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Policy Conflicts and Sustainable Water Resources Development in New Mexico's Rio Grande Basin

Edited by

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CONTENTS

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PREFACE

The chapters of this report represent the work of students who took Water Resources 573, Interdisciplinary Water Resources III, during summer 1999. This course is the required capstone seminar for Master of Water Resources (MWR) graduate students in the Water Resources Program at the University of New Mexico. Drs. Michael E. Campana (hydrology), Paul Matthews (water law and policy), and David Brookshire (environmental economics) were the instructors. The class focused on three contemporary issues within the Rio Grande basin: 1) arsenic in the waters of the basin, including both the conflict between the City of Albuquerque and Isleta Pueblo over arsenic in the Rio Grande and the impending change in drinking water standards for arsenic; 2) the hydrologic impacts and fire management aspects of the restoration of the ponderosa pine forest in the Sangre de Cristo Mountains; and 3) the economic and environmental impacts of preserving the silvery minnow, an endangered species living in the Rio Grande.

Three chapters deal with the issues of arsenic in the Rio Grande and the City of Albuquerque's drinking water. The City of Albuquerque and Isleta Pueblo have a significant conflict over water quality standards for arsenic in the Rio Grande. In 1987, Congress amended the Clean Water Act to allow Indian tribes to be treated as states in some circumstances, including the establishment of water quality standards. The Isleta Pueblo established its own standards, and in 1992 they were approved by the U.S. EPA. Isleta's standard for arsenic is more stringent than that mandated by the EPA, which is permissible under the Clean Water Act. The more stringent standard is justified because Pueblo members use the Rio Grande for ceremonial purposes. Five miles upstream from the Isleta Pueblo boundary is the City of Albuquerque's discharge point for its water reclamation plant. Discharge from the plant is controlled by a National Pollution Discharge Elimination System (NPDES) permit. The permit was being revised when Isleta's water quality standards were approved by the EPA, and as a result, the City of Albuquerque was required to meet these more stringent standards. However, implementation was delayed for four years by a negotiated settlement between the parties. The standards were challenged in court, but the Supreme Court ruled they were valid. A related arsenic issue concerns the levels of natural arsenic in the City of Albuquerque's ground water supply. The U.S. EPA is about to promulgate an interim standard for arsenic in drinking water which will almost surely be lower than the current 50 parts per billion (ppb) standard. The City will have to treat its ground water to meet the new lower standard; the cost for treatment will depend upon how low the standard is set and the treatment option.

Two chapters focus on ponderosa pine forest restoration and its potential effects on watershed hydrology and fire management. Water quality and water quantity depend on how a watershed is managed. One of the current controversies in the Southwest is the restoration of ponderosa pine forests. Under natural conditions, a ponderosa pine forest consisted of huge pine trees and glades with the forest floor exposed to sunlight. Periodic fires would burn the grass and smaller trees while leaving the larger ponderosa unharmed. Fire suppression, grazing and logging have changed the nature of the forest. Today the forest is made up of thickets of puny trees that are often so thick it is difficult to walk through the woods. Sunlight seldom reaches the forest floor. Restoration would consist of thinning the forest to allow larger trees to grow and glades to be reestablished. National Forest managers have started some experimental efforts to restore the forests in the Southwest. But restoration may have a significant impact on water quantity and quality, which could impact the traditional Hispanic and Indian communities that rely on water from the forest lands. Although these communities may benefit by providing a labor force to thin the forest, this effect is temporary and will be insufficient to sustain the communities. The tradeoffs are difficult to balance; on one hand, restoration of a natural system is generally viewed as positive, but what impact will this have on water availability and quality and how will this impact the traditional communities? An equitable solution may be difficult. Fire management policy will also be affected.

The Rio Grande's population of silvery minnows is on the endangered species list. To protect this species, sufficient water must be left in the river, but New Mexico water law does not recognize in-stream flow as a beneficial use. Although a recent Attorney General's opinion recognizes the right to establish in-stream flows in New Mexico, this opinion has not yet been tested. No application for an in-stream flow permit has been made, and the process for making such an application has not been established. The Endangered Species Act protects the silvery minnow, but since the Rio Grande is a fully appropriated stream, where will the water come from to preserve it? Will the agricultural community surrender its water? Or the City of Albuquerque? Four chapters address this complex issue, which will likely have far-reaching implications for water management in the basin.

The instructors wish to thank the students for their efforts, and hope that this report may help to solve some of the problems now facing the Rio Grande basin. These problems must be solved before sustainable development can occur in the basin.

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WATER QUALITY STANDARDS FOR ARSENIC IN THE RIO GRANDE: ISLETA PUEBLO WATER QUALITY PROTECTION AND THE CLEAN WATER ACT

Linda I. Gordan

Executive Summary. Isleta is the most southern of the eight northern Rio Grande Pueblos. People have lived on or near the site continuously since about 1200, clearly demonstrating a long term sustainable way of life. However, early in the 1980s the Isleta Pueblo Elders became concerned with water quality in the Rio Grande and how deterioration in the quality may affect the sustainability of their culture. In 1982 the City of Albuquerque announced its plans to build a new wastewater treatment plant. This meant they would be temporarily making discharges of partially treated effluent to the Rio Grande.

Before the Tribal Amendments to the Clean Water Act (CWA), the Environmental Protection Agency (EPA) had the responsibility for establishing and enforcing pollution standards. Federal environmental laws didn't allow tribes to establish their own standards, and states lacked authority to enforce environmental laws on reservations.

The EPA implemented its Indian Policy in 1984. The policy recognizes tribal governments as primary parties for setting environmental standards, making environmental policy and managing the programs on Indian lands. The policy also states EPA's trust responsibility to ensure compliance with environmental statutes and regulations on Indian lands. The goals of the policy are to improve environmental quality on reservation lands; support tribal self government; and encourage cooperation between tribal, state, and local governments.

In 1987, tribes were allowed to apply for status as a state under the Clean Water Act. This meant that they could now establish their own water quality standards and programs under the CWA. Isleta Pueblo was the first to meet the EPA's criteria for treatment as a state under the 1987 amendments of the CWA.

Isleta then began the process of defining their water quality problems. There was a general understanding of the tribe's surface water quality problems and needs. The tribe had to define its beneficial uses of the waters, set water quality goals and standards, and define ways of attaining the goals. They also had to define specific actions for better tribal planning.

Due to the rapidly changing population dynamics in the West, the question of keeping up with municipal waste water treatment came up. Albuquerque's water reclamation plant discharges 50 to 60 million gallons per day (mgd). This is equal to 1/3 the flow of the Rio Grande at low-flow, which occurs from March 1 to October 1. The New Mexico

Water Quality Control Commission estimates that only 2% of pollution in the Rio Grande comes from industrial or sewage discharge, and 98% comes from storm runoff, mining, and other similar sources.

In December 1992, EPA approved Isleta's water quality standards (WQS). The water quality standards developed by EPA and the Pueblo were applied to the NPDES permit for the City of Albuquerque's wastewater treatment plant. The City of Albuquerque challenged EPA approval of Isleta WQS and litigation ensued.

1.0 TRIBAL WATER

The Pueblo of Isleta lies along the southern edge of Bernalillo County. The reservation measures 9 by 40-miles and runs from the crest of the Manzanos to the Rio Puerco. On October 24, 1992, the Pueblo changed the political balance of power and the state of awareness in New Mexico by achieving status as a state in water quality matters. Isleta was the first Indian nation in the country to meet the U.S. Environmental Protection Agency's (EPA) criteria for "TAS" (treatment as a state) status under the Clean Water Act Amendments of 1987 (Albuquerque Tribune, 13 Dec.1993). Isleta adopted standards for surface water quality that will require all who hold permits to discharge into the Rio Grande upstream - Albuquerque, Bernalillo, Santa Fe, Española, Los Alamos National Laboratory - to negotiate with Isleta as if they were dealing with the state of New Mexico. Two more New Mexico pueblos, Sandia and San Juan, have followed the Isletans by getting the EPA to approve identical water quality standards (Albuquerque Tribune, 13 Dec. 1993).

The Pueblo of Isleta's water quality protection program began in the early 1980s. The waters of the Rio Grande hold traditional significance to the Pueblo's religious leaders. These elders had become concerned with the gradual deterioration of the Rio's waters due to upstream discharges. Because the elders do not concern themselves with secular matters, they requested the Isleta Governor and Tribal Council to address the quality of the Rio's water in order to preserve traditional religious practices (Gover, Stetson and Williams, 1994). The Pueblo of Isleta is located a short distance downstream from the City of Albuquerque, and the City soon became the focus of the Pueblo's water quality protection program.

In 1982, the City announced its intention to build a new wastewater treatment facility. The new facility was to be located several miles closer to the Pueblo than the old plant and, because of the move, the City temporarily would be discharging partially treated effluent directly into the Rio Grande. The Pueblo elders became concerned with the possibility of further pollution and again asked the Isleta Governor for assistance. Through discussions with the Bureau of Indian Affairs (BIA), the Pueblo received a commitment that the waters of the Rio Grande would be monitored on a regular basis and a report would be submitted to the Pueblo at least once a month. The Pueblo never received any reports, even though it transmitted several requests for information directly to the City.

In 1986, the problems with water pollution again were brought to the Isleta Governor. By now, the new facility was in place, but intermittent discharges of partially treated effluent were still occurring. The Pueblo hired a consultant to assist in its attempts to prevent further pollution. The consultant was a hydrologist with extensive experience in the region. The consultant later would play a key role in preparing and defending the Pueblo's water quality standards (Gover, Stetson and Williams, 1994).

In 1988, the Pueblo elected a new administration which began working with EPA Region 6 to develop water quality codes. At this time, Pueblo leaders began to consider adopting water quality standards that would limit upstream discharges of pollution into the Rio. Governor Alex Lucero got the EPA to approve the Pueblo's water quality standards in December 1992. At the core of Isleta's new water quality standards is the Pueblo's pre-Christian religious traditions, which involves being immersed in and drinking the Rio Grande's waters (Fox, 1992). The New Mexico Environment Department has declared that the Rio Grande is unfit even for incidental recreational contact from the mouth of the Jemez River to Isleta. Continued practice of those religious traditions demands a cleaner river (Gover, Stetson and Williams, 1994). Isleta's initial statement of new standards follows the logic of use: since we must come into contact with it, it must be designated as a stream for "primary contact-ceremonial use." That includes immersion and drinking the water intentionally or incidentally. Water is integral to the Pueblo's spiritual life. Along with fire, air and the Earth itself, Pueblo residents view water as a life-giver, one to be protected and celebrated in various ceremonies (Fox, 1992).

Armed with the authority provided by Congress, Isleta and the EPA developed Tribal water quality standards, and those standards were applied in the NPDES permit for the City of Albuquerque's wastewater plant. Despite efforts to work cooperatively with the City, litigation soon ensued.

The tribe is not proposing that the Rio Grande meet the "drinking water" standards of either the state or EPA. The City, seeing "drinking" among the ceremonial uses, sees it that way. Isleta has used the EPA guidelines on toxics levels, which allow more fecal coliform bacteria than EPA drinking water standards would allow.

The Rio Grande contains so much arsenic naturally that the City doesn't think that even with cleanup, it can meet the pueblo's stringent 17 parts per trillion measure. The standard is 1,000 times lower than the river's typical and natural arsenic level. The standard means that the City must clean its wastewater to meet the higher Isleta standard. The cost to Albuquerque water rate payers is $10.00 to $15.00 a month in higher sewer bills. The money was needed to upgrade the City's southside sewage treatment plant which dumps up to 60 million gallons of effluent in the river each day (Albuquerque Tribune, 13 Dec. 1993).

The City, Pueblo, and New Mexico Environment Department signed a stipulated settlement setting certain conditions on the City's federal NPDES permit regulating its wastewater discharge into the River (Gover, Stetson and Williams, 1994). The variance allowed Albuquerque four years to attain compliance with the Pueblo's water quality standards. Under terms of the settlement the Pueblo of Isleta split the cost of a $350,000 three year study with the New Mexico Environment Department and the City of Albuquerque. The study was designed to adjust the standard to reflect the "ambient" quality of the Rio Grande (Albuquerque Journal, 11 May 1994). It addressed the unique aspects of water which have made the river vital to Isleta's culture. In particular it determines what standards are necessary to allow people to safely conduct their ceremonial uses of the river, to allow for the renewal of natural habitats for fish and fowl, and to allow for irrigation uses. Certain pollutants, arsenic, fecal coliform, and nitrates are restricted.

Isleta and other Pueblo tribes in the process of achieving TAS status have been assisted by the Pueblo Office of Environmental Protection, formed in 1991 by the 19 Pueblos of the All Indian Pueblo Council. It has been no small feat to convene meetings among these diverse groups now arrayed in new roles. No one thinks the Rio Grande can be made drinking-water pure, including the Isletans (Fox, 1992).

2.0 SOCIAL AND ECONOMIC GEOGRAPHY

Isleta is the most southern of the Rio Grande Pueblos. It is also the largest of them in land area. Isleta and Sandia are called the Southern Tiwas, and are related through language to the most northern Pueblos, Taos and Picuris. The name Isleta is Spanish for "little island". At high stage, the Rio Grande used to flow on both sides of the village, making it an island. Legend and archaeology indicate that the people have lived on and near the site continuously since about 1200. There were close relations with villages up Tijeras Canyon and with Piro and Tompiro - speaking towns down toward Socorro. When the Spanish came, Isleta was already operating four irrigation ditches. The Spanish reported more than 30 towns in the province they called Tiguex (extending from Bernalillo to Los Lunas), mostly on the east side of the Rio Grande.

In 1680 the Isleta Pueblo population was doubled with refugees from the Bernalillo area fleeing the Pueblo Revolt massacres. In 1681 the Spanish governor Otermin, having fled to El Paso, dashed back to Tiguex and took more than 500 captives back to El Paso (Ysleta del Sur in El Paso is the remnant of these hostage-migrants). Most original Isletans escaped that exile and went to the Hopi mesas, staying until 1747. A hill at Isleta was later named Oraibi in memory of that sojourn. In 1879 or 1880, the conservative faction at Laguna Pueblo, left Laguna and trekked toward Sandia. The move was in resistance to the faction intermarried with the Marmons, Gunns, and Menauls - white missionaries and traders. Stopping at Isleta, they were given the hill of Oraibi as a center if they promised never to take their Kachina masks and rituals away. Many eventually returned to Laguna, but the Kachina Father kept the promise to stay, adding a significant religious, political, and cultural strand to the village. Ties to Laguna are still many. So Isleta Pueblo has a cosmopolitan history well acquainted with migration, acculturation, asylum and survival. Like all the Pueblos, they have a genius for enduring (Fox, 1992).

In the 1700s and 1800s Isleta grew slowly and developed close relations, sometimes happy, sometimes tense, with the surrounding Spanish farming communities. Isleta exercised close community control over irrigated farmland, with the Pueblo governor assigning an acre at a time to individuals who could sell it to another Isletan after farming it for a year. Some accumulated 20 or 30 acres, but the average was 10. Village life was ordered by overlapping and interwoven social clan groups, the two village moieties, medicine societies, Catholic Church roles, and majordomo ditch activities. A rich calendar cycle of ceremonial activities reflecting both pre-Christian agricultural and hunting observances and Catholic liturgy is still followed. About 4,000 people now live at Isleta, about 3,000 of whom are registered on tribal rolls under blood criteria (Fox, 1992).

Agriculture is the principal occupation of the Isleta people. Additional revenue is derived from land leased to local business concerns and the United States Government. A high proportion of the population works outside the reservation, but a recent revival of pottery making is giving work to a number of artisans. The Chiwiwi family, which is noted for its high quality work, has created fine products in the traditional style of pottery which are gaining the attention of collectors. Embroidery and jewelry making are also experiencing a revival. Isleta is also known for excellent bread.

Camping and fishing at Sunrise Lake at the Isleta Lakes Recreation Area is a key element in the Pueblo's economic self -sufficiency. To reduce unemployment, Isleta pueblo has invested in bingo operations and in a casino under the Indian Gaming Regulatory Act as a means of generating income and jobs. While somewhat successful, it is too early to tell what the advantages of Indian gaming approaches will be.

3.0 TRIBAL AND STATE REGULATORY JURISDICTION BEFORE THE TRIBAL AMENDMENTS TO THE CLEAN WATER ACT

Federal environmental laws generally have required the Environmental Protection Agency to establish standards for various sources of pollution, to enforce those standards through a permitting system, and where a state so requests, to delegate primary enforcement authority to the state. In general, no person or activity is beyond the reach of federal environmental statutes. However, when states exercise jurisdiction special rules apply when the regulated person is an Indian or Indian Tribe or the regulated activity takes place within Indian country. As originally enacted, the federal environmental laws failed to give tribes the same choices of self regulation given to the states (Reetz et al., 1998).

4.0 TRIBAL AUTHORITY TO ENFORCE ENVIRONMENTAL LAWS

Tribes have the power to enforce their laws, including environmental laws, against their members. Tribal governments are the only non-federal entities that have plenary jurisdiction over Indians on Indian reservations. In order to regulate the environment effectively, a Tribe must also have authority over all persons and lands within a reservation. Therefore, Tribes retain broad sovereign authority to regulate activities within their territory. This power extends to non-Indian activities on non-tribal lands when those activities affect or threaten important Tribal interests. The courts recognize that Congress may properly delegate federal authority to Indian Tribes, including authority over non-Indian activities on Indian lands.

EPA built its Indian policy on the proposition that Tribes could and should regulate throughout their reservations. Congress ratified that policy with the enactment of the

Tribal amendments to the Clean Water Act 1. (Reetz et al., 1998)

5.0 STATE AUTHORITY TO ENFORCE ENVIRONMENTAL LAWS IN INDIAN COUNTRY

Primary enforcement responsibility may be delegated to states under most federal environmental regulatory statutes. Before a state may assume primary enforcement responsibilities for federal environmental laws on reservations the state must have jurisdiction. However, Congress did not delegate jurisdiction to the states when the environmental statutes were passed. When state jurisdiction on reservations was challenged, the United States Ninth Circuit Court of Appeals found that federal retention of environmental authority over Indian lands is consistent with the United States trust responsibility owed to Tribes. Congress understood that, at the time Section 518 was passed, states lacked jurisdiction to enforce environmental laws on Indian reservations (Gover, Stetson and Williams, 1994).

6.0 TRIBAL WATER QUALITY PROGRAMS ADMINISTERED BY THE ENVIRONMENTAL PROTECTION AGENCY

The EPA and other federal agencies have made substantial progress in assisting Indian tribes to develop water quality capabilities. Much work remains to be done in terms of water quality monitoring, funding and technical assistance. The overall status of water quality on Indian lands cannot be well-documented. Despite significant recent increases in the EPA's support for tribal water programs, many western tribes still face enormous challenges in building strong programs for water quality monitoring and pollution prevention and control. EPA needs to increase environmental protection in Indian country. This can only be achieved through a concerted outreach program and continued efforts to provide tribes the opportunity, as EPA has provided the states, to receive assistance as they build their water quality protection programs.

The EPA has approved three New Mexico Pueblo tribal stream standards that impact the central Rio Grande. The Pueblo of Isleta's water quality standard requires water clean enough to support tribal ceremonial uses. A judicial decision has affirmed EPA's power to approve tribal water quality standards despite the potentially profound impact on upstream sources. As in this case jurisdictional conflicts, compliance questions, and permitting issues may arise when standards set by a tribe differ from those set by a state that has concurrent jurisdiction over the same stream or body of water.

1 U.S. Code of Federal Regulations Title 33 § 1377. Indian Tribes [FWPCA §518] states "Indian Tribes shall be treated as States for purposes of such section 1251(g) of this title." Section 1251(g) establishes the rights of States over water.

7.0 TRIBAL VIEWS ON ENVIRONMENTAL PROTECTION

A survey conducted by the Americans for Indian Opportunity in the mid-1980s showed that out of 74 Indian Tribes in the survey, only 28 tribes were implementing environmental protection programs. The number is lower than it should be because some tribes include "environmental protection" under the aegis of natural resources management. Many tribal programs are self-supported and receive limited funds for environmental protection from federal agencies. Of the programs developed by tribes, twenty-seven (27) had implemented water quality monitoring programs. Less than one-half of the tribes (31) were enforcing water quality standards. Tribes stated that water quality and emergency preparedness were their higher priorities. Eighteen (18) respondents revealed that they had agreements with federal, state, and county governments for the development of and enforcement of water quality standards. This survey was conducted over 10 years ago and is noted to provide a historical perspective (Reetz et al., 1998).

Formal government programs are the only approach to environmental programs in Indian country. The Indigenous Environmental Network (IEN) was founded in 1990. The network isn't simply a combination of the Native American movement with environmental activism. IEN has popularized a new angle on native sovereignty that includes appropriate technology and the defense of natural resources. It has also introduced a new angle on environmentalism that includes supporting the survival of endangered cultures, and putting the protection of nature in a larger social, cultural, and economic context.

IEN's strategies have come directly from the grassroots Native groups on the frontlines. Most of IEN's workshops focus on giving these groups necessary technical skills such as testing and sampling, computer mapping, and restoring damaged lands.

On the federal level, indigenous environmentalists have received a mixed response. The EPA has backed enhanced environmental regulatory powers for some tribes partly because of the federal trust responsibility (Grossman, 1995).

8.0 ENVIRONMENTAL PROTECTION AGENCY INDIAN POLICY

In 1984, the EPA adopted a policy providing environmental protection in Indian country. The purposes of the policy were to:

- Consolidate and expand on existing EPA Indian Policy in a manner consistent with the overall federal position in support of tribal self-government, and

- To improve environmental quality on reservation lands (Reetz et al., 1998).

The major EPA focus was in seeking amendments to environmental statutes which clarified the role of Indian tribal governments; outreach activities; and incorporating responses to tribal environmental problems into the broader EPA management approaches (Gover, Stetson and Williams, 1994).

The policy recognizes Indian tribes as the appropriate government to carry out environmental protection in Indian country. The policy sets forth nine principles (Gover, Stetson and Williams, 1994).

1. The Agency stands ready to work directly with Indian Tribal Governments on a one-to-one basis (the "government-to- government" relationship), rather than as subdivisions of other governments.

2. The Agency will recognize tribal governments as the primary parties for setting standards, making environmental policy decisions, and managing programs for reservations, consistent with agency standards and regulations.

3. The Agency will take affirmative steps to encourage and assist Tribes in assuming regulatory and program management responsibilities for reservation lands.

4. The Agency will take appropriate steps to remove existing legal and procedural impediments to working directly and effectively with Tribal Governments on reservation programs.

5. The Agency, in keeping with the Federal Trust Responsibility, will assure that Tribal Concerns and interests are considered whenever EPA's actions and/or decisions may affect Tribal environments.

6. The Agency will encourage cooperation between tribal, state, and local governments to resolve environmental problems of mutual concern.

7. The Agency will work with other Federal agencies, which have responsibilities on Indian reservations to enlist their interest and support in cooperative efforts to help Tribes assume environmental program responsibilities for reservations.

8. The Agency will strive to assure compliance with environmental statutes and regulations on Indian reservations.

9. The Agency will incorporate these Indian policy goals into its planning and management activities, including its budget, operating guidance, legislative initiatives, management accountability system and ongoing policy and regulations development processes.

In a 1991 Concept Paper, the EPA reaffirmed its commitment to the principles enumerated in the Indian Policy and again recognized that Indian Tribes are the "appropriate non-Federal parties for making decisions and carrying out program responsibilities affecting Indian reservations, their environments, and the health and welfare of others on the reservations (Gover, Stetson and Williams, 1994).

In 1994, EPA Administrator Carol M. Browner reaffirmed the EPA Indian Policy by establishing a plan entitled the "Tribal Operations Action Memorandum" (July 12, 1994) which established specific steps to attain the goals in the EPA Indian Policy.

With the enactment of the Water Quality Act Amendments of 1987, Indian Tribes gained the opportunity to develop water quality programs. While the EPA Regions had competent water quality staff, very few were available to assist the tribes with the development of tribal programs. (Reetz et al., 1998)

9.0 TRIBES AS STATES UNDER THE CLEAN WATER ACT

The 1987 amendments to the Clean Water Act (U.S. Code of Federal Regulations Title 33 § 1377) were particularly important for tribal governments. Section 518 provided opportunity for tribes to establish their own programs under the Clean Water Act in a manner similar to the role of states under the Act.

The recognition of tribal governments is found in Section 518(e), and allows the EPA to treat Indian tribes as states to carry out eleven major Clean Water Act programs. To qualify for treatment as a state under Section 518, a tribe must satisfy three basic criteria:

- The Indian tribe must have " ... a governing body carrying out substantial governmental duties and powers..."
- "The functions to be exercised by an Indian tribe pertain to the management and protection of water resources held by the tribe, held by the United States in trust for Indians, held by a member of an Indian tribe if such property interest is subject to a trust restriction on alienation, or otherwise within the borders of an Indian reservation..." and
- The Indian tribe is reasonable expected to be capable ..." ... of carrying out the functions to be exercised in a manner consistent with the terms and purposes of this Act and all applicable regulations..." (Clean Water Act, §518(e), 1989).

By 1997, over 129 Indian tribes had met eligibility requirements under the Act to initiate water quality programs. Fifteen tribes including Isleta Pueblo in New Mexico and the Confederated Salish & Kootenai Tribes of the Flathead Indian Reservation in Montana, applied for and were approved for a water quality standards program to develop standards for tribal waters.

The City of Albuquerque and the State of Montana both filed separate law suits against EPA on the approval of the Water Quality Standards Program of Isleta Pueblo and the Confederated Salish and Kootenai Tribes respectively. The Courts have ruled that EPA acted correctly in the Isleta case2 and in Montana3. These lawsuits reflect the seriousness of the jurisdictional issues involved in tribal environmental management (Reetz et al., 1998).

10.0 CITY OF ALBUQUERQUE V. BROWNER

In City of Albuquerque v. Browner, the City challenged in federal district court the EPA's approval of the water quality standards of Isleta Pueblo. The heart of the issue centered on differing state and Tribal water quality standards for the Rio Grande, which flows first through the City and then the Pueblo.

The City's wastewater treatment facility discharges into the river about five miles upstream of the Pueblo's northern boundary and is under an NPDES permit issued by the EPA. The Pueblo then uses the river water for irrigation, ceremonial, and recreational purposes. While the EPA was revising the City's NPDES permit to meet new, more stringent water quality standards issued by the State of New Mexico, the EPA also authorized the Pueblo to be treated as a state under the Clean Water Act. On December 24, 1992, the EPA approved the Pueblo's proposed water standards, which are more stringent than the state's standards. The EPA thus revised the City's NPDES permit to comply with both the state's and the Pueblo's water quality standards.

In order to comply with the conditions of the revised permit, the City would need to clean up its wastewater effluent. The City claimed this would cost about $250 million and raise the average residential sewer bill by $10 to $15 per month. To avoid this consequence the City filed a complaint in federal district court seeking a temporary restraining order and preliminary injunction against the EPA. The district court denied both requests. After receiving the EPA's draft NPDES permit, the City amended its complaint and renewed its motion for a preliminary injunction, and both the City and the EPA filed cross motions for summary judgment.

The City challenged the EPA's approval of the Pueblo's water quality standards on a number of grounds. First, the City asserted that the EPA failed to follow proper

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2 City of Albuquerque v. Browner 865 F. Supp. 773 (D.N.M. 1993) 97 F. 3d 425 (10th Cir 1996) aff'd. 118 S.Ct. 410 (1997) cert. denied.
3 Montana v. E.P.A., 941 F.Supp 945 (D. Mont. 1996), aff'd, 137 F. 3d 1135 (9th Cir), cert denied 119 S. Ct. 275 (1998).

procedures in approving the Pueblo's standards. Specifically, the City alleged that the approval itself was rule making, requiring the EPA to give public notice and provide a comment period before issuing the approval. The court noted that, while states and tribes treated as states must hold public hearings when reviewing or revising water quality standards, and while the EPA must provide public notice and comment before issuing federal water quality standards, the Clean Water Act does not expressly require the EPA to provide additional notice and comment periods before approving state or tribal standards. The court concluded that the EPA reasonably complied with the Clean Water Act's procedural requirements for approving standards, and no purpose would be served by requiring the Administrator to take additional comments before making the decision to approve the standards.

Second, the City asserted that the EPA implemented Section 518 improperly by determining that Section 510 of the Clean Water Act applied to Indian Tribes as well as states. Section 510 prohibits states from imposing any standard that is less stringent than the federal standards, but expressly preserves state rights to set standards that are more stringent than the federal standards. The court upheld EPA's recognition of the Pueblo's authority to set water quality standards more stringent than the federal standards.

Third, the City contended that the EPA's regulations on how to resolve conflicts between different tribal and state water quality standards on a common water body failed to meet the requirements of the Clean Water Act. The City pointed to the fact that the regulations allowed only a state or Tribe to initiate the resolution process, not any affected party such as the City. The court found that the EPA met the statutory mandate of the Clean Water Act. The court ruled that the EPA's regulations were developed only after careful consideration of relevant factors and were not arbitrary or capricious.

Fourth, the City charged that the EPA's approval of the Pueblo's standards was improper because the standards are not stringent enough to protect the designated uses (primary contact ceremonial and recreational use). All parties agreed that the ceremonial use of the River included some ingestion of water. The court found that the primary contact use more closely resembled a fishable/swimmable standard under the Clean Water Act, which assumes some ingestion of water. The court ruled that the Pueblo's standards were sufficiently stringent to protect this use.

Fifth, the City urged that the Pueblo's standards were unconstitutional on two grounds. The City first asserted that recognition of a ceremonial use standard violated the Establishment Clause of the United States Constitution by aiding tribal religion at the City's expense. The court upheld the EPA's determination that the primary purpose of a designated use is to support the goals of the Clean Water Act citing Lemon v. Kurtzman (403 US 602, 1971). The court ruled that the EPA is not advancing religion through its actions, and no excessive entanglement between government and religion resulted. Then the City argued that the standards were unconstitutionally vague. The court rejected this argument. In this case the court emphasized that while water quality standards are narrative descriptions that do not require a particular conduct, the City will have notice of the standards applicable to it when the EPA issues the City's revised NPDES permit.

Finally, the City argued that the Pueblo's water quality standards were unattainable. The court recognized that the City had realistic concerns, nevertheless the court ruled that the EPA reviews proposed standards only to determine if they will be stringent enough to protect the proposed uses. The administrative record provided the court with evidence that the EPA and the Pueblo had conferred extensively on the technical aspects of the standards. It showed that the Pueblo had documented the technical basis of the standards. The Pueblo had shown that it was during the low flow periods of the Rio Grande that Tribal members used the river more extensively for ceremonial purposes. For this reason the EPA and the Pueblo concluded that it would be particularly inappropriate to relax the standards during low flows. The court ruled that the EPA was not arbitrary and capricious in its decision-making process.

Despite the ruling, the court was troubled with the EPA's position on the effect of NPDES permits on downstream water quality standards. The court noted that the EPA was prepared to include limits in the City's NPDES permit to ensure that its wastewater discharge would meet the Pueblo's downstream water quality standards without first determining that the quality of the river five miles downstream would be measurably improved. The court noted the fact that the Pueblo's arsenic standards for the river is three orders of magnitude (1000 times) more stringent than the federal Safe Drinking Water Act standard and is below the amount measurable by laboratory equipment. Arsenic occurs naturally in the groundwater supply of the City of Albuquerque and is not know to be discharged by any local polluter. The court reasoned that even if the City discharged pure water from its facility, the river flowing through the Pueblo could contain high levels of arsenic. The court decided that the issue of the revised NPDES permit was not a matter before it. Following the court's decision, the City of Albuquerque appealed to the United States Tenth Circuit Court of Appeals where it lost again. The Supreme Court refused to hear the appeal from the 10th Circuit[4]

Near the end of 1993, a new mayor of Albuquerque was elected. Even before his inauguration, he approached the Pueblo for a meeting on the water issues. It became apparent that the parties would be able to talk one-on-one, and Pueblo officials decided that it would be advantageous to bring the New Mexico Environmental Department (NMED) into the discussions. (Not only was the City violating the water quality standards adopted by the Pueblo, but it was also violating the less stringent state standards.) By this time it was clear from the Supreme Court's decision in Oklahoma v. E.P.A. (1992), that the EPA was able to enforce downstream water standards against an upstream user, even if the standards were more stringent than those enforced at the point of discharge5. The EPA's application of the Pueblo's higher standards would effectively result in the City's meeting the state standards as well.

Early in negotiating, all parties agreed that lawyers should not be present during

4 City of Albuquerque v. Browner 865 F. Supp. 773 (D.N.M. 1993) 97 F. 3d 425 (10th Cir 1996) aff'd. 118 S.Ct. 410 (1997) cert. denied.
5 Oklahoma v. E.P.A. 503 U.S. 91 (1992).

discussions on scientific and technical issues. This agreement was at the request of the Pueblo leadership, who believed that differences in opinion regarding jurisdictional issues would cloud the issues related to water quality. Attorneys were present only when absolutely necessary. The initial meetings were between the Pueblo, the NMED, and the EPA. At the meetings, the parties carefully compared the Tribal and state standards, identifying substantive differences. Once the comparison was completed and differences reconciled, the state and the Pueblo approached the City for further negotiations. Attorneys were barred from the discussions once again. The parties wanted to focus on the technical/scientific issues, not the jurisdictional/legal ones. Because of the cooperation among agencies and governmental entities, the parties were able to negotiate a compromise NPDES permit.

On April 7, 1994, the City, Pueblo, and New Mexico Environment Department signed a stipulated settlement agreement setting certain conditions on the City's federal NPDES permit. Under the agreement, the EPA would impose current limits on arsenic, silver, ammonia, and other chemicals pending the outcome of a study to measure what levels of the chemical were being discharged. The three-year study was funded by the City paying $150,000 and the Pueblo and the EPA splitting the cost of the remaining $100,000. Everyone coordinated with the U.S. Geological Survey regarding the plan for the study.

11.0 WATER QUALITY CONCERNS ON TRIBAL LANDS

Water quality impairment, a reservation management problem, is attributed to population increases, water resource demands, and on- and off-reservation land uses.

As the most southern Pueblo, with Albuquerque screening it from those to the north, Isleta is sometimes overlooked. It is impossible for Isleta to ignore Albuquerque. Directly north of the Pueblo boundary lie a succession of industrial operations producing various kinds of waste, including Cal-Maine Foods' egg farm, the Karler Meatpacking plant and feedlot, bulk oil and chemical storage facilities, the City's wastewater reclamation plant, a Superfund site of contaminated groundwater in the San Jose neighborhood, the polluted Mountainview subdivision, and the junkyards and scrap vistas of South Broadway.

Paul Robinson of Southwest Research and Information Center (SRIC) has observed that approximately 12,000 cattle (the number in the South Valley in the late 1970s) produced 100,000 tons of wastes per year, including some 90 acre-feet of urine. Robinson found that proper disposal of that amount of waste, by spreading on fields, would have required all the cultivated land in the South Valley. Feedlot operators were spreading the manure on far fewer acres, of course, loading those acres and the ground water beneath, with nitrogen, ammonia, and salt. The nitrate plume from the company's blood pit has now migrated offsite to the trapshooting club area south of Karler. Isleta is concerned because just south of this groundwater pollution is Isleta Lakes Recreation Area, a key element in the Pueblo's economic self-sufficiency. Fish will not tolerate increased salinity or nitrate, and the Lakes are excavated into groundwater. Karler is now trucking the 30,000 gallons per day of blood and brine (from hide-tanning) to lined pits on the West Mesa.

The Pueblo recently became aware of the extent of heavy metals pollution from a steel-plating plant operation on a 20-year lease that expired at the end of 1992. Preliminary analysis by EPA in July 1992 showed 172 ppm of hexavalent chromium (the form most toxic to humans) in soils near the plant, and 14,000 ppm of unoxidized chromium (Leyendecker, 1994). The safe levels for children have been calculated at 35 ppm.

The color of river water has changed - partly because the 18 year old Cochiti Dam now holds back river salts and increased sewage effluent makes the water clear and green. The silt that once traveled downstream is gone. The crust of silt doesn't settle over the fields like it did before Cochiti was built and the crops dry out quickly. Isletans irrigate every 10 days instead of waiting two weeks like they used to when the clay silt was deposited on the fields holding in the moisture. Production has been reduced by one third. Farmers have had sudden crop wilting, often just after irrigating. They believe the cause is ammonia or pesticides used upstream. Some Pueblo residents used to hunt for bullfrogs at one of the large ditches, where frogs 12 to 18 inches long could be found. That has stopped since many frogs were found with large yellowish growths on their legs, some of them oozing puss. Other farmers have reported that the number of frogs has vastly diminished in irrigation ditches in recent years. Fewer people eat the fish from the river, and they don't see frogs in their fields and yards any more.

Arsenic in the Rio Grande is nearly all in the dissolved phase. The mean dissolved-arsenic concentration in the Rio Grande increases downstream from 1.8 micrograms per liter at the Pueblo of San Felipe to 3.6 micrograms per liter at Los Lunas. Mean dissolved-arsenic concentrations in the riverside drains is slightly higher (2.8 to 4.5 micrograms per liter) than those in the Rio Grande and are higher still in the wastewater-treatment plant outfalls (7.9 to 16.2 micrograms per liter) and the Jemez River (18.2 micrograms per liter). The mean total-arsenic concentration in fish-tissue samples from the Rio Grande and Albuquerque Riverside Drain is 14.53 micrograms per kilogram. (Wilcox, 1997)

11.1 Federal Response

Tribal water quality needs have triggered responses from several federal agencies. The U.S. Geological Survey (USGS), together with the Bureau of Indian Affairs (BIA), conducted two studies examining water resource quality on over twenty Indian reservations. One study deals with trace elements near Albuquerque (U.S. Geological Survey, 1996) and another deals with trace elements in fish tissue (U.S. Geological Survey, 1997).

The Clean Water Act, Safe Drinking Water Act, and Clean Air Act, authorize EPA to treat Indian tribes as states for purposes of certain types of grant awards and program authorizations. The only statutory requirements are that a tribe be federally recognized, have a governing body "carrying out substantial duties and powers, and have adequate jurisdiction and capability to carry out the proposed activities." The Agency has promulgated regulations for implementing this authority. Although the CWA amendments were enacted in 1987, the regulations were not enacted until 1989, and then only for funding which allowed for the monitoring of tribal waters (Reetz, et al. 1998).

11.2 Water Quantity and Quality

Tribes, the EPA and other federal agencies have a general understanding of tribal water quality problems and needs. Reservation waters have not been completely characterized in terms of beneficial uses, attainment of water quality goals and standards, or the impacts which stand in the way of attainment. The monitoring programs for Indian tribes, however, are too new to identify the specific water quality trends and problems. Based on these concerns, specific actions are needed for better tribal planning. In particular, the tribes that have been monitoring for longer periods of time, or have set water quality standards, should provide data pertaining to the attainment of water quality standards (Reetz, et al. 1998).

The legal and institutional separation of the management of water quantity (flow) from that of water quality presents a challenge for effectively addressing water quality problems arising from hydro-modification. Unfortunately most western states have traditionally divided the administrative protection of public health (water quality) from that of water allocation (water quantity). This has led to an unrealistic separation of two natural attributes that are integral to one another.

Maintenance of appropriate instream flows is receiving increased attention throughout the West and has both water quantity and water quality implications. As a better understanding of stream ecology develops and other instream flow needs are quantified (water quality, and stream channel morphology), there has been a trend toward trying to "mimic" the natural hydrograph within the constraints of existing water allocation systems.

As demands for water in the West continue to increase, there can be little doubt that hydro-modification and the relationships between water quantity and water quality will prove difficult challenges. It appears that states, rather than the federal agencies, will have primary responsibilities for addressing these challenges. However, since the federal government has been a major participant in the development of water in the West, it will also play a significant role in addressing some of the major environmental problems which have been created by this development.

The EPA regulates the concentrations of discharges allowed into rivers by calculating the river's "critical low-flow" rate. Maximum allowable concentrations are figured on the river's lowest volume of water. Since these lowest flow standards were set on Eastern U.S. rivers with perennial strong flows, EPA's calculations in the past regarded the Rio Grande's "off" periods as naturally occurring dry spells. This required lower discharges from the Albuquerque sewage plant than its operators thought necessary. With some creative accounting, Albuquerque has asserted that the U.S. Geological Survey flow meter installed at the Central Avenue Bridge in Albuquerque indicates that there has been 90 to 95 percent probability that the low flow was equal to, or greater than, 250 cubic feet per second, year-round. City hydrologists raised that probability to 100 by pledging release when necessary of city-owned (San Juan - Chama) water stored upstream at El Vado reservoir on the Chama River (Fox, 1992).

11.3 Municipal Discharges

Much of the discussion of water quality in the West has, rightfully, focused on nonpoint sources (NPS) such as irrigated agriculture, and grazing and timber harvesting. However, the significance of municipal discharges cannot be overlooked. The West includes some of the most urbanized areas of the country, and is becoming more so. As a result the water quality issues associated with municipal discharges may become even more significant in the future. With rapidly changing population dynamics in the West, the issue is raised as to whether municipal wastewater treatment facilities are keeping up with population growth. (Reetz, et al. 1998)

The Albuquerque sewage treatment plant operates at a constant 80 cubic feet per second (or 50 million gallons per day) and is contributing about a third of the flow in the Rio Grande channel at low-flow times between March 1 and October 1. Albuquerque officials argue that it is not their plant that causes Isleta Pueblo problems, but nonpoint sources or diffuse runoff pollutes the river the most. The New Mexico Water Quality Control Commission (WQCC) claims that only two percent of pollution in the Rio Grande comes from industrial or sewage discharge, with 98 percent coming from storm runoff, mining, and the like (Leyendecker 1994). The WQCC statistic reflected statewide totals. The Albuquerque Waste Water Utility Division has confirmed (Hogrefe, 1999) the figures and has stated that at the border of Isleta the majority of pollution is from non-point sources; they were unsure of where the high fecal coliform bacteria counts came from - septic leakage, dogs, the feedlots - even the raven and duck flocks that roost in the river bosque could be contributors (Fox, 1992).

11.4 Difficulties Experienced By Isleta Pueblo

Pueblo officials have been hesitant to point out any specific problem areas, with the exception of those that occurred at the early stages of program development. The main problem in the beginning was an absence of any basis for enforcement of the Pueblo's water quality standards. Until the tribal amendments to the Clean Water Act were adopted in 1987, tribal governments did not possess authority to restrict off-reservation conduct polluting the reservations waters. Under Section 518 of the Clean Water Act, the EPA was authorized to treat Indian Tribes as states for certain purposes. Isleta Pueblo was then able to apply for financial assistance from the EPA, adopt enforceable water quality standards, and take steps to limit discharges that would violate the Pueblo's standards.

When the Pueblo first raised its concerns about pollution of the Rio Grande, Albuquerque city government was insensitive to the Pueblo's needs. Later City Administrations have been willing to address the Pueblo's concerns and have dealt directly with the Pueblo on a government - to - government basis. Political happenstance solved the problem of a hostile neighbor government. Another problem was the failure of both the City and the Bureau of Indian Affairs to provide monitoring information during construction of the new City wastewater treatment facility.

Like many other Tribal governments, the Pueblo was unfamiliar with the need for public relations assistance and the potential impact of media activities. In attempting to thwart the Pueblo's effort to limit effluent discharges by the wastewater treatment plant, the old City administration publicly claimed that the Pueblo's standards would cost the City $250 million. This was a total misstatement of the facts. The publicized cost accurately reflected the City's project expenditures, but only a fraction of that cost was attributable to conditions imposed by the Pueblo. Most of the $250 million was needed to meet NMED water quality standards. Minimal additional funds were needed to meet the stricter standards of the Pueblo. While the Court did not accept the claims of the City, the media's report of exaggerated information resulted in a public relations crisis for the Pueblo. With the right advice, the harm to the Pueblo's image could have been avoided. (Gover, Stetson and Williams, 1994)

12.0 RECOMMENDATIONS

In addition, other federal agencies must be encouraged to assist in attaining environmental protection in Indian country. For water quality, the sharing of monitoring and special studies data would help to better define tribal water quality needs. Coordinated approaches with the tribes, other federal agencies, and the EPA could serve in conserving scarce water quality resources. (Reetz, et al. 1998)

A number of specific activities could address these problems and should be incorporated into current federal efforts to work with tribes to address water quality issues.

- EPA's funding strategies should be revised so that funding resources are directed to the tribes with the greatest need.
- Tribes should be required to monitor water quality and report the results under Section 305(b) of the Clean Water Act.
- The EPA should provide more direct technical assistance to Indian tribes.

- The EPA should determine the best methods and practices, especially in terms of enforcement and compliance, that enable tribes to meet tribal water quality needs.
- Tribal water quality should be a major component in the Tribal-EPA Environmental Agreements.
- Federal agencies, like the Bureau of Indian Affairs and the U.S. Geological Survey, need to be more involved in assisting Indian tribes in water pollution prevention and control as part of each agency's trust responsibilities.
- A database relating to tribal water quality should be developed as a means of increasing tribal and EPA's understanding of water quality impairment.

12.1 Changes To Existing EPA Applications Processes

Separate "TAS" approval should be eliminated and included as part of the process of reviewing program approval applications.

Use of the term "treatment-as-a-state" should be minimized because the term is somewhat misleading and may be offensive to tribes.

Uniform requirements for "recognition" and "governmental" requirements under each statute should be established so that meeting the requirements under one meets the requirements for all.

13.0 CONCLUSION

Water quality on Indian reservations has come a long way since the enactment of Section 518. The Tribes are moving along as fast as their resources permit, but they are frustrated with the pace of the EPA's implementation and the EPA's inability to provide adequate funding for their programs (Gover, Stetson and Williams, 1994).

Several years of a sinking economy have made business people very defensive about new requirements to reduce pollution. Few can afford large capital layouts for new technology. Thin profit margins make people susceptible to scare stories. The Isletans understand poverty and unemployment better than most Albuquerque business people, and their history of adaptation and willingness to negotiate should reassure the other parties involved (Fox, 1992).

Isleta's cultural difference has always been protected by isolation. Now its health depends on connecting with larger and more diverse groups, in newer ways. The Isletans' sense of violation highlights everyone's realization that there is no sanctuary. They remind us of one of the founding ideas of conservation: interconnectedness. As Aldo Leopold said decades ago, "When you go to pick out anything, you find it's hitched to everything in the universe." Pueblo philosophy states far more clearly that connectedness and a dignified role for every living thing is the way of a healthy world. The segments we divide the Rio Grande into are not as real as pieces of plumber's pipe. They are segments only in the mind.

Other Pueblos are making new coalitions and speaking up. As University of California regents deliberated in November about renewing the University's contract to manage Los Alamos National Laboratories, two Pueblo officials joined with northern New Mexico environmental groups in asking for more attention to their problems. San Juan Pueblo Governor Herman Agoyo told the regents that the Indians of northern New Mexico will no longer keep silent over not being hired at the Lab and about the Lab's environmental threat to adjoining Indian lands. San Ildefonso Governor Gilbert Sanchez and Stan Crawford, Dixon resident and author of *Majordomo*, also spoke to the regents. In the 500th year since Columbus's arrival, it is clear that indigenous and land-based people are reaffirming their stewardship of their lands and reminding everyone else that we are all in this together (Fox, 1992).

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ARSENIC AND ISLETA PUEBLO: A PERSPECTIVE ON THE STANDARD

Chris McLean

Executive Summary. Arsenic is a naturally occurring element in the earth's crust. It exists in an organic or inorganic form. Humans can be exposed to arsenic compounds through air, soil, water, and food.

Since the inception of the Clean Water Act (CWA) there have been regulations put in place to protect the general public. These regulations require the Environmental Protection Agency (EPA) to develop water quality criteria from which water quality standards can be established. Standards are put in place to limit the level of certain elements that might be discharged into the water. Arsenic is one of the elements that is regulated by these standards.

The federal government, represented by the EPA, is responsible for the enactment of water quality criteria and standards. States or tribes are allowed to promulgate their own standards as long as they are at least as stringent as the federal standards. The standards can be changed if new scientific evidence suggests that the old standard is no longer valid. A new standard may be developed if the old standard is shown to be invalid.

The Isleta Pueblo, as a federally recognized tribe, promulgated their own water quality standards, ncluding an arsenic standard. The number adopted in the Isleta standard is lower than the background levels of arsenic prevalent in New Mexico. With this information, it is doubtful that this water quality standard can be met.

The EPA has published new guidelines on establishing water quality criteria for arsenic. With this change new standards can be developed using the new criteria. These guidelines can be used by any entity wanting to establish a new standard based on sound scientific evidence.

The State of Arizona has established a new standard for arsenic. They have calculated a new standard based on the EPA's new scientific evidence. This new standard is based on the separation of arsenic into the organic and inorganic forms, therefore allowing a separate standard for fish consumption and water.

1.0 FEDERAL DEVELOPMENT OF WATER QUALITY STANDARDS

1.1 Initial Development

With the enactment of the Clean Water Act (CWA) in 1972 a push was made to control pollution at the source. A system was developed using technology-based permit effluent limitations on point sources. Congress soon recognized that this system would not be entirely adequate to meet the goals of the act. To remedy this problem, they adopted a water quality program using standards under section 303 of the Act. These standards consisted of designated uses for waterbodies, water quality criteria to protect those uses, and an antidegradation policy to maintain water quality. These standards represent what the desired water quality should be for a particular water body.

1.2 Section 303 and 510

Under section 303 of the CWA a process for adopting, revising and reviewing, water quality standards is set forth and must be followed by states and tribes. Sections 303 (a) and (b) are a transition from the previous statute. These statutes are designed so that states will have to develop standards that protect interstate and intrastate streams. Under section 303 (c) when a state or tribe adopts a new or revised standard they must submit it to the EPA for approval. If the EPA administrator determines that the standard meets the requirements, the standard is then considered as the applicable standard for the waters of the state or tribe. Section 510 of the CWA states that a state or tribe can adopt and enforce any standard as long as it is as stringent as the standard already in effect under the CWA.

1.3 Standards and Amendments

The first water quality standards promulgated by EPA were in 1975. This regulation was very limited and in 1983 EPA revised and expanded the water quality regulations. These new regulations specified in more detail the requirements for water quality standards. Now included in the regulations were stipulations of specific elements that must be in a state's water quality standards. In 1991, EPA amended the water quality regulations. This amendment gave tribes the ability to promulgate their own standards.

1.4 Review and Approval of State and Tribal Water Quality Standards

In July 1999, EPA proposed to change the regulation that specifies when new and revised state and tribal water quality standards become effective for Clean Water Act purposes. Under the proposal, new and revised standards adopted after the effective date of the final rule will not be used for Clean Water Act purposes until approved by EPA, unless such new and revised standards are more stringent than the standards previously in effect. The proposal also provides that standards already in effect at the effective date of the new rule may be used for Clean Water Act purposes, whether or not approved by EPA, unless EPA subsequently disapproves them and replaces them with Federal water quality standards.[1]

1.5 Less Stringent Standards

With the new regulations passed the only delay would be the passage of a less stringent standard by a state or tribe. EPA's proposed regulation states: "of course, the mere fact that a standard is less stringent than the previous standard does not mean that it is not justified (e.g., new scientific information may show that a less stringent criterion may have been based on incomplete or inaccurate information)." With EPA's review of a less stringent standard they are able to confirm that the new standard meets the requirements of the CWA. However, section 510 of the Act also makes it clear that this process was not intended to preempt the right of states or tribes to adopt and enforce more stringent standards if they so choose. Thus, if a new or revised standard is more stringent than the otherwise applicable water quality standard, the proposed rule would continue to allow the promulgating state or tribe to enforce within its boundaries such standards without prior EPA review and approval. Accordingly, the practical consequences of the proposed rule requiring EPA approval are largely confined to new or revised standards which are less stringent than the preceding standards. (Federal Register, July 1999)

2.0 PUEBLO OF ISLETA WATER QUALITY STANDARDS

2.1 Passage of the Isleta Water Quality Standards

In 1991 the EPA approved the Pueblo of Isleta's request to promulgate their own standards. The Pueblo of Isleta's standards were approved, passed, and adopted on February 11, 1992. With EPA approval the Pueblo is able to put constraints on the amount of pollution flowing through the Pueblo of Isleta.

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[1] Section 510 of the Act provides that nothing in the Act restricts the right of any State or authorized Tribe (or political subdivision thereof, or interstate agency) to adopt or enforce any standard, as long as it is not less stringent than a standard in effect under the Act. The proposed rule acknowledges this reserved state and tribal authority by stating explicitly that a state or authorized tribe may adopt and enforce a water quality standard which is not less stringent than the applicable water quality standard under the rule. As explained above, the applicable standard would be either the standard in effect as of the effective date of the rule, or a superseding approved standard, or a federally promulgated standard. Section 510 is self-implementing meaning that a standard adopted under authority preserved by section 510 may be used immediately to control pollution originating in the state or tribe adopting the standard, without first obtaining EPA approval or EPA concurrence that the standard is not less stringent (Federal Register: July 9, 1999 Volume 64, Number 131, Proposed Rules Page 37072-37081.)

2.2 Purposes of the Pueblo of Isleta's Water Quality Standards

The purposes of the standard are as follows:

1. To designate the existing uses for which the surface water of the Pueblo of Isleta shall be protected,

2. To prescribe water quality standards (narrative and numeric) imposed in order to sustain the designated uses,

3. To assure that degradation of existing water quality does not occur, and

4. To promote the social welfare and economic well being of the Isleta Pueblo.

These purposes coincide with the purposes of the CWA and allow the Isleta Pueblo to develop their own standards in order to protect these purposes.

2.3 Isleta Pueblo Use Designation for the Rio Grande

The use designations for the Rio Grande are:

1. Warm water fishery use,
2. Primary contact ceremonial use,
3. Primary contact recreational use,
4. Secondary contact recreational use,
5. Agricultural water supply use, and
6. Industrial water supply use.

2.4 Alternate Use Designations

The primary contact use designation, both ceremonial and recreational, is contrary to New Mexico's designation on the adjacent sections of the Rio Grande. New Mexico's designation includes secondary recreational use but not for use as a fishery or ceremonial usage involving the ingestion of water and fish.

The quantitative standard adopted by Isleta Pueblo for arsenic in surface water is inconsistent with New Mexico's. The Pueblo of Isleta has based their standard for arsenic on consumption of fish in relation to ceremonial uses. The amount of arsenic allowed under the Pueblo's standard is very small compared to the amount allowed by the State of New Mexico as illustrated by Table 2-1 (New Mexico Water Quality Control Commission, 1994 and 1996).

Table 2-1. Arsenic Standards For Designated Uses

DESIGNATED USE	ASSOCIATED ARSENIC STANDARD
Ceremonial (Isleta Pueblo)	0.0000175 mg/l *
Domestic Water Supply (State of NM)	0.05 mg/l (Dissolved)
Irrigation (State of NM)	0.10 mg/l (Dissolved)
Livestock Watering (State of NM)	0.20 mg/l (Dissolved)

* This number corresponds to the number published in EPA's National Water Quality Criteria Correction for human health consumption of water + organism.

2.5 Arsenic Standard in Question

The standard adopted by the Pueblo can be questioned on two grounds. First, the standard is not detectable with current technology[2]. According to the regulations, if a standard is not detectable at the value promulgated, then the standard will be protected at the level that is detectable. Secondly, the standards require cleaner water than the background ambient water quality of the Rio Grande which is in contradiction to Isleta's own wording in the standard, "Water quality standards are not used to control, and are not invalidated by, natural background phenomena or acts of God." Table 2-2 shows the results of U.S. Geological Survey (USGS) sampling as reported in the Water Resources Data New Mexico Water Year 1996 for three separate stream segments.

Table 2-2. Arsenic Analytical Results for Selected Stream Reaches

STREAM REACH	DATE SAMPLED	ARSENIC ANALYTICAL RESULT
Rio Grande at Otowi Bridge	November 27, 1995	0.002 mg/l (Dissolved)
	August 28, 1996	0.002 mg/l (Dissolved)
Jemez R. near Jemez, NM	November 9, 1995	0.01 mg/l (Dissolved)
	August 28, 1996	0.045 mg/l (Dissolved)
Rio Grande at Isleta, NM	October 3, 1995	0.003 mg/l (Dissolved)
	February 14, 1996	0.003 mg/l (Dissolved)
	May 20, 1996	0.003 mg/l (Dissolved)
	August 20, 1996	0.003 mg/l (Dissolved)

[2] Current detection limits in surface water range from .02 to .05 mg/l, however EPA considers both the limits and the analysis methods to be uncertain (EPA Feb 98).

The numbers in Table 2-2 show Isleta Pueblo's arsenic standard is unattainable without significant treatment. The Jemez River, which is a major contributor to the Rio Grande in this area, contains high quantities of naturally occurring arsenic. The area around the Jemez River is mostly undeveloped and can be considered to be without anthropogenic inputs. With this natural input of arsenic the arsenic standard of Isleta Pueblo will be continuously exceeded. This shows the unrealistic nature of the standard promulgated by Isleta Pueblo and the need for sound scientific revisement.

3.0 COMPARISON OF SURROUNDING STATES' ARSENIC STANDARDS

3.1 Standards of Arizona, Colorado, Nevada and Utah

Each state is allowed to develop its own standard under section 303 of the CWA as long as they are at least as stringent as the standards promulgated by EPA. This led to many different standards being adopted. In Table 2-3 the arsenic standards of Arizona, Colorado, Nevada and Utah are shown. These standards are less stringent than Isleta Pueblo's standards.

Table 2-3. Comparison of Neighboring States' Arsenic Standards (Concentrations are in mg/L)

STATE	DWS	FC	FBC	PBC	AGI	AGL
Arizona	0.05	1.45	0.05	0.05	2.00	0.20
Colorado	Aquatic Life					
		Acute	Chronic			
	0.05	0.36	0.15		0.10	0.10
Nevada	Aquatic Life					
		1hr average	96hr average			
	0.05	0.342	0.18		0.10	0.20
Utah	0.05				0.10	0.10

DWS = Drinking Water Supply

FC = Fish Consumption

FBC = Full Body Contact

PBC = Partial Body Contact

AgI = Agricultural Irrigation

AgL = Agricultural Livestock Watering

4.0 REGION 6 INTERIM STRATEGY: ARSENIC- FRESHWATER HUMAN HEALTH CRITERION FOR FISH CONSUMPTION

4.1 Background

With new information available in 1995, the EPA began a process for revising the arsenic criterion. This interim strategy was designed to facilitate the development of arsenic standards based on this new information. The report recognizes the elevated levels of arsenic naturally occurring in some parts of the country. Arsenic was broken into the two existing forms, organic and inorganic. The inorganic form is the one more toxic to humans. Toxicity risk analysis was used to establish a new criterion for the inorganic form. With this interim strategy, the criteria varied a little from the previous standards published in the National Recommended Water Quality Criteria - Correction. With the original standards, there were numbers published for the consumption of fish alone (0.00014 mg/l) or fish + water consumption (0.000018 mg/l). The new interim strategy allowed for the water quality criteria to protect the consumption of water and/or fish. Water was now isolated allowing for a criterion for the consumption of water alone. The standard for the Safe Drinking Water Act (SDWA) could be applied here at 0.05 mg/l.

4.2 Development of New Arsenic Criterion

The conflict over the new criterion for arsenic arose during the promulgation of the National Toxics Rule. During the public comment period, the EPA received two letters expressing concern over the different forms of arsenic in fish and the associated carcinogenicity in each. In December 1992, when the final National Toxics Rule was issued, a footnote was added stating EPA's determination to use only the inorganic form of arsenic when applying the criterion for fish only consumption or water plus fish consumption.

4.3 Problems with Implementation

Even with the EPA footnote, states and tribes have continued to use arsenic criteria for standards without recognizing that most of the arsenic in freshwater finfish is in the form of organic arsenic. With the knowledge that most arsenic present in freshwater finfish is organic, there can be a change in the criteria used in developing the standards. But, the added expense in analytical testing and monitoring of fish tissue can be a deterrent in promulgating standards based on these new criteria.

4.4 Recommendations for Arsenic Criterion

There are several different ways to account for the different forms of arsenic in freshwater finfish. The EPA Region 6 recommends that states and tribes adopt an arsenic criterion based upon the inorganic fraction that would be found in edible fish tissue (EPA Jun 98) This method does not reevaluate the toxicity information but rather looks at the bioconcentration of arsenic in freshwater finfish tissue. This method gives states and tribes the ability to adopt a risk-based criterion to protect human health from the ingestion of the inorganic form of arsenic through freshwater finfish.

5.0 ARIZONA ARSENIC STANDARD

5.1 Reasons for Study

The state of Arizona completed a study of their fish population in 1995 (Rector, 1995) to determine the amount of organic and inorganic forms of arsenic present in the freshwater finfish resident in the Verde River. The study was completed to determine if there was a human health risk. The Verde River was used due to the fact that there had been previous exceedances of the arsenic concentrations in the human health standards for fish consumption. The study was also done to test the scientific basis for the human health standards for fish consumption. Although Arizona is in EPA's Region 9 and not Region 6 their study correlates well with what Region 6 recommends for arsenic standards criteria. Therefore Arizona's study is a model that could be used in Region 6 and specifically New Mexico due to similar geologic makeup in regards to the high amounts of naturally occurring arsenic.

5.2 Study Basis

Arizona noted the difference in carcinogenic properties of arsenic in its organic and inorganic form. The organic form was shown to be much lower in toxicity and carcinogenicity. Also noted was the high mobility arsenic has in water. All sediment samples taken in the Arizona study exceeded the Human Health Based Guidelines for the consumption of sediments and soils. Also exceeded in the Verde River were the State fish consumption arsenic standards of 0.0031 mg/l. This standard was promulgated to protect the public from bioaccumulation in edible fish tissues due to pollutants in the water.

In 1995, the EPA (EPS, 1995) released information that changed the arsenic standard for fish consumption from a carcinogen to non-carcinogen. This information led to the development of a new standard for fish consumption in Arizona.

5.3 Development of New Standard

In the development of new standards risk assessment is routinely used. With the development of the fish consumption water quality standard, Arizona followed closely the method proposed by the EPA. The method proposed by the EPA calculates a fish tissue screening value for arsenic. This same method for non-carcinogens was used by Arizona and is shown by the following equation:

$$SV = (RfD \times BW)/CR$$

SV = Screening value (mg/kg: ppm)

RfD = Oral reference dose (mg/kg/d)

BW = Mean body weight of the general population (70kg)

CR = Mean daily consumption rate over a 70 year lifetime (0.0065 kg/d)

Arizona used the same equation but added a bioconcentration factor (BCF) of 2 that was developed during the study. This was to address the possibility that arsenic concentration in tissue may exceed the concentration in the ambient water column. In the EPA Region 6 Interim Strategy a BCF of 1 was proposed for use in the calculation of human health criteria (EPA Jun 98). The RfD of 0.3 mg/kg/d used for calculation of the screening value is the number estimated from the Taiwan studies where no adverse effects were observed. The possibility of up to ten percent organic arsenic present in the fish tissue was also added to the following equation:

$$SV = ((RfD \times BW)/(CR \times BCF)) * 0.9$$

$$SV = ((0.3 \times 70)/(0.0065 \times 2 \times 1000)) \times 0.9 = 1.453 \text{ mg/l*}$$

*This number is shown previously in Table 2-3 as the standard adopted by Arizona for fish consumption

Calculation using the EPA's recommended BCF of 1:

$$SV = ((0.3 * 70)/(0.0065 \times 1 \times 1000)) * 0.9 = 2.907 \text{ mg/l}$$

With this BCF proposed for EPA Region 6, which New Mexico resides in, the standard could be more lenient than the standard promulgated and passed by EPA in Arizona due to the lower BCF.

6.0 CONCLUSIONS AND RECOMMENDATIONS

Compared to other states, the Isleta Pueblo's current arsenic standard is very stringent and is based on a carcinogenic scenario which has since been redefined by the EPA. The EPA's new regulations divide arsenic into the organic and inorganic forms allowing for new criteria and thus new standards. The Isleta Pueblo standard should be re-evaluated based on the criteria and standard developed by Arizona. The EPA Region 6 has already put forth a recommendation paralleling what Arizona has done in developing their standards. Also, the EPA has already reviewed, and passed, the Arizona standards. This shows the support and the validity of the science supporting the new arsenic standard. Arizona's geological makeup is very close to New Mexico in terms of the large quantities of naturally occurring arsenic. This shows the direct applicability of the Arizona standards to New Mexico and Isleta Pueblo.

Although under the EPA's July 1999 propsed regulation change, any new less stringent standard must be submitted for a 303(c) review, the EPA has also stated that just because the standard is less stringent than a previous standard does not mean it is not justified.

7.0 REFERENCES

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ARSENIC, REGIONAL PLANNING, AND THE COST OF WATER

Richard M. DeSimone

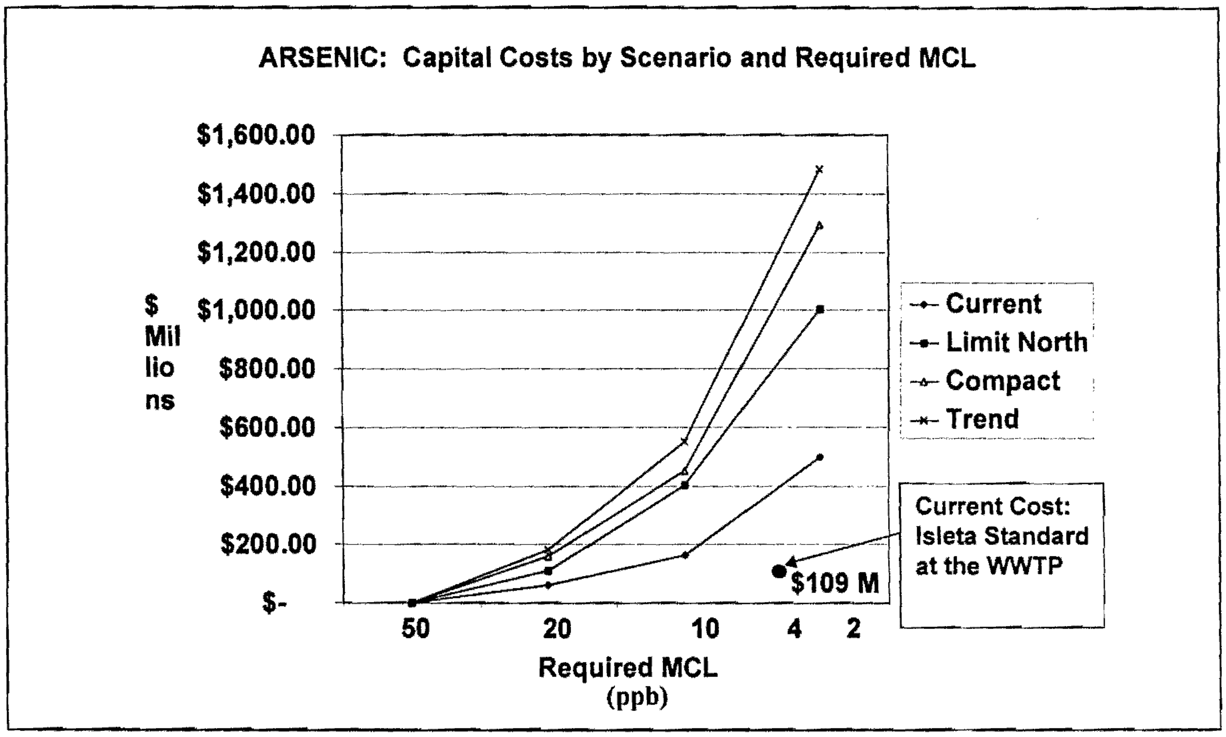
EXECUTIVE SUMMARY. This paper explores the relationship between current growth and space planning activities, arsenic water quality standards and the capital costs of water treatment for arsenic in the Middle Rio Grande (MRG) region. For purposes of this report, the MRG region is defined as the counties of Socorro, Valencia, Bernalillo, Torrance and S. Santa Fe, New Mexico. Specifically, the paper develops capital costs associated with meeting both the Isleta Pueblo's water discharge standard for arsenic and the to-be-proposed federal drinking water standard for arsenic under different growth scenarios for the region. Capital costs only, as opposed to life cycle costs, are developed. It is the opinion of the author that large public capital budgeting decisions are generally made based on first cost versus life cycle. No attempt is made to split the costs out by city, county or drinking water utility.

The paper analyzes three growth scenarios for their effects on treatment costs for the region. The first two are the trend dispersed and compact growth scenarios contained in the Middle Rio Grande Council of Governments "FOCUS 2050" plan. The third is a hybrid composed of the compact growth scenario only with growth limited in the area North of Rio Rancho where high arsenic concentrations exist. The cost comparisons by scenario are shown in Table ES-3-1 and Figure ES-3-1 on the next page.

Table ES-3-1. Capital Cost Comparison By Scenario

CAPITAL COSTS IN $ MILLIONS					
MCL Level (ppb)	**50**	**20**	**10**	**4**	**2**
Scenario					
Current	$0	$ 61	$164	$ 399	$ 498
Limit North	$0	$112	$401	$ 803	$1,003
Compact	$0	$158	$452	$1,035	$1,293
Trend	$0	$182	$549	$1,185	$1,481

Figure ES-3-1. Plot of Capital Costs by Scenario



An analysis of these results yields the following conclusions:

- COST SAVINGS BY SCENARIO. The trend dispersed scenario is the most costly and the compact development scenario a close second. However, substantial savings can be realized by limiting growth north of the City of Rio Rancho where groundwater with high arsenic is found.

- COSTS BY REQUIRED MCL. The cost growth functions are not linear in that costs increase substantially below a limit of 10 ppb MCL in all scenarios.

- ISLETA STANDARDS. The analysis assumed that in order to comply with Isleta Pueblo River discharge standards, up-stream wastewater would have to be discharged at the river background level of 4 ppb[1]. With this assumption, the cost to treat at the plant is $109 million for current conditions. This cost figure is less than treating at the well head for two reasons. First, the economy of scales that are realized by treating at one location and being on the low end of the unit capacity cost curve; and second, because only about half of the water actually pumped reaches the treatment plant for discharge into the river.

[1] 1 part per billion equals .001 mg/l.

1.0 PURPOSE

This paper will explore the relationship between current growth and space planning activities, arsenic water quality standards and the capital costs of water treatment for arsenic in the Middle Rio Grande (MRG) region. For purposes of this report, the MRG region is defined as the counties of Socorro, Valencia, Bernalillo, Torrance and South Santa Fe, New Mexico. Specifically, the paper will develop the capital costs associated with meeting both the Isleta Pueblo's water discharge standard for arsenic (Pueblo of Isleta, 1992) and the to-be-proposed federal drinking water standard for arsenic under different growth scenarios for the region. Capital costs only, as opposed to life cycle costs, are presented. It is the opinion of the author that large public capital budgeting decisions are generally made based on first cost versus life cycle cost. No attempt is made to split the costs out by city, county or drinking water utility.

Section One of the paper will discuss the occurrence of arsenic in the region's hydrogeology, concluding with a presentation of arsenic concentrations in the Albuquerque water-well fields. Section Two presents the projected population growth numbers for the region and the proposed space planning scenarios. Section Three discusses the costs of water treatment for arsenic and concludes by presenting the costs of arsenic treatment under each of three growth scenarios.

2.0 OCCURRENCE OF ARSENIC IN THE MIDDLE RIO GRANDE REGION

2.1 Arsenic Distribution in Riverwater

Dissolved arsenic and total arsenic samples compiled for sites along the Rio Grande from Colorado to El Paso, TX, are displayed in Table 3-1. The data were taken from the STORET database of the U.S. EPA and reported in Chapin and Dunbar (1994).

As can be seen, wide variations occur, with dissolved arsenic concentrations ranging from less than 1 ppb[2] to over 38.3 ppb at the Bernalillo wastewater treatment plant and 28.3 ppb at the confluence of the Jemez River. The arsenic content of the Rio Grande continues to be relatively high from the confluence of the Jemez to below Elephant Butte Dam. The highest concentrations occur between San Acacia and San Marcial (average 5 ppb) where the Rio Grande flows through an abundant rhyolitic volcanic rock formation (Goff and Shevenell, 1987). Below Bernalillo, The Rio Grande is an exotic river (Chapin and Dunbar, 1994), meaning that it flows through desert terrain with no perennial tributaries. For most of this region, it flows through sedimentary basins within or bordering volcanic fields. Thus, the high arsenic concentrations in this area reflect significant contributions from groundwater, from both natural in-flow to the river and artificially pumped groundwater from municipal water systems circulated through

[2] 1 part per billion equals 0.001 mg/l

wastewater treatment plants that do not control for arsenic. Discharges from the Bernalillo (38 ppb) and Rio Rancho (12-18 ppb) wastewater treatment plants reflect the volcanic nature of the region.

Table 3-1. Arsenic Concentrations in the Rio Grande

Average arsenic concentrations in water and sediment of the Rio Grande and selected tributaries (including some wastewater treatment plant discharges). All analyses from STORET data base as of 11/7/94. Number of samples given in parentheses.

Location	Geologic setting	When Sampled	Arsenic in Water: Dissolved Arsenic ppb (# samples)	Arsenic in Water: Total Arsenic ppb (# samples)
Near Lobatos, Co	San Luis Basin	3/75-8/91	2.3 (52)	2.7 (20)
Rio Lucero near Arroyo Seco	Taos Plateau	3/87-3/92	<1 (32)	<1 (32)
Above San Juan Pueblo	Española Basin	7/87-11/87	2.0 (2)	2.0 (2)
Rio Chama near Chamita, NM	Española Basin	8/71-11/91	1.8 (16)	2.2 (5)
Otowi Bridge	Española Basin	8/71-11/91	1.8 (57)	3.1 (20)
Cochiti Reservoir near Cochiti Pueblo	Santo Domingo Basin	6/81-6/91	2.2 (10)	2.2 (10)
San Felipe Pueblo	Santo Domingo Basin	2/74-1/92	1.9 (24)	2.2 (32)
Jemez River below Jemez Dam	Albuquerque Basin	1/74-5/80	28.1 (17)	39.5 (6)
Bernalillo wastewater treatment plant	Albuquerque Basin	7/88-9/91	38.3 (6)	
Rio Rancho utilities wastewater treatment plant #3	Albuquerque Basin	7/88-9/91	12.3 (6)	
Rio Rancho utilities wastewater treatment plant #2	Albuquerque Basin	6/91-9/91	17.8 (6)	
Alameda north Floodway channel	Albuquerque Basin	5/82-7/83	3.4 (15)	9.5 (26)
Albuquerque waste Drain	Albuquerque Basin	3/74	17.0 (4)	
Albuquerque	Albuquerque Basin	5/81-11/88	3.3 (8)	4.1 (8)
Albuquerque wastewater treatment plant #2	Albuquerque Basin	11/81-5/94	7.3 (10)	8.4 (7)
Interstate 25 Bridge	Albuquerque Basin	11/83-5/94	4.7 (9)	4.6 (5)
Los Lunas Bridge Near Isleta	Albuquerque Basin	8/75-2/92	4.1 (41)	5.4 (41)
Los Lunas wastewater treatment plant	Albuquerque Basin	5/94	12 (1)	16 (1)
Near Bernardo Floodway	Albuquerque Basin	5/82-3/92	4.3 (10)	5.3 (10)

(Source: Chapin and Dunbar, 1994)

However, in spite of these high discharges the dissolved arsenic in the Rio Grande as it flows through Albuquerque is only 3.3 to 4.7 ppb with an average of about 4 ppb. The reason for this appears to be the self-purification effect of arsenic sorbing onto iron, manganese and aluminum oxides in suspension and along the riverbed (Chapin and Dunbar, 1994).

2.2 Arsenic Concentration in Groundwater

A number of geochemical factors are associated with arsenic concentrations. In a study for the City of Albuquerque, The engineering firm of CH2MHILL reports that arsenic correlates positively with temperature, depth, flouride, sodium, chloride, silica, nitrate, alkalinity and pH of water. Inverse correlations are associated with hardness (Ca, Mg) and Eh[3]. Depth, temperature and fluoride content appear to be significant factors in increased arsenic concentrations (CH2MHILL, 1999).

Tables 3-2 and 3-3 contrast groundwater types in the MRG basin and their corresponding arsenic concentrations. As can be seen, shallow concentrations along the river, which tend to be recharged from the river, have lower concentrations while deeper wells moving away from the river produce higher concentrations. This water may or may not be, recharged from the river (Chapin and Dunbar 1994; and CH2MHILL, 1999). Albuquerque water wells range from 500 to over 1200 feet in depth.

Table 3-2. Changes in Water Chemistry and Arsenic Content Above and Below 1,200 feet in Total Depth in Albuquerque Municipal Wells. Taken From CH2MHILL (1999).

$Ca-Mg-HCO_3$, Water < 20 ppb Arsenic **pH 7-8 Eh 300 mV**
Avg TD 1200 ft
Alkaline Na – HCO_3, Water > 30 ppb Arsenic **Higher flouride** **pH 8-9 Eh 100mV**

Table 3-3. Contrasted Groundwater Types in the MRG Basin. Data Taken From CH2MHILL (1999).

Shallow Along River	Low Temp (10-20° C) Low Arsenic (< 20 ppb) Low flouride (< 1000 ppb) pH 7-8
Deeper Away From River	Higher temp (20- 40°) Higher Arsenic (30-50 ppb) Higher flouride (>1000 ppb) pH 7-8

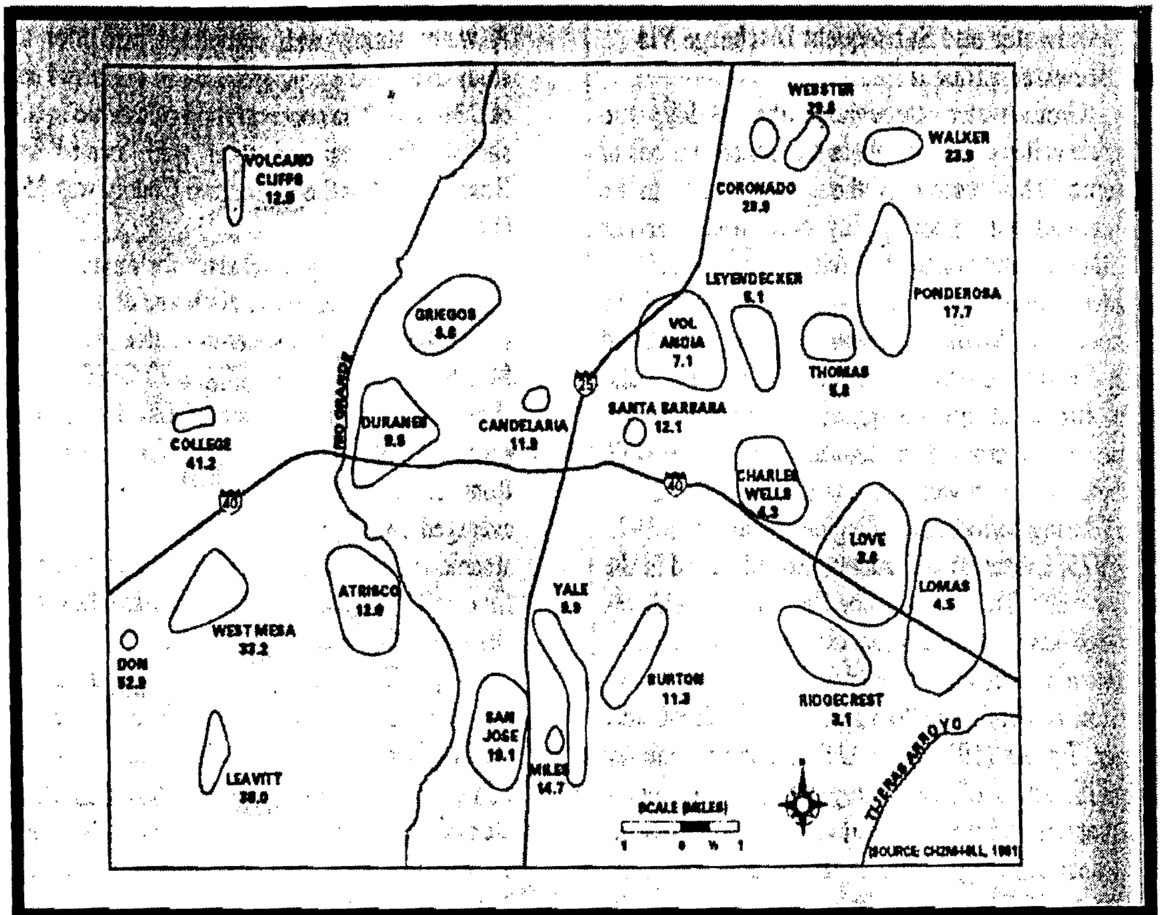
2.3 Arsenic Concentration in Albuquerque and Regional Water Wells

With the exception of the Bernalillo plant, which discharges at a mean concentration of 38 ppb, municipal wastewater treatment plants in the region discharge in the range of

[3] Eh is the electric potential of the solution it is used as a measure of the dissolved ion concentration.

7-18 ppb. Since these communities derive all of their municipal water from groundwater, 7-18 ppb may be a good approximation for average dissolved arsenic in groundwaters throughout the basin. However, the distribution in the Albuquerque well fields is highly variable as shown in Figure 3-1 which depicts the Albuquerque well fields and mean arsenic concentration levels.

Figure 3-1. Arsenic Concentrations in Albuquerque Well Fields



(Source: Flanigan, 1994)

The mean and ranges of arsenic in groundwater produced in Albuquerque wells between 1973 and 1994 and in the MRG basin between 1972 and 1989 are shown in Table 3-4 and their distribution is shown in Table 3-5. The mean arsenic content of 4,343 samples taken from 138 sample points in Albuquerque production wells between 1989 and 1994 is 12.8 ppb. Individual analyses range from 2 to 79.1 ppb. Only one well had a mean above 50 ppb and was closed. 77% of the sample sites had mean arsenic concentrations below 20 ppb while 11% were above 30 ppb.

Table 3-4. Arsenic (ppb) in Groundwater in the MRG Basin. From City of Albuquerque Unpublished Data and CH2MHILL (1999)

YEARS	MEAN	MIN	MAX	NUMBER
Albuquerque				
1973-1989	18.7	2.0	90	118
1894-1994	12.8	2.0	79	4343
Regional				
1972-1898	16.9	2.0	780	319

Table 3-5. Distribution of Arsenic in 138 Samples in Albuquerque Well Fields

CONCENTRATION	NUMBER OF SAMPLES
30 to 50 ppb	14 sample points
20 to 30 ppb	17 sample points
10 to 20 ppb	35 sample points
5 to 10 ppb	32 sample points
2 to 5 ppb	40 sample points

3.0 REGIONAL GROWTH AND SPACE PLANNING

To accommodate projected growth in the MRG region, the Middle Rio Grande Council of Governments (MRCOG) developed (and is still in the process of enhancing) the "FOCUS 2050 Scenarios." The scenarios constitute projected land growth patterns, displayed in visual geographic information format. Originally, six scenarios were developed but currently only four remain active: the compact growth, moderately compact growth, save the valley/develop the mesas, and the trend dispersed scenarios. These scenarios are shown in Appendix 3-1 along with an explanation of the density clusters.

To allow for "apples to apples" comparisons, all of the scenarios are based on a common set of population, employment and housing characteristics projected to the year 2050. The projections are detailed in MRGCOG Publication TR-127, *Socioeconomic Estimates and Forecasts to 2050*, Mar 1997. The projections include:

- Regional population is projected to increase at a rate of approximately 1.6% per year from approximately 700,000 persons today to approximately to 1.55 million by the year 2050.
- Dwelling units are projected to increase from 277,000 today to 694,100 by the year 2050.
- The average household size is projected to decrease from 2.6 persons per household to 2.4 persons per household in 2050.
- Employment is projected to increase from approximately 395,000 jobs today to 854,000 jobs in 2050.

Table 3-6 shows the projected population in each of the five counties under the four scenarios plus a fifth hybrid scenario. The hybrid scenario, called the Limit North Scenario, is used to calculate arsenic treatment cost savings if growth is restricted in the Bernalillo area north of Rio Rancho where high arsenic-groundwater concentrations exist. This paper will only look at the two extreme case scenarios shown in bold, the compact and trend dispersed growth scenarios, plus the hybrid Limit North Scenario.

Table 3-6. 2050 Population by County for Each Scenario

COUNTY	CURRENT	TREND SCENARIO	SAVE THE VALLEY	MODERATE COMPACT	COMPACT	COMPACT LIMIT GROWTH NORTH OF RIO RANCHO
Bernalillo	**480,577**	**838,900**	870,000	913,800	**890,800**	**890,800**
East ABQ	360,577	(400,000)			(600,000)	(600,000)
West Mesa	120,000	(438,900)			(290,800)	(290,800)
Sandoval	**63,319**	**400,000**	380,000	340,300	**392,300**	**392,300**
Rio Rancho	32,505	(300,000)			(200,000)	(361,486)
N of Rio Rancho	30,814	(100,000)			(192,300)	(30,814)
Valencia	**45,235**	**246,500**	248,500	232,800	**211,000**	**211,000**
Torrance	**10,285**	**41,000**	40,600	48,000	**35,000**	**35,000**
S Santa Fe	**16,000**	**29,600**	16,000	21,800	**25,000**	**25,000**
Approx. Totals		**1,555,100**	1,555,100	1,555,100	**1,555,100**	**1,555,100**

In order to determine future arsenic concentrations in water, we need to overlay these population projections with the spatial growth patterns and the well-field and groundwater arsenic concentrations presented earlier. To do this, average groundwater arsenic concentrations were determined for each of seven well field areas using information developed above (Figure 3-1, Albuquerque well field map, and Table 3-1, arsenic concentration in the river). Table 3-7 presents the results of this determination.

Table 3-7
Average Arsenic Concentrations in Well Fields Served By Population Projections

WELL FIELD AREA	AVERAGE AS CONCENTRATION (PPB)
East Albuquerque	6.25
West Mesa	36.80
Rio Rancho	15.00
Bernalillo City	38.30
Valencia County	22.50
Torrance County	Not Avail
S. Santa Fe	Not Avail

Combining Tables 3-6 and 3-7, with the City of Albuquerque's projected water consumption planning figure of 175 gallons per person per day (gpcd) (City of Albuquerque sustainable water plan, Public Works Department), we can create Table 3-8 below depicting the future arsenic treatment requirements in million of gallons per day (MGD) for each arsenic concentration level under each scenario (See Appendix 3-2 for detailed calculations).

Table 3-8. As Level by Scenario and Million of Gallons per Day Delivered (MGD) at That As Level in Each Area

Area	As Level (ppb)	Current (MGD)	Trend (MGD)	Compact (MGD)	Limit North (MGD)
East Albuquerque	6.25	63.10	70.00	105.00	105.00
West Mesa	36.79	21.00	76.81	50.89	50.89
Rio Rancho	15.00	5.69	52.50	35.00	63.26
Bernalillo City	38.30	5.39	17.50	33.65	5.39
Valencia County	22.50	7.92	43.14	36.93	36.93
Torrance County	Not Avail	1.80	7.18	6.13	6.13
S. Santa Fe	Not Avail	2.80	5.18	4.38	4.38

The next section will discuss treatment costs in terms of treatment plant capacity in MGD, desired maximum contaminant level (MCL), and average arsenic concentration.

4.0 ARSENIC TREATMENT COSTS

This section draws heavily upon the *Arsenic Treatment Evaluation Report* done by the engineering firm of CH2MHILL for the City of Albuquerque, April 1999. The purpose of the report was to evaluate three technologies proven to remove arsenic from drinking water – ion exchange, coagulation/microfiltration (CMF) and activated alumina. Each technology was investigated to determine the capital and operating and maintenance costs (Note: this study will determine capital costs only) as well as other decision criteria such as implementability and effectiveness. The overall most feasible method was determined to be CMF. This report develops extended capital costs for the CMF method under different growth scenarios. Also note that the CH2MHILL report caveats that its cost values are to be considered for feasibility analysis only and are generally considered to be in the range of –15% to +30% (CH2MHILL, 1999).

Using the CMF method, the capital costs of treatment is a function of three parameters:

(1) **Capital Costs,** $\mathbf{P_c = f(F, C, M)}$

Where P_c = The capital price of the plant in dollars

F = The design flow rate of the plant in MGD

C = The average arsenic concentration in the well field

M = The desired arsenic output level in ppb
(also known as the maximum contaminant level (MCL))

To determine these parameters, the CH2MHILL unit cost curves for treatment plant capacity and required MCL were used (see Figures 3-2 and 3-3).

Figure 3-2. System Wide Capital Costs by Capacity

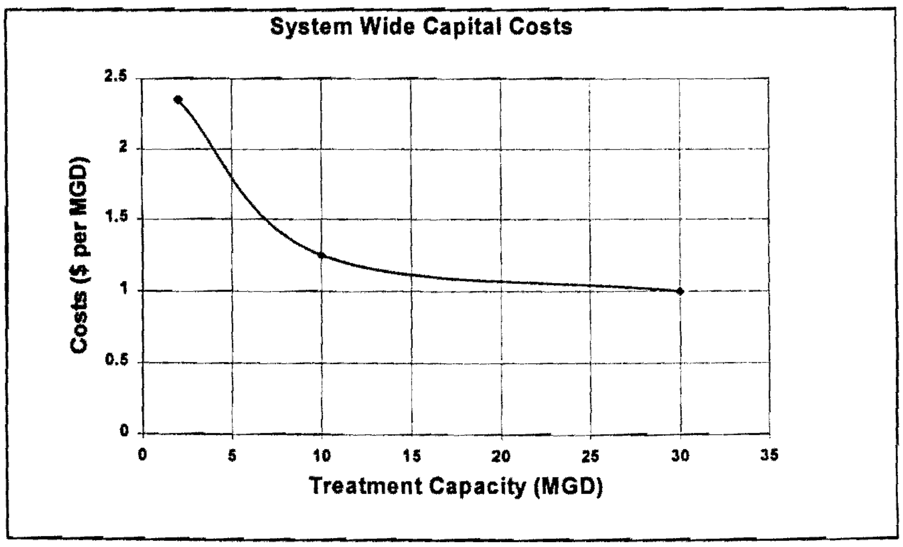
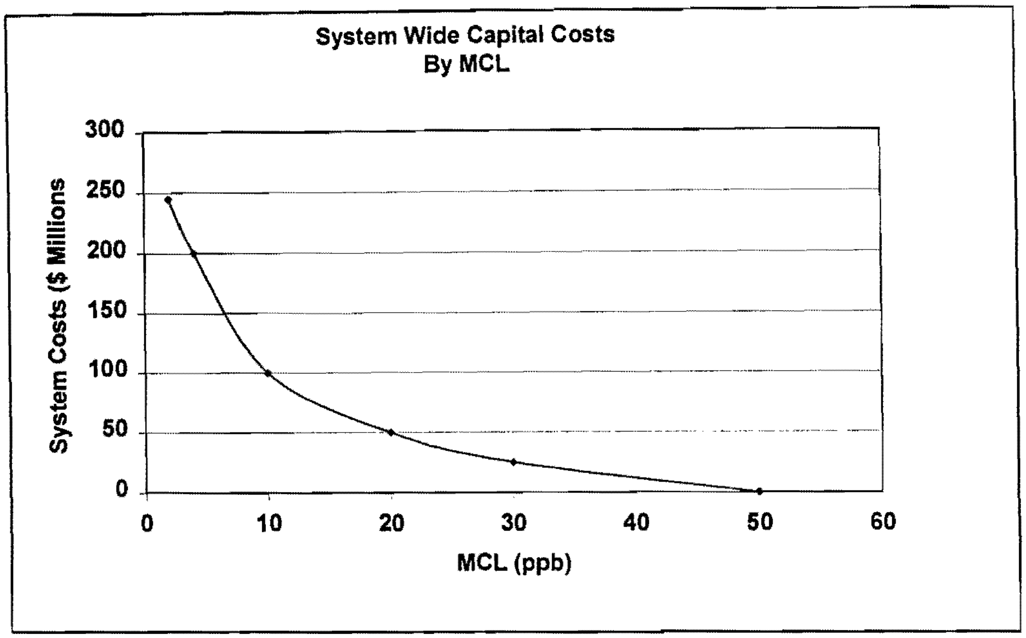


Figure 3-3. System Wide Capital Costs by MCL



Figures 3-2 and 3-3 depict system-wide capital costs for arsenic treatment. Figure 3-3 shows capital costs as a function of the required MCL. Fig 3-2 shows capital costs per MGD treated as a function of overall treatment plant capacity. In Figure 3-3, it can clearly be seen that the marginal cost of treatment (or the cost to treat to one more unit) rises at an increasing rate as the MCL is lowered. Conversely, the marginal cost of treatment decreases sharply as the treatment plant capacity is expanded.

The slopes, elasticities and ranges of these curves were used to develop the factor tables in Appendix 3-2. Each factor table corresponds to one of the three parameters F, C or M above. The factor tables were then applied to the population and required MGD distributions for each scenario to develop total system costs for that scenario. The tables, analyses and calculations are in Appendix 3-2.

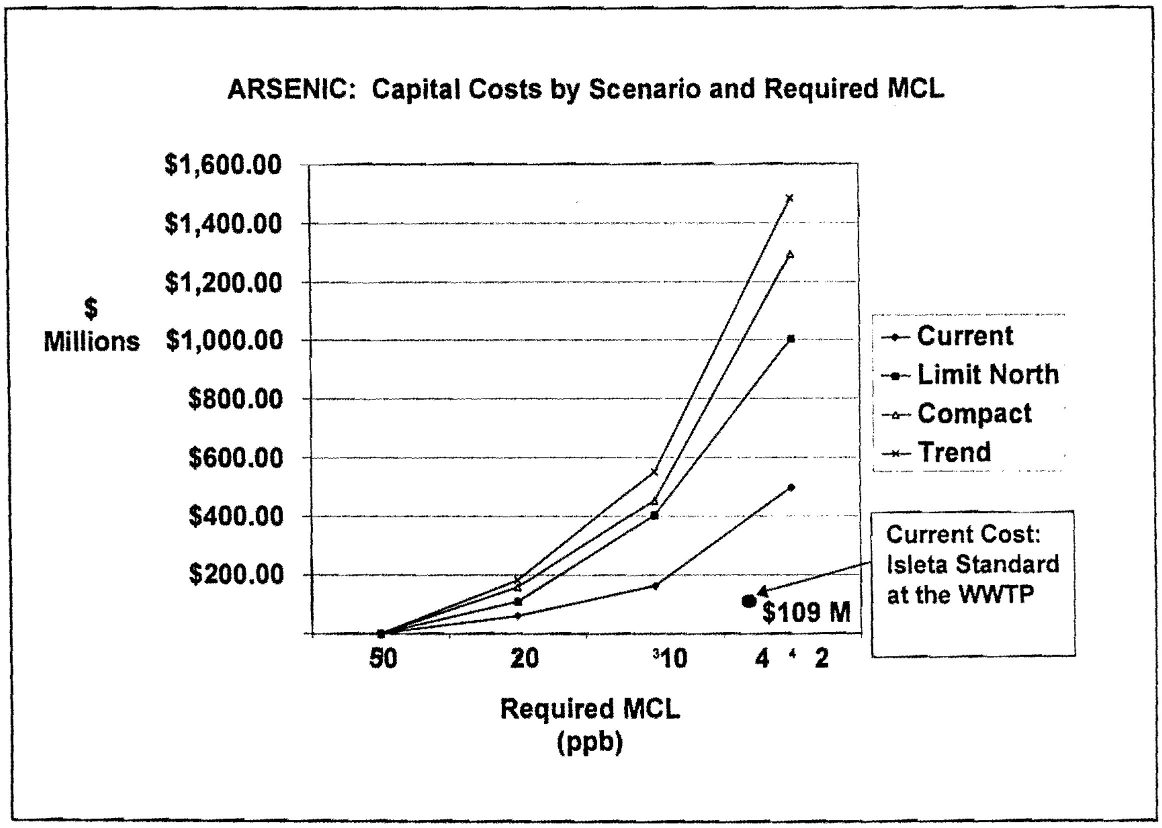
To ensure accuracy the current situation scenario costs developed using this model were compared and calibrated against the current costs determined in the CH2MHILL study. The calibration factor was applied to bring our model within the –15% to +30% error range of the CH2MHILL model. The calibration factor was only –3.0% at the low MCL range, or high cost range, of the model. This confirms that our model is conservative in that it reflects the high range of costs in each scenario.

The results of the analysis are shown in Table 3-9 and Figure 3-4 on the next page.

Table 3-9. Capital Cost Comparison by Scenario

CAPITAL COSTS IN $ MILLIONS					
MCL Level (ppb)	50	20	10	4	2
Scenario					
Current	$0	$ 61	$164	$ 399	$ 498
Limit North	$0	$112	$401	$ 803	$1,003
Compact	$0	$158	$452	$1,035	$1,293
Trend	$0	$182	$549	$1,185	$1,481

Figure 3-4. Plot of Capital Costs by Scenario



5.0 CONCLUSIONS

An analysis of these results yields the following conclusions:

- COST SAVINGS BY SCENARIO. The trend dispersed scenario is the most costly and the compact development scenario a close second. However, substantial savings can be realized by limiting growth north of the City of Rio Rancho where groundwater with high arsenic is found.

- COSTS BY REQUIRED MCL. The cost growth functions are not linear in that costs increase substantially below a limit of 10 ppb MCL in all scenarios.

- ISLETA STANDARDS. The analysis assumed that in order to comply with Isleta Pueblo River discharge standards, up-stream wastewater would have to be discharged at the river background level of 4 ppb. With this assumption, the cost to treat at the plant is $109 million for current conditions. This cost figure is less than treating at the well head for two reasons. First, the economy of scales that are realized by treating at one location and being on the low end of the unit capacity cost curve; and second, because only about half of the water actually pumped reaches the treatment plant for discharge into the river.

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APPENDIX 3A

Middle Rio Grande Council of Governments
"FOCUS 2050" Planning Scenarios

FOCUS
2050

FOCUS 2050 ALTERNATIVE REGIONAL SCREEN SCENARIOS
August 18, 1998

The four Focus 2050 Screen Scenarios have been developed by the Middle Rio Grande Council of Governments (MRGCOG) at an "intermediate" level of detail displaying an array of urban form patterns. The Screen Scenarios will be used to: (1) refine the Focus 2050 Concept Scenarios (issued March 23, 1998), (2) give guidance to developing more detailed land use alternatives, and (3) provide the basis for a comprehensive, qualitative analysis of alternative growth patterns. During the Fall of 1998, evaluations of the Screen Scenarios will be conducted by MRGCOG staff and several technical groups.

In mid-January, 1999 the Screen Scenarios will be exhibited, described, compared, and "debated" at public conferences held throughout the Region.

The ultimate goal of the alternative scenarios process is to arrive at the preferred regional land use alternative. The Focus 2050 planning process is an extensive forum for gathering information about regional growth and development, sharing ideas, discussions of impacts and, ultimately, choices about the qualities of the future. The preferred alternative should provide for the most sustainable regional assemblage of communities, give us the highest quality of life and best preserve and enhance the most cherished qualities of our communities, as defined in the **Focus 2050 Regional Vision Statement and Goals.**

Each of the scenarios shows for the total region approximately 1.55 million residents, 416,900 housing units and 854,000 jobs projected by year 2050, with variations of plus or minus 5%. The scenarios are briefly described below, followed by comparative tables.

1. *Trend Dispersed Growth Scenario* continues patterns of urban build-out generally ringing the metropolitan area and around Valencia County municipalities and substantial rural development flanking the metropolitan area and scattered across mesas and towards mountain edges.

2. *Save the Valley, Develop the Mesas Growth Scenario,* minimizes additional disturbance of the Rio Grande Valley irrigated agricultural lands and Bosque and develops identified major development projects and other areas in contiguous areas. More in-fill, mixed use centers and corridors are shown to accommodate development in existing urban areas.

3. *Moderate Compact In-Fill and New Communities Growth Scenario* minimizes new development in the Rio Grande Valley and emphasizes in-fill in existing communities and clusters of satellite urban communities on the Bernalillo County West Mesa and Rio Rancho area, Mesa del Sol and Valencia County East Mesa.

4. *Compact Growth Scenario* also minimizes new development in the Rio Grande Valley and contains a hierarchy of centers mainly in existing communities, including regional centers, subregional centers, neighborhood centers, and Main Streets where in-fill and redevelopment are focused. A limited amount of new urban land area is located contiguous to existing communities. Very little rural subdivision expansion would occur.

Accompanying August 18, 1998
Focus 2050 Screen Scenarios;
September 11, 1998 Calculations 1/

Total Urbanized Land
(Square Miles)

Scenario	Bernalillo 2/	Sandoval	Valencia	Torrance	Santa Fe	Total
Existing 3/	154.37	37.31	33.77	29.92	12.53	267.9
Trend Dispersed	296.23	187.02	122.83	70.93	74.4	751.41
Save the Valley	260.64	143.28	112.36	42.2	31.32	589.81
Moderate Compact	221.75	101.6	85.75	43.27	23.09	475.46
Compact Development	209.84	76.51	59.46	35.64	22.08	403.53

Total Population

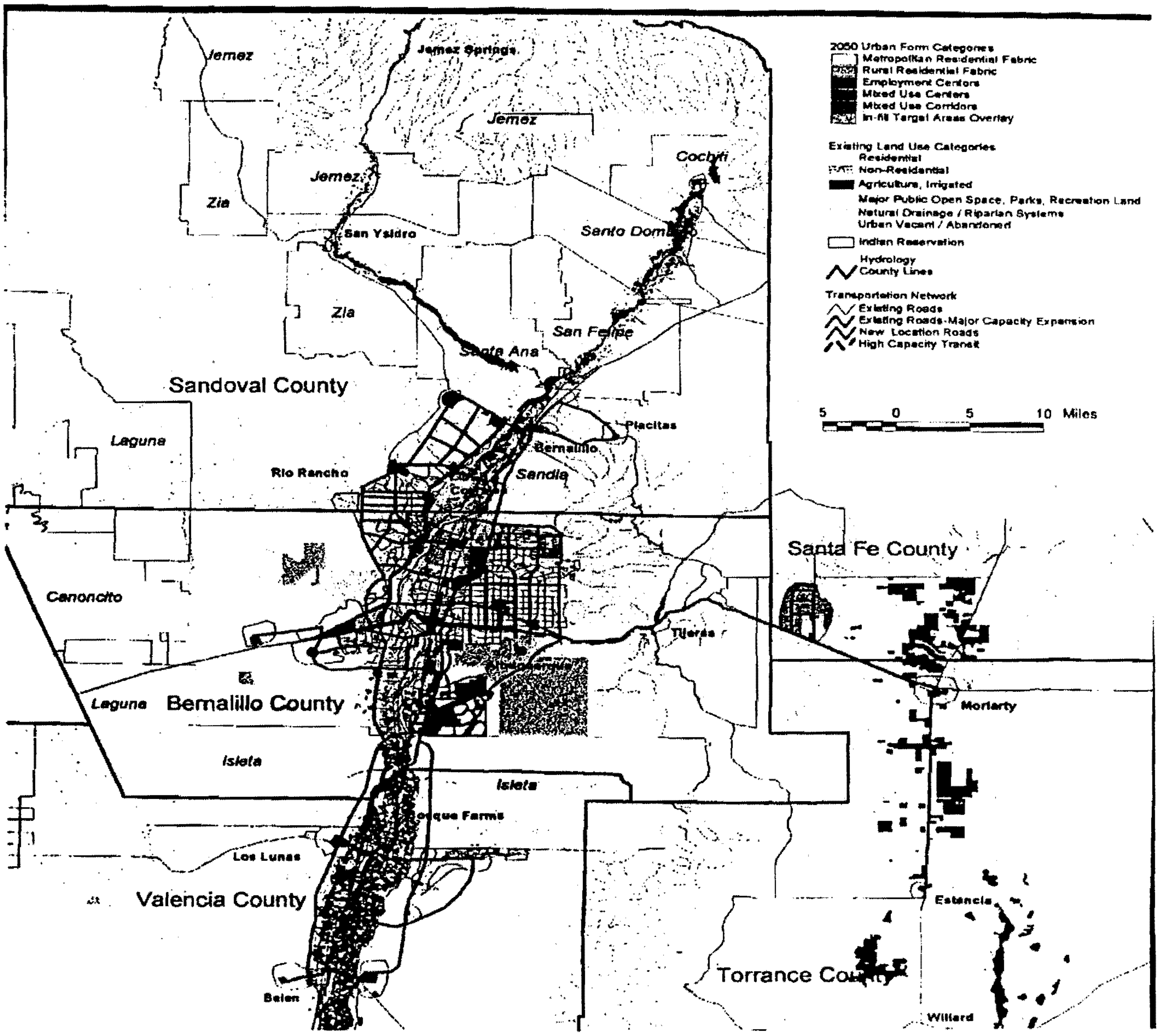
Scenario	Bernalillo	Sandoval	Valencia	Torrance	Santa Fe	Total
Existing 4/	524,820	79,268	56,833	13,038	8,000	681,959
Trend Dispersed	835,700	372,900	243,100	82,000	29,800	1,563,500
Save the Valley	861,100	369,300	180,600	33,600	43,800	1,488,400
Moderate Compact	910,400	309,300	229,800	48,700	25,100	1,523,300
Compact Development	886,400	363,900	216,400	37,400	25,700	1,529,800

Total Employment

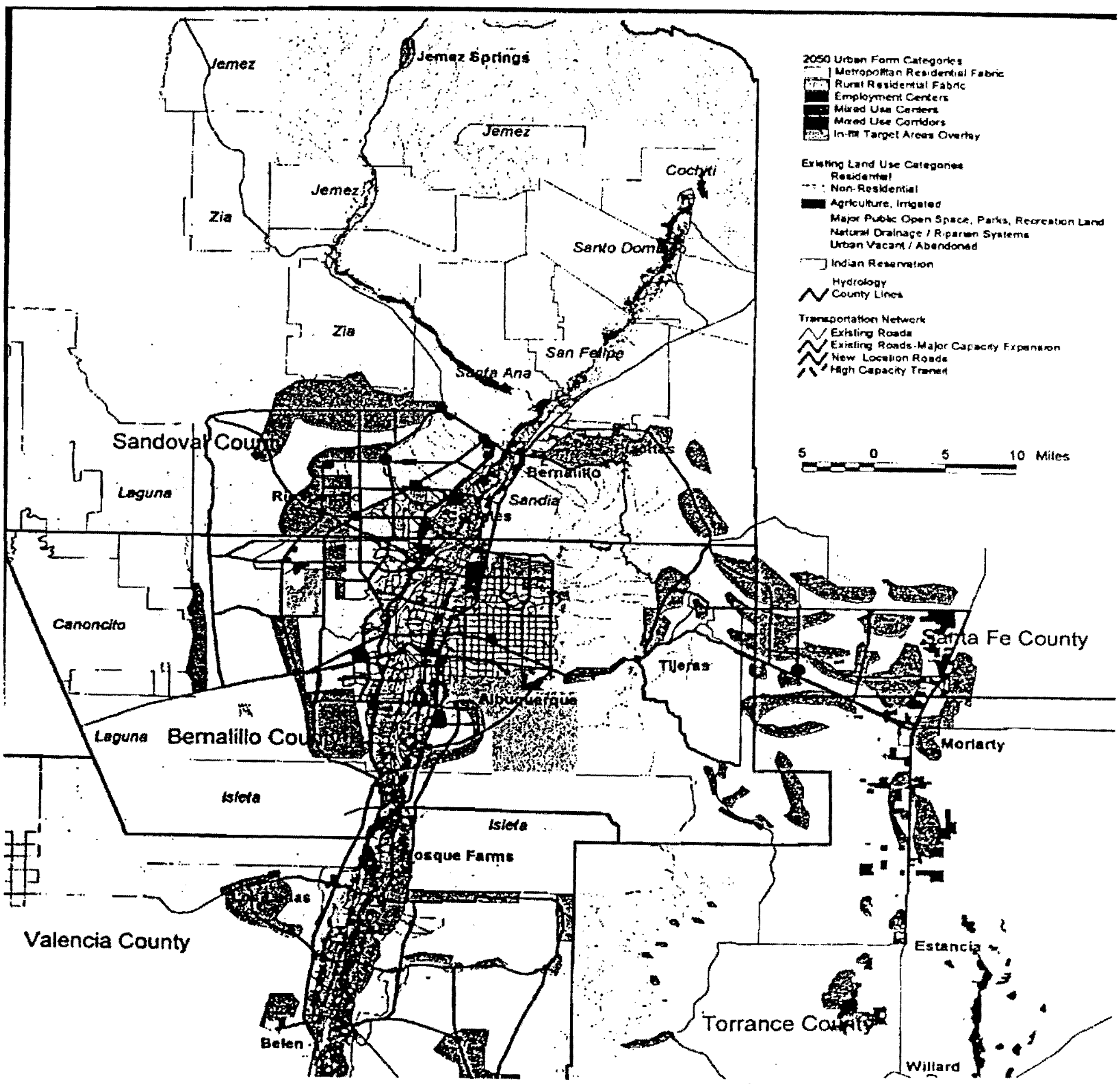
Scenario	Bernalillo	Sandoval	Valencia	Torrance	Santa Fe	Total
Existing 4/	302,649	21,463	12,453	2,581	470	339,616
Trend Dispersed	616,900	156,500	67,500	8,600	4,300	853,800
Save the Valley	609,700	154,600	63,000	7,700	5,400	840,400
Moderate Compact	617,400	154,500	57,600	8,800	4,500	842,800
Compact Development	614,700	158,900	63,400	7,100	3,800	847,900

1/ These calculations are provisional for the Screen Scenario series. More refined numbers are anticipated for the scenarios resulting from the LAM model run to replace these numbers.
2/ Urbanized land in Bernalillo County excludes Kirtland Air Force Base due to the large acreage that is not developed
3/ Base year of existing land use is 1996/97 from Existing Land Use Inventory Report. 1998, MRGCOG, unpublished.
4/ Base year for population and employment is 1995 from 1995 Socioeconomic Estimates, MRGCOG, TM-126.

FOCUS 2050
Compact Development Scenario



FOCUS 2050
Trend Dispersed Scenario



APPENDIX 3B

Capital Costs by Scenario – Calculation Tables

Capital Costs By Scenario
And Required MCL

Current Situation					Total Capital Costs ($Millions)			
Scenario	Avg As Well Level	Well Field MGD	Well As Concentration Factor	Plant Capacity Factor	MCL Level 20 ppb	MCL Level 10 ppb	MCL Level 4 ppb	MCL Level 2 ppb
Required MCL Factor					1	2	4	5
East Albuquerque	6.25	63.10	0.31	1.00	$0	$0	$71	$89
West Mesa	36.79	21.00	1.84	1.10	$42	$85	$170	$212
Rio Rancho	15.00	5.69	0.75	1.75	$0	$15	$30	$37
Bernalillo City	38.30	5.39	1.92	1.75	$18	$36	$72	$90
Valencia County	22.50	7.92	1.13	1.55	$0	$28	$55	$69
Torrance County	Not Avail	1.80	0.00					
S. Santa Fe	Not Avail	2.80	0.00					
Total					$61	$164	$399	$498

NOTE:
CH2MHILL's Capital Costs Computed for Albuquerue's Current Situation Were as Follows
Compared to The Cost for East and West Albuquerque as Computed Here

Calc Method	MCL Level 50 ppb	MCL Level 20 ppb	MCL Level 10 ppb	MCL Level 4 ppb	MCL Level 2 ppb
CH2MHILL	$0.00	$50.00	$100.00	$215.00	$250.00
Computed Here	$0.00	$42.49	$84.98	$241.27	$301.59
Error Margin*	0	15.02%	15.02%	-12.22%	-20.64%

* Compare to CH2MHILL's Estimated error Range of -15% to +30%

TREND DISPERSED SCENARIO					Total Capital Costs ($Millions)			
Scenario	Avg As Well Level	Well Field MGD	Well As Concentration Factor	Plant Capacity Factor	MCL Level 20 ppb	MCL Level 10 ppb	MCL Level 4 ppb	MCL Level 2 ppb
Required MCL Factor					1	2	4	5
East Albuquerque	6.25	70.00	0.31	1.00			$88	$109
West Mesa	36.79	76.81	1.84	1.00	$141	$283	$565	$706
Rio Rancho	15.00	52.50	0.75	1.00		$79	$158	$197
Bernalillo City	38.30	17.50	1.92	1.20	$40	$80	$161	$201
Valencia County	22.50	43.14	1.13	1.10		$107	$214	$267
Torrance County	Not Avail	7.18						
S. Santa Fe	Not Avail	5.18						
Total					$182	$549	$1,185	$1,481

COMPACT GROWTH SCENARIO					Total Capital Costs ($Millions)			
Scenario	Avg As Well Level	Well Field MGD	Well As Concentration Factor	Plant Capacity Factor	MCL Level 20 ppb	MCL Level 10 ppb	MCL Level 4 ppb	MCL Level 2 ppb
Required MCL Factor					1	2	4	5
East Albuquerque	6.25	105.00	0.31	1.00			$131	$164
West Mesa	36.79	50.89	1.84	1.00	$94	$187	$374	$468
Rio Rancho	15.00	35.00	0.75	1.00		$53	$105	$131
Bernalillo City	38.30	33.65	1.92	1.00	$64	$129	$258	$322
Valencia County	22.50	36.93	1.13	1.00		$83	$166	$208
Torrance County	Not Avail							
S. Santa Fe	Not Avail							
Total					$158	$452	$1,035	$1,293

LIMIT GROWTH NORTH SCENARIO					Total Capital Costs ($Millions)			
Scenario	Avg As Well Level	Well Field MGD	Well As Concentration Factor	Plant Capacity Factor	MCL Level 20 ppb	MCL Level 10 ppb	MCL Level 4 ppb	MCL Level 2 ppb
Required MCL Factor					1	2	4	5
East Albuquerque	6.25	105.00	0.31	1.00			$131	$164
West Mesa	36.79	50.89	1.84	1.00	$94	$187	$374	$468
Rio Rancho	15.00	63.26	0.75	1.00		$95	$190	$237
Bernalillo City	38.30	5.39	1.92	1.75	$18	$36	$72	$90
Valencia County	22.50	36.93	1.13	1.00		$83	$166	$208
Torrance County	Not Avail	6.13						
S. Santa Fe	Not Avail	4.38						
Total					$112	$401	$803	$1,003

ANTICIPATED HYDROLOGIC EFFECTS OF MANAGEMENT PRACTICES IN PONDEROSA FORESTS

Kelly A. Bitner

Executive Summary. The present state of the ponderosa pine forests in the southwest is unhealthy. The accumulation of organic matter in the forests is an invitation for catastrophic fires. Studies show that the forest must be thinned to restore its health and reduce the fire danger. A significant change in the forests may result in changes to the hydrologic cycle. It is important to recognize and mitigate, if necessary, any adverse impacts those hydrologic changes may have on the people who depend on the water.

There are no available experiments, studies, or investigations that have been conducted in the northern New Mexico region that would help in developing a prediction of hydrologic response. However, in the 1960s and 1970s, scientists conducted a number of watershed studies to assess increasing water yield by manipulating vegetation. The watershed studies conducted in areas with similar characteristics (conifer forests on mountainous slopes) can provide analogies. Hydrologic responses that were consistently observed in these analogous watersheds are likely to also occur in the Sangre de Cristo Mountains. The hydrologic observations of 125 watershed studies were reviewed for hydrologic responses to vegetation changes.

The ponderosa pine forest in the Carson and Santa Fe National Forests has a much different appearance and structure than they did 100 years ago, at the time of euro-american settlement. Pre-settlement ponderosa pine forests were open grassy areas with single large trees or stands of trees widely separated. The current forest structure is densely packed with predominantly small trees. These conditions have been attributed to grazing, logging, and fire.

The anticipated hydrologic responses to restoring the ponderosa pine forests to approximate pre-settlement conditions are decreases in interception and evapotranspiration, which will result in increases of overland flow and subsurface flow. As surface and subsurface water are increased, the water yield is expected to increase. Factors that confound the predictions of the magnitude of these changes are the site-specific nature of the responses and extrapolation of small-scale studies to the watershed scale of restoration. With the information currently available it is not possible to discern whether the responses observed on the drainage scale are accurate predictors of the watershed-scale response or if the synergistic effects of all the drainages in a watershed would result in an additive response at the watershed scale. Process-based modeling may be the best approach to extrapolating the effects to the watershed scale.

The restoration of ponderosa forests would not only result in healthy forests and decreased risk of catastrophic fires, but would also likely result in a sustainable water supply for the residents on the flanks of the Sangre de Cristo Mountains.

1.0 INTRODUCTION

Water from the Sangre de Cristo Mountains flows through and is affected by the ponderosa pine forests. The water is used by residents of small towns for irrigation of the crops that are their livelihood. This water has been a sustainable resource for the past 200 years; it met the needs of the present without compromising the ability of future generations to meet their own needs. Changes made to the ponderosa forest must be carefully evaluated to ensure this water remains a sustainable resource into the future.

1.1 Purpose

The present state of the ponderosa pine forests is unhealthy (Forest Service, 1997). The accumulation of organic matter in the forests is an invitation for catastrophic fires. Studies show that the forest must be thinned to restore its health and reduce the fire danger. A significant change in the forests may result in changes to the hydrologic cycle. It is important to recognize and mitigate, if necessary, any adverse impacts those hydrologic changes may have on the people who depend on the water. This paper examines the anticipated effects of restoring ponderosa forests on the hydrologic system.

1.2 Scope

The actual response of the hydrologic system to thinning the ponderosa pine forests in the Sangre de Cristo Mountains can not be predicted quantitatively or with much certainty. There are no available experiments, studies, or investigations that have been conducted in this geographic region that would help in developing a prediction of hydrologic response. However, in the 1960s and 1970s, scientists conducted a number of watershed studies to assess increasing water yield by manipulating vegetation. The watershed studies conducted in areas with similar characteristics (conifer forests on mountainous slopes) can provide analogies. Hydrologic responses that were consistently observed in these analogous watersheds are likely to also occur in the Sangre de Cristo Mountains.

The hydrologic observations of 125 watershed studies were reviewed for hydrologic responses to vegetation changes. The results of this review are summarized in Appendix 4A. Observations on some easily measured elements of the forest hydrologic cycle, such as stream flow and snow accumulation, are plentiful. Observations regarding other elements, such as infiltration and low flows, are essentially absent.

Reported observations of hydrologic responses that occurred that were consistent across watersheds were used to construct a qualitative conceptual model of the forest hydrologic cycle under restored forest conditions. A quantitative estimate of hydrologic response could not be constructed because the reported results vary so widely and are watershed-specific. Thus, the direction of change (i.e. increase or decrease) in elements of the hydrologic cycle that might be expected from restoring the ponderosa pine forests can be reasonably predicted, but the magnitude of those changes cannot be. Similarly, while predictions of how each element of the hydrologic cycle may change, the result of the synergistic interaction of all of the elements cannot be predicted without site-specific data.

1.0 PAST AND PRESENT FOREST CONDITIONS

Ponderosa pine (*Pinus ponderosa)* forests are present in the Sangre de Cristo Mountains of northern New Mexico. These forests occupy a swath of the mountain flanks between the elevations of 2,300 to 4,300 meters (7,500 to 14,000 feet) (Dahms and Geils, 1997). The precipitation ranges from 600 to 700 millimeters (24 to 28 inches) (Dahms and Geils, 1997). The ponderosa pine forest that can be seen in the Carson and Santa Fe National Forests has a much different appearance and structure than it did 100 years ago, at the time of euro-american settlement (Covington and Moore, 1994; Dahms and Geils, 1997; Nijhuis, 1999; Savage, 1991). The current forest structure has been attributed to grazing, logging, and fire (Covington and Moore, 1994; Dahms and Geils, 1997). Restoring the ponderosa pine forests will require reestablishing the forests to approximate pre-settlement conditions and allowing the ecological processes that maintained the pre-settlement conditions to function. This section describes the pre-settlement ponderosa pine forests, the changes brought about by euro-american settlement, and the current forest conditions.

2.1 Pre-Settlement Ponderosa Pine Forests

Ponderosa pine forests in the southwest prior to European settlement in the early 1800s were characterized as open park-like forests with lush grass carpeting the forest floor (Dahms and Geils, 1997; Covington and Moore, 1994; Savage, 1991). The pre-settlement condition of the southwestern pine forests is documented in the diaries of travelers at the time. Covington and Moore (1994) quoted from E.F. Beale's 1858 report:

> *We came to a glorious forest of lofty pines, through which we have traveled ten miles. The country was beautifully undulating, and although we usually associate the idea of barrenness with the pine regions, it was not so in this instance; every foot being covered with the finest grass, and beautiful broad grassy vales extending in every direction. The forest was perfectly open and unencumbered with brush wood so the traveling was excellent.*

Savage (1991) quoted from C. E. Dutton's 1882 journal:

> *The trees are large and noble of aspect and stand widely apart....Instead of dense thickets where we are shut in by impenetrable foliage, we can look far beyond and see the tree trunks vanishing away like an infinite colonnade....There is a constant succession of parks and glades....*

These written records along with photographs and archaeological reconstructions suggest that the characteristic vegetative assemblage in the ponderosa pine forests was a grass matrix with individuals, clumps, and stringers of large and variously-sized ponderosa pine trees (Dahms and Geils, 1997). The average canopy coverage was on the order of 17% to 30% (Covington and Moore, 1994). On a larger scale, these forests were likely a mosaic of open grass savanna with clumps of large pine trees mixed in with dense patches and stringers of young ponderosa pine (Dahms and Geils, 1997).

This ponderosa pine forest mosaic was primarily the result of two processes: ponderosa pine reproduction and fires. The dense stands of young ponderosa pine trees were the result of the reproduction process. Ponderosa pines naturally regenerate only when the seeds fall on a mineralized seedbed where there is little vegetative competition. A certain sequence of events leads to these conditions. First, the death of one tree or a stand of mature trees occurs, usually by lightning (and associated fire), dwarf mistletoe, bark beetles, windthrow or senescence (Dahms and Geils, 1997). Next, the dead trees fall to the forest floor and are eventually burned by surface fires. The presence of the dead wood made the fires hotter in these localized areas, producing the mineral seedbed and reduced grass competition conducive to ponderosa pine seedling establishment. Finally, within the severely burned microsites, seedlings could survive, grow and develop their competitive ability and resistance to fire (Dahms and Geils, 1997). Covington and Moore (1994) report that the pre-settlement ponderosa pines were aggregated in groups of 2 to 44 stems that occupy areas of 0.03 to 0.3 hectares (0.08 to 0.7 acres). Repetition of the reproduction sequence led to a landscape of uneven-aged forest composed of small, relatively even-aged stands of trees (Dahms and Geils, 1997).

The open grassy savanna portions of the ponderosa pine forest mosaic were maintained by the fire regime of frequent low-intensity burns. Prior to settlement, fires burned these areas every 2 to 12 years (Covington and Moore, 1994; Dahms and Geils, 1997). Studies of fire scars suggest that the average burned area covered 1,200 hectares (3,000 acres) and crown fires were rare or nonexistent (Covington and Moore, 1994). Fires of this frequency were sufficient to normally prevent reproduction by ponderosa pine or other conifers and to encourage the development of grassy understories (Dahms and Geils, 1997). Mature ponderosa pine trees have thick bark that makes them quite fire resistant, so the large ponderosa pines were retained in this fire regime.

Thus, the pre-settlement ponderosa pine forest consisted of open grassy savanna with a mosaic of singular mature pine trees, stringers of trees, and clumps of even-aged trees. This mosaic was maintained by a fire regime of frequent low-intensity fires that increase nutrient cycling in the soil, encourage the growth of grasses and forbs, and kills small woody vegetation.

2.2 Effects of Euro-American Settlement

Euro-american settlement affected the ponderosa pine forests in three principal ways: grazing, logging, and fire suppression. The introduction of domestic livestock, primarily sheep, began with the Spanish occupation in the late 1500s (Dahms and Geils, 1997). By 1890, cattle numbers in New Mexico and Arizona had increased to more than 1.5 million and additional large numbers of sheep were also being grazed (Dahms and Geils, 1997). The ponderosa pine forest was used for summer grazing until the forest reserves were set aside in 1891 (Dahms and Geils, 1997). The effect of grazing on the mountains was illustrated by Theodore Rixon in 1912, one of the first foresters in the southwest (Dahms and Geils, 1997):

> *The mountains were denuded of their vegetative cover, forest reproduction was damaged or destroyed, the slopes were seamed with deep erosion gullies, and the water-conserving power of the drainage basins became seriously impaired.*

The result of the removal of grasses from the forests was to remove the fuel for fires. Without the dried grasses, there was no fuel to carry the fires through the open savanna areas. It also left open soil areas that are conducive to ponderosa pine seedling establishment. Thus, grazing encouraged the reproduction of ponderosa pine trees, with the concomitant decrease in open areas by removing fuel and fires and encouraging the establishment of seedlings.

Commercial logging has been conducted in the southwest for over 100 years. Major logging efforts were associated with the harvest of railroad ties and other products during the construction of the transcontinental railroad (Dahms and Geils, 1997; DeBuys, 1985). Logging not only removes trees, but also requires the construction of roads. The combined effects of clear cutting trees and building roads increased the soil erosion and left a mineral seedbed that favors the establishment of ponderosa pine seedlings. The result of logging is a dense growth of ponderosa pines that are nearly all the same age.

Fire suppression began in the early 1900s (Covington and Moore, 1994; Dahms and Geils, 1997). Fire suppression has led to the buildup of fire fuel materials on the forest floor and to the establishment of younger trees that act as fuel ladders that carry fire into the canopy. The result is that when fires occur they are catastrophic stand-replacing fires. This type of fire regime results in mineral seedbeds over large areas, again encouraging the establishment of dense even-aged stands of ponderosa pines.

2.3 Current Ponderosa Pine Forest Conditions

The most basic forest health problem in the southwest is the overstocking of small and mid-size trees (Forest Service, 1997). The forests consist of dense thickets of ponderosa saplings and pole stands (Dahms and Geils, 1997). In New Mexico and Arizona national forests, the ponderosa pine density in 1996 averaged 294 trees per acre (Dahms and Geils, 1997) and has been reported up to 750 trees per acre (Covington and Moore, 1994).

In addition to tree density, another feature of today's forests is the number of small trees. Forest inventories conducted in 1910 and in 1985 illustrate this point. In 1910, a typical acre of trees in a ponderosa forest consisted of 3 large (>60 cm [24 inches] diameter at breast height [dbh]) trees, 5 medium (46-60 cm [18-24 inches] dbh), and 17 small (< 46 cm [18 inches] dbh). In contrast, the 1985 inventory suggests that an acre of ponderosa pine forest would contain 2 large, 6 medium, and 149 small trees (Dahms and Geils, 1997). In a study of ponderosa pine forest in the Chuska Mountains of New Mexico, from 1935 to 1979, the area of moderately dense forest increased up to 39% and the area of dense forest increased up to 24% (Savage, 1991).

Dense tree stands have nearly 100 % canopy cover, which limits energy to the forest floor and intercepts precipitation. Less energy results in a reduction in the rate of nutrient cycling and limits the diversity of understory plants. In the Chuska Mountains, the extent of grassy areas was reduced by 30% from 1935 to 1979 (Savage, 1991). The grassy understory that used to be prevalent has been replaced by thick accumulation of pine needle duff that breaks down slowly with the limited energy inputs. Interception decreases the amount of water reaching the forest floor. The water that does reach the floor is absorbed and held by the duff (White, 1999), decreasing infiltration of water into the soil.

Increased tree density in the current ponderosa pine forests has resulted in unhealthy forests in the following ways (Dahms and Geils, 1997; Covington and Moore, 1994):

- Reduced tree growth and increased mortality
- Reduced abundance and diversity of understory plants
- Increased ladder fuels and thus crown fires
- Increased susceptibility to insect and parasitic infestations
- Decreased decomposition rates and stagnated nutrient cycles
- Lower water yields and decreased stream flows

3.0 ANTICIPATED HYDROLOGIC RESPONSE TO FOREST RESTORATION

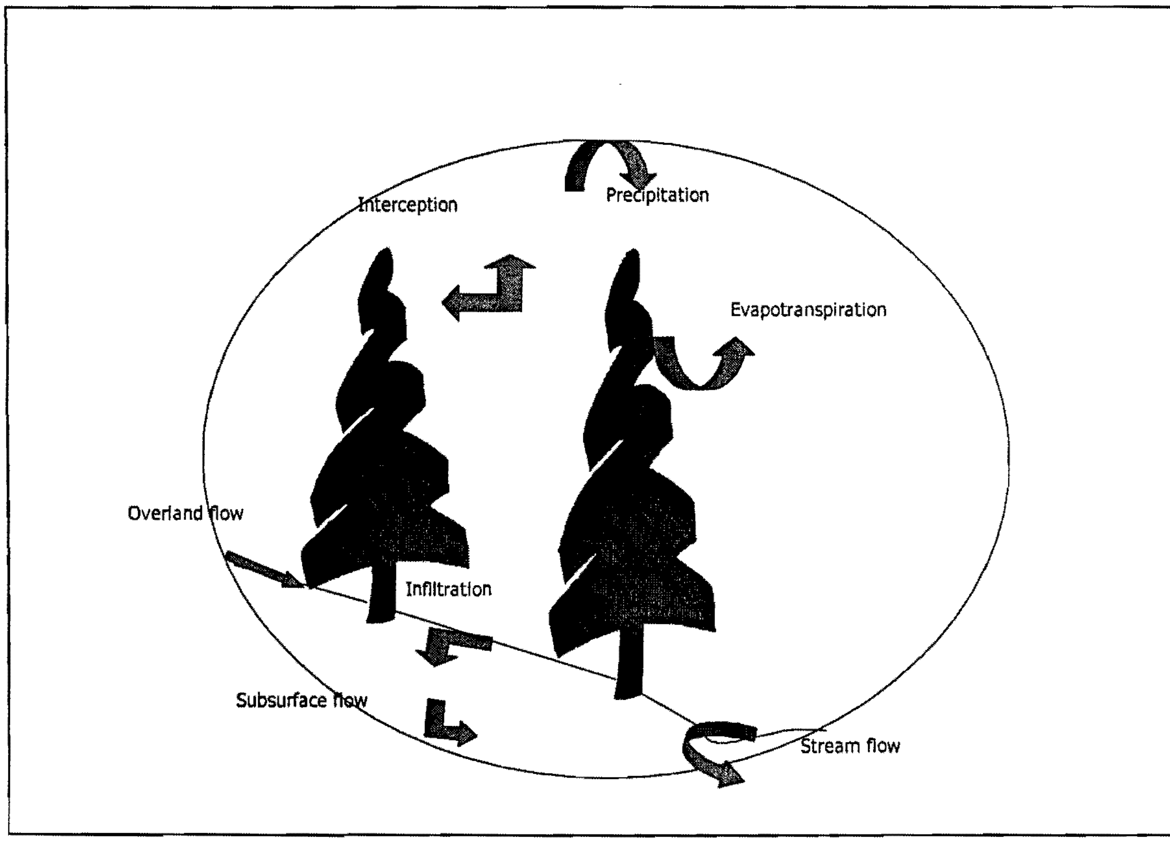
Restoration of the forests and the ecological processes that sustain them will eventually lead to healthy forests and decreased risk of catastrophic fires. As with any effort to return conditions to pre-population conditions, the effects of restoration on the existing population must be taken into consideration. Prior to euro-american settlement, the flanks of the Sangre de Cristo Mountains were inhabited by small villages of Hispanic peoples who farmed the valleys using water from the streams for irrigation (DeBuys, 1985). Today those villages are still there and the need for irrigation water is as important as it was in the 1800s. However, the population has grown and with it the need for water. It is critical that in restoring the ponderosa forests there is no disruption in the supply of water to the people who have depended on it for 200 years.

Water yield from the forest is the result of the complex interplay of all of the elements of the forest hydrologic cycle. This section describes the forest hydrologic cycle and how each element might respond to forest restoration.

3.1 Forest Hydrologic Cycle

The forest hydrologic cycle is shown on 4- 1. It illustrates the ways in which water moves and is stored in the forest environment. During the endless circulation of water, it is stored temporarily in streams, soil, as groundwater, and becomes available for use by living things.

Figure 4-1. Forest Hydrologic Cycle



Precipitation can be either rain or snow, depending on the conditions near the ground surface. Before reaching the ground surface, precipitation is intercepted by the vegetation. Some of the intercepted precipitation is stored on the leaves and then evaporated. The remainder falls to the ground from the leaves or runs down the trunks.

Upon reaching the ground surface, water is absorbed by the organic matter or soil at the forest floor. Water that is not absorbed remains on the surface of the ground and flows down slope in a process called overland flow. Overland flow generally ends up in streams and directly supplies water for stream flow.

The absorbed water seeps into the organic matter or soil by the process of infiltration and is held there as soil moisture by capillary forces. As more water is infiltrated, it displaces the soil moisture that was already in place. This water moves deeper and becomes subsurface flow. Subsurface flow moves down gradient and can supply streams with baseflow.

Soil moisture undergoes evapotranspiration, a combination of two processes: evaporation and transpiration. These processes are lumped together because it is usually impossible to separate the effects of the two processes when computing water loss from a vegetated surface (Dunne and Leopold, 1978). The net effect of evapotranspiration is the loss of water from the forest.

Restoration of the ponderosa pine forests by thinning of trees and encouraging growth and maintenance of a grassy understory would affect all of the elements of the forest hydrologic cycle. By definition the cycle is in balance; a perturbation of the system will effect a responsive change in the elements. Whether the impact of this responsive change is negative or positive depends on the perspective of the viewer.

3.2 Response of Precipitation

Precipitation is the total input of water to the hydrologic cycle. In the ponderosa pine forests of the Sangre de Cristo Mountains it provides 30% of water from snow and 70% from rain, based on snow monitoring sites at Senorita Divide and Quemazon (Western Regional Climate Center, 1999). The snowpack is nearly continuous from late November to May (Gary, 1960).

Restoration of the ponderosa pine forests will not affect the precipitation, but it will affect how it is distributed and stored, in the form of snow accumulation. More snow accumulates in open areas than under canopy (Anderson, 1956; Berris and Harr, 1987; Ffolliott and Thorud, 1969; Gary and Watkins, 1985; Gary and Troendle, 1982; Moore and McCaughey, 1997; Packer, 1967; Stanton, 1966; Troendle, 1987; Troendle, 1983; Troendle and King, 1985, 1987; Ziemer, 1964). Reported increase of snow content ranges from 3% in shelterwood cuts in Alberta (Stanton, 1966) to 30% in thinned lodgepole pine in Wyoming (Gary and Watkins, 1985) and clearcut strips in Colorado (Troendle and King, 1985). However, there was a concomitant decrease in snow in the forested areas adjacent to the openings (Gary and Troendle, 1982; Troendle, 1983; Troendle and King, 1987). Thus, the amount of precipitation input to the forest remains the same; the forest structure will affect how it is distributed.

3.3 Response of Interception

Interception is the portion of precipitation caught by vegetation before it reaches the ground. Water that is intercepted is either evaporated or is dripped from the leaves or flows down the stems (Dunne and Leopold, 1978). Storck and Lettenmaier (1999) measured interception as 60% of the snowfall by a mature canopy of Douglas fir in

Oregon. Storck (1999) found that ponderosa pines had the same degree of interception as the Douglas fir. Anderson (1956) found that 8.6% of precipitation in a California red fir full canopy forest was intercepted and evaporated.

Restoration of the ponderosa pine forests will have a significant change in the amount of interception. Canopy coverage restored to approximate pre-settlement condition of 20%-30% will result in more water reaching the forest floor. Troendle and King (1987) found a 50% increase in water yield from the spruce-fir and lodgepole pine forest in the Deadhorse Creek watershed in Colorado as a result of thinning. The increase in water yield was attributed directly to interception decreases. Interception decreases have a direct effect on the accumulation of snow, resulting in increased snow accumulation in openings (Packer, 1967; Troendle, 1987).

3.4 Response of Evapotranspiration

Evaporation is the change of state from water to vapor and the net transfer of this vapor to the atmosphere. Transpiration is the loss of water from the cuticle or the stomatal openings in the leaves of plants. Transpired water is replaced by water taken up by the roots of plants from the soil. Brooks et al. (1997) estimate that 85% to 95% of annual precipitation in arid regions is evaporated or consumptively used.

Few watershed studies attempted to quantify the loss of water by evapotranspiration. It is assumed to be the difference in depth of soil moisture between a cleared area and a forested area. Troendle (1987) estimated an average loss of 0.4 cm (0.17 inches) of soil moisture per day during the summer in a Colorado partially cut forest of spruce-fir and lodgepole pine. Rothacher (1970) found as much as 15 cm (6 inches) more water in clear cut areas than in forested areas in a Douglas fir forest in Oregon. Ziemer (1964) found a savings of 18 cm (7 inches) per 1 meter (3.3 feet) of soil in openings in a mixed conifer forest in California. In the California mixed conifer forest, the soil moisture profile was high under the openings and depressed under the forested areas in the summer (Ziemer, 1964).

The restored openings in the ponderosa pine forests will have a decrease in evapotranspiration. Although the understory will also evapotranspire, the amount is expected to be much less than the trees that previously occupied the openings. In over 100 watershed studies, every one found an increase in water yield with a decrease in the amount of vegetation. Soil moisture that is not lost to evapotranspiration means more moisture in the soil and an increase in overland flow, because less water is required to fill the capillaries in the soil. It is also likely to increase the amount of subsurface flow, resulting in more baseflow in the streams.

3.5 Response of Stream Flow

Stream flow, or water yield, is the measure of the amount of surface water discharging from a watershed. It is the cumulative effect of snowmelt, overland flow and baseflow. Water yield has two components that are important to down stream water-users: volume and timing of flow.

Increases in water yield have been reported from all of the watershed studies reviewed (Appendix 4A). The magnitudes of the increases range from 3% to 50% and are completely dependent on site-specific factors including: annual precipitation, vegetation, elevation, slope, aspect, and soil type. Covington and Moore (1994) simulated the change in stream flow that would be expected between pre-settlement tree density and current tree density at a site in Arizona. The model output predicted that the stream flow was 2 cm (1 inch) greater with pre-settlement tree density.

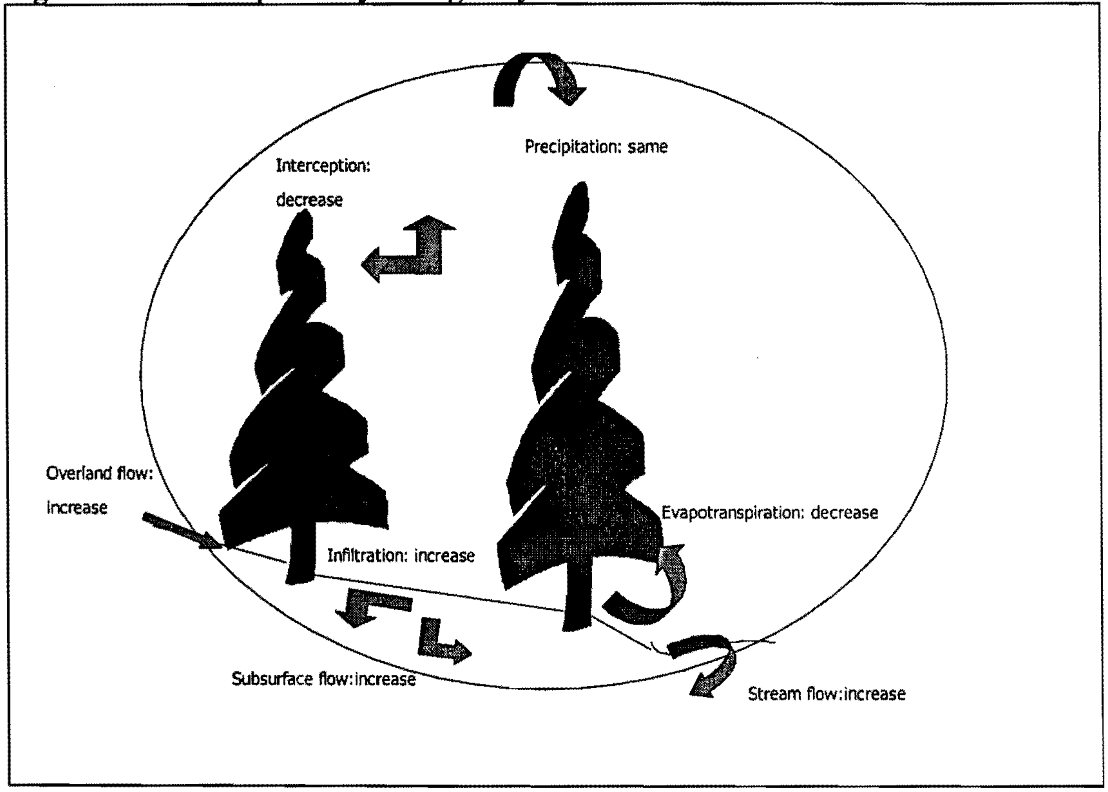
The timing of stream flow in arid environments is dependent on snow melt (Hibbert, 1979). Ffolliott and Thorud (1969) found that 93% of the snowpack water content left a ponderosa pine forest in Arizona as stream flow. Increasing the openings in the ponderosa pine forest will allow more solar energy to melt the snow in the openings. Anderson (1956) found that snow in the forest openings melted 53% faster than in a California red fir forest. Similarly, Berris and Harr (1987) found a 40% faster melt rate in Oregon conifer forests. However, the snow is thicker in the openings, so the timing of melting is changed very little. Gary and Troendle (1982) found that the late season melt was prolonged by just one week in dense forest in Wyoming. Troendle and King (1987) found the initiation of snowmelt was unchanged, although the duration was slightly longer in a thinned spruce-fir forest in Colorado. In another spruce-fir drainage in Colorado, the volume of flow was increased 40%, but the timing was unchanged (Troendle and King, 1985).

The effect of scale is a large uncertainty in the prediction of water yield increases. It has been noted that while significant water yield increases have been observed in individual drainages, the increases were not detectable at the watershed scale (EPA, 1991; Troendle and King, 1987). The likely explanation of these observations is that the watershed experiments are done on relatively small drainages that represent a minor contribution to the stream flow in the entire watershed. Although the stream flow may be greatly increased from that drainage, it is too small a contribution to be measured at the base of the watershed. Similarly, the timing of snowmelt was not significantly changed in the drainages studied, but at the watershed scale the timing of stream flow may be noticeably altered. Restoration of ponderosa pine forests in entire watersheds is likely to result in an observable increase in the volume and change in the timing of water yield, but the magnitude can not be estimated based on the studies completed to date.

4.0 SUMMARY AND CONCLUSIONS

The anticipated hydrologic responses to restoring the ponderosa pine forests to approximately pre-settlement conditions are summarized on Figure 4-2.

Figure 4-2. Conceptual Hydrologic Cycle for Restored Ponderosa Pine Forest.



The decreases in interception and evapotranspiration will result in increases of overland flow and subsurface flow. Taken altogether, the water yield is expected to increase. Factors that confound the predictions of the magnitude of these changes are the site-specific nature of the responses and extrapolation of small-scale studies to the watershed scale of restoration.

The restoration of ponderosa forests would not only result in healthy forests and decreased risk of catastrophic fires, it would also likely result in a sustainable water supply for the residents on the flanks of the Sangre de Cristo Mountains. One might even speculate that restoring the ponderosa pine forests on a watershed scale may even provide enough flow for the streams discharging from the mountains to contribute greater flows in the Rio Grande.

The dreams of increasing the amount of water through vegetation manipulation (Hibbert, 1979) were not borne out when tested on the scale of individual drainages. With the information currently available it is not possible to discern whether the responses observed on the drainage scale are accurate predictors of the watershed-scale response or if the synergistic effects of all the drainages in a watershed would result in an additive response at the watershed scale. Process-based modeling may be the best approach to predicting the effects on a watershed scale.

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APPENDIX 4A

Summary of Hydrologic Observations from Watershed Experiments

Appendix 4A: Summary of Hydrologic Observations from Watershed Experiments

REF	FOREST STATUS/ LOCATION	INTERCEPTION	EVAPOTRAN SPIRATION	SNOW ACCUMULATION	INFILT RATION	SOIL MOISTURE	WATER YIELD	PEAK FLOW	LOW FLOW
Anderson (1956)	Various treatments in red fir, Sierra Nevada, CA	8.6% intercepted and evaporated from full canopy		Melt rate 53% slower in dense forest than in openings; 13% more snow in openings					
Berris and Harr (1987)	Clear cut douglas fir and hemlock, Oregon	Most snow was intercepted and melted		Snow accumulation was much greater in openings, but snow under canopy had greater water equivalents			Melt rate was 40% greater in clear cut than in canopy		
Bosch and Hewlett (1982)	Survey of 94 catchment experiments						40 mm change in water yield per 10% change in forest cover		
Brooks et al. (1997)	Ponderosa pine, southwestern US		85-95% annual precipitation evaporated or consumptively used in arid and semi-arid regions			Reduced transpiration leaves more moisture in the soil which encourages runoff rather than infiltration	Water yield increases of 25-165 mm/yr depending on the percent of forest cover removed		
Covington and Moore (1994)	Simulated pre-settlement Ponderosa pine, Arizona						Simulation predicts stream flow 1 inch greater with pre-settlement density		
EPA (1991)	Various treatments in conifer Pacific Northwest						Changes are generally only detectable in	Changes in peak flow seem	In Rocky Mountains increases of

Appendix 4A: Summary of Hydrologic Observations from Watershed Experiments

REF	FOREST STATUS/ LOCATION	INTERCEPTION	EVAPOTRAN SPIRATION	SNOW ACCUMULATION	INFILT RATION	SOIL MOISTURE	WATER YIELD	PEAK FLOW	LOW FLOW
							the immediate proximity of the harvested area; sustainable increases of 3-6% in WA and OR	to be a concern only in rain on snow events	0-12% following forest harvest
Ffolliott and Thorud (1969)	Various treatments ponderosa pine, Arizona			Greater water content measured under sparser stands; density of 0.37 gm/cm^3 represented "ripe" snowpack			93% of snowpack water content left the watershed as surface runoff		
Fosberg (1977)	Ponderosa duff and humus				As bulk density increases, permeabil ity decreases				
Gary (1960)	Ponderosa pine, Santa Fe New Mexico			Average density of snowpack 0.92 – 0.32 gm/cm^3 over one winter					
Gary and Watkins (1985)	Thinned lodgepole pine, Wyoming			30% increase in snow water equivalent					
Gary and Troendle (1982)	Various treatments in lodgepole pine, Wyoming and Colorado			Snow accumulation remains the same, but it is distributed differently over the watershed			Dense forest cover had little effect on prolonging late season melt, with only 1 week		

Appendix 4A: Summary of Hydrologic Observations from Watershed Experiments

REF	FOREST STATUS/ LOCATION	INTERCEPTION	EVAPOTRAN SPIRATION	SNOW ACCUMULATION	INFILT RATION	SOIL MOISTURE	WATER YIELD	PEAK FLOW	LOW FLOW
							difference in different thinning levels		
Harr (1976)	Various treatments Douglas fir, Oregon				Soil moisture higher in clear cuts		Significant increases in annual water yield from clear cut, but not from shelterwood cut	Peak flows increased by roads and skid trails, but not by timber removal alone	Low flows were not affected by patch cut or shelterwood cut
Hibbert (1983)	Clear cut, ponderosa pine, southwest US						Stream flow increases of 25-75mm expected		
Hibbert (1979)	Ponderosa pine, Colorado Basin						Removal of 1/3 of the trees is expected to result in water yield increase of 1- 2 inches		
Kaufman (1984)	Various treatments, lodgepole pine, Colorado		Subalpine forests the humidity remains constant under the canopy						
Luce et al. (1997, 1998)	Sagebrush, southwestern Idaho						Snow drifts result in delayed surface water inputs and sustains melt into late		

Appendix 4A: Summary of Hydrologic Observations from Watershed Experiments

REF	FOREST STATUS/ LOCATION	INTERCEPTION	EVAPOTRAN SPIRATION	SNOW ACCUMULATION	INFILT RATION	SOIL MOISTURE	WATER YIELD	PEAK FLOW	LOW FLOW
							spring		
Moore and McCaughey (1997)	Various treatments of subalpine fir, Montana			6.4% decrease in peak snow water equivalent per 10% increase in forest canopy					
Packer (1967)	Various treatments in white pine, Idaho	Increases in maximum snow water content assumed to be result of decreased interception		Maximum snow water content increased in direct proportion to the amount of openings					
Rothacher (1970)	Clear-cut Douglas fir, Oregon					As much as 6 inches more water in clear cuts than in forest at end of the dry season	12% incease in annual yield in 30% patch cut		
Stanton (1966)	Various treatments, spruce-fir, Alberta			3% increase in accumulated snow in shelterwood cut					
Storck and Lettenmaier(1999)	Mature canopy Douglas fir, Oregon	Interception 60% of total snowfall							
Troendle (1987)	Partial cut, Lodgepole pine, Colorado			Snow pack increased proportionally to stand volume decrease					
Troendle (1987)	40% basal area removed, subalpine, Colorado	Increase in snow attributed to interception savings		16% increase in peak water equivalent		Averaged 0.14-0.17 inches per day in soil during			

Appendix 4A: Summary of Hydrologic Observations from Watershed Experiments

REF	FOREST STATUS/ LOCATION	INTERCEPTION	EVAPOTRAN SPIRATION	SNOW ACCUMULATION	INFILT RATION	SOIL MOISTURE	WATER YIELD	PEAK FLOW	LOW FLOW
						summer			
Troendle (1983)	Clear cut in small circles, spruce-fir and lodgepole pine, Colorado			18% increase in water equivalent in openings; equal decrease under canopy; no overall change in water equivalent		Decreased soil water deficits from less tree consumption	36% increase in total flow	No change in magnitude of peak discharge; no change in time of peak discharge	
Troendle and King (1987)	Unit 8 thinned Spruce-fir and lodgepole pine Colorado	Increased water yield attributed to decreased interception		Snow content 18% higher in openings; but balanced by ablation loss in southern exposures			4.8 cm increase in drainage, but not a significant change for the whole watershed	50% greater, initiation no change, duration longer	
Troendle and King (1985)	Clearcut in strips, spruce-fir and lodgepole			30% increase in openings; 14% overall increase in snow pack			9% peak water equivalent for entire watershed	40% greater flow volume, timing no change	23% increase in daily discharge; however summer precipitation did not result in streamflow increases
Ziemer (1964)	Clear-cut openings in red fir, lodgepole pine, white fir, Jeffrey pine			Greater in openings	Openings were wetted down to 4 feet, but forested areas only	Soil moisture in openings indicates a savings 7 inches of water /4 feet of soil			

Appendix 4A: Summary of Hydrologic Observations from Watershed Experiments

REF	FOREST STATUS/ LOCATION	INTERCEPTION	EVAPOTRAN SPIRATION	SNOW ACCUMULATION	INFILT RATION	SOIL MOISTURE	WATER YIELD	PEAK FLOW	LOW FLOW
					wetted to 1 foot during summer storm	Profile is low under trees and high under openings			

FIRE MANAGEMENT POLICY AND ITS IMPACT ON SUSTAINABLE WATER RESOURCE DEVELOPMENT IN THE PONDEROSA PINE FORESTS OF THE RIO DE TRUCHAS WATERSHED

Sarita Nair

Executive Summary. I examine the Fire Management and Protection Policy for Carson National Forest, focusing on the policy relevant to the ponderosa pine forests of the Rio de Truchas watershed. This paper seeks to study the links between fire management and water resource development, with a view to creating sustainable policies for forest management.

First, I give a brief overview of the historical and current states of the ponderosa pine (*Pinus ponderosa*) forests of northern New Mexico. Forests in the pre-colonial days were relatively open stands of even-aged trees and a dense understory. Today's forests are dense stands dominated by younger trees, and the understory has given way to a thick layer of needle litter.

Section Two describes the historical role of fire in the forests. Pre-colonial forest systems saw a regular regime of cool, non-lethal fires that played several roles in the forest ecology. Section Three examines these roles, which included thinning and clearing, alteration of wildlife habitat, nutrient cycling and other plant-specific functions.

Section Four introduces water into the equation, and examines the role of fire in the hydrological cycle. Regular fire regimes decreased evapotransipration and interception, while increasing infiltration, runoff and snowdrift sizes. I describe a best case scenario for the hydrological effects of fire, which would result in a net increase in water delivery from a cool burn. This contrasts with the worst case scenario, which would result in higher water yield with increased nutrient and sediment loads created by a hot wildfire.

Section Five outlines current fire management policies within the Carson National Forest, which consists of the *Federal Wildland Fire Management Policy and Program*, the *Carson Fire Management Plan* and the *Guidelines for Prescribed Burns in New Mexico*. I examine the possible effects of these policies on water resources. Fire suppression policies will probably result in no net change to the water resources of the area, because this policy has been in place for over 100 years. Wildfires will continue to produce the hydrological "worst case scenario." Prevention policies outlined in the Carson plan may increase water yield through mechanical thinning. Prescribed burn plans will not be able to stand alone as reforestation policies, but may produce slight increases in water yield.

Finally, I make three recommendations for a sustainable fire and water resource policy. A sustainable fire management policy must look to the long-term health of the ecosystem as a whole. By including a consideration of water resources, new fire policies have the opportunity to advance sustainable forest management, and to ensure the health of the

ponderosa pine forests for future generations. Management must be interdisciplinary and include cooperation among government agencies. Finally, money and manpower must be devoted to research and monitoring to enhance our understanding of the interaction between fire management and water resource development.

1.0 THE PONDEROSA PINE FORESTS OF NORTHERN NEW MEXICO: AS IT WAS, AS IT IS

1.1 Introduction

Forest health is a controversial subject. Forest managers, policy makers and academics have not achieved consensus regarding the parameters of a healthy forest (Suckling, 1996). The debates arise from, among other things, differing views on pre-colonial forest conditions, optimal forest conditions, paths of succession and the role of human intervention. Disputes also stem from varying goals of forest management, which in turn inform views on the issues stated above. While the timber industry might use timber production as a parameter for measuring health, an environmental group may cite biodiversity or restoration to pre-settlement conditions as the optimal state.

Recent studies of the ponderosa pine (*Pinus ponderosa*) forests of northern New Mexico indicate that there have been changes to the forest ecosystem within recorded history. There is not complete agreement on the cause of these changes, their contribution to or deterioration of forest health, the need for human intervention to stop changes, or the proper way to proceed with those interventions. However, the changes themselves can be categorized into three major groups: forest density; loss of diversity; and susceptibility to crown fire. Each will be discussed below.

1.2 Forest Density

Early accounts of ponderosa pine forests characterize the area as containing "open park-like stands" (Suckling, 1996). The National Forest Service suggests that pre-colonial ponderosa pine forests were, "a mosaic not only with an open, grass savanna and clumps of large, yellow-bark ponderosa pine, but also with a few dense patches and stringers of small, blackjack pines" (Dahms and Geils, 1997). Historical studies of the Turnbull ponderosa pine forests in Arizona suggest that large diameter trees, greater than 40 inches diameter breast height (d.b.h.), characterized the "small, even-aged stands of 15 to 20 trees per acre" (U.S. Fish and Wildlife Service, 1999).

Today, however, stand densities average 294 stems per acre in the southwest (Dahms and Geils, 1997). In New Mexico and Arizona, densities range from 500 to 1000 trees per acre, and consist mainly of younger trees fewer than three inches in diameter (Covington and Moore, 1994; Biswell, 1972). The higher density results in a thicker canopy, which causes greater shading and intercepts a great deal of precipitation. More trees also create more needle litter.

1.3 Loss of Diversity

The metamorphosis of the ponderosa pine forest has also been characterized by a loss of diversity, most notably in the understory grass population. Logging, grazing and fire exclusion has resulted in the predominance of even-aged trees, and many old growth trees have been lost to stand-replacing crown fires (Dahms and Geils, 1997).

1.4 Susceptibility to Crown Fire

This facet is in fact the result of the first two aspects. Vertical fuel arrangement and increased litter have resulted in a prime situation for crown fires, which burn hot and are difficult to control. These fires, most often caused by lightning strikes and human negligence, represent a threat to human life and property as well as forest resources.

Figure 5-1 shows a ponderosa pine forest in the Manzano Mountains of central New Mexico, where reforestation efforts are underway. It illustrates the diverse understory vegetation, open canopy and even-aged stands that were thought to be characteristic of pre-colonial ponderosa pine forests. Figure 5-2, a photo taken in Las Trampas, New Mexico, shows the current state of ponderosa pine forests. It is possible to see the dense arrangement of trees, the lack of understory vegetation and obstruction of light from the thick canopy.

Figure 5-1. Ponderosa Pine Forest In The Manzano Mountains, Simulating Pre-Colonial Forest Conditions.

Figure 5-2. Ponderosa Pine Forest In Las Trampas, NM, Illustrating Current Conditions.

2.0 THE HISTORICAL ROLE OF FIRE IN THE PONDEROSA PINE FOREST

Researchers generally agree that pre-colonial ponderosa pine forests experienced a 'nonlethal understory fire regime of frequent low-intensity fires. The National Forest Service suggests that ponderosa pine forests in the southwest generally burned every two to ten years (Dahms and Geils, 1997). Studies from New Mexico and Arizona suggest a frequency range from 4.8 to 23.2 years, as illustrated in Table 5-1.

Table 5-1. Number and Frequency Of Fires In Ponderosa Pine Forests As Indicated By Fire Scar Analysis.

LOCATION	INCLUSIVE DATES	NUMBER OF FIRES	MEAN INTERVAL
Kaibab National Forest, AZ	1708 - 1934	19	11.9
San Carlos Apache Indian Reservation, AZ	1847 - 1943	14	6.9
White Mountain Apache Indian Reservation, AZ	1831 - 1889	11	6.1
White Mountain Apache Indian Reservation, AZ	1846 - 1906	9	6.7
White Mountain Apache Indian Reservation, AZ	1851 - 1913	13	4.8
Bandelier National Monument, NM	Scars from 18 different years	7 (on four or more trees)	20
Carson National Forest, NM	1781 - 1896	6	23.2
Cibola National Forest, NM	1737 - 1900	10	18.2
Gila National Forest, NM	1822 - 1862	7	6.8
Gila National Forest, NM	1766 - 1924	21	8

(Source: Oppenheimer, 1978)

During the Spanish and Mexican colonial period (1540 - 1848), the fire regime was interrupted and eventually halted. As grazing in the forest became increasingly common, cows removed the understory more quickly than it could regenerate. This in turn allowed weaker trees to be established, increasing the density of the forest. The stage was set for fewer regular fires and more intense crown fires resulting from lightning strikes.

During the U. S. period (1848 - present), many of the forests fell under the management of the U.S. Government, through the National Forest Service and the Bureau of Land Management. Most ponderosa pine forests in the Rio de Truchas watershed fall within the

Carson National Forest, which was created in 1908 from the Pecos River Forest Reserve of 1892, the Taos Forest Reserve of 1906, and part of the Jemez National Forest of 1905 (Romero and Poese, 1999). The Forest Service engaged in a policy of wildfire suppression. Forest resource management was primarily focused on sustained yields of timber, cattle forage and water.

Within the Rio de Truchas watershed, current fire activity is mostly limited to wildfires caused by lightning strikes or human negligence. Throughout the Carson National Forest, fire activity ranges from 25 to 100 fires annually, primarily in a fire season that extends from mid-May to the end of September (Carson National Forest, 1999).

3.0 THE RELATIONSHIP BETWEEN FIRE AND FOREST CHANGES

3.1 Introduction

The link between the loss of the fire regime and the changes in the ponderosa pine forest is a matter of some speculation. The primary investigation in this field has been conducted through point frequency studies that utilize fire scar analysis and historical research, which are subject to pitfalls.

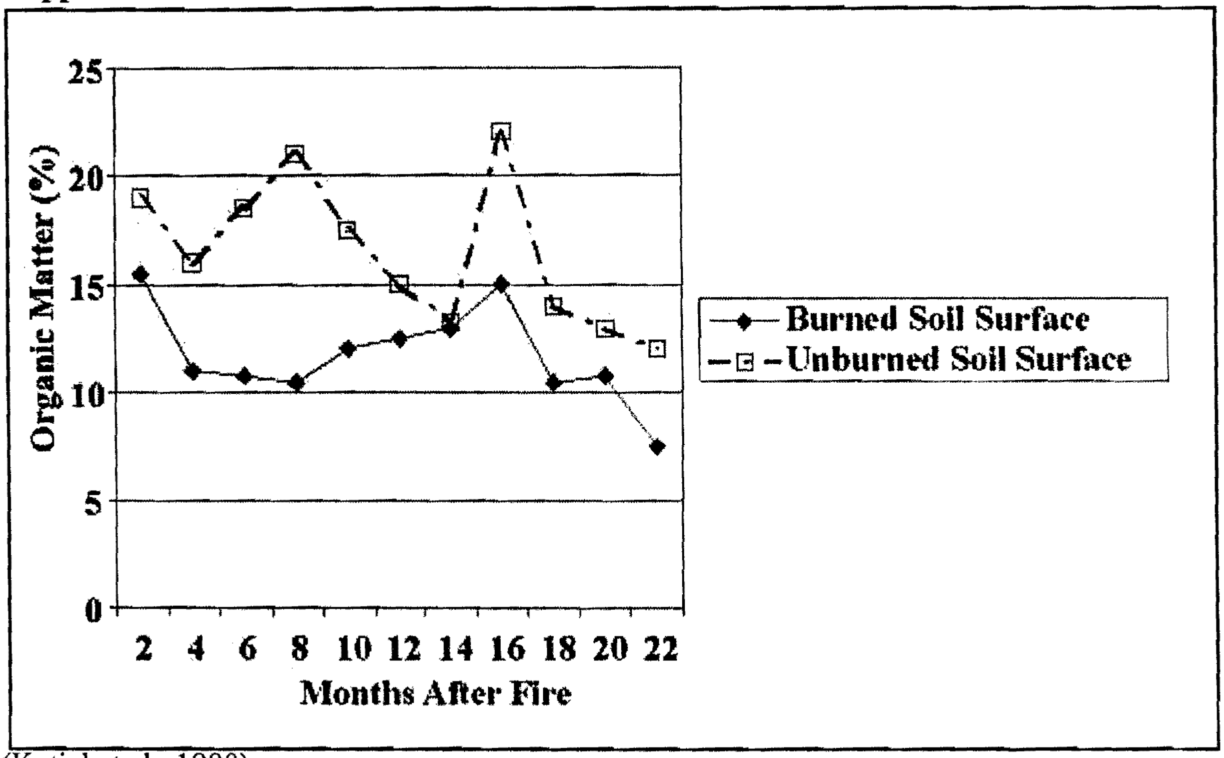
Complicating this picture is a variety of other factors that have influenced the ponderosa pine forest dynamic. Grazing, logging, insect populations and climate change have all played a role. The relative importance of these factors and direction of causality in their relationships with each other is a matter of much contention. For the purposes of this study, I will focus on the role of fire in the ecosystem.

The regular, low-intensity fire regime was a cyclical influence in the forest ecosystem. Fire's effects on the ecosystem can be categorized into four basic groups, which are all related and interdependent.

3.2 Nutrient Cycling

Fires alter nutrient availability in the soil through a variety of means. First, fires on the forest floor heat organic matter, speeding its decomposition. Like compost, this matter serves to make the soil more nourishing for new plants and fire survivors. Figure 5-3 shows the results of research on organic matter content in the soil after an Aleppo pine forest fire.

Figure 5-3. Changes In Organic Matter At The Soil Surface After A Wildfire In An Aleppo Pine Forest.

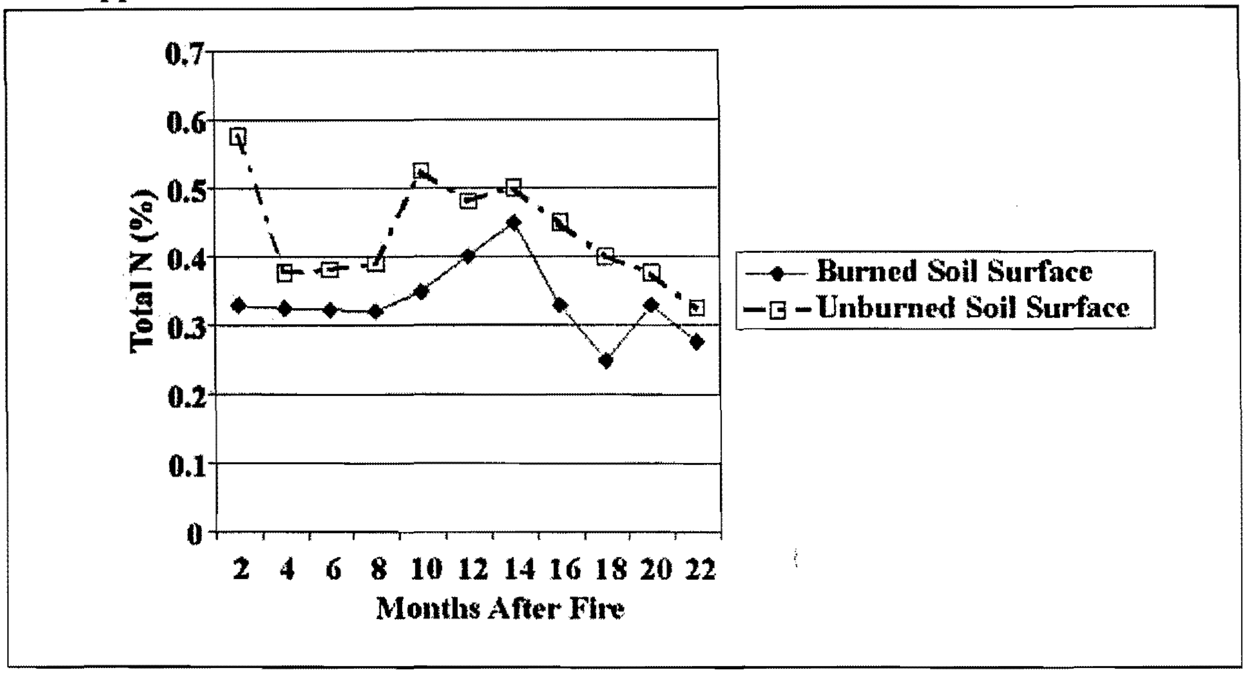


(Kutiel et al., 1990)

Second, fire changes the soil pH. Most studies show that there is a sharp increase in soil pH immediately following the fire that tapers off after a few months. This is due to the release of basic cations, most notably Ca^{++}, K^{+} and Na^{+} (Bond and van Wilgen, 1996).

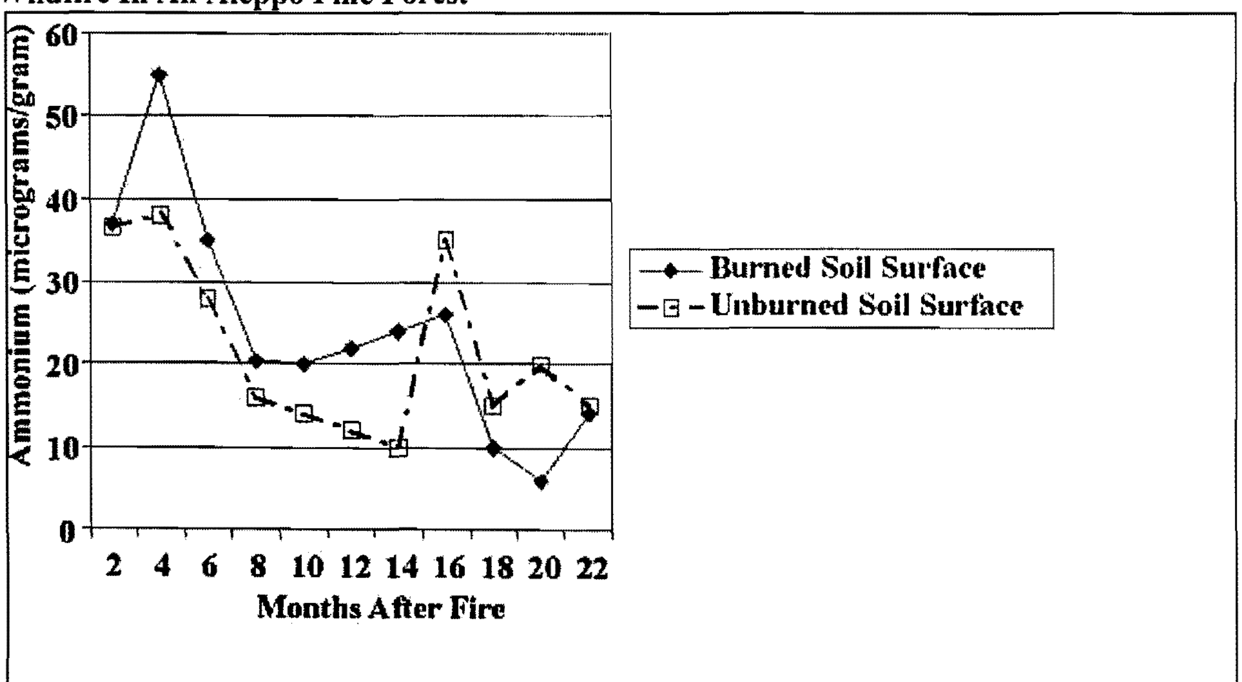
At the same time there is also an increase in available nitrogen. Although some nitrogen is consumed through volatilization, even more becomes available as ammonium (NH_4^+-N) and nitrate (NO_3^--N). Figures 5-4, 5-5 and 5-6 illustrate this increased availability as evidenced in the same Aleppo pine forest studies mentioned above.

Figure 5-4. Changes In Nitrogen Availability At The Soil Surface After A Wildfire In An Aleppo Pine Forest.



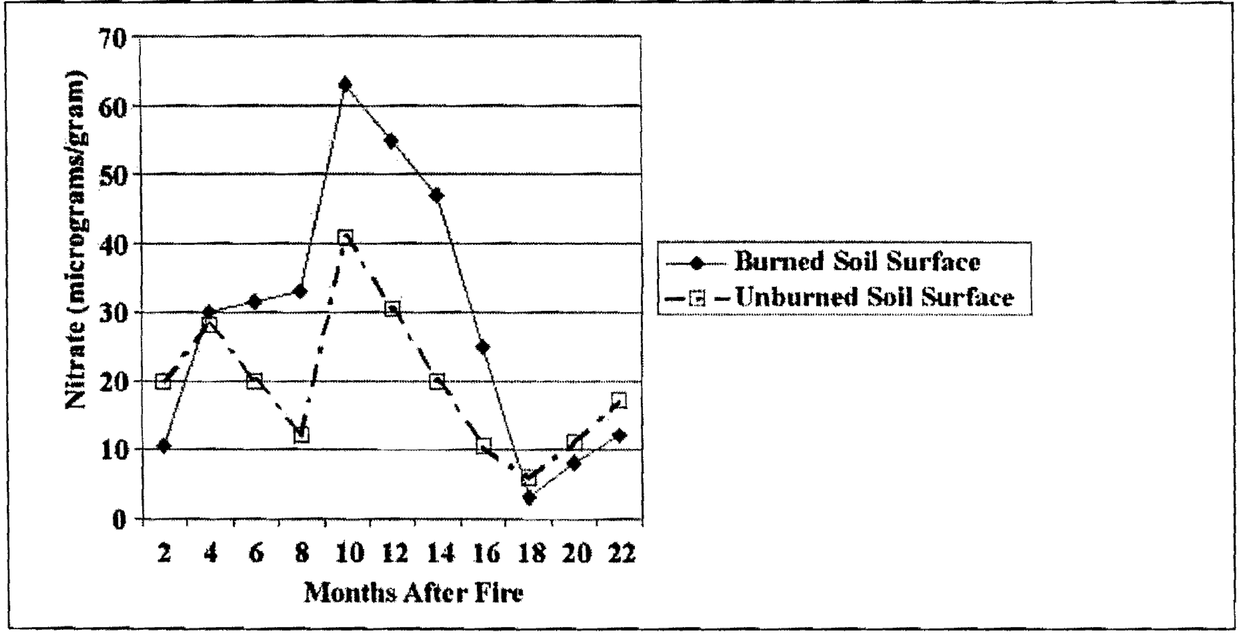
(Kutiel et al., 1990)

Figure 5-5. Changes In Ammonium (NH_4^+-N) Availability At The Soil Surface After A Wildfire In An Aleppo Pine Forest



(Kutiel et al., 1990)

Figure 5-6. Changes In Nitrate (NO_3^--N) Availability At The Soil Surface After A Wildfire In An Aleppo Pine Forest.



(Kutiel et al., 1990)

Finally, stimulation of biological mineralization and addition of ash to the soil also affect nutrient cycling in post-fire soils (Bond and van Wilgen, 1996, Crutzen and Goldammer, 1993).

3.3 Thinning and Clearing of the Forest

Fires consume fuel, and in the ponderosa pine forest, this includes understory vegetation, weak young trees, needle litter and woody materials. With more space on the forest floor, increased light and soil availability create a prime condition for new plants. There is also less competition for soil nutrients and water.

3.4 Change in Wildlife Habitat

Following a fire, the habitat in the ponderosa pine forest becomes difficult for small animals. Many rodents and other animals that consume seeds and young trees must leave the environment, making an even more favorable habitat for new plants.

3.5 Other Effects

Fire can also have a wide range of effects depending on the characteristics of the plant species. Some plants are cued to release or germinate their seeds by the increase in temperature. Still others hold reserve seed banks that are released during a fire event. Each member of the mosaic of plants that made up the under- and overstories of pre-colonial forests had its own relationship with the fire regime.

When the fire regime ended, these processes were all brought to a halt. With the build-up of fuels and loss of understory (as described in Section 2.0), crown fires became the only type of fire event to occur in the ponderosa pine forests. Crown fires burn hot and vertically, often stretching out over large areas. The hotter, more intense fires also stimulate nutrient cycling, but often to a greater extent than plants can absorb.

4.0 WATER RESOURCES

Water is the vital component of any ecosystem. Water resources are more than the surface flows of lakes and rivers; they include ground water and the water that is absorbed and returned to the atmosphere by plants and trees. Any one of these processes can be an opportunity for loss, conservation or contamination.

Fire interacts with the hydrological cycle at every stage. The hydrological cycle is the path that water travels from its entry into an area as precipitation. All precipitation eventually leaves the watershed as it evaporates, is used by plants, transpires, enters the soil and ground water system and is carried to surface waters. Thus precipitation is a good starting point from which to examine the role of fire in the cycle.

Average precipitation in the Rio de Truchas watershed ranges from 0.67 inches in November to 2.33 inches in August. High rainfall coincides with high temperatures in July and August, while the colder months tend to see the most snow (See Table 5-2).

Table 5-2. Period Of Record Monthly Climate Summary For Truchas, New Mexico Period Of Record : 1/ 1/1914 to 5/31/1962

MONTH	AVERAGE MAX. TEMP. (F)	AVERAGE MIN. TEMP. (F)	AVERAGE TOTAL PRECIP. (IN.)	AVERAGE TOTAL SNOW FALL (IN.)	AVERAGE SNOW DEPTH (IN.)
Jan	42.6	14.4	0.83	10.5	1
Feb	45.2	17.6	0.90	7.5	3
Mar	49.5	18.7	0.97	9.6	1
Apr	58.9	27.6	0.97	3.0	0
May	66.9	35.4	1.18	1.6	0
Jun	76.8	45.5	0.94	0.0	0
Jul	80.7	49.4	2.13	0.0	0
Aug	78.2	48.2	2.33	0.0	0
Sep	74.4	43.2	1.57	0.0	0
Oct	63.4	34.1	1.25	0.9	0.1
Nov	52.6	21.9	0.67	7.0	0
Dec	44.2	15.6	0.80	3.8	0
Ann. Avg.	61.1	31.0	14.53	43.9	0.5

(Source: Western Regional Climate Center, 1999)

As rain falls, its first stop in the forest is the canopy. As mentioned earlier, the high-density ponderosa pine forests currently prevalent in the southwest intercept a great deal of this water. Although the exact amount of canopy interception is difficult to quantify, it has been estimated that one-eighth inch to one-fourth inch of rain must fall in order for any precipitation to proceed beyond the canopy (White, 1999). Water intercepted and used by plants results in transpiration. Combined with evaporation from the ground and surface water, these two figures are often combined as "evapotranspiration." Under current conditions, a ponderosa pine forest may have evapotranspiration rates nearing 85 – 95% of precipitation (Troendle, 1987). As fire thins the forest and decreases the number of stems per acre, the evapotranspiration and interception rates may decrease.

Precipitation that makes it through the canopy can infiltrate into the soil. Because many ponderosa pine forests currently have a duff layer of two inches or more, infiltration becomes difficult and the organic matter on the forest floor absorbs much of the remaining precipitation. By clearing the forest floors, fires may increase infiltration rates, creating more water-rich soils.

Water that neither infiltrates nor is intercepted can be carried to surface waters as runoff. Attempts to quantify any change in runoff quantity or quality after fire events have been few and inconclusive. It is generally agreed that fire may increase runoff through three means (Rice et al., 1982):

- Decrease in vegetative cover / increase in bare soil
- Reduction in the mean age of vegetation
- Reduction in root biomass

These changes could also result in snow packs that are both larger in area and deeper. There could also be a corresponding change in surface water delivery during the snowmelt, which could be longer in duration and/or higher in volume (Graham et al., 1998).

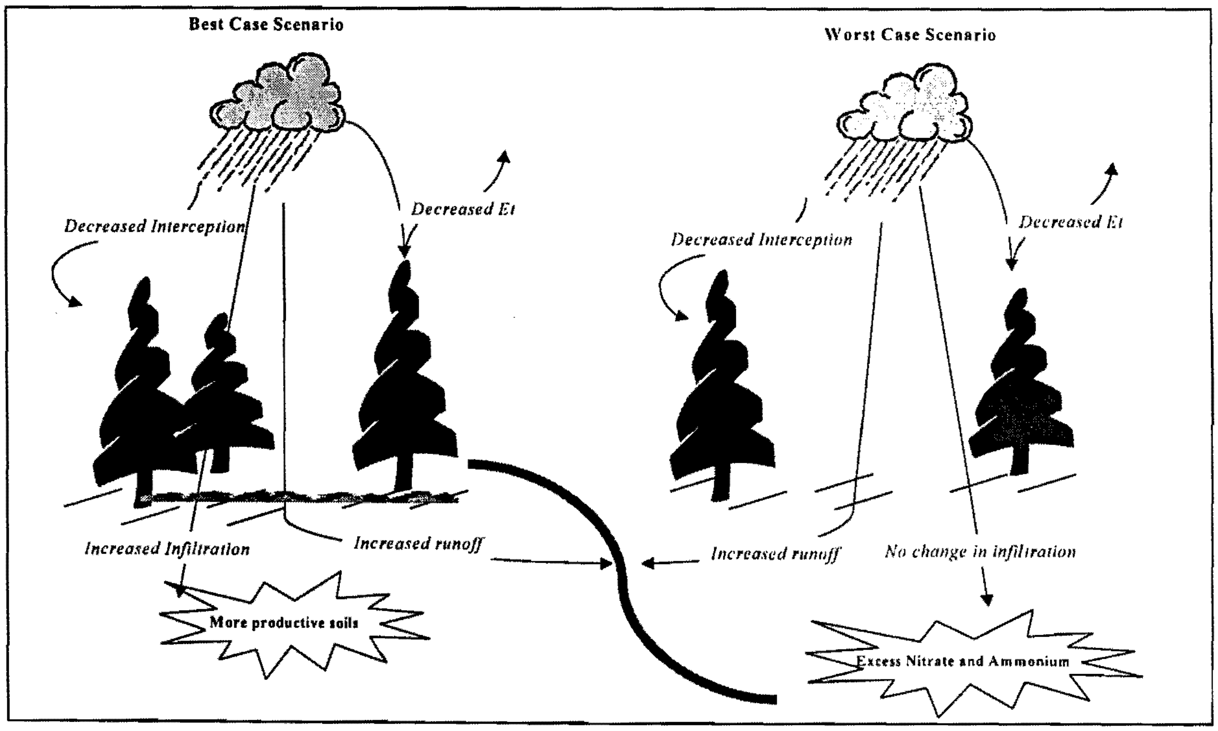
In addition, more bare soil could result in increased sediment loads in runoff waters. Furthermore, if nutrient availability is increased to a greater extent than plant production can absorb, these nutrients could be delivered to surface waters as well.

The range of impacts that fire may have on the hydrological cycle depends on the intensity and timing of the fire. For example, the Yellowstone Fire caused massive erosion and soil loss (Bond and van Wilgen, 1996). However, this was due to the placement of the fire, the high intensity and the occurrence of major rain events immediately following the burn. Prescribed fires, controlled by chains and plow lines and set at times when heavy rains are not expected, can have much less drastic effects on the water cycle.

The timing and frequency of precipitation also has a critical role in the impacts of the fire regime on surface and ground water resources. Since wild fires in the Rio de Truchas watershed tend to be caused by summer lightning strikes, they also tend to fall during the heavy rainfall months. Recreational use of the forest is also highest during summer months, leading to a greater likelihood of human-ignited fires. It stands to reason that during the summer months, anything made more available by a fire event (like loose soil or available nitrogen) is also more likely to be carried to surface waters by heavy rain events.

The potential impacts of fire on the hydrological cycle are summarized in Figure 5-7, presented as best and worst case scenarios. The best case scenario would most likely be the result of the historical fire regime, or of cool prescribed burns. The worst case scenario would be the result of a hot crown fire. In between these two extremes is a wide range of possible outcomes. Both scenarios result in an increase in water yield. The main difference between the two scenarios presented in Figure 5-7 is that the worst case scenario also leads to the deterioration of water quality, while the best case scenario results in more productive soils.

Figure 5-7. Best / Worst Case Scenarios For Fire Impacts On The Hydrological Cycle



5.0 PLANS FOR FIRE MANAGEMENT IN THE PONDEROSA PINE FORESTS: THEIR EFFECTS ON WATER RESOURCES

5.1 Introduction

Just as the current state of the ponderosa pine forest is primarily the result of management decisions, the potential impacts of fire in the ecosystem will ultimately be determined by fire management policy.

In 1996, the Forest Service of the U.S. Department of Agriculture and the U.S. Department of the Interior promulgated the *Federal Wildland Fire Policy*. This policy strongly advocates the reintroduction of fire into forest ecosystems, although it recognizes the constraints of public perception, threat to human settlement, smoke management and lack of information. The goal, as stated in the policy, is as follows (USDA and USDI, 1996):

> "Based upon sound scientific information and land, resource and fire management objectives, wildland fire is used to restore and maintain healthy ecosystems and to minimize undesirable fire effects. Fire management practices are consistent for areas with similar management objectives, regardless of jurisdiction."

As mandated by federal policy, the Carson National Forest is in the process of finalizing its fire management plan, which covers 1,391,692 acres in northern New Mexico. The plan states, "Fire is not an end but the beginning of the life cycle; it needs to play out its natural role in order to provide a healthy, sustainable ecosystem." (Carson National Forest, 1999). It also emphasizes the need to plan for "sustained yield of goods and services," which includes timber, livestock production, water yield and recreation.

The ponderosa pine forest comprises its own "fuel management area," consisting of about 5.2% of the forest, or over 72,000 acres. There is an estimated fuel loading of 5 to 15 tons per acre (Carson National Forest, 1999). The plan states that in this area, "fire occurrence is the highest on the forest [and]...risk of person-caused fires is high" (Carson National Forest, 1999).

Complete fire management analysis and planning will be completed over the next ten years. However, for the time being, all ranger districts are slated for "full suppression" of wildfires, and prescribed burns each require a management plan that will be judged individually. The maximum sizes of prescribed burns are 500 acres for "unsuitable timber" and 100 acres for "suitable timber." (This is a general prescription for all management areas, as listed in Carson National Forest, 1999) Retainment of visual qualities is cited as a management objective for wilderness areas, as are cultural resources. A Joint Powers Operating Plan will be formed among the U.S. Department of the Interior, Bureau of Land Management, Bureau of Indian Affairs, the Forest Service and the State of New Mexico.

In order to analyze the potential impacts that these policies may have on water resources and ponderosa pine forest restoration, I will divide the fire management policy into two areas: wildfires and prescribed burns.

5.2 Wildfires

As mentioned earlier, wildfires are slated for full suppression. This is the current policy, and has been over the past century. This approach reflects a desire to curb the effects of fire on human life, property and natural resources. It is accompanied by detailed suppression strategies for land and aviation, as well as preventive measures that include mechanical thinning and education.

The Carson Fire Management Plan also states that it will take "an ecological approach to the Wildland/Urban Interface," or the area where human settlement is adjacent to or within forested areas (Carson National Forest, 1999). Possible actions include an increase in prescribed burns, timber harvesting around the urban interface, the establishment of pilot demonstration plots, mechanical thinning and education. Other initiatives focus on readiness in the event of a wildfire.

If the Forest Service pursues this path, it can be expected that wildfires in many areas will continue at their present rate. In this case, the fires that do ignite will burn until suppression with the effect modeled in the "worst case scenario" figure (Figure 5-7). Fires will burn hot and will be carried vertically. They may reduce canopy cover and ground litter, but will create ground conditions that make infiltration difficult and host to an overabundance of nutrients. These nutrients will most likely be carried as runoff, along with loose sediment, where they can potentially pollute surface flows. Excess nutrients in the water may also contaminate ground water.

Some of the preventive measures slated for the suppression program may increase water delivery. Mechanical thinning has had mixed impacts on water resources, as outlined in a companion chapter in this report. However, since wildfire suppression has been the dominant policy since colonial times, it is unlikely that there will be a perceptible difference in water resources as a result of this policy.

5.3 Prescribed Burns

The *Guidelines for Prescribed Fire in New Mexico* list the following reasons to prescribe burns (New Mexico Department of Energy, 1992):

- Reduce hazardous fuels
- Improve wildlife habitat
- Improve forage and grazing
- Enhance appearance
- Remove noxious/competitive weeds
- Increase water yield on-site and downstream
- Prepare site/seed bed for regeneration

Objectives, determined by management goals and priorities, must be set prior to any burn. In addition, there must be "thorough review of the planned burning and discussion of other disciplines to identify potential current and future influences and impacts on the burn on all resources" (New Mexico Department of Energy, 1992).

The general prescriptions for the ponderosa pine forest are listed in Table 5-3.

Table 5-3. General Prescription Levels For Prescribed Burns

FACTOR	PONDEROSA PINE WITH UNDERSTORY, MUCH DEAD WOODY FUELS AND NEEDLE DRAPE	LITTLE DEAD, WOODY FUEL AND NEEDLE DRAPE
Wind (MPH)	3 – 7 (in stand)	1 – 10
Relative Humidity (%)	30 – 85	20 – 50
Moisture content of fine dead fuels (%)	8 – 12	5 – 12
Temperature (degrees F)	20 – 80	20 – 80
Season	Spring, early summer, fall or winter; avoid mid-summer	Anytime, once stand is in condition
Precipitation	One or more days after significant rainfall	
Fireline	Slowly widen lines with backfires and strip head fires	
Firing pattern	Backfire, strip head fire, flank fire; may want to burn in stages	Once stand is in condition, can also use head fire
Comment	Winter burning when ground is frozen may result in excessive needle desiccation and stand reddening but little permanent damage to stand	Burning heavy needle drape can be accomplished shortly after rain with humidities to 85%; may need to complete burn in second stage to consume other fuels.

(Source: New Mexico Department of Energy, 1992)

It is generally agreed, however, that prescribed burns can not be used as the sole method of ponderosa pine forest restoration. They are too unpredictable, and need to be done with regularity over a long period of time to produce the desired effects (Graham et al., 1998). When prescribed burns are undertaken, usually to reduce fuel loading or improve forage, their hydrological effects likely will be similar to those of the "best case scenario" described in Figure 5-7: a slight increase in water yield without a significant change in water quality.

6.0 CAN FIRE BE A PART OF SUSTAINABLE WATER RESOURCE DEVELOPMENT?

6.1 Introduction

The following are three recommendations for making fire management policy and water resource development more sustainable. Agenda 21 from the United Nations' 1992 Conference on Environment and Development broadly defined sustainable development as, "development choices that will be economically efficient, socially equitable and responsible, and environmentally sound" (United Nations Conference on the Human Environment, 1992). Based on that explanation, I propose the following definition:

Sustainable development is planned use and management of resources that is economically viable, politically feasible, socially and culturally acceptable and environmentally friendly. Decisions are made with consideration of their long-term consequences and with the goal of equity for all people and the natural communities upon which they depend.

6.2 Recommendation One: Adopt the Ecosystem Approach

The ecosystem approach to fire management recognizes that fire is one component of a dynamic and evolving system. Water resources are another part of that system, and the two interact at every level. A sustainable fire management policy will recognize the impacts that wildfires and prescribed burns have on hydrological processes. A sustainable water policy for the ponderosa pine forests will, in turn, recognize the critical role of fire in developing healthy forest ecosystems. People, too, are part of the ecosystem approach, and it will also be necessary to include local values and traditions in the formulation of a sustainable fire management policy.

6.3 Recommendation Two: Interagency and Interdisciplinary Cooperation

The *Federal Wildland Fire Policy* states that past approaches to fire management policy resulted in "an inefficient, fragmented, short-term approach to management that tends to ignore broad, interdisciplinary-based, long-term resource issues that cross agency boundaries" (USDA and USDI, 1996). Clearly this approach was ineffective and had severe implications for forest health. As mandated by federal policy, fire management officials should work with all other agencies, groups and individuals that have a stake in the ponderosa pine forest. Participation in a watershed council is one possible avenue for this type of cooperation; community meetings and town halls are another. Each management team must decide upon the best approach for its community.

6.4 Recommendation Three: Research, Evaluation and Monitoring

The biggest obstacle to successful fire policies is the lack of information available on the interaction of fire with various parts of the ecosystem. The Rocky Mountain Research Station notes, "Understanding the role of fire in ecosystem development is fundamental to restoring and maintaining ecosystem health and productivity" (USDA, 1998). They cite several research initiatives completed and underway, including vegetation recovery, smoke management, soil erosion and wildland/urban interface protection measures. Furthermore, the Federal Wildland Fire Policy mandates that each local fire management plan "develop research programs that provide a sound scientific basis for the integration of wildland fire into land-use and resource management" (USDA and USDI, 1996).

The interchanges between fire and water are perhaps some of the least known relationships in this arena, and clearly merit further study. A sustainable fire management policy will include experiments and monitoring stations that help quantify relationships between fire and water, and observe the short and long-term interactions at the ecosystem level.

7.0 SUMMARY AND CONCLUSIONS

Since the pre-colonial era in northern New Mexico, the ponderosa pine forests have changed dramatically. Today's dense stands, crowded canopies and thick duff layers have little resemblance to the open, park-like stands of centuries ago. The role of fire in the forest has also changed, from a regular, non-lethal regime to a sporadic series of wild crown fires. In this process, the balance of the hydrological cycle shifted from the development of moisture-rich, nourishing soils to a cycle dominated by evapotranspiration and interception.

As fire management officials look to new policy directions, they will find it necessary to consider hydrological effects of fire. Through interdisciplinary efforts to undertake an ecological approach to fire, officials can make more sustainable resource management decisions. Through research and monitoring of these linkages, we can all begin to understand the long-term effects of forest and fire management decisions.

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SUSTAINABLE WATER RESOURCES AND THE RIO GRANDE SILVERY MINNOW: A BIOLOGICAL PERSPECTIVE

Claire Kerven

Executive Summary. The Rio Grande Silvery Minnow (RGSM), *Hybognathus amarus*, was declared an endangered species in 1994 following investigations which revealed its habitat to be only 5% of its original reach. The morphologic and hydrologic alteration of the Rio Grande, originally characterized as a plains stream, has significantly changed the aquatic environment and riparian zone of the river. The consequence of these alterations has been the extirpation of native cyprinid pelagic spawners. The RGSM is the last of its reproductive guild still found in the Rio Grande. Preferred habitat has been severely reduced by a channelized, high velocity river and reproductive strategy is threatened by river fragmentation. This vulnerable species has a short life span and could be irreversibly damaged by two consecutive dry years.

Water releases to keep the river wet and free of isolated pools will probably impact the water rights of other stakeholders on the Rio Grande during dry years. Major stakeholders include the City of Albuquerque, the Middle Rio Grande Conservancy District, the Office of the State Engineer, the U. S. Fish and Wildlife Service and environmental groups.

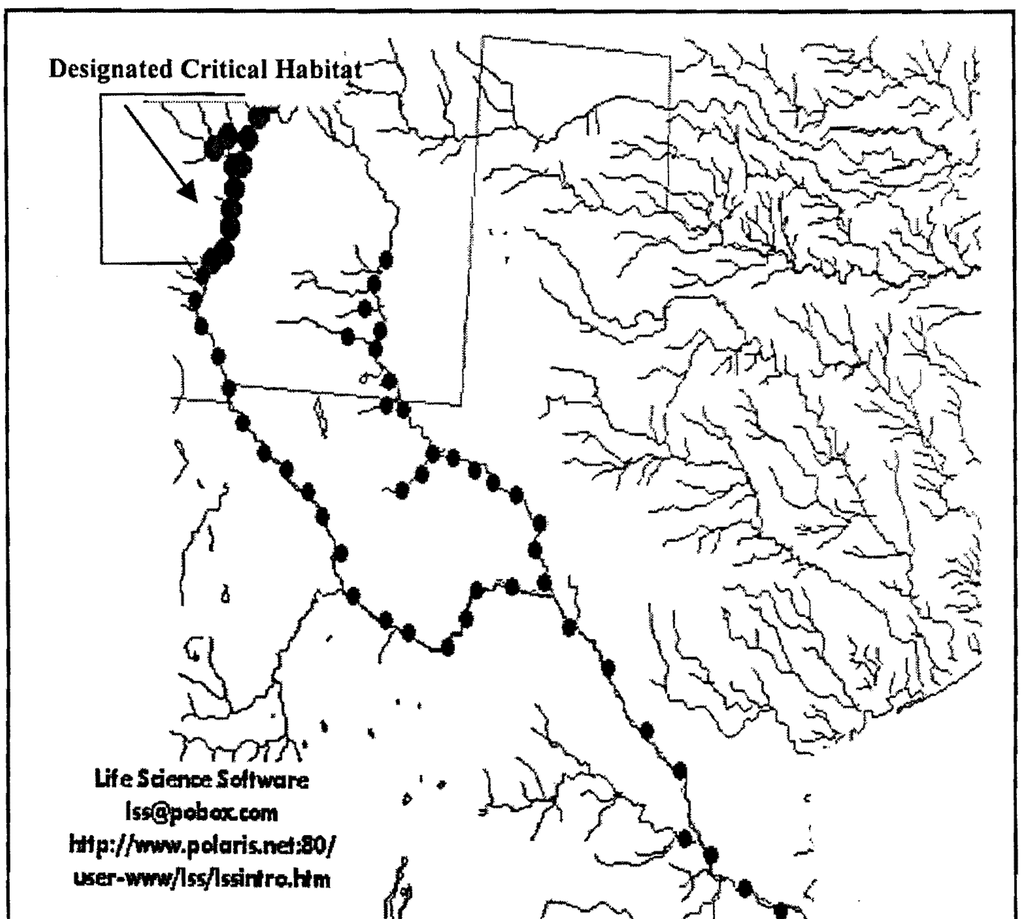
Species extinction is accelerating due to destruction of habitat. The disappearance of species and ecosystems means the possible loss of undiscovered medical cures and forfeited economic benefits. The extinction of a keystone species could trigger a dangerous ripple effect bringing down other species with it.

Sustainable development is achieved when economic growth does not diminish natural resources. The Western Water Policy Review Advisory Commission and the President's Council on Sustainable Development recognize the critical need for proper management of natural resources and the evaluation of the real cost of projects which degrade ecosystems and endanger species. Many western states are successfully reclaiming damaged ecosystems.

1.0 INTRODUCTION

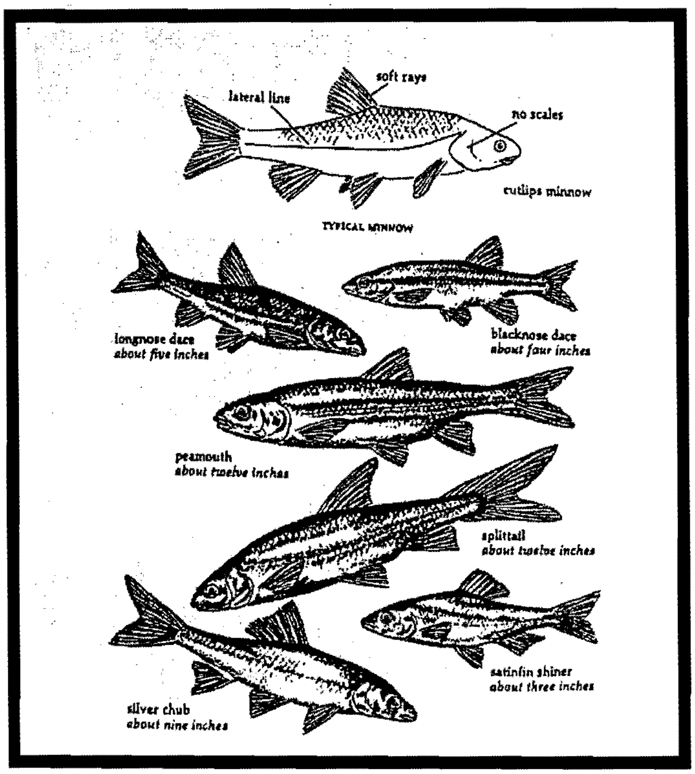
The Rio Grande Silvery Minnow (RGSM), *Hybognathus amarus*, was declared an endangered species by the U.S. Fish and Wildlife Service in 1994, following investigations which revealed its habitat to be only 5% of its original reach (Dudley and Platania, 1997) (Figure 6-1). On June 23, 1999, the main stem of the Rio Grande between Cochiti Dam and Elephant Butte Reservoir was designated a critical habitat for the RGSM. The Endangered Species Act (ESA) provides for federal land acquisition and cooperation with the States and authorizes recovery plans for all listed species. In addition, the federal government may not authorize, fund or carry out any activities that jeopardize the continued existence of a species or adversely modify critical habitat. This could affect the operation and maintenance of dams and diversion structures that regulate flow on the river and could involve the International Boundary and Water Commission, the Bureau of Reclamation, Army Corps of Engineers, Environmental Protection Agency and Bureau of Indian Affairs.

Figure 6-1. Historic RGSM Habitat (All Dots) and Designated Critical Habitat (Larger Dots).



The Rio Grande is considered to be completely appropriated and the release of water in order to keep the main stem wet on a continuous basis could have a significant impact on other water users during dry years. Growing conflict exists among stakeholders on how to resolve this issue. Stakeholders include the Middle Rio Grande Conservancy District, the City of Albuquerque, the Office of the State Engineer, the Interstate Stream Commission, the Pueblos, the U.S. Fish and Wildlife Service and others.

Figure 6-2. Cyprinid Family Minnows



Historically, the silvery minnow was one of the most abundant and widespread fish in the basin (Figure 6-2). Prior to 1968, *H. amarus* was found in the Pecos River downstream from Santa Rosa as well as in the Rio Grande from Española to the Gulf of Mexico (Bestgen and Platania 1991). In 1968, *H. placitus* was introduced into the Pecos drainage, probably as bait fish collected from the Arkansas River drainage, where it completely displaced *H. amarus* within a decade, a unique occurrence for this genus (http://bluegoose). This leaves the main stem of the Rio Grande as the *only* existing habitat for this endangered species.

Although there are other factors involved in the decline of the RGSM, maintaining an instream flow is paramount. It is frequently pointed out that the Rio Grande has not historically been a perennial river, and yet the RGSM has survived. Since gauging records and anecdotal reports do not predate development on the river, this is certainly contestable. According to Biella and Chapman (1977) the river *was* perennial prior to human development if we go back 600-700 years. Regardless of the answer to this interesting question we do know that within this century the river has been drastically altered by several main stem and tributary reservoirs and a series of diversion dams. During dry years some of these stretches can and have become dewatered by agricultural diversion (Platania, 1995).

A second factor in species decline is river fragmentation (Platania, 1999). Main stem impoundments on the Rio Grande since 1925, including Cochiti Reservoir, Isleta, Angostura and San Acacia diversion dams have resulted in 1) the destruction of habitat; 2) water which is clearer and accommodates visual predators; 3) a segmented river which defeats the 'pelagic' reproductive strategy; 4) the prevention of migration to refugia during dry periods; 5) reduced nutrient and food supply below dams; and 6) a fragmented and weakened gene pool.

By 1964, the silvery minnow had been preceded to extinction in the Rio Grande by the extirpation of four other members of its reproductive guild: speckled chub, Rio Grande shiner, bluntnose shiner, and phantom shiner. (U. S. Fish and Wildlife Service, n.d.) Significant changes in the fish community of the main stem of the Rio Grande have been documented since 1958 when the first icthyofaunal survey was done (Platania, 1995).

2.0 THE RIO GRANDE SILVERY MINNOW

2.1 Distribution and Abundance

Prior to 1958 there are no historical surveys on icthyofauna for the 22 mile reach occupied by Cochiti, Santo Domingo and San Felipe Pueblos. Between 1958 and 1964, four collections of fish were done which documented the existence of the Rio Grande bluntnose shiner, and speckled chub. The last collection in 1964 was just before the completion of Cochiti Dam and was the last time these two native fish were found (Platania, 1995). Collections made after 1964 found far fewer specimens of RGSM than before, with the last RGSM being collected in the Cochiti vicinity in 1988 and none in subsequent collections (Platania, 1993). Rio Grande chub and flathead chub have also disappeared from collections since 1987. At the same time as native fish declined, non-native game fish were introduced into Cochiti Reservoir for sport fishing (U. S. Fish and Wildlife Service, n.d.). These pisciverous game fish escaped from the reservoir and now inhabit the slower velocity habitats previously frequented by native cyprinids, upon whom they predate and compete with for food.

River fragmentation has eliminated upstream migration to canyons such as White Rock and Jemez where fish could remain until more favorable conditions allowed them to repopulate the main stem (Hatch,1999). These relatively impermeable rock canyons stay wet when sandy stretches of the river dry out.

In dry years the river can be dewatered from the Isleta diversion dam downstream for as many as 111 miles for two months or more (http://bluegoose). It is the southern reaches of the main stem that have the highest count of RGSM and so dewatering of this area can pose a substantial threat to the continued existence of RGSM.

2.2 Reproductive Strategy

The Rio Grande Silvery Minnow is a pelagic spawner. Gravid females release non-adhesive eggs into the middle or upper part of the open water column in a series of clutches. Three to eighteen clutches may be produced with a mean clutch containing 270 eggs (U. S. Fish and Wildlife Service, 1998).

Females are born with eggs which must mature to ripeness before they are released. From laboratory observations of induced spawning, it was deduced that eggs begin to mature at the onset of increased flow and require an additional 4-6 hours to ripen depending on temperature and egg maturity, thereby allowing time for a peak flow spike to occur. Under conditions of extended high flow, egg releases could continue for hours or days (Platania, 1995).

The eggs are fertilized by males and must stay suspended for 10-30 minutes until the perivitelline space fills with water and renders the eggs semi-buoyant. Eggs are approximately 1.6 mm upon fertilization but quickly swell to about twice that size (Platania, 1995). Hatching occurs over a 24 - 48 hour period and appears to be temperature-dependent. The newly hatched larvae drift downstream while swimming up in the water column. During this time the eggs require enough of a flow to stay suspended in the water column so they do not sink to the bottom and suffocate. About three days after hatching, a gas bladder develops, the yolk sac is depleted and the fish end their swim up period and begin to feed. When feeding begins, fish swim horizontally and appear to seek warm, shallow, low velocity areas with good food availability (Dudley and Platania, 1997).

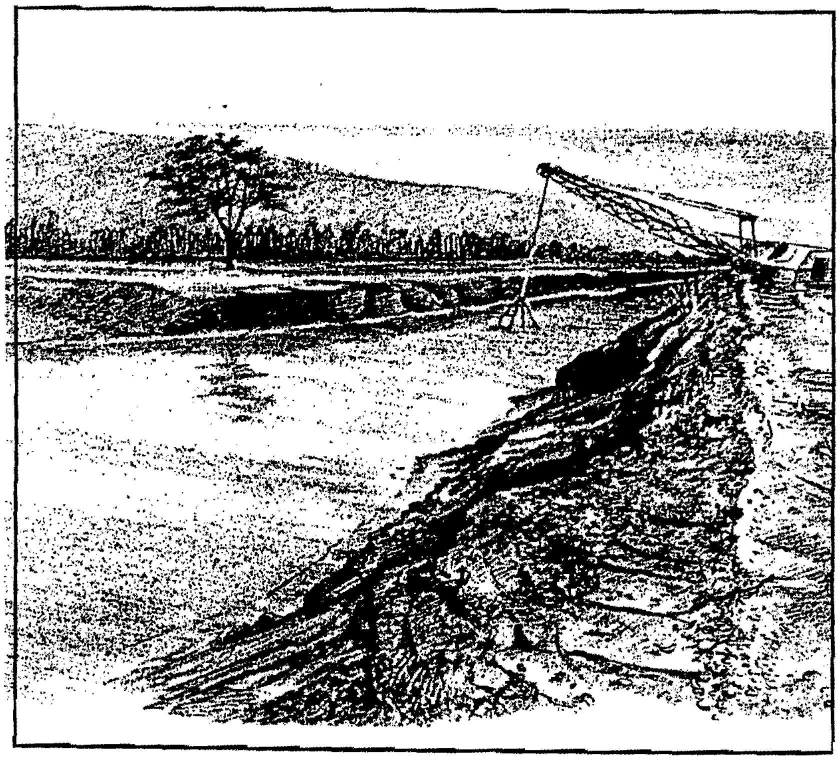
According to icthyofaunal biologists Dudley and Platania (1997), reproductive behavior, egg physiology and larval fish behavior suggest that high flow events are important factors in this species life history. These events appear to trigger spawning and provide the flow for eggs to stay adrift in the current for 3-5 days, transporting eggs and larvae up to 134-223 miles downstream (Dudley and Platania, 1997). They state:

"The Rio Grande silvery minnow is one of a group of fish that evolved reproductive and early life history strategies for living in aquatic ecosystems in arid lands of the west-central United States. In New Mexico, both the Rio Grande and Pecos River are typical of plains lotic ecosystems characterized by flashy or unpredictable flow" (Dudley and Platania, 1997).

Young require a nursery environment of warm, slowly flowing or no flowing shallow water with plenty of phytoplankton and zooplankton. Here they grow quickly from a hatched length of 3.7 mm to lengths of 45 to 49 mm (Dudley and Platania, 1997). This sort of environment is usually found in backwater pools and embayments, now in short supply particularly at peak flow when a constricted river can no longer overflow its banks (Bullard and Wells, 1992) (Figures 6-3 and 6-4).

Figure 6-3. Meandering Plains Stream

Figure 6-4. Straightened Channel Reduces Habitat



2.3 Habitat

The preferred habitat of the silvery minnow is low velocity, shallow water over a silty substrate, although this is not the most commonly available (Dudley and Platania, 1997). Most individuals were collected in depths under 20 cm or between 31 and 40 cm. Few were found at depths greater than 50 cm. The greatest abundance of silvery minnows was found in velocities of less than 10 cm/sec and almost none were found in velocities over 40 cm/sec (U. S. Fish and Wildlife Service, n.d.). More than 90% of individuals were found over a silty substrate and less than 1% were found over gravel and cobble. The most frequently selected habitats were eddies formed by debris piles, pools and backwaters. In winter the mature fish are found almost exclusively in debris piles where the water is fairly still, despite other available habitats (U. S. Fish and Wildlife Service, 1998). This habitat allows them to conserve their energy during a season when they will not be eating.

2.4 Life Cycle

The life cycle of the RGSM is fairly short. Most fish do not live beyond 13 months, although some as old as 25 months have been collected (U. S. Fish and Wildlife Service, 1998). Fish of one year old dominate and constitute over 95% of the population prior to spawning in the spring. By December the majority is comprised of fish less than a year old. Age 2 females can produce twice as many eggs as Age 1 females, but constitute less than 5% of the population (U. S. Fish and Wildlife Service, 1998). What is significant is that the entire species could be irreversibly damaged by two consecutive dry years.

3.0 BIODIVERSITY AND SPECIES CONSERVATION

> Like winds and sunsets, wild things were taken for granted until progress began to do away with them. Now we face the question whether a still higher "standard of living" is worth its cost in things natural, wild and free.
>
> Aldo Leopold, A Sand County Almanac, (1949)

Conservation biology is the science that studies biodiversity and the dynamics of extinction. The focus is on how genes, species, ecosystems, and landscapes interact and how human activities affect these processes. The accent is on ecology, and not economics as with other natural resource management fields (Grumbine, 1993).

Two of the pioneers of conservation biology are MacArthur and Wilson (1967), who studied species population and extinction rates as they relate to the size of an island. According to their island biogeography studies the species most likely to disappear are those with large bodies, low population growth, small numbers of individuals, poor dispersal ability and complex social structures. This description does not readily apply to the RGSM. The cyprinidae family is the most abundant fish family in North America

(Pringle, 1976) probably because of tiny size, ability to reproduce abundantly, simple social structure and ability to migrate over extensive stretches of river. It is human interference that has changed this equation.

Ehrlich and Wilson (1990) asserted in the beginning of this decade that we are in the midst of an accelerating extinction of wild species and ecosystems brought about by human activity and that biodiversity reduction is accelerating due to destruction of habitat. The U.S. Fish and Wildlife Service currently lists over a thousand threatened and endangered species of plants and animals in the United States alone.

Though riparian areas constitute only a fraction of the total land area, they are more productive in terms of both plant and animal species diversity and biomass per unit area than the remainder of the land base (U. S. Forest Service, 1990). The decline of a healthy riverine ecosystem like the Rio Grande represents a large loss of biota and vast biological potential. Undeveloped medicines, crops, pharmaceuticals, timbers, fibers, pulp, soil restoring vegetation, petroleum substitutes and a wealth of scientific information is lost when species and ecosystems disappear (Ehrlich and Wilson, 1990).

4.0 SUSTAINABLE RESOURCES

What is sustainable development? It is development that coexists with and does not diminish the legacy of the natural world and its resources. Sustainable natural resources are assets like water, soil, wildlife, and air that must continue to be available for generations to come.

In 1993, President Clinton established the President's Council on Sustainable Development (PCSD), a partnership of leaders from industry, government and non-governmental organizations concerned with environmental quality and economic development, two concepts frequently in conflict with each other. The mission of the natural resources component is to develop an ethic of stewardship based on collaborative approaches, ecosystem integrity and incentives that will accomplish this goal (President's Council on Sustainable Development, 1996).

Currently, subsidies encourage *consumption-based* rather than *conservation-based* behavior by obscuring the true costs of decisions. Examples of subsidies in direct conflict with other laws and policies include subsidized overgrazing of public lands and subsidized diversion of water for irrigation which jeopardize species like the RGSM and Columbia River salmon. The PCSD made several concrete suggestions that would establish balance between economic development and shrinking resources. Policy recommendation #3 for creating and promoting incentives to maintain natural resources include (PCSD, 1996):

- Passing the real cost of public resource use on to commercial users, e.g., irrigators who pollute the river with fertilizer could be charged for ecosystem degradation.

- Public infrastructure projects that account for the real cost to the ecosystem of proposed projects and reengineer these projects if they are not ecosystem friendly.
- Tax deductions to property owners who practice good conservation.
- Identification of sensitive habitats and mitigation fees levied for use of these.
- Establishment of public trust funds from general taxes or user fees on public resources for purchasing sensitive and valuable habitats.
- A matching fund program from the federal government to encourage state, local and tribal investment in sustainable programs.

Policy Recommendation #8 encourages partnerships that would foster environmentally responsible management and protection of biodiversity with some similar suggestion for tax credits and donation of land into protected status (PCSD, 1996).

Fish and waterfowl protection are the basis of four of six river basin studies prepared for the Western Water Policy Review Advisory Commission (WWPRAC) including the Sacramento-San Joaquin, Columbia, Platte and Truckee-Carson, and are playing an increasing role in the Colorado River and Rio Grande. The Commission recognizes that the construction of dams and the diversion of water from river systems or basins has contributed to the decline of historic natural fish populations in river basins throughout the West. Dams and water diversion patterns have also increased predation, reduced wildlife habitat, increased pollution, damaged floodplains and increased risk from flooding by the aggradation of streambeds (Western Water Policy Review Advisory Commission, 1998).

Throughout the West, states like Montana and Texas are finding innovative ways to protect instream flow and flow values with purchase or lease arrangements of water rights and the creation of trust funds for the environment. Washington is budgeting water for endangered species, and Idaho and Oklahoma protect instream flows with the scenic river designation.

In California, research and pilot programs are making water diversion friendlier with fish ladders and chutes. On the Columbia River, the Northwest Power Planning Council administers $400 million a year for a salmon recovery program (Western Water Policy Review Advisory Commission, 1998).

Dams are being taken down or breached all over the United States to revitalize failing fish populations and fishing industry. In 1999, the Edwards Dam in Maine was breached in order to reverse the environmental damage to salmon, striped bass and shad that were prevented from reaching spawning grounds. The Federal Energy Regulatory Commission (FERC) is refusing to relicense dams where the environmental costs outweigh the value of the hydropower or demanding that a dam be retrofitted with fish ladders, an extremely expensive undertaking. The effects of dam removal on fish populations in some places has been immediate and positive. The Quaker Neck Dam on the Neuse River in North Carolina came down in 1997-1998; bass and striped shad are already running again. On Butte Creek in northern California, the removal of three dams in 1998 allowed the salmon run to jump from zero to 20,000 (Begley, 1999). According to Dudley and Platania (1997), the level of flow manipulation needed to maintain the Rio Grande silvery minnow community is minimal compared to other regions of the American Southwest.

5.0 SUMMARY

A good deal of information now exists regarding the altered morphology of the Rio Grande, hydrologic flow, icthyofaunal surveys and habitat studies which, when combined, produce a good understanding of why the RGSM is in decline. The silvery minnow is part of a reproductive guild that is adapted to the flashy, flood-flow regimes of arid lands of the Great Plains region of the central and western United States. The addition of reservoirs and diversion dams that control flow for irrigation and flood prevention, and the constriction of the river by jetty jacks and levees has rendered the Rio Grande a different river – no longer suited to the habitat needs of a pelagic spawner.

The quantity of water needed to maintain habitat has not been determined; however, it is clear that some level of water is essential. Where there is no water, there is no habitat. The most critical period for the RGSM appears to be between July 1-October 30, when 90% of mature fish have spawned and died leaving larval RGSM to perpetuate the species. It is at this point that irrigation can and has claimed all the surface water between the Isleta and San Acacia diversion dams (Dudley and Platania, 1997). The reach below San Acacia has historically been the most frequently-desiccated section as there are very few places for a return flow after water is diverted. In 1996 extensive portions of the San Acacia reach were dewatered leading to the loss of thousands of gravid female silvery minnows as well as other fish (Dudley and Platania, 1997). Some steps to resolve this serious issue have already been taken although the problem is far from being solved. In 1997, the Middle Rio Grande Conservancy District (MRGCD) agreed to allow the U.S. Fish and Wildlife Service the use of its equipment for the transfer of non-district water to lower reaches of the main stem below Isleta Dam and also to release 3,000 cfs of MRGCD water in the event of a drought in 1997 (Figure 6-5). In 1996 the U.S. Bureau of Reclamation connected the low-flow conveyance channel with the Rio Grande making it possible to keep the river wet below San Acacia diversion dam (http://bluegoose).

The impact of population growth and development on natural resources, land, water and open spaces must be carefully considered in relation to the available resource base. Water and related resources must be managed so that environmental, economic, social and cultural values can be supported indefinitely (Dudley and Platania, 1997).

Figure 6-5. 1997 Agreement Between MRGCD and USFWS to Transfer Water for Minnows.

http://sturgeon.irm1.r2.fws.gov/news-rel/mrgcd.sax

Subhas Shah 505-247-0234
Middle Rio Grande Conservancy District
May 19, 1997
Hans Stuart 505-248-6911
U.S. Fish and Wildlife Service

FISH AND WILDLIFE SERVICE, MIDDLE RIO GRANDE CONSERVANCY DISTRICT SIGN AGREEMENT TO PROTECT ENDANGERED SILVERY MINNOW

The U.S. Fish and Wildlife Service and Middle Rio Grande Conservancy District signed an agreement last week that calls for the parties to cooperate in protecting endangered Rio Grande silvery minnow from drought or other events that could dewater Rio Grande in the fish's range during this year's irrigation season.

Provisions in the agreement call for the parties to coordinate water deliveries fish with other water management agencies, including the Bureau of Reclamation, U.S. Corps of Engineers, and the State Engineer's Office, to sustain minnow habitat in th Rio Grande.

"This agreement provides a framework for cooperation and coordination between t Service and the Conservancy District which I believe will become a model for other e the Rio Grande," said Southwestern Regional Director Nancy Kaufman. "We are pleased we could work together on this issue to develop conservation strategies for the minn

"While protecting the interests of Conservancy farmers and water users, the Dis agreed to work cooperatively with the U.S. Fish and Wildlife Service for the protect survival of the Rio Grande silvery minnow. In the spirit of cooperation, the Conser District has used and will allow the use of its facilities to convey non-District wa benefit of the minnow," Conservancy District Chairman Lawrence Troncosa said.

The Fish and Wildlife Service is simultaneously working with other federal agen plans to provide water in the River to protect the minnow throughout its range, Kauf added. However, in the event of a drought emergency in which the agencies cannot pr water to the River in a timely fashion this year, the Conservancy District will prov 3,000 acre-feet for the fish if requested by the Service.

- more -

In the agreement both parties agreed to pursue long-range water management and planning that involves all Rio Grande system users and managers. Goals of the effor

- federal efforts to provide flows in the Rio Grande through releases from upstream reservoirs;
- Conservancy efforts to avoid unpermitted take of the minnow from its operatio and water management;
- equitable sharing of shortages by all Rio Grande system users;
- collection of better data on the flow requirements of the silvery minnow;
- collection and sharing of data on transmission losses in the middle valley;
- collection and sharing of data on potential effects of groundwater pumping on surface flows and habitat for the silvery minnow.

6.0 CONCLUSIONS AND RECOMMENDATIONS

The river is not a giant water pipe. It has a complex life of its own which has been overlooked and devastated by excessive demands that are not supported by the climate. The demise of the river and its community reduce the quality of life in New Mexico and remove potential recreation and wildlife dollars.

Although instream flows are recognized and protected in many western states, it is a curious fact of New Mexico law that the river itself has no legal claim to water. Re-engineering nature has been done at great cost to the environment of the bosque and the biodiversity of the river and riparian areas. The Rio Grande Silvery Minnow is an endangered species in a severely altered and sometimes desiccated riverine ecosystem.

Biodiversity of flora and fauna are links in a global ecosystem which can be compared to a single living organism. When pieces are lost, damaged or re-engineered there is an effect to the rest of the organism which is not always understood and anticipated. It is likely that Bureau of Reclamation engineers did not realize that straightening the river would change the habitat for fish enough to extirpate most species from the Rio Grande or that the cottonwoods would cease to have the flood pulse they needed to continue as the dominant tree species of the riparian corridor or that exotics would gain a foothold as a result of the change in water table depth. Or perhaps they thought such changes were not significant.

How do we decide which species are expendable? According to Wilson (1992), the loss of a keystone species can trigger a ripple effect in other species demographics, bringing down other species. The loss of biodiversity will affect us in many areas:

- Ethical and aesthetic: we are the dominant species and it is our responsibility to steward the earth and its species. The companionship of other species is clearly rewarding, as witness the popularity of ecotourism, wildlife films and pets.
- Direct economic benefits: foods, medicines, industrial products and unlimited potential for more. Throughout the world almost 25% of all prescriptions are for chemical compounds or synthetic derivatives of plants and microorganisms. This is the genetic library of our world and it is linked in ways we have yet to understand.
- The diverse species are the keys to natural ecosystems which maintain a crucial world balance of atmospheric gases, climate control, generation and maintenance of soils, nutrient cycling, pest control by predacious insects, crop pollination, and food sources (Barbault, 1995).

"The ecosystem services in which biodiversity plays the critical role are provided on such a grand scale and in a manner so intricate that there is usually no real possibility of substituting for them, even in cases where scientists have the requisite knowledge. .... One might assume that one grass or tree species can function as well as any other in helping to control the hydrologic cycle in a watershed, or that one predator will be as good as another in controlling a potential pest. But of course, organisms are generally highly adapted to specific physical and biotic environments – and organic substitutions, like inorganic ones, are likely to prove unsatisfactory" (Ehrlich and Wilson, 1990).

The Rio Grande ecosystem must be restored to a reasonable functioning level if it is to be sustained in the future. New Mexico should look to neighbor states which have already solved similar problems successfully for guidance. The Endangered Species Act and Clean Water Act continue to play an important role in spearheading such restoration. A collective effort by government at all levels should aim to manage or contain economic development so that natural resources last in perpetuity.

The validity of instream flow values must be recognized by New Mexico law. A healthy Rio Grande can stimulate additional tourism, recreation and fishing dollars and offer alternatives to an already withering agricultural economy. Instream flow will benefit water quality, and can be used as part of our compact obligation to Texas and Mexico.

It is critical to recognize the importance of preserving biodiversity and divest ourselves of the notion that it is a luxury for naturalists. Beyond our own unwitting self destruction, it is a matter of respect for all living things that we should seek to preserve and not diminish life. We must develop an attitude of stewardship towards the earth and its inhabitants who preceded us.

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ESTABLISHING CONTINUOUS INSTREAM FLOW ON THE MIDDLE RIO GRANDE FOR THE RIO GRANDE SILVERY MINNOW: OPPORTUNITIES AND OBSTACLES

Lynne Marie Paretchan

Executive Summary. An inherent conflict exists between the needs of fresh water fisheries and the practices on Western rivers to divert water for agricultural, urban and industrial users. In response, most Western states have established strategies to institute instream flow rights for conservation and ecological purposes. These strategies frequently create conflicts with other water users where no unallocated water is available for instream flow purposes.

Examples of water allocation conflicts in basins outside of New Mexico generated by endangered species issues, reveal that agricultural interests are willing to accept their inevitable reductions in water allocations for 1) a greater measure of certainty about future water allocations in light of any newly designated endangered species and 2) federal and state dollars for delivery and storage system improvements.

The U.S. Fish and Wildlife Service's 1999 designation of continuous instream flow as part of the critical habitat for the endangered Rio Grande Silvery Minnow on the Middle Rio Grande, highlights the need for the state of New Mexico to further refine its water laws to protect instream flows for conservation and ecological purposes. New Mexico needs to formally define conservation and ecological values as public welfare and beneficial uses and allow the sale of conservancy district water rights for instream flow purposes. New Mexico must also look to the examples in other basins where agricultural, environmental, urban and tribal interests, and states and the federal government have successfully collaborated to reallocate resources to protect endangered species. It will be necessary to reallocate resources to establish instream flows for the silvery minnow and to restore the habitat of the Middle Rio Grande Basin.

"The Rio Grande silvery minnow is a relative newcomer in the hierarchy of Middle Rio Grande water priorities, having been designated as an endangered species only in 1994. Firm plans to ensure a sustaining supply for this small fish during low flow years should be put into effect as quickly as possible."
John Hernandez (1999)

1.0 INTRODUCTION

An inherent conflict exists between the needs of fresh water fisheries and the practices on Western rivers that divert water for agricultural, urban and industrial users. Freshwater fisheries typically require a minimum of thirty percent of a river's annual flow to sustain the fishery (Moore et al., 1996). Consequently, dams and diversion works have wreaked havoc on the ecosystems of rivers, wetlands, lakes, and estuaries in the West.

In New Mexico, the 1994 listing of the Rio Grande Silvery Minnow (*Hybognathus amarus*) as an endangered species and the subsequent designation of a continuous instream flow in New Mexico's Middle Rio Grande are the forces driving significant collaborative efforts and litigation strategies among stakeholders. The critical habitat designation presents a serious challenge to water users on the river because historic diversionary practices on New Mexico's Middle Rio Grande routinely result in dry stretches of river bed, especially during periods of drought and heavy irrigation.

The obvious remedy to ensure the instream flow on the Middle Rio Grande is to reallocate water from offstream, consumptive uses to instream flow. Generally, the primary incentive for water users to attempt to negotiate water reallocation issues generated by the presence of endangered species is simply the hope that they will lose less water than if the solution is imposed on them by the federal government (Rieke, 1996).

U.S. Fish & Wildlife Service's (FWS) designation of the silvery minnow's critical habitat in 1999 reignited fractious debate over the sustainability of the economies dependent on water diversions from the Middle Rio Grande and the sustainability of the riparian and aquatic environments along the Middle Rio Grande. Agricultural users, municipalities, Indian Pueblos, ecosystem advocates, federal agencies and the states of New Mexico, Colorado and Texas face significant incentives and obstacles to creating a new water management paradigm to deliver flow on the Middle Rio Grande to accommodate the needs of the silvery minnow.

After an introduction to the Middle Rio Grande basin, the legal impacts of the minnow's listing under the Endangered Species Act, and the tools available to acquire instream flow rights for the silvery minnow, this paper will 1) examine approaches used in other basins to provide instream flow to support fish and wildlife while accommodating consumptive uses and 2) evaluate the opportunities to adopt those approaches in New Mexico.

2.0 THE MIDDLE RIO GRANDE BASIN

2.1 Physical Setting

For purposes of this paper, the Middle Rio Grande is defined as the 163 mile stretch of the Rio Grande in New Mexico between Cochiti Dam in the North and the Santa Fe and Topeka Railroad crossing bridge just above Elephant Butte Reservoir in the South. This corresponds with the area the U.S. Fish and Wildlife Service has designated as critical habitat for the Rio Grande Silvery Minnow. The Rio Grande/Rio Bravo river system is 1,890 miles long and drains a 355,500 square mile region from its headwaters in Colorado to its terminus in the Gulf of Mexico. The Rio Grande passes through Colorado and New Mexico, and then becomes the Rio Bravo where it forms the Texas-Mexico border. The Middle Rio Grande is a long, relatively narrow valley with the groundwater table very close to the ground surface in the valley areas (Martinez, 1999). The valley is constricted in places to less than a mile[1] and beyond these points the valley widens appreciably. This area is home to about forty percent of New Mexico's population (Fort, 1998).

Because the Middle Rio Grande water supply relies on snowpack and runoff from mountains in southern Colorado, northern New Mexico, and along the length of the basin, this section of the river is subject to periodic low flows with high rates of surface flow loss occurring during the irrigation season (Martinez, 1999). The diversionary practices of agricultural users have historically diverted the entire river flow at certain times of the year creating a dry river channel below the diversions. Evaporative and infiltration losses are particularly severe when the river channel has been allowed to become dry for a period of a week or more.

2.2 Rio Grande Compact of 1938

The Rio Grande Compact of 1938 (53 Stat. 785) provides the overall framework for water deliveries on the Middle Rio Grande. The Compact was executed by the states of Colorado, New Mexico and Texas and was consented to by Congress in 1939. The Rio Grande Compact is based on the notion of equitable apportionment and forces Colorado and New Mexico to allow certain

[1] Near Cochiti, near Iselta just south of Albuquerque, and at San Acacia just above Socorro.

levels of water to reach downstream users. The allocation to each state is based on percentages of the water flow which varies with the volume of water available. The Compact specifies New Mexico's delivery obligations into Elephant Butte Reservoir for the state of Texas. Nothing in the Compact may be construed as affecting the obligation of the United States to Mexico under existing treaties or as impairing the rights of Indian tribes.

2.3 Storage of Flow for the Middle Rio Grande Basin

The Bureau of Reclamation and the Army Corp of Engineers operate a series of multi-purpose water resources facilities on the upper Rio Grande that are the primary storage facilities for the flow of the Rio Grande delivered to the Middle Rio Grande basin and the state of Texas. The reservoirs are operated so the water delivery requirements under the Rio Grande Compact and Mexican Water Treaty (43 Stat. 118) are satisfied.

2.4 Rio Grande Silvery Minnow

The Middle Rio Grande is the historic home to the Rio Grande Silvery Minnow, a freshwater fish listed as endangered in 1994. Throughout much of the silvery minnow's historical range, the decline of the species may be attributed to modifications of stream discharge patterns and channel drying because of impoundments, water diversion for agriculture, and stream channelization (64 Fed. Reg. 36724-25, July 6, 1999).

3.0 IMPLICATIONS OF SILVERY MINNOW'S LISTING UNDER THE ENDANGERED SPECIES ACT

3.1 Endangered Species Act

The Endangered Species Act of 1973 (ESA) (16 U.S.C. §§ 1531 – 1543) prohibits federal agencies from taking any action which is likely to "jeopardize the continued existence" of any "endangered" or "threatened" species or result in the "destruction or adverse modification" of any habitat designated as "critical" in order to ensure the protection and recovery of a listed species. The ESA prohibits any person from "taking" any listed animal species, unless a special permit authorizes the "take." Under the Act, "take" means to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, collect, or attempt to engage in any such conduct. The ESA authorizes civil and criminal penalties up to $50,000 and one year in jail for violation of provisions of the Act or permits issued pursuant to the Act (16 U.S.C. §1540 (b) (1)).

The ESA allows the taking of endangered species on private land under limited circumstances. In order to qualify for an incidental take permit, a landowner must receive the approval of a "habitat conservation plan" (HCP) that minimizes and mitigates any harm to the listed species (Welner, 1995).

3.2 Supremacy of the Endangered Species Act

In 1978, the Supreme Court determined that the "language, history and structure" of the Endangered Species Act "indicates beyond doubt that Congress intended endangered species to be afforded the highest of priorities." (Tennessee Valley Authority v. Hill, 437 U.S. 153, 174 (1978)). The undeniable conflict between established water users and endangered species in western rivers was raised in congressional hearings on the 1982 amendments to the ESA. An unsuccessful attempt was made to amend the ESA to make the ESA water needs secondary to a state's system of established water rights (Estes, 1992). Instead, Congress included a weak policy statement in the 1982 amendment: "It is further declared to be the policy of the Congress that Federal agencies shall cooperate with State and local agencies to resolve water resource issues in concert with conservation of endangered species." (16 U.S.C. § 1531 (b) (1988)). Since then, courts have held that the ESA supports actions by agencies not to sell waters under their control for offstream uses when those waters are needed for an endangered species. (Carson-Truckee Water Conservancy District v. Clark, 741 F.2d 257 (9th Cir. 1983)).

3.3 Silvery Minnow's Critical Habitat Designation

On the Middle Rio Grande, loss of habitat is the primary factor driving the silvery minnow to extinction. The critical habitat designated in 1999 are those areas on the Middle Rio Grande where the species has been collected in the recent past and where species are currently known to exist. FWS delineated four reaches to reflect the prescribed management of water and habitat within this one hundred and sixty three mile stretch of river. The critical habitat includes only the active channel of the Rio Grande.

Much of the land that abuts the critical habitat is within the administrative boundaries of the state chartered Middle Rio Grande Conservancy District. Approximately forty-five miles of the critical habitat run through the Indian Pueblos of Cochiti, Santo Domingo, San Felipe, Santa Ana, Sandia and Isleta. The reaches of designated critical habitat include the lands of the communities of Algodones, Bernalillo, Corrales, Albuquerque, Los Lunas, Belen, Socorro, and a number of smaller incorporated and unincorporated communities (64 Fed. Reg. 36724, July 6, 1999).

3.4 "Takings" of Silvery Minnows During the Drought of 1996

In the low flow year of 1996, diversions on the Middle Rio Grande left the riverbed dry and caused the death of thousands of minnows. The Department of Interior did not pursue the civil and criminal penalties available following that event after negotiations with the involved parties. However, any future unpermitted "takings" caused by insufficient river flow will be subject to the heightened public awareness of the issues developed since 1996. In all probability, persons responsible for any future unpermitted takings of minnows will be subject to the penalty provisions of the ESA.

4.0 SURFACE WATER APPROPRIATION IN NEW MEXICO

All natural water flowing in streams and watercourses, whether such be perennial or torrential, within the limits of the state of New Mexico, belong to the public and are subject to appropriation for beneficial use." (N.M. Stat. Ann. § 72-1-1 (Michie 1997). New Mexico's water law is based on the doctrine of "prior appropriation" where the first user (appropriator) has the right to take and use water, and that right continues as against subsequent users as long as the appropriator puts the water to beneficial use (DuMars and Minnis, 1989). Beneficial use" is a very broad standard, not defined by statute or regulation. The requirement for continuing usage means "use it or lose it" became the legal norm for New Mexico water rights holders.

Since New Mexico's statehood in 1907, the state's surface waters have almost been fully appropriated (DuMars and Minnis, 1989). Water rights are defined by priority date, type of use, place of use, quantity and point of diversion. The vast majority of water rights in New Mexico's are pre-1907 rights (territorial rights) and constitute most of the state's surface water rights. Many of these have never been formally defined in adjudication suits (Fleming and Hall, 2000).

4.1 Water Banking in New Mexico

By establishing water banks, the state is attempting to counteract the prior appropriation doctrine's negative impact on water conservation. Traditionally, New Mexicans were penalized for conserving water because conserved waters were forfeited back to public ownership after four years of non-use (N.M. Stat. Ann § 72-5-28 (Michie, 1997). In 1997, New Mexico adopted a statute that allows water to be "banked" by state chartered conservancy districts in accordance to a water conservation plan approved by the state engineer. (N. M. Stat. Ann. § 72-5-28(G), (Michie Cum. Supp. 1998)). Conservancy districts are therefore assured that any water not used due to conservation will not be forfeited for non-use.

4.2 Transfer of Water Rights and Public Welfare Considerations

Water rights may be transferred upon application to the state engineer. The applications are publicized and protests may be filed with the state engineer. The protest to the proposed transfer must be based on a claim that the transfer will impair existing rights, will be contrary to the conservation of water, or will be detrimental to the public welfare. The state engineer will then hold a formal due process hearing on the issues (N. M. Stat. Ann. §§, 72-5-5, 72-12-7 (Michie 1997)).

New Mexico is among one of seven western states[2] that mandates public interest (welfare) review for transfers and one of fifteen western states[3] that mandates public interest (welfare) review for new appropriations. In New Mexico, "public welfare" is not statutorily defined leaving the state engineer without direction on what factors to consider in transfer applications. Hoffman-Dooley (1996) found that the state engineer equated public welfare with beneficial use in a recent decision by the Office of State Engineer (OSE) to grant an application for appropriation of groundwater by Intel Corporation. (In Re the Applications of Intel Corporation to Appropriate the Underground Waters of the State of New Mexico in the Rio Grande Underground Water Basin, No. RG-57125, RG-57125-S and RG-57125-S-2 (June 10, 1994) (Findings and Order)).

Hoffman-Dooley cautions that absent guidance which prescribes consideration of public welfare factors such as preservation and enhancement of natural resources, aesthetic and cultural values, and recreation, broad public welfare values beyond economic development are difficult to mandate. The two approaches used in other states to define the public welfare review component are 1) legislative lists of unweighed criteria and 2) statutes defining how public welfare factors should be weighed.

Commentators have steadily outlined the need for New Mexico's legislature to establish minimum standards for public welfare and direct the state engineer to consider local public interests and regional water plans as a part of the public welfare considerations (DuMars and Minnis, 1989; Hoffman-Dooley, 1996; Klein-Robbenharr, 1996). In order to assist the process of future transfers of water rights to benefit silvery minnow habitat, public welfare should be defined to include conservation and ecological values and provide the state engineer some guidance on how to weigh ecological values against short-term economic values.

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[2] These states are: Idaho, Kansas, Montana, Nebraska, Nevada, New Mexico, and North Dakota.

[3] Alaska, Arizona, California, Idaho, Kansas, Montana, Nebraska, Nevada, New Mexico, North Dakota, Oregon, Texas, Utah, Washington, Wyoming. The two states without public interest review are Colorado and Oklahoma.

5.0 ESTABLISHMENT OF INSTREAM FLOW RIGHTS FOR CONSERVATION PURPOSES IN NEW MEXICO

5.1 Definition of Instream Flow

"Instream flow" refers to the concept of leaving water in a streambed where it is used by way of providing aquatic and riparian environments for fish and wildlife and of providing for aesthetic and recreational purposes. Of necessity, instream use involves free-flowing water in a natural channel, rather than diversion of water out of the streambed or impoundment of water behind a dam or dike.

5.2 Background

Instream uses for conservation purposes compete with agricultural and urban water demands. Non-consumptive uses have long been recognized, but these uses, such as fishery maintenance flows, were relatively minor until the 1970s. Environmental and recreational interests are increasingly pursuing an agenda that includes the restoration of watersheds and sufficient instream flows to restore and sustain the river's historic, ecological, and hydrogeologic functions (Tarlock, 1999a). However, historically New Mexico's state engineers have rejected the applicability of strategies used by other Western states to protect instream flow in New Mexico.

5.3 Western Strategies to Protect Instream Flow

Given the inherent need to establish a continuous regime of flow for many fisheries, five major strategies have been adopted in fourteen Western states to protect instream flows.

1. **Appropriation, purchase, condemnation and cancellation.** Instream flow rights may be acquired by new appropriations on rivers that are not fully allocated, or by acquiring or transferring an existing water right on fully appropriated rivers. Several states have adopted statutes that limit who may hold a permit for instream flows (Kaiser and Binion, 1998). The limits vary from mandating that only the state's water resources agency or fish and game agency may hold instream flow rights on behalf of the public, to allowing any state agency to purchase water rights to be used as instream flow. In other states, statutes allow private organizations and individuals to establish water rights for environmental flow purposes with a variety of limitations (Kaiser and Binion, 1998). In Nevada, the right to submit private applications for instream flow was established as a

result of a Nevada Supreme Court decision (Nevada v. Morris, 766 P.2d 263 (Nev. 1998)).

If an outright purchase option is not available, leases, dry-year options and transfers can provide water during critical periods or even on a long-term basis. Dry-year arrangements are worthwhile alternatives to purchase and leases. Dry-year options can be used to provide water to endangered fisheries during times of drought and otherwise not hinder water use in wetter years.

Condemnation of a water right by a public agency is a viable alternative, although it is often expensive and accompanied by "bad publicity." Cancellation of rights for waste or non-use is possible on flows that are adjudicated and gauged, however, this is not often the case for surface water flows in New Mexico.

2. Flow management. The object here is to coordinate water use and release from reservoirs in order to maximize both vested rights and desirable stream flows (Utton and Utton, 1999). This often involves coordination with the federal and state agencies responsible for reservoir releases. States can directly protect instream flows by imposing conditions on water permits that will guarantee a minimum level of stream flow. Under the public welfare rubric, state water agencies may incorporate in water permits any condition, restriction, limitation or provision reasonably necessary to insure minimum instream flows (Kaiser and Binion, 1998). Conditioning permits works well when new permits are issued for unappropriated waters. However, retroactively conditioning permits could be considered an unconstitutional "taking" of a property right.

3. State designation of wild and scenic rivers. Patterned after the national Wild and Scenic Rivers Act, (16 U.S.C. §§ 1271-1287 (1968)), states have preserved unique streams in their free-flowing form by restricting dams, impoundments and other obstructions. This approach is often politically difficult and only four states – California, Oklahoma, Oregon and South Dakota — have passed such legislation (Utton and Utton, 1999).

4. Reservation of instream flow rights. Through legislative or administrative action, a state may reserve a certain flow of unappropriated water in specified stream segments. A reservation of flow rights is not a water right under the prior appropriation doctrine, but instead is a method of excluding a certain quantity of water from further appropriation.

Montana has reserved approximately 70 percent of the average annual flow in the upper basin of the Yellowstone River and 62 percent of the lower basin for instream flow purposes (McKinney, 1990). Washington has withdrawn over three hundred waterways from future appropriations (Wahl, 1990). Instream flow reservations only work where unappropriated waters are available.

5. Public trust doctrine. Kaiser and Binion (1998) observe that the public trust doctrine is a collection of common-law principles used to protect the public's interest in property owned by the state in trust for the people. The most celebrated public trust case is the Mono Lake decision, where the California Supreme Court held that "the public trust doctrine imposes a duty of continuing supervision over the taking and use of appropriated water." (National Audubon Society v. Superior Court, 658 P.2d 709 (Cal. 1983)). Use of the public trust doctrine to redefine water rights is controversial for its effect of trumping the priority system of prior allocations. The public trust doctrine has also been invoked by courts in Montana, Idaho, Utah, Washington and North Dakota (Kaiser and Binion, 1998) but has had little impact outside of California.

5.4 Status of Instream Flow Rights in New Mexico

In New Mexico, the OSE historically refused to interpret New Mexico's water law to allow allocation of water rights for instream flow insisting that a diversion structure was necessary to establish a water right. However, there may be a change in this stance as a result of a recent opinion by New Mexico's Attorney General. In March of 1998, after a request by two state legislators, the Attorney General issued an opinion that would allow a water right to instream flow for recreational, fish and wildlife, or ecological purposes in New Mexico as long as there is a gauging device to measure the instream flow beneficially used (New Mexico-AG Opinion 98-01). At this time, it is uncertain how receptive the OSE is to the Attorney General's opinion or how instream flow permit applications will be handled.

5.5 Conclusion

The best strategies to establish continuous instream flows on the fully appropriated Middle Rio Grande are through instream flow rights acquisitions and flow management. If the political situation is such that the state engineer continues to reject permits for instream flow rights despite the Attorney General's legal opinion, it may be necessary to go to the courts or the legislature to establish the right to hold instream flows for conservation purposes.

6.0 EXAMPLES OF OTHER WESTERN WATER CONFLICTS GENERATED BY THE PRESENSE OF ENDANGERED FISHERIES

This paper now turns to a review of examples of recent western water reallocations in response to endangered fisheries. The four projects reviewed all created place-based solutions where responsibility is shared for ecosystem management. The federal government typically plays a major role in creating incentives for stakeholders to accept new water allocations when there are endangered species involved. According to Tarlock (1999b), the federal government's role is changing as its mission changes from regional development to resource stewardship as a new federalism paradigm is created.

6.1 California's Bay-Delta Region: A State-Federal Collaboration

6.1.1 Background

The Delta provides forty percent of California's drinking water and irrigation for the crops that supply forty-five percent of the nation's fruit and vegetables. By the spring of 1993, two fish species in the Delta had been listed under the Endangered Species Act, and petitions to list others had been filed. The listings would significantly affect the amount of water able to be exported to cities and farms (Rieke, 1996).

At the time, the state had yet to adopt water-quality standards in the Delta as required by the Clean Water Act. After twenty months of negotiations, a joint statement of state-federal "Principles for Agreement was announced " to protect the Bay-Delta's natural resources and to provide reliable water supplies to farms and cities dependent on Delta diversions. Joining in that announcement were representatives of the agricultural, business, environmental and urban sectors. The accord allocated more water for the environment and less water *but more certainty in allocations* for agricultural and urban users (Rieke, 1996).

6.1.2 Water Reallocation Regime

The agreement calls for increased fresh water flows through the Delta and into the Bay to allow 400,000 acre-feet of additional flows in normal years and 1.1 million acre-feet of additional flows in critically dry years. Additional water needed due to new endangered species must be met by water purchases financed with federal funds and undertaken on a willing seller basis. Agricultural and municipal users have a guarantee that any additional water needed for ESA purposes will not be taken from them through additional regulatory reallocations of water.

6.1.3 Factors Responsible for Evolution of Agreement

Rieke (1996) attributes the creation of the agreement to four factors: (1) a favorable interest group configuration existed in the sense that the goals, positions, technical and financial resources and previous relationships of the parties were such that a pathway to an agreement could be found and the possibility of mutual gains was apparent; (2) Delta water users anticipated that the plans underway to develop alternatives to move water to protect fish eggs and juveniles would increase the amount of water that could be moved; (3) a federal strategy designed to leverage the state to adopt new water-quality standards was in place; and (4) the environmental community decided to negotiate a compromise before the state adopted new water quality standards which would then have allowed little opportunity to leverage improvements in the plan.

6.2 California's Central Valley: A Federal Solution

6.2.1 Background

The decline in central California's fisheries influenced the passage of a new federal water policy for the Bureau of Reclamation's Central Valley Project (CVP) which is integral to agriculture in central California. In 1992, the federally funded Central Valley Project Improvement Act (CVPIA) was instituted to improve fishery habitat, in addition to achieving several other water management objectives.

6.2.2 Reallocation Regime

The CVPIA permanently allocates 800,000 acre-feet of CVP water in normal water supply years (almost 20 percent of CVP contracted irrigation supply) for restoration of fish habitat. Reallocation of agricultural water will likely supply most of the water needed. The CVPIA requires the Secretary of the Interior to implement by the year 2007, a least-cost plan to replace the 800,000 acre-feet allocated to fish habitat. Voluntary water transfers, voluntary agricultural land retirement, and water conservation requirements must be among the options considered (Moore et al., 1996).

6.3 The Upper Snake River Basin: A Federal Solution

6.3.1 Background

The upper Snake River Basin, in southern Idaho and east-central Oregon is one of the major areas of irrigated agriculture in the United States. Since 1991, three salmon varieties in the lower Snake River have been listed as threatened or endangered under the ESA with an additional 10 salmon runs considered in critical condition. The Bureau of Reclamation operates nine water projects upstream from the endangered salmon. The National Marine Fisheries Service designated Reclamation solely responsible for providing an additional 427,000 acre-feet per year from 1995-97 for downstream users. Additional water is needed after that to recover the salmon runs (Blumm, 1998).

6.3.2 Reallocation Regime

Voluntary water transfers appear to be the preferred method for acquiring water from irrigators in the basin. Originally both incentive and regulatory programs were considered as mechanisms for obtaining water for flow augmentation. Some observers recommend water acquisition through expansion of voluntary water markets in the region (Kaiser and McFarland, 1997).

6.4 Truckee-Carson River Basins: A State and Federal Collaboration

6.4.1 Background

The Truckee-Carson basins in northern Nevada are closed basins characterized by extremely arid lands and limited water supplies. There are two listed endangered fish species in the basins. In 1984, the Pyramid Lake Paiute Tribe successfully used the Endangered Species Act to reserve water from a dam and reservoir for the endangered species and control the unallocated drought carry-over storage in the basins. This created an incentive for the urban stakeholders in the basins to seek a more comprehensive system-wide long term settlement. Unfortunately, the reallocations came at the expense the World Heritage wetlands and wildlife refuges. Many return flows were also highly polluted because they were concentrated in drainage ditches (Tarlock, 1999b).

6.4.2 Reallocation Regime

In 1990, Congress intervened in the basins to end the decades of interstate dispute and to create a process to develop a comprehensive new physical solution. (See Falon Paiute Shoshone Indian Tribes Water Rights Settlement Act of 1990, Pub. L. No. 101-618, 104 Stat. 3289 (1990)). The 1990 legislation ordered the Secretary of the Interior to negotiate an operating agreement with the states of Nevada and California and the major stakeholders in the regions, with the exception of the Truckee-Carson Irrigation District (Tarlock, 1999b). The primary purpose of the Draft Truckee River Operating Agreement (TROA) is more efficient operation of the five federal and two non-federal reservoirs in order to facilitate distribution of water in the Truckee River basin. Under the TROA, water would be exchanged physically or administratively by category among the reservoirs to conserve storage, enhance instream flows, and maintain reservoir recreational pools. As of mid-1999, the negotiators have an "initialed" TROA and hope to publish a revised draft of the EIS/EIR in August of 1999.

6.5 Conclusions

One of the central lessons demonstrated by these four projects is the management of natural resources on larger geographic, more ecologically rational, scale. The state-federal collaborations provide the best opportunities for place-based decisions. Repeatedly, less water is available to agricultural interests after the listing of an endangered fishery. Agricultural interests are willing to accept their inevitable reductions in water allocations for 1) a greater measure of certainty about future water allocations in light of any new endangered species and 2) federal and state dollars for delivery and storage system improvements.

7.0 ADAPTIVE MANAGEMENT OPTIONS FOR MIDDLE RIO GRANDE BASIN WATER CONFLICTS

Water reallocations in the Middle Rio Grande due to the silvery minnow will have a significant impact on the historical practices of water diversion for agricultural users. The conflict between agricultural demands and the silvery minnow was dramatically played out in the summer of 1996 when thousands of minnows were left high and dry after agricultural users diverted the entire flow of the river.

The Middle Rio Grande Conservancy District (District) holds the water rights to almost all of the surface water used for agriculture in the Middle Rio Grande. The flows not due to the District are primarily used to satisfy New Mexico's

Compact obligations to Texas, or flows delivering the City of Albuquerque's San Juan-Chama Project water via the Middle Rio Grande.

The District is a politically savvy organization and well aware that when agricultural interests meet endangered species, water reallocations lay ahead. An understanding of the structure and services of the District are presented next to provide a context for some suggested legislative changes to establish secure instream flow rights for the silvery minnow.

7.1 Background: Middle Rio Grande Conservancy District

The District is a political subdivision of the State of New Mexico authorized by the Conservancy Act of New Mexico of 1923 and founded in 1925 (N.M. Stat. Ann. §§73-14-1 - 19-5 (Michie 1978)). The District provides for flood protection, river control, drainage, irrigation and other improvements for public health and welfare (N. M. Stat. Ann § 72-14-2 (Michie 1978)). The District is managed by a board of directors elected by a "natural person who owns real property within the benefited area of the conservancy district or [who] resides on and owns legal or equitable title in tribal lands, and who is over the age of majority." (N. M. Stat Ann. § 73-14-20 (Michie 1978)).

The District currently furnishes water to almost all of the 50,000 to 80,000 (O'Brien, 1999; Martinez, 1999) non-Pueblo irrigated acres in the Middle Rio Grande in addition to 8,000 acres of Pueblo lands under cultivation in the basin. The Pueblos have an aboriginal water right to irrigate their land, however, the extent of their rights have not yet been adjudicated. The bulk of the District's state water rights, pursuant to state permit, are based on pre-1907 water appropriations made when New Mexico was still a territory. Many claimed rights are still unadjudicated today.

The District's permits entitle it to irrigation water for approximately 123,000 acres (O'Brien, 1999). In addition to providing water for agriculture, the District's enabling statute also permits it to provide water for municipal and industrial use, domestic use and even power purposes. Historically, the District supplied water to approximately 90,000 irrigated acres, and more recently provided water for conservation purposes, and leased water for municipal and industrial purposes (O'Brien, 1999). The language of the Conservancy Act prohibits the District from permanently selling or otherwise disposing of the District's water rights (N. M. Stat. Ann § 73-14-47 (Michie 1978)).

7.2 Water Banking and the Middle Rio Grande Conservancy District

Given the disparity between the District's historical use and actual current use, the District is implementing a system of water banking to facilitate the voluntary transfer of water rights. The focus of the District's water bank, however, is also on preventing the permanent severance of water rights from agricultural lands (O'Brien, 1999). To establish its water bank, the District must inventory its water rights, document the beneficial uses of the water, and provide an efficient administrative mechanism to facilitate using District water for a beneficial use. This is a complex task given that many of the District's water rights are not yet formally adjudicated, that the extent of the Pueblos' water rights are unknown, and that deciding the Pueblo's rights is outside the jurisdiction of the OSE. Consequently, the District's water bank is unlikely to be a short-term adaptive management tool.

7.3 Acquisition of District Water Rights

Just as agricultural interests recognize the value of certainty as a tradeoff in water reallocation negotiations, environmental interests recognize that instream flow rights are most certain when there is an acquisition by purchase, rather than lease or dry year options. Currently, the District, the major water right holder on the Middle Rio Grande, is prohibited by the Conservancy Act from permanently selling its water rights. A revision to this statute that allows the District to sell no more than ten percent (for example) of its rights for instream flow purposes would give the District the ability to be more flexible in its approach to the current water conflicts and provide funds to the District to improve its water delivery operations.

8.0 OPPORTUNITIES FOR STATE-FEDERAL COLLABORATION ON THE MIDDLE RIO GRANDE

State-federal collaborative solutions to water reallocations in light of endangered species issues are most successful when the involved parties at the local, regional and state-wide levels have already established working groups. Success is even better if the working group has formulated a big-picture approach to the conflicts.

The situation in the Middle Rio Grande is analogous to the Truckee-Carson basins where the involved parties had little prior collaborative experience with each other and a history of solving conflicts with litigation. The Truckee-Carson basins settlement process demonstrates that water use conflict can evolve from litigation, to the use of legislation, voluntary transfers, and collaborative consensus-based management to deal with the dislocations of change (Tarlock, 1999b). The water users and conservation interests in the Middle Rio Grande Basin can benefit from other regions' experience by bringing the federal government in as a collaborative partner in crafting a place-based solution.

The State of New Mexico is in a good position to leverage federal dollars for environmental restoration projects given New Mexico's substantial contribution to national security by way of the national laboratories and military bases sited in New Mexico whose operations are known to be less than environmentally friendly. New Mexico can readily follow the example of other regions and engage the federal government in a fiscal and technical collaboration to reallocate water and restore habitat in the Middle Rio Grande Basin. The first step is for the local and regional stakeholders to establish a working coalition. Once established, the coalition should present a plan for restoring habitat and reallocating water to New Mexico's congressional delegates in order to secure the federal government as a partner in resource reallocation.

9.0 CONCLUSIONS

The water allocation conflicts in the Middle Rio Grande Basin are best solved by new state legislation that permits the establishment of permanent instream flow rights for conservation and ecological purposes, defines "public welfare" in water transfers to include conservation and ecological values, and changes New Mexico's Conservancy Act to allow the sale of conservancy's water rights for instream flows. Finally, collaboration between state and local interests and the federal government must be instituted to facilitate resource management and reallocation in the basin.

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CHANGES IN UPSTREAM WATER MANAGEMENT: SUSTAINABLE WATER SUPPLY FOR THE SILVERY MINNOW

Kathy Smith

Executive Summary. In 1998 the U.S. Fish and Wildlife Service released a draft for the recovery plan for the silvery minnow in the Rio Grande in New Mexico. The recommendations were listed under the following 5 headings: 1) acquisition of water; 2) conjunctive groundwater and surface water use; 3) upstream water management; 4) water-use increases; and 5) water rights administration. The recovery plan stated that ensuring the survival of the Rio Grande silvery minnow and the aquatic community that supports this species would require maintaining some level of flow in most of the middle Rio Grande throughout the year.

This paper addresses the required changes in authorizations for upstream water management for procuring water for instream flows, specifically: 1) storing native water in Heron Reservoir, as well as utilizing San Juan Chama Project (SJCP) water; 2) transferring water from El Vado Reservoir to Abiquiu Reservoir; 3) increasing the storage capability at Abiquiu and Jemez Canyon Reservoirs; and 4) using Cochiti for a reregulation reservoir during the irrigation season. In order to understand the necessary requirements, I first looked at how the individual reservoirs were operated and by whom.

The Bureau of Reclamation (BuRec) manages Heron and El Vado. The Army Corps of Engineers manages Abiquiu, Cochiti, and Jemez. Heron stores SJCP water. El Vado stores both native Rio Grande and SJCP water. Abiquiu is utilized for sediment and flood control, as well as storing SJCP water. Cochiti is for flood and sediment control, as well as maintaining a pool for recreation and conservation of fish and wildlife. Jemez is also utilized for flood and sediment control, and retains additional SJCP water for improved sedimentation. All native water is subject to the conditions of the Rio Grande Compact, which regulates apportionment of water for Colorado, New Mexico, and Texas, based on yearly flows (NMSA § 72-15-23). In addition the treaty with Mexico guarantees the delivery to Mexico of 60,000 acre-feet annually (34 Stat. 2953 T.S. 455).

Changes in existing policies must be made before instream flow can be established at the state level. The New Mexico Office of the State Engineer (OSE) must recognize instream flows as a "beneficial use" of New Mexico's water. A recent attorney general's opinion (A.G. op. #98-01) states that instream flows are beneficial, but no one has tested this opinion by applying for an instream use permit. Acts of Congress are required to designate additional storage space at Heron, Abiquiu, Cochiti, and the Jemez Reservoirs within the flood control portions of their reservoirs. Storage and movement of water at flood control reservoirs are subject to releases if flood conditions exist, and so availability when needed is not guaranteed. Reregulation of Cochiti typically has been utilized for a maximum of 5 days, and thus involves a short-term solution. The New Mexico Interstate Stream Commission (ISC) authorizes allocation of SJCP water, and so would have to approve a new contractor, such as the U. S. Fish and Wildlife Service, for procurement of water for the minnow. The SJCP water stored at Jemez is regulated by the ISC, and the

current contract expires in December of 2000. Any new contracts for storage and release of water for the minnow would require approval by the ISC.

Regulating agencies evolved in an era of water use for commodities such as agriculture. Today, the public also values water for aesthetics, as well as for preservation of ecosystems and endangered species. Creation of a water forum representing all stakeholders and regulating agencies, with ecosystem conservation as a driving force, would be an initial step in proposing water reallocation with the least individual and societal discomfort.

1.0 INTRODUCTION

On January 6, 1998, the U. S. Fish and Wildlife Service released a draft of the Rio Grande Silvery Minnow Recovery Plan. The silvery minnow was listed as an endangered species in July, 1994 due to: 1) present or threatened destruction, modification or curtailment of its habitat or range, 2) the inadequacy of existing regulatory mechanisms, and 3) other natural and manmade factors (www.fguardians, 1998). The recovery plan recommended the implementation of a combination of actions for the survival and conservation of the silvery minnow. They were described under the following headings:

1) Acquisition of water
2) Conjunctive groundwater and surface water use
3) Upstream water management
4) Water-use efficiency increases; and
5) Water rights administration

While I recognize that it will require a combination of actions for the recovery of the minnow and the Rio Grande ecosystem, in this paper I address only the third recommendation involving changes to upstream water management. Specific recommendations from the U.S. Fish and Wildlife Service are:

1) Storing Rio Grande water in vacant storage space in Heron Reservoir when space is available, as well as utilizing San Juan-Chama Project (SJCP) water
2) Transferring water from El Vado Reservoir to Abiquiu Reservoir
3) Increasing the storage capability in Abiquiu and Jemez Canyon Reservoirs; and
4) Using Cochiti Lake for a re-regulation reservoir during the irrigation season (U.S. Fish and Wildlife Service, 1998).

My purpose is to explain the changes or new authorizations that would be necessary to carry out the recommendations. In order to understand why the changes are necessary, it is first useful to understand the difference between "native" and SJCP water, which laws regulate each water system, the original purposes of the individual reservoirs, and which agencies regulate them.

2.0 RIO GRANDE WATER

"Native water" refers to water that originates within the Rio Grande Basin. A basin is all the land drained by a river and its branches. The basin begins at the headwaters of the river, which for the Rio Grande, occurs along the Continental Divide in the San Juan Mountains of southern Colorado. The river flows south from Colorado through the length of New Mexico, and then forms the international boundary between Texas and Mexico. In Mexico it flows south and then east, emptying into the Gulf of Mexico.

Annual runoff in headwater regions ranges from 215,000 to 1,100,000 ac-ft., and average discharge into the Gulf of Mexico is about 9,000,000 ac-ft. (Bullard and Wells, 1992).

Rio Grande water is allocated by the Rio Grande Compact (1938) and the treaty with Mexico. The compact stipulates the amount of flows allocated to the 3 states, based on percentages of actual flows. By treaty the U.S. consistently must deliver 60,000 acre-feet (ac-ft) annually to Mexico, except during extreme drought. Colorado must deliver 20 to 33% of gaged flows to New Mexico, and New Mexico 57 to 90% of gaged flows to Texas. The New Mexico Office of the State Engineer (OSE) grants permits for water rights for Rio Grande water if the water is put to beneficial use in accordance with the laws of the state (Niemi and McGuckin, 1997). Currently beneficial use refers to diverting water from the river for municipal, industrial, or agricultural uses. A recent attorney general's opinion expands the definition to include instream uses, but the state engineer is not bound by this opinion.

3.0 SAN JUAN CHAMA PROJECT WATER

The San Juan Chama Project (1971), which was authorized as a part of the Colorado River Storage Project, provides an average annual diversion of about 110,000 ac-ft. of water from the upper tributaries of the San Juan River for use in the Rio Grande Basin in New Mexico. San Juan Chama water is used for municipal, domestic, and industrial purposes.

The New Mexico Interstate Stream Commission is responsible for prioritizing which entities can contract for the water and what their allocation will be. San Juan Chama water allotments in acre feet is shown in Table 9-1.

Table 8-1. San Juan Chama Water Allotments

ENTITY	AC-FT	ENTITY	AC-FT
Cochiti Reservoir Recreational Pool	5,000	Department of Energy	1,200
City of Albuquerque	48,200	Taos	400
Middle Rio Grande Conservancy District	20,900	Twining	15
Los Lunas	400	Pojoaque Valley Irrigation District	1,030
Bernalillo	400	Jicarilla Apache Tribe	6,500
Belen	500	Red River	60
Santa Fe County	5,605	Taos Area (reserved)	2,990
Española	1,000		
San Juan Pueblo (reserved)	2,000		
Total Allocation: 96,200 Ac-Ft			

(Romero, 1999)

4.0 HERON DAM AND RESERVOIR

Heron Reservoir and Dam is the regulating and storage reservoir for SJCP water and is located on Willow Creek, just above its confluence with the Chama River. The Chama River lies west of the Rio Grande. The Bureau of Reclamation (BuRec) maintains and operates Heron Reservoir and Dam. The reservoir originally had a storage capacity of 401,320 ac-ft., but available storage declines annually due to sediment deposition. In 1998, storage capacity was at 376,510 ac-ft. (Romero,1999). There are no provisions for storage of native water in Heron, therefore all Rio Grande water from the surrounding basin is bypassed to the Rio Chama. Estimates of how much of the surface water coming into the reservoir is native water can be calculated because the SJCP water is gaged as it comes through the Azotea channel into Heron. Losses due to evaporation and seepage are attributed to native water when determining the water allocations (Romero, 1999). Inflow from the San Juan Diversions are turned off from November through January to allow for maintenance of the tunnels. Peak diversion water is delivered March through July, reaching maximum storage in July. Deliveries for downstream use occur through December (Romero, 1999).

Heron Reservoir is operated in compliance with the Rio Grande Compact. Two principles control the release schedule. One is that depletions of Rio Grande water from groundwater pumping by contractors of SJCP water are offset by releases from Heron Reservoir. This applies to situations where the water user is substituting their SJCP right for a groundwater right. The Interstate Stream Commission (ISC) determines the timing and amount of discharges.

The second principle is that carryover storage into the next year is not permitted. If a water user does not use their allocation for that year they cannot use it in a subsequent year. Water not released for contractors by December 1 normally remains in Heron as part of the Project supply. Occasionally the Bureau grants temporary waivers to contractors until April 30 in order to provide release rates on the Rio Chama that benefit fisheries between El Vado and Abiquiu (U. S. Bureau of Reclamation, 1982). It was emphasized by Dennis Romero, a hydraulic engineer at the Bureau, that the releases that benefit the fisheries in terms of instream flow are released for use by downstream contractors, and it is the timing of the releases that permits benefits for the fisheries, not the actual allocation of the water.

Bureau policy does state, however, that unallocated SJCP water could be provided to interested water users via year to year, short term contracts. Currently, the only unallocated water is 4,990 ac-ft, held in reserve for the San Juan and Taos Pueblos. This will be discussed later in reference to water releases for the silvery minnow. Unused balances of allotments are typically given to the City of Albuquerque or the Middle Rio Grande Conservancy District (MRGCD), or temporarily stored in El Vado or Abiquiu.

5.0 EL VADO DAM AND RESERVOIR

El Vado Dam, located on the Chama River, was originally constructed in 1935 by the MRGCD to provide conservation storage for irrigation use. The outlet works were enlarged in 1965-66 so that SJCP releases could be passed unimpeded through the dam. El Vado is maintained and operated by the BuRec. The county of Los Alamos owns and operates a hydroelectric facility at El Vado. The reservoir operations for storage and release of native water are subject to the terms and restrictions of the Rio Grande Compact. SJCP water storage and release are not. Some SJCP water released from Heron is passed through, while other volumes are stored, sometimes for extended periods of time (U. S. Bureau of Reclamation, 1982).

6.0 ABIQUIU DAM AND RESERVOIR

Abiquiu Dam and Reservoir (1963) are located on the Rio Chama, 32 river miles above the confluence with the Rio Grande. The Albuquerque District of the Army Corps of Engineers (CoE) is responsible for regulation of the project and for directing the flows to be maintained by the hydroelectric plant, operated by the County of Los Alamos. The reservoir is operated primarily for flood and sediment control . In 1981, authorization was extended to include temporary storage for 200,000 ac-ft. of SJCP water within the unused sediment and flood control space (Bullard and Wells, 1992). The actual storage of SJCP water by Albuquerque and other entities began in 1974 (U.S. Army Corps of Engineers, 1995). Contractors for storage for SJCP in ac-ft. are shown in 9- 2.

Table 8-2. San Juan Chama Contractors

CONTRACTOR	QUANTITY (AC-FT)	CONTRACTOR	QUANTITY (AC-FT)
City of Albuquerque	170,900	Department of Energy	1,685
MRGCD	2,000	City of Espanola	1,404
Sangre de Cristo Water Co.	7,871	Twining Water and Sanitation District	21

(Gallegos, 1999)

As is the case for all of the reservoirs, storage availability varies from year to year because of sediment deposition. At Abiquiu, the City of Albuquerque and the MRGCD do not lose storage space because of sediment. The loss is accounted for by the other contracting entities. As of July 8, 1999, the 200,000 ac-ft. delegated for SJCP water was reduced to 183,881 ac-ft due to sediment (Gallegos, 1999).

Abiquiu is operated for flood control on the Rio Chama and the Rio Grande by regulating flows at non-damaging flow rates. Operation is integrated with the Cochiti, Galisteo, and Jemez Canyon Reservoirs. Water stored in flood spaces is evacuated as rapidly as downstream conditions permit. While flood conditions do not exist, upstream reservoir releases and natural Rio Chama water is passed through with a minimum of regulation. Stored SJCP water may be evacuated as necessary to limit flood storage to the top of the flood control pool, or to permit repair or maintenance of the dam. Release of flood storage is withheld after July 1, if the Rio Grande gage at Otowi is below 1,500 cubic feet per second (cfs). Water carried over during the summer is released after October and before March 31 of the following year (U. S. Army Corps of Engineers, 1995).

7.0 COCHITI DAM AND LAKE

Cochiti Dam (1974) is located on the Rio Grande, on the Pueblo de Cochiti lands, about 50 river miles north of Albuquerque. It is operated by the Albuquerque District of the CoE. It is a multipurpose dam with the following functions: 1) regulating damaging floods by controlling flows between Cochiti and Elephant Butte Dam (EBD); 2) retaining sediment; and 3) providing conservation and development of fish and wildlife resources and recreation with water acquired from the SJCP. The lake is divided into 3 natural geographic areas, the upper portion which lies in White Rock Canyon, the lower more open portion immediately above the dam, and the Santa Fe wetlands on the Santa Fe River channel (U. S. Army Corps of Engineers, 1996).

A perpetual easement for 4,065 acres was purchased from Cochiti Pueblo in 1965. An additional 9,621 acres was acquired for project purposes from the U.S. Forest Service, Atomic Energy Commission, the University of New Mexico, and private parties. Upon completion of the dam, a Memorandum of Agreement was signed between the CoE and Cochiti Pueblo, describing the individual responsibilities for construction of public use and concession facilities. Neither the Cochiti easements nor the Memorandum authorizes water storage at the reservoir for water management or conservation purposes, other than flood or sediment control, or recreational or fish and wildlife enhancement (U. S. Army Corps of Engineers, 1996).

The Flood Control Act of 1960 authorized construction of the dam and the permanent recreation pool. The same Act exempted the storage pool from conforming with the requirements of the Rio Grande Compact, as long as the water required to fill and maintain the pool came from outside the Rio Grande Basin. Congress authorized the Secretary of the Interior to make SJCP water available for the establishment and development of the permanent pool at Cochiti.

Flood control begins at Cochiti Lake when the flow in the Rio Grande below the dam approaches the channel capacity of 7,000 cfs, as measured at the Albuquerque gage. When the lake water surface reaches 5,450 feet in elevation, releases are restricted to hold the Rio Grande flow at 7,000 cfs for as long as possible. Storage in the flood space is evacuated as soon as possible, while maintaining the permanent pool at approximately 50,000 ac-ft. No releases from summer carryover space are made when natural flow at

Otowi, above Cochiti, is less than 1500 cfs. Water stored in the summer carryover space is evacuated on or after November 1 and by March 31 of the next year (U. S. Army Corps of Engineers, 1996).

8.0 JEMEZ DAM AND RESERVOIR

Jemez Canyon Dam (1953) is located 5 miles northwest of the town of Bernalillo, and 2.8 miles upstream on the Jemez River from its confluence with the Rio Grande. It is operated by the Albuquerque office of the Army Corps of Engineers. It regulates the Jemez River for flood and sediment control. In 1979, a sediment retention space of about 2,000 acre feet was established by the ISC. The pool was expanded in 1986. The ISC leases 5,500 ac-ft of SJCP water the City of Albuquerque is not using, and retains the water in the pool for improved sediment retention. An additional 1,500 ac-ft per year is released for compensation from evaporation. This contract expires on December 31, 2000. Unless a new agreement is reached, the CoE will release the stored water over a 3.5 year period (Gallegos, 1999).

The Jemez Canyon Reservoir storage is restricted when Rio Grande flows increase, and is utilized when flows decrease. Storage from flood water is released as rapidly as downstream conditions permit, so space is available for subsequent floods. Currently the top of the flood control and spillway crest is at 97,425 ac-ft minus the 24,425 ac-ft. of sediment space. Emergency regulations state that flow regulation may not be made for fish and wildlife purposes.

9.0 MODIFICATIONS TO EXISTING LAWS TO IMPLEMENT RECOVERY RECOMMENDATIONS

9.1 Heron Reservoir

As seen from the above interweaving of regulations that determine water storage and releases from the reservoirs, both state and federal agencies need to make changes. The first proposal is to store native water at Heron Reservoir for later release for instream purposes. The problem is the office of the State Engineer has no process for granting a permit for instream uses. The native water that passes through Heron Reservoir into the Chama River presently is allocated to the Rio Chama Acequia Association (Romero,1999). To transfer this water to an instream use requires a transfer of water rights from the acequia association to an agency charged with the protection of the minnow, such as the U. S. Fish and Wildlife Service. An act of Congress is necessary to change storage purposes at Heron from strictly SJCP storage to mixed storage of native and SJCP water.

Table 9-3 is a summary of available storage space in ac-ft. calculated at Heron Reservoir, after deliveries were completed to contractors at the end of each year.

Table 8-3. Available Storage Space at Heron Reservoir 1991 to 1998

YEAR	MAX STORAGE (AC FT	WATER STORED (AC FT)	AVAILABLE STORAGE (AC FT)
1998	376,510	172,441	204,069
1997	366,678	170,220	196,458
1996	376,681	179,785	196,896
1995	400,330	180,132	220,198
1994	402,100	174,200	227,190
1993	missing report		
1992	401,569	164,940	236,692
1991	401,579	173,980	227,595

(Romero,1999)

These calculations show that some storage space is available at the end of the year. However, December is usually a time of snow pack accumulation, not surface water runoff. Because many of the water agreements involve transfers of water on paper, some of the unused or unallocated physical SJCP water remaining at Heron could be allocated as if it were native water.

The second recommendation concerning Heron, involves use of SJCP water directly for instream flows. Unused water from a previous year, or unallocated water held in reserve for the pueblos, can be leased with ISC approval. According to Dennis Romero, this has been done unofficially in the past.

9.2 El Vado Reservoir

Transferring water from El Vado to Abiquiu involves the previous issues for establishing an instream water right and allocation of SJCP water. In addition it involves the third recommendation regarding storage at Abiquiu which will be addressed next. Releases of native water from El Vado are governed by the Rio Grande Compact and treaty with Mexico restrictions regarding deliveries to Texas and Mexico. Releases of SJCP water are not.

9.3 Abiquiu Reservoir

Increasing storage space at Abiquiu for water for the silvery minnow would require Congress to change the statute controlling how flood space is used. Storage space is not evaluated at a particular time of year, as changes in water elevation vary in response to releases from Heron and El Vado, and to precipitation runoff and snowmelt. Water stored for the minnow would also be subject to release when emergency flood conditions occur.

9.4 Cochiti Reservoir

Donald Gallegos, a hydraulic engineer at the Albuquerque CoE, explained the principle of reregulating Cochiti as a reservoir during the irrigation season. Reregulation has been used as a temporary solution in the past. Water released from Abiquiu, or upstream storm water would be stored in Cochiti for a maximum of five days. In order to do this Congress must change the approved uses of storage space at Cochiti and the OSE must issue a permit for an instream flow right.

9.5 Jemez Canyon Reservoir

Increasing storage space at Jemez and reducing flood space would also require Congressional action. Currently the sediment pool remains full with SJCP water to improve sedimentation. When the contract expires in December of 2000, the ISC will decide if native water can be retained and released for instream flows (Gallegos, 1999).

10.0 CONCLUSION: SUSTAINABLE WATER DELIVERY FOR THE SILVERY MINNOW

"Sustain" can be defined as keeping in existence or providing support, sustenance or nourishment. When addressing the issue of providing water for the silvery minnow, we are dealing with just that, keeping the minnow alive by providing one of its basic needs. The fact that the silvery minnow is endangered reflects the extreme stress within the Rio Grande ecosystem (Niemi and McGuckin, 1997), and illustrates the need to provide instream flows for the protection and health of the watershed and the aquatic ecosystem.

I acknowledge that water delivery is just one of the measures needed; restoration of the floodplain and a reduction to the diversions are others. Just as the institutions and regulations for operating the river and the reservoirs are interwoven and complex, so are the changes that must occur in order for management practices to provide for the present and future demands for the water. Malcolm Newson states that "important elements of any river basin development scheme must be refined to the point where they can be interactively managed through time to reflect the changing needs of society and the environment" (Newson, 1997).

The institutions regulating water use in the Rio Grande Basin evolved in the context and for the support of diverting water for economic uses. Today, there are additional values placed on the water by the public, such as appreciation of the aesthetics of water in a river, along with preservation of the species and their ecosystems. The BuRec did redefine its mission in the 1980s to change from a water development organization to a water management institution. This new mission included an objective to protect the environment. However, the Bureau does not operate independently within a state. As mentioned previously, state and federal agencies must act in cooperation in order to provide water for instream flows for fish and ecosystems.

11.0 RECOMMENDATIONS

Newson (1997) places ecosystem functional integrity at the core of policies on sustainability. Guidelines for water allocation in the Basin need to be provided that would insure incorporation of ecological impacts in all water related developments. In addition, I think that the creation of a regional water forum, as suggested by Frank Titus (consultant, advisor to the state engineer and geologist), would begin the process for broad-based policy making. Titus (1994) suggested a forum in which all stakeholders and representatives from all jurisdictions would be represented in order to access information and be heard. Having all stakeholders involved would provide an opportunity for the different interest groups to describe their needs and goals. The mission of the forum would be to plan for, and optimize, future water reapportionments, so that the nonexpendable resources would support the greatest use with the least discomfort to society and individuals (Titus, 1994).

12.0 SUMMARY

Changes in upstream water management are one of several requirements necessary for preserving the silvery minnow, as well as the Rio Grande ecosystem. The OSE has said this is beneficial and that they will accept applications for a transfer of rights to an instream use for fish and recreation purposes. This commitment has not been tested. Further authorization involves allocation by the Interstate Stream Commission, as well as provision for storage by an act of Congress. Only then can the Bureau of Reclamation and the Army Corps of Engineers officially allow for storage and release of water for the fish. Because competition for the Basin's water now involves procurement of instream flows for aesthetic value and conservation of the ecosystem, instead of merely diversion for commodity uses, it would be wise to include all stakeholders and regulating agencies when proposing policy changes. Then the mission of Frank Titus's Water Forum might be accomplished, where water reallocation results in the least discomfort of individuals and society.

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ECONOMIC IMPLICATIONS OF MAINTAINING INSTREAM FLOW TO SUPPORT THE RIO GRANDE SILVERY MINNOW

Robin L. Just

Executive Summary. The Rio Grande silvery minnow is currently listed as an endangered species. The exact cause of its decline is unknown, though one potential contributing factor is the lack of continual flow throughout the Middle Rio Grande. It has been proposed that a safe minimum standard flow might mitigate the decline of this fish. However, there have been predictions that such an action might result in harm to the agricultural economy.

In order to ascertain the economic effects imposing a safe minimum standard flow on the river might have, I constructed a simple, mathematical model. The model accounts for agricultural, urban and instream water use (what people are willing to pay to save the fish) and predicts a total net benefit for all three categories. The results of the model vary greatly depending on human population, the willingness to pay value, and flow at the beginning of the Middle Rio Grande. Both negative and positive net benefits were obtained with small manipulations of these numbers. Research is needed to find more precise values for the input numbers. Additionally, more sophisticated models could also be used to account for optimizing the behavior of farmers that is likely to occur in times of water shortage.

1.0 INTRODUCTION

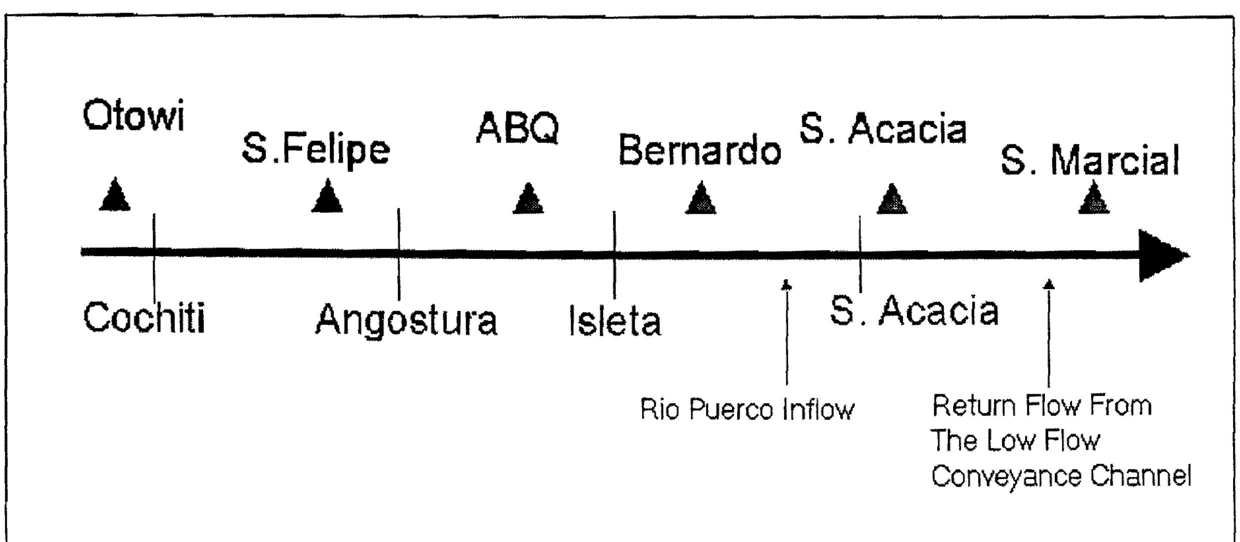
That the Rio Grande silvery minnow (*Hybognathus amarus)* population is in decline is not generally disputed. The biology of the fish is still being investigated, thus the current disagreement concerns the appropriateness of actions that can be taken to save this endangered species. There is frequent drying of the Rio Grande bed in certain reaches during the irrigation months. It has been suggested that this is one of the factors contributing to the decline of the fish, but it is unclear to what extent this is true (Platania, 1999). Until these questions are resolved comprehensive economic analysis of an effective recovery plan is impossible. However, general trends regarding agriculture, urban and instream water use can be predicted and incorporated into a simple cost benefit analysis of maintaining a safe minimum standard (SMS) flow sufficient to keep the river wet from Otowi to San Marcial.

I have created a model that accounts for water use by agriculture, urban and instream flows, and assigns a value to each. The purpose of this paper is to describe this model and its related assumptions, and provide net benefit values for scenarios with varying available water, population and the value of instream flows. First I will describe the model development, including an overview of the hydrology, the inputs used and the assumptions and simplifications that were made. Then I will discuss the affects varying inputs have on the total net benefit of having a SMS flow.

2.0 HYDROLOGY

Figure 9-1 provides a simplified overview of the hydrology of the Middle Rio Grande. The large arrow represents flow direction. The triangles represent the six gages used in this analysis: Otowi, San Felipe, Albuquerque, Bernardo, San Acacia and San Marcial. The lines below the arrow, Cochiti, Angostura, Isleta and San Acacia, are irrigation diversion dams. The two smaller arrows indicate significant areas of inflow into the Rio Grande from the Rio Puerco and return flow from the low flow diversion channel.

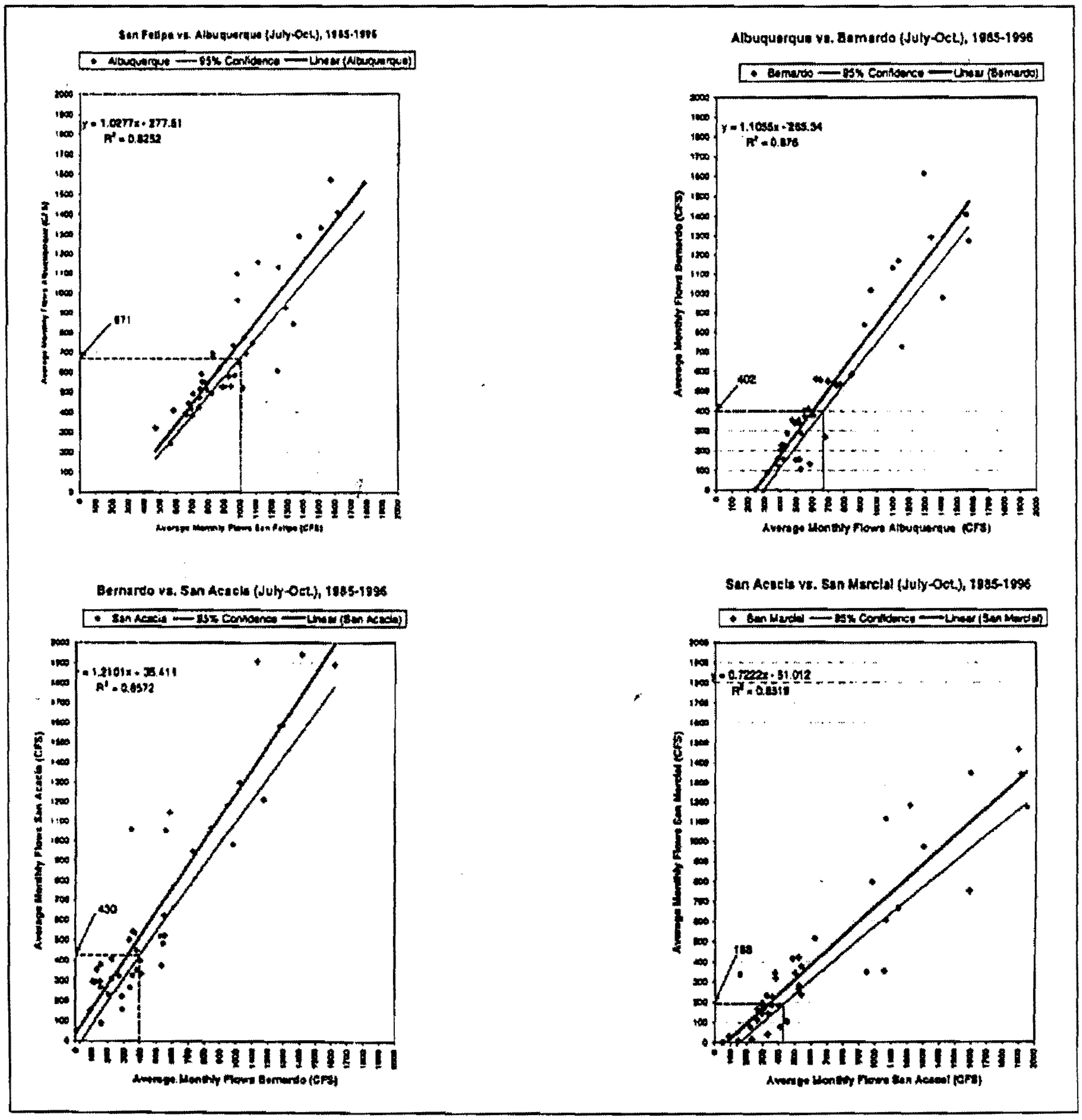
Figure 9-1. Middle Rio Grande Hydrology.



3.0 SAFE MINIMUM STANDARD

In a report to the City of Albuquerque concerning low-flow hydrology in the Middle Rio Grande, the engineering firm of CH2MHILL (1999) reports a minimum flow of 200 cubic feet per second (cfs) is needed at the San Acacia gage to provide a wet riverbed to Elephant Butte. In the report, CH2MHILL develops regression curves (Figure 9-2) for the amount of water needed at each of the five relevant gages to meet a safe minimum standard flow in that reach, as well as to provide the necessary 200 cfs at San Acacia.

Figure 9-2. Regression Models Indicating Safe Minimum Flow Requirements Between Gages (CH2MHILL, 1999).



As the curves in Figure 9-2 indicate, a flow of approximately 1,000 cfs at San Felipe results in 671 cfs at Albuquerque, which yields 402 at Bernardo, 430 at San Acacia (the gain is due to return flows and the Rio Puerco), and 168 at San Marcial.

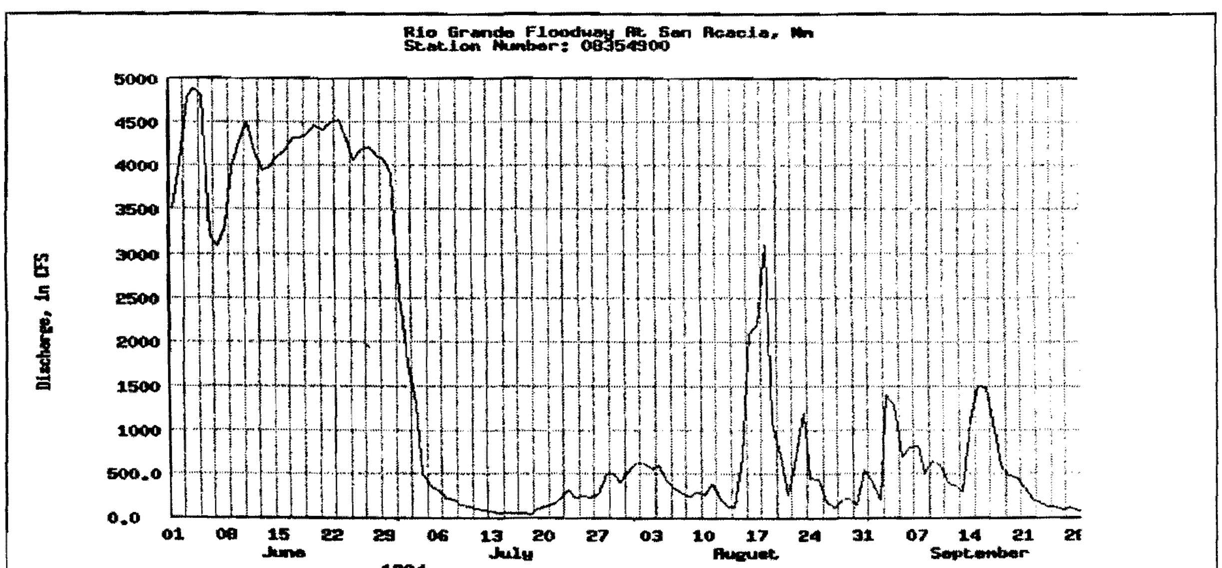
The monthly average flow from 1971 to 1966 at each gage is listed in Table 9-1. However, the average numbers are misleading, as they do not indicate specific times at which the bed is completely dry. For example, in September the average flow is 379 cfs at San Marcial, which is above the SMS. However there could have been dry days during the month, and while water is present at the gage, this is not necessarily an indication that it is available in the entire reach. In fact, the low flow at San Felipe is below the SMS. Therefore, based on the above regression curves, it can be concluded that dry reaches occur in stretches of the Middle Rio Grande.

Table 9-1. Average Monthly Flow At Each Gage From 1971 to 1996.

AVERAGE DAILY FLOW (CFS)						
	Otowi	**San Felipe**	**ABQ**	**Bernardo**	**San Acacia**	**San Marcial**
June	3,420	3,251	2,939	2,535	2,176	2,098
July	1,610	1,923	1,573	1,206	1,106	1,029
August	953	1,033	766	479	573	485
September	868	819	566	382	556	379

A look at daily flows at one of the gages throughout an irrigation season is useful to better understand why the monthly averages do not provide a full picture of the hydrology. Figure 9-3 indicates there were several days in July1994 when the flow dropped below the SMS however the average daily flow for the month was greater than the SMS.

Figure 9-3. Daily Flow At San Acacia for The 1994 Irrigation Season (USGS, 1999).



4.0 MODEL DEVELOPMENT

In order to develop an economic model, I had to first create a simplified hydrologic model. Inflows and outflows were identified using monthly daily flow averages at each gage. Losses to the river fell into three use categories: agricultural, urban and instream flow. Natural river losses were accounted for in the CH2MHILL regression equations. A hierarchy of uses was assigned, with urban first, instream flow for the SMS second and agriculture last[1]. A water budget was created for two scenarios: without constraints (no SMS) and with. Finally, I developed a net benefit equation that added the value of agriculture, urban and instream use.

4.1 Inflows and Outflows

In developing a water budget, I had to account for the varying hydrologic parameters in each reach. Table 9-2 illustrates the water budget calculations used to determine the amount of water available for agriculture (the least valued use) in each reach after first subtracting for urban use and for the SMS. The first case (without SMS) assumes an SMS requirement of zero and the second case imposes the SMS as determined from the regression equations with the SMS at San Acacia set at 200cfs. In the table, the river reach number identifies the area between two consecutive gages. Reach 1 is from San Felipe to Albuquerque, reach 2 is Albuquerque to Bernardo, 3 is Bernardo to San Acacia and 4 is San Acacia to San Marcial. Qc is the initial flow entering at San Felipe. Qe (for each reach) is the amount of water entering each reach (a function of Qc). Qe for each reach is calculated from the regression tables developed by CH2MHILL (1999). I assumed that flow is uniform between each gage, and that all diversions for a reach occur at the beginning of the reach. Similarly all return flows for each reach occur at the end of the reach. Thus, water diverted for irrigation is completely lost to its respective reach.

In the first case scenario used in Table 9-2, (without an SMS), water is available for agricultural use in all reaches, even with the urban diversion in reach 2. However, in the second case (with an SMS) there is no water available for agricultural use in any reaches. Table 9-2 is based on an extremely dry month. In my net benefit equations I varied Qc to simulate both wet and dry months.

[1] This was necessary since my model would not be able to optimize for best use. Since my objective was to identify the cost to agriculture, I felt this was a reasonable simplification.

Table 9-2. Illustration of Water Budget Calculations

WATER BUDGET Using Worst Case Month (all units are cfs)				
Without SMS				**Water Available for Agriculture**
Reach 1	Qc	SMS		Qag =Qc – SMS
	950.00	0		950.00
Reach 2	Qe = 12/13Qc	SMS	Qur	Qag = Qe-sms-Qur
	876.92	0	174.97	701.95
Reach 3	Qe = 6/13Qc	SMS		Qag=Qe-sms
	438.46	0		438.46
Reach 4	Qe = 2/13Qc	SMS		Qag=Qe-sms
	146.15	0		146.15
With SMS				
Reach 1	Qc	SMS		Qag =Qc – SMS
	950.00	1300		-350.00
Reach 2	Qe = 12/13Qc	SMS	Qur	Qag = Qe-sms-Qur
	876.92	1200.00	0	-323.08
Reach 3	Qe = 6/13Qc	SMS		Qag=Qe-sms
	438.46	600		-161.54
Reach 4	Qe = 2/13Qc	SMS		Qag=Qe-sms
	146.15	200		-53.85

4.2 Agriculture

In the model agriculture was assumed to consume all water available water that was not used for urban or SMS purposes[2]. Weighted average values for each of four different crop types with differing water use intensities and net income values (Niemi and McGuckin, 1997) were calculated as shown in Table 9-3. For example, 4 acre-feet per acre are needed to grow alfalfa. I converted this number to cfs then multiplied this value

[2] Cropping patterns in the Middle Rio Grande Valley indicate this is not necessarily true (USDA, 1997), but again, due to the fact that this is not an optimization model it was a necessary simplification.

by the number of acres of alfalfa reported to be grown in the four counties (Niemi and McGuckin, 1997).

Table 9-3. Weighted Average Net Income And Water Use Per Crop

CROP	NET INCOME/ACRE	ACRES	NI/A X ACRE (NET INCOME)	AC-FT/ ACRE/YR	CFS/ ACRE	CFS/ACRE X ACRE
Alfalfa	$195	30,837	$6,013,215	4	0.005524	170.343
Pasture	($80)	15,848	$-1,267,840	3	0.004143	65.658
Corn Silage	$18	3,621	$65,178	3	0.004143	15.001
Green Chile	$385	896	$344,960	4	0.005524	4.949
Total		51,202	$5,155,513			255.953
Net Income	$100.69			Average Water (cfs)		0.005

I then multiplied the income generated by selling one acre of alfalfa by the total number of acres grown. I did this for each crop type then divided by total acreage (for water use) and total net income (for value) to get weighted average values. The resulting values were used in the net benefit equations. An average value of $100.69 is the net income per acre, and an average of 0.005 cfs is needed per acre throughout the growing season. The negative value for pastureland reflects personal consumption of crops. It is unclear from the report by Niemi and McGuckin whether this value considered sale of animal products using the pastures.

4.3 Urban

Per capita urban water use in Bernalillo County is currently declining due to conservation awareness campaigns in the City of Albuquerque. The targeted rate of consumption is 175 gallons per capita per day (City of Albuquerque, 1995). Currently, all of Albuquerque's water is pumped from the aquifer below the city, however this supply is not sustainable and the City has plans for using surface water diverted from the Rio Grande (City of Albuquerque, 1997). To account for this eventuality I have included a sustainable amount of groundwater consumption per year (Kernodle at al., 1995) in the model, then assumed that the rest will come from surface diversions.

4.4 Instream Flows

A recent survey-based contingent valuation study indicates that New Mexicans are willing to contribute money (willing to pay) to a trust-fund to purchase instream flow water rights for the SMS for the Rio Grande Silvery Minnow (Berrens et al, 1996). Willing to pay values in other Western States range from approximately $20 to $80 per household, depending on the study used (Douglas and Johnson, 1993). I multiplied these values by the number of households in New Mexico to find a range of net benefit for SMS instream flows. I varied the number of households to represent growth to determine if the effects of increasing this number would offset the loss to agriculture. The impact of increasing this number is twofold. Not only does it increase total net benefit for instream flows, but it also creates a greater need for urban water use.

4.4 Net Benefit Equation

The net benefit (NB) in this model is NBagriculture + NBurban + NBinstream. I calculated net benefits under various scenarios by varying three variables: population, total flow and willingness to pay. Each scenario examined two cases: the without SMS case and the with SMS case. The total net benefit of applying the SMS was determined by the difference between the two cases. An illustrated scenario is shown in Table 4. In the illustration the NB with SMS is greater than the NB without SMS, so there is a positive total net benefit of imposing an SMS. Note that there is a negative net benefit in Valencia and Socorro counties due to agricultural losses.

Table 9-4. Illustration of Total Net Benefit Results.

WITHOUT SMS		WITH SMS	
Reach	**Net Benefit**	**Reach**	**Net Benefit**
Sandoval	$19,135,287	**Sandoval**	$19,603,358
Bernalillo	$758,568	**Bernalillo**	$730,173
Valencia	$12,196	**Valencia**	$(4,493)
Socorro	$4,065	**Socorro**	$(1,497)
Total	$19,910,117	**Total**	$20,327,541
Total Net Benefit with SMS			$417,424

5.0 RESULTS AND DISCUSSION

The results of this model varied depending largely upon the instream flow value. Table 9-5 summarizes the results of salient model runs.

Table 9-5. Results of Total Net Benefit Calculations

Pop (Bernalillo)	# Households (NM)	Water (cfs)	WTP forSMS ($ per household)	Total Net Benefit ($)	Comments
526,000	655,106	3000	$ 80.00	$ (14,061,857.88)	Wet year
526,000	655,106	3000	$ 101.46	$ (3,268.10)	
526,000	655,106	3000	$ 101.47	$ 3,282.97	Changing point for WTP
578,600	675,094	3000	$ 101.47	$ 2,031,552.69	10% increase in population
578,600	675,094	3000	$ 80.00	$ (12,462,731)	
578,600	675,094	3000	$ 20.00	$ (52,968,413)	
1,052,000	854,986	3000	$ 80.00	$ 1,928,907	Doubled population
1,052,000	854,986	3000	$ 77.00	$ (636,053)	
1,052,000	854,986	900	$ 77.00	$ 49,526,289	Dry year
1,052,000	854,986	900	$ 20.00	$ 792,048	
526,000	655,106	900	$ 20.00	$ (3,205,920)	Current population
526,000	655,106	900	$ 30.00	$ 3,345,147	Increase WTP by $10
526,000	655,106	1950	$ 30.00	$ (20,632,062)	Midpoint flow (wet+dry)/2
526,000	655,106	1950	$ 62.00	$ 331,352	Changing point for WTP

In the initial run of the model I used our current population, a wet year and a high willingness to pay (WTP). This resulted in a large negative benefit. In other words, it is more beneficial to use the water for agriculture than for the fish. I then found the changing point for the WTP number to be $101.46 per household, which gave a modest positive net benefit for using a SMS flow. A 10% increase in population produced a 600% increase in net benefit (this model was extremely sensitive to population chan However, lowering the WTP to a more reasonable number led to a negative benefit doubling our current population I found a changing point of (above this number there was a positive net benefit for imposing an SMS. I then changed the flow to one more typical of a dry year and got a dramatic difference, from $-636,053 to $49,526,289. This difference can be explained by the fact that there is less water available for agriculture to lose than in a wet year, so the decrease in profit due to loss of water is much smaller. Using the lowest value for WTP ($20) still gave a positive net benefit. When using these parameters, I lowered the population back to current numbers the net benefit once again became negative. However, raising the WTP by $10 gave a positive net benefit. Therefore, given current populations and a dry year, there is a greater benefit in using the water for a SMS than agriculture. However, in a wet year, it largely depends on the WTP value. In the final two runs I used a middle value for flow, and found this trend remained. The changing point for the WTP value was around $62.

6.0 RECOMMENDATIONS

The model I created was a simplification of an extremely complicated system. There were many assumptions made in order to obtain meaningful results without relying on extensive statistical and empirical techniques. However, the results are quite useful, in that they indicate extreme variability of the total net benefit with changes in the population, flow and WTP numbers. In other words, all the variables involved are very influential to the total net benefit. More certainty is needed for each of these variables.

A more comprehensive contingent valuation survey would decrease the possibility of errors in the model due to the WTP number. A more sophisticated total net benefit model that could optimize water use would also decrease uncertainty. Additionally, a model that incrementally increases population to its projected doubling in 2050 would provide insight as to the real effect over time of growth.

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