that the demands followed the average monthly demand pattern exhibited historically from 1971-2000, which reflected municipal and industrial contract demands historically being carried over into the following year and taken largely in March and April, the Middle Rio Grande Conservancy District demand occurring largely in December to move water to El Vado Reservoir storage, the demands for release to replace evaporative losses from the Cochiti Lake recreation pool occurring in the spring rather than being distributed in accordance with said evaporative losses, and the Pojoaque Valley Irrigation District demand for exchange water occurring during the spring runoff.[57] The demand pattern for the

[55] See Responses to Public Comments Received on Drafts of the San Juan River Basin in New Mexico Navajo Nation Water Rights Settlement, Interstate Stream Commission, December 2004, page B-3; and see Hydrologic Determination 2007, Water Availability from Navajo Reservoir and the Upper Colorado River Basin for Use in New Mexico, Bureau of Reclamation, April 2007, signed by the Secretary of the Interior on May 23, 2007, Appendix D.

[56] See Draft San Juan River Basin Recovery Implementation Program Hydrology Model, Hydrologic Model and Data Development, Keller-Bliesner Engineering and Bureau of Reclamation, October 2000; and see Draft San Juan Recovery Implementation Program Hydrology Documentation, Hydrology Data and Models, Bureau of Reclamation, September 2004, pages 62-63.

[57] The City of Albuquerque historically has taken delivery of its San Juan-Chama water from Heron Reservoir for storage in downstream reservoirs for subsequent use or sale and for offsetting effects of its ground water pumping on Rio Grande stream flow. The City recently constructed works to directly divert and utilize its project water from the Rio Grande, and will begin more fully using its project water allocation for municipal uses once construction is complete. Although the City anticipates that it will divert its San Juan-Chama water from the Rio Grande at a nearly constant diversion rate after it re-regulates its San Juan-Chama water delivered into Abiquiu Reservoir, it is not anticipated that operation of Albuquerque's Drinking Water Project will change the current monthly pattern of releases made at Heron Dam to deliver water to Albuquerque under its San Juan-Chama Project contract (see the memorandum entitled Biological Opinion on the Effects of Actions Associated with the Programmatic Biological Assessment for the City of Albuquerque Drinking Water Project, US Fish and Wildlife Service,

Generation 2 modeling was different than that used in the Generation 3 model, reflecting the monthly distribution of demands that occurred historically prior to 1996.

The results of the Heron Reservoir operations study in the Generation 2 version of the San Juan River Basin Hydrology Model indicated that for the period 1929-1993 there would be no shortages to an annual demand of 96,200 acre-feet per year for the San Juan-Chama Project at Heron Dam, and that the reservoir storage would reach a minimum of about 44,600 acre-feet at the end of April 1978. Based on the remaining storage at the end of the 1945-1978 critical period, the Generation 2 model data might suggest that the firm yield of the project that could be maintained at Heron Dam exceeds 96,200 acre-feet annually. However, the results of the Heron Reservoir operations study in the September 2006 version of the proposed Generation 3 model would indicate that for the period 1929-2004 and an annual project demand of 96,200 acre-feet per year at Heron Dam, there would be shortages in contract deliveries totaling about 99,400 acre-feet for the period, including annual shortages to the demand of about 25,100 acre-feet (26 percent of the demand) in 1965, about 2,600 acre-feet (3 percent of the demand) in 1972, about 37,100 acre-feet (39 percent of the demand) in 1973 and about 34,600 acre-feet (36 percent of the demand) in 1978. Based on the computed total shortage annualized over the 33-year critical period (about 3,000 acre-feet per year average shortage), the hydrologic analysis in the September 2006 version of the proposed Generation 3 model might suggest that the firm yield of the project that could be maintained at Heron Dam is only approximately 93,200 acre-feet annually.[58]

Albuquerque, New Mexico, February 13, 2004, pages 11-17; and see Hydrologic Effects of the Proposed City of Albuquerque Drinking Water Project on the Rio Grande and Rio Chama Systems, Updated for New Conservation and Curtailment Conditions, CH2MHill, City of Albuquerque Public Works Department, October 2003, pages 7-1 through 7-4).

[58] The data in the June 2006 version of the proposed Generation 3 model indicated that with an annual project demand of 96,200 acre-feet per year at Heron Dam, there would be shortages in contract deliveries totaling about 266,800 acre-feet for the period of record, including annual shortages to the demand of about 27,000 acre-feet (28 percent of the demand) in 1965, about 69,400 acre-feet (72 percent of the demand) in 1972, about 68,000 acre-feet (71 percent of the demand) in 1973, about 15,000 acre-feet (16 percent of the demand) in 1974, about 49,900 acre-feet (52 percent of the demand) in 1975 and about 37,500 acre-feet (39 percent of the demand) in 1978. Based on the computed total shortage annualized over the 33-year critical period (about 8,100 acre-feet per year average shortage), the hydrologic analysis in the June 2006 version of the Generation 3 model might have suggested that the firm yield of the project that could be maintained at Heron Dam is only approximately 88,100 acre-feet annually.

UPPER RIO GRANDE WATER OPERATIONS MODEL

A. Background

The Upper Rio Grande Water Operations Model is a set of daily time-step, river-reservoir models for the Upper Rio Grande Basin.[59] The model was developed for use in flood control operations, San Juan-Chama Project water accounting, and the evaluation of water operation alternatives for federal water projects in the basin. The physical accounting portion of the model is used to account the flows and storage of water in the Upper Rio Grande Basin, including at Heron Reservoir in the Rio Chama drainage, and is used specifically to track the delivery, use and storage of San Juan-Chama Project water. The model has not been used as a water supply model.

Section 8(e) of Public Law 87-483 provides that details of San Juan-Chama Project operations essential to accounting for diverted San Juan and Rio Grande flows shall be developed through the joint efforts of the Rio Grande Compact Commission, the Upper Colorado River Commission, the appropriate agencies of the United States and of the States of Colorado, New Mexico and Texas, and the various project entities. Accordingly, the Bureau of Reclamation has established, and the Rio Grande Compact Commission has approved, procedures to account for the storage, loss, delivery and use of imported San Juan-Chama water in the Rio Grande Basin. The accounting procedures are intended to ensure that delivery and use of native Rio Grande waters are not impaired by storage and movement of imported San Juan River water throughout the Rio Grande system.[60]

B. Heron Reservoir Operations and Water Accounting

Principles controlling the storage and release of water from Heron Reservoir include: (1) no native Rio Grande Basin inflow to the reservoir is to be stored, and therefore, any Rio Grande inflow is to be released as soon as possible; (2) San Juan-Chama Project water is to be released from the reservoir to offset depletions made by authorized project developments in the Rio Grande Basin; and (3) project contractors are not to be allowed to carry over their annual water allocations into the next calendar year, except that Reclamation may negotiate temporary waivers with contractors that allow carry over until April 30 to provide flexibility in managing river flows, particularly if it would be unsafe to release water during a given winter because of ice conditions on the surface of the reservoir.[61] The Upper Rio Grande Water Operations Model also reduces annual deliveries under contract allocations in accordance with the amount of storage in Heron Reservoir on January 1 if such storage is insufficient to provide a full supply to contractors for the upcoming

[59] The Upper Rio Grande Basin is defined as the Rio Grande Basin above Fort Quitman, Texas. The waters of the basin are administered in accordance with the Rio Grande Compact. The model can simulate the river and reservoir hydrology, water accounting and operation logic in the Rio Grande Basin from the Colorado-New Mexico state line to Elephant Butte Reservoir, and flood control from Elephant Butte Dam to the American Dam at El Paso, Texas.

[60] See Draft Upper Rio Grande Water Operations Model, Physical Accounting Model Documentation, June 2005, page 1.

[61] See Draft Upper Rio Grande Water Operations Model, Physical Accounting Model Documentation, June 2005, page 2.

calendar year, with possible increases in deliveries in a shortage year up to the amount of the contract allocations based on the amount of storage in the reservoir on July 1 of that year.[62]

For the Water Operations Model, Reclamation uses as input for San Juan-Chama Project diversions into the Rio Grande Basin the flow at the Azotea Tunnel outlet to account San Juan-Chama and Rio Grande water, and Reclamation uses diversion data for the three project diversion sites in the San Juan River Basin in Colorado for the physical simulation of project diversions in the San Juan River Basin for planning and operations forecasting purposes.[63] Reclamation uses the area-capacity table for Heron Reservoir dated 1986, which provides a reservoir capacity of about 401,300 acre-feet at spillway crest, and does not adjust the reservoir capacity or capacity table for sediment deposition. The model also uses a minimum pool storage level for Heron Reservoir of less than 1,000 acre-feet.[64] The model uses the following procedures to account the inflow, storage and release of San Juan-Chama Project water and native Rio Grande water at Heron Reservoir on a monthly basis.[65]

Inflow to Heron Reservoir from imported San Juan River water is estimated by deducting from the measured Azotea Tunnel outflow an average channel conveyance loss of 0.2 percent between the tunnel outlet gage and the stream flow gage on Willow Creek above Heron Reservoir. The native inflow to Heron Reservoir originating in the Rio Grande drainage above the dam is estimated essentially as the maximum of the inflow calculated using the following three methods: (1) dam seepage; (2) inflow computed from inflow ratios or regressions; and (3) net monthly gain computed from a reservoir water budget. First, based on a correlation between measured seepage channel discharges below Heron Dam and historic reservoir water surface elevations, dam seepage

[62] See Draft Upper Rio Grande Water Operations Planning Model, Base Run Start-up and Initial Conditions Assumptions, October 2004, page 17. For the annual water allocations made in early January, the model does not consider projected runoff in the San Juan River Basin, and the consequent projections of San Juan-Chama Project diversions from the San Juan River Basin into Heron Reservoir, during the first half of the year. However, in such a storage-short year, this does not necessarily result in annual shortages to the contract demands depending upon project diversions from the San Juan River Basin prior to the July 1 supplemental water allocations and the ability of project contractors to adjust to altered timing of contract deliveries.

[63] See Conceptualization of the Test Case Reach of the Upper Rio Grande Water Operations Model, Bureau of Reclamation, Corps of Engineers and US Geological Survey, circa 1998, pages 27-30, 37-38 and 42; see Draft Upper Rio Grande Water Operations Model, Physical Accounting Model Documentation, June 2005, page 3; and see email from Marc Sidlow, Corps of Engineers, Albuquerque District staff, to Pat Turney, Interstate Stream Commission staff, regarding URGWOM Data, dated September 26, 2006.

[64] See Draft Upper Rio Grande Water Operations Planning Model, Base Run Start-up and Initial Conditions Assumptions, October 2004, page 10. Dead storage below the outlet works of Heron Dam at elevation 7003 feet is about 1,220 acre-feet (see Conceptualization of the Test Case of the Upper Rio Grande Water Operations Model, Bureau of Reclamation, Corps of Engineers and US Geological Survey, circa 1998, page 23). Subtracting dead storage from the reservoir capacity of 401,330 acre-feet gives an active storage for Heron Reservoir of 400,110 acre-feet (based on the capacity table dated 1986).

[65] See Draft Upper Rio Grande Water Operations Model, Physical Accounting Model Documentation, June 2005, pages 3-7. The Upper Rio Grande Water Operations Model for daily operational decisions makes daily calculations of Rio Grande inflow to Heron Reservoir, but final determinations of Rio Grande inflow, and corresponding adjustments to reservoir operations to balance releases of Rio Grande water with estimated Rio Grande inflow, are made at the end of each month. The water accounting module within the model uses the San Juan-Chama and Rio Grande water accounting procedures approved by the Rio Grande Compact Commission Engineer Advisers (see, for example, 2005 Water Accounting Report to the Rio Grande Compact Commission Engineer Advisers, US Department of the Interior, Bureau of Reclamation, Upper Colorado Region, Albuquerque, New Mexico, March 2006).

is estimated to be zero when reservoir elevations are below 7064.4 feet (about 27,700 acre-feet of storage per the 1986 capacity table) and to increase linearly from there to about 2.60 cfs at spillway crest elevation 7186.1 feet.[66] Monthly Rio Grande inflow to the reservoir is presumed to be no less than the monthly estimated dam seepage based on the rationale that seepage should be accounted as native Rio Grande water because it cannot be charged against a contractor's account at times when no delivery demand is placed on the reservoir, and that Rio Grande inflow should be at least equal to Rio Grande outflow.[67] Second, based on a correlation between measured monthly stream flows at the Willow Creek above Heron Reservoir gage and the Willow Creek at Parkview gage near the dam site for the period 1943-1970, natural flow at Heron Dam is estimated as a ratio of the Rio Grande flow at the Willow Creek gage.[68] Monthly Rio Grande flow at the Willow Creek gage above the reservoir is computed as the measured flow at the gage less the computed inflow to the reservoir from imported San Juan River water, but not less than zero. The natural flow at the dam site is then estimated as either 1.20 or 2.46 times the Rio Grande flow at the gage above the reservoir depending upon whether the Rio Grande flow at the gage exceeds or is equal to or less than 360 acre-feet for the month, respectively. Third, a modified water budget equation is used to compute the monthly net gain within the Heron Reservoir pool area, including any Rio Grande component of precipitation and unaccounted gains within the reservoir pool, after consideration also of both San Juan River water inflow and Rio Grande inflow computed from the Willow Creek inflow ratios.[69]

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[66] The period of record used to develop the statistical correlation and the goodness of fit of the statistical relationship are not presented in the model documentation.

[67] On the other hand, the rationale for the dam seepage method ignores the fact that dam seepage may originate as San Juan River water stored in Heron Reservoir and may be available for making contract deliveries when delivery demands are placed on the reservoir. It also may result in the accounting of Rio Grande outflow from the reservoir when no apparent surface inflow to the reservoir is occurring from other than imported water. Thus, to some extent, San Juan-Chama Project water imported to Heron Reservoir may effectively be converted on paper to Rio Grande water and not be made available to project contractors.

[68] The goodness of fit of the statistical relationship is not presented in the model documentation. In addition, while consistent application of regression equations or correlations over the long term will produce results that maintain the water balance between stations, on average, use of such relationships only when the result shows a greater Rio Grande inflow than is estimated from dam seepage tends to skew or bias the average natural flow estimated at Heron Dam upwards as compared to the average result obtained from and reflected by the regressions or correlations alone. Base inflows to Willow Creek within the reservoir pool area under pre-dam conditions might be anticipated to be less than dam seepage when seepage is estimated to exceed Rio Grande inflow computed using ratios or correlations.

[69] In the modified water budget equation to compute net Rio Grande water gains within the reservoir pool, net evaporation is removed because only imported San Juan River water is supposed to be stored in the reservoir, and therefore, all evaporation is charged to San Juan-Chama Project water. Effective precipitation on the reservoir surface that is estimated using the US Bureau of Reclamation method is considered San Juan River water because it represents salvage by the project of water that would have been lost under pre-dam conditions. When accounting losses from Heron Reservoir, the model assigns to San Juan-Chama Project water the total amount of physical evaporation loss from the reservoir measured as gross lake evaporation minus total precipitation (see Draft Upper Rio Grande Water Operations Model, Physical Accounting Model Documentation, June 2005, page 9). This amount of physical evaporation loss from the reservoir is less than the net evaporation loss that is measured against pre-dam conditions using the formula gross lake evaporation minus effective precipitation, but the difference may reduce the potential impacts to project water supply resulting from the release of stored San Juan-Chama Project water to cover, in effect, computed Rio Grande water gains within the reservoir pool that include that part of the precipitation within the pool area that would have contributed to stream flow under pre-reservoir conditions. Heron Reservoir evaporation losses are determined using monthly evaporation, temperature and precipitation data collected at Heron Dam when available, or monthly data collected at El Vado Dam when data at Heron Dam are not available. Pan evaporation data were used for April-October, and monthly relationships correlating mean temperature and estimated free water surface evaporation rates derived by Reclamation were used for November-March (see Hydrology Report, San Juan-Chama Project Yield Update, Bureau of

The modified net gain computation for native Rio Grande water inflow to Heron Reservoir may result in the calculation of negative Rio Grande inflow and can be sensitive to inaccuracies due to bank storage effects, uncertainty in unmeasured reservoir seepage losses, imprecision in computed inflows from above the reservoir pool area, and other factors. Because each of the three methods has its shortfalls, various combinations of the methods are checked and compared to determine a conservatively high estimate of natural Rio Grande flow at Heron Dam, the use of which is conservative towards operating the project without impairment to Rio Chama acequias and other Rio Grande Basin water users.[70]

Reclamation, April 1986, page 21; and see 2005 Water Accounting Report to the Rio Grande Compact Commission Engineer Advisors, Bureau of Reclamation, March 2006, page 16). Heron Dam pan evaporation, temperature and precipitation data used in the Upper Rio Grande Water Operations Model were derived from the Bureau of Reclamation's Chama office field notes, and differ from the official reviewed data that had undergone quality assurance and quality control evaluations and that were published in Rio Grande Compact Commission annual reports and in Bureau of Reclamation annual Water Accounting Reports provided to the Commission (see email from Garret Ross, Bureau of Reclamation, Albuquerque Area Office staff, to Marc Sidlow, Corps of Engineers, Albuquerque District staff, regarding Heron Data Differences, dated November 27, 2006). Gross lake evaporation rates during winter months may be reduced for the fraction of lake surface area covered by ice, and percent ice cover observations are made periodically throughout the winter months.

[70] Although the 1986 yield study used a somewhat different water budget accounting method for simulating the operation of Heron Reservoir in accordance with then-current San Juan-Chama Project operations and water accounting criteria, the 1986 yield study still can be used to illustrate that such methods may impact project operations and the water supply available to project contractors. In the 1986 yield study, total Heron Reservoir losses, including dam seepage and the residual effects of Rio Grande inflow computations and release requirements, charged against reservoir storage exceeded computed net evaporation losses by an average of about 2,400 acre-feet per year over the period 1971-1984 (see Hydrology Report, San Juan-Chama Project Yield Update, Bureau of Reclamation, April 1986, page 21). The 1989 Addendum charged only net evaporation losses against reservoir storage, and thus, the firm annual yield in the 1989 Addendum was computed to be about 2,000 acre-feet greater than that found by the 1986 yield study. Current accounting procedures for the movement, storage and delivery of San Juan-Chama water at Heron Reservoir that were adopted in 1988 were assumed, for purposes of the Interstate Stream Commission staff's evaluation presented in section 3 of this report, to be carried forward into the future without speculating as to whether procedures might be improved further to more reliably reflect actual Rio Grande inflows.

Section 3:

NEW MEXICO SAN JUAN-CHAMA PROJECT SUPPLY ANALYSIS

NEW MEXICO SAN JUAN-CHAMA PROJECT WATER SUPPLY ANALYSIS

The Interstate Stream Commission staff has considered the strengths and weaknesses of the Bureau of Reclamation's previous water supply studies, yield updates and hydrologic modeling relating to the San Juan-Chama Project. The Commission staff offers the following analysis of the San Juan-Chama Project water supply. The analysis covers water years 1936-2005 for which the available data are reasonably reliable. Data to generate daily or monthly flows at the project diversion sites prior to water year 1936 are not available with the same degree of reliability as post-1935 data.[71]

A. Project Diversions

Irrigation conditions and uses on pasture lands above and near the San Juan-Chama Project points of diversion in Colorado have not materially changed since 1970. Conditions causing irrigators to not fully irrigate in accordance with the computed consumptive use demand likely will exist in the future as they have occurred for decades in the past. Although water users above and near the project diversion points retain their rights to fully divert water to deplete the entire computed consumptive use demand when needed, rights to beneficially use water are limited to actual irrigation needs. In addition, there are several technical problems and uncertainties with estimating daily historic and baseline irrigation depletions. For these reasons, the flows historically available at the project diversion sites should for planning purposes be considered available for diversion in the future, and they should not be reduced to incorporate the reservation of rights for possible future uses.[72]

The following procedure was used to estimate daily historic flows available for diversion by the project for the period of analysis. First, the monthly gaged diversion records for the three

[71] Gaged flow records for the San Juan River near Blanco, New Mexico, are available for use in flow correlations for the water years 1931-1954, but the flow records are affected by completion of Vallecito Dam in March 1941 and the subsequent storage and regulation of Pine River flows by Vallecito Reservoir beginning April 1941. The reservoir development for the Pine River Project was to provide for the irrigation of up to about 69,000 acres of land, including supplemental irrigation on about 37,000 acres (see Reclamation Project Data, US Department of the Interior, Bureau of Reclamation, pages 349-350). Therefore, any correlation using post-1941 data of gaged flows of the San Juan River near Blanco with gaged flows at sites in the San Juan River Basin above Carracas, Colorado, would not be applicable prior to water year 1936. Gaged flow records for the Animas River at Durango, Colorado, are available for use in flow correlations from 1929 to the present, but the flow records are affected by upstream development over time and the drainage area above the gage site is not connected to, and is not within the proximity of, the drainages from which the San Juan-Chama Project diverts. Substitution of StateMod computed natural flows for historic gaged flows at either the San Juan River near Blanco gage or the Animas River at Durango gage would not materially increase their accuracy for use in generating monthly and daily historic flows at the project diversion sites prior to water year 1936 because estimates of historic depletions prior to 1936 are based on little actual data and lack precision (see San Juan/Dolores River Basin Water Resources Planning Model User's Manual, Colorado Water Conservation Board, November 2005; and see footnotes 41 and 45-47). Also, flow records for the Navajo River at Edith prior to 1935 are incomplete, and many of the available pre-1935 records were estimated and not measured (see Addendum to Hydrology Report, San Juan-Chama Project Yield Update, Bureau of Reclamation, Upper Colorado Region, Albuquerque, New Mexico, February 1989, pages 7-8).

[72] See footnotes 49 and 78. Use of natural flows, instead of historic flows, to determine current-condition flow availability at each project diversion site also would introduce significant error into the analysis due to error and uncertainty in estimating historic depletions above each site, particularly irrigation depletions prior to 1975 for which very limited data are actually available (see footnotes 45 and 46).

project diversions from the San Juan River Basin for October 1970-September 2005 were adjusted proportionately so that the sum of the adjusted diversions each month matched the measured flow of the Azotea Tunnel at Outlet.[73] The adjusted monthly diversions were distributed daily using the historic daily gaged diversion pattern for each month.[74] Monthly and daily flows at the diversion sites beginning March 1971 were then computed for the Rio Blanco diversion as the gaged flow of the Rio Blanco below Blanco Diversion Dam plus the adjusted historic diversion at the Blanco Diversion Dam, for the Navajo River diversion as the gaged flow of the Navajo River below Oso Diversion Dam plus the adjusted historic diversion at the Oso Diversion Dam, and for the Little Navajo River diversion as the gaged flow of the Little Navajo River below Little Oso Diversion Dam plus the adjusted historic diversion at Little Oso Diversion Dam.[75] Second, the monthly historic flows available at the project diversion sites prior to March 1971 were determined based on gaged flows at other stream flow gaging stations that were available prior to March 1971 and on monthly correlations of flows at the diversion sites to flows at these other stations regressed using data available beginning March 1971. For the Rio Blanco diversion, monthly historic flows at the diversion dam prior to March 1971 were estimated by correlation with monthly flows of the San Juan River at Pagosa Springs for water years 1936-1956 and of the East Fork San Juan River above Sand Creek for the period October 1956-February 1971.[76] For both the Navajo River and the Little

[73] See footnote 21. There are no data to suggest how to distribute to each diversion site the differences between the sum of the gaged diversions at the three project diversion sites and the measured Azotea Tunnel flows at outlet. No adjustments were made for any tunnel leakage losses. During seven months from October 1970-September 2005, flow was recorded for the Azotea Tunnel at Outlet when no diversions were recorded at the project diversion sites. The amount of flow at the Azotea Tunnel at Outlet during these months was small (about 75 acre-feet for November-December 1970 prior to gaging of the project diversions in Colorado initiated in March 1971, about 46 acre-feet for November-December 1973, about 2 acre-feet for February-March 1982, and about 12 acre-feet for September 1986). For these seven months, the measured flow at the Azotea Tunnel at Outlet was distributed one-half to the Rio Blanco diversion and one-half to the Navajo River diversion. Also, the following gaged diversion records were adjusted to reflect probable hydrographs and project operations: Rio Blanco diversions for March 26-31, April 4-6 and May 25, 1971; Navajo River diversions for March 30-31, April 24 and May 3, 1971; and Little Navajo River diversions for March 31 and April 10, 1971. In addition, days of missing record for the flow of the Azotea Tunnel at Outlet were assumed to be days of no flow, except that the monthly and daily flows of the Azotea Tunnel at Outlet for October-November 1983 were assumed equal to the sum of the gaged diversions at the three project diversion sites in Colorado for these months. See Appendix A, tables A-1 through A-11.

[74] See Appendix C, table C-1. Daily average flows in the Azotea Tunnel in excess of 950 cfs are common for short periods during the peak of the snowmelt runoff season due to flow diurnals. The Bureau of Reclamation attempts to operate the tunnel at or below a safe operating limit of 950 cfs maximum flow, but overnight surges in flow with the diurnals may cause flows at the tunnel outlet to exceed 950 cfs for short durations during the early morning hours. In these instances, the project diversion gates at the start of the work day are adjusted to cut the total flow in the Azotea Tunnel back to 950 cfs (Bureau of Reclamation, Chama Field Office staff, oral communication, October 2006). The gate adjustments are made to reset the total project diversion to 950 cfs at the time of the gate adjustment, not to limit daily flow through the tunnel to an average of 950 cfs for the day.

[75] See Appendix A, tables A-9 through A-17; and see Appendix D, table D-1(b). This procedure was used for the Little Navajo River beginning only June 1971 because gaged flows for the Little Navajo River below Little Oso Diversion Dam are not available until May 26, 1971. The flow of the Little Navajo River below Little Oso Diversion Dam for October 1-November 3, 1994, and for October 1-December 5, 1996, was assumed to be 2 cfs.

[76] See Appendix B, tables B-1 through B-10 and tables B-31 through B-34. Monthly linear correlations between historic flows at the Rio Blanco diversion site and the East Fork San Juan River above Sand Creek for the period 1971-2005 had r-squared values ranging from 0.67-0.96, and between historic flows at the Rio Blanco diversion site and the San Juan River at Pagosa Springs for the period 1971-2005 had r-squared values ranging from 0.61-0.94 (see tables B-3 and B-7, respectively). Monthly log-log correlations between historic flows at the Rio Blanco diversion site and the East Fork San Juan River above Sand Creek

Navajo River diversions, monthly historic flows at the diversion dams prior to March 1971 were estimated by correlation with monthly flows of the Navajo River at Edith for water year 1936 and of the Navajo River at Banded Peak Ranch for the period October 1936-February 1971.[77] The daily

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for the period 1971-2005 had r-squared values ranging from 0.60-0.97, and between historic flows at the Rio Blanco diversion site and the San Juan River at Pagosa Springs for the period 1971-2005 had r-squared values ranging from 0.64-0.97 (see tables B-4 and B-8, respectively). Comparison of the monthly regression equations to the data indicate that the log-log correlations tend to better represent low flow conditions, and that the linear correlations tend to better represent high flow conditions (see tables B-6 and B-9). Based on the regression analyses, the linear flow correlation equations generally were used to best represent all ranges of flow on the Rio Blanco, the East Fork San Juan River and the San Juan River, with modifications to some monthly correlations at low flows as needed to more accurately reflect the data (see tables B-6(a) through B-6(l), tables B-9(a) through B-9(l), and table 31).

No adjustments were made to the historic flows of the East Fork San Juan River above Sand Creek or to the San Juan River at Pagosa Springs. No change in physical conditions significantly affecting runoff has been documented in the East Fork San Juan River drainage above Sand Creek, and data are not available to reliably determine that the net of irrigation plus non-irrigation average depletions above Pagosa Springs has significantly changed relative to 1936 conditions (see footnote 72). Municipal and domestic water development in the vicinity of Pagosa Springs from the drainage of the San Juan River above the Pagosa Springs gage primarily has relied on the transfer of water rights associated with historic irrigation uses, as opposed to new consumptive use appropriations (Randy Seaholm, Colorado Water Conservation Board staff, oral communication, February 2007). Thus, for purposes of this investigation, it was assumed that the flows of the San Juan River at Pagosa Springs measured during the period 1936-1956 reasonably represent the flows that would occur under recent or current conditions and 1936-1956 period hydrology, and no adjustments were made to the flow records. The resultant monthly stream flows for 1936-1971 estimated at the Rio Blanco diversion site are shown in table B-34.

[77] See Appendix B, tables B-11 through B-31 and tables B-35 through B-38. Monthly linear correlations between historic flows at the Navajo River diversion site and the Navajo River at Banded Peak Ranch for the period 1971-2005 had r-squared values ranging from 0.81-0.99, and between historic flows at the Navajo River diversion site and the Navajo River at Edith for the period 1971-2005 had r-squared values ranging from 0.37-0.91 (see tables B-13 and B-17, respectively). Monthly log-log correlations between historic flows at the Navajo River diversion site and the Navajo River at Banded Peak Ranch for the period 1971-2005 had r-squared values ranging from 0.79-0.99, and between historic flows at the Navajo River diversion site and the Navajo River at Edith for the period 1971-2005 had r-squared values ranging from 0.50-0.90 (see tables B-14 and B-18, respectively). Comparison of the monthly regression equations to the data indicate that the log-log correlations tend to better represent low flow conditions, and that the linear correlations tend to better represent high flow conditions (see tables B-16 and B-19). Based on the regression analyses, the linear flow correlation equations generally were used to best represent all ranges of flow on the Navajo River, with modifications to some monthly correlations at low flows as needed to more accurately reflect the data (see tables B-16(a) through B-16(l), tables B-19(a) through B-19(l), and table 31). No change in physical conditions affecting runoff has been documented above Banded Peak Ranch, and evaluation of any change in net average depletions above Edith since 1936 is not warranted for estimating flows for 1936 only. The resultant monthly stream flows for 1936-1971 estimated at the Navajo River diversion site are shown in table B-37.

Monthly linear correlations between historic flows at the Little Navajo River diversion site and the Navajo River at Banded Peak Ranch for the period 1971-2005 had r-squared values ranging from 0.05-0.89, and between historic flows at the Little Navajo River diversion site and the Navajo River at Edith for the period 1971-2005 had r-squared values ranging from 0.09-0.93; however, the linear correlations to flows of the Navajo River at Banded Peak Ranch for the months of April-July when most diversions from the Little Navajo River occur had r-squared values ranging from 0.75-0.89, which were significantly better than the linear correlations to flows of the Navajo River at Edith for the same months (see tables B-23 and B-27, respectively). Monthly log-log correlations between historic flows at the Little Navajo River diversion site and the Navajo River at Banded Peak Ranch for the period 1971-2005 had r-squared values ranging from 0.60-0.94, and between historic flows at the Little Navajo River diversion site and the Navajo River at Edith for the period 1971-2005 had r-squared values ranging from 0.40-0.88 (see tables B-24 and B-28). Comparison of the monthly Little Navajo River regression equations to the data indicate that the log-log correlations tend to better represent low to medium range flow conditions, and that the linear correlations better represent high flow conditions (see tables B-26 and B-29). Based on the regression analyses, the linear flow correlation equations generally were used to best represent all ranges of flow on the Little Navajo River and Navajo River, with modifications to some monthly correlations as needed to more accurately reflect the data (see tables B-26(a) through B-26(l), historic flows at each of the three project diversion sites for each month were then computed by distributing the estimated monthly historic flow at each site using the same daily flow pattern or distribution for the month that was exhibited by the gaged flows at the key station used in the associated correlation analysis for that month.[78]

The daily flows theoretically available for diversion at each project diversion site for the 1936-2005 period of analysis were then determined based on the estimated historic daily flows at the diversion dams less the following daily diversion bypass requirements in cfs adopted by Reclamation pursuant to section 8(f) of Public Law 87-483 and the Upper Colorado Regional Director's January 7, 1977, memorandum:

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rio Blanco	15	15	20	20	40	20	20	20	20	20	20	15
Navajo River	30	34	37	37	88	55	55	55	55	37	37	37
Little Navajo River	4	4	4	4	27	27	27	27	27	4	4	4

The bypass requirements at each of the diversion sites were met from only the flows originating above the diversion sites. Daily theoretical diversions by the project from each of the three streams were limited based on the following San Juan-Chama Project diversion feeder capacities, and the sum of the project diversions were further limited by the following tunnel operational criteria:

Diversion Feeder Capacities:		Conduit Capacities:	
Rio Blanco Diversion	520 cfs	Blanco Tunnel	520 cfs
Little Navajo River Diversion	150 cfs	Oso Tunnel	550 cfs
Navajo River Diversion	650 cfs	Azotea Tunnel	950 cfs

The computations of the daily and monthly theoretical project diversions are shown in Appendix D, tables D-1(a) and D-1(b).

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tables B-29(a) through B-29(l), and table 31). In estimating the pre-1971 historic flows at the Little Navajo River diversion, the following minimum monthly flow amounts in acre-feet were used for the Little Navajo River at the Little Oso Diversion Dam based on the post-1970 historic flow records:

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Minimum Flow (af)	50	40	120	390	170	110	40	30	40	40	30	30

This procedure was used for the Little Navajo River until June 1971 (see footnote 75). The resultant monthly stream flows for 1936-1971 estimated at the Little Navajo River diversion site are shown in table B-38.

[78] See Appendix D, table D-1(a). As compared to the stream gaging and drainage area ratio assumptions and methodologies employed in the Bureau of Reclamation's San Juan-Chama Project water planning studies in the late 1950s and early 1960s and in Reclamation's project yield studies of the late 1980s and 1990s, more confidence can be placed in the monthly flow correlation method for capturing flow variability over time at each specific location as reflected by the available flow gaging records now available. The flow correlation method used in this investigation provides estimates of flows at each of the project diversion sites prior to 1971 that reflect both 1936-1970 hydrology and the water use conditions above the diversion sites that were in place, on average, during the 1971-2005 period used in the flow regression analyses. Still, combining the use of monthly flow correlations, with the associated r-squared values for the monthly correlations, and the use of pro-rata flow distributions between gages on a daily basis each month does not necessarily reflect the full extent of actual variation in daily flows between gage sites.

The computed monthly theoretical diversions for the project through the Azotea Tunnel were then refined to reflect actual historic San Juan-Chama Project operations, including allowance for gage error in real-time measurement of the bypass flows below the project diversion dams, short-duration flow surges in the Azotea Tunnel resulting in daily average diversions exceeding 950 cfs, delays in making gate adjustments at the diversion dams in response to changes in hydrologic conditions, sediment sluicing requirements, and other factors.[79] The refinements consisted of

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[79] See Memorandum of the Upper Colorado Regional Director, Bureau of Reclamation, dated January 7, 1977; and see footnotes 27 and 74. Historically, daily bypass flows at each of the three project diversion sites have exceeded the daily minimum flow bypass requirements by up to 5 percent, or 1-3 cubic-feet-per-second, to allow for possible gage errors at the gaging stations located below the project diversion dams, and may further exceed the required daily bypass flow rates if necessary to meet the target monthly flow volumes specified in San Juan-Chama Project, Colorado-New Mexico, Bureau of Reclamation, November 1955, Appendix D, at page D2-7 (see Bureau of Reclamation Commissioner G.G. Stamm's letter to Henry M. Jackson, dated December 26, 1974; also Bureau of Reclamation, Chama Field Office staff, oral communication, October 2006). Section 8(f) of Public Law 87-483 requires that the Bureau of Reclamation bypass the monthly diversion minimum bypass quantities in acre-feet for the Rio Blanco and the Navajo River that are set forth at page D2-7 of Appendix D of the Bureau of Reclamation's November 1955 report entitled "San Juan-Chama Project, Colorado-New Mexico." The US District Court in *Schutz v. Stamm, et al.*, in 1977 ruled that Reclamation's establishment of daily-average minimum bypass flow rates for each month for the Rio Blanco and Navajo River diversions is a reasonable application of the operation requirements for the San Juan-Chama Project set forth in section 8(f) (see footnote 22). Reclamation also established daily-average minimum bypass flow rates for each month for the Little Navajo River, which rates for the irrigation season were determined from the monthly diversion bypass quantities for the Little Navajo River also specified at page D2-7 of Appendix D of the Bureau of Reclamation's November 1955 report. However, the daily bypass flows may exceed the daily-average bypasses required when Reclamation applies the minimum bypass requirement on an instantaneous basis rather than a daily-average basis.

Reclamation is not required to bypass additional amounts of water over and above the indicated monthly bypass flow amounts. Any biased error in measuring monthly bypass amounts can be addressed through corrective measures taken to improve the gaging of stream flow below the project diversion sites, and random error in estimating daily bypass flows can be presumed to balance out over the course of a month such that the monthly minimum bypass quantities are preserved so long as the daily-average minimum bypass flow rates are met each day, to the extent that flow is available, after any minor and compensating irregularities. Daily operational adjustments of the project diversions could reduce these excess bypass flows to result in monthly bypass flows that more closely correspond to the amounts of bypass water required each month. Also, Reclamation in real-time operations at the Little Oso diversion dam should consider inflows to the reach between the diversion dam and the mouth of the Little Navajo River that are available to meet the water demands to be supplied by bypass flows. Such consideration would allow for increased project diversions from the Little Navajo River, particularly during the spring, and would be consistent with the operating assumptions used in the Bureau of Reclamation's San Juan-Chama Project yield studies (see Hydrology Report, San Juan-Chama Project Yield Update, US Department of the Interior, Bureau of Reclamation, Southwest Region, Amarillo, Texas, April 1986, pages 10-11; and Draft Hydrology Report, Revised San Juan-Chama Firm Yield, US Department of the Interior, Bureau of Reclamation, Albuquerque Area Office, Albuquerque, New Mexico, October 1999, page 4).

Additional flows that might be made available for diversion by reducing the 4 cfs non-irrigation season bypass flow rate on the Little Navajo River to only the flow rate determined necessary to meet current stock and domestic needs should not be considered because wintertime flows often are less than 4 cfs and ice conditions would preclude effective diversion of said flows. During winter months, Reclamation sets the diversion gates at a particular setting, but the gates typically are not operable due to icing conditions (Bureau of Reclamation, Chama Field Office staff, oral communication, October 2006). Ice may also prevent flows from entering the diversion feeders. Due to winter weather and associated icing and access difficulties at the project diversions, it is uncertain as to whether Reclamation can effectively improve on its historic record and consistently divert the flows theoretically available for diversion at any of the project diversion sites from late November through early March, although based on the limited data available Reclamation might during winters of above-average flow be able to increase its project diversions. In addition, while actual diversion gate operating decisions are made based on real-time stream flow data, the water supply analysis in this report relies on published data that may include corrections or refinements to the real-time data.

adjusting the monthly theoretical project diversions based on monthly relationships of historic flows of the Azotea Tunnel at Outlet to the computed theoretical diversions for water years 1971-2005, excluding periods when the historic diversions were impacted by full or near-full storage conditions in Heron Reservoir.[80] The monthly relationships of actual project diversions to computed theoretical diversions derived from the historic data using envelope curves are shown in Appendix E, table E-5, and generally reflect the maximum diversion efficiency achieved at times in the past under historic project operations criteria and practices (considering also the range of data and computational error). The potential diversions were also adjusted to reflect those months after 1970 in which historic diversions actually exceeded the estimated potential diversions.[81] The resulting monthly estimates of San Juan-Chama Project adjusted potential diversions are shown in Appendix E, table E-7. While the monthly adjusted potential project diversions range from about 90 percent

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[80] See Appendix E, tables E-1 through E-9. Comparison of the computed monthly theoretical project diversions through the Azotea Tunnel to the historic flows of the Azotea Tunnel at Outlet for water years 1971-2005 indicates that actual project diversions are less overall than the theoretical diversions (see table E-3). Historically, the San Juan-Chama Project diversions begin in earnest about mid to late March, or perhaps later if Heron Reservoir is projected to fill based on anticipated snowmelt runoff forecasts and anticipated project diversion operations, and may continue through late October or into November. Flows historically were bypassed during March through November that might be practicably diverted if Reclamation improves its operations at the project diversion dams to better maximize the diversion of the water available to the project by more quickly adjusting the diversion gates in response to increases in flows at the diversion sites and by diverting more than 950 cfs through the Azotea Tunnel for longer periods of time than has been done historically if additional hours or days of such operation can be accomplished without physically damaging the tunnel. Significant increases in wintertime diversions might be difficult to achieve operationally due to icing effects, except for months with above-average flows.

To evaluate the relationship between theoretical project diversions and actual potential project diversions, envelope curves (lines) were utilized to effectively disqualify data for periods when diversions were limited due to full or near-full storage conditions in Heron Reservoir (see tables E-4 and E-5). In setting the envelope lines, data for the few months in which actual project diversions exceeded theoretical diversions also were not considered. Daily project diversions averaging more than 950 cfs might occur during May or June in years of above-average runoff as they have since 1970, but in most such years do not cause the monthly diversions to exceed theoretical diversions. Project diversions in excess of 950 cfs that might occur under estimated hydrology prior to 1970 might lend support to the anticipated yield of the project at Heron Dam, but would not be expected to materially increase the long-term average annual project diversion because offsetting diversion curtailments would occur later to prevent physical spills from Heron Reservoir. The resulting relationships between potential diversions and theoretical diversions are shown in table E-5. For the months of March-November, the envelope lines indicate that the monthly potential diversions can be expressed as the following percentages of theoretical diversions (see table E-5):

	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
Potential Diversion as Percent of Theoretical Diversion	96.0	98.0	99.0	99.5	97.0	93.0	91.0	90.0	90.0

For the winter months of December-February, equations indicating potential diversions only when monthly theoretical diversions exceed 300 acre-feet were used to better reflect historic wintertime operations (notwithstanding occasional wintertime project diversions of up to about 80 acre-feet per month during months with theoretical diversions of less than 300 acre-feet). The higher diversion efficiencies in the springtime and early summer reflect the relative magnitudes of runoff available for diversion over and above the bypass requirements during that time of year as compared to later in the year, and the lower diversion efficiencies during the monsoon season and fall also reflect difficulty in operating diversion gates during thunderstorm runoff events. The assumptions used in this investigation regarding potential project diversion efficiencies are for purposes of this water supply investigation only, and are not an assessment of the range of Reclamation's options for improving the efficiencies of project operations to maintain the yield of the project.

[81] For those months during water years 1971-2005 in which the estimated potential project diversion was less than the historic project diversion, the potential project diversion was set equal to the historic project diversion; except, that the potential diversions for September 1972, February 1975, November 1976, February 1977, December 1977, January 1978, July 2000 and June 2002 were not so increased to avoid diversions in excess of theoretical diversions during months of low flows. The adjusted potential diversions for the project for the period of analysis are shown in table E-7, and a comparison of the adjusted potential project diversions to the theoretical project diversions is shown in tables E-8 and E-9.

to 99.5 percent of theoretical project diversions during non-winter months, the adjusted potential project diversions estimated for this study overall amount to about 98 percent of the computed theoretical project diversions on an average annual volumetric basis. The potential project diversions were further refined as a result of the Heron Reservoir operations studies described in the following section of this report so as to avoid physical spills from the reservoir and to reflect, as necessary, the San Juan-Chama Project diversion amount limitations imposed by section 8(a) of Public Law 87-483.[82]

B. Heron Reservoir San Juan-Chama Operations Study

Monthly operations studies were prepared for Heron Reservoir for the 1936-2005 period of record using the following criteria. First, gross lake evaporation rates for April-October were estimated as pan evaporation times a pan coefficient of 0.7 and for November-March were estimated as monthly functions of mean air temperature developed by Reclamation and used by Reclamation to account San Juan-Chama water in the Rio Grande Basin. Net lake evaporation rates were estimated as gross lake evaporation minus US Bureau of Reclamation effective precipitation to reflect the difference between post-reservoir and pre-reservoir losses within the reservoir pool area.[83] Monthly pan evaporation, temperature and precipitation measurements available at Heron Dam beginning 1975 were used to compute monthly lake evaporation for 1975-2005, and correlations of Heron Dam weather data to data collected at nearby weather stations, principally at El Vado Dam and Chama, were used to derive weather data at Heron Dam prior to 1975 and to fill missing data.[84] A comparative analysis was then made for the period 1971-2005 of resultant Heron Reservoir net evaporation losses and total San Juan-Chama water losses estimated using current Rio Grande Compact water accounting and project operations criteria and monthly water budget calculations that reflect lake evaporation, dam seepage and other factors.[85] The

[82] Section 8(a) of Public Law 87-483 provides that San Juan-Chama Project diversions from the San Juan River Basin shall not exceed 270,000 acre-feet in any one water year and 1,350,000 acre-feet in any period of ten consecutive water years.

[83] Effective precipitation within the reservoir pool area is assumed to have been consumed by vegetation prior to inundation. The difference between precipitation and effective precipitation reflects natural runoff within the reservoir pool area under pre-reservoir conditions, which as native Rio Grande water cannot be stored or used for San Juan-Chama Project contractors (with the exception of about 350 acre-feet annually associated with pre-reservoir irrigation depletions salvaged within the Heron Reservoir pool area).

[84] See Appendix F, tables F-1 through F-10, for the analyses of monthly pan evaporation, precipitation and temperature data at Heron Dam, including the correlations used to develop pre-1975 weather data for Heron Dam. Data used in the analyses are primarily from National Oceanic and Atmospheric Administration (US Weather Bureau) climate data reports, Rio Grande Compact Commission reports, or Bureau of Reclamation San Juan-Chama accounting reports as noted in tables F-1 through F-10. Upper Rio Grande Water Operations Model weather data for Heron Reservoir for 1975-2000 were used only to fill missing data not available from published records. The derived monthly gross lake evaporation, effective precipitation, and net lake evaporation loss rates for Heron Reservoir for water years 1936-2005 are provided in Appendix F, tables F-15 through F-17, respectively. The monthly net evaporation loss rates shown in table F-17 are not reduced for wintertime lake ice cover, which may significantly affect evaporation rates particularly at low storage.

[85] See Appendix F, tables F-11 through F-14. Table F-11 provides monthly computations of Heron Reservoir historic net evaporation loss amounts for the period 1971-2005 both with and without proportionate reductions in loss rates for the percentage of lake surface area covered by ice in any given month; and table F-12 provides monthly computations of San Juan-Chama total water losses, including reservoir evaporation losses, at Heron Reservoir for the same period. The computations in both tables F-11 and F-12 follow the same procedures applied in the Bureau of Reclamation's 2005 Water Accounting Report to the Rio Grande Compact Commission Engineer Advisors, dated March 2006 (San Juan-Chama water accounting in the Rio

results of the comparative analysis are shown in Appendix F at tables F-13 and F-14. Although the total computed San Juan-Chama losses at Heron Reservoir, reduced to reflect 350 acre-feet of credit for pre-reservoir Rio Grande water rights used to offset Heron Reservoir evaporation, vary annually in relation to the net evaporation losses from Heron Reservoir, the total volume of San Juan-Chama losses is about equal to the total volume of net evaporation losses over the 1971-2005 period of analysis if the net evaporation losses are not reduced for ice cover. Ice cover may vary each year based on water storage and heat content, and no attempt is made in this Heron Reservoir operations study to predict ice cover each year. Therefore, based on the comparative analysis, the net lake evaporation loss rates for Heron Reservoir derived for water years 1936-2005 and provided in Appendix F at table F-17 were used directly in the reservoir operations study and were neither increased to reflect any additional San Juan-Chama losses nor decreased to reflect any wintertime ice cover or credit for offsetting use of Rio Grande rights. For purposes of this investigation, the monthly and annual net evaporation losses also were not adjusted for weak correlations of San Juan-Chama losses to net evaporation rates or to storage changes at Heron Reservoir that might indicate movement of water into or out of bank storage.

Second, the area-capacity table for Heron Reservoir derived from the 1984 resurvey, and effective 1986, was used in the reservoir operations studies to determine the average monthly

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Grande Basin is conducted on a calendar year basis for Rio Grande Compact accounting purposes and project contract administration). Because the San Juan-Chama accounting procedures currently used were not employed in earlier years, and because this investigation uses published US Geological Survey flow data and weather data that may differ from the data used in the actual accounting made each year in the past (except, that USGS data of no flow for Willow Creek below Heron Dam for October-December 1994 was replaced with Willow Creek flow data from the Bureau of Reclamation 1994 Water Accounting Report to the Rio Grande Compact Commission Engineering Advisors), the results shown in tables F-11 and F-12 do not precisely match each year's historic San Juan-Chama water accounting, particularly in years prior to 1988 in which year the current accounting procedures were adopted. For the purpose of making San Juan-Chama loss estimates in table F-12 that reflect current accounting procedures to compare to Heron Reservoir net evaporation loss amounts each year, end-of-year Rio Grande and San Juan-Chama contents in the reservoir were reset to match Reclamation's annual water accounting report results. More or less water would have been released from Heron Reservoir each year had current accounting procedures and published data been used. Small amounts of difference occur because the sum of daily flows is used in table F-12, as compared to rounded monthly flows. Computed San Juan-Chama losses are reduced by 350 acre-feet of credit annually to reflect the use of that amount of Rio Grande water rights to offset Heron Reservoir evaporation losses.

The net San Juan-Chama losses at Heron Reservoir computed for water accounting purposes using current procedures generally ranges from 40 percent less to 50 percent more than the estimated Heron Reservoir net evaporation losses, depending on the year (see table F-13). The methods used to compute net reservoir evaporation losses are empirical methodologies, and actual net reservoir evaporation may vary from estimated net evaporation each year due to spatial and temporal variations in lake heat content and other physical factors at the lake surface that affect evaporation losses, including air humidity, wind speed, solar radiation and precipitation. The pan coefficient value of 0.7 used to compute gross lake evaporation rates from pan evaporation data is an average value calibrated to regional lake water budget data for several years. On the one hand, the computed net reservoir evaporation losses might tend over the long-term to overstate San Juan-Chama losses because they are not reduced for the use of Rio Grande water rights to offset a portion of the evaporation losses or for reductions in evaporation caused by ice cover; and on the other hand, the computed net reservoir evaporation losses might tend to understate San Juan-Chama losses because they do not include reservoir seepage losses that are considered lost to the extent that continuous seepage is not fully credited as part of the San Juan-Chama Project contract deliveries. Overall, the total San Juan-Chama losses are about equal to the net reservoir evaporation losses over the 1971-2005 period, particularly beginning 1976 when published Heron Dam weather station data became available and after much of the initial filling of Heron Reservoir. To evaluate possible relationships of Heron Reservoir San Juan-Chama losses, table F-14 shows plots of losses against time, reservoir storage changes, net lake evaporation and reservoir inflows. The plots indicate no definitive correlation of reservoir losses to inflows, and only weak correlations of reservoir losses to evaporation rates and amounts and to storage changes that might affect possible movement of water to and from bank storage.

reservoir surface area as a function of the average of the beginning-of-month and end-of-month reservoir storage contents. One Heron Reservoir operations study used the total reservoir capacity at spillway crest of 401,330 acre-feet, of which 399,990 acre-feet is active capacity, to determine San Juan-Chama Project estimated diversions from the San Juan River Basin and evaluate the project yield under 1984 storage capacity conditions. A second reservoir operations study used an estimated active reservoir capacity of 390,730 acre-feet to determine San Juan-Chama Project estimated diversions and evaluate the project yield under future reservoir sedimentation conditions that might be anticipated to occur about 2070.[86] Rather than attempt to distribute the sediment accumulation with depth to estimate future reductions in water surface area within the reservoir pool, it was assumed that the relationship between surface or loss area and storage contents would not materially change over time. The beginning Heron Reservoir content for the operation studies was set equal to 140,000 acre-feet, or about 35 percent of active capacity, which essentially provides for both filling the reservoir prior to the critical period to evaluate project yield and maximizing the amount of project diversion that could be made from the San Juan River Basin without spill from Heron Reservoir prior to the critical period.

Third, the monthly distribution of demands of San Juan-Chama Project contractors for releases from Heron Reservoir was based on historic releases of San Juan-Chama water from the reservoir beginning 1996. The monthly San Juan-Chama water demands at Heron Dam starting in 1996 reflect all relevant operational factors, including scheduling Heron Reservoir releases to provide secondary recreational fishery and rafting benefits in the Rio Chama, storage and re-regulation of Heron Reservoir releases at El Vado and Abiquiu reservoirs to meet downstream San Juan-Chama water diversion or exchange demands of contractors, regulation of San Juan-Chama releases from all three reservoirs to provide benefits for conserving populations of endangered Rio Grande silvery minnow in the middle Rio Grande valley, releases to the Middle Rio Grande Conservancy District either during the irrigation season in years of low runoff and low available storage in the Rio Grande Basin if needed then or during the non-irrigation season for storage in El Vado Reservoir in years of adequate irrigation water supply, and approvals of waivers for contractors to take delivery of annual calendar-year contract allocations in succeeding years if in the interest of the United States.[87] Annual variations in amount and monthly timing of demands

[86] Comparison of the 1986 area-capacity table for Heron Reservoir and the original 1971 area-capacity table for Heron Reservoir indicates that the total capacity of the reservoir had not materially changed between 1971 and 1984. Compared to the original area-capacity table, the 1986 table shows slightly less dead storage capacity and slightly more active storage capacity. The Bureau of Reclamation previously estimated that the sediment accumulation rate within Heron Reservoir would amount to 10,600 acre-feet over 100 years (see Definite Plan Report, San Juan-Chama Project, Colorado-New Mexico, Volume I, US Department of the Interior, Bureau of Reclamation, Region 5, May 1963, Revised June 1964, Appendix B, pages B-8 and B-9). Reducing the total reservoir capacity of 401,330 acre-feet by 10,600 acre-feet for sediment accumulation that Reclamation estimated would occur within the Heron Reservoir pool area over a period of 100 years, including about 1,340 acre-feet of sediment accumulation assumed to completely fill dead storage space and about 9,260 acre-feet of sediment accumulation assumed to occur within the active capacity of the reservoir, gives a future active Heron Reservoir capacity of about 390,730 acre-feet representing conditions that might occur about 2070.

[87] See Appendix G, tables G-1(b) and G-1(c). Annual deliveries of San Juan-Chama water to project contractors are administered on a calendar year basis. In accordance with past practice and the Bureau of Reclamation's Final Rio Grande Supplemental Water Programmatic Environmental Assessment, Reclamation may concur with temporary waiver requests from San Juan-Chama Project contractors to modify the date of their annual water delivery from the end of a calendar year into the following calendar year (see 2003 Supplemental Water Program Report, Department of the Interior, Bureau of Reclamation, Albuquerque, New Mexico, February 23, 2004, page 1). The approval of waivers is a common administrative practice that is reflected in the historic San Juan-Chama water releases from Heron Reservoir on a yearly basis beginning about 1984 (see table

could influence the amounts of any monthly shortages computed in an operation study for Heron Reservoir; nevertheless, hydrological and water use factors and operational considerations in the Rio Grande Basin were not analyzed yearly to derive variations in annual and monthly demands for the 1936-2005 period under current operating practices, and average monthly demands for San Juan-Chama water at Heron Dam were used each year for the reservoir operations studies. The reservoir operations studies also did not consider use of operations rules to implement shortage criteria as reservoir storage reaches critically low levels (such as those used by the 1964 San Juan-Chama Project Definite Plan Report to begin allocation of shortages to demands if the projected reservoir storage on July 1 in a given year is less than 68,700 acre-feet). Such shortage criteria have not been institutionalized, and could have the effect of redistributing shortages and causing additional shortage in anticipation of otherwise running out of water in storage.

C. Project Yield

Annual summaries of both Heron Reservoir operations studies are provided in tables 2 and 3 attached hereto, respectively. The results of the reservoir operations studies indicate that with a demand at Heron Dam of 96,200 acre-feet annually and assuming 1936-2005 period hydrology, there would be no water supply shortages to project uses in the Rio Grande Basin under either

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G-1(b)). Prior to 1984, contract deliveries were generally completed at the end of the calendar year. Delivery of the full San Juan-Chama Project contract demand amounts, in part to provide supplemental water benefits for conservation of Rio Grande silvery minnow in the middle Rio Grande valley, did not begin until 1996. Therefore, average monthly demands for San Juan-Chama water at Heron Dam for the reservoir operations studies were determined by distributing the annual demand monthly in the same percentage distribution as the historic San Juan-Chama water releases from Heron Reservoir for the period 1996-2005 to reflect current operations (see table G-1(c)). The City of Albuquerque's surface water diversion project recently constructed to provide for direct diversion of its San Juan-Chama water from the Rio Grande will not affect how releases are scheduled from Heron Reservoir to meet the City's contract delivery demands (see Hydrologic Effects of the Proposed City of Albuquerque Drinking Water Project on the Rio Grande and Rio Chama Systems, Updated for New Conservation and Curtailment Conditions, CH2MHill, City of Albuquerque Public Works Department, October 2003, pages 7-1 through 7-4; and see footnote 57).

For comparison purposes, a theoretical monthly distribution of demands on the annual project yield at Heron Dam was estimated assuming direct delivery of San Juan-Chama water from Heron Reservoir to the point of use or exchange without consideration of intervening storage, re-regulation and fishery benefit considerations (see Appendix G, table G-1(a)). Theoretical municipal and industrial demands were assumed uniform throughout the year, the theoretical Middle Rio Grande Conservancy District demand generally occurs in December (possible deliveries during the irrigation season in years of low Rio Grande water supply availability due to low runoff, low storage or storage use constraints under the Rio Grande Compact were not analyzed), the demands for releases to replace evaporative losses from the Cochiti Lake recreation pool are made each spring rather than distributed in accordance with said evaporative losses, the Pojoaque Valley Irrigation District demand for exchange water occurs during the spring runoff, and the San Juan Pueblo allocation demand occurs during the irrigation season. Such theoretical monthly demands at Heron Dam were used in previous Bureau of Reclamation San Juan-Chama Project yield studies. Comparison of the theoretical monthly demands at Heron Dam for releases of San Juan-Chama water to the historic monthly releases of San Juan-Chama water from Heron Reservoir illustrate the impact on actual release demands of delivery deadline waivers, downstream storage and re-regulation, operations for fishery benefits and other yearly operational considerations. While annual variations in future demands, waivers, and computed San Juan-Chama losses (as compared to Heron Reservoir net evaporation losses) might influence the occurrence or annual amounts of shortage, the use in this investigation of a constant demand and annual Heron Reservoir net evaporation losses is believed to result in a reasonable estimate of the overall water budget for the period of record and the critical period.

historic 1984 or projected 2070 storage sedimentation conditions in Heron Reservoir.[88] Although the reservoir operations studies suggest that the firm yield at Heron Dam might slightly exceed 96,200 acre-feet per year if the small amount of storage remaining at the end of the critical period were utilized to meet demands, the remaining storage amount is within the computational accuracy of this hydrologic investigation. Thus, the hydrologic investigation presented herein indicates that no change is warranted to the Bureau of Reclamation's previous determination that the firm yield of the San Juan-Chama Project at Heron Dam is 96,200 acre-feet based on historic hydrology.

The average annual San Juan-Chama Project diversion from the San Juan River Basin for the period 1936-2005 is estimated from the Heron Reservoir operations studies to be as much as about 105,500 acre-feet per year under 1984 conditions and about 105,200 acre-feet per year under 2070 sedimentation conditions in Heron Reservoir, the difference reflecting the fact that less diversion will be required to fill the reservoir as its capacity is reduced in the future due to sedimentation. The results of the Heron Reservoir operations studies assume no reduction in San Juan-Chama Project diversions due to implementation of section 11 of Public Law 87-483. Based on the Bureau of Reclamation's hydrologic modeling for the San Juan River Basin, it is unlikely that project diversions under 1936-2005 period hydrology would be administratively curtailed pursuant to section 11 of Public Law 87-483.[89]

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[88] See also Appendix G, tables G-2 and G-3. The results of the operations studies are similar. The effect on the project yield at Heron Dam of relatively small reductions in storage capacity due to future sedimentation would be largely offset by reductions in water surface area and reservoir evaporation caused by delta deposits in the reservoir.

[89] Section 11 of Public Law 87-483 provides for the allocation of shortage to the normal diversion requirement of the San Juan-Chama Project in any year that the water supply in the San Juan River Basin is insufficient to meet the diversion demands of the project in that basin and the contract water demands of Navajo Reservoir contractors. Based on the Bureau of Reclamation's hydrologic modeling analyses for the San Juan River Basin that incorporate operation of Navajo Reservoir to meet the San Juan River Basin Recovery Implementation Program's flow recommendations for the San Juan River and the depletions associated with the proposed Navajo-Gallup Water Supply Project in addition to completion of the Navajo Indian Irrigation Project, no such shortages would occur during the 1929-1993 period of record in the Generation 2 model and an overall basin shortage would occur only in 2003 based on the September 2006 version of the proposed Generation 3 model. The occurrence of an overall shortage in any year would not necessarily translate to an actual administrative curtailment of San Juan-Chama Project diversions depending upon hydrology at the project diversion sites that year, the numerical definition of the project normal diversion requirement, the amount of the overall basin shortage that would be taken against the flow recommendations, and the shortage allocation measured against the normal diversion requirement. Based on the amount of potential San Juan-Chama Project diversion for 2003 shown in this report, as compared to the long-term average annual diversion for the project, it is unlikely that the project diversions under 2003 conditions would be administratively curtailed pursuant to section 11 of Public Law 87-483.

BASELINE AND ANTICIPATED DEPLETIONS FROM THE SAN JUAN RIVER

The US Fish and Wildlife Service in past biological opinions on planned water development projects in the San Juan River Basin has used the estimated long-term average annual San Juan-Chama Project diversion from the basin to define environmental baseline conditions. For example, the 1991 Animas-La Plata Project Biological Opinion assumed a baseline depletion of 110,000 acre-feet per year for the San Juan-Chama Project based on the 1964 Definite Plan Report for the project. The 2007 Draft Navajo-Gallup Water Supply Project Biological Opinion used a baseline depletion of about 107,500 acre-feet per year for the San Juan-Chama Project based on the estimated San Juan River Basin Generation 2 model hydrology for the period 1929-1993.[90] If the Fish and Wildlife Service were now to rely on the Bureau of Reclamation's proposed San Juan River Basin Generation 3 hydrology model results to define the environmental baseline, the baseline depletions would include a long-term average San Juan-Chama Project diversion of only 101,900 acre-feet per year as a consequence of revisions to flow and depletion estimates in Colorado above the project's points of diversion.[91] Under the hydrology of the proposed Generation 3 model as presented in September 2006, the yield of the San Juan-Chama Project at Heron Dam of 96,200 acre-feet per year (including the amounts of yield that are contracted plus the amount of water that is needed to maintain the Cochiti Lake recreation pool) could be determined to be not sustainable as a firm yield due to infrequent small shortages to the annual demand on the project at Heron Dam.

The Bureau of Reclamation is preparing the proposed Generation 3 model in response to recommendations made by the San Juan River Basin Recovery Implementation Program's Hydrology Committee. However, the Hydrology Committee's suggested revisions to the San Juan River Basin hydrology model should not have affected modeled San Juan-Chama Project operations or diversions, with the exception of extending the hydrologic record from 1993 to 2004. The reductions in project diversions and project yield suggested by Reclamation's proposed Generation 3 model apparently are the result of modeling made by the Colorado Water Conservation Board, and accepted by Reclamation staff without its prior review, to the flow and depletion data used to compute stream flows available at the San Juan-Chama Project points of diversion. The natural flows at the project's diversion sites are about 2,300 acre-feet per year greater, on average, in the Generation 3 model as compared to the previous model versions, and the baseline depletions above the project's diversion sites are about 3,500 acre-feet per year greater, on average, in the Generation 3 model. The differences in natural flows and depletions between models might appear to have a result of nearly offsetting each other on the long-term average, but significant differences in annual and monthly natural flows and depletions occur between the models, especially during the 1945-1978 critical period for the San Juan-Chama Project. The State of Colorado's procedures for estimating flows available at or above the project's diversion sites under baseline conditions are not appropriate for project planning purposes because: (1) the baseline depletions estimated by Colorado for use in determining flow availability are based on the full amount of computed crop consumptive uses rather than on actual irrigation demands after consideration of historical land

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[90] See Draft Biological Opinion for the Navajo-Gallup Water Supply Project, U.S. Bureau of Reclamation, Durango, Colorado, approved by Field Supervisor, U.S. Fish and Wildlife Service, New Mexico Ecological Services Field Office, Albuquerque, New Mexico, Biological Opinion Number 2-22-01-F-532, transmitted to Reclamation via memorandum dated January 23, 2007, page 10.

[91] The average annual San Juan-Chama Project diversion for the period 1929-2004 modeled by the September 2006 revised version of the proposed Generation 3 model is about 101,900 acre-feet per year (see table 1).

fallowing, seasonal diversion practices and other factors that are accounted for in the estimation of historic irrigation depletions; and (2) the hydrology at the project diversion sites does not reflect actual measured Azotea Tunnel outflows, and does not adequately reflect diversion data for months in which historic diversions substantially exceeded average diversions.[92]

The Interstate Stream Commission staff's hydrologic investigation presented herein suggests that the maximum long-term average annual diversion from the San Juan River Basin by the San Juan-Chama Project will decline from about 105,500 acre-feet per year under 1984 conditions to about 105,200 acre-feet per year under 2070 conditions, assuming historic hydrology for the period 1936-2005.[93] Interpolating between 1984 and 2070 conditions, the maximum long-term average annual diversion from the basin by the project under current conditions and historic hydrology is estimated to be as much as 105,400 acre-feet per year. These diversion amounts are maximum diversion rates that reflect: (1) a 98 percent overall (volumetric) level of diversion efficiency that might be attainable on a consistent basis assuming improvements over historic project operations to more fully take advantage of the diversion amounts that are theoretically and currently available to the project under sections 8(a) and 8(f) of Public Law 87-483; (2) the occurrence at times of actual project diversions in excess of the 950 cfs operating criterion for sustained flow through the Azotea Tunnel, which excess diversions to some degree offsets the inefficiencies in project diversion operations at other times of the year; and (3) the arbitrary selection of a beginning Heron Reservoir storage content for the reservoir operations studies that would purposefully result in a maximum amount of diversion by the project, with a minimum amount of reduction to avoid spill, during the years preceding the critical hydrologic period.[94] Also, regardless of the minimum bypass flow

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[92] See footnote 49. Also, the State of Colorado's estimations of historic depletions, natural flows and flows available for diversion at each of the project's diversion sites contain significant uncertainties and shortcomings (see the subsection on San Juan River Basin Hydrologic Modeling Studies in section 2 of this report; and see footnotes 21, 76 and 77). The Bureau of Reclamation and the State of Colorado have committed to making adjustments to the historic hydrology at the project diversion sites to reflect measured Azotea Tunnel outflows, but a revised version of the proposed Generation 3 model incorporating the adjustments has not yet been provided for review.

[93] The Bureau of Reclamation previously estimated that with Generation 2 model hydrology updated through the year 2000, the long-term future average annual depletion in the San Juan River Basin by the San Juan-Chama Project would be about 105,200 acre-feet per year. Consequently, the anticipated San Juan-Chama Project depletion that is included in the State of New Mexico Schedule of Anticipated Upper Basin Depletions that is appended to the Bureau of Reclamation's May 2007 Hydrologic Determination is 105,200 acre-feet per year under both current and future conditions through 2060 (see Hydrologic Determination 2007, Water Availability from Navajo Reservoir and the Upper Colorado River Basin for Use in New Mexico, Bureau of Reclamation, April 2007, signed by the Secretary of the Interior on May 23, 2007, Appendix D). The fact that the results of the Interstate Stream Commission staff's analysis presented in this report are nearly identical to Reclamation's previous estimate of the long-term average project diversion used in the 2007 Hydrologic Determination is fortuitous.

[94] The Bureau of Reclamation might improve its historic diversion efficiency by: (1) operating the project diversions more closely in accordance with section 8(f) of Public Law 87-483 to meet only the minimum monthly bypass flow amounts that are required, without also bypassing additional amounts of water to cover presumed daily gage error or to maintain the adopted daily-average bypass flow rates on an instantaneous basis; (2) beginning operation of the diversion works earlier in the spring than it has historically, and fill Heron Reservoir as early in the year as possible, once divertible flows become available; and (3) keeping closer tabs on flows and manipulate the diversion gates, trash racks and other operational factors to more fully take advantage of divertible flows. Although Reclamation until recently did not need to tighten its project diversion operations in the San Juan River Basin because there was less than a full demand on the project at Heron Dam until the late 1990s, Reclamation now has reason to do so. However, while Reclamation can improve its San Juan-Chama Project operations, it is not realistic to assume that Reclamation can and will operate each of the three project diversions in the San Juan River Basin in the future with 100 percent efficiency in capturing all water that New Mexico believes is legally available to the San Juan-

amounts for the Blanco and Oso diversion dams required by section 8(f) of Public Law 87-483, the Bureau of Reclamation is constrained by section 8(b) of Public Law 87-483 to operate the project diversions so that there shall be no injury, impairment, or depletion of existing or future beneficial consumptive uses of water within the State of Colorado consistent with Article IX of the Upper Colorado River Basin Compact.

Given actual project operations limitations, and given the data and computational uncertainties involved in this hydrologic investigation, it is reasonable for water planning purposes at this time to include in both New Mexico's schedule of future anticipated depletions and the environmental baseline a long-term average annual depletion from the San Juan River Basin of about 105,200 acre-feet per year for the San Juan-Chama Project.[95] Therefore, no change is warranted to the New Mexico depletion schedule appended to the Bureau of Reclamation's 2007 Hydrologic Determination, which was signed by the Secretary of the Interior on May 23, 2007, and included an annual average depletion for the project of 105,200 acre-feet per year under conditions anticipated through 2060.[96] The proposed San Juan River Basin Generation 3 hydrology model should be revised to reflect a future long-term average annual depletion by the San Juan-Chama Project of 105,200 acre-feet per year consistent with the 2007 Hydrologic Determination and New Mexico's hydrologic analysis presented herein.

The baseline depletion amount for the San Juan-Chama Project suggested herein should not be used, however, for regulatory purposes because the project diversions in the future will be driven by actual future hydrology, not estimated or modeled hydrology for some defined past period of

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Chama Project under historic hydrology because of icing, debris on trash racks, sluicing requirements, flow diurnals, rapid changes in flows and other physical or administrative factors that affect actual operations. In addition, the term diversion efficiency as used herein, along with the associated monthly potential diversion envelope curves derived by relating historic project diversion data to computed theoretical project diversions (see footnote 80), reflect also computational error in the computed theoretical diversions such that the monthly relationships between measured historic, or potential, diversions and computed theoretical diversions provide also, to some extent, a measure of calibration for estimating actual project diversions that might be anticipated to occur in the future. Even if computed theoretical project diversions are considered for a Heron Reservoir operations study, the long-term average annual estimated San Juan-Chama Project diversion would not increase by more than a few hundred acre-feet because most of the corresponding increase in project diversions in any given year would result in offsetting diversion curtailments in later years to avoid physical spills from the reservoir, all other study assumptions being equal.

[95] The hydrologic investigation presented in this report provides an anticipated or baseline San Juan-Chama Project future operations scenario that relies on reasonable project diversion operations and historic hydrology. The historic flows should not be reduced through the use of the Colorado River Decision Support System (CRDSS) modeling wherein the State of Colorado administratively reserves rights of users to fully divert and use water to deplete the entire computed crop consumptive use demand even at times when irrigation is not needed (see footnote 49). The Bureau of Reclamation in the proposed Generation 3 model gives deference to the State of Colorado's estimates of depletions in the San Juan River Basin by its water users, and Reclamation should defer to the State of New Mexico's determinations of depletions in the basin by its water users (see footnotes 2 and 42).

[96] See Hydrologic Determination 2007, Water Availability from Navajo Reservoir and the Upper Colorado River Basin for Use in New Mexico, Bureau of Reclamation, April 2007, signed by the Secretary of the Interior on May 23, 2007, Appendix D. The depletion amounts for the San Juan-Chama Project and other water uses shown in the New Mexico depletions schedule are anticipated average annual future depletions for planning purposes only. The New Mexico depletions schedule is not a tabulation of water rights or actual water uses. The 2007 Hydrologic Determination evaluated the availability of water for the Navajo Nation's uses under the proposed Navajo-Gallup Water Supply Project.

time. The Bureau of Reclamation's hydrology model, including all model data, should not be used to establish depletion limits on the San Juan-Chama Project or other water uses in the basin.[97]

[97] The Navajo Nation and the Bureau of Reclamation proposed, and the Fish and Wildlife Service accepted, a depletion guarantee as a means to allow implementation of the Navajo-Gallup Water Supply Project to move forward in compliance with the Endangered Species Act (see Draft Biological Opinion for the Navajo-Gallup Water Supply Project, U.S. Bureau of Reclamation, Durango, Colorado, approved by Field Supervisor, U.S. Fish and Wildlife Service, New Mexico Ecological Services Field Office, Albuquerque, New Mexico, Biological Opinion Number 2-22-01-F-532, transmitted to Reclamation via memorandum dated January 23, 2007, pages 9-11). The proposed depletion guarantee relies on the Navajo Nation reducing its uses in New Mexico as necessary to keep the long-term average modeled baseline depletion for the entire San Juan River Basin from being exceeded during any future administrative period of five years. The flow recommendations are specifically based on modeled hydrology and depletions statistics for the 64-year period 1929-1993 (see Flow Recommendations for the San Juan River, San Juan River Basin Recovery Implementation Program Biology Committee, May 1999, pages S-5 through S-8 and Chapters 7-8). The Generation 2 model baseline itself includes five-year periods during which depletions were greater, on average, than the average depletions for the 64-year period 1929-1993. For the San Juan-Chama Project, the annual diversions averaged over five-year administrative periods would range from about 79,000 acre-feet per year to about 145,000 acre-feet per year based on the Heron Reservoir operations study shown in table 3 attached hereto (as compared to a long-term average annual diversion by the project of about 105,200 acre-feet per year). The occurrence in the future of depletions that for a five-year administrative period exceed the average of the modeled depletions in the basin over the 64-year period 1929-1993 does not mean that the physical baseline condition in the basin has been exceeded either in reality or in the modeling, and should not be cause to require the Navajo Nation to reduce its water use in New Mexico.

Table 1. San Juan-Chama Project Annual Diversions from the San Juan River Basin
(Units: Acre-Feet)

Year	1961 Congress Hearings - San Juan-Chama Project: Bureau of Reclamation (1)	1961 Congress Hearings - San Juan-Chama Project: New Mexico Study No. 8 (2)	1964 USBR Definite Plan Report, SJ-Chama Project (3)	Bureau of Reclamation San Juan-Chama Project Yield Studies: 1986 Yield Study (4)	Bureau of Reclamation San Juan-Chama Project Yield Studies: 1989 Yield Study Addendum (5)	Bureau of Reclamation San Juan-Chama Project Yield Studies: 1999 Draft Yield Study Revision (6)	Bureau of Reclamation San Juan Basin Hydrologic Modeling Studies: 2005 Generation 2 Model (7)	Bureau of Reclamation San Juan Basin Hydrologic Modeling Studies: June 2006 Generation 3 Model (8)	Bureau of Reclamation San Juan Basin Hydrologic Modeling Studies: Sept. 2006 Revised G3 Model (9)	New Mexico SJ-Chama Project Yield Study, 2007 (10)
1928	81,000	81,000								
1929	178,000	178,000					148,413	148,622	159,426	
1930	82,000	82,000					90,748	96,586	104,639	
1931	56,000	56,000					66,821	51,905	55,859	
1932	194,000	194,000					170,218	171,261	179,837	
1933	69,000	69,000					79,521	82,442	85,255	
1934	21,000	21,000					38,344	37,437	42,660	
1935	182,000	182,000	171,200	171,200	171,200	171,200	151,089	145,567	144,178	
1936	124,000	124,000	121,200	121,200	121,200	121,200	100,017	112,818	105,136	154,940
1937	158,000	158,000	146,200	146,200	146,200	146,200	143,334	164,619	148,395	140,441
1938	149,000	149,000	148,600	148,600	148,600	148,600	150,508	148,619	145,676	141,848
1939	78,000	78,000	77,100	77,100	77,100	77,100	72,573	82,278	84,983	83,224
1940	68,000	68,000	71,100	71,100	71,100	71,100	61,295	65,497	68,665	69,357
1941	214,000	214,000	230,100	230,100	230,100	230,100	201,047	186,869	174,976	180,229
1942	163,000	163,000	146,600	146,600	146,600	146,600	120,622	101,599	101,569	181,099
1943	86,000	86,000	85,300	85,300	85,300	85,300	94,796	95,151	95,521	97,379
1944	117,000	117,000	125,200	125,200	125,200	125,200	120,999	119,588	119,371	128,773
1945	124,000	124,000	134,200	134,200	134,200	134,200	108,972	110,316	110,075	113,304
1946	47,000	47,000	51,300	51,300	51,300	51,300	45,788	42,089	45,196	46,830
1947	88,000	76,000	89,700	89,700	89,700	89,700	88,633	75,828	78,765	82,294
1948	112,000	112,000	110,500	110,500	110,500	110,500	148,344	112,708	118,520	124,192
1949	130,000	130,000	134,000	134,000	134,000	134,000	149,969	138,888	133,767	139,620
1950	62,000	62,000	60,600	60,600	60,600	60,600	73,135	58,922	61,722	66,848
1951	45,000	39,000	46,900	46,900	46,900	46,900	49,827	43,726	44,540	48,195
1952	155,000	155,000	158,500	158,500	158,500	158,500	164,745	166,433	160,291	158,500
1953	64,000	64,000	71,800	71,800	71,800	71,800	73,553	62,683	65,402	71,592
1954	53,000	53,000	57,600	57,600	57,600	57,600	57,941	53,852	55,543	58,358
1955	49,000	49,000	56,800	56,800	56,800	56,800	60,847	48,118	51,969	58,325
1956	67,000	55,000	73,200	73,200	73,200	73,200	70,800	61,015	62,490	73,226
1957	161,000	159,000	173,800	173,800	173,800	173,800	171,540	171,380	159,557	152,822
1958	127,000	126,000		130,100	130,100	130,100	124,411	138,923	131,355	127,600
1959	40,000	38,000		51,700	51,700	51,700	40,830	35,150	38,489	44,423
1960	110,000			117,600	117,600	117,600	124,201	115,200	116,871	131,920
1961				79,200	79,200	79,200	71,837	74,830	79,355	81,522
1962				112,600	112,600	112,600	113,191	107,123	108,604	121,431
1963				57,900	57,900	57,900	49,783	51,006	52,981	58,480
1964				63,800	63,800	63,800	60,083	56,246	58,315	61,578
1965				164,600	164,600	164,600	179,821	149,927	147,451	152,788
1966				107,200	107,200	107,200	103,636	98,742	103,324	119,198
1967				80,000	80,000	80,000	81,251	72,793	77,808	84,912
1968				101,700	101,700	101,700	108,589	86,433	88,866	97,892
1969				136,100	136,100	136,100	123,485	122,223	121,052	119,956
1970				94,000	94,000	94,000	98,162	88,777	94,078	97,131
1971				69,844	69,773	69,773	70,564	31,347	58,008	64,730
1972				63,362	63,362	62,916	46,019	16,879	42,981	42,420
1973				164,969	164,969	164,351	200,920	80,040	182,942	181,354
1974				53,921	53,921	53,349	52,776	48,638	49,566	50,969
1975				155,017	155,017	154,387	157,023	147,508	147,508	150,439
1976				92,803	92,803	92,257	88,463	84,351	84,346	88,097
1977				23,380	23,380	22,908	23,457	20,114	20,102	21,782
1978				111,276	111,276	110,741	106,106	102,141	102,141	107,589
1979				166,149	166,149	165,479	175,010	158,618	158,845	165,938
1980				147,044	147,044	146,301	145,194	138,999	139,237	145,972
1981				68,143	68,143	67,469	55,194	52,459	52,460	56,198
1982				184,729	185,493	185,010	179,988	174,126	174,229	174,745
1983				154,746	154,746	154,182	164,745	153,047	153,297	153,648
1984				148,789	148,789	148,493	152,785	136,010	135,978	136,919
1985					182,547	211,846	153,003	207,446	207,534	203,394
1986					105,261	213,530	108,867	150,847	150,084	112,480
1987					74,547	137,935	102,717	77,463	77,351	88,816
1988						77,958	79,428	70,216	70,216	76,663
1989						81,831	79,682	75,494	75,501	76,178
1990						101,031	76,116	71,103	71,132	74,027
1991						137,576	142,729	138,669	138,619	138,846
1992						134,450	132,409	128,506	128,370	129,664
1993						167,611	141,524	158,705	158,935	151,069
1994						133,453		127,988	128,003	85,113
1995						178,357		116,232	116,232	119,584
1996						64,315		58,768	58,768	61,110
1997						161,086		147,503	147,514	146,898
1998								109,574	109,535	97,835
1999								120,093	120,119	119,295
2000								42,281	42,264	44,435
2001								110,437	110,433	113,496
2002								7,023	6,897	7,176
2003								61,429	61,448	64,435
2004								83,238	83,226	85,947
2005										158,309

Table 1. San Juan-Chama Project Annual Diversions from the San Juan River Basin
(Continued)
(Units: Acre-Feet)

Year	1961 Congress Hearings - San Juan-Chama Project: Bureau of Reclamation (1)	1961 Congress Hearings - San Juan-Chama Project: New Mexico Study No. 8 (2)	1964 USBR Definite Plan Report, SJ-Chama Project (3)	Bureau of Reclamation San Juan-Chama Project Yield Studies: 1986 Yield Study (4)	Bureau of Reclamation San Juan-Chama Project Yield Studies: 1989 Yield Study Addendum (5)	Bureau of Reclamation San Juan-Chama Project Yield Studies: 1999 Draft Yield Study Revision (6)	Bureau of Reclamation San Juan Basin Hydrologic Modeling Studies: 2005 Generation 2 Model (7)	Bureau of Reclamation San Juan Basin Hydrologic Modeling Studies: June 2006 Generation 3 Model (8)	Bureau of Reclamation San Juan Basin Hydrologic Modeling Studies: Sept. 2006 Revised G3 Model (9)	New Mexico SJ-Chama Project Yield Study, 2007 (10)
Averages:										
Record	104,667	103,406	110,500	108,843	109,532	114,867	107,514	99,493	101,926	105,226
1929-1959	105,258	104,129	n/a	n/a	n/a	n/a	104,506	100,996	101,091	n/a
1929-1993	n/a	n/a	n/a	n/a	n/a	n/a	107,514	101,183	104,029	n/a
1936-1959	103,375	101,917	n/a	106,338	106,338	106,338	103,939	99,878	98,416	105,976
1936-1984	n/a	n/a	n/a	107,571	107,585	107,437	106,670	97,238	100,251	106,347
1936-2004	n/a	n/a	n/a	n/a	n/a	n/a	n/a	98,952	101,080	104,456
1946-1978	n/a	n/a	n/a	94,417	94,415	94,299	96,355	83,759	89,209	93,546

Notes:

(1) San Juan-Chama Reclamation Project and Navajo Indian Irrigation Project, Hearings before the Subcommittee on Irrigation and Reclamation of the Committee on Interior and Insular Affairs, House of Representatives, Eighty-Seventh Congress, First Session on H.R. 2552, H.R. 6541, and S. 107, April 24, 25, 26, and June 1, 1961, page 116. Water year diversions. Diversion of 110,000 af assumed for 1960 in the absence of records. Diversions based on Bureau of Reclamation hydrology, presented by the Commissioner of Reclamation. Considering the drought in the middle 1950s to be not representative of average long-term conditions, 110,000 af/yr was assumed to be the long-term average.

(2) San Juan-Chama Reclamation Project and Navajo Indian Irrigation Project, Hearings before the Subcommittee on Irrigation and Reclamation of the Committee on Interior and Insular Affairs, House of Representatives, Eighty-Seventh Congress, First Session on H.R. 2552, H.R. 6541, and S. 107, April 24, 25, 26, and June 1, 1961, page 144. Water year diversions. State of New Mexico Navajo Reservoir Operation Study No. 8, presented by the State Engineer. In New Mexico's study No. 8, shortages in the Navajo Reservoir supply proportioned to the normal diversion demand of the San Juan-Chama Project resulted in diversions less than the divertable flows in 1947, 1951 and 1956 by a cumulative amount of 25,000 af.

(3) Definite Plan Report, San Juan-Chama Project, Colorado-New Mexico, Volume I, US Department of the Interior, Bureau of Reclamation, Region 5, Revised June 1964, page 17. Calendar year diversions.

(4) Hydrology Report, San Juan-Chama Project Yield Update, US Department of the Interior, Bureau of Reclamation, Southwest Region, Amarillo, Texas, April 1986, page 29. Calendar year diversions. Includes about 4,900 af/yr average winter diversions (November-March).

(5) Addendum to Hydrology Report, San Juan-Chama Project Yield Update, US Department of the Interior, Bureau of Reclamation, Upper Colorado Region, Albuquerque, New Mexico, February 1989, Table A. Calendar Year Diversions.

(6) Draft Hydrology Report, Revised San Juan-Chama Firm Yield, US Department of the Interior, Bureau of Reclamation, Upper Colorado Region, Albuquerque, New Mexico, October 1999, Table 7. Calendar year diversions.

(7) San Juan River Basin Hydrology Model, Generation 2. Model used for August 2005 Navajo-Gallup Water Supply Project Biological Assessment, Bureau of Reclamation, Durango, Colorado. Flows available at San Juan-Chama Project points of diversion developed cooperatively by Bureau of Reclamation and Bureau of Indian Affairs. Water year diversions.

(8) San Juan River Basin Hydrology Model, Generation 3 Proposed. Presented for discussion to the San Juan River Basin Recovery Implementation Program Hydrology Committee on June 13, 2006. Bureau of Reclamation. Flows available at San Juan-Chama Project points of diversion developed by State of Colorado using its StateMod model after changes to Colorado hydrology and depletions. Water year diversions.

(9) San Juan River Basin Hydrology Model, Generation 3 Revised. Presented for discussion to the San Juan River Basin Recovery Implementation Program Hydrology Committee on September 12, 2006. Bureau of Reclamation. Flows available at San Juan-Chama Project points of diversion developed by State of Colorado using its StateMod model after changes to Colorado hydrology and depletions. Water year diversions.

(10) Results from the Heron Reservoir operations study presented in section 3 of this report and in table 3. Water year diversions.

Table 2. Heron Reservoir Operations Study, 1984 Reservoir Conditions · Annual Summary

Water Year	SJCP Adjusted Potential Diversions (af)	Reduction in SJCP Diversions for 1-yr or 10-yr limits (af)	Reduction in SJCP Diversions to Avoid Spill (af)	SJCP Estimated Diversion (af)	Heron Reservoir Inflow (af)	Heron Reservoir Net Evap Rate (feet)	Heron Reservoir Evap Loss (af)	SJCP Release from Heron Reservoir (af)	Shortage to Demand at Heron Dam (af)	Minimum EOM Reservoir Contents (af)	Maximum EOM Reservoir Contents (af)	Ten-Year Total SJCP Estimated Diversion (af)
1936	154,940	0	0	154,940	154,630	1.84	6,508	96,200	0	103,812	200,040	1,104,483
1937	140,441	0	0	140,441	140,160	1.84	7,780	96,200	0	156,013	245,427	1,139,419
1938	141,848	0	0	141,848	141,565	1.67	7,585	96,200	0	187,451	275,572	1,175,762
1939	83,224	0	0	83,224	83,058	2.55	11,644	96,200	0	230,376	266,823	1,153,482
1940	69,357	0	0	69,357	69,218	1.94	8,090	96,200	0	197,699	236,734	1,117,334
1941	180,229	0	0	180,229	179,869	1.10	5,069	96,200	0	159,853	287,726	1,192,058
1942	181,099	0	0	181,099	180,737	2.16	11,845	96,200	0	280,924	374,845	1,267,652
1943	97,379	0	0	97,379	97,184	2.47	13,426	96,200	0	314,273	366,981	1,259,526
1944	128,773	0	0	128,773	128,515	1.99	10,869	96,200	0	293,372	382,466	1,282,794
1945	128,500	0	4,551	123,949	123,701	1.96	11,182	96,200	0	323,709	401,330	1,301,238
1946	46,830	0	0	46,830	46,736	2.14	11,517	96,200	0	321,657	378,347	1,193,129
1947	82,294	0	0	82,294	82,130	2.15	10,725	96,200	0	271,937	318,692	1,134,983
1948	124,192	0	0	124,192	123,944	1.93	9,787	96,200	0	257,433	334,402	1,117,326
1949	139,620	0	0	139,620	139,341	1.45	7,778	96,200	0	273,046	363,800	1,173,721
1950	66,848	0	0	66,848	66,714	2.36	12,297	96,200	0	307,354	345,912	1,171,213
1951	48,195	0	0	48,195	48,098	2.39	11,232	96,200	0	249,065	303,790	1,039,178
1952	158,500	0	0	158,500	158,183	1.93	9,299	96,200	0	206,199	313,038	1,016,579
1953	71,592	0	0	71,592	71,449	2.33	11,115	96,200	0	254,232	296,723	990,792
1954	58,358	0	0	58,358	58,241	2.03	8,842	96,200	0	219,082	261,707	920,377
1955	58,325	0	0	58,325	58,208	2.18	8,167	96,200	0	162,500	215,208	854,753
1956	73,226	0	0	73,226	73,079	2.64	8,656	96,200	0	127,648	168,784	881,149
1957	152,822	0	0	152,822	152,516	1.40	4,624	96,200	0	91,060	197,321	951,677
1958	127,600	0	0	127,600	127,345	1.70	7,085	96,200	0	156,798	237,361	955,085
1959	44,423	0	0	44,423	44,334	2.44	8,843	96,200	0	156,189	212,933	859,888
1960	131,920	0	0	131,920	131,656	2.15	8,001	96,200	0	125,514	206,494	924,960
1961	81,522	0	0	81,522	81,359	1.37	4,799	96,200	0	138,780	182,488	958,287
1962	121,431	0	0	121,431	121,188	1.64	6,010	96,200	0	126,875	202,329	921,218
1963	58,480	0	0	58,480	58,363	1.88	6,243	96,200	0	138,904	179,388	908,107
1964	61,578	0	0	61,578	61,455	1.92	4,874	96,200	0	82,440	134,838	911,327
1965	152,788	0	0	152,788	152,482	1.26	3,255	96,200	0	54,887	156,383	1,005,790
1966	119,198	0	0	119,198	118,960	1.82	6,263	96,200	0	123,413	190,295	1,051,762
1967	84,912	0	0	84,912	84,743	1.56	4,861	96,200	0	119,819	164,406	983,853
1968	97,892	0	0	97,892	97,696	1.72	5,202	96,200	0	99,122	155,641	954,145
1969	119,956	0	0	119,956	119,716	1.15	3,714	96,200	0	106,295	175,245	1,029,678
1970	97,131	0	0	97,131	96,937	1.86	6,040	96,200	0	118,929	169,120	994,889
1971	64,730	0	0	64,730	64,601	2.13	6,405	96,200	0	121,007	162,006	978,098
1972	42,420	0	0	42,420	42,335	2.37	4,952	96,200	0	66,462	124,341	899,086
1973	181,354	0	0	181,354	180,991	1.37	3,986	96,200	0	43,721	157,140	1,021,960
1974	50,969	0	0	50,969	50,867	2.33	6,059	96,200	0	95,874	143,888	1,011,350
1975	150,439	0	0	150,439	150,138	1.71	4,379	96,200	0	45,224	155,086	1,009,001
1976	88,097	0	0	88,097	87,921	2.62	7,656	96,200	0	98,475	150,110	977,901
1977	21,782	0	0	21,782	21,738	2.38	4,363	96,200	0	50,676	126,036	914,770
1978	107,589	0	0	107,589	107,373	2.49	3,515	96,200	0	10,302	78,278	924,467
1979	165,938	0	0	165,938	165,606	1.68	4,201	96,200	0	16,823	134,295	970,449
1980	145,972	0	0	145,972	145,680	2.05	6,542	96,200	0	78,992	177,592	1,019,289
1981	56,198	0	0	56,198	56,086	2.31	6,876	96,200	0	113,930	162,517	1,010,757
1982	174,745	0	0	174,745	174,395	1.35	4,000	96,200	0	85,318	193,682	1,143,082
1983	153,648	0	0	153,648	153,341	1.37	5,554	96,200	0	156,837	252,775	1,115,377
1984	136,919	0	0	136,919	136,646	1.66	7,665	96,200	0	211,991	288,826	1,201,327
1985	203,394	0	0	203,394	202,987	1.06	5,964	96,200	0	258,208	384,098	1,254,282
1986	183,701	0	63,951	119,750	119,510	0.88	5,093	96,200	0	361,853	401,330	1,285,934
1987	159,225	3,024	70,353	85,848	85,676	1.38	8,057	96,200	0	378,509	401,330	1,350,000
1988	76,663	0	0	76,663	76,509	1.34	7,382	96,200	0	336,012	374,661	1,319,074
1989	76,178	0	0	76,178	76,025	2.48	13,117	96,200	0	318,145	346,705	1,229,314
1990	74,027	0	0	74,027	73,879	1.69	8,336	96,200	0	266,449	316,039	1,157,369
1991	138,846	0	0	138,846	138,568	1.56	7,895	96,200	0	257,946	334,901	1,240,017
1992	129,664	0	0	129,664	129,405	1.25	6,681	96,200	0	283,194	360,612	1,194,936
1993	158,433	0	3,606	154,827	154,517	1.55	8,851	96,200	0	311,626	401,330	1,196,115
1994	131,774	0	46,590	85,184	85,013	1.24	7,243	96,200	0	362,558	401,330	1,144,379
1995	173,384	0	53,642	119,742	119,503	1.20	6,998	96,200	0	348,593	401,330	1,060,727
1996	61,110	0	0	61,110	60,988	2.17	12,159	96,200	0	348,455	391,689	1,002,087
1997	146,898	0	0	146,898	146,604	1.16	6,526	96,200	0	311,391	392,948	1,063,137
1998	108,561	0	10,305	98,256	98,060	1.82	10,493	96,200	0	353,993	401,330	1,084,731
1999	129,493	0	10,008	119,485	119,246	1.52	8,660	96,200	0	345,361	401,330	1,128,038
2000	44,435	0	0	44,435	44,346	3.13	17,266	96,200	0	328,966	393,447	1,098,446
2001	113,496	0	0	113,496	113,269	2.01	10,685	96,200	0	287,864	355,368	1,073,097
2002	7,176	0	0	7,176	7,162	2.96	13,993	96,200	0	232,319	330,373	950,609
2003	64,435	0	0	64,435	64,306	2.42	9,589	96,200	0	181,169	228,390	860,217
2004	85,947	0	0	85,947	85,775	2.78	10,164	96,200	0	154,821	192,821	860,981
2005	158,309	0	0	158,309	157,992	2.30	9,271	96,200	0	134,764	231,462	899,548
Average	109,305	43	3,757	105,505	105,294	1.89	7,911	96,200	0			

Note: Ten-year totals of San Juan-Chama Project estimated diversions for 1936-44 assume average diversions annually prior to 1936.

Table 3. Heron Reservoir Operations Study, 2070 Reservoir Conditions - Annual Summary

Water Year	SJCP Adjusted Potential Diversions (af)	Reduction in SJCP Diversions for 1-yr or 10-yr limits (af)	Reduction in SJCP Diversions to Avoid Spill (af)	SJCP Estimated Diversion (af)	Heron Reservoir Inflow (af)	Heron Reservoir Net Evap Rate (feet)	Heron Reservoir Evap Loss (af)	SJCP Release from Heron Reservoir (af)	Shortage to Demand at Heron Dam (af)	Minimum EOM Reservoir Contents (af)	Maximum EOM Reservoir Contents (af)	Ten-Year Total SJCP Estimated Diversion (af)
1936	154,940	0	0	154,940	154,630	1.84	6,508	96,200	0	103,812	200,040	1,101,971
1937	140,441	0	0	140,441	140,160	1.84	7,780	96,200	0	156,013	245,427	1,137,185
1938	141,848	0	0	141,848	141,565	1.67	7,585	96,200	0	187,451	275,572	1,173,808
1939	83,224	0	0	83,224	83,058	2.55	11,644	96,200	0	230,376	266,823	1,151,807
1940	69,357	0	0	69,357	69,218	1.94	8,090	96,200	0	197,699	236,734	1,115,938
1941	180,229	0	0	180,229	179,869	1.10	5,069	96,200	0	159,853	287,726	1,190,942
1942	181,099	0	0	181,099	180,737	2.16	11,845	96,200	0	280,924	374,845	1,266,815
1943	97,379	0	0	97,379	97,184	2.47	13,426	96,200	0	314,273	366,981	1,258,968
1944	128,773	0	0	128,773	128,515	1.99	10,869	96,200	0	293,372	382,466	1,282,515
1945	128,500	0	15,196	113,304	113,078	1.96	11,077	96,200	0	323,709	390,730	1,290,594
1946	46,830	0	0	46,830	46,736	2.14	11,310	96,200	0	311,345	367,839	1,182,484
1947	82,294	0	0	82,294	82,130	2.15	10,524	96,200	0	261,675	308,388	1,124,338
1948	124,192	0	0	124,192	123,944	1.93	9,602	96,200	0	247,336	324,388	1,106,681
1949	139,620	0	0	139,620	139,341	1.45	7,647	96,200	0	263,110	353,949	1,163,077
1950	66,848	0	0	66,848	66,714	2.36	12,085	96,200	0	297,582	336,127	1,160,568
1951	48,195	0	0	48,195	48,098	2.39	11,005	96,200	0	239,707	294,222	1,028,533
1952	158,500	0	0	158,500	158,183	1.93	9,125	96,200	0	196,844	303,807	1,005,934
1953	71,592	0	0	71,592	71,449	2.33	10,909	96,200	0	245,096	287,562	980,148
1954	58,358	0	0	58,358	58,241	2.03	8,642	96,200	0	210,305	252,743	909,733
1955	58,325	0	0	58,325	58,208	2.18	7,910	96,200	0	153,787	206,447	854,753
1956	73,226	0	0	73,226	73,079	2.64	8,311	96,200	0	119,200	160,454	881,149
1957	152,822	0	0	152,822	152,516	1.40	4,447	96,200	0	82,929	189,291	951,677
1958	127,600	0	0	127,600	127,345	1.70	6,926	96,200	0	148,790	229,437	955,085
1959	44,423	0	0	44,423	44,334	2.44	8,573	96,200	0	148,621	205,108	859,888
1960	131,920	0	0	131,920	131,656	2.15	7,786	96,200	0	117,943	199,030	924,960
1961	81,522	0	0	81,522	81,359	1.37	4,653	96,200	0	131,452	175,237	958,287
1962	121,431	0	0	121,431	121,188	1.64	5,850	96,200	0	119,653	195,222	921,218
1963	58,480	0	0	58,480	58,363	1.88	6,043	96,200	0	132,057	172,354	908,107
1964	61,578	0	0	61,578	61,455	1.92	4,613	96,200	0	75,658	128,004	911,327
1965	152,788	0	0	152,788	152,482	1.26	3,111	96,200	0	48,318	149,914	1,005,790
1966	119,198	0	0	119,198	118,960	1.82	6,091	96,200	0	116,986	183,963	1,051,762
1967	84,912	0	0	84,912	84,743	1.56	4,704	96,200	0	113,608	158,156	983,853
1968	97,892	0	0	97,892	97,696	1.72	5,025	96,200	0	93,054	149,685	954,145
1969	119,956	0	0	119,956	119,716	1.15	3,603	96,200	0	100,363	169,413	1,029,678
1970	97,131	0	0	97,131	96,937	1.86	5,870	96,200	0	113,135	163,293	994,889
1971	64,730	0	0	64,730	64,601	2.13	6,212	96,200	0	115,397	156,357	978,098
1972	42,420	0	0	42,420	42,335	2.37	4,669	96,200	0	61,283	118,882	899,086
1973	181,354	0	0	181,354	180,991	1.37	3,871	96,200	0	38,520	152,030	1,021,960
1974	50,969	0	0	50,969	50,867	2.33	5,832	96,200	0	91,037	138,838	1,011,350
1975	150,439	0	0	150,439	150,138	1.71	4,228	96,200	0	40,393	150,361	1,009,001
1976	88,097	0	0	88,097	87,921	2.62	7,449	96,200	0	93,863	145,569	977,901
1977	21,782	0	0	21,782	21,738	2.38	4,156	96,200	0	46,402	121,571	914,770
1978	107,589	0	0	107,589	107,373	2.49	3,267	96,200	0	6,099	74,140	924,467
1979	165,938	0	0	165,938	165,606	1.68	4,079	96,200	0	12,784	130,351	970,449
1980	145,972	0	0	145,972	145,680	2.05	6,412	96,200	0	75,103	173,790	1,019,289
1981	56,198	0	0	56,198	56,086	2.31	6,733	96,200	0	110,204	158,751	1,010,757
1982	174,745	0	0	174,745	174,395	1.35	3,916	96,200	0	81,691	190,135	1,143,082
1983	153,648	0	0	153,648	153,341	1.37	5,496	96,200	0	153,298	249,278	1,115,377
1984	136,919	0	0	136,919	136,646	1.66	7,607	96,200	0	208,506	285,370	1,201,327
1985	203,394	0	0	203,394	202,987	1.06	5,931	96,200	0	254,771	380,689	1,254,282
1986	183,701	0	71,221	112,480	112,255	0.88	5,029	96,200	0	358,458	390,730	1,278,665
1987	159,225	0	70,409	88,816	88,638	1.38	7,943	96,200	0	368,549	390,730	1,345,698
1988	76,663	0	0	76,663	76,509	1.34	7,291	96,200	0	328,514	367,157	1,314,772
1989	76,178	0	0	76,178	76,025	2.48	12,946	96,200	0	310,893	339,295	1,225,012
1990	74,027	0	0	74,027	73,879	1.69	8,223	96,200	0	259,231	308,794	1,153,067
1991	138,846	0	0	138,846	138,568	1.56	7,789	96,200	0	250,805	327,822	1,235,715
1992	129,664	0	0	129,664	129,405	1.25	6,601	96,200	0	276,162	353,621	1,190,634
1993	158,433	0	7,364	151,069	150,767	1.55	8,729	96,200	0	304,667	390,730	1,188,055
1994	131,774	0	46,661	85,113	84,943	1.24	7,130	96,200	0	351,980	390,730	1,136,249
1995	173,384	0	53,800	119,584	119,345	1.20	6,890	96,200	0	338,049	390,730	1,052,439
1996	61,110	0	0	61,110	60,988	2.17	11,956	96,200	0	338,069	381,118	1,001,068
1997	146,898	0	0	146,898	146,604	1.16	6,422	96,200	0	301,011	382,656	1,059,151
1998	108,561	0	10,726	97,835	97,640	1.82	10,329	96,200	0	343,734	390,730	1,080,323
1999	129,493	0	10,197	119,295	119,057	1.52	8,520	96,200	0	334,856	390,730	1,123,441
2000	44,435	0	0	44,435	44,346	3.13	16,970	96,200	0	318,674	382,882	1,093,849
2001	113,496	0	0	113,496	113,269	2.01	10,494	96,200	0	277,591	345,179	1,068,500
2002	7,176	0	0	7,176	7,162	2.96	13,699	96,200	0	222,512	320,293	946,012
2003	64,435	0	0	64,435	64,306	2.42	9,300	96,200	0	171,428	218,590	859,378
2004	85,947	0	0	85,947	85,775	2.78	9,795	96,200	0	145,374	183,519	860,212
2005	158,309	0	0	158,309	157,992	2.30	9,016	96,200	0	125,626	222,505	898,937
Average	109,305	0	4,080	105,226	105,015	1.89	7,760	96,200	0			

Note: Ten-year totals of San Juan-Chama Project estimated diversions for 1936-44 assume average diversions annually prior to 1936.