United States Department of the Interior

FISH AND WILDLIFE SERVICE
New Mexico Ecological Services Field Office
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July 14, 1999

Cons. 2-22-91-F-241
Cons. 2-22-92-F-080
Cons. 2-22-99-F-381

To: Navajo Area Director, Bureau of Indian Affairs, P.O. Box 1060, Gallup, New Mexico 87325

From: Field Supervisor, New Mexico Ecological Services Office, Albuquerque, New Mexico

Subject: Biological Assessment for Completion of the Navajo Indian Irrigation Project

This responds to your request of June 14, 1999, for our concurrence with your finding that the completion of the Navajo Indian Irrigation Project (NIIP) may affect but is not likely to adversely affect the endangered Colorado pikeminnow (*Ptychocheilus lucius*) and razorback sucker (*Xyrauchen texanus*), and is not likely to adversely modify or destroy designated critical habitat within the San Juan River basin for the two endangered fish species.

The principal purpose of NIIP is to irrigate 110,630 Navajo-owned acres in northwestern New Mexico, generally south of Farmington on an elevated plain above the San Juan River between Highway 44 of the east and the Chaco River on the west. The development of the project has occurred and is planned for completion in blocks of approximately 10,000 acres each. A previous consultation addressed the potential effects of the construction and operation of Blocks 1 through 8 on the Colorado pikeminnow and razorback sucker (Cons. 2-22-91-F-241) with a Biological Opinion issued by the Service on October 26, 1991. That consultation was reinitiated at the request of the Bureau of Indian Affairs in 1994 to address the effects of the eight agricultural blocks on the newly designated critical habitat for the endangered fish, with a Biological Opinion issued on January 12, 1995. The biological data and information provided in the consultation documents formulated for the previous consultation and its reinitiation are included herein by reference, with updated, corrected, or additional data submitted in the June 11, 1999, Biological Assessment. The following information concerning the proposed action and your analysis of effects is taken from the June 11, 1999, Biological Assessment that was furnished with your request for concurrence.

Completion of NIIP, as proposed, will entail the addition of three more blocks of irrigated lands, bringing the total to 11 blocks within the project. Every block is divided into fields, or water-delivery units, with access roads and individual sprinkler systems. Water for the irrigation activities will be brought from Navajo Reservoir on the San Juan River through tunnels, siphons, open concrete-lined canals, and pipelines. All of the infrastructure to deliver the water from Navajo Dam to the project boundary is sized for full development and is in place. Completion of NIIP will require further development and expansion of water delivery systems within the project itself. One pumping plant (Kutz) exists to lift the water from the main delivery network to open laterals to the fields. Completion of NIIP will require the addition of two more pumping plants, Gallegos and Moncisco. One regulating reservoir will be required to meet peak irrigation demand during the summer when the total irrigated area exceeds about 97,000 acres. Two alternative sites have been selected and are under investigation for feasibility. The active storage requirement for either reservoir option is 7,735 af; either dam would be a zoned earth embankment dam with concrete spillway.

The acreage through Block 8 that will be completed and in full operation by 2002 totals 76,481 acres. The currently authorized depletion for these first eight blocks is 149,420 acre-feet (af), requiring 8,000 acres of conservation reserve and additional conservation measures for irrigation of all acreage in the first eight blocks. Included in the 149,420 af depletion allowance is 16,420 af of depletion transferred from other Navajo Nation projects to the NIIP. Completion of NIIP will result in agricultural development of 110,630 acres. Future planning excludes conservation acreage and plans for full irrigation on the aggregate 110,630 acres. Hence, the current proposed action is to fully develop the agricultural lands within NIIP, removing the acreage restrictions of the previous consultation. This action will increase annual depletions from the San Juan River by about 120,580 af on average under equilibrium conditions and by about 137, 580 af on average until return flows reach equilibrium. This depletion will require an average annual diversion of about 337,500 af.

The proposal for full development of NIIP also includes project elements designed to support the recovery of the endangered Colorado pikeminnow and razorback sucker. In 1998, three fish rearing ponds were constructed within the boundaries of NIIP. Ojo Pond was constructed to accommodate up to 10,000 early life stage razorback suckers transferred from the Lower Colorado River. The pond is used for rearing of these fish to a size suitable for stocking in the San Juan River as part of the razorback sucker augmentation plan of the San Juan River Recovery Implementation Program. The pond has a surface area of about 2.4 acres. It was constructed by raising an existing earthen dam on a tributary of Ojo Amarillo that collects seepage and runoff water from NIIP lands. The shallow areas were deepened, a fish screen was installed and a boat ramp constructed to facilitate fish harvest. The water level can be lowered by about 2.0 feet for harvesting fish by removing flash boards in the outlet structure. Avocet Ponds were also constructed in 1998 but have not yet received fish. The 2-cell configuration covers a total area of about 7.5 acres. Water is supplied from a turnout on the NIIP water supply system. Each cell can be filled independently and each has an emergency overflow. Each cell has the capacity of at least 10,000 fish. Water levels will be maintained by releases from the NIIP water supply system with water requirements a part of the depletion allocation for NIIP.

Exterior to the NIIP project, the Navajo Nation owns two irrigation projects with diversion dams impacting the movement of fish within the San Juan River. As a part of the completion of NIIP, these dams will be modified by the Bureau of Indian Affairs to remove impediments to passage by Colorado pikeminnow, thereby allowing access by the species to portions of its designated critical habitat upstream from the diversion dams and removing the potential threat of entrainment of downstream moving fish. Cudei Diversion Dam is located about 6 miles downstream of Shiprock on the San Juan River. The quarry rock dam spans the entire width of the river as it diverts water to the Navajo-owned Cudei Irrigation Project. This is the lowermost diversion dam on the San Juan River. To allow expansion of range, plans are underway to remove the diversion dam, replacing it with a 21-inch diameter inverted siphon crossing under the river. Construction is anticipated for fall/winter of 1999/2000 or 2000/2001. The Hogback Diversion Dam crosses the San Juan River about 10 miles east of Shiprock, diverting water for the Navajo Nation's Hogback Irrigation Project. The quarry rock diversion dam has failed and the diversion is maintained by bulldozing up a dike across the river during low flow periods and routing most of the water through the canal intake and sluiceway. During storms and other high water events the dike is again breached and must be re-built. The Bureau of Reclamation is currently designing a low gradient riprap dam with steel sheet pile cutoff wall to replace the existing temporary dike arrangement. A low-flow fish passage channel will be incorporated into the structure adjacent tot the sluiceway. At high flow, the entire structure will be passable by most fish species.. Downstream moving fish, including larval drift, will pass through the fish passage channel.

The Biological Assessment addressed the potential of the project to affect listed, proposed, and candidate species, and species of concern. For listed species the Biological Assessment provided the following findings:

Black-footed ferret *(Mustela nigripes)* - No effect. The Service concurs, based on the lack of any prairie dog colonies on or adjacent to the project.

American peregrine falcon/arctic peregrine falcon *(Falco peregrinus anatum/F. p .tundrius)* No effect. The Service concurs, based on the lack of nesting habitat on project lands. Any use of the project area would be incidental and associated with movements between areas of suitable habitat.

Bald eagle *(Haliaeetus leucocephalus)* No effect. The Service concurs; although bald eagles winter in small numbers along the San Juan River, the project area does not contain suitable habitat or forage species of concentration to attract feeding eagles. The reoperation of Navajo Dam that is considered a component of this project will return the management of the San Juan River to a more natural hydrograph. Such modification of flows may affect fish populations but is not expected to result in discernible changes in the availability of fish as prey for the eagles.

Brown pelican *(Pelecanus occidentalis)* No effect. The Service concurs; an accidental occurrence may occur from storm driven individuals making landfall on the project, but no habitat exists for this species on NIIP lands or the surrounding area.

Mexican spotted owl (*Strix occidentalis lucida*) No effect. The Service concurs; no habitat exists for this species in the area.

Mountain plover (*Charadrius montanus*) No effect. The Service concurs. The plover may be a rare visitor to the general area, but it would be very infrequent.

Southwestern willow flycatcher (*Empidonax traillii extimus)* May affect, not likely to adversely affect. The Service concurs. Although there is no habitat for this species found on project lands, the reoperation of Navajo Dam to mimic a more natural hydrograph, included as a feature of the proposed project, will contribute to the potential for use of the San Juan River's corridor by the endangered flycatcher. The one nesting area found in proximity to NIIP receives a water supply from irrigation return flow from the Hogback Irrigation Project and would not be affected by the agricultural program at NIIP.

Knowlton cactus *(Pediocactus knowltonii)* No effect. The Service concurs; the species has not been found on project lands.

Mancos milkvetch (*Astragalus humillimus*) No effect. The Service concurs, the species has not been found on project lands.

Mesa Verde cactus *(Sclerocactus mesae-verdae)* No effect. The Service concurs, the species has not been found on project lands.

Colorado pikeminnow and razorback sucker. May affect, not likely to adversely affect. The Service concurs, based on the following components of the proposed action, the capability of the river to achieve the flows recommended for the endangered fish species over and above the depletions caused by the proposed action, and on the commitments made by the Bureau of Indian Affairs and the Navajo Nation to the San Juan River Recovery Implementation Program.

Reoperation of Navajo Dam to mimic a natural hydrograph of the San Juan River and to meet the flow recommendations for recovery of the endangered Colorado pikeminnow and razorback sucker. The information presented in the Biological Assessment reflects the findings of the San Juan River Recovery Implementation Program's Flow Recommendations Report (1999)-that the depletion of water from the San Juan River necessary to support the proposed project would still allow the flow recommendations formulated for the recovery of the two endangered fish species to be met through the reoperation of Navajo Dam.

Removal of two Navajo-owned diversion dams currently impeding fish movement in the San Juan River and barring Colorado pikeminnow from accessing upstream areas of designated critical habitat has been included as a component of this project, to be completed by the Bureau of Indian Affairs and Bureau of Reclamation. With the completion of these two projects, as components of NIIP, the potential range of the endangered fish species will be expanded by about 22 miles to the Four Corners Generating Station weir, representing a 15% expansion in range.

As an element of the proposed action, the Bureau of Indian Affairs has constructed and will operate three ponds to rear razorback sucker to sizes that will support successful stocking of this species in the San Juan River.

The question of long term risk caused by the potential of project return flows to increase levels of selenium in the San Juan River and on-project ponds and the effects of such exposure on the endangered fish is a matter of debate among scientific experts. In order to address these concerns, the Bureau of Indian Affairs has included a monitoring program as an integral element of the proposed project. This program will be followed to track selenium levels and provide data to assess risk as additional research is completed concerning chronic toxicity, particularly in razorback sucker. It will be composed of three parts: 1) on-farm monitoring, 2) San Juan River monitoring, and 3) razorback sucker grow-out pond monitoring.

1. Irrigation return flow from the project is the main source of selenium discharged to the San Juan River. This irrigation return flow leaves the project either through deep percolation and discharge from springs along bedrock contact lines or as artificial drain outflow. Artificial drainage was first installed in the winter of 1998-1999 in two fields, with a total of three drain outfalls. The drainage system completion study is now underway to identify and prioritize drain construction to intercept groundwater before it saturates the soils within the rootzone of the fields. The on-farm selenium sampling program will have three elements: 1)groundwater wells, 2) subsurface drain outfalls, and 3) main natural drain outflow.

There are 51 groundwater observation wells on Blocks 1-7 of the project. Much of Blocks 6 and 7 do not have water tables above the bedrock since irrigation is relatively recent. As water levels rise, observation wells will be added. Also as Blocks 8-11 develop and water tables rise, wells will be added to these blocks. It is anticipated that there will be as many as 100 observation wells at project completion.

Water samples will be taken from these wells and selenium levels determined on a semi-annual basis. Sampling will occur in the spring, before irrigation begins, and in the fall, at the end of the irrigation season (typically March and October).

Upon installation of subsurface drains, each drain outfall to a main collector or natural drainage way will be monitored twice annually until selenium levels fall below 1.0 part per billion (ppb).

Monitoring of selenium levels in the natural return flow channels to the San Juan River (currently Ojo Amarillo and Gallegos Wash) will be monitored quarterly.

2. Water quality sampling in the San Juan River is described in the San Juan River Recovery Implementation Program monitoring program. In addition, sediment, periphyton, macroinvertebrates (by species), small fish and flannelmouth sucker ovaries or eggs will be monitored from above Gallegos Canyon to Bluff, Utah. In addition, non-lethal samples (muscle plugs) will be collected from endangered fish on an opportunistic basis and with the approval of the San Juan River Recovery Implementation Program Biology Committee. The sampling program will be designed to assess not only the main channel, but typical low velocity habitats used by native fish, including backwaters, secondary channels and tributary mouths. An initial sampling will take place in 2000 with subsequent sampling every 5 years or as determined in collaboration with the Fish and Wildlife Service. The details of the plan will be developed in concert with Fish and Wildlife Service staff.

3. Selenium monitoring will continue on the razorback sucker grow-out ponds. They are currently sampled weekly for pH, dissolved oxygen, conductivity, and temperature. They will be sampled quarterly for trace elements.

Prior to removing fish and stocking in the San Juan River, non-lethal (e.g. muscle plug) samples will be collected from the juvenile razorback suckers. Sample size and protocol will be developed with Fish and Wildlife Service and San Juan River Recovery Implementation Program Biology Committee input.

The Bureau of Indian Affairs has committed to continued funding of and participation in the San Juan River Recovery Implementation Program.

Based on the analysis of impacts provided by the Bureau of Indian Affairs during the informal consultation that has occurred on this proposal, the determination that flows recommended for the recovery of the endangered fish species will be met with the depletions of this proposed action, and the commitments provided in the Biological Assessment, including the incorporation of recovery actions as integral project elements of the proposed action, the Fish and Wildlife Service concurs with your finding that the full completion of the Navajo Indian Irrigation Project, as described in the June 11, 1999, Biological Assessment, may affect, but is not likely to adversely affect the endangered southwestern willow flycatcher, Colorado pikeminnow, or razorback sucker; nor is the project likely to result in adverse modification or destruction of critical habitat designated in the San Juan River basin for the Colorado pikeminnow or razorback sucker.

The Fish and Wildlife Service would like to thank you for your efforts on behalf of endangered species in the San Juan Basin. This concludes section 7 consultation on

Blocks 1-11 of the Navajo Indian Irrigation Project. If you have any questions or concerns about this consultation, please contact me at the letterhead address and telephone number.

Jennifer Fowler-Propst

cc:
Mr. Robert Krakow, Bureau of Indian Affairs, 304 North Auburn, Suite B, Farmington, New Mexico 87401
Mr. Ron Bliesner, Keller-Bliesner Engineering, 78 East Center, Logan, Utah 84321
Chairman, Southern Ute Indian Tribe, P.O. Box 737, Ignacio, Colorado 81137
President, Jicarilla Apache Indian Tribe, P.O. Box 507, Dulce, New Mexico, 87528
Chairman, Ute Mountain Ute Indian Tribe, Towaoc, Colorado 81321
President, Navajo Nation, P.O. Box 9000, Window Rock, Arizona 86515
Regional Solicitor, U.S. Department of the Interior, Albuquerque, New Mexico
Regional Director, Fish and Wildlife Service, Mountain and Prairie Region, Denver, Colorado
Field Supervisor, Fish and Wildlife Service, Grand Junction Ecological Services Office, 764 Horizon Drive, South Annex A, Grand Junction, Colorado 81506- 3946
Field Supervisor, Fish and Wildlife Service, Utah Ecological Services Office, Salt Lake City, Utah
Geographic Assistant Regional Director, AZ/NM, Fish and Wildlife Service, Southwest Region, Albuquerque, New Mexico
Project Leader, New Mexico Fishery Resources Office, Fish and Wildlife Service, Albuquerque, New Mexico
Native American Liaison, Fish and Wildlife Service, Southwest Region, Albuquerque, New Mexico
Mr. Joel Farrell, Bureau of Land Management, Farmington Field Office, 1235 La Plata Highway, Farmington, New Mexico 87401
Southern Division Manager, Bureau of Reclamation, 835 East 2nd Avenue, Suite 300, Durango, Colorado 81301
Ms. Jessica Aberly, Nordhaus, Haltom, Taylor, Taradash & Frye, Suite 1050, 500 Marquette NW, Albuquerque, New Mexico 87102
Mr. Scott McElroy, Greene, Meyer & McElroy, 1007 Pearl Street, Suite 220, Boulder Colorado 80302
Mr. Dan Israel, P.O. Box 2182, Carefree, Arizona 85377
Mr. Stanley Pollack, Special Counsel for Water Rights, Navajo Nation Department of Justice, P.O. Box 2010, Window Rock, Arizona 86515
John Whipple, New Mexico Interstate Stream Commission, Bataan Memorial Building, Room 101, Santa Fe, New Mexico 87504
Mr. Randy Seaholm, Colorado Water Conservation Board, 1313 Sherman Street, Denver, Colorado 80203

Director, New Mexico Department of Game and Fish, P.O. Box 25112, Santa Fe, New Mexico 87504
Director, Colorado Division of Wildlife, 6060 Broadway, Denver, Colorado 80216
Executive, Director, Utah Department of Natural Resources, 1636 West North Temple, Suite 316, Salt Lake City, Utah, 84116
Mr. Tom Pitts, Water Consult, 535 North Garfield Avenue, Loveland, Colorado 80537

July 14, 1999

Ms. Jessica R. Aberley
Nordhaus, Haltom, Taylor, Taradash & Frye, LLP
Suite 1050
500 Marquette Ave., NW
Albuquerque, NM 87102

Re: Jicarilla Apache Tribe's Water Rights

Dear Ms. Aberly:

Thank you for your letters of June 28, 1999, to Acting Deputy Secretary David Hayes and myself regarding actions by the Bureau of Indian Affairs (BIA) and the U.S. Fish and Wildlife Service (FWS) in connection with the Navajo Indian Irrigation Project. You express concern that the BIA's request of FWS to concur in its finding made pursuant to the Endangered Species Act, that completion of the Navajo Indian Irrigation Project is not likely to adversely affect endangered species or designated critical habitat in the San Juan River Basin, may foreclose the ability of the Jicarilla Apache Tribe to develop its water rights in the San Juan River. You asked this office to withdraw the BIA's request for concurrence to permit the Navajo Nation and the Jicarilla Apache Tribe time to resolve this issue.

After careful consideration of the relevant provisions of the Endangered Species Act, and its implementing regulations, we have decided that seeking an extension of the ESA regulatory deadlines in this context is unnecessary. Any biological judgments inherent in the FWS's decision will not foreclose the Department's ability to assist the Jicarilla Apache Tribe in exercising its water rights secured in the Jicarilla Water Rights Settlement Act. Further, the FWS decision will not compromise the Department's commitment, as stated in the San Juan River Recovery Implementation Program document, to use its authority to preserve and protect the water resources of all the tribes in the Basin. The Department has an obligation to resolve San Juan River issues in a way that enables the Jicarilla Tribe to utilize its settlement water and enables completion of the Navajo Indian Irrigation Project.

It is my understanding that discussions between the two Tribes have begun that could resolve many of the issues, and that a meeting is scheduled for July 21. An inter-tribal agreement is clearly preferable to any solution that may be imposed by the Department. It is our expectation that the July 21st meeting will be productive. Please be advised that this Department will make every effort to aid in obtaining an inter-tribal resolution of this matter.

Based upon the decision not to withdraw the BIA's request, there appears to be no need to schedule a meeting in the immediate future. If you would like to discuss this matter further, please contact M. Sharon Blackwell on my staff or Mike Connor in the Office of the Indian Water Rights.

Sincerely,

Assistant Secretary - Indian Affairs

cc: Stanley Pollack, Water Rights Counsel, The Navajo Nation
David J. Hayes, Counselor to Secretary Babbitt
Eloise Chicarello, Acting Area Director, Navajo Area Office, BIA
Bob Krakow, Navajo Indian Irrigation Project, BIA
Rob Baracker, Area Director, Albuquerque Area Office, BIA
Nancy Kaufman, Regional Director, Southwest Region, FWS
Renne Lohoefener, Geographic Manager - New Mexico, FWS
Jennifer Fowler-Propst, New Mexico Ecological Services Field Office, FWS

United States Department of the Interior

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July 30, 1999

Cons. 2-22-91-F-241
Cons. 2-22-92-F-080
Cons. 2-22-99-F-381

To: Navajo Area Director, Bureau of Indian Affairs, P.O. Box 1060, Gallup, New Mexico 87325

From: Field Supervisor, New Mexico Ecological Services Office, Albuquerque, New Mexico

Subject: Biological Assessment for Completion of the Navajo Indian Irrigation Project

This is in further response to your request of June 14, 1999, for the concurrence of the Fish and Wildlife Service with your findings of "may affect, not likely to adversely affect" listed species arising from the proposed completion of the Navajo Indian Irrigation Project (NIIP). Our letter of concurrence provided to you on July 14, 1999, contained a typographical error concerning the depletions arising from the project.

Your action will increase annual depletions from the San Juan River by about 120,580 af on average under equilibrium conditions and by about 131,180 af on average until return flows reach equilibrium. This depletion will require an average annual diversion of about 337,500 af. Please amend your records to reflect this correction.

Jennifer Fowler-Propst

cc:
Mr. Robert Krakow, Bureau of Indian Affairs, 304 North Auburn, Suite B, Farmington, New Mexico 87401
Mr. Ron Bliesner, Keller-Bliesner Engineering, 78 East Center, Logan, Utah 84321
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Mr. Tom Pitts, Water Consult, 535 North Garfield Avenue, Loveland, Colorado 80537

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July 9, 1999

Via Facsimile: (505) 248-6910
& U.S. Mail

Ms. Nancy Kaufman
U.S. Fish and Wildlife Service
Regional Director
P. O. 1306
Albuquerque, NM 87103

Re: Section 7 Consultation on Navajo Indian Irrigation Project ("NIIP")

Dear Ms. Kaufman:

The Southwestern Water Conservation District ("District"), which represents water users in southwest Colorado, has been involved in the San Juan River Recovery Implementation Program ("RIP") since its inception and supports the RIPS's dual goals of recovery of the endangered fish while allowing for further water development. The RIP Coordination Committee's recent approval of the Flow Recommendations for the San Juan River is a major step toward meeting both goals.

The Flow Recommendations identified 122,000 acre-feet/year of additional water depletions that may occur in the San Juan Basin without impacting the flows recommended for endangered fish recovery by the RIP Biology Committee. A sub-committee of the Coordination Committee is now developing recommendations to the U.S. Fish and Wildlife Service ("Service") concerning the conduct of future section 7 consultations, and, more particularly, what will happen, under the RIP's adaptive management program, after the identified 122,000 acre-feet of depletions is exhausted. The sub-committee will not complete its work until late this year or next year.

The District understands that the Bureau of Indian Affairs has submitted a Biological Assessment which permits approximately 122,000 acre-feet of depletions for the construction and operation of all remaining blocks of the Navajo Indian Irrigation Project ("NIIP"). The District further understands that the Service may approve the Assessment, as submitted, by the middle of July, 1999. The District is very supportive of the irrigated agriculture, including the irrigated acres NIIP would provide, and strongly supports the completion of NIIP.

Since the District has not yet seen the Biological Assessment, however, the District is concerned whether the NIIP will still be required to meet any of the reasonable and prudent alternative conditions in the NIIP 1991 Biological Opinion for the additional depletions of up to 122,000 AF per year and what, if any, new conditions are included in the Assessment.

Ms. Nancy Kaufman
Regional Director, U.S. Fish and Wildlife Service
July 9, 1999
Page 2

The District is especially concerned because the District understands that the Service is considering issuing an opinion that NIIP's additional depletions do not cause jeopardy because the Flow Recommendations will be met, even with NIIP in place, and therefore, no reasonable and prudent alternative is necessary. This is contrary to all past Service opinions where projects (e.g., Animas-La Plata, Red Mesa, City of Durango, minor depletions) were considered to cause jeopardy but re-regulation of Navajo Reservoir and the RIP were the reasonable and prudent alternative. All of the projects for which opinions were previously issued were considerably smaller than NIIP. Logically, this must mean that all projects added to the baseline since 1991 with jeopardy opinions will now have non-jeopardy opinions because they can be provided water and still meet the Flow Recommendations. To handle the situation in any other manner would be inconsistent and unfair. If non-jeopardy is determined for NIIP, we trust that the appropriate non-jeopardy options will be forthcoming for the others.

The Service must take into account the ramifications of granting the full depletion to NIIP on other water users, since the Flow Recommendations are not fully implemented and future section 7 consultation criteria are not yet defined. Other water users need to be protected. Should participation in the RIP not be required to offset jeopardy, there would be little reason for water users to support funding for capital improvements to benefit the endangered fish.

Sincerely,

SOUTHWESTERN WATER CONSERVATION DISTRICT

Fred V. Kroeger
President

FVK:sps

cc: Board of Directors, Southwestern Water Conservation District
Board of Directors, Animas-La Plata Water Conservancy District
Maynes, Bradford, Shipps & Sheftel, LLP
Steve Harris
Scott McElroy
Stanley Pollack
Dan Israel
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Water Development Steering Committee

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June 28, 1999

Ms. Jennifer Fowler-Propst
Fish & Wildlife Service
New Mexico Ecological Services Field Office
2105 Osuna NE
Albuquerque, NM 87113

RECEIVED
JUN 30 1999
USFWS - NMESO

Re: Endangered Species Act Section 7 Determinations of the United States Fish & Wildlife Service ("Service") Regarding the Navajo Indian Irrigation Project ("NIIP")

Dear Ms. Fowler-Propst:

Enclosed is a courtesy copy of my correspondence to David Hayes regarding the above referenced matter.

Very truly yours,

NORDHAUS, HALTOM, TAYLOR,
TARADASH & FRYE, LLP

Jessica Aberly

Jessica R. Aberly

JRA\slg
Enclosure

D:\user\Jessica\wptext\letters\jf-p6-28.jra
6/7/99

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June 28, 1999

VIA FACSIMILE AND U.S. MAIL

David J. Hayes
Counselor to Secretary Babbitt
Department of the Interior
1849 C Street NW
Washington, DC 20240

Re: Urgent Request for Meeting to Discuss Endangered Species Act Actions Taken by Department Interior Agencies Which Adversely Affect the Jicarilla Apache Tribe

Dear Mr. Hayes:

On behalf of the Jicarilla Apache Tribe, we write to request a meeting or conference call with you before July 14, 1999. We would like to discuss recent actions taken by staff at the United States Fish & Wildlife Service ("FWS") and the Bureau of Indian Affairs ("BIA") which may unnecessarily pit the water rights of the Jicarilla Apache Tribe against those of the Navajo Nation.

As of June 14, 1999, pursuant to section 7 of the Endangered Species Act, the BIA has requested FWS concurrence in a finding that completion of the Navajo Indian Irrigation Project ("NIIP") "may affect" but is "not likely to adversely affect" listed species or critical habitat in the San Juan River Basin. The FWS has thirty (30) days to determine whether it concurs with the BIA's finding; thus, time is of the essence. It appears the BIA made this request after the "point person" at the BIA for NIIP received a copy of correspondence from this law firm to the FWS detailing some of the serious concerns that the Jicarilla Apache Tribe has with the NIIP consultation. Even more remarkable is the fact that the FWS' response to this law firm, written after June 14, 1999, makes no mention that the deadline "clock" had already started ticking, even though the FWS was fully aware that such a strict timeline could effectively negate the FWS' own recommendation that the Tribe "pursue productive discussions" with the water users in the basin to resolve its concerns.[1]

The BIA and the FWS appear to be taking unnecessarily narrow and inflexible views of their Endangered Species Act responsibilities and trust responsibilities, in spite of the commitment of the Department of the Interior "to use its authority to the fullest extent possible to preserve and protect the water resources of the [four] tribes in the [San Juan River] Basin." San Juan River Basin Recovery Implementation Program p. 7, § 1.6 (February 1995)(unpublished document on file with the FWS Region 2 office). No one disputes that the agencies have a trust responsibility to the Navajo Nation to finally fulfill the federal government's promises to that Tribe to complete construction of NIIP. The Jicarilla Apache Tribe recognizes and appreciates that completion of NIIP is decades overdue. However, the federal government can -- and should -- complete NIIP in a manner that does not foreclose the ability of the Jicarilla Apache Tribe to develop its recently-attained settlement water rights. Creative solutions exist which allow <u>all four Tribes</u> within the San Juan River Basin to exercise at least part of their reserved water rights while recovery efforts continue for the endangered Colorado pikeminnow and razorback sucker. Such solutions are in the best interest of all four Tribes and the federal government. It is, however, extremely unlikely that such solutions can be sufficiently developed before July 14, 1999.

The FWS' response-to-date notwithstanding, the FWS could in fact "stop the clock" in accordance with its own policies. Moreover, the BIA, in keeping with its trust responsibility to the Jicarilla Apache Tribe, has sufficient discretion to withdraw its "may affect, not likely to adversely affect" request which set in motion the current collision course. There are creative solutions which allow the federal government to fulfill its trust responsibilities to both the Navajo Nation and the Jicarilla Apache Tribe. There is no good reason, however, for the agencies to force the Jicarilla Apache Tribe to have to assume an adversarial role with its sister Tribes within the San Juan River Basin. We ask for the opportunity to discuss this matter with you as soon as possible. We will be in contact with your scheduler immediately. Thank you.

---

[1] Copies of correspondence between the Nordhaus law firm and the FWS are enclosed for your convenience.

Very truly yours,

NORDHAUS, HALTOM, TAYLOR,
TARADASH & FRYE, LLP

Jessica R. Aberly

JRA\slg

encl:

1. Letter from Jessica Aberly to Jennifer Fowler-Propst dated June 8, 1999.
2. Letter from Jennifer Fowler-Propst dated June 18, 1999.

cc: Honorable Rodger Vicenti, Acting President, Jicarilla Apache Tribe
Honorable Ronald Julian, Jicarilla Apache Tribal Council Member
Honorable Harrison Elote, Jicarilla Apache Tribal Council Member
Honorable Hubert Velarde, Jicarilla Apache Tribal Council Member
Honorable Ty Vicenti, Jicarilla Apache Tribal Council Member
Honorable Stanley Montoya, Jicarilla Apache Tribal Council Member
Honorable Joe Muniz, Jicarilla Apache Tribal Council Member
Honorable Barbara Gonzales, Jicarilla Apache Tribal Council Member
Honorable Stanford Salazar, Jicarilla Apache Tribal Council Member
Honorable Kevin Gover, Assistant Secretary -- Indian Affairs
Solicitor John Leshy
Regional Solicitor Tim Vollmann
Stanley Pollack, Water Rights Counsel, Navajo Nation
Bob Krakow, Bureau of Indian Affairs - Navajo Indian Irrigation Project
Nancy Kaufman, Regional Director, United States Fish & Wildlife Service
Renne Lohoefener, Geographic Manager - New Mexico, United States Fish & Wildlife Service

United States Department of the Interior

FISH AND WILDLIFE SERVICE
New Mexico Ecological Services Field Office
2105 Osuna NE
Albuquerque, New Mexico 87113
Phone: (505) 346-2525 Fax: (505) 346-2542

June 18, 1999

Ms. Jessica Aberly
Nordhaus Haltom Taylor Taradash & Frye
Suite 1050
500 Marquette Avenue NW
Albuquerque, New Mexico 87102

Dear Ms. Aberly:

Thank you for your letter of June 8, 1999, concerning Fish and Wildlife Service (Service) concurrence with any findings rendered by the Bureau of Indian Affairs (Bureau), on behalf of the Navajo Nation's Navajo Indian Irrigation Project (NIIP), of "no effect" or "may affect, not likely to adversely affect" on listed species or designated critical habitat in the San Juan River basin. Your letter requests that the Jicarilla Apache Indian Tribe participate in discussions between the Bureau and the Service during informal consultation, as it would within the process set forth by Secretarial Order 3206 for formal consultation under section 7 of the Endangered Species Act. Your request is based on the assumption that the Bureau may render its finding concerning water depletions necessary for the proposed action through the use of the hydrologic model developed under the auspices of the San Juan River Recovery Implementation Program. The Riverware model was formulated for use by all participants and other entities desiring a determination of whether specific water depletions from the river would still provide for the recommended flows to be delivered to the endangered fish. Although the Jicarilla Apache Tribe voted with the rest of the Coordination Committee to accept the flow recommendations provided for the endangered fish species, that vote did not address acceptance of the modeling process by which the recommendations (and now the determination of available water for development) were generated.

You state in your letter that there has been no opportunity for the Jicarilla Apache Tribe to review the assumptions of the model and determine if these assumptions are acceptable to the Tribe. The process of model formulation and refinement has been the assigned responsibility of the Bureau contractor, as a portion of the funding and other support provided by the Bureau to the Recovery Implementation Program. During this process of constructing the model and running scenarios of water development through the model, the Biology Committee was a participating entity. The Jicarilla Apache Tribe has a representative on the Biology Committee. To my knowledge, no objection to the model or its assumptions has been voiced by any of the members of the Biology Committee, including the Jicarilla Apache Tribal representative. Although I am aware that the Jicarilla Apache Tribe has requested information concerning the model, I am unaware of any other information proffered by either the Jicarilla Apache Tribe or any other entity concerning inaccuracies of the model. For these reasons, I can find no reason to assume that the model and its results are not the best information available at this time and for this consultation.

The Service is constrained to expeditiously respond to requests for compliance with the Endangered Species Act (Act). Should an agency document a finding of "may affect, not likely to adversely affect" and request Service concurrence; that determination is made within 30 days, thus ending informal consultation. Should the Bureau find that the use of water from the San Juan River for completion of NIIP "may affect, but not likely to adversely affect" the listed fish and their critical habitats and provide the information to substantiate that finding, the Service will make every effort to render its concurrence or other finding within the 30-day time frame. We do not make this decision lightly and are fully aware of the trust responsibilities that we have for all Indian tribes in the basin. However, the trust responsibility to the Navajo Nation is equally compelling, thus, the Service will respond to the request we have received within the context of our responsibilities under section 7 of the Act. I understand that this would not provide the opportunity you seek for the Jicarilla Apache Tribe within the context of formal consultation; but formal consultation may not occur for this proposal. Instead, I earnestly recommend that the Jicarilla Apache Tribe pursue productive discussions concerning the allocation of water resources in the basin with the remaining sovereign tribes, including the Navajo Nation, and other water users in the basin. The existing structure of the Recovery Program's Coordination Committee may provide a forum for these discussions; and they would not require the initiation of consultation by any entity.

If I may be of further assistance, please do not hesitate to contact this office at the letterhead address and telephone number.

Sincerely,

Jennifer Fowler-Propst
Field Supervisor

cc:
Honorable Arnold Cassador, President, Jicarilla Apache Tribe
Honorable Rodger Vicenti, Vice President, Jicarilla Apache Tribe
Honorable Ronald Julian, Jicarilla Apache Tribal Council Member
Honorable Harrison Elote, Jicarilla Apache Tribal Council Member
Honorable Hubert Velarde, Jicarilla Apache Tribal Council Member
Honorable Ty Vicenti, Jicarilla Apache Tribal Council Member
Honorable Stanley Montoya, Jicarilla Apache Tribal Council Member
Honorable Joe Muniz, Jicarilla Apache Tribal Council Member
Honorable Barbara Gonzales, Jicarilla Apache Tribal Council Member
Honorable Stanford Salazar, Jicarilla Apache Tribal Council Member

Honorable Kevin Gover, Assistant Secretary, Bureau of Indian Affairs, Washington, D.C.
David Hayes, Counselor to Secretary Babbitt, Department of the Interior, Washington, D.C.
U.S. Department of the Interior, Office of the Regional Solicitor, Albuquerque, New Mexico
Stanley Pollack, Water Rights Counsel, Navajo Nation
Bob Krakow, Bureau of Indian Affairs - Navajo Indian Irrigation Project
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June 8, 1999

Ms. Jennifer Fowler-Propst
Fish & Wildlife Service
New Mexico Ecological Services Field Office
2105 Osuna NE
Albuquerque, NM 87113

Re: Endangered Species Act Section 7 Determinations of the United States Fish & Wildlife Service ("Service") Regarding the Navajo Indian Irrigation Project ("NIIP")

Dear Ms. Fowler-Propst:

The Nordhaus law firm represents the Jicarilla Apache Tribe. On behalf of the Tribe, I am writing to express the concerns of the Tribe regarding NIIP-related Service determinations that are occurring, or may soon occur, in conjunction with the Service's duties to implement Section 7 of the Endangered Species Act of 1973, as amended, 16 U.S.C. § 1536 ("ESA").

It is my understanding that the Bureau of Indian Affairs ("BIA"), on behalf of NIIP, is engaged in informal consultation with the Service regarding the remaining blocks of NIIP. See 50 C.F.R. § 402.13. It is also my understanding that, if the Service determines that the remaining blocks of NIIP do not affect, or "may affect" but are "not likely to adversely affect," listed species or designated critical habitat, then formal consultation under the ESA is not required. See id.; see also U.S. Fish & Wildlife Service and National Marine Fisheries Service, Endangered Species Consultation Handbook, p. xiv, "definition of formal consultation" (March 1998) (unpublished handbook on file with the U.S. Fish & Wildlife Service) ("Consultation Handbook").

As you know, Secretarial Order No. 3206, entitled "American Indian Tribal Rights, Federal-Tribal Trust Responsibilities, and the Endangered Species Act," requires that the Jicarilla Apache Tribe be notified as soon as the Service is aware that a proposed federal agency action which may affect tribal trust resources is subject to formal consultation. Secretarial Order No. 3206, app. at 12, § 3(C) (1997). In addition, pursuant to Secretarial Order 3206, if the Service enters into formal consultation on NIIP, as proposed by the BIA, then the Jicarilla Apache Tribe, as an "affected" tribe, shall be considered to be an applicant entitled to full participation in the consultation process. The Jicarilla Apache Tribe will not be a meaningful participant in the process, however, if the Service determines that the remaining blocks of NIIP need not undergo formal consultation.

While under normal circumstances this result might be acceptable, circumstances are far from normal in the San Juan River Basin. At this point, the San Juan River Recovery Implementation Program ("SJRRIP") has adopted flow recommendations to promote recovery for the endangered Colorado pikeminnow and razorback sucker. However, the SJRRIP participants, including the Jicarilla Apache Tribe, have not agreed on the underlying assumptions used in the river system model to develop the flow recommendations. In fact, there are very few individuals, if any, who understand and can relay all of the assumptions used in the San Juan River Basin version of Riverware that was developed by the SJRRIP. Indeed, preliminary investigation reveals that individuals at the Bureau of Reclamation know some pieces of the puzzle, but that the one entity that knows the most about this very complicated model is the engineering firm that is under contract for the BIA, on behalf of NIIP exclusively. Model documentation is under way, but may not be completed before the Service makes important determinations regarding NIIP's effect on the San Juan River endangered fishes or their critical habitat.

Use of the model (with all of its, as yet, unknown assumptions) to implement the flow recommendations has revealed thus far that only 122,000 afy are available in the river system for additional water development. It is my understanding that the vast majority, if not all, of the available depletions identified in the model would be used for the remaining blocks of NIIP currently being discussed. It is also my understanding that the BIA, on behalf of NIIP, proposes to use the model to demonstrate that the remaining blocks of NIIP may affect, but will not adversely affect, the Colorado pikeminnow and razorback sucker or their critical habitat.

To date, the Service's position has been that, until told otherwise, the Service will assume that the San Juan River version of Riverware represents the "best available scientific and commercial data" for purposes of ESA Section 7 consultations within the San Juan River Basin. This position is taken in spite of the fact that the assumptions made in the San Juan River version of Riverware are in dispute within the SJRRIP. Moreover, such a position is contrary to the Service's own policy. The Service's and the National Marine Fisheries Service's handbook on

ESA Section 7 consultations states that:

> to assure the quality of the biological, ecological, and other information used in the implementation of the Act, it is the policy of the Services to: (1) evaluate all scientific and other information used to ensure that it is reliable, credible, and represents the best scientific and commercial data available . . . .

Consultation Handbook at xi, "best available scientific and commercial data" (emphasis added).

Because the Service is on notice from participants in the SJRRIP, including the Jicarilla Apache Tribe, that use of, and assumptions in, the model are in dispute, and because the vast majority of the SJRRIP participants, including the Jicarilla Apache Tribe, do not yet have access to the full scope of the underlying documentation for the model, the Service must not just take the model at "face value" and use it to make decisions about the NIIP consultation. Instead, pursuant to the Service's policy, the Service must evaluate the model, and its appropriateness for use, in light of concerns raised by SJRRIP participants.

This is especially important given the Service's trust responsibility to the Jicarilla Apache Tribe. As you know, as of April 15, 1999, the Jicarilla Apache Tribe completed all of the requirements of the Jicarilla Apache Tribe Water Rights Settlement Act, Pub. L. No. 102-441, 106 Stat. 2237 (1992). Until April of this year, however, the Tribe was not entitled to deplete its 25,500 afy of "future use" or perpetual contract rights from the San Juan River Basin, which the Tribe received in settlement of various lawsuits that it brought against the United States government. These San Juan River Basin perpetual contract depletions need not necessarily be taken from Navajo Reservoir but could be taken by the Jicarilla Apache Tribe from that portion of the Navajo River which runs through the Jicarilla Apache Indian Reservation. Thus, the Jicarilla Apache Tribe is rather concerned about the Service making determinations regarding NIIP which could foreclose the only meaningful possibility of the Tribe's participation and review of a disputed model, especially since the Service has not independently evaluated the model, and since the use of the model within the context of the proposed action could foreclose the possibility of the Jicarilla Apache Tribe being able to develop its settlement water rights for the foreseeable future. The Service, as trustee for the Jicarilla Apache Tribe, should share these concerns.

Make no mistake: the Jicarilla Apache Tribe recognizes and appreciates that completion of NIIP is decades overdue. The Jicarilla Apache Tribe has no desire to prevent the Navajo Nation from realizing the completion of NIIP. The Jicarilla Apache Tribe merely wishes to ensure that the Service does not take actions which arbitrarily assist one Indian nation in using its water rights at the expense of the water rights of another Indian nation. There is no need to be on this collision course. At a minimum, given the delicate circumstances within the San Juan River Basin, the Jicarilla Apache Tribe respectfully requests that the Service not concur in any finding by the BLA, on behalf of NIIP, of "no affect" or "may affect, but not likely to adversely affect" listed species or designated critical habitat without first allowing the Jicarilla Apache Tribe an opportunity to meaningfully participate in these crucially important discussions.

Very truly yours,

NORDHAUS, HALTOM, TAYLOR,
TARADASH & FRYE, LLP

Jessica R. Aberly

JRA\slg

cc: Honorable Arnold Cassador, President, Jicarilla Apache Tribe
Honorable Rodger Vicenti, Vice President, Jicarilla Apache Tribe
Honorable Ronald Julian, Jicarilla Apache Tribal Council Member
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Joel, See Pages 1593 and 1594 for NO2 + NH3 discussion.

ACUTE TOXICITY OF FIRE-RETARDANT AND FOAM-SUPPRESSANT CHEMICALS TO EARLY LIFE STAGES OF CHINOOK SALMON (*ONCORHYNCHUS TSHAWYTSCHA*)

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U.S. Geological Survey, Biological Resources Division, Environmental and Contaminants Research Center, 31247 436th Avenue, Yankton, South Dakota 57078-6364

(*Received* 11 *April* 1997; *Accepted* 12 *December* 1997)

Abstract—Laboratory studies were conducted to determine the acute toxicity of three fire retardants (Fire-Trol GTS-R, Fire-Trol LCG-R, and Phos-Chek D75-F), and two fire-suppressant foams (Phos-Chek WD-881 and Ansul Silv-Ex) to early life stages of chinook salmon, *Oncorhynchus tshawytscha*, in hard and soft water. Regardless of water type, swim-up fry and juveniles (60 and 90 d posthatch) exhibited similar sensitivities to each chemical and these life stages were more sensitive than eyed eggs. Foam suppressants were more toxic to each life stage than the fire retardants in both water types. The descending rank order of toxicity for these chemicals tested with swim-up fry and juveniles (range of 96-h median lethal concentrations [LC50s]) was Phos-Chek WD-881 (7–13 mg/L) > Ansul Silv-Ex (11–22 mg/L) > Phos-Chek D75-F (218–305 mg/L) > Fire-Trol GTS-R (218–412 mg/L) > Fire-Trol LCG-R (685–1,195 mg/L). Water type had a minor effect on the toxicity of these chemicals. Comparison of acute toxicity values with recommended application concentrations indicates that accidental inputs of these chemicals into stream environments would require substantial dilution (237- to 1,429-fold) to reach concentrations equivalent to their 96-h LC50s.

Keywords—Fire retardants   Fire-suppressant foams   Acute toxicity   Chinook salmon

INTRODUCTION

Millions of liters of fire control chemicals are used each year in the United States to control and suppress range and forest fires. For example, about 127 million liters of ammonia-based fire retardants were applied during fire control operations in the United States in 1996 (C. Johnson, personal communication). These chemicals are often used in environmentally sensitive areas that may contain endangered, threatened, and economically important plant and animal species. Aquatic habitats are subject to inputs of these chemicals via accidental applications to the water surface or spills at field mixing sites. Although most fire-retardant formulations are essentially fertilizer formulations and are thought to have minimal toxicity, fish kills have occurred in streams accidentally contaminated by fire-retardant chemicals [1]. Almost complete mortality of trout was reported in a section of the Little Firehole River following an accidental drop of fire retardant into the River during the 1988 fires in Yellowstone National Park [2]. Aside from these reports, little information is available on the effects of these chemicals on aquatic biota.

There are two general types of fire control chemicals typically used in fire fighting: fire-suppressant foams and long-term fire-retardant chemicals. Fire-suppressant foams contain wetting agents that enhance the extinguishing ability of water by increasing its retention on fuel sources and/or reducing its evaporation. Typically, fire-suppressant foams are composed of a mixture of anionic surfactants, foam stabilizers, inhibiting agents, and solvents [3]. Fire-suppressant foam solutions are applied at concentrations ranging from 0.1 to 1.0% [4,5]. The use of fire-suppressant foams in fire fighting is becoming more prevalent because the amount of water required can be reduced significantly [6]. However, the effectiveness of fire-suppressant foams decreases as water is evaporated from the fuel source.

Long-term fire-retardant formulations are typically composed of ammonium polyphosphate salts with an attapulgite clay thickener or diammonium phosphate or ammonium sulfate with a guar gum-derivative thickener. These formulations also contain corrosion inhibitors and trace amounts of colorants, such as ferric oxide, to mark drop sites. Fire-retardant chemicals form a long-term combustion barrier after the water carrier has evaporated and their effectiveness depends greatly on the amount of salt deposited per unit surface area. Fire retardants change the combustion properties of the fuel so that they char instead of burn, which deprives the fire of fuel [7].

Several studies have reported on the toxicity to fish of ammonium salts [8,9] and anionic surfactants [10–12], which are major constituents of fire control chemicals. However, relatively few studies have investigated the toxicity of the actual fire control formulations to fish and other aquatic biota. Early studies of Blahm and Snyder [13] and Johnson and Sanders [14] determined the acute toxicity of fire-retardant formulations that are no longer in use. Results of their studies showed that these formulations are toxic to salmonids at relatively high concentrations, with 96-h median lethal concentrations [LC50s] ranging from 90 to more than 1,500 mg/L.

Recent investigations have assessed the relative toxicity of five fire control chemicals currently in use to standard species [15–17]. However, there is a lack of published information on the effects of these chemicals on important native salmon species inhabiting surface waters prone to contamination by fire control chemicals in the heavily forested Pacific Northwest. This information is needed so that fire managers and policy developers can make sound decisions regarding the use of these chemicals on private and public lands.

* To whom correspondence may be addressed (kevin_buhl@usgs.gov).

References to trade names, commercial products, or manufacturers do not imply or constitute government endorsement or recommendation for use.

Table 1. Life stages and sizes of chinook salmon tested with fire control chemicals in soft and hard water[a]

Life stage	Age[b]	Weight (g)	Total length (mm)	n
Eyed egg	—	0.193–0.205[c]	—	20
Swim-up fry	29	0.287 (0.186–0.368)	35 (31–38)	40
Juvenile (60 dph)	57	0.805 (0.603–0.962)	50 (45–53)	40
Juvenile (90 dph)	92[d]	2.555 (1.960–3.168)	71 (67–77)	29
	102[e]	2.863 (2.118–3.549)	74 (66–78)	30

[a] Sizes are means (ranges in parentheses) of control fish.
[b] Days posthatch (dph) to test initiation.
[c] Calculated from pooled weight.
[d] Tested in hard water.
[e] Tested in soft water.

The purpose of this study was to determine the acute toxicity of five fire control chemicals currently in use to early life stages of chinook salmon (*Oncorhynchus tshawytscha*). Chinook salmon are an important commercial and recreational species in many streams along the Pacific Coast, where large amounts of fire control chemicals are used. Of the 220 million liters of fire retardants applied from 1977 to 1981 in the United States, about 70% of this amount was used in California, Oregon, and Washington [18]. Chinook salmon accounted for over 69% of the salmon caught along the California coast between 1971 and 1983 [19]. More recently, widespread declines in Pacific salmon (genus *Oncorhynchus*) populations have been identified and many of these populations are believed to be facing a high risk of extinction [20]. Consequently, any reduction in their abundance in this region resulting from the use of fire control chemicals could have significant conservation and socioeconomic consequences.

METHODS AND MATERIALS

Test fish

Fish were obtained as eyed eggs from the Garrison Dam National Fish Hatchery, Riverdale, North Dakota, USA. Upon arrival at our laboratory, all eggs were treated with iodophor Betadine (100 mg/L as iodine) and held in a vertical-flow incubator with aerated well water maintained at 11 ± 1°C. Typical characteristics of the well water used to culture the fish were hardness, 282 to 1,010 mg/L as $CaCO_3$; alkalinity, 194 to 286 mg/L as $CaCO_3$; and pH, 7.6 to 7.8. Alevins and swim-up fry were cultured in a fiberglass trough and the juveniles in a fiberglass circular tank at 13 ± 1°C. Swim-up fry were fed a krill-based diet (BioTrainer®, Bioproducts, Warrenton, OR, USA) supplemented with live nauplii of brine shrimp (*Artemia* sp.), and the juveniles were fed a standard commercial salmon diet (BioDiet®, Bioproducts, Warrenton, OR, USA). The life stages tested were eyed eggs (eggs with a visible eye spot), swim-up fry (fry that had absorbed most of their yolk sac and had begun actively swimming), and two age groups of juveniles that were 60-and 90-d posthatch (dph; Table 1).

Dilution water

Fish were tested in standardized reconstituted hard water and soft water [21]. Dilution water was prepared by adding appropriate amounts of reagent-grade salts ($CaSO_4 \cdot 2H_2O$, $MgSO_4$, $NaHCO_3$, and KCl) to deionized (DI) water in a polyethylene tank. Each tank of dilution water prepared was analyzed following standard procedures [22] to insure that the water quality met American Society for Testing and Materials (ASTM) criteria [21] (Table 2).

Table 2. Characteristics of dilution waters used in acute toxicity tests with fire control chemicals and chinook salmon[a]

Characteristic (unit)	Water type: Soft	Hard
pH	7.4 ± 0.1 (7.3–7.5)	8.2 ± 0.1 (8.1–8.2)
Conductivity (μmhos/cm @ 25°C)	162 ± 4 (159–168)	545 ± 6 (537–552)
Hardness (mg/L as $CaCO_3$)	40 ± 1 (40–41)	162 ± 2 (160–164)
Alkalinity (mg/L as $CaCO_3$)	32 ± 0 (32–32)	111 ± 2 (110–113)
Calcium (mg/L)	7 ± 0 (7–7)	27 ± 0 (27–27)
Magnesium (mg/L)	6 ± 0 (6–6)	23 ± 1 (22–23)
Chloride (mg/L)	<1	4 ± 1 (3–4)
Sulfate (mg/L)	40 ± 1 (38–40)	172 ± 8 (166–184)

[a] Data are means ± SD and ranges in parentheses (n = 4).

Test chemicals

The fire control chemicals were obtained from the U.S. Forest Service, Missoula, Montana, USA. The specific composition of these chemicals is proprietary. A description of the general components in each formulation and the range of concentrations tested are given in Table 3. For simplification, the chemicals are abbreviated as follows: Fire-Trol GTS-R = GTS-R, Fire-Trol LCG-R = LCG-R, Phos-Chek D75-F = D75-F, Phos-Chek WD-881 = WD-881, and Ansul Silv-Ex = Silv-Ex.

Test procedures

Eyed eggs were acclimated to the test water over a 2-d period prior to testing. All other life stages were acclimated to the test temperature and test water over a 2-d period and then held in tempered test water for 2 d before they were tested.

Static test procedures used in this study closely followed those recommended by ASTM [21]. Each test consisted of exposing groups of 10 fish to a geometric series of eight test concentrations and a control treatment for 96 h. Eyed eggs were tested in 3.8-L glass jars containing 3 L of solution and the postembryonic life stages were tested in 19.6-L glass jars containing 15 L of solution. In tests with 90-dph juveniles, groups of five fish were exposed in duplicate treatments to maintain loading densities close to 0.8 g/L, as recommended by ASTM [21]. Temperature was maintained at 12 ± 1°C by immersing the jars in temperature-controlled water baths.

Test solutions of GTS-R, LCG-R, and D75-F were prepared by adding appropriate amounts of the chemical directly to the test vessel and mixing each solution for 3 min with a polyethylene stirrer attached to an electric drill. After all of the solutions were prepared, each treatment was mixed again (as above) for 0.5 min. This mixing was sufficient to bring the test material into suspension. However, some of the inert ingredients (attapulgite clay and guar gum thickeners) settled out of solution within 24 h of exposure.

Phos-Chek WD-881 and Silv-Ex solutions were prepared by pipetting appropriate aliquants of stock solution (prepared

Table 3. Composition of fire control chemicals tested with chinook salmon

Name	Category of fire control	Manufacturer and lot number	Concentrations tested (mg/L)[a]	Ingredients	Reference
Fire-Trol GTS-R	Fire-retardant powder	Chemonics Industries, Inc., 84FT232	60–6,000	Ammonium sulfate, diammonium phosphate, guar gum thickener, spoilage and corrosion inhibitors, and iron oxide.	[48]
Fire-Trol LCG-R	Fire-retardant liquid concentrate	Chemonics Industries, Inc., 91FT11	280–10,000	Ammonium polyphosphate, attapulgite clay thickener, corrosion inhibitor, and iron oxide	[45]
Phos-Chek D75-F	Fire-retardant powder	Monsanto Company, 2468762A	47–3,600	Ammonium sulfate, ammonium phosphate, guar gum thickener, orange coloring agent, and other additives	[42]
Phos-Chek WD-881	Fire-suppressant foam liquid	Monsanto Company, 3616836A	1.3–78	Anionic surfactants, foam stabilizers, and inhibitors dissolved in solvents (hexylene glycol)	[4]
Ansul Silv-Ex	Fire-suppressant foam liquid	Ansul Fire Protection, 75451	2.16–130	Anionic surfactants, stabilizers, inhibitors, and solvents (diethylene glycol monobutylether)	[5]

[a] Highest and lowest concentrations given were not used in all tests.

in DI water) into the test vessel. These solutions were mixed by hand with a Teflon stir rod to prevent excessive foaming.

Observations on mortality and behavioral alterations were made at 24-h intervals and all dead fish were removed after each observation. Criteria for death were whitening of the embryo or yolk in the eggs, absence of a heart beat (under 30× magnification) in swim-up fry, and cessation of opercular movement in juveniles. At the end of each test, control eggs and fish were weighed, and control fish were measured for total length (Table 1).

Dissolved oxygen (YSI model 58 dissolved oxygen meter [Yellow Springs Instrument, Yellow Springs, OH, USA]) and pH (Orion model 250A pH meter and Orion model 9107 pH electrode [Orion Research, Boston, MA, USA]) were measured in the control, low, medium, and high test concentrations (with live eggs or fish) at 0, 48, and 96 h of exposure. Temperature was monitored twice daily in the water baths.

Ammonia, nitrate, and nitrite analysis

Total ammonia (TA) concentrations were measured in 100-ml samples from the control, low, medium, and high test concentrations (with live eggs or fish) at 0, 48, and 96 h of exposure using an Orion model 95-12 ammonia ion-selective electrode connected to a Fisher Accumet model 610 pH meter (Fisher Scientific, Pittsburgh, PA, USA). Un-ionized ammonia (NH_3) concentrations in these treatments were calculated by the ammonia equilibrium equations of Emerson et al. [23] using measured TA and pH values and a temperature of 12°C. A regression equation was derived for each test to estimate the concentrations of TA (as N) and NH_3 (as N) at the 96-h LC50s of each chemical in both water types. The detection limit of the method for TA was 0.08 mg/L.

Nitrate and nitrite analyses were performed on solutions of GTS-R, LCG-R, and D75-F prepared in hard water and soft water as described above, except that no fish were added to the jars. The concentrations of the fire retardants tested bracketed the range of 96-h LC50s obtained for the postembryonic life stages. Nitrate-nitrogen (NO_3-N) and nitrite-nitrogen (NO_2-N) concentrations were measured using ion-selective electrodes (Orion models 93-07 and 9346, respectively) connected to an Orion model 901 ionalyzer and following the procedures for low concentration measurements [24,25]. The detection limits of the methods were 0.1 mg/L NO_3-N and 0.01 mg/L NO_2-N. Recoveries of nitrate in samples spiked at concentrations of 0.5 mg/L NO_3-N were 118% for GTS-R, 120% for LCG-R, and 104% for D75-F. Recoveries of nitrite in samples spiked at concentrations of 0.05 mg/L NO_2-N were 122% for GTS-R, 120% for LCG-R, and 94% for D75-F.

Anionic surfactant analysis

Concentrations of anionic surfactant were measured in solutions of WD-881 and Silv-Ex prepared in hard water and soft water as described above, except that no fish were added to the jars. The concentrations of WD-881 and Silv-Ex tested bracketed the range of 96-h LC50s obtained for all life stages. Anionic surfactant concentrations were determined using the spectrophotometric method of Hach [26] standardized with linear alkylbenzene sulfonate (LAS; molecular weight 342). This method measures alkyl benzene sulfonate and LAS. Concentrations are expressed as mg anionic surfactant/L, calculated as LAS (molecular weight 342). Percent recoveries from single spiked samples were 106% for WD-881 and 109% for Silv-Ex. A regression equation was derived for each chemical and water type to estimate the concentrations of anionic surfactant at the 96-h LC50s of the fire-suppressant foams.

Statistical analysis

The 96-h LC50 values and their 95% confidence intervals (CI) were calculated using the moving-average angle method [27]. In tests where no partial kills occurred, the 95% CI were estimated as follows: the lower limit was the highest concentration with 0% mortality and the upper limit was the lowest concentration with 100% mortality. The criterion of nonoverlapping 95% CI was used to determine significant differences ($p = 0.05$) between LC50 values [22]. All 96-h LC50 values are expressed as nominal concentrations of the fire control chemicals. To determine overall differences in toxicity of the formulations across species, life stage, and water type, the 96-h LC50s were ranked and the rank sums compared by the Friedman test [28]. Regression analyses of the chemistry data were performed using SAS procedures [29].

RESULTS

The initial pH of WD-881 and Silv-Ex solutions were within 0.1 unit of the controls and ranged from 8.0 to 8.3 in hard water and 7.2 to 7.6 in soft water. The addition of the fire-

Table 4. Acute toxicity (mg/L) of five fire control chemicals to early life stages of chinook salmon in soft and hard water at 12°C

Chemical	Water type	96-h LC50[a] (95% confidence interval)[b] Eyed egg	Swim-up fry	Juvenile (60 dph)[c]	Juvenile (90 dph)	Ratio of high to low 96-h LC50[d]
Fire-Trol GTS-R	Soft	>3.600A	385B (312–482)	412B (336–523)	363B (280–470)*	1.1
	Hard	>6.000A	218B (170–280)*	269B (221–347)	218B (170–280)*	1.2
Fire-Trol LCG-R	Soft	>10.000A	1,141B (933–1,445)	1,195B (979–1,532)	1,080B (880–1,353)	1.1
	Hard	>10.000A	1,007B (780–1,300)*	969B (748–1,237)	685B (561–866)	1.5
Phos-Chek D75-F	Soft	>1.700A	218B (170–280)*	305B (212–401)	218B (170–280)*	1.4
	Hard	>3.600A	218B (170–280)*	258B (212–329)	218B (170–280)*	1.2
Phos-Chek WD-881	Soft	47A[e]	13B (10–17)*	13B (10–17)*	13B (10–17)*	1.0
	Hard	29A (21–36)	10B (8–13)	8B (6–10)	7B (6–9)	1.4
Ansul Silv-Ex	Soft	39A (32–49)	22B (17–28)*	22B (17–28)*	16B (13–21)	1.4
	Hard	43A (35–56)	17BC (14–23)	22B (17–28)*	11C (9–14)	2.0

[a] The 96-h LC50s sharing the same uppercase letter in a row are not significantly different ($p = 0.05$).
[b] Asterisks denote tests with no partial kills; 95% confidence interval: lower limit = highest test concentration with 0% mortality, and upper limit = lowest test concentration with 100% mortality.
[c] dph = days posthatch.
[d] Toxicity values for the eyed eggs were excluded.
[e] Fifty percent mortality in highest test concentration.

retardant chemicals changed the pH of the test water. The range of initial pH values in hard water and soft water were 7.6 to 8.1 and 7.3 to 7.6 for GTS-R, 6.9 to 7.3 and 6.7 to 7.0 for LCG-R, and 6.7 to 8.2 and 6.5 to 7.1 for D75-F. Regression analyses of pH values (converted to hydrogen ion concentrations) pooled across life stage revealed a significant correlation between pH and fire-retardant concentration. In hard water, pH was inversely related to D75-F (adj $r^2 = 0.907$, $p < 0.01$) and GTS-R (adj $r^2 = 0.527$, $p < 0.01$). In soft water, pH was inversely related to D75-F (adj $r^2 = 0.776$, $p < 0.01$) and directly related to LCG-R (adj $r^2 = 0.332$, $p = 0.01$) and GTS-R (adj $r^2 = 0.297$, $p = 0.02$).

Average dissolved oxygen (DO) concentrations at 48 and 96 h were, respectively, 86 and 79% saturation for the eggs, 73 and 66% for the swim-up fry, 55 and 46% for the 60-dph juveniles, and 36 and 25% for the 90-dph juveniles. In tests with 90-dph juveniles, fish in treatments with DO concentrations <40% saturation at 96 h did not exhibit any overt signs of stress, such as surfacing, labored respiration, or lethargy.

Formulation toxicity

Regardless of water type, the two fire-suppressant foams (WD-881 and Silv-Ex) were at least an order of magnitude more toxic to a given life stage of chinook salmon than the three fire retardants (GTS-R, LCG-R, and D75-F; Table 4). Fire-Trol LCG-R was the least toxic chemical to the three postembryonic life stages in both water types. The descending rank order of toxicity of the chemicals to postembryonic life stages of chinook salmon in both water types was (> denotes significant difference at $p = 0.05$) WD-881 > Silv-Ex > D75-F > GTS-R > LCG-R.

Life stage and water type

Eyed eggs were the least sensitive life stage to all five chemicals in hard water and soft water (Table 4). Mortalities among the eggs exposed to the three fire retardants (GTS-R, LCG-R, and D75-F) were ≤10%. Consequently, the 96-h LC50s of these chemicals for the eggs are reported as being greater than the highest concentration tested. Differences in sensitivity between the eggs and postembryos were greater for the fire-retardant formulations than for the fire-suppressant foams. Overall, the three postembryonic life stages were equally sensitive to a given chemical within the same water type.

For each chemical tested with a given postembryonic life stage, the 96-h LC50 value obtained in hard water was equal to or lower than that obtained in soft water (Table 4). Three of the chemicals (GTS-R, LCG-R, and WD-881) were more toxic to one life stage of chinook salmon in hard water than in soft water.

Ammonia

Only the 0-h readings for ammonia were used because in tests with the fire retardants and postembryonic life stages, 100% mortality occurred in all of the high concentrations and in most of the medium concentrations within 24 h. Test solutions of the three fire retardants had considerably higher concentrations of TA and NH_3 than those of the two fire-suppressant foams (Table 5). Among the fire-retardant formulations, TA concentrations at the 96-h LC50s were the highest for LCG-R and the lowest for D75-F; whereas NH_3 concentrations at the 96-h LC50s were the highest for GTS-R and the lowest for D75-F. Within each chemical and water type, concentrations of TA and NH_3 at the 96-h LC50s were similar among the postembryonic life stages. The mean (range) percentages of TA in the fire-retardant formulations were 20.7% (18.7–23.0%) in GTS-R, 10.7% (9.6–12.7%) in LCG-R, and 18.0% (14.2–21.2%) in D75-F.

Estimated concentrations of TA at the 96-h LC50 of Silv-Ex for all life stages of chinook salmon ranged from 0.13 to 0.41 mg/L. Concentrations of TA in WD-881 solutions at 0 h

Table 5. Estimated concentrations (mg/L) of total ammonia (TA as N) and un-ionized ammonia (NH_3 as N) at the 96-h LC50 of five fire control chemicals tested with different life stages of chinook salmon in soft and hard water

Chemical	Water type	Eyed egg TA	Eyed egg NH_3	Swim-up fry TA	Swim-up fry NH_3	Juvenile (60 dph)[a] TA	Juvenile (60 dph)[a] NH_3	Juvenile (90 dph) TA	Juvenile (90 dph) NH_3
Fire-Trol GTS-R	Soft	>776	>5.81	79	0.48	92	0.62	75	0.54
	Hard	>1,306	>12.30	43	0.74	56	0.76	44	0.77
Fire-Trol LCG-R	Soft	>1,069	>2.33	116	0.21	132	0.26	133	0.28
	Hard	>987	>1.96	102	0.19	106	0.21	70	0.17
Phos-Chek D75-F	Soft	>321	>0.22	40	0.06	61	0.07	35	0.05
	Hard	>745	>0.71	40	0.14	46	0.16	35	0.17
Phos-Chek WD-881	Soft	<0.08	<0.01	<0.08	<0.01	<0.08	<0.01	<0.08	<0.01
	Hard	<0.08	<0.01	<0.08	<0.01	<0.08	<0.01	<0.08	<0.01
Ansul Silv-Ex	Soft	0.34	<0.01	0.18	<0.01	0.21	<0.01	0.14	<0.01
	Hard	0.41	0.01	0.15	<0.01	0.27	<0.01	0.13	<0.01

[a] dph = days posthatch.

of exposure were below the detection limit of the method (0.08 mg/L).

Nitrate and nitrite

All nitrate and nitrite concentrations in solutions that bracketed the 96-h LC50s of the fire retardants were at or below the detection limit of the method (0.1 mg/L NO_3-N and 0.01 mg/L NO_2-N). Because these findings differed markedly from previous analyses on the same formulations using spectrophotometric methods [26], an additional test was conducted in which solutions of GTS-R, LCG-R, and D75-F were analyzed for nitrate and nitrite by both methods simultaneously. The results of this study showed a large discrepancy in measured nitrate and nitrite concentrations between the two methods (Table 6). The largest differences in measured values between the two methods were for nitrite, where the values differed by two to four orders of magnitude.

Anionic surfactant

Estimated concentrations of anionic surfactant at the 96-h LC50s of WD-881 and Silv-Ex ranged from 1.9 to 11.5 mg/L (Table 7). Based on the analysis of five concentrations of WD-881 and Silv-Ex, the mean and range percentage of anionic surfactant in each chemical were identical, 24.5% and 21.8 to 27.8%, respectively.

DISCUSSION

Life-stage sensitivity

Our findings that eyed eggs were considerably more tolerant then swim-up fry or juveniles is consistent with other studies that tested different life stages of salmonids against fire control chemicals [15], heavy metals [30], and other pollutants [31]. The higher resistance of eyed eggs relative to posthatch stages may be attributed to the chorion, which provides a protective barrier around the egg that restricts the uptake of waterborne contaminants by the embryo [31,32].

The relative sensitivity of swim-up fry and young juveniles to each fire control chemical was similar; differences in sensitivity among the postembryos to each chemical and water type combination were ≤twofold (Table 4). These results indicate that swim-up fry, 60-dph juveniles, or 90-dph juveniles may serve as an appropriate surrogate life stage for assessing the acute toxicity of fire control chemicals to chinook salmon and possibly to other species of Pacific salmon. In static tests with chinook salmon, the use of swim-up fry or 60-dph juveniles instead of 90-dph juveniles would help insure that DO concentrations could be maintained at or above 40% saturation after 96 h.

Ammonia

In order to assess the potential toxic contribution of ammonia in these formulations, it is necessary to consider the

Table 6. Comparison of nitrate and nitrite concentrations measured by potentiometric (Pot)[a] and spectrophotometric (Spec)[b] methods in solutions of three fire-retardant chemicals in hard water

Chemical and concentration	Nitrate (mg/L NO_3-N) Pot	Nitrate Spec	Nitrate Ratio[c]	Nitrite (mg/L NO_2-N) Pot	Nitrite Spec	Nitrite Ratio
Fire-Trol GTS-R, 470 mg/L	<0.1 (118)[d]	0.4 (116)[e]	>4.0	0.01 (122)	42 (91)	4,200
Fire-Trol LCG-R, 1,300 mg/L	0.1 (120)	9.6 (50)	96	0.01 (120)	227 (112)	22,700
Phos-Chek D75-F, 280 mg/L	<0.1 (104)	1.1 (94)	>11	0.01 (94)	9.4 (120)	940

[a] Potentiometric analysis using Orion nitrate and nitrite specific-ion electrodes [24,25].
[b] Spectrophotometric analysis using the Hach method [26].
[c] Ratio of high-to-low concentrations between methods.
[d] Percent recovery for the potentiometric method in samples spiked at the time of collection with nitrate at 0.5 mg/L NO_3-N and nitrite at 0.05 mg/L NO_2-N.
[e] Percent recovery for the spectrophotometric standard additions method of spikes recommended by Hach [26]; mean of three samples spiked at the time of analysis.

Table 7. Estimated concentrations of anionic surfactant (mg/L)[a] at the 96-h LC50 of two fire-suppressant foams tested with different life stages of chinook salmon in soft and hard water

Chemical	Water type	Eyed egg	Swim-up fry	Juvenile (60 dph)[b]	Juvenile (90 dph)
Phos-Chek WD-881	Soft	11.5	3.3	3.3	3.3
	Hard	6.8	2.6	2.1	1.9
Ansul Silv-Ex	Soft	9.5	5.5	5.5	4.1
	Hard	9.8	3.9	5.1	2.6

[a] Calculated as linear alkylbenzene sulfonate, molecular weight 342.
[b] dph = days posthatch.

effect of pH on the speciation and relative toxicity of ammonia. In aqueous solution, the dissociation of TA into ionized ammonia (NH_4^+) and NH_3 is dependent on pH and temperature and to a lesser extent on dissolved solids [23]. The toxicity of ammonia, expressed as TA, increases with increasing pH due to an increase in the relative concentration of NH_3, which is considerably more toxic than NH_4^+ [33]. However, there is evidence that the toxicity of NH_3 increases with decreasing pH [9,34]. Thurston et al. [34] studied the effect of pH on ammonia toxicity to juvenile rainbow trout (9.5 g, *Onchorhynchus mykiss*) in hard water (hardness, 200 mg/L as $CaCO_3$) and reported that the 96-h LC50s expressed as NH_3 decreased and those expressed as TA increased with decreasing pH in the range of 6.5 to 8.3.

Based on the above findings, comparisons of NH_3 concentrations at the 96-h LC50s of the fire retardants with published toxicity values of ammonia (as N) is confounded by differences in pH. Consequently, comparisons should be limited to tests conducted at similar pH values. Due to the lack of mortality in the eggs, the following comparisons are limited to the postembryonic life stages. Geometric mean (GM) concentrations of NH_3 at the 96-h LC50 of GTS-R tested in soft water at pH 7.4 to 7.6 (0.54 mg/L) and hard water at pH 7.7 to 8.1 (0.76 mg/L) are slightly higher than reported 96-h LC50s of NH_3 obtained at similar pH values (0.37 mg/L at pH 7.3 and 0.51–0.59 mg/L at pH 7.8–7.9) in tests with rainbow trout [34]. Geometric mean concentrations of NH_3 at the 96-h LC50s of LCG-R in soft water (0.25 mg/L) and hard water (0.19 mg/L) at a pH range 6.8 to 7.3 fall between reported NH_3 96-h LC50s of 0.15 mg/L at pH 6.8 and 0.37 mg/L at pH 7.3 in tests with rainbow trout [34]. The similarity between NH_3 concentrations at the 96-h LC50s of GTS-R and LCG-R and those reported to be acutely toxic to rainbow trout at similar pH values indicates that ammonia, expressed as NH_3, was the primary toxic component in these formulations.

Comparisons of ammonia concentrations at the 96-h LC50s of D75-F with those reported to be acutely toxic to salmonids are more difficult because of the inverse relation between pH and D75-F concentration (adj r^2, 0.776 in soft water and 0.907 in hard water). For comparisons with published acute toxicity values of ammonia, the pH at each 96-h LC50 of D75-F was estimated from linear regression equations relating pH (converted to hydrogen ion concentration) to D75-F concentration. Based on these regressions, estimated pH values at the 96-h LC50s of D75-F were 6.9 to 7.0 in soft water and 7.3 to 7.4 in hard water. The GM concentrations of NH_3 at the 96-h LC50s of D75-F in soft water (0.06 mg/L, pH 6.9–7.0) and hard water (0.16 mg/L, pH 7.3–7.4) are about 0.4 times lower than reported 96-h LC50s of NH_3 for rainbow trout tested at similar pH values (0.15 mg/L at 6.8 and 0.37 mg/L at 7.3) [34]. Moreover, GM concentrations of TA at the 96-h LC50s of D75-F (44 mg/L in soft water at pH 6.9–7.0 and 40 mg/L in hard water at pH 7.3–7.4) are also about 0.4 to 0.5 times lower than reported TA 96-h LC50s of 100 mg/L at pH 6.8 and 73 mg/L at pH 7.3 in tests with rainbow trout [34]. These results indicate that although ammonia is a major toxic component in D75-F, other components in the formulation may have had a significant influence on the toxicity of D75-F to chinook salmon.

Nitrate and nitrite

It is well established that nitrite is considerably more toxic to fish than nitrate [35]. Measured nitrite concentrations in solutions that bracketed the 96-h LC50s of the three fire retardants for swim-up fry and juveniles (≤0.01 mg/L NO_2-N) are at least an order of magnitude lower than reported 96-h LC50s of 0.19 to 0.28 mg/L NO_2-N for juvenile rainbow trout [36] and 0.88 mg/L NO_2-N for juvenile chinook salmon [37]. Similarly, measured nitrate concentrations in solutions of GTS-R, LCG-R, and D75-F (≤0.1 mg/L NO_3-N) are at least four orders of magnitude lower than reported 96-h LC50s of 1,310 mg/L NO_3-N for juvenile chinook salmon and 1,355 mg/L NO_3-N for juvenile rainbow trout tested in reconstituted water [37]. These findings strongly indicate that nitrate and nitrite were present at such low concentrations that they did not significantly influence the toxicity of the fire retardants.

Concentrations of nitrate and nitrite in solutions that bracketed the 96-h LC50s of GTS-R, LCG-R, and D75-F and that we measured by potentiometric methods (≤0.1 mg/L NO_3-N and ≤0.01 mg/L NO_2-N) are considerably lower than those reported in earlier studies with the same chemicals [15–17] that analyzed for nitrate and nitrite using spectrophotometric methods of Hach [26]. The nitrate and nitrite concentrations they reported at the acutely toxic concentrations of these fire retardants to *Daphnia magna* and postembryonic life stages of fathead minnow (*Pimephales promelas*) and rainbow trout are at least 1 to 72 and 13 to 8,400 times higher, respectively, than those obtained in our study. Although standard additions methods were used as an accuracy check for the Hach method [26], we believe that the nitrate and nitrite values for the three fire retardants determined by the Hach method are in error due to matrix interferences. The three fire-retardant formulations contain a coloring agent (iron oxide in GTS-R and LCG-R and orange coloring agent in D75-F, Table 3) and when added to the dilution water, the solution became colored and the intensity of the color was related to the concentration of the coloring agent. Test solutions of GTS-R and LCG-R were red and those of D75-F were orange. The coloring agents in these formulations may have caused the high results in the Hach method. Ferric iron will interfere with the Hach method for nitrate [26] and may also interfere with the nitrite method (R. Kimble, personal communication). Moreover, the color of the reaction products of the Hach procedures (which was measured spectrophotometrically) may have been affected by the color of the fire-retardant solutions (R. Kimble, personal communication). Conversely, iron is not listed as an interference in the potentiometric methods for nitrate or nitrite, and commercially prepared interference suppressor solutions were used in both analyses [24,25]. Furthermore, sample color and turbidity do not affect the measurements of ion-selective electrodes [38].

Surfactants

The toxicity of the foam suppressants, WD-881 and Silv-Ex, may be partly due to the anionic surfactant portion of their

Table 8. Comparison of the lowest reported acute toxicity values (mg/L) of five fire control chemicals for three fishes (postembryonic life stages, 96-h LC50s), *Daphnia magna* (48-h EC50s), and *Hyalella azteca* (96-h LC50s) in soft and hard water[a]

Chemical	Water type	Chinook salmon[b]	Rainbow trout[c]	Fathead minnow[d]	*Daphnia magna*[e]	*Hyalella azteca*[f]
Fire-Trol GTS-R	Soft	363	363 (1.00)	233 (1.56)	257 (1.41)	127 (2.86)
	Hard	218	207 (1.05)	135 (1.61)	339 (1.56)	363 (1.67)
Fire-Trol LCG-R	Soft	1,080	910 (1.19)	1,080 (1.00)	848 (1.27)	73 (14.79)
	Hard	685	872 (1.27)	519 (1.32)	813 (1.19)	535 (1.28)
Phos-Chek D75-F	Soft	218	218 (1.00)	420 (1.93)	140 (1.56)	53 (4.11)
	Hard	218	218 (1.00)	168 (1.30)	280 (1.28)	394 (1.81)
Phos-Chek WD-881	Soft	13	13 (1.00)	14 (1.08)	11 (1.18)	10 (1.30)
	Hard	7	11 (1.57)	13 (1.86)	4 (1.75)	22 (3.14)
Ansul Silv-Ex	Soft	16	20 (1.25)	20 (1.25)	7 (2.29)	24 (1.50)
	Hard	11	13 (1.18)	19 (1.73)	7 (1.57)	27 (2.45)
Geometric mean of high-to-low ratios			1.14	1.43	1.48	2.51
Range of high-to-low ratios			1.00–1.57	1.00–1.93	1.18–2.29	1.28–14.79

[a] Values in parentheses are the high-to-low ratios of the species' toxicity value to that of chinook salmon.
[b] This study.
[c] Gaikowski et al. [15].
[d] Gaikowski et al. [16].
[e] McDonald et al. [17].
[f] McDonald et al. [49].

formulation. Estimated concentrations of anionic surfactant at the 96-h LC50s of WD-881 (1.9–3.3 mg/L) and Silv-Ex (2.6–5.5 mg/L) for swim-up fry and juveniles are comparable to toxicity values reported by other investigators for anionic surfactants. McKim et al. [11] tested four freshwater fishes with LAS (alkyl chain length not reported) and obtained 96-h LC50s of 3.4 to 4.0 mg/L, which are similar to our estimated concentrations of anionic surfactant at the 96-h LC50s of the foams. Holman and Macek [12] exposed 2- to 3-month old fathead minnow to three LAS surfactants with different mean alkyl chain lengths in soft water (hardness, 40 mg/L as $CaCO_3$) and found that toxicity increased with increasing alkyl chain length. The range of 96-h LC50s they obtained for LAS with a mean chain length of 11 to 13 carbon units (0.86–12.3 mg/L) encompasses the range of estimated anionic surfactant concentrations at the 96-h LC50s of WD-881 and Silv-Ex for all life stages of chinook salmon (1.9–11.5 mg/L). Although the exact anionic surfactants used to formulate WD-881 and Silv-Ex are not known, estimated concentrations of anionic surfactant at the 96-h LC50s of both foams tested with postembryonic life stages of chinook salmon in soft water (3.3–5.5 mg/L) fall within the 95% CI (2.9–5.5 mg/L) of the 96-h LC50 for $C_{11.7}$ LAS (4.1 mg/L) reported by Holman and Macek [12] for juvenile fathead minnow in soft water.

Water hardness had a minor influence on the toxicity of the two foams to chinook salmon. Although WD-881 and Silv-Ex were generally more toxic in hard water than in soft water, differences in 96-h LC50s between water types were ≤1.9-fold (Table 4). These results are consistent with the findings of Hokanson and Smith [39] who reported that lethal threshold concentrations of LAS (chain length of 10–13 carbon units) to bluegill (*Lepomis macrochirus*) were significantly higher in soft water (hardness, 15 mg/L as $CaCO_3$) than in hard water (hardness, 290 mg/L as $CaCO_3$), but differences in their lethal threshold concentrations were ≤1.6-fold. McKim et al. [11] also reported that hardness had a minimal influence on LAS toxicity to fish.

Intralaboratory comparisons

It is recognized that comparisons of toxicity values obtained in this study with those reported in the literature for a given chemical are somewhat limited because of differences in test conditions, species and life stage tested, and the response measured. Fortunately, several studies that have examined the acute toxicity of these chemicals were conducted in our laboratory using very similar experimental conditions. A comparison of our results with acute toxicity values reported for other fishes and invertebrates tested in our laboratory is given in Table 8. The lowest 96-h LC50 reported for each fish species was used in the comparisons to account for sensitivity differences among life stages. For the invertebrates, the single 48-h EC50 or 96-h LC50 value was considered as the lowest toxicity value for that species. The ratio of the high-to-low toxicity value for each species to that of chinook salmon was used as a measure of the sensitivity differences between chinook salmon and the other species.

Comparison of toxicity values given in Table 8 clearly shows that the relative sensitivity of chinook salmon to the five fire control chemicals is similar to that of the three standard test animals: rainbow trout, fathead minnow, and *D. magna*. For each chemical and water type, sensitivity differences between chinook salmon and rainbow trout, fathead minnow, or *D. magna* are ≤1.9-fold, except for *D. magna* tested with Silv-Ex in soft water. The GM difference in sensitivity between the two salmonids (1.1-fold) is smaller than that between chinook salmon and fathead minnow (1.4-fold) or *D. magna* (1.5-fold). These interspecific sensitivity differences between chinook salmon and the standard test species are within the expected intralaboratory variation in LC50s of twofold for repeated acute toxicity tests with the same species–toxicant combination [40]. These results indicate that (within the limits of intraspecific variation) the two standard fish species and *D. magna* are appropriate surrogates of the relative sensitivity of chinook salmon to these fire control chemicals.

In contrast to the comparisons with standard species, chinook salmon are about 3 to 15 times more tolerant to the three fire retardants in soft water and about two to three times more sensitive to the fire-suppressant foams in hard water compared to *Hyalella azteca* (Table 8). Of the species compared, *H. azteca* showed the largest variation in sensitivity to these chemicals between water types. For four of the five chemicals,

Table 9. Acute toxicity values (mg/L) for five fire control chemicals reported by manufacturers or their contract laboratories[a]

Chemical	Species	Weight (g)	Water type[b]	96-h LC50	Reference
Fire-Trol GTS-R	Rainbow trout	NR[c]	NR	1,000	[48]
	Rainbow trout	0.5	Soft	899	[d]
	Chinook salmon	0.3–2.9	Soft	386	This study
	Chinook salmon	0.3–2.6	Hard	234	This study
Fire-Trol LCG-R	Rainbow trout	NR	NR	790	[45]
	Chinook salmon	0.3–2.9	Soft	1,138	This study
	Chinook salmon	0.3–2.6	Hard	874	This study
Phos-Chek D75-R	Rainbow trout	0.4	Soft	>1,000	[41]
D75-F	Chinook salmon	0.3–2.9	Soft	244	This study
D75-F	Chinook salmon	0.3–2.6	Hard	231	This study
Phos-Chek WD-881	Rainbow trout	0.6	Soft	22	[50]
	Chinook salmon	0.3–2.9	Soft	13	This study
	Chinook salmon	0.3–2.6	Hard	8	This study
Ansul Silv-Ex	Rainbow trout	0.4	Soft	25	[51]
	Chinook salmon	0.3–2.9	Soft	20	This study
	Chinook salmon	0.3–2.6	Hard	16	This study

[a] Geometric mean 96-h LC50 values from this study are included for comparison.
[b] Water type: soft = hardness, 40 to 45 mg/L as $CaCO_3$; hard = hardness, 160 to 164 mg/L as $CaCO_3$.
[c] NR = not reported.
[d] C. Chang, personal communication.

H. azteca had the lowest toxicity value in soft water and the highest toxicity value in hard water.

Interlaboratory comparisons

Outside of the studies conducted in our laboratory, the only acute toxicity information found for these formulations was that reported by the manufacturer or their contract laboratory. Toxicity data from studies that did not present sufficient information on the test conditions to make a judgement as to the validity of the results were not included in this comparison. Comparative toxicity data for rainbow trout are available for four of the five formulations (Table 9). No toxicity data were found for D75-F, but information is available for a similar formulation: Phos-Chek D75-R (D75-R). The GM 96-h LC50s we obtained for chinook salmon (excluding the eggs) and GTS-R, LCG-R, WD-881, and Silv-Ex are within a factor of four of the 96-h LC50s reported for rainbow trout. These differences in toxicity values are within the expected interlaboratory variation in LC50s of fourfold for a given species–toxicant combination tested under similar conditions [40].

Monsanto's contract laboratory reported a 96-h LC50 of >1,000 mg/L for the formulation D75-R and 0.4-g rainbow trout [41], which is at least four times higher than our GM 96-h LC50s of 244 mg/L in soft water and 231 mg/L in hard water for D75-F and chinook salmon. Differences in toxicity between the two D75 formulations may be related to the colorant; D75-F contains a fugitive color pigment and D75-R contains iron oxide [42].

Relation to environmental considerations

Accidental inputs of fire control chemicals into streams during fire control operations have occurred, but documentation of fish kills directly attributable to a misapplication is fragmentary. Even though the fire retardants have a relatively low order of acute toxicity to fish (96-h LC50s >100 mg/L, Table 4), exposure concentrations in streams may approach or exceed toxic concentrations for a short period immediately following a direct application to a stream. Using simulation models of fire-retardant drops on mountain streams during aerial application operations, Norris and Webb [43] concluded that fish mortality could occur as far as 10,000 m below the drop site, depending on application patterns and characteristics of the stream. A recent fish kill in Oregon on September 16 to 17, 1995, was caused when an airtanker dropped a partial load of Fire-Trol LCG-F (LCG-F) on a section of Murderers Creek in the South Fork John Day River, Oregon, USA (T. Unterwegner, personal communication). The retardant killed about 23,000 fish along 2,700 m of stream, including an estimated 718 rainbow/steelhead trout. They attributed the fish kill to ammonia toxicity derived from the retardant. Murderers Creek is the most significant steelhead trout production stream in the South Fork John Day River sub-basin, and the fish losses were considered biologically significant.

Although the wild fires themselves are likely to have a substantial impact on native fauna in streams located in the fire perimeter, this study is limited to addressing the potential direct effects of fire control chemicals on native salmonids. This information may be used by fire managers in planning fire control operations in areas containing trout or salmon production streams and in assessing the potential damage to native salmonid populations in streams accidentally treated with these fire control chemicals.

To assess the potential impacts of these chemicals on salmonids, toxicity data must be related to expected or measured environmental concentrations. Due to the lack of data on measured concentrations of these chemicals in aquatic systems, toxicity values were compared to their field application concentrations in tank mixtures (Table 10). The ratio of the field tank mixture concentration to its 96-h LC50 value indicates the amount of dilution needed to reach a concentration that is lethal to 50% of the fish. For example, an accidental drop of a field tank mixture of D75-F in an aquatic environment would have to be diluted 660-fold to approach a concentration lethal to 50% of the chinook salmon. The U.S. Environmental Protection Agency [44] presumes that a pesticide does not pose an acute risk to fish if its environmental concentration is less than 1/10 of its 96-h LC50 value for fish. Applying a factor of 10 to these ratios indicates that a field tank mixture of LCG-R requires the lowest dilution in soft water (2,370-fold) and a field tank mixture of WD-881 requires the highest dilution in hard water (14,290-fold) to reach concentrations that do not pose an acute hazard to chinook salmon.

Table 10. Concentrations of five fire control chemicals used in field tank mixtures and the ratio of the mixture concentration to its acute toxicity value

Chemical	Field tank mixture Unit[a]	(mg/L)	Water type	Ratio: field tank mixture/ 96-h LC50[b]
Fire-Trol GTS-R	1.66 lb/gal	198,930	Soft	548
			Hard	913
Fire-Trol LCG-R	1 gal:4.75 gal	256,350	Soft	237
			Hard	374
Phos-Chek D75-F	1.20 lb/gal	143,810	Soft	660
			Hard	660
Phos-Chek WD-881	1%	10,000	Soft	769
			Hard	1,429
Ansul Silv-Ex	1%	10,000	Soft	625
			Hard	909

[a] Weight or volume of chemical concentrate combined with water to produce a recommended field tank mixture (C. Johnson, personal communication).
[b] The 96-h LC50 for the most sensitive life stage of chinook salmon.

It is difficult to estimate the amount of dilution and initial peak concentration of a fire control chemical in a stream following an accidental aerial application because of the uniqueness of each event. The peak concentration of a fire control chemical that has been applied directly to the stream surface is dependent on several site-specific characteristics of the stream (channel morphology, water discharge, and vegetation canopy) and event-specific characteristics of the application (orientation of flight line, size of load dropped, and weather conditions) [43]. Due to the lack of measured concentrations of these chemicals or their major components, we calculated the potential peak concentration of a fire retardant in a river where one of its tributaries received a direct application of the chemical and a fish kill occurred. The calculations are based on field data from the drop site and several assumptions about the application. The calculated peak concentration was then compared to acute toxicity data for a similar fire-retardant formulation to estimate its hazard potential to salmonids. This approach provides a crude estimate of the amount of dilution that may occur in a stream following a direct application of a fire control chemical to the stream.

During a fire control operation in the South Fork John Day River sub-basin, a fish kill occurred in the South Fork John Day River after an airtanker dropped a partial load of LCG-F on one of its tributaries, Murderers Creek. The section of Murderers Creek receiving a direct application of LCG-F was 55 m long and 4.6 m wide with a mean depth of 0.2 m (T. Unterwegner, personal communication). If the recommended tank mixture concentration of 256,350 mg/L and deposition rate of 4 L/m^2 (C. Johnson, personal communication) were used, 1,012 L (2.594262 × 10^8 mg) of LCG-F was applied to the stream surface. Assuming that vertical mixing was instantaneous, the estimated peak concentration of LCG-F in this section of Murderers Creek (estimated volume, 51,612 L) was 5,026 mg/L. The accidental drop occurred about 100 m upstream from the confluence of Murderers Creek with the South Fork John Day River. Based on water discharge values of 85 L/s in Murderers Creek and 566 L/s in the South Fork John Day River below the confluence with Murderers Creek (T. Unterwegner, personal communication), and assuming instantaneous mixing, the estimated peak concentration of LCG-F that may have occurred in the South Fork John Day River below the confluence with Murderers Creek was 755 mg/L. The estimated dilution factor for LCG-F in this example is only 340-fold, which is similar to the dilution factors for LCG-R but smaller than those for GTS-R, D75-F, WD-881, and Silv-Ex that are required to dilute a field tank mixture of these chemicals to concentrations acutely lethal to chinook salmon (Table 10).

The estimated LCG-F concentration of 755 mg/L in the South Fork John Day River falls in the range of acutely toxic concentrations of LCG-R obtained for juvenile life stages of chinook salmon in this study (96-h LC50s, 685–1,195 mg/L). These two Fire-Trol chemicals are believed to be similar in toxicity to fish because Chemonics Industries [45] only reports a single 96-h LC50 of 790 mg/L for their Fire-Trol liquid concentrates and rainbow trout. The fish kill occurred along a 2,700-m reach of the South Fork John Day River starting just below the mouth of Murderers Creek. These results indicate that direct application of fire control chemicals to streams during fire control operations may produce toxic concentrations of these chemicals to salmonids (and other organisms with similar or greater sensitivities) along a given section of a stream.

In addition to assessing the acute hazard of these chemicals, consideration should be given to their potential sublethal effects on native salmonids because many populations of Pacific salmon are in decline and one of these populations (Sacramento River, CA, USA, winter chinook salmon) is federally listed as endangered [20]. The limited data available on the persistence of these chemicals in streams following an accidental application indicates that the foam suppressants are more persistent than the fire retardants. Norris and Webb [43] reported that most of the ammonia in a stream derived from a fire-retardant application was transformed into nitrate and soluble organic nitrogen after 24 h. Consequently, an accidental drop of ammonia-based fire retardants on a stream does not seem to pose a chronic hazard to native salmonids. Norecol [3] reported biodegradation rates of 42% in 20 d for a 1% solution of Silv-Ex and 80% in 21 d for WD-881 concentrate. Based on these values, 20 to 58% of these chemicals may be present 20 d after an accidental drop and pose a chronic hazard to native salmonids.

Considering that few data are available on the sublethal effects of foam suppressants coupled with the high value of Pacific salmon, a conservative approach for estimating safe concentrations of these chemicals to salmonids seems to be warranted. One conservative approach to estimating safe concentrations of chemicals is to apply a safety factor to the acute toxicity data. A safety factor is the inverse of an application factor, which is the ratio of the maximum acceptable toxicant concentration (MATC) derived from chronic tests to its acute toxicity value [46]. Using the toxicity data given in Larson and Woltering [47] for C_{12} LAS, calculated safety factors for LAS and freshwater fishes range from 1 to 25. Assuming that the biological activity of C_{12} LAS is similar to that of the anionic surfactants in Silv-Ex and WD-881 and considering the high value of native salmonid populations, a conservative safety factor of 25 for these foam suppressants could be used. Applying a safety factor of 25 to the foam suppressants indicates that field tank mixtures of Silv-Ex and WD-881 require dilutions of about 16,000- to 36,000-fold to approach safe concentrations.

SUMMARY

Eyed eggs were the least sensitive and swim-up fry and juveniles were the most sensitive life stages tested with five fire control chemicals. In general, the rank order of toxicity (from most toxic to least toxic) was WD-881 > Silv-Ex > D75-F > GTS-R > LCG-R. The two foam suppressants (WD-881 and Silv-Ex) were substantially more toxic than the three fire retardants (D75-F, GTS-R, and LCG-R). The major toxic component in GTS-R and LCG-R was probably NH_3, whereas in the foam suppressants it was probably anionic surfactants. The toxicity of D75-F was probably due to an interaction between NH_3 and other ingredients in the formulation.

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June 21, 1999

Mr. Ron Bliesner
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Logan, UT 84321

RE: Concerns regarding misinterpretation of data in Draft Progress Report of Buhl and Hamilton (1998).

Dear Ron:

I would like to point out an erroneous interpretation of our preliminary test results from the chronic dietary and waterborne selenium study with adult Colorado pikeminnow. I received a copy of your April 30, 1999 letter to Jennifer Fowler-Propst regarding the NIIP Biological Assessment because Joel Lusk wanted me or Steve Hamilton to respond to your concerns about the high nitrite values given in the Ouray Final Report (Hamilton et al. 1996). You are to be complimented for making this observation on the nitrite (and nitrate) data. I reviewed the raw data for the nitrite and nitrate assays from this study and have enclosed a copy of my response to Joel about this concern. Basically, I concluded that the nitrite and nitrate values given in the report are erroneously high and invalid due to matrix interferences with the chemical procedures used.

On page 4 of your letter, in referring to the study of Hamilton and Buhl (1998), it was stated that the study "demonstrated no effect at feed concentrations of 11.8 ppm and water at 7.9 μg/L" and "There was no difference between control conditions and the highest concentration conditions in terms of spawning success, hatching success or growth of larval fish." These statements are incorrect because no statistical comparisons of the reproductive data (i.e., number of females spawned, hatchability, and growth and survival of progeny) could be made due to the poor spawning success of females across treatments. On page 18 of the draft progress report (Buhl and Hamilton 1998, emailed to you on December 4, 1998), it states that

"Because there were no replicate spawns for half of the treatments, the reproduction data for the adults and subsequent biological data for the resulting progeny were not amenable to any meaningful statistical comparisons. Consequently, no conclusions can be drawn about the effects of dietary and waterborne selenium exposures tested in this study on reproduction of Colorado squawfish." It is quite clear from these statements and the data that the results for reproductive endpoints are inconclusive. Moreover, because the effects on reproduction cannot be compared or linked to selenium concentrations in the diet, water, or tissues, no selenium threshold concentration for reproductive impairment was determined in this study.

The letter to Fowler-Propst should have mentioned that only one of six females in the control, lowest, and highest selenium treatments spawned and that only 28% of all females spawned in this study. It is important to inform the reader about the lack of replicate spawns in the control and two selenium treatments (lowest and highest), so they can see why we stated that the data for reproductive effects in Colorado pikeminnow were inconclusive.

Moreover, by not realizing the lack of statistical amenability of the reproductive data (i.e., $n = 1$ for three of six treatments), one could also erroneously conclude that selenium concentrations as low as 2.18 μg/g (dry weight) in the diet and 0.15 μg/L in water adversely affected reproduction because only 16% of females exposed to these concentrations spawned. Thus the selenium threshold concentration in food chain organisms to Colorado pikeminnow could be interpreted as being lower than 2.18 μg/g (dry weight). Moreover, if the toxic threshold concentration for selenium was exceeded in the control fish, it is reasonable to assume that one would not observe a concentration-response relation at the higher exposure concentrations.

The preceding paragraph illustrates the danger of taking data out of context or not presenting it in its entirety. Obviously, we hoped that this study would have yielded better results in terms of more females spawning so that the appropriate statistical comparisons and inferences drawn from them could have been made. However, reproduction studies are risky ventures and many times produce either highly variable or inclusive results.

I hope this letter clarifies any misinterpretation of the data from this study. If you have any questions or comments, please let me know.

Sincerely,

Kevin J. Buhl
Fishery Biologist

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Enclosure as stated.

cc: Steve Hamilton
Joel Lusk

Joel

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JUN 21 1999
USFWS - NMESO

June 16, 1999

To Parties who have received the following report.

Re. Hamilton et al. 1996. Evaluation of toxicity to larval razorback sucker of selenium-laden food organisms from Ouray NWR on the Green River, Utah. Final report to the U.S. Fish and Wildlife Service, Colorado River Recovery Implementation Program (RIP).

On June 4, 1999, I was called by Mr. Joel Lusk, U.S. Fish and Wildlife Service (FWS), Albuquerque, NM, about nitrite and nitrate concentrations given in the above report. He was responding to a written communication received by the FWS office from Mr. Ron Bliesner. The concern was raised that nitrite concentrations in water may have caused the toxicity in the Ouray study. I asked Mr. Kevin Buhl, who I consider very knowledgeable about water quality methods, to review the original data sheets and report on the validity of the analytical methods used in the nitrite and nitrate measurements, and comment on the accuracy of the data. Attached is Kevin Buhl's response, which was written to Joel Lusk.

The conclusion of Kevin's evaluation of the methods and data are that the concentrations of nitrite and nitrate given in the above report are erroneous and invalid due to problems with the methods employed in the analysis. Therefore, his memo is being distributed to all parties who received the original report. We could find no information to indicate that nitrite and nitrate concentrations in the Ouray NWR, UT, area have been considered a problem in the past and presently. Mr. Bliesner correctly pointed out in his written communication that (1) the nitrate/nitrite ratio in the above report conflicted with those reported for other natural aquatic ecosystems, and (2) the nitrite values appeared to be too high for an oxygenated aquatic ecosystem.

I regret any confusion that the erroneous data for nitrite and nitrate concentrations may have caused. Unfortunately, reviews by six people prior to submission of the draft report to the RIP Biology Committee, and review comments from seven Biology Committee members after submission, did not mention concerns about the nitrite and nitrate data at the time the draft report was reviewed, which would have allowed me to address this concern at an earlier time.

Steven J. Hamilton

Steven J. Hamilton, PhD
Leader, Yankton Ecotoxicology Research Station

Attachment

USGS
science for a changing world

United States Department of the Interior
U.S. Geological Survey
Biological Resources Division

Columbia Environmental Research Center
Ecotoxicology Research Station
31247 436th Avenue
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June 16, 1998

Joel Lusk
Division of Environmental Contaminants
U.S. Fish and Wildlife Service
2105 Osuna Road, NE
Albuquerque, NM 87113

Re: Erroneous nitrite and nitrate values in Hamilton et al. (1996) Final Report

Dear Joel:

Thanks for bringing the concern about the high nitrite values in Hamilton et al. (1996) to my attention. In revisiting the water quality data given in Hamilton et al. (1996), I do agree that the nitrite values reported for site waters at Ouray NWR, Utah, in 1994 are high and overlap the acutely toxic concentrations of nitrite reported for fathead minnow (2.3-3.0 mg/L as N; Russo and Thurston 1977). However, the nitrite and nitrate concentrations given in the report are expressed as mg/L NO_2 and NO_3, which are 3.33 and 4.40 times higher than those expressed as mg/L NO_2-N and NO_3-N, respectively. To facilitate comparisons of nitrite and nitrate concentrations, they are expressed as mg/L NO_2-N and NO_3-N in this letter. Upon further review of the raw data, I strongly believe that the nitrite and nitrate concentrations given in the report are erroneously high due to unexpected matrix interferences with the analytical methods used (discussed below), and thus are probably inaccurate and should be omitted from the report.

Nitrite was measured by the colorimetric ferrous sulfate method and nitrate by the colorimetric cadmium reduction method using a Hach model DR2000 spectrophotometer and Hach reagents (Hach 1992). We chose these methods because other researchers at our Center used them in conducting field studies (S. Finger, Columbia Environmental Research Center, personal communication) and they seemed to be relatively easy to use for on-site analysis in a mobile laboratory. At that time, we had no reason to suspect that there would be any problems with these methods and believed that they were accurate and reliable. Furthermore, we considered the nitrite and nitrate data as ancillary because previous information indicated that their concentrations in wetlands at Ouray NWR were low and not a potential confounding factor in our study (D. Stephens, USGS, personal communication to S. Hamilton). If nitrite was present at potentially toxic concentrations in our test sites at Ouray NWR, it seems reasonable to assume that the zooplankton communities in these waters would have been adversely affected, and we would not have been able to consistently collect the large biomass of zooplankton needed for feeding the fish and trace element residue analyses.

In both methods, the analyte of interest forms a colored complex in an acid medium and the intensity of the color formed is directly proportional to the amount of analyte in the sample. Nitrite forms a greenish-brown complex and nitrate forms an amber-colored complex. The water samples collected from the six sites at Ouray NWR usually had a yellow hue, which varied from light yellow to brownish-yellow (resembling that of straw). At the beginning of the study, the technician doing the nitrite and nitrate analysis did not recognize that the color in the test waters may be a potential interference in both methods. Hach (1992) did not list natural yellow color in water as an interference in either of their methods. After doing several analyses, the technician suspected a potential bias and started analyzing sample blanks (sample without addition of reagents) along with the prepared samples as a spectrophotometric compensation to correct for this interference.

Two slightly different spectrophotometric procedures were used in both assays. During the first 2-3 weeks of the study, the concentration of each analyte was read directly from the spectrophotometer. In this procedure, the instrument was calibrated by analyzing a duplicate set of standards and reagent blank. For each sample, the spectrophotometer calculates and displays the concentration of the analyte (in mg/L) from the measured absorbance. For the remainder of the study, all standards, blanks, and samples were measured in absorbance units (AU), and the concentrations were interpolated from a standard curve. The second procedure using AU allows the analyst to observe where the readings are occurring on the spectrophotometric scale, because the instrument is not uniformly accurate over its entire scale. At this point in the study, the analyst discovered that the absorbance readings for nitrite analysis of site waters were less than 0.050 AU. At very low absorbances, slight differences in measurement procedures can cause large changes in the readings. It is recommended by APHA (1989) that absorbance readings for samples, corrected for the blank reading, should be made to fall between 0.1 and 1.0 AU by diluting or concentrating the sample.

In reviewing the raw data, I observed that the spectrophotometric readings obtained for most of the sample blanks were quite high. For nitrite analysis of S-1 (Sheppard Bottom pond 1, exposure water for all razorback sucker tested) waters, sample blanks accounted for 0 to 83% of the readings (concentration or AU) for the unknown samples (Table 1). Sample blanks were not analyzed for the first three S-1 samples of the study (collected May 21-23, 1994), which had the two highest recorded nitrite values. Except for samples collected on June 1- 6, which were analyzed on June 6, the blank value accounted for more than 50% of the sample readings for 16 of 18 samples. The reason for the very low sample blank readings for samples analyzed on June 6 is not known. All these samples were analyzed in one run by the same technician. One possible explanation is that the analyst inadvertently used water from S-1 (instead of deionized water) to prepare the reagent blank, which was used to zero the instrument between measurements. Nitrite values for these samples (where the validity of the sample blank is suspect) are 1.2 to 4.9 times higher than those for the other samples analyzed by the direct concentration readout procedure.

For nitrate analysis of S-1 waters, sample blank readings accounted for 50 to 88% of the readings for the unknown samples (Table 2). As was observed for nitrite, the four highest nitrate values were recorded for samples analyzed without using a sample blank by the direct concentration readout procedure.

Similar findings were observed for water samples from the other sites (S-3, S-4, S-5, SP, and NP). Except for samples collected on June 3, which were analyzed for nitrite on June 6, sample blanks contributed between 28 and 100% of the spectrophotometric readings for nitrite in the unknown samples (Table 3). For nitrate analysis of the same waters, sample blanks contributed between 16 to 82% of the readings for the unknown samples (Table 4). If the data from North Pond are excluded, the sample blanks (i.e., natural water color) accounted for at least 50% of the nitrate readings for these samples.

Upon further review of the raw data for nitrite and nitrate measurements made in AU, I discovered that the absorbance values for the unknown samples were corrected for the sample blank, but not for the reagent blank, before the concentration was interpolated. The difference between absorbance values for the unknown sample and sample blank was less than or equal to the average absorbance of the reagent blank for 16 of 20 nitrite analyses (Tables 1 and 3) and 12 of 13 nitrate analyses (Tables 2 and 4). Obviously these corrected concentrations are below the detection limit of the method. Only three nitrite samples had corrected absorbance readings higher than that for the lowest standard. Moreover, the absorbance reading for the two lowest nitrite standards of 0.30 and 1.50 mg/L as N (0.005 and 0.028 AU) are well below the recommended lower limit of 0.100 AU for colorimetric determinations (APHA 1989).

In addition, most nitrate concentrations in S-1 waters determined by the direct concentration readout procedure were lower than that of the lowest standard (1.00 mg/L as N; Table 2). For 19 of 23 samples from S-1, measured nitrate values were only 24-56% of the lowest standard. For the other sites, only North Pond water had measured nitrate values above the lowest standard (Table 4).

We recently encountered a similar problem for nitrite and nitrate determinations in test solutions of fire retardant chemicals using the same methods of Hach (Hach 1992). Test solutions of fire retardants, which had a red or orange color, were initially analyzed for nitrite and nitrate as above. The results of these analyses were suspected of and then proven to be erroneously high. In this study (Buhl and Hamilton 1998, attached), nitrite concentrations in fire retardant solutions measured by the Hach method were three to five orders of magnitude higher than those measured potentiometrically using a nitrite specific-ion electrode. Similarly, nitrate concentrations in the same solutions measured by the Hach method were at least one to three orders of magnitude

The erroneous nature of the nitrite and nitrate data is supported by the incongruity between measured nitrite and nitrate concentrations in the same sample. The Hach method for nitrate reduces nitrate to nitrite prior to forming a colored complex and registers both nitrite and nitrate in the sample. Consequently, measured concentrations of nitrate should be equal to or higher than those of nitrite in the same sample. For 15 of 17 (88%) S-1 samples analyzed for nitrite and nitrate using the direct concentration readout procedure, the nitrite concentration was higher than the corresponding nitrate concentration (Table 5). The same trend was observed for the other sites, except at North Pond, where 9 of 12 samples (75%) had higher nitrite concentrations compared to nitrate concentrations (Tables 3 and 4). Concentrations of nitrate at North Pond were always higher than those of nitrite.

Considering that nitrite is usually present in trace amounts in most natural waters (Russo 1985), the nitrite concentrations reported in this study using the direct concentration readout procedure seem anomalously high. In an earlier investigation at Ouray NWR by the U.S. Geological Survey, D. Stephens provided written communication (attached) that reported a nitrite concentration of 0.020 mg/L as N and a nitrate concentration of 0.770 mg/L as N for North Pond water collected in 1991. The reported nitrite concentration is only about 1-2% of those measured in North Pond using the direct concentration readout procedure (Table 3). Moreover, the reported nitrate concentration is about 40 times higher than the nitrite concentration.

In conclusion, the accuracy of the nitrite and nitrate values given in Hamilton et al. (1996) are highly suspect because the effect of matrix interferences on the measurements were not determined analytically. Even though sample blanks were used in the nitrite and nitrate analyses, the interferences present in the site waters (presumably color) were not adequately compensated because the standards were prepared in colorless deionized water and no sample spikes were analyzed. In retrospect, the method of standard additions (aliquots of standard added to portions of the sample) should have been used to confirm the presence of an interference and this technique may have provided accurate determinations of nitrite and nitrate in these samples, if they were present at detectable concentrations for the Hach methods.

Another factor that may compromise the validity of the nitrite and nitrate data reported in this study is the length of the holding times for these water samples. The maximum recommended holding time for nitrite and nitrate under refrigeration is 48 hours (Hach 1992). For S-1 waters, about 63% of the samples for nitrite and 52% of those for nitrate were held longer than 2 days before being analyzed (Tables 1 and 2). Similarly, about 80% of the water samples from the other sites were held longer than 2 days before being analyzed for nitrite (Table 3). These samples were not analyzed within 2 days after collection due to time constraints during the study. The priority of the study was to maintain the designed experimental conditions for the fish (daily observations and water renewals, field collections of zooplankton from six sites, and enumeration and feeding of zooplankton to fish), monitor major water quality parameters during the exposures (alkalinity, calcium, chloride, conductivity, dissolved oxygen, hardness, pH, and sulfate), and preserve water and zooplankton for trace element analyses (selenium and 31 other elements).

To correct the problem of erroneous nitrite and nitrate values in the Final Report, Steve Hamilton has decided to attach this memo as an erratum that addresses the validity of the nitrite and nitrate data. The erratum will be sent to all recipients of the report. However, we believe that the data for the other water quality parameters (i.e., alkalinity, calcium, chloride, conductivity, dissolved oxygen, hardness, pH, and sulfate) are valid. These parameters were analyzed according to standard methods within recommended holding times (APHA 1989, USEPA 1979). Moreover, these assays are run routinely at our laboratory on a variety of water types and all personnel performing these assays during the on-site study were very familiar with each of the methods used.

If you have any questions or comments, please let me know.

Sincerely,

Kevin J. Buhl
Fishery Biologist (Research)

Enclosures: Data tables as stated.

References:

APHA (American Public Health Association, American Water Works Association, and Water Pollution Control Federation). 1989. Standard methods for the examination of water and wastewater, 17th edition. APHA, Washington, D.C.

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Environmental Protection Agency, Ecological Research Series, EPA-600/3-77-085. Corvallis, OR.

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Table 1. Summary of nitrite analysis of reference water from site S-1 at Ouray NWR, Utah, during studies with larval razorback sucker in 1994.

Sample date	Instrument reading[a]			Ratio[b]: (Blank/ Sample)	Corrected conc. (mg/L as)		Holding time (d)	Study number
	Sample[c]	Sample blank	Unit[d]		NO_2	N		
05/21	13.3	NM[e]	mg/L	-	13.3	3.99	6	1
05/22	5.52	NM	mg/L	-	5.52	1.66	5	1
05/23	10.7	NM	mg/L	-	10.7	3.21	4	1
05/24	5.24	3.24	mg/L	0.62	2.00	0.60	3	1
05/25	7.68	4.75	mg/L	0.62	2.93	0.88	2	1
05/26	6.86	3.96	mg/L	0.58	2.90	0.87	1	1, 2
05/27	5.72	3.80	mg/L	0.66	1.92	0.58	0	1, 2
05/28	6.20	3.30	mg/L	0.53	2.90	0.87	3	1, 2
05/29	5.32	3.20	mg/L	0.60	2.12	0.64	2	1, 2
05/30	7.74	3.34	mg/L	0.43	4.40	1.32	1	1, 2
05/31	6.56	3.51	mg/L	0.54	3.05	0.92	0	1, 2
06/01	10.26	0.85	mg/L	0.08	9.41	2.83	5	1, 2
06/02	7.31	0.00	mg/L	0.00	7.31	2.20	4	1, 2, 3
06/03	6.75	0.00	mg/L	0.00	6.75	2.03	3	1, 2, 3
06/04	5.29	0.00	mg/L	0.00	5.29	1.59	2	1, 2, 3
06/05	5.62	0.00	mg/L	0.00	5.62	1.69	1	1, 2, 3
06/06	7.40	0.00	mg/L	0.00	7.40	2.22	0	1, 2, 3, 4
06/07	0.014	0.008 (0.006)[f]	AU	0.57	BD[g]	BD	11	1, 2, 3, 4
06/08	0.014	0.008 (0.006)	AU	0.57	BD	BD	10	1, 2, 3, 4

Table 1. cont.

Sample date	Instrument reading[a]			Ratio[b]: (Blank/ Sample)	Corrected conc. (mg/L as)		Holding time (d)	Study number
	Sample[c]	Sample blank	Unit[d]		NO_2	N		
06/09	0.013	0.008 (0.006)	AU	0.62	BD	BD	9	1, 2, 3, 4
06/10	0.012	0.008 (0.006)	AU	0.67	BD	BD	8	1, 2, 3, 4
06/11	0.022	0.009 (0.006)	AU	0.41	1.20	0.36	7	1, 2, 3, 4
06/12	0.014	0.011 (0.006)	AU	0.79	BD	BD	6	1, 2, 3, 4
06/13	0.016	0.010 (0.006)	AU	0.62	BD	BD	5	1, 2, 3, 4
06/14	0.014	0.009 (0.006)	AU	0.64	BD	BD	4	1, 2, 3, 4
06/15	0.015	0.010 (0.006)	AU	0.67	BD	BD	3	2, 3, 4
06/16	0.018	0.015 (0.006)	AU	0.83	BD	BD	2	2, 3, 4

[a]Reading from Hach DR2000 spectrophotometer.
[b]Ratio of sample blank reading to unknown sample reading.
[c]Average of duplicate analysis.
[d]mg/L as NO_2; AU = absorbance units.
[e]NM = not measured.
[f]Absorbance reading for reagent blank.
[g]BD = below limit of detection.

Table 2. Summary of nitrate analysis of reference water from site S-1 at Ouray NWR, Utah, during studies with larval razorback sucker in 1994.

Sample date	Instrument reading[a]			Ratio[b]: (Blank/ Sample)	Corrected conc. (mg/L as)		Holding time (d)	Study number
	Sample[c]	Sample blank	Unit[d]		NO_3	N		
05/21	0.38	NM[e]	mg/L	-	1.67	0.38	2	1
05/22	0.94	NM	mg/L	-	4.14	0.94	1	1
05/23	0.96	NM	mg/L	-	4.22	0.96	0	1
05/24	1.02	0.78	mg/L	0.76	1.06	0.24	4	1
05/25	1.00	NM	mg/L	-	4.40	1.00	3	1
05/26	1.03	0.91	mg/L	0.88	0.53	0.12	2	1, 2
05/27	1.11	NM	mg/L	-	4.88	1.11	1	1, 2
05/28	0.94	0.80	mg/L	0.85	0.62	0.14	0	1, 2
05/29	1.96	1.47	mg/L	0.75	2.16	0.49	7	1, 2
05/30	1.82	1.38	mg/L	0.76	1.94	0.44	6	1, 2
05/31	1.93	1.54	mg/L	0.80	1.72	0.39	5	1, 2
06/01	1.87	1.42	mg/L	0.76	1.98	0.45	4	1, 2
06/02	1.07	0.63	mg/L	0.59	1.94	0.44	3	1, 2, 3
06/03	1.00	0.70	mg/L	0.70	1.32	0.30	2	1, 2, 3
06/04	1.12	0.69	mg/L	0.62	1.89	0.43	1	1, 2, 3
06/05	1.22	0.71	mg/L	0.58	2.24	0.51	0	1, 2, 3
06/06	1.12	0.65	mg/L	0.58	2.07	0.47	6	1, 2, 3, 4
06/07	1.24	0.68	mg/L	0.55	2.46	0.56	5	1, 2, 3, 4
06/08	1.09	0.68	mg/L	0.62	1.80	0.41	4	1, 2, 3, 4
06/09	1.10	0.64	mg/L	0.58	2.02	0.46	3	1, 2, 3, 4
06/10	1.06	0.55	mg/L	0.52	2.24	0.51	2	1, 2, 3, 4

Table 2. cont.

Sample date	Instrument reading[a]			Ratio[b]: (Blank/ Sample)	Corrected conc. (mg/L as)		Holding time (d)	Study number
	Sample[c]	Sample blank	Unit[d]		NO_3	N		
06/11	1.05	0.53	mg/L	0.50	2.29	0.52	1	1, 2, 3, 4
06/12	1.08	0.63	mg/L	0.58	1.98	0.45	0	1, 2, 3, 4
06/13	0.119	0.072 (0.050)[f]	AU	0.61	BD[g]	BD	8	1, 2, 3, 4
06/14	0.104	0.067 (0.050)	AU	0.64	BD	BD	7	1, 2, 3, 4
06/15	0.122	0.074 (0.050)	AU	0.61	BD	BD	6	2, 3, 4
06/16	0.110	0.081 (0.050)	AU	0.74	BD	BD	5	2, 3, 4
06/18	0.120	0.091 (0.050)	AU	0.76	BD	BD	3	2, 3, 4
06/19	0.134	0.104 (0.050)	AU	0.78	BD	BD	2	2, 3, 4
06/20	0.140	0.105 (0.050)	AU	0.75	BD	BD	1	2, 3, 4
06/21	0.148	0.113 (0.050)	AU	0.76	BD	BD	0	3, 4

[a]Reading from Hach DR2000 spectrophotometer.
[b]Ratio of sample blank reading to unknown sample reading.
[c]Average of duplicate analysis.
[d]mg/L as N; AU = absorbance units.
[e]NM = not measured.
[f]Absorbance reading for reagent blank.
[g]BD = below limit of detection.

Table 3. Measured nitrite concentrations (mg/L as N) in water from non-reference sites at Ouray NWR, Utah, where zooplankton were collected in 1994.

Site	Sample date	Instrument reading[a]			Ratio[b]: (Blank/ Sample)	Corrected conc. (mg/L as)		Holding time (d)
		Sample[c]	Sample blank	Unit[d]		NO_2	N	
S-3	05/21	2.32	1.37	mg/L	0.59	0.95	0.29	6
	05/28	4.68	1.60	mg/L	0.34	3.08	0.92	3
	06/03	7.34	1.42	mg/L	0.19	5.92	1.78	3
	06/11	0.018	0.018 (0.006)[e]	AU	1.00	BD[f]	BD	7
	06/17	0.016	0.012 (0.006)	AU	0.75	BD	BD	1
S-4	05/21	2.90	1.45	mg/L	0.50	1.45	0.44	6
	05/28	4.90	1.80	mg/L	0.37	3.10	0.93	3
	06/03	9.20	1.20	mg/L	0.13	8.00	2.40	3
	06/11	0.016	0.012 (0.006)	AU	0.75	BD	BD	7
	06/17	0.017	0.012 (0.006)	AU	0.71	BD	BD	1
S-5	05/21	3.18	1.36	mg/L	0.43	1.82	0.55	6
	05/28	5.30	3.21	mg/L	0.61	2.09	0.63	3
	06/03	9.24	4.56	mg/L	0.49	4.68	1.41	3
	06/11	0.040	0.015 (0.006)	AU	0.38	3.26	0.98	7
	06/17	0.027	0.015 (0.006)	AU	0.56	1.03	0.31	1
SP	05/21	1.66	0.67	mg/L	0.40	0.99	0.30	6
	05/28	4.50	1.87	mg/L	0.42	2.63	0.79	3
	06/03	7.2	2.55	mg/L	0.35	4.65	1.40	3

Table 3. cont.

Site	Sample date	Instrument reading[a]			Ratio[b]: (Blank/ Sample)	Corrected conc. (mg/L as)		Holding time (d)
		Sample[c]	Sample blank	Unit[d]		NO_2	N	
	06/11	0.013	0.006 (0.006)	AU	0.46	< 1.00	< 0.30	7
	06/17	0.014	0.008 (0.006)	AU	0.57	BD	BD	1
NP	05/21	8.18	2.28	mg/L	0.28	5.90	1.77	6
	05/28	5.12	2.16	mg/L	0.42	2.96	0.89	3
	06/03	5.34	0.00	mg/L	0.00	5.34	1.60	3
	06/11	0.014	0.010 (0.006)	AU	0.71	BD	BD	7
	06/17	0.016	0.010 (0.006)	AU	0.62	BD	BD	1

[a]Reading from Hach DR2000 spectrophotometer.
[b]Ratio of sample blank reading to unknown sample reading.
[c]Average of duplicate analysis.
[d]mg/L as NO_2; AU = absorbance units.
[e]Absorbance reading for reagent blank.
[f]BD = below limit of detection.

Table 4. Measured nitrate concentrations (mg/L as N) in water from non-reference sites at Ouray NWR, Utah, where zooplankton were collected in 1994.

Site	Sample date	Instrument reading[a]			Ratio[b]: (Blank/ Sample)	Corrected conc. (mg/L as)		Holding time (d)
		Sample[c]	Sample blank	Unit[d]		NO_3	N	
S-3	05/21	0.44	NM[e]	mg/L	-	1.94	0.44	2
	05/28	0.56	0.39	mg/L	0.70	0.75	0.17	0
	06/03	1.17	0.75	mg/L	0.64	1.85	0.42	2
	06/11	1.08	0.88	mg/L	0.81	0.88	0.20	1
	06/17	0.097	0.062 (0.050)[f]	AU	0.64	BD[g]	BD	4
S-4	05/21	0.60	NM	mg/L	-	2.64	0.60	2
	05/28	0.66	0.48	mg/L	0.73	0.79	0.18	0
	06/03	1.22	0.89	mg/L	0.73	1.45	0.33	2
	06/11	1.21	0.78	mg/L	0.64	1.89	0.43	1
	06/17	0.121	0.075 (0.050)	AU	0.62	BD	BD	4
S-5	05/21	0.50	NM	mg/L	-	2.20	0.50	2
	05/28	0.68	0.46	mg/L	0.68	0.97	0.22	0
	06/03	1.64	1.35	mg/L	0.82	1.28	0.29	2
	06/11	1.41	1.15	mg/L	0.82	1.14	0.26	1
	06/17	0.159	0.130 (0.050)	AU	0.82	BD	BD	4
SP	05/21	0.50	NM	mg/L	-	2.20	0.50	2
	05/28	0.47	0.29	mg/L	0.62	0.79	0.18	0
	06/03	0.92	0.60	mg/L	0.65	1.41	0.32	2
	06/11	1.27	0.63	mg/L	0.50	2.82	0.64	1

Table 4. cont.

Site	Sample date	Instrument reading[a]			Ratio[b]: (Blank/ Sample)	Corrected conc. (mg/L as)		Holding time (d)
		Sample[c]	Sample blank	Unit[d]		NO_3	N	
	06/17	0.096	0.060 (0.050)	AU	0.62	BD	BD	4
NP	05/21	2.10	NM	mg/L	-	9.24	2.10	2
	05/28	1.32	0.31	mg/L	0.23	4.44	1.01	0
	06/03	3.51	0.55	mg/L	0.16	13.02	2.96	2
	06/11	2.78	0.48	mg/L	0.17	10.12	2.30	1
	06/17	0.198	0.056 (0.050)	AU	0.28	< 4.40	< 1.00	4

[a]Reading from Hach DR2000 spectrophotometer.
[b]Ratio of sample blank reading to unknown sample reading.
[c]Average of duplicate analysis.
[d]mg/L as N; AU = absorbance units.
[e]NM = not measured.
[f]Absorbance reading for reagent blank.
[g]BD = below limit of detection.

Table 5. Comparison of nitrite and nitrate concentrations (mg/L as N) in reference water from site S-1 at Ouray NWR, Utah, in 1994 measured by the direct concentration readout procedure.

Sample date	Nitrite (as NO_2-N)	Nitrate (as NO_3-N)	Ratio: NO_2-N/NO_3-N	Comment
05/21	3.99	0.38	10.50	no sample blanks
05/22	1.66	0.94	1.77	no sample blanks
05/23	3.21	0.96	3.34	no sample blanks
05/24	0.60	0.24	2.50	
05/25	0.88	1.00	0.88	no nitrate sample blank
05/26	0.87	0.12	7.25	
05/27	0.58	1.11	0.52	no nitrate sample blank
05/28	0.87	0.14	6.21	
05/29	0.64	0.49	1.31	
05/30	1.32	0.44	3.00	
05/31	0.92	0.39	2.36	
06/01	2.83	0.45	6.29	nitrite sample blank low
06/02	2.20	0.44	5.00	nitrite sample blank = 0
06/03	2.03	0.30	6.77	nitrite sample blank = 0
06/04	1.59	0.43	3.70	nitrite sample blank = 0
06/05	1.69	0.51	3.31	nitrite sample blank = 0
06/06	2.22	0.47	4.72	nitrite sample blank = 0

Table 6. Comparison of nitrite and nitrate concentrations (mg/L as N) in water from non-reference sites at Ouray NWR, Utah, in 1994 measured by the direct concentration readout procedure.

Site	Sample date	Nitrite (as NO_2-N)	Nitrate (as NO_3-N)	Ratio: NO_2-N/NO_3-N	Comment
S-3	05/21	0.29	0.44	0.66	no nitrate sample blank
	05/28	0.92	0.17	5.41	
	06/03	1.78	0.42	4.24	
S-4	05/21	0.44	0.60	0.73	no nitrate sample blank
	05/28	0.93	0.18	5.17	
	06/03	2.40	0.33	7.27	
S-5	05/21	0.55	0.50	1.10	no nitrate sample blank
	05/28	0.63	0.22	2.86	
	06/03	1.41	0.29	4.86	
SP	05/21	0.30	0.50	0.60	no nitrate sample blank
	05/28	0.79	0.18	4.39	
	06/03	1.40	0.32	4.38	
NP	05/21	1.77	2.10	0.84	no nitrate sample blank
	05/28	0.89	1.01	0.88	
	06/03	1.60	2.96	0.54	nitrite sample blank = 0

DATE 6-08-99 UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY PROCESS

MULTIPLE STATION ANALYSES

STATION NUMBER	DATE	NITRO-GEN, NITRATE DIS-SOLVED (MG/L AS N) (00618)	NITRO-GEN, NITRITE DIS-SOLVED (MG/L AS N) (00613)	NITRO-GEN, NO2+NO3 DIS-SOLVED (MG/L AS N) (00631)	STATION NAME
401035109340801	08-23-89	--	--	<.100	LEOTA POND L3
400737109392501	08-23-89	--	--	.100	NORTH ROADSIDE POND OUTFLOW AT OURAY NWR
	08-27-91	.770	.020	.790	NORTH ROADSIDE POND OUTFLOW AT OURAY NWR
400812109394501	07-30-93	--	--	1.10	NORTH ROADSIDEWELL NR1 AT OURAY NWR
400805109394401	07-30-93	--	--	.550	NO. ROADSIDE WELL NR2 AT OURAY NWR
400755109394101	08-28-91	.740	.030	.770	NO. ROADSIDE WELL NR3 AT OURAY NWR
400638109395201	08-28-91	--	<.010	.077	SHEPPARD WELL SOUTH OF S3 AT OURAY NWR

OPTIONAL FORM 99 (7-90)

FAX TRANSMITTAL # of pages ▶ 1

To Steve Hamilton	From Doyle Stephens
Dept./Agency	Phone #
Fax # 605-665-9335	Fax #

NSN 7540-01-317-7368 5099-101 GENERAL SERVICES ADMINISTRATION

United States Department of the Interior
BUREAU OF INDIAN AFFAIRS

IN REPLY REFER TO:

June 14, 1999

92-080
99-381

Elouise Chicharello
BIA Navajo Area Director
P.O. Box 1060
Gallup, New Mexico 87325

RECEIVED
JUN 14 1999
USFWS - NMESSO

To:
Jennifer Fowler-Propst
U.S. Fish and Wildlife Service
2105 Osuna, NE
Albuquerque, New Mexico 87113

RE: Biological Assessment for Completion of the Navajo Indian Irrigation Project

Dear Ms. Fowler-Propst

Enclosed are three copies of the Biological Assessment for the completion of the Navajo Indian irrigation Project (NIIP). The Biological Assessment concludes that the completion of this project will have no effect on the endangered species or critical habitat in the area, with the exception of the endangered Colorado Pikeminnow and the Razorback Sucker. For these two species and their critical habitat, it was found that they will be affected. Some of these effects will be beneficial (e.g. removal of migration barriers & provisions for fish rearing facilities). The one potential detrimental effect is a possible increase of selenium in the San Juan River resulting from irrigation return flows. However, this effect is both insignificant in that it is not likely to be measurable and discountable, in that it is unlikely to occur. Taken together, the effects are not likely to be adverse to the recovery of the species. A monitoring program is proposed to verify this conclusion.

We hereby request concurrence with the finding that no species will be adversely affected by the completion of this project as described in the Biological Assessment.

Thank you for your prompt attention to this matter and your participation in the informal consultation process over the last six months. If further information is required, Bob Krakow in the NIIP office in Farmington, NM is coordinating this project. He may be contacted at (505) 325-1864. For technical questions, you may contact Ron Bliesner of Keller-Bliesner Engineering in Logan, UT at (435) 753-5651.

Sincerely

Elouise Chicharello
Navajo Area Director

KELLER-BLIESNER ENGINEERING
IRRIGATION AND AGRICULTURAL DEVELOPMENT

78 EAST CENTER
LOGAN, UTAH 84321-4619

PHONE (435) 753-5651
FAX (435) 753-6139

April 28, 1999

Jennifer Fowler-Propst
U.S. Fish and Wildlife Service
2105 Osuna NE
Albuquerque, NM 87113

RE: NIIP Biological Assessment - Answers to Questions

Dear Jennifer:

This letter is to address your questions concerning the Draft BA for the completion of NIIP. I thought it would be better to respond informally rather than prepare a second draft. If these changes are satisfactory to you, they will be incorporated into the BA. We may need some discussion on the selenium issue before finalizing, however, due to conflicting research results.

Base Map and Hydrology

The symbols in Plate 1 along the river represent different irrigation projects (e.g. Hammond, Fruitland, Hogback, etc). We will refine the hatch patterns and add them to the legend.

Figure 6 has been modified to include all the water balance parameters.

Table 6 has some errors. These tables will be updated, based on the latest version of Environmental Baseline. ALP has been adjusted to 57,100, the 3,000 af minor depletions have been added and the Jicarilla historic demand from their settlement has been included per the baseline table I sent you. That changes all the numbers in the hydrology a bit. With these increased depletions, the completion schedule shown in Table 1 for the full 110,630 acres had to be extended to 2032, rather than 2022. With this scenario, the average annual project depletion peaks at 280,600 af rather than 287,000 af. The average annual equilibrium depletion remains at 270,000 af. I have attached the updated tables with these new conditions.

Field Selenium Data and Interpretation

We will clarify the language on pages 43 and 46 dealing with selenium. To answer your question, some of the fields do overlay the shales. From the studies we have completed, the first 15 ft of soil leaches to detection limit rapidly, regardless of the underlying bedrock. The results we present on projected selenium levels include the integrating effect of contact with both shales and sandstones. However, bedrock is typically 20 - 50 ft below the ground surface, so leaching in the first 15 feet will reduce selenium to detection in the drain water that will be collected at a depth of 8-12 ft, leaving the deeper water to leak out at natural seep points. We have assumed that this natural drainage will continue with the same selenium level as exists presently. In truth, this value will likely decrease eventually, but it will be a very long time.

Figure 16 is a bit confusing. The time scale is not uniform. Enclosed is an edited version of the figure. The apparent increase at the later times is due to the time of year the samples were taken. If you notice, the 1991 samples were taken April through December, while the 1996 sample was taken in January. The concentration increases in the winter as irrigation return flow decreases and the seeps become more concentrated. Therefore, the valid comparison is between December 91 and January 96. When comparing these two data sets, the difference is not statistically significant. You can compare these results to the monthly distribution of selenium in Ojo Amarillo shown in Figure 20. You can see that the values are higher in January than in December, so the increase on the graph between December 1991 and January 1996 is primarily due to the time of year rather than an increasing trend. Additionally, the seeps sampled were not all the same for the two periods, causing some of the difference seen. The washes are the integrators of these seeps and better represent the impact to the river.

The Ojo razorback pond is on a side channel to Ojo Amarillo that has a lower selenium level. However, the selenium levels are elevated a bit in the winter, even in this pond. They have occasionally been as high as 10 ppb, but typically under 5 ppb. The water quality was reviewed with Frank Pfeifer before putting the fish in. He was comfortable with the selenium levels he saw.

Selenium Toxicity Threshold for Razorback Sucker

The report by Hamilton[1] you cite for a threshold selenium level of food for larval fish of 2.3 ppm has been broadly dismissed among upper basin researchers as invalid (talk to Frank Pfeifer orDan Beyers). The conclusions are not supported by the data presented in the report. There are several problems. First, in the first two studies, all the fish died, even those at the lowest selenium level (2.3 ppm). Second, the report appears to pre-suppose that the mortality was caused by selenium, when there was no dose response. In fact, in study 1, there is an inverse response in terms of days to death and selenium concentration in the feed. This is particularly interesting, since the fish fed highest level of selenium (95.2 ppm) lived 50% longer than those fed the lowest feed

[1] Hamilton, , S.J., K.J. Buhl, Fern A. Bullard, and Susan F. McDonald. (1996) Evaluation of toxicity to larval razorback sucker of selenium-laden food organisms from Ouray NWR on the Green River, Utah. Final report to U.S. FWS, Colorado River Recovery Implementation Program.

concentration (3.5 ppm). In the other studies there were no statistically significant differences in time to death with about the same range in selenium concentration in the feed.

The increased survival times with the diets highest in Se relative to S1, in both Studies 1 and 2, would suggest that it was not selenium that killed the fish larvae. The various water quality parameters and analyses were reviewed and seemed usual for most parameters, although the conductivity is much elevated over San Juan River water (from 5 to 30 times higher). The major exception to this conclusion was nitrite concentration. In most natural waters, the nitrate/nitrite ratio is >10, where as it is about 1 in these samples. In addition, nitrite is lethal to adult fish at about 1 mg/l, a concentration exceeded by every measured value for nitrite in Table 1 (p 10). The nitrite concentrations reported in the table appear too high for an oxygenated system at the reported pH. If nitrate is being denitrified under some transient condition as the water stands, there may arise a condition that nitrate is partially reduced to nitrite. Hence, any nitrite formed momentarily could be detected during analysis. Also under the experimental conditions, where new water (a new supply of reducing agent) is added each day and although the exposure water was aerated, a low concentration of nitrite might form which is chronically toxic to the fish larvae. So nitrate, present in most streams, could under possible reducing conditions in wetlands form some nitrite during denitrification. Also when nitrite is present, the ammonia concentration should have been determined. Ammonia, if detected, would provide further evidence that denitrification is occurring and would be another potential toxicant. Finally, in study 1, the concentration of nitrite among treatments directly correlates with death rate (higher nitrite, shorter life).

We did not cite this study because of these problems, therefore being left to the acute tests and the associated low hazard assessment that was assigned to the expected level of selenium concentration in the system. There have been other studies aimed at answering these questions for larval razorback sucker since we completed the BA. At the January Upper-Basin Research Meeting, Daniel Beyers of the larval fish lab at CSU reported on a selenium feed/water concentration study[2] just completed in which rotifers (the food source for the study) were grown with algae in waters with selenium concentrations of 0.0, 2.5, 5.0, 10 and 20 µg/l. The larvae were placed in waters with the same Se concentration and fed either uncontaminated or contaminated rotifers. They found no difference among treatments with mortality being low in all treatments. (Summary of presentation attached). At the time of the paper presentation, they had not received the lab data for the Se analysis of the rotifers from the various trials. In personal communication with Dr. Beyers, the data are now back and the highest rotifer concentration is 1.5 ppm. So larval fish raised in 20 µg/l water and fed 1.5 ppm feed had no effect. Obviously, the Se bio-magnification in the food chain in this study did not occur at the same rate as the literature

[2] Beyers, Daniel W. (1998) Assessment and prediction of effects of selenium exposure to larval razorback sucker. FY 98 Annual Project Report. Project Number CAP-6-SE

would suggest. For example, this is only 1/10 the minimum bio-magnification reported by Hamilton.

Studies by Hamilton and Buhl[3],[4] (1995 and 1996) show that Selenium LC_{96} concentrations are lowest for razorback sucker larvae followed by flannelmouth sucker, with Colorado pikeminnow being the least sensitive. The ratios are: 0.69 - razorback sucker to flannelmouth sucker and 0.49 - flannelmouth sucker to Colorado Pikeminnow when averaging selenate and selenite. For all three species, selenium concentrations in the river represent low hazard.

The study by Hamilton and Buhl (1998)[5] on chronic toxicity and reproductive effect of selenium in feed and water on Colorado pikeminnow demonstrated no effect at feed concentrations of 11.8 ppm and water at 7.9 µg/l. There was no difference between control conditions and the highest concentration conditions in terms of spawning success, hatching success or growth of larval fish. There was a difference in the selenium concentration in the adult fish muscle, eggs and larvae, with the eggs and swim-up larvae having about the same selenium concentration as the feed. Therefore, the toxic threshold for reproductive impairment for Colorado Pikeminnow is higher than 11.8 ppm in feed and 7.9 ppb in water.

If the ratios of acute toxicity apply to chronic toxicity and reproductive impairment, then applying the ratio of LC_{96} for selenium for razorback sucker to pikeminnow of 0.34 to the feed concentration of 11.8 ppm and water of 7.9 ppb would suggest no effect to razorback sucker with feed at 4.0 ppm and water at 2.7 ppb. Projected levels for feed and water are both below these no-effect levels.

---

[3] Hamilton, S.J. and K. J. Buhl, 1995, Hazard assessment of inorganics, singly and in mixtures, to Colorado squawfish and razorback sucker in the San Juan River, New Mexico, final report to U.S. Bureau of Reclamation for the San Juan Recovery Implementation Program.

[4] Hamilton, S.J. and K. J. Buhl, 1996, Hazard assessment of inorganics, singly and in mixtures, to flannelmouth sucker in the San Juan River, New Mexico, final report to U.S. Bureau of Reclamation for the San Juan Recovery Implementation Program.

[5] Hamilton,S.J. and K. J. Buhl, 1998, The chronic toxicity of dietary and waterborne selenium to adult Colorado squafish in a water quality simulating that in the San Juan River. Draft progress report for the San Juan Recovery Implementation Program.

To further assess the probability of adverse effect, the method for assessing toxic threat proposed by Lemly[6] (1996) was applied. This process computes an index of combined toxicity for selenium concentrations in water, bottom sediments, macroinvertebrates and fish eggs. To allow application of this process, Tables 12 and 15 (attached) in the Biological Assessment have been updated to include sediment and flannelmouth ovary data (the only egg data available). The following table summarizes the criteria for toxicity assessment from Lemly (1996). An adjustment is applied since his method includes bird eggs for effects to water fowl for which we have no data. Since only 4 parameters exist, the cumulative effect indices proposed by Lemly (1996) and shown in the table were multiplied by 4/5 to arrive at the criteria for fish hazard. In the table, it is assumed that all parameters will increase at the same rate (19%) as the computed increase in water concentration assuming 100% conservation of Se in the system and the same bio-concentration factors that presently exist.

	Index	Water	Sediment	Macro-invertebrates	fish eggs	Overall Hazard: fish 4 parameters	Overall Hazard: aquatic birds 5 parameters Inc. bird eggs
High	5	>5	>4	>5	>20	13-20	16-25
Moderate	4	3-5	3-4	4-5	10-20	10-12	12-15
Low	3	2-3	2-3	3-4	5-10	7-9	9-11
Minimal	2	1-2	1-2	2-3	3-5	5-7	6-8
None	1	<1	<1	<2	<3	≤4	≤5
San Juan		1.4	0.47	3.28	4.3		
With NIIP		1.9	0.56	3.9	5.12		
Beyers study		20		1.5			
Hazard Index							
Present		2	1	3 4	2	8	Low
With full NIIP		2	1	3 4 or 5	3	9	Low
Beyers study		5	1	1	1	8	Low

Also shown on the table are the values from the Beyers study where no effect to larval fish was seen. Assuming no effect from sediment or fish eggs, the hazard index is the same as the present condition for the San Juan.

While the values in the table show an increase in the hazard index due to a change in category in fish eggs due to increased selenium load, the rating according to the system proposed by Lemly remains as low hazard.

[6] Lemly, A. D., 1996, Assessing the toxic threat of selenium to fish and aquatic birds, Environmental monitoring and assessment 43:19-35.

While the information for razorback sucker is not as solid as that for Colorado pikeminnow, based on the best available data it appears that the potential risk of toxic effect is low, although not non-existent. Even with this low hazard assessment, additional data collection is warranted. We propose one comprehensive sampling of the San Juan River from Gallegos Canyon downstream covering sediments, macro-invertebrates, periphyton and fish eggs to allow better sampling distribution. Flannelmouth sucker would be used for egg collection due to the similarities to razorback sucker feeding habits and relative abundance in the system. We also propose, if the program agrees, to sample eggs from razorback suckers in the system, along with muscle plugs for comparison to flannelmouth sucker and to compare to the samples previously taken on razorbacks in the system. This would be non-lethal sampling to be conducted in the spring of the year prior to runoff. A second sampling of macro-invertebrates would occur in the summer after runoff since this would be the time the yoy razorbacks would be feeding.

In addition, Beyers is conducting a second series of studies on larval razorback suckers with higher feed concentrations to arrive at a dose-response curve for selenium in feed and water. With these two data sets available, we should be able to more definitively answer the question of toxicity risk to razorback suckers in the San Juan River.

Conclusions

- The flow recommendations can be met with the project as proposed.
- Selenium levels projected to occur at project equilibrium (and at all times prior) are not likely to adversely effect Colorado pikeminnow.
- Based on the best available data, selenium hazard in the system for razorback sucker is low. Given all the project features proposed, including razorback rearing ponds and removal of migration barriers, the razorback sucker are not likely to be adversely effected. However, additional data will be collected to verify this conclusion.

The third conclusion is the one that you may consider troublesome. It is true that we cannot positively conclude that there will be no impact. We do believe, however, with all that is included in the project description, that the overall impact is positive to the species. The question is: what the best way to describe this. Obviously, we would like to avoid a jeopardy opinion due to the time involved. We are willing to include in the project description the conditions that you believe are necessary given what we know about the system and the species. I believe some discussion is warranted to work out the details. If this cannot be resolved, then we need to enter formal consultation as soon as possible.

We appreciate the opportunity to work with you in this important consultation. The BIA remains committed to the recovery of these species and will continue to support every effort to see that this is the end result. I look forward to hearing from you after you have had a chance to review this material.

Sincerely,

Ronald D. Bliesner, P.E.
President

cc Bob Krakow
Vince Lamarra

⑥ The use of the Lemly (1995) hazard assessment is meaningful for evaluating ecosystems or particular habitats known or suspected of being contaminated with selenium, but does not substitute or constitute a risk assessment for the health of an individual or population of endangered razorback suckers. Nonetheless, while your projected hazard ranking is indicated as Low (7-9), it is neither Minimal(5-7) or None (<4) and depending on the round off in your 4/5 calculation could be as high as Moderate, especially if the mean invertebrate selenium concentration is 4 ppm or greater as is indicated on the NIIP by Thomas et al. (1998). Possibly, a no effect decision might equate with a Lemly (1995) hazard assessment index of None; a may effect, not likely to adversely affect decision might equate to hazard assessment index of Minimal; but adverse effects would be expected at the hazard assessment index of Low and certainly adverse population impacts would be expected at the hazard assessment index of Moderate to High. Again, the evaluation of effects to individual razorback suckers or their populations does not easily translate to the Lemly hazard index rating system, but as presented, the Low hazard indicated likely represents adverse effects until a more-refined evaluation can be performed.

⑦ We agree that additional data collection might be warranted, however, the collection of additional samples in the mainstem itself will not address the likely razorback sucker larvae habitat and food requirements than would a study of backwaters and tributaries. Also, we disagree that the flannelmouth sucker is a surrogate for the razorback sucker. The flannelmouth sucker appears to be more an omnivorous fish as compared to the more insectivorous razorback sucker. Sampling eggs and tissues from the razorbacks in the rearing pond and/or subsequent to their environmental release and exposure would be necessary to validate the biological assessment, its findings and any "take." The overall impact of expanded irrigation, in and of itself, will not be beneficial to the species. Backwater and tributary habitats of the San Juan River near the NIIP will likely be contaminated with selenium and other contaminants and would likely have associated adverse effects in these areas if used extensively.

Hamilton, S.J., K.J. Buhl, N.L. Faerber, R.H. Wiedmeyer, and F.A. Bullard. 1990. Toxicity of Organic Selenium in the Diet to Chinook Salmon. *Environmental Toxicology and Chemistry*, pp. 347-358.

Hamilton, S.J., K.J. Buhl, F.A. Bullard, and S.F. McDonald. 1996. Evaluation of Toxicity to Larval Razorback Sucker of Selenium-Laden Food Organisms from Ouray NWR on the Green River, Utah. National Biological Service, Midwest Science Center, Ecotoxicology Research Station.

Lemly, A.D. 1995. A Protocol for Aquatic Hazard Assessment of Selenium. *Ecotoxicology and Environmental Safety* **32**, 280-288.

Lemly, A.D. and G.J. Smith. 1987. Aquatic Cycling of Selenium - Implications for Fish and Wildlife. U.S. Fish and Wildlife Service Leaflet 12.

Thomas, C.L., R.M. Wilson, J.D. Lusk, R.S. Bristol, and A.R. Shineman. 1998. Detailed Study of Selenium and Selected Constituents in Water, Bottom Sediment, Soil, and Biota associated with Irrigation Drainage in the San Juan River Area, New Mexico, 1991-1995. U.S. Geological Survey Open-File Report 98-4213.

Table 5. Summary of hydrograph statistics for historic conditions and projected future conditions for current, baseline and baseline plus full NIIP with 10,600 af/year additional depletion due to groundwater storage.

Parameter	Pre-dam	Post-dam	Study Period	Current	Baseline	Full NIIP plus 10600 af g.w. Storage
Average Peak Daily Runoff - cfs	12,409	6,749	8,772	10,041	9,795	8,871
Average Runoff - af	1,263,890	891,712	1,132,899	1,042,635	963,549	862,123
	Frequency	Frequency	Frequency	Frequency	Frequency	Frequency
Peak > 10,000 cfs	55%	20%	33%	43%	43%	42%
Peak > 8,000 cfs	67%	37%	83%	77%	72%	62%
Peak > 5,000 cfs	91%	53%	83%	97%	97%	77%
Peak > 2,500 cfs	100%	90%	100%	100%	100%	97%
AF > 1,000,000	55%	40%	67%	42%	40%	34%
AF > 750,000	67%	47%	83%	63%	58%	54%
AF > 500,000	91%	67%	83%	82%	74%	69%
> 10,000 cfs for 5 days	39%	13%	33%	35%	34%	31%
> 8,000 cfs for 8 days	48%	27%	50%	48%	46%	43%
> 8,000 cfs for 10 days	45%	17%	50%	46%	45%	40%
> 5,000 cfs for 21 days	64%	37%	83%	68%	62%	58%
> 2,500 cfs for 10 days	100%	83%	100%	97%	97%	86%
Maximum years between flow events for minimum duration						
10,000 cfs - 5 days	4	14	n/a	6	6	9
8,000 cfs - 10 days	4	7	n/a	6	6	6
5,000 cfs - 21 days	4	7	n/a	3	4	4
2,500 cfs - 10 days	0	1	n/a	1	1	2
Non-corrected Perturbation	12%	27%	0%	17%	18%	22%
Average Date of Peak	31-May	01-Jun	07-Jun	04-Jun	04-Jun	04-Jun
Standard Deviation of Peak Date	23	35	8	12	12	15
Days > 10,000 cfs	14	3	2	6	5	5
Days > 8,000 cfs	23	8	10	16	14	13
Days > 5,000 cfs	46	28	51	43	38	33
Days > 2,500 cfs	82	67	90	71	65	56
Meets recommendation	yes	no	yes	yes	yes	yes

Table 6. Summary of backwater habitat area for historic conditions and projected future conditions for current, baseline and baseline plus full NIIP with 10,600 af/year additional depletion due to groundwater storage.

Parameter	Pre-dam	Post-dam	Study Period	Current	Baseline	Full NIIP plus 10600 af g.w.
Backwater availability, Reach 1-4 - acres						
Average before storms	21.32	14.34	23.05	23.53	24.16	22.71
August	16.94	11.89	17.69	18.65	19.19	18.18
September	14.92	11.69	15.22	17.08	17.66	16.55
October	13.75	10.46	14.61	16.16	16.76	15.79
November	14.78	11.04	14.10	16.26	16.74	15.85
December	15.92	10.29	15.66	15.61	16.28	15.70
Average (Aug-Dec)	15.26	11.07	15.46	16.75	17.33	16.38
Average Perturbation	28%	23%	33%	29%	28%	28%
Change from pre-dam conditions		-27%	1%	10%	14%	7%
Backwater availability, Reach 1-5 - acres						
Average before storms	26.36	19.39	26.51	28.36	29.35	28.24
August	21.67	17.35	21.24	23.48	24.30	23.53
September	19.89	17.53	18.28	22.20	22.92	21.77
October	18.36	15.21	17.69	20.99	21.74	20.66
November	19.76	15.36	17.15	21.37	22.18	21.30
December	21.54	14.76	19.80	20.47	21.68	21.17
Average (Aug-Dec)	20.24	16.04	18.83	21.70	22.56	21.68
Average Perturbation	23%	17%	29%	23%	23%	23%
Change from pre-dam conditions		-21%	-7%	7%	11%	7%
Razorback sucker backwater availability, Reach 1-4 - acres						
May	14.64	15.29	18.53	15.67	16.10	15.56
June	14.11	14.72	17.22	17.21	16.54	16.23
July	16.35	17.34	14.56	19.50	20.74	19.05
Razorback sucker backwater availability, Reach 1-5 - acres						
May	21.65	19.02	20.34	21.80	21.85	21.43
June	21.24	18.60	22.48	23.96	23.13	22.50
July	22.20	21.57	25.58	23.84	25.41	23.68

Table 7. Compliance with frequency distribution for flow/duration recommendations

Duration	Discharge			
	>10,000 cfs	>8,000 cfs	>5,000 cfs	>2,500 cfs
	Average Frequency - Recommendation (Full NIIP)			
1 day	30% (42%)	40% (62%)	65% (77%)	90% (97%)
5 days	20% (31%)	35% (51%)	60% (72%)	82% (89%)
10 days	10%(20%)	33% (40%)	58% (68%)	80% (86%)
15 days	5% (11%)	30% (34%)	55% (60%)	70% (78%)
20 days	(8%)	20% (28%)	50% (58%)	65% (74%)
30 days		10% (14%)	40% (48%)	60% (68%)
40 days			30% (32%)	50% (60%)
50 days			20% (26%)	45% (51%)
60 days			15% (20%)	40% (42%)
80 days			5% (12%)	25% (28%)

Table 12. Mean selenium concentrations (mg/kg) in biological samples collected 1991-1997.

Sample type	All Fish	Bluehead sucker	Brown Trout	Common Carp
Number	350	108	7	45
Se concentration	2.61	1.65	4.73	2.95
Standard deviation	1.67	0.58	1.17	1.38

Sample type	Channel catfish	Flannelmouth sucker	Razorback sucker	Small fish
Number	10	127	11	42
Se concentration	2.23	2.10	4.39	5.51
Standard deviation	0.78	0.71	0.56	2.30

Sample type	Macroinvertebrates	Periphyton	Sediment	Flannelmouth Ovaries
Number	34	24	18	48
Se concentration	3.28	1.05	0.44	4.30
Standard deviation	1.16	0.65	0.31	0.92

Table 15. Mean projected selenium concentrations (mg/kg) in biota based on samples taken during 1991-1997.

Sample type	All Fish	Bluehead sucker	Brown Trout	Common Carp
Number	350	108	7	45
Se concentration	3.11	1.96	5.63	3.51

Sample type	Channel catfish	Flannelmouth sucker	Razorback sucker	Small fish
Number	10	127	11	42
Se concentration	2.65	2.50	5.22	6.56

Sample type	Macroinvertebrates	Periphyton	Sediment	Flannelmouth Ovaries
Number	35	24	18	48
Se concentration	3.90	1.25	0.52	5.12

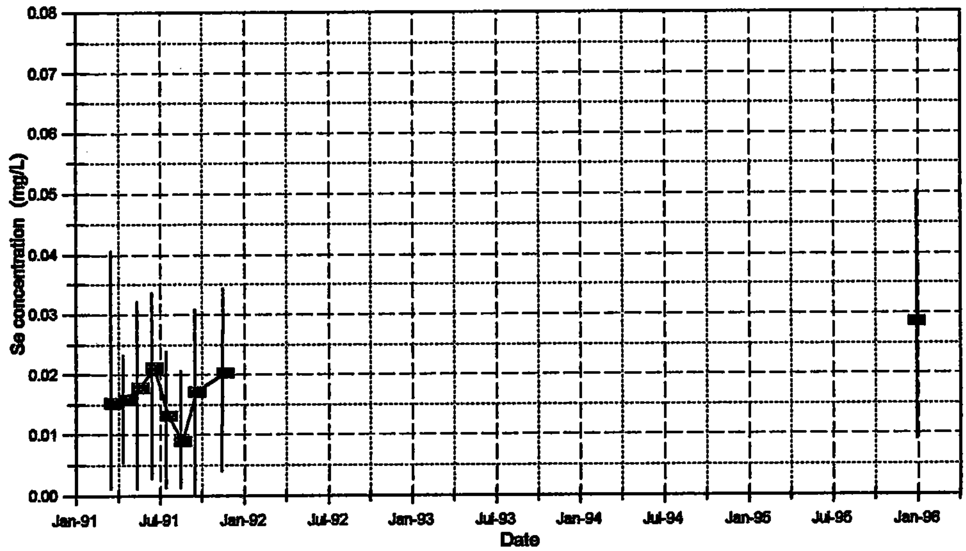

Figure 16. Time Series Plot of Selenium Concentration for Ojo Amarillo Seeps

United States Department of the Interior

FISH AND WILDLIFE SERVICE
New Mexico Ecological Services Field Office
2105 Osuna NE
Albuquerque, New Mexico 87113
Phone: (505) 761-4525 Fax: (505) 761-4542

April 18, 1996

Memorandum

To: Geographic Manager, New Mexico Ecosystems, Region 2

From: Field Supervisor, New Mexico Ecological Services Office, Albuquerque, New Mexico

Subject: Request for Solicitor's Opinion on Extension of Time for Consultation on Blocks 9-11, Navajo Indian Irrigation Project

Based on the discussions held at the April 11, 1996, meeting of the San Juan River Basin Recovery Implementation Program's Coordination Committee, I have drafted the attached request for an opinion by the Regional Solicitor. Also attached hereto are the copies of the documents referenced in that request. The draft has also been mailed to you electronically on this date.

Jennifer Fowler-Propst

Attachments

DRAFT

Memorandum

To: Regional Solicitor, Department of the Interior, Albuquerque, New Mexico

From: Regional Director, Fish and Wildlife Service, Region 2

Subject: Request for Opinion on Extensions of Time Periods for Section 7 Consultation

At a recent meeting of the San Juan River Basin Recovery Implementation Program, the representative from the Bureau of Indian Affairs requested clarification on the Fish and Wildlife Service's position regarding holding open a section 7 consultation for an extended period of time. The consultation in question is that requested for Blocks 9 through 11 of the Navajo Indian Irrigation Project on the San Juan River in northwest New Mexico. The Bureau of Indian Affairs requested consultation on Blocks 9-11 on December 11, 1991. A copy of that request and the response by the Service are attached for your information. The request and response noted an extension of time until information could be developed to determine the requirements of the endangered Colorado squawfish and razorback sucker in the San Juan River. This extension would last for the period of the 7-year research program on the river. The information gathered during the research would then be used in the preparation of a biological assessment for the proposed action that would be required to complete the section 7 consultation. The Service would base its biological opinion on the information provided in that biological assessment. Four years have passed since that exchange of correspondence and the research efforts to gather the needed information are ongoing. However, as discussed at the April 11, 1996, Recovery Implementation Program meeting, the Bureau of Indian Affairs is concerned that other consultations completed during the extension period would identify and implement reasonable and prudent alternatives (if jeopardy is found) that could be used to avoid jeopardy to their larger proposal, thus limiting the ability to avoid jeopardy in their consultation.

The questions of priority of processing section 7 consultation requests by chronological receipt of those requests, the viability of extending consultations for several years to retain priority in time of requests (but without information upon which consultation can be concluded and a biological opinion issued by the Service), and the priority of section 7 requests dealing with Service trust responsibilities to Native Americans will significantly affect the progress not only of section 7 consultations in the San Juan basin, but also of the Recovery Implementation Program. Therefore, I am requesting your opinion on the following questions:

1. Can the Fish and Wildlife Service accept a request for consultation that includes a prolonged extension of time in which the action agency can submit the required information upon which to base the analysis of impacts to endangered species and conclude the consultation?

DRAFT

2. If such an extension of time is granted, is there a standard of a reasonable period of time for such an extension, and how should the Service respond to other subsequent or concurrent requests for section 7 consultation that are received during the extension period for the first request?

3. Given a circumstance such that the first request for consultation deals with a Native American proposed action and any subsequent requests, or concurrent requests, deal with proposed actions not involving Native American trust resources and responsibilities, would the Native American request for consultation receive priority?

Should you require clarification of this request, or desire further information regarding the specific consultation request for Blocks 9-11 of the Navajo Indian Irrigation Project, please contact Field Supervisor Jennifer Fowler-Propst at the New Mexico Ecological Services Office. Ms. Fowler-Propst can be reached at (505) 761-4525.

Regional Director

Attachments

cc(w/out attach):
Field Supervisor, New Mexico Ecological Services Office, Albuquerque, New Mexico

United States Department of the Interior

BUREAU OF INDIAN AFFAIRS
NAVAJO AREA OFFICE
P.O. Box 1060
Gallup, New Mexico 87301

IN REPLY REFER TO:

DEC 11 1991

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Memorandum

From: Area Director, Navajo Area, Bureau of Indian Affairs

Subject: Re-initiation of formal consultation in compliance with Section 7 of the Endangered Species Act, Navajo Indian Irrigation Project, Blocks 9 through 11

To: Regional Director, U.S. Fish and Wildlife Service, Albuquerque, New Mexico

This letter constitutes the Bureau of Indian Affairs' official request for re-initiation of a formal consultation in compliance with Section 7 of the Endangered Species Act on the Navajo Indian Irrigation Project, specifically Blocks 9 through 11. The re-initiation of consultation is necessary due to information related to water quality, the listing of new species and the inclusion of the San Juan River as being important to the recovery of the Colorado River Squawfish becoming available since the initial biological opinion issued April 26, 1979.

Consultation has been completed on the first 8 blocks of NIIP. Included in the reasonable and prudent alternative for the first 8 blocks is the irrigation of 76,481 acres including 8,000 acres of conservation reserve acreage and an associated depletion of 149,420 acre-feet per year (afy). The depletion associated with the first 8 blocks can only exceed this amount by acquiring water from other sources to be left in the stream or by re-initiation of consultation.

This consultation is for the irrigation of 32,806 acres in Blocks 9-11, with an associated depletion of 80,046 afy, plus irrigation of 4,343 acres at unspecified locations within the project boundaries to bring the acreage to the full 110,630 acres authorized by Congress. The associated depletion increase on the project under this consultation will be 120,517 afy, including 80,046 afy for Blocks 9-11 and 40,471 afy for Blocks 1-8 to bring the total up to the authorized limit. The attached project description covers the details of the proposed project.

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AWE

Rec'd Region 2
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At this time, it is not possible to complete a biological assessment since the water requirements for and water quality impacts on the endangered fish are not known. The Bureau of Indian Affairs is participating in a 7-year research plan, along with the Bureau of Reclamation, U.S. Fish and Wildlife Service and others, designed to produce the information required to allow completion of the biological assessment and better determine the requirements of the endangered fish. We request that this consultation be extended until such time as sufficient information is developed to allow determination of the requirements of the endangered fish to a level sufficient for the completion of the biological assessment.

Since delivery of water to the Navajo Indian Irrigation Project involves operation of Navajo Dam by the Bureau of Reclamation and any modification to reservoir operation as a result of this consultation would involve the Bureau of Reclamation, we may also request their participation in this consultation at the time sufficient information is available to move forward. However, the Bureau of Indian Affairs will be lead agency.

We are looking forward to working closely with you on this consultation. Please feel free, until further notice, to contact our consultant, Mr. Ron Bliesner of Keller-Bliesner Engineering, for any technical information and for coordination of the consultation process. Please address all formal correspondence concerning this consultation to me at the above address.

Walter R. Mills

Copy to:

Ron Bliesner, Keller-Bliesner Engineering, Logan, Utah
Joe Little, Rights Protection, BIA Albuquerque Area Office
Leo Soukup, BIA-NIIP, Farmington, NM

UNITED STATES
DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
Ecological Services
Suite D, 3530 Pan American Highway, ~~NE~~
Albuquerque, New Mexico 87107

December 26, 1991

Cons. #2-22-92-F-080

File 2-22-92-F-08

Memorandum

To: Area Director, Bureau of Indian Affairs, Navajo Area Office, Gallup, New Mexico

From: Field Supervisor, Fish and Wildlife Service, New Mexico Ecological Services Office, Albuquerque, New Mexico

Subject: Re-initiation of Formal Section 7 Consultation: Navajo Indian Irrigation Project, Blocks 9 through 11

Your request, dated December 11, 1991, for re-initiation of formal Section 7 consultation was forwarded from the Regional Office of the Fish and Wildlife Service and received in this office on December 17, 1991. The proposed action is the construction and operation of Blocks 9 through 11 of the Navajo Indian Irrigation Project (Project) and the addition of those blocks to the agricultural and range operations of the existing Project.

The Bureau of Indian Affairs is participating in ongoing research on water requirements for and water quality impacts to the endangered fish of the San Juan River that may be affected by the proposed action. In order to provide adequate time to gather needed information, we concur with your request that the consultation be extended until such time as sufficient information is developed to allow determination of the requirements of the endangered fish to a level required for the completion of the biological assessment for the proposed action.

All further correspondence on this consultation and the research should be addressed to this office. Please furnish a copy of all correspondence to the Utah Ecological Services Office at the following address.

Field Supervisor
U.S. Fish and Wildlife Service
Utah Ecological Services Office
2060 Administration Building
1745 West 1700 South, Room 2078
Salt Lake City, Utah 84104-5110

We look forward to working with you in this consultation and in the ultimate recovery of the endangered fish species of the San Juan River basin. If you have any questions or require further information, please phone me at (505) 883-7877 or FTS 474-7877.

Jennifer Fowler-Propst

cc:
Regional Director, Bureau of Reclamation, Salt Lake City, Utah
Regional Director, Fish and Wildlife Service, Denver, Colorado
Regional Director, Fish and Wildlife Service, Fish and Wildlife Enhancement, Albuquerque, New Mexico
Field Supervisor, Fish and Wildlife Service, Utah Ecological Services Office, Salt Lake City, Utah

[11] From: Susan MacMullin 1/29/96 1:15PM (7020 bytes: 1 ln)
To: Joe Mazzoni, Jennifer FowlerPropst
Subject: Draft note to Susan McMullen - 1/26 meeting w/ Navajo
---------------------------------- Forwarded ----------------------------------
From: Jamie Clark at 9AR~MAIN 1/29/96 6:48AM (6779 bytes: 1 ln)
To: Nancy Kaufman at 2AL~MAIN, Susan MacMullin at 2AL~MAIN
Subject: Draft note to Susan McMullen - 1/26 meeting w/ Navajo
---------------------------- Forwarded with Changes ----------------------------
From: Laverne Smith at 9AR~FWE1 1/28/96 12:34PM (5970 bytes: 103 ln)
To: Jamie Clark at 9AR~MAIN
Subject: Draft note to Susan McMullen - 1/26 meeting w/ Navajo
------------------------------- Message Contents -------------------------------

TO: Nancy and Susan
FROM: Mary Bates

Notes from Jamie's Jan. 26 meeting with the Navajo Agricultural Products Industry (NAPI)

Present at the meeting were:

Ferdinand Notah, Chief Financial Officer, NAPI
LoRenzo Bates, General Manager, NAPI
Jo'e Nakai, Legislative Associate, Navajo Nation Washington Office
Dwayne Yazyie (spelling ?), representing Navajo farmers
Jamie Clark, Assistant Director - Ecological Services
LaVerne Smith, Chief - Division of Endangered Species
Mary Bates, Division of Endangered Species

Two main issues were presented.

1) Mr. Notah spoke for the Navajos. He handed out a report called "Fiscal Year 1996 and 1997 Appropriations Request, Navajo Indian Irrigation Project, January 23, 1996" which was presented to Congress this week to secure appropriations for the NIIP from Congress.

There has been a new development in one of the projects in the NIIP. BIA is currently consulting with the Service on Block 8 of the NIIP. Concerns have been raised concerning the presence of selenium in the return water flow into the river. As a solution to the selenium problem, BIA has proposed a reservoir to divert, dilute and filter the selenium-laden water, and then pipe the improved water onto nearby agricultural fields as irrigation. This would keep the selenium contaminated water localized within the reservoir and the project area. To compensate for the resulting water loss, BIA proposed to release a comparable amount of clean water back into the river.

The proposed reservoir would cost $8 million. How will it be funded ? Through Congressional appropriation. The NAPI would have to take $8 million of their appropriations, and is expecting the BIA to include the remaining dollars in their 1997 appropriation request to Congress. NAPI wants the construction schedule moved up to coincide with their plans to build a french fry factory within the project boundary. The factory would get its water from the reservoir.

NAPI concerns: if the reservoir is not built, then the selenium contamination would force delay or end of their plans. NAPI wants to complete the reservoir with 1997 and 1998 funds. $4 million in 1997 and the remaining $4 million in 1998. BIA is currently consulting with the Service's Albuquerque Regional Office. The Section 7 consultation needs to be finished for Blocks 7 and 8. Will the consultation be accomplished under the existing consultation for Blocks 1 through 6 ? or does there need to be a separate consultation for Blocks 7 through 11 ?

San Juan Recovery Implementation Program: a committee has been set up to implement the Program. The local Service offices has reduced their participator dollars. NAPI wants the Service to consider increasing funding back to previous levels. Jamie explained the current funding crisis of the endangered species program and why we had to reduce our funding (Congressional cut backs, furloughs.) She promised to pass along to Nancy the concerns and expresssed our hope to be back up to better funding levels and full participation soon. Jamie suggested that the NAPI pay Nancy a visit in person to brief on NAPI concerns.

The development of Blocks 9 through 11 is planned. BIA may initiate consultation with the Service this year for Blocks 9 through 11. NAPI needs development Block 9 started before they can go ahead with making any plans for the rest of the remaining Blocks.

2) Dwayne Yazyie spoke about an issue of serious concern to the Navajo family farmers along the San Juan River. He presented a report called "A Proposal to Obtain $600,000 for A Permanent Design and Construction for the Navajo Nation's San Jaun River Diversion Dams." Earthern dams have been built under the 7 year study required by the Animas-LaPlata. Unfortunately, the flow rates required under Animas-LaPlata have washed out the Navajo farmer's earthern dams every

Spring. They need the dams to retain water for their crops. This is especially critical in the late summer and fall.

They have met with Ms. Russell in the BIA Assistant Secretary's office on

this issue. The squawfish is considered a trash fish to the Navajos. Is the survival of 7 to 9 fish more important than the survival of the Navajo families ? (their comment, not ours) Navajos have previously talked with the Service and BIA about this.
Jamie promised to share their concerns with our Regional Office for inclusion in the ongoing discussions on the San Juan River Implementation Plan.

A copy of both reports will be mailed to you.

Nancy/Susan:

the discussion on consultation on NIIP may be a bit garbled but the main point is the clearance of the reservoir construction to dilute out the selenium. Also, it will support construction of a French Fry factory within the project boundaries.

I strongly urged them to meet with you guys in Albq. Nancy, you may remember meeting them last year in here when they were on the annual

Congressional funding trip. Hopefully, you will hear from them soon.

JRC

UNITED STATES
DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
Ecological Services
Suite D, 3530 Pan American Highway, NE
Albuquerque, New Mexico 87107

✓ Fowler-Propst 5/21/92
Donahoo
Adornato
Burton
A. Cully
B. Cully
Gorresen
Hamilton-McLean
Hanson
Mullins
Orms
Roehm
Roy
Shomo
Ward
File 92-F-080

May 19, 1992

Cons. ~~#2-22-92-F-080~~

Memorandum

To: Area Director, Bureau of Indian Affairs, Navajo Area Office, Gallup, New Mexico

From: Field Supervisor, Fish and Wildlife Service, New Mexico Ecological Services Office, Albuquerque, New Mexico

Subject: Formal Section 7 Consultation - Navajo Indian Irrigation Project, Blocks 9 through 11

As per your request of December 11, 1991, formal section 7 consultation for the proposed action of construction and operation of Blocks 9 through 11 of the Navajo Indian Irrigation Project has been re-initiated. Also per your request of December 11, 1991, the consultation has been extended until such time as sufficient information is developed to allow determination of the requirements of the endangered fish to a level required for the completion of the biological assessment for the proposed action. The attached study proposal concerning the assessment of inorganic effects on early life stages of flannelmouth sucker may provide some of the data necessary for your ultimate preparation of the biological assessment. It is forwarded for your review and consideration in meeting the requirements you may have in gathering information for the ongoing and extended formal consultation.

Should you have any questions, or require further information, please do not hesitate to contact this office at (505) 883-7877 or Dr. Steven J. Hamilton at the National Fisheries Contaminant Research Center Field Research Station at (605) 665-9217.

Gerald T. Burton for
Jennifer Fowler-Propst

Attachment

cc: (w/o atch)
Dr. Steve Hamilton, Fish and Wildlife Service, National Fisheries Contaminant Research Center, Field Research Station, Yankton, South Dakota
Leader, Fisheries Assistance Office, Fish and Wildlife Service, Dexter, New Mexico
Assistant Regional Director, Fish and Wildlife Enhancement, Fish and Wildlife Service, Albuquerque, New Mexico

PROPOSAL

Assessment of inorganic effects on early life stages of flannelmouth sucker (*Catostomus laptipinnis*)

Submitted to

Bureau of Indian Affairs
United States Department of Interior
Regional Office
Albuquerque, New Mexico

by

National Fisheries Contaminant Research Center
Field Research Station
RR 1 Box 295
Yankton, South Dakota 57078-9214

and

New Mexico Ecological Services Office
Suite D, 3530 Pan American Highway, NE
Albuquerque, New Mexico 87107

Fish and Wildlife Service
United States Department of Interior

I. Introduction

Since the discovery of contaminated irrigation return waters in the San Joaquin Valley of Central California in 1982 (Ohlendorf et al. 1986, Saiki 1986), the Department of Interior (DOI) initiated a program to identify other areas in the western U.S. that have water quality problems induced by irrigation drainage. These investigations have been conducted by scientists from the U.S. Geological Survey, U.S. Fish and Wildlife Service, and U.S. Bureau of Reclamation, and focused on irrigation projects constructed or managed by DOI, where the receiving water was a national refuge or has the potential to impact migratory birds or endangered species. The San Juan River basin located in southwestern Colorado and northwestern New Mexico was identified as one area needing further study.

The San Juan River basin is situated on the Colorado Plateau and flows into the Colorado River near Rainbow Bridge National Monument, Utah. Four DOI sponsored projects (Navajo Indian Irrigation, Hammond, Fruitland, and Hogback) contribute surface and subsurface irrigation return flows to tributaries of the San Juan River, backwater wetlands, and artificial wetlands. Return flows from four private acequias that have been rehabilitated by funding from the U.S. Army Corps of Engineers (Farmers Mutual, Jewett Valley, Eledge, and Twin Rocks) and discharge similar irrigation return flows as DOI projects to backwater habitats adjacent to the San Juan and Animas Rivers. In 1983 about 3,400 acres were irrigated in San Juan County. The Hammond project includes 3,900 acres, the Fruitland project 3,700, the Hogback project 8,900, and the Navajo Indian Irrigation Project 100,000 acres when completed (USGS et al. 1989). The expected quantity of irrigation return flow, particularly the Navajo Indian Irrigation Project, is very significant and will comprise about

15% of the annual flow of the San Juan River (USGS et al. 1989).

Coal-fired power production along the San Juan River may also be contributing elevated concentrations of trace elements to the river. The Arizona Public Service's Four-Corners Power Plant and the Public Service Company of New Mexico's San Juan River Plant are located on the river. Particulate fallout from the plants and blow-down water from Morgan Lake, the Four-Corners Plant cooling reservoir, are released to the San Juan River via the Chaco River. High concentrations of dissolved selenium, chromium, and aluminum, and total concentrations of iron, manganese, copper, lead, zinc, silver, cadmium, mercury, and arsenic have been reported in the San Juan River drainage (USBR 1980, USBLM 1984).

Following the release of information about elevated trace element concentrations in the San Juan River basin by USBR (1980) and USBLM (1984), the USFWS undertook an Environmental Contaminant Biomonitoring Program along the San Juan and Animas Rivers in 1984 (O'Brien 1987). The results of that study indicated elevated selenium concentrations in fish and birds were of particular concern because some samples were as high as any in the National Contaminant Biomonitoring Program.

A recent analysis of water and biological tissue collected from the San Juan River basin have confirmed the presence of selenium and other trace elements at concentrations that could be potentially harmful to fish and wildlife (Roy, personal communication 1991).

The San Juan River provides sensitive habitats for two endangered fish species, Colorado squawfish (Ptychocheilus lucius) and razorback sucker (Xyrauchen texanus). These species are listed under the provisions of the Endangered Species Act of 1973 (USFWS 1974, USFWS 1991). Although the San

Juan River Seven-Year Research Plan places emphasis on Colorado squawfish, bonytail, roundtail chub, and razorback sucker, the Plan has as its overall goal the development of a strategy to conserve the native fish fauna of the river (USBR et al. 1992). An important endemic food fish for these endangered species is the flannelmouth sucker (Catostomus laptipinnis). This sucker is apparently abundant in the San Juan River (Platania 1990). Nevertheless, the flannelmouth sucker has been listed as a category 2 species, i.e., listing as endangered or threatened is possibly appropriate (Federal Register 1991).

In the Colorado Squawfish Recovery Plan, environmental contaminants have been identified as a potential threat to the recovery of the species (USFWS 1990). Likewise, contaminants may be adversely affecting other fish species in the San Juan River. Preliminary information from the DOI irrigation drainwater survey found that selenium and other trace elements concentrations in irrigation return flows may be elevated sufficiently enough to cause adverse effects in native fish fauna in the San Juan River (Table 1; Blanchard, personal communication 1991).

Based on acute toxicity data, Colorado squawfish and razorback suckers may be at risk to several waterborne trace elements found at elevated concentrations in the DOI study. Hatchery-supplied Colorado squawfish and razorback suckers have been used in acute toxicity tests to determine their sensitivity to two forms of selenium and five other trace elements (Table 2; Hamilton, personal communication 1991). Survival was recorded in the tests, and was used to calculate 96-hour LC50 values (concentration that kills 50% of the test animals in a 96-hour exposure). Comparing these biological effect concentrations (i.e., 96-hour LC50) with environmental concentrations such as that found in the DOI study results in moderate margins of safety (biological effects concentration ÷ expected environmental concentrations) for several inorganics in irrigation drainwater and backwaters of the San Juan River (Table 3). Margins of safety, based on acute toxicity data, of >5000 indicate low hazard, 100-1000 indicate moderate hazard, and <100 indicate high hazard (Cairns et al. 1978). Because of the low accuracy of acute toxicity tests for identifying important biological effects at sublethal toxicant concentrations, these moderate margins of safety indicate that additional research is needed to more accurately identify sublethal waterborne effects on Colorado squawfish and razorback suckers.

Equally important, these preliminary results showed a difference in sensitivity among the three species tested. Razorback suckers, 0.9 g and 2.0 g in size, were about 10-fold more sensitive to selenate than Colorado squawfish and bonytail. Consequently, there may be other native species with equal or greater sensitivities than razorback suckers.

This research proposal is designed to determine the biological effects on the flannelmouth sucker of exposure to selenium and other prominent inorganics associated with irrigation return flows in the San Juan River.

II. Scope of Research

The National Fisheries Contaminant Research Center (Yankton Field Research Station, Yankton, SD), and the New Mexico Ecological Services Office (Albuquerque, NM) have developed the following research proposal to address potential impacts of irrigation drain waters on flannelmouth sucker in the San Juan River. The continued quality of this habitat is essential to the conservation of native fishes in the San Juan River. The proposal is designed to provide data to the U.S. Bureau of Indian Affairs and the Bureau of Reclamation so that they can evaluate various management alternatives for disposal of drain waters and minimize impacts on these fisheries. The research thrust emphasizes toxicological assessment of elevated inorganic contaminants in the San Juan River on survival of flannelmouth suckers, and assessment of the hazard of the inorganics to the fish.

The toxicological research will determine the acute toxicity of waterborne cadmium, copper, chromium, boron, lead, lithium, mercury, selenate, selenite, uranium, vanadium, and zinc to flannelmouth sucker. The studies will focus on survival of sensitive early life stages, and will include tests with individual inorganics and with environmentally relevant mixtures. The design will incorporate a water quality that simulates the San Juan River.

This joint research effort will be coordinated with the FWS' Fisheries Assistance Office, Dexter, NM, whose personnel will spawn wild-caught fish collected from the San Juan River in conjunction with other fisheries activities.

Information from these studies will expand the data base to provide information needed by the U.S. Bureau of Reclamation and Bureau of Indian Affairs in managing the disposal of irrigation return flows with elevated inorganic concentrations.

III. Study Plan

Task 1. Toxicological Assessment of the Effects of Waterborne Inorganics on Flannelmouth Suckers in the San Juan River

1) Introduction

In recent years, high concentrations of inorganics have been found in the San Juan River and its backwaters. These high concentrations are seemingly high enough to cause incidences of mortality and abnormalities among fish. The impact of inorganic-laden irrigation return flow water on associated fisheries and aquatic ecosystems of the San Juan River needs to be addressed adequately before biological assessments can be expressed concerning irrigation management practices or expansion of irrigation projects.

Information is needed on the sublethal effects of direct, acute exposures of waterborne inorganics found in irrigation return water to native flannelmouth suckers that inhabit the San Juan River. Adverse impacts could occur in sensitive early life stages, which are generally considered to be the most sensitive life stage (Rand and Petrocelli 1985).

To derive the necessary toxicological information for linking waterborne inorganic exposure to adverse biological effects in native fish of the San Juan River, it is essential that toxicity tests be conducted in accordance with accepted procedures adapted from EPA and ASTM protocols. Using actual drain water in toxicological studies has severe shortcomings because the water quality of the drain water varies due to location and time of year. There is a need to establish standardized test waters that would simulate irrigation drain water and the receiving waters. There are considerable advantages to using standardized water qualities in these toxicological investigations:

a. If multiple studies are needed to adequately evaluate the components of the irrigation water, the use of standardized waters would provide uniformity and consistency in the toxicity data bases throughout the duration of the studies.

b. Various concentrations of drain water representing "average seasonal", "worst case" and "best case" irrigation return flow situations, as well as specific resource contamination situations, could be simulated in the laboratory which are not possible with using actual drain water from periodic or seasonal samplings.

c. It is more economical to conduct well-controlled laboratory studies using standardized waters because the multiple water quality variables that must be addressed in using actual drain water in either laboratory or field investigations would result in more complex experimental designs, especially when attempting to establish "safe" concentrations of toxic components of drain water.

d. Well-controlled laboratory toxicity studies using standardized waters are more reproducible and generally more acceptable by state and federal regulatory agencies in establishing "safe" exposure concentrations of toxic chemicals to aquatic species, especially if on-site field toxicity studies are subsequently conducted to confirm laboratory assessments.

e. Water quality characteristics, such as pH, hardness, sulfate, etc., can influence the toxicity of inorganics to fish, especially early life stages, which are generally more sensitive than older fish. It is essential that studies with early life stages be conducted with site-specific water qualities that simulate as closely as possible realistic environmental conditions.

The criteria for developing a standardized drain water will be developed from USGS and USBR information. Likewise, the proposed receiving waters that would serve as dilution water in studies should be characterized as to their various qualities and standardized for water quality and other constituents. Thus, the standardized drain water and standardized receiving water would be based upon actual analytical measurements by USGS and other organizations for water quality measurements such as alkalinity, hardness, calcium, magnesium, sulfate, chloride, conductivity, etc., as well as a consideration for flow rates of drain and receiving waters and mixing zones in receiving waters.

The use of site-specific, reconstituted exposure waters in aquatic toxicological investigations has gained considerable acceptance over the past several years, and is currently being used not only by the National Fisheries Contaminant Research Center (NFCR) but many other aquatic toxicology laboratories. For example, NFCR's Field Research Station, Yankton, SD, has been conducting toxicological studies to determine the impacts of contaminants and contaminant mixtures associated with the San Luis Drain/Kesterson Reservoir selenium contamination problem in California on chinook salmon. Results from those investigations demonstrated that no single waterborne contaminant was causing significant mortality in early life stages of chinook salmon, but that combinations of chemical contaminants could adversely effect survival. In these laboratory toxicity studies the water quality of the San Luis Drain, San Joaquin River, as well as the water quality of saline environments in the Chipps Island Estuary and 28 ppthousand sea water, were simulated in the laboratory and used as exposure water in both acute and chronic toxicity investigations with early life stages of salmon (Hamilton et al. 1989, Hamilton and Buhl 1990). In these investigations the toxicity and bioaccumulation of aquatic contaminants were assessed under environmentally realistic exposure water conditions.

The NFCR's Field Research Station, Yankton, SD, has the capability, expertise, and experience in conducting acute and chronic toxicity studies with reconstituted exposure water that simulates resource contaminant problems. This experience and capability will be valuable in establishing a standardized exposure water that simulates irrigation return water and San Juan River water.

2) Objective

To determine the acute toxicity of waterborne inorganics to early life stages of flannelmouth suckers in a water quality simulating the San Juan River.

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Wild fish will be collected from the San Juan River and spawned by personnel of the Fisheries Assistance Office (Dexter, NM) while conducting other fisheries activities. Fertilized eggs will be shipped by overnight delivery service to the Yankton FRS, SD. Upon arrival at Yankton, an aliquant of eggs will be collected for residue analysis to determine background concentrations of the inorganics that will be used in toxicity testing.

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The acute toxicity studies will be conducted with early life stages of flannelmouth suckers exposed to concentrations of waterborne inorganics for 96 hours according to standard methods (Committee on Methods for Toxicity Tests with Aquatic Organisms 1975). Fish will be exposed to either individual inorganics and to environmentally relevant mixtures. Inorganics that will be tested include cadmium, copper, chromium, boron, lead, lithium, mercury, selenate, selenite, uranium, vanadium, and zinc. Test temperature will be maintained within 1°C of the desired temperature.

The exposures will be started with early life stages of flannelmouth suckers. Ten fish each will be placed in separate 3.9-L or 19.6-L glass jars containing either 3L or 15L of reconstituted water. Eight waterborne toxicant concentrations and a control treatment will be used in each test. The waterborne exposures are based on a 60% dilution factor between concentrations.

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Dilution water (San Juan River water quality) will be prepared by addition of synthetic sea salts, well water, and other appropriate additives (e.g., calcium sulfate, magnesium sulfate, calcium chloride, sodium bicarbonate) to ultra-pure water prepared by reverse osmosis. The reconstituted dilution water will reflect the water quality of the natural counterparts in terms of salinity, hardness, alkalinity, and other parameters. The dilution waters will be analyzed using standard methods (APHA et al. 1975) to insure that water quality meets the criteria of the experimental design in terms of hardness, alkalinity, and concentrations of major cations (calcium, magnesium) and anions (chloride, sulfate).

IV. Results and Interpretation

A final written report will be prepared. Analytical and observational data generated from this study will allow the Fish and Wildlife Service to determine if concentrations of inorganics found in the San Juan River fish populations have the potential to create a significant threat to the survival of early life stages of flannelmouth suckers.

V. Roles and Responsibilities

The Environmental Contaminant Specialist from the New Mexico Ecological Services Office (NMESO) and Leader of the National Fisheries Contaminant Research Center's Field Research Station (NFCR-FRS) in Yankton, SD will be responsible for managing, scheduling, and reporting project accomplishments and tracking of project funds. The Leader of the NFCR-FRS will be the principal investigator for this toxicological assessment study plan.

VI. Schedule

The toxicological assessment study will begin in June 1992 and will terminate in December 1992. A final report will be submitted 2 months after completion of the study.

VII. Reports and Publications

The NFCR-FRS in cooperation with NMESO will publish a final report. One report will be submitted for publication in peer reviewed journals or presented at professional meetings by the NFCR-FRS.

VIII. Budget

Supplies	$ 6,000
Equipment	3,000
Analytical	1,000
Salaries	17,000
(Contributed salaries)	(12,600)
Travel	1,000
Total	$28,000

IX. Literature Cited

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Table 1. Maximum inorganic concentrations ($\mu g/L$) measured in water samples collected as part of the DOI Reconnaissance Investigation in San Juan County, NM.

Inorganic	Irrigation project drains	San Juan River backwaters	San Juan River
Boron	540	480	70
Uranium	87	21	6
Selenium	67	4	2
Arsenic	48	1	1
Copper	32	12	8
Vanadium	27	9	2
Zinc	20	10	13
Molybdenum	15	6	2
Lead	12	1	1
Chromium	3	3	2
Cadmium	2	1	1
Mercury	0.2	0.2	0.2

Source: P. Blanchard, USGS, Albuquerque, NM.

Table 2. Acute toxicity (96-h LC50s, mg/L; 95% confidence intervals in parentheses) of selected inorganics to early life stages of bonytail chub, Colorado squawfish, and razorback sucker tested in reconstituted middle Green River basin water at 25°C.

	Bonytail chub			Colorado squawfish			Razorback sucker		
Inorganic	Swim-up fry	1.1g juveniles	2.6g juveniles	Swim-up fry	0.4-1.1g juveniles	1.7g juveniles	Swim-up fry	0.9g juveniles	2.0g juveniles
Vanadium	4.9 (3.6-6.5)	2.2 (1.7-2.8)	5.1 (4.0-6.3)	7.8 (4.7-13.0)	3.8 (3.1-4.7)	4.2 (2.8-4.7)	8.7 (6.7-11.2)	4.0 (2.8-4.7)	3.2 (1.7-4.7)
Zinc	4.1 (2.7-7.0)	5.8 (4.6-7.2)	23 (13-36)	1.7 (1.0-5.1)	4.2 (2.8-4.7)	12 (10-16)	4.0 (2.8-4.7)	6.4 (4.7-7.8)	15 (11-20)
Selenite	18 (13-22)	17 (13-22)	15 (8-22)	14 (11-17)	36 (22-60)	31 (22-36)	15 (12-19)	9.2 (4.7-13.0)	16 (13-22)
Lithium	22 (13-36)	61 (49-76)	64 (49-83)	17 (13-22)	28 (22-36)	42 (22-60)	25 (21-31)	58 (45-76)	184 (130-285)
Uranium	46 (36-60)	46 (36-60)	46 (36-60)	46 (36-60)	46 (36-60)	46 (36-60)	46 (36-60)	46 (36-60)	46 (36-60)
Selenate	55 (44-67)	254 (130-360)	216 (172-273)	67 (53-83)	297 (237-422)	320 (216-360)	48 (39-60)	35 (23-49)	26 (19-33)
Boron	279 (232-335)	>100	534 (360-600)	279 (216-360)	>100	511 (360-600)	254 (130-360)	279 (216-360)	>100

Table 3. Tentative hazard assessment of inorganics measured in the DOI Reconnaissance Investigation in San Juan County, NM. Hazard values are derived by dividing the biological effect concentration (i.e., 96-hour LC50 for the approximate average of values for the three species and three life stages is given in Table 1) by the expected environmental concentration (as reported in the DOI study and given in Table 2).

Inorganic	Irrigation project drains	San Juan River backwaters	San Juan River
V	148	555	2,500
Se^{+4}	224	3,750	7,500
Se^{+6}	746	12,500	25,000
Zn	200	400	308
U	529	2,190	8,364
B	519	583	4,000

Based on acute data: >5000 -- low hazard, 100-1000 -- moderate hazard, and <100 -- high hazard (modified from Cairns et al. 1978).

United States Department of the Interior

Fish and Wildlife Service
National Fisheries Contaminant Research Center

Field Research Station
RR 1 Box 295
Yankton, South Dakota 57078-9214

Commercial No: 605-665-9217 FAX No: 605-665-9335 FTS No: 751-9217

TAKE PRIDE IN AMERICA

Fowler-Propst 5/15/92
Donahoo 5/14/92
Adornato
Burton
A. Cully
B. Cully
Gorrsen
Hamilton-McLean
Hanson
Mullins
Orms
Boehm
Roy
Shomo
Ward

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MAY 14 '92

May 13, 1992

MEMORANDUM

TO: Jennifer Fowler-Propst, Field Supervisor
NMESO, Albuquerque, NM

FROM: Leader, NFCR Field Research Station, Yankton, SD

SUBJECT: Proposal to Evaluate the Effects of Prominent Inorganics in the San Juan River on Flannelmouth Suckers

Attached for your review is the subject proposal. The proposal was prompted from a discussion, primarily with Jim Brooks, at the March 24 meeting in Albuquerque concerning fishery research activities on the San Juan River. I confirmed with Jim today that he is confident flannelmouth suckers can be collected and spawned in mid-June to supply the necessary eggs for this research. Next year, I will prepare a proposal to conduct similar research with two additional fish, bluehead sucker and roundtail chub. All three species were recommended for toxicological assessment by fisheries researchers at the March 24, 1992, and December 10-11, 1991, meetings.

If this proposal is acceptable to you, please submit it to the BIA or whatever agency you think should be responsible for funding it.

If you have any questions or suggestions for improving the proposal, please do not hesitate to contact me.

Steven J. Hamilton
Steven J. Hamilton

kkf
cc: Leader, Fisheries Assistance Office, Dexter, NM (w/attachment)
Assistant Chief, NFCR, Columbia, MO (w/attachment)

PROPOSAL

Assessment of inorganic effects on early life stages of flannelmouth sucker (Catostomus laptipinnis)

Submitted to

Bureau of Indian Affairs
United States Department of Interior
Regional Office
Albuquerque, New Mexico

by

National Fisheries Contaminant Research Center
Field Research Station
RR 1 Box 295
Yankton, South Dakota 57078-9214

and

New Mexico Ecological Services Office
Suite D, 3530 Pan American Highway, NE
Albuquerque, New Mexico 87107

Fish and Wildlife Service
United States Department of Interior

I. Introduction

Since the discovery of contaminated irrigation return waters in the San Joaquin Valley of Central California in 1982 (Ohlendorf et al. 1986, Saiki 1986), the Department of Interior (DOI) initiated a program to identify other areas in the western U.S. that have water quality problems induced by irrigation drainage. These investigations have been conducted by scientists from the U.S. Geological Survey, U.S. Fish and Wildlife Service, and U.S. Bureau of Reclamation, and focused on irrigation projects constructed or managed by DOI, where the receiving water was a national refuge or has the potential to impact migratory birds or endangered species. The San Juan River basin located in southwestern Colorado and northwestern New Mexico was identified as one area needing further study.

The San Juan River basin is situated on the Colorado Plateau and flows into the Colorado River near Rainbow Bridge National Monument, Utah. Four DOI sponsored projects (Navajo Indian Irrigation, Hammond, Fruitland, and Hogback) contribute surface and subsurface irrigation return flows to tributaries of the San Juan River, backwater wetlands, and artificial wetlands. Return flows from four private acequias that have been rehabilitated by funding from the U.S. Army Corps of Engineers (Farmers Mutual, Jewett Valley, Eledge, and Twin Rocks) and discharge similar irrigation return flows as DOI projects to backwater habitats adjacent to the San Juan and Animas Rivers. In 1983 about 3,400 acres were irrigated in San Juan County. The Hammond project includes 3,900 acres, the Fruitland project 3,700, the Hogback project 8,900, and the Navajo Indian Irrigation Project 100,000 acres when completed (USGS et al. 1989). The expected quantity of irrigation return flow, particularly the Navajo Indian Irrigation Project, is very significant and will comprise about

15% of the annual flow of the San Juan River (USGS et al. 1989).

Coal-fired power production along the San Juan River may also be contributing elevated concentrations of trace elements to the river. The Arizona Public Service's Four-Corners Power Plant and the Public Service Company of New Mexico's San Juan River Plant are located on the river. Particulate fallout from the plants and blow-down water from Morgan Lake, the Four-Corners Plant cooling reservoir, are released to the San Juan River via the Chaco River. High concentrations of dissolved selenium, chromium, and aluminum, and total concentrations of iron, manganese, copper, lead, zinc, silver, cadmium, mercury, and arsenic have been reported in the San Juan River drainage (USBR 1980, USBLM 1984).

Following the release of information about elevated trace element concentrations in the San Juan River basin by USBR (1980) and USBLM (1984), the USFWS undertook an Environmental Contaminant Biomonitoring Program along the San Juan and Animas Rivers in 1984 (O'Brien 1987). The results of that study indicated elevated selenium concentrations in fish and birds were of particular concern because some samples were as high as any in the National Contaminant Biomonitoring Program.

A recent analysis of water and biological tissue collected from the San Juan River basin have confirmed the presence of selenium and other trace elements at concentrations that could be potentially harmful to fish and wildlife (Roy, personal communication 1991).

The San Juan River provides sensitive habitats for two endangered fish species, Colorado squawfish (Ptychocheilus lucius) and razorback sucker (Xyrauchen texanus). These species are listed under the provisions of the Endangered Species Act of 1973 (USFWS 1974, USFWS 1991). Although the San

Juan River Seven-Year Research Plan places emphasis on Colorado squawfish, bonytail, roundtail chub, and razorback sucker, the Plan has as its overall goal the development of a strategy to conserve the native fish fauna of the river (USBR et al. 1992). An important endemic food fish for these endangered species is the flannelmouth sucker (Catostomus laptipinnis). This sucker is apparently abundant in the San Juan River (Platania 1990). Nevertheless, the flannelmouth sucker has been listed as a category 2 species, i.e., listing as endangered or threatened is possibly appropriate (Federal Register 1991).

In the Colorado Squawfish Recovery Plan, environmental contaminants have been identified as a potential threat to the recovery of the species (USFWS 1990). Likewise, contaminants may be adversely affecting other fish species in the San Juan River. Preliminary information from the DOI irrigation drainwater survey found that selenium and other trace elements concentrations in irrigation return flows may be elevated sufficiently enough to cause adverse effects in native fish fauna in the San Juan River (Table 1; Blanchard, personal communication 1991).

Based on acute toxicity data, Colorado squawfish and razorback suckers may be at risk to several waterborne trace elements found at elevated concentrations in the DOI study. Hatchery-supplied Colorado squawfish and razorback suckers have been used in acute toxicity tests to determine their sensitivity to two forms of selenium and five other trace elements (Table 2; Hamilton, personal communication 1991). Survival was recorded in the tests, and was used to calculate 96-hour LC50 values (concentration that kills 50% of the test animals in a 96-hour exposure). Comparing these biological effect concentrations (i.e., 96-hour LC50) with environmental concentrations such as that found in the DOI study results in moderate margins of safety (biological effects concentration ÷ expected environmental concentrations) for several inorganics in irrigation drainwater and backwaters of the San Juan River (Table 3). Margins of safety, based on acute toxicity data, of >5000 indicate low hazard, 100-1000 indicate moderate hazard, and <100 indicate high hazard (Cairns et al. 1978). Because of the low accuracy of acute toxicity tests for identifying important biological effects at sublethal toxicant concentrations, these moderate margins of safety indicate that additional research is needed to more accurately identify sublethal waterborne effects on Colorado squawfish and razorback suckers.

Equally important, these preliminary results showed a difference in sensitivity among the three species tested. Razorback suckers, 0.9 g and 2.0 g in size, were about 10-fold more sensitive to selenate than Colorado squawfish and bonytail. Consequently, there may be other native species with equal or greater sensitivities than razorback suckers.

This research proposal is designed to determine the biological effects on the flannelmouth sucker of exposure to selenium and other prominent inorganics associated with irrigation return flows in the San Juan River.

II. Scope of Research

The National Fisheries Contaminant Research Center (Yankton Field Research Station, Yankton, SD), and the New Mexico Ecological Services Office (Albuquerque, NM) have developed the following research proposal to address potential impacts of irrigation drain waters on flannelmouth sucker in the San Juan River. The continued quality of this habitat is essential to the conservation of native fishes in the San Juan River. The proposal is designed to provide data to the U.S. Bureau of Indian Affairs and the Bureau of Reclamation so that they can evaluate various management alternatives for disposal of drain waters and minimize impacts on these fisheries. The research thrust emphasizes toxicological assessment of elevated inorganic contaminants in the San Juan River on survival of flannelmouth suckers, and assessment of the hazard of the inorganics to the fish.

The toxicological research will determine the acute toxicity of waterborne cadmium, copper, chromium, boron, lead, lithium, mercury, selenate, selenite, uranium, vanadium, and zinc to flannelmouth sucker. The studies will focus on survival of sensitive early life stages, and will include tests with individual inorganics and with environmentally relevant mixtures. The design will incorporate a water quality that simulates the San Juan River.

This joint research effort will be coordinated with the FWS' Fisheries Assistance Office, Dexter, NM, whose personnel will spawn wild-caught fish collected from the San Juan River in conjunction with other fisheries activities.

Information from these studies will expand the data base to provide information needed by the U.S. Bureau of Reclamation and Bureau of Indian Affairs in managing the disposal of irrigation return flows with elevated inorganic concentrations.

III. Study Plan

Task 1. Toxicological Assessment of the Effects of Waterborne Inorganics on Flannelmouth Suckers in the San Juan River

1) Introduction

In recent years, high concentrations of inorganics have been found in the San Juan River and its backwaters. These high concentrations are seemingly high enough to cause incidences of mortality and abnormalities among fish. The impact of inorganic-laden irrigation return flow water on associated fisheries and aquatic ecosystems of the San Juan River needs to be addressed adequately before biological assessments can be expressed concerning irrigation management practices or expansion of irrigation projects.

Information is needed on the sublethal effects of direct, acute exposures of waterborne inorganics found in irrigation return water to native flannelmouth suckers that inhabit the San Juan River. Adverse impacts could occur in sensitive early life stages, which are generally considered to be the most sensitive life stage (Rand and Petrocelli 1985).

To derive the necessary toxicological information for linking waterborne inorganic exposure to adverse biological effects in native fish of the San Juan River, it is essential that toxicity tests be conducted in accordance with accepted procedures adapted from EPA and ASTM protocols. Using actual drain water in toxicological studies has severe shortcomings because the water quality of the drain water varies due to location and time of year. There is a need to establish standardized test waters that would simulate irrigation drain water and the receiving waters. There are considerable advantages to using standardized water qualities in these toxicological investigations:

a. If multiple studies are needed to adequately evaluate the components of the irrigation water, the use of standardized waters would provide uniformity and consistency in the toxicity data bases throughout the duration of the studies.

b. Various concentrations of drain water representing "average seasonal", "worst case" and "best case" irrigation return flow situations, as well as specific resource contamination situations, could be simulated in the laboratory which are not possible with using actual drain water from periodic or seasonal samplings.

c. It is more economical to conduct well-controlled laboratory studies using standardized waters because the multiple water quality variables that must be addressed in using actual drain water in either laboratory or field investigations would result in more complex experimental designs, especially when attempting to establish "safe" concentrations of toxic components of drain water.

d. Well-controlled laboratory toxicity studies using standardized waters are more reproducible and generally more acceptable by state and federal regulatory agencies in establishing "safe" exposure concentrations of toxic chemicals to aquatic species, especially if on-site field toxicity studies are subsequently conducted to confirm laboratory assessments.

e. Water quality characteristics, such as pH, hardness, sulfate, etc., can influence the toxicity of inorganics to fish, especially early life stages, which are generally more sensitive than older fish. It is essential that studies with early life stages be conducted with site-specific water qualities that simulate as closely as possible realistic environmental conditions.

The criteria for developing a standardized drain water will be developed from USGS and USBR information. Likewise, the proposed receiving waters that would serve as dilution water in studies should be characterized as to their various qualities and standardized for water quality and other constituents. Thus, the standardized drain water and standardized receiving water would be based upon actual analytical measurements by USGS and other organizations for water quality measurements such as alkalinity, hardness, calcium, magnesium, sulfate, chloride, conductivity, etc., as well as a consideration for flow rates of drain and receiving waters and mixing zones in receiving waters.

The use of site-specific, reconstituted exposure waters in aquatic toxicological investigations has gained considerable acceptance over the past several years, and is currently being used not only by the National Fisheries Contaminant Research Center (NFCR) but many other aquatic toxicology laboratories. For example, NFCR's Field Research Station, Yankton, SD, has been conducting toxicological studies to determine the impacts of contaminants and contaminant mixtures associated with the San Luis Drain/Kesterson Reservoir selenium contamination problem in California on chinook salmon. Results from those investigations demonstrated that no single waterborne contaminant was causing significant mortality in early life stages of chinook salmon, but that combinations of chemical contaminants could adversely effect survival. In these laboratory toxicity studies the water quality of the San Luis Drain, San Joaquin River, as well as the water quality of saline environments in the Chipps Island Estuary and 28 ppthousand sea water, were simulated in the laboratory and used as exposure water in both acute and chronic toxicity investigations with early life stages of salmon (Hamilton et al. 1989, Hamilton and Buhl 1990). In these investigations the toxicity and bioaccumulation of aquatic contaminants were assessed under environmentally realistic exposure water conditions.

The NFCR's Field Research Station, Yankton, SD, has the capability, expertise, and experience in conducting acute and chronic toxicity studies with reconstituted exposure water that simulates resource contaminant problems. This experience and capability will be valuable in establishing a standardized exposure water that simulates irrigation return water and San Juan River water.

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To determine the acute toxicity of waterborne inorganics to early life stages of flannelmouth suckers in a water quality simulating the San Juan River.

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Wild fish will be collected from the San Juan River and spawned by personnel of the Fisheries Assistance Office (Dexter, NM) while conducting other fisheries activities. Fertilized eggs will be shipped by overnight delivery service to the Yankton FRS, SD. Upon arrival at Yankton, an aliquant of eggs will be collected for residue analysis to determine background concentrations of the inorganics that will be used in toxicity testing.

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IV. Results and Interpretation

A final written report will be prepared. Analytical and observational data generated from this study will allow the Fish and Wildlife Service to determine if concentrations of inorganics found in the San Juan River fish populations have the potential to create a significant threat to the survival of early life stages of flannelmouth suckers.

V. Roles and Responsibilities

The Environmental Contaminant Specialist from the New Mexico Ecological Services Office (NMESO) and Leader of the National Fisheries Contaminant Research Center's Field Research Station (NFCR-FRS) in Yankton, SD will be responsible for managing, scheduling, and reporting project accomplishments and tracking of project funds. The Leader of the NFCR-FRS will be the principal investigator for this toxicological assessment study plan.

VI. Schedule

The toxicological assessment study will begin in June 1992 and will terminate in December 1992. A final report will be submitted 2 months after completion of the study.

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The NFCR-FRS in cooperation with NMESO will publish a final report. One report will be submitted for publication in peer reviewed journals or presented at professional meetings by the NFCR-FRS.

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(Contributed salaries)	(12,600)
Travel	1,000
Total	$28,000

IX. Literature Cited

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Table 1. Maximum inorganic concentrations (μg/L) measured in water samples collected as part of the DOI Reconnaissance Investigation in San Juan County, NM.

Inorganic	Irrigation project drains	San Juan River backwaters	San Juan River
Boron	540	480	70
Uranium	87	21	6
Selenium	67	4	2
Arsenic	48	1	1
Copper	32	12	8
Vanadium	27	9	2
Zinc	20	10	13
Molybdenum	15	6	2
Lead	12	1	1
Chromium	3	3	2
Cadmium	2	1	1
Mercury	0.2	0.2	0.2

Source: P. Blanchard, USGS, Albuquerque, NM.

Table 2. Acute toxicity (96-h LC50s, mg/L; 95% confidence intervals in parentheses) of selected inorganics to early life stages of bonytail chub, Colorado squawfish, and razorback sucker tested in reconstituted middle Green River basin water at 25°C.

	Bonytail chub			Colorado squawfish			Razorback sucker		
Inorganic	Swim-up fry	1.1g juveniles	2.6g juveniles	Swim-up fry	0.4-1.1g juveniles	1.7g juveniles	Swim-up fry	0.9g juveniles	2.0g juveniles
Vanadium	4.9 (3.6-6.5)	2.2 (1.7-2.8)	5.1 (4.0-6.3)	7.8 (4.7-13.0)	3.8 (3.1-4.7)	4.2 (2.8-4.7)	8.7 (6.7-11.2)	4.0 (2.8-4.7)	3.2 (1.7-4.7)
Zinc	4.1 (2.7-7.0)	5.8 (4.6-7.2)	23 (13-36)	1.7 (1.0-5.1)	4.2 (2.8-4.7)	12 (10-16)	4.0 (2.8-4.7)	6.4 (4.7-7.8)	15 (11-20)
Selenite	18 (13-22)	17 (13-22)	15 (8-22)	14 (11-17)	36 (22-60)	31 (22-36)	15 (12-19)	9.2 (4.7-13.0)	16 (13-22)
Lithium	22 (13-36)	61 (49-76)	64 (49-83)	17 (13-22)	28 (22-36)	42 (22-60)	25 (21-31)	58 (45-76)	184 (130-285)
Uranium	46 (36-60)	46 (36-60)	46 (36-60)	46 (36-60)	46 (36-60)	46 (36-60)	46 (36-60)	46 (36-60)	46 (36-60)
Selenate	55 (44-67)	254 (130-360)	216 (172-273)	67 (53-83)	297 (237-422)	320 (216-360)	48 (39-60)	35 (23-49)	26 (19-33)
Boron	279 (232-335)	>100	534 (360-600)	279 (216-360)	>100	511 (360-600)	254 (130-360)	279 (216-360)	>100

Table 3. Tentative hazard assessment of inorganics measured in the DOI Reconnaissance Investigation in San Juan County, NM. Hazard values are derived by dividing the biological effect concentration (i.e., 96-hour LC50 for the approximate average of values for the three species and three life stages is given in Table 1) by the expected environmental concentration (as reported in the DOI study and given in Table 2).

Inorganic	Irrigation project drains	San Juan River backwaters	San Juan River
V	148	555	2,500
Se^{+4}	224	3,750	7,500
Se^{+6}	746	12,500	25,000
Zn	200	400	308
U	529	2,190	8,364
B	519	583	4,000

Based on acute data: >5000 -- low hazard, 100-1000 -- moderate hazard, and <100 -- high hazard (modified from Cairns et al. 1978).

UNITED STATES
DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
Ecological Services
Suite D, 3530 Pan American Highway, NE
Albuquerque, New Mexico 87107

December 26, 1991

Cons. #2-22-92-F-080

File 2-22-92-F-080

Memorandum

To: Area Director, Bureau of Indian Affairs, Navajo Area Office, Gallup, New Mexico

From: Field Supervisor, Fish and Wildlife Service, New Mexico Ecological Services Office, Albuquerque, New Mexico

Subject: Re-initiation of Formal Section 7 Consultation: Navajo Indian Irrigation Project, Blocks 9 through 11

Your request, dated December 11, 1991, for re-initiation of formal Section 7 consultation was forwarded from the Regional Office of the Fish and Wildlife Service and received in this office on December 17, 1991. The proposed action is the construction and operation of Blocks 9 through 11 of the Navajo Indian Irrigation Project (Project) and the addition of those blocks to the agricultural and range operations of the existing Project.

The Bureau of Indian Affairs is participating in ongoing research on water requirements for and water quality impacts to the endangered fish of the San Juan River that may be affected by the proposed action. In order to provide adequate time to gather needed information, we concur with your request that the consultation be extended until such time as sufficient information is developed to allow determination of the requirements of the endangered fish to a level required for the completion of the biological assessment for the proposed action.

All further correspondence on this consultation and the research should be addressed to this office. Please furnish a copy of all correspondence to the Utah Ecological Services Office at the following address.

Field Supervisor
U.S. Fish and Wildlife Service
Utah Ecological Services Office
2060 Administration Building
1745 West 1700 South, Room 2078
Salt Lake City, Utah 84104-5110

We look forward to working with you in this consultation and in the ultimate recovery of the endangered fish species of the San Juan River basin. If you have any questions or require further information, please phone me at (505) 883-7877 or FTS 474-7877.

Jennifer Fowler-Propst

cc:
Regional Director, Bureau of Reclamation, Salt Lake City, Utah
Regional Director, Fish and Wildlife Service, Denver, Colorado
Regional Director, Fish and Wildlife Service, Fish and Wildlife Enhancement, Albuquerque, New Mexico
Field Supervisor, Fish and Wildlife Service, Utah Ecological Services Office, Salt Lake City, Utah

United States Department of the Interior

BUREAU OF INDIAN AFFAIRS
NAVAJO AREA OFFICE
P.O. Box 1060
Gallup, New Mexico 87301

IN REPLY REFER TO:

DEC 11 1991

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Ct 12-18

Memorandum

From: Area Director, Navajo Area, Bureau of Indian Affairs

Subject: Re-initiation of formal consultation in compliance with Section 7 of the Endangered Species Act, Navajo Indian Irrigation Project, Blocks 9 through 11

To: Regional Director, U.S. Fish and Wildlife Service, Albuquerque, New Mexico

This letter constitutes the Bureau of Indian Affairs' official request for re-initiation of a formal consultation in compliance with Section 7 of the Endangered Species Act on the Navajo Indian Irrigation Project, specifically Blocks 9 through 11. The re-initiation of consultation is necessary due to information related to water quality, the listing of new species and the inclusion of the San Juan River as being important to the recovery of the Colorado River Squawfish becoming available since the initial biological opinion issued April 26, 1979.

Consultation has been completed on the first 8 blocks of NIIP. Included in the reasonable and prudent alternative for the first 8 blocks is the irrigation of 76,481 acres including 8,000 acres of conservation reserve acreage and an associated depletion of 149,420 acre-feet per year (afy). The depletion associated with the first 8 blocks can only exceed this amount by acquiring water from other sources to be left in the stream or by re-initiation of consultation.

This consultation is for the irrigation of 32,800 acres in Blocks 9-11, with an associated depletion of 80,046 afy, plus irrigation of 4,343 acres at unspecified locations within the project boundaries to bring the acreage to the full 110,630 acres authorized by Congress. The associated depletion increase on the project under this consultation will be 120,517 afy, including 80,046 afy for Blocks 9-11 and 40,471 afy for Blocks 1-8 to bring the total up to the authorized limit. The attached project description covers the details of the proposed project.

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At this time, it is not possible to complete a biological assessment since the water requirements for and water quality impacts on the endangered fish are not known. The Bureau of Indian Affairs is participating in a 7-year research plan, along with the Bureau of Reclamation, U.S. Fish and Wildlife Service and others, designed to produce the information required to allow completion of the biological assessment and better determine the requirements of the endangered fish. We request that this consultation be extended until such time as sufficient information is developed to allow determination of the requirements of the endangered fish to a level sufficient for the completion of the biological assessment.

Since delivery of water to the Navajo Indian Irrigation Project involves operation of Navajo Dam by the Bureau of Reclamation and any modification to reservoir operation as a result of this consultation would involve the Bureau of Reclamation, we may also request their participation in this consultation at the time sufficient information is available to move forward. However, the Bureau of Indian Affairs will be lead agency.

We are looking forward to working closely with you on this consultation. Please feel free, until further notice, to contact our consultant, Mr. Ron Bliesner of Keller-Bliesner Engineering, for any technical information and for coordination of the consultation process. Please address all formal correspondence concerning this consultation to me at the above address.

Walter K. Mills

Copy to:

Ron Bliesner, Keller-Bliesner Engineering, Logan, Utah
Joe Little, Rights Protection, BIA Albuquerque Area Office
Leo Soukup, BIA-NIIP, Farmington, NM

Legend

- Canals
- Highways/Roads
- Streams/Rivers
- Field Boundaries
- 0-0 Observation Wells
- Project Outline

REV	Revisions	Date	Design	Draw	Check

Status:	Draft
Designed	RDB
Drawn	MJL
Checked	RDB
Approved	
File Name:	NIIP-SPNAD27.dwg

12000 0 12000 24000 36000
SCALE - feet

Coordinate System: State Plane - New Mexico West (NAD 27)
Datum: USGS MSL
Survey Data Source: Digitized 7.5 min Topo Maps & USGS DLG

Keller-Bliesner Engineering
Irrigation & Water Resources
78 E. Center
Logan, Utah 84321

Navajo Indian Irrigation Project
Irrigation Impact Analysis
Project Layout

Job No. ###-##
Date: 12/11/98
Sheet 1 of 4
PLATE NO. 1
REV