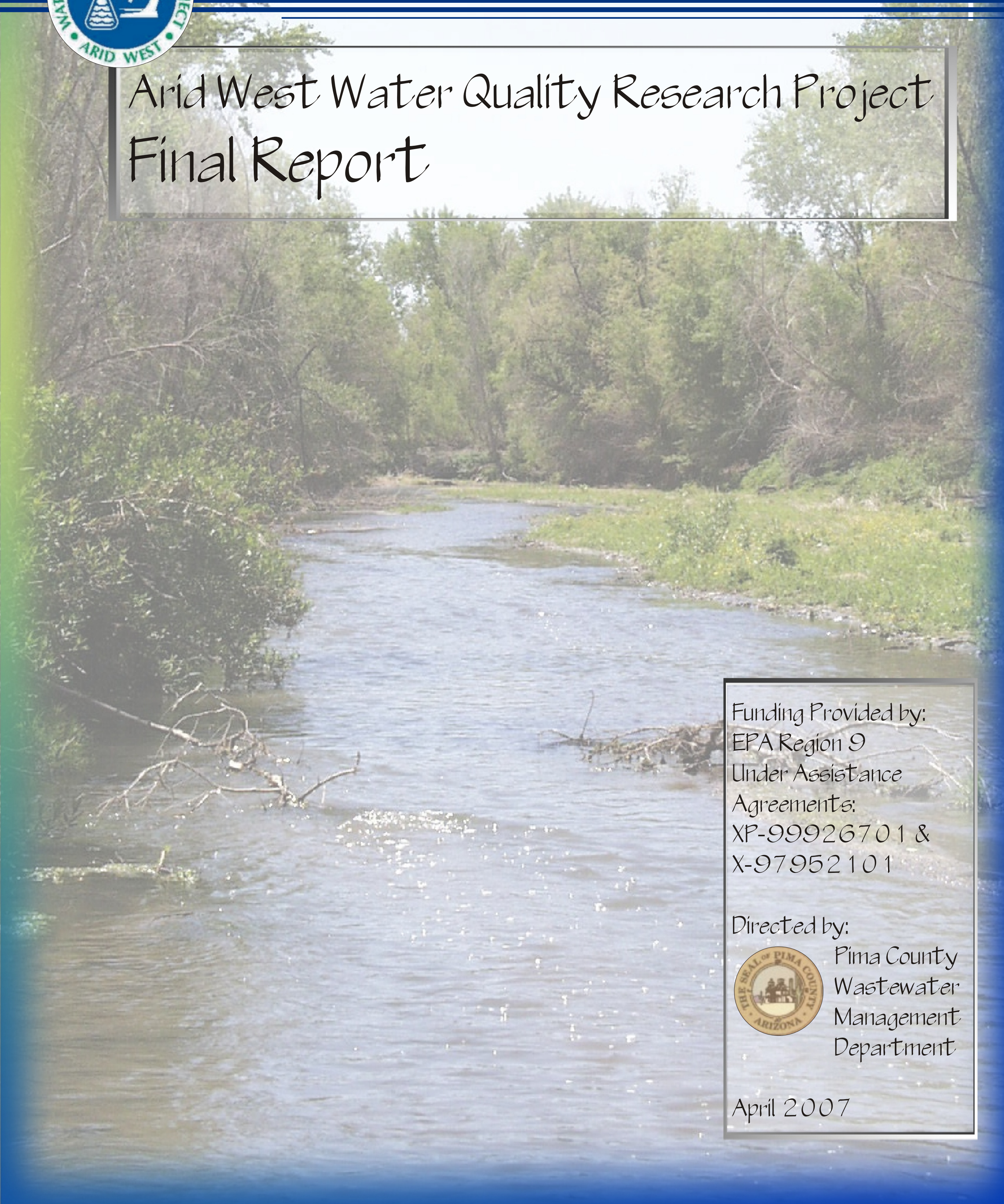

Arid West Water Quality Research Project

Final Report

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Section 1
Arid West Water Quality Research Project

Project Origin

The Arid West Water Quality Research Project (AWWQRP or "Project") began as an idea in the early 1990s out of concerns regarding the applicability of national water quality criteria to western ephemeral and effluent-dependent waters. Two key issues were originally identified: (1) national water quality criteria were based on aquatic species and flow regimes not necessarily representative of ephemeral and effluent-dependent streams; and (2) the methods provided by the U.S. Environmental Protection Agency (EPA) to modify national water quality criteria for use in effluent-dependent and ephemeral streams were not readily applicable primarily because of the lack of basic data on organisms of importance in these arid west waters (Note: References to the arid west include both arid and semi-arid areas).

The AWWQRP was established in 1995 as the result of a $5,000,000 federal appropriation (Public Law 103-327) and the establishment of an Assistance Agreement between EPA and Pima County Wastewater Management Department, Tucson, Arizona. The establishment of the Agreement provided the opportunity for Pima County, EPA Region 9, and others throughout the arid west to work cooperatively to conduct scientific research to support development of appropriate water quality criteria and standards for the region and improve the scientific basis for regulating wastewater and stormwater discharges in the arid and semi-arid west. An additional federal appropriation of $500,000 (Public Law 107-73) was received in 2001.

Project Purpose

The purpose of the AWWQRP is to conduct scientific research and disseminate scientific information on western ephemeral and effluent-dependent waters to help resolve issues of significance to both the regulated community and regulators at state, tribal, and federal levels. To accomplish this purpose, research activities have focused on the following areas:

- Water quality criteria and standards for arid west habitats
- Water quality criteria for chemicals of concern
- Biological and ecological criteria and standards for arid west ecosystems
- Whole effluent toxicity (WET) testing guidance for arid west waters
- Arid west water quality policy and implementation issues

Section 2
Organization

Roles and Responsibilities

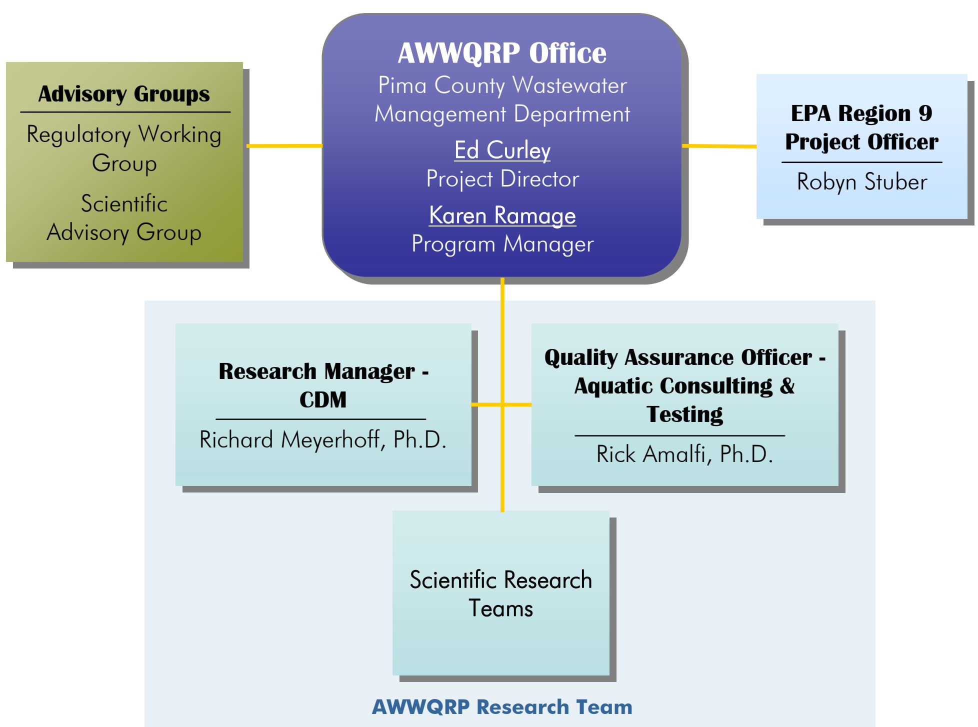
Following is a description of each element of the AWWQRP organization:

AWWQRP Office—The AWWQRP is directed and managed by the AWWQRP Office established within Pima County Wastewater Management Department (PCWMD), Tucson, Arizona. Since project inception, the Project Director has been Ed Curley and the Program Manager has been Karen Ramage.

EPA Region 9 Project Officer—The EPA Project Officer serves as the primary point of contact with EPA and participates to the extent possible in Project meetings, especially those involving the direction and management of the Project. The current EPA Project Officer is Robyn Stuber.

Research Manager—Scientific management of the AWWQRP is the responsibility of the Research Manager. Richard Meyerhoff, Ph.D., CDM, has provided scientific management services for the AWWQRP since 2001.

Quality Assurance Officer—The grant awards specify that the Project will comply with EPA quality assurance requirements. Consequently, the Project has developed a Quality Assurance Project Plan (QAPP) that specifies quality assurance procedures, and retains an experienced investigator in quality assurance to review individual research project work plans for compliance with the QAPP. Dr. Rick Amalfi with Aquatic Consulting & Testing, Inc. has provided this service for the Project.



Regulatory Working Group (RWG)—The RWG is comprised of a 15-member group of stakeholders representing both public and private interests. The RWG was established to ensure that the research undertaken by the AWWQRP has a sound regulatory basis, and that, to the extent practicable, the regulatory needs of arid west states are addressed by the Project. Accordingly, the RWG advises the AWWQRP Office on the types of research projects that should be funded by the Project.

Current Arid West Water Quality Research Project Regulatory Working Group*

Name	Affiliation/Title/Address/Email
Michael Gritzuk, Chairperson	Director, Pima County Wastewater Management 201 N. Stone, 8th Floor Tucson, AZ 85701
Edward C. Anton	California EPA, State Water Resources Control Board 7601 Still River Way (home) Sacramento, CA 95831
Rodney W. Cruze	Riverside Regional Water Quality Control Compliance & Monitoring Manager 5950 Acorn Street Riverside, CA 92504
Paul D. Frohardt	Colorado Water Quality Control Commission Administrator 4300 Cherry Creek Drive South Denver, CO 80246
Gary Ullinskey	City of Phoenix Water Services 200 W. Washington Street, 9th Floor Phoenix, AZ 85003-1611
Andy Laurenzi	Sonoran Institute, Phoenix Office 4835 East Cactus Road Suite 270 Scottsdale, AZ 85254
Patrick J. Maley	Strategic Environmental Management 12449 West Muir Ridge Drive Boise, ID 83709
James F. Pendergast	US EPA Chief, Health Protection and Modeling Branch 1200 Pennsylvania Avenue, NW, (4205T) Washington, DC 20460
Sam Rector	Arizona Department Environmental Quality 1110 W. Washington Street Phoenix, AZ 85007
Eric Rich	Navajo Nation EPA Post Office Box 3780 Tuba City, AZ 86045
Daniel Santantonio, Ph.D.	City of Las Cruces, Utility/Water Division Regulatory Compliance Officer P.O. Box 20000 Las Cruces, NM 88004-9002
Lynn Wellman	U.S. Fish & Wildlife Service Habitat Conservation and Environmental Contaminants 500 Gold Street, SW, Room 4012 Albuquerque, NM 87103
Robyn Stuber Project Officer**	EPA, Region 9 Clean Water Act Standards & Permits Office 75 Hawthorne Street (WTR-5) San Francisco, CA 94105

* Others who have served on this advisory group include: Catherine Kuhlman (EPA Region 9), Terry Oda (EPA Region 9), Susan MacMullin (U.S. Fish & Wildlife Service), Dan Beard (National Audubon Society), Barbara Tellman (University of Arizona), and Neil Stessman (Billings, MT)

** Additional EPA Region 9 staff who served as Project Officers include: Kathleen Goforth, Gary Wolinsky, and Janis Gomes

Scientific Advisory Group (SAG)—This advisory group is comprised of established scientists from throughout the West with experience in water quality research and peer review of scientific literature. The function of the SAG is to recommend research topics for study that are consistent with RWG recommendations, to ensure that authorized studies are designed appropriately, and to assist in the technical review of research products.

Arid West Water Quality Research Project Scientific Advisory Group

Name	Affiliation/Address/Email	Specialty
Paul Adamus, Ph.D.	6028 NW Burgundy Dr. Corvallis, OR 97330	Terrestrial ecology, wetland-riparian systems, ornithology, and aquatic invertebrates
Gary Chapman, Ph.D.	Paladin Water Quality Consulting 3725 NW Polk Ave. Corvallis, OR 97330-6539	Water quality criteria, site-specific water quality criteria (WER, species deletion, etc.), heavy metal toxicity, aquatic toxicology, dissolved oxygen, WET testing, sediment toxicity
Karmen King	Envirotech 18050 Rd. G Cortez, O 81321	Aquatic toxicology, fisheries, biology, aquatic chemistry
Bob McFarlane, Ph.D.	McFarlane & Associates Environmental Consultants 2604 Mason St. Houston, TX 77006-1207	Aquatic and terrestrial ecology, endangered and threatened species, environmental impact assessment, habitat evaluation, wetlands
Benjamin Parkhurst, Ph.D.	HAF, Inc. 1059 Granito Dr. Laramie, WY 82072	Ecological risk assessment, aquatic toxicology, fisheries biology, and aquatic ecology
Bob Gray, Ph.D.	2867 Troon Ct. Richland, WA 99352	Aquatic toxicology, environmental assessment, environmental compliance, fisheries, herpetology/amphibian malformations, environmental monitoring, natural resources, water quality
Carl White, Ph.D.	Department of Biology University of New Mexico 167 Castetter Hall Albuquerque, NM 87131-1091	Nutrient cycling (nitrogen in particular), ecosystems

Project Researchers/Contributors

Many contributors have ensured that the research conducted by the AWWQRP is of high quality. These participants and their area of contribution include:

- Colorado State University, Department of Civil Engineering (Habitat Characterization Study)
- University of Arizona, Environmental Research Laboratory (Research Manager 1997 to 2001, Dischargers Survey, Habitat Characterization Study)
- University of Arizona, School of Renewable Natural Resources (Habitat Characterization Study)
- U.S. Geological Survey, Tucson Desert Laboratory (Habitat Characterization Study)
- Aquatic Consulting and Testing, Inc. (QA/QC Officer)
- CDM (Research Manager, 2001 to present; Habitat Characterization Study, User's Guide)
- Chadwick Ecological Consulting, Inc. (now a division of GEI Consultants) (Habitat Characterization Study, Recalculation Procedure Evaluation, Ammonia Water Effect Ratio Study, Aquatic Communities of Ephemeral Streams)
- Ecotox (Extant Criteria Evaluation)
- ENSR International (Extant Criteria Evaluation)
- Environmental Planning Group (especially Linwood Smith, Ph.D.) (Habitat Characterization Study)
- Hydroqual (Extant Criteria Evaluation, Biotic Ligand Model Study)
- Parametrix (Extant Criteria Evaluation, Ammonia Water Effect Ratio Study, Recalculation Procedure Evaluation)
- Risk Sciences, Inc. (Habitat Characterization Study, User's Guide)
- Tetra Tech (Whole Effluent Toxicity Study with Water Environment Research Foundation)
- URS Corporation (Habitat Characterization Study, Aquatic Communities of Ephemeral Streams, Recalculation Procedure Evaluation)
- Law Offices of Tad Foster, Colorado Springs, CO (Habitat Characterization Study)

Section 3
Arid West Characteristics

The arid west is defined as the arid and semi-arid portions of the western United States that extend from south-central Texas west to southeastern California and north along the east side of the Sierra Nevada and Cascade Ranges to the Canadian Border in eastern Washington. The eastern boundary of this region extends from central North Dakota south through central South Dakota, Nebraska, western Kansas, and Oklahoma to south-central Texas. The arid and semi-arid areas of this region, which incorporate portions of 17 western states, is characterized generally by annual precipitation of less than 10 and 20 inches, respectively (Figure 3-1). While much of the region can be classified as arid or semi-arid based on annual precipitation, the northern portions are characterized by strong seasonality with warm summers and cold winters. By contrast, southeastern California, southern Arizona, New Mexico, and west Texas are characterized by comparatively mild winters and warm to hot summers.

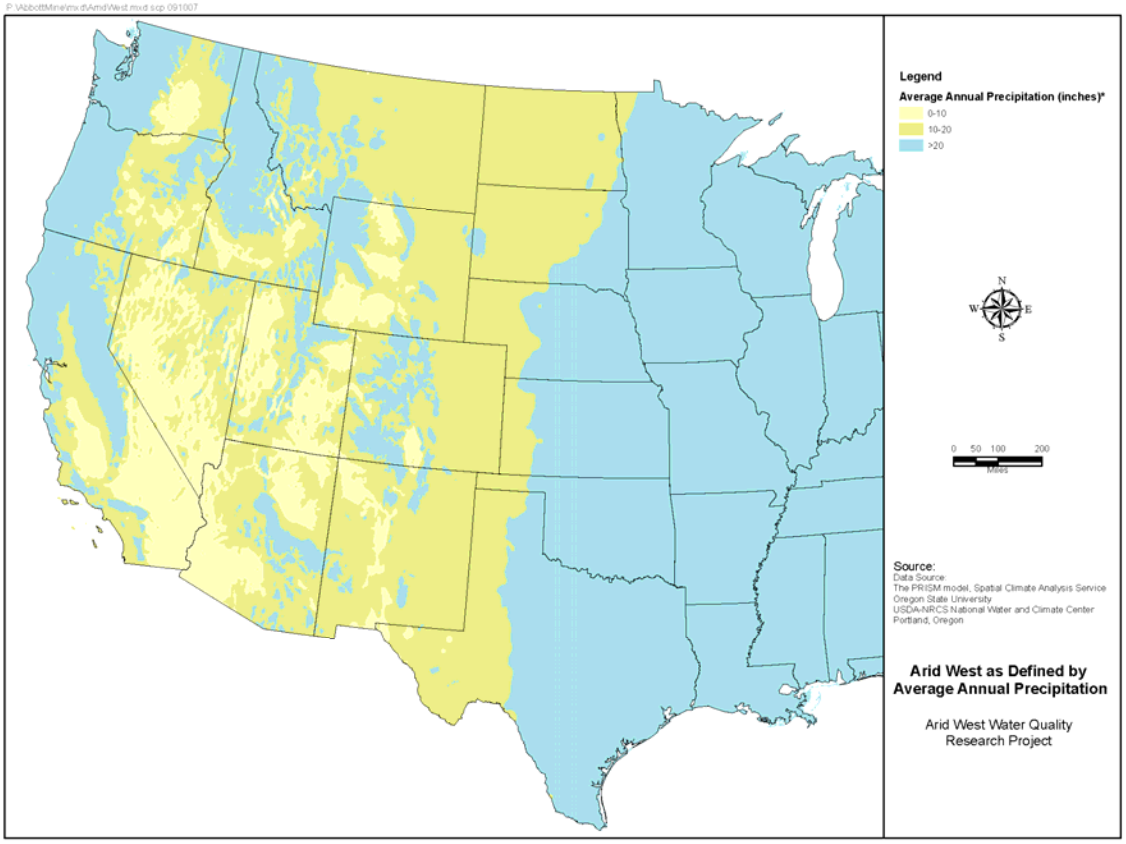


Figure 3-1
Average Annual Precipitation

Hydrologic Characteristics

The hydrology in the arid west differs from that in stream systems in humid regions. Arid region streams are typically more "flashy" after precipitation events. The stream flow hydrographs generally have steeper limbs signifying the potential for more dynamic flooding. The modification of the flow regime from effluent discharge has implications for the physical characteristics of the waterbody. In effluent-dependent streams, the imposition of constant flow in an otherwise dry channel creates a number of physical changes. For example, since wastewater is typically free of sediment, the flow often causes erosion and incision, although the erosive effects are attenuated downstream. In addition, constant flow creates a saturated zone below the channel that can extend laterally from the channel edge to the edge of or beyond the floodplain. The development of riparian vegetation along effluent-dependent streams is largely controlled by the extent, depth, timing, and duration of the saturated zone. These physical changes also affect effluent-dominated streams, but often to a lesser extent.

The hydrology of arid west streams can affect the application of water quality standards, especially for ephemeral and effluent-dependent waters. For example:

- Flashy nature of flow in ephemeral streams means that they are dry for significant lengths of time and then temporarily filled with water. Accordingly, the exposure duration assumptions inherent in federally recommended criteria may not be appropriate, and as such could be modified.

- Effluent-dependent streams are artificially created habitats where the ecological community present is, by definition, adapted to the flow regime, i.e., the existing aquatic life use is dependent on the nature of the waterbody created. The extent to which aquatic life becomes established in an effluent-dependent stream will be influenced by the duration and frequency of the effluent discharge. For example, some wastewater facilities are designed primarily to provide reclaimed water for reuse. However, occasionally these facilities may have to discharge to an ephemeral waterbody for a few days or weeks. The expectations for the aquatic community that develops downstream of these intermittently discharging facilities systems will be quite different from the community that develops in a waterbody that receives effluent all of the time.

Figure 3-2
Effluent-dependent Santa Fe River, west of Santa Fe, New Mexico, upstream (left) and downstream (right) of point of discharge of treated effluent.

Water Quality Characteristics

Water quality in effluent-dependent and effluent-dominant streams was studied as part of the AWWQRP Habitat Characterization Study. The chemical nature of flows in effluent-dependent water reflects the characteristics of the effluent discharged to the stream channel. The chemical composition of effluent is directly related to the types of treatment processes and generally remains constant over a long period of time. It is possible to have variations in effluent quality reflecting diurnal or seasonal patterns associated with influent entering the treatment plant. Although the chemical and physical composition of effluent is fairly constant at the point of discharge, these characteristics often change with distance downstream of the discharge as instream physical, chemical, and biological processes modify the chemistry (Figure 3-3).

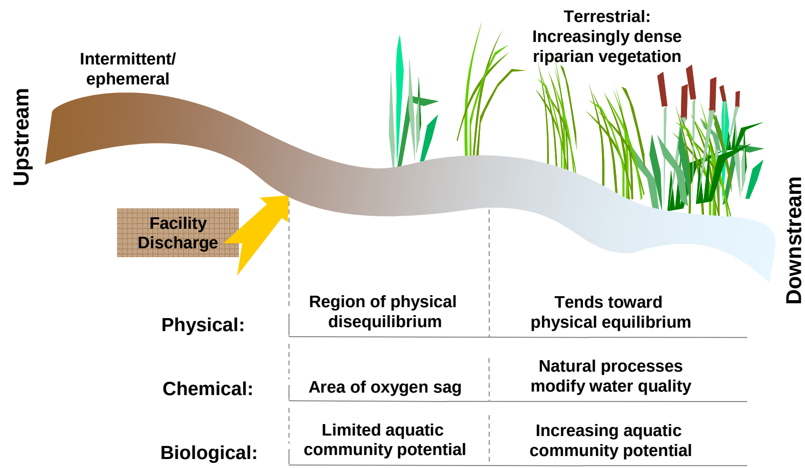


Figure 3-3
Conceptual model of an effluent-created aquatic ecosystem (adapted from Habitat Characterization Study).

In effluent-dominant waters, the water quality is dependent on how much instream flow is available for mixing. The quality of effluent will be significantly different from the quality of the upstream flow. Mixing of effluent and upstream flow temporarily changes instream water quality; however, the extent of this temporary change is dependent on the relative volumes of upstream and effluent flow.

As part of the Habitat Characterization Study, the water chemistries from 10 study sites were compared to the toxicity database water chemistries used in deriving aquatic life criteria and water chemistries of non-arid sites, using eastern Kansas and North Carolina waters as examples. The purpose of these analyses was two-fold: to assess whether arid west water quality differs from the waters used in laboratory waters used for criteria development, and to assess whether water quality in arid west streams is substantively different from water quality in streams in more humid regions. Table 3-1 summarizes the results of this comparison.

Table 3-1 Comparison of Water Quality Characteristics between Waterbodies in Arid and Non-Arid Regions and Waters Used for Toxicity Studies to Support Ambient Water Quality Criteria Development

Source	Concentration			
	Hardness (milligrams/Liter)	Alkalinity (milligrams/Liter)	Conductivity (umhos/centimeter)	pH (Standard Units)
North Carolina Sites	≈ < 25	≈ < 25	0 – 400	6.0 – 9.0
Toxicity Studies[1]	50 – 200	25 – 175	0 – 500	6.0 – 9.0
Kansas River	100 - 400	100 – 250	300 – 1600	6.0 – 9.0
Case Study Sites[2]	100 - 500	50 – 300	500 – 1200	6.0 – 9.0
Las Vegas Wash[2]	600 - 900		2000 - 3000	

[1] Water quality characteristics of test waters used by EPA to develop national ambient water quality criteria for cadmium, copper, zinc, and ammonia (see Habitat Characterization Study).
[2] For specific parameters, Las Vegas Wash is separated from other case study sites.

Biological Communities

The aquatic community is often limited at the point of discharge, but with increasing distance downstream from the point of discharge, the stream flow regime equilibrates with its surroundings resulting in an improved physical environment to which the biological community often positively responds (Figure 3-3). For example, with increased distance downstream of the discharge, biological indices such as species richness or diversity often increase, unless there are other mitigating factors such as flow variation, presence of engineered structures, other pollutant sources, e.g., stormwater, or limiting habitat characteristics, e.g., sandy substrates or bedrock.

Effluent-dependent streams support valuable riparian communities with high biodiversity of terrestrial plants and animals. In arid west waters, the differences between terrestrial vegetation upstream and downstream of a discharge can be striking, especially where the water is effluent-dependent. For example, vegetative structural diversity is usually greater in the effluent-dependent or effluent-dominated riparian zones when compared to upstream areas that are dry or have less flow. In addition, the width of the riparian zone associated with the effluent-supported stream reach will be related to the quantity of water available and to the geomorphologic characteristics of the stream channel. Like other riparian areas, the effluent-dependent riparian areas are particularly important for migratory bird species. The additional plant species diversity and vegetative structural diversity of these areas may provide temporary resting and foraging locations as well as possibly providing movement corridors for some species.

Deciding what defines the appropriate level of protection for aquatic life in effluent-dependent ecosystems can be quite difficult. A long-standing presumption exists that if you increase the level of wastewater treatment to improve effluent quality, then this improved treatment will be manifested in an improved aquatic community, e.g., as might be measured by increased richness and diversity. This presumption has been found to be highly dependent on site-specific conditions including flow frequency and duration.

When an aquatic life designated use is adopted, it is assumed that through water quality management programs the designated use can be achieved. In practice, this approach works if an appropriate goal has been established. Establishment of this goal requires knowledge of the full potential for the aquatic ecosystem created by the discharged effluent. However, because the stream system is created and in a sense, "evolving" (Figure 3-4), it is difficult, if not impossible, to determine the ultimate potential of the system.

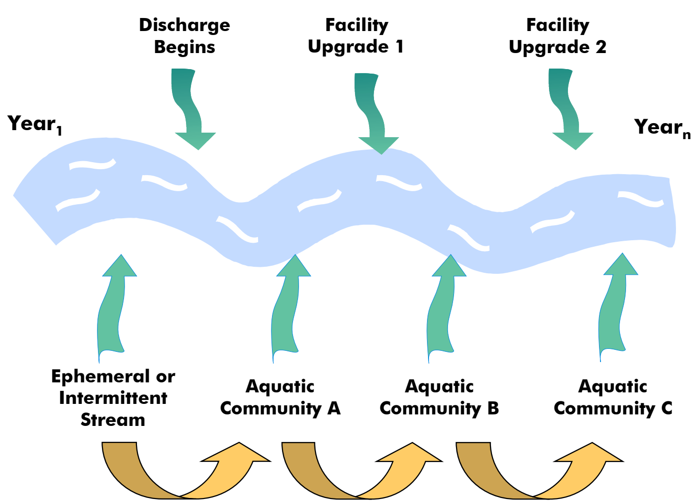


Figure 3-4
Characteristics of the aquatic community are expected to "evolve" as the primary source of flow, treated wastewater, changes. Expectations for the aquatic community are further influenced by watershed activities and local habitat limitations.

Effluent-Dependent Water Examples

Santa Fe River, New Mexico

The Santa Fe River is an example of a relatively high elevation effluent-dependent water. The headwaters of the Santa Fe River are located in the upper Rio Grande basin. The river drains southwest for almost 40 miles. Elevations range from 12,409 feet at Lake Peak to 5,332 feet at the river's confluence with the Rio Grande at Cochiti Reservoir.

Three water-supply dams upstream from Santa Fe impound runoff from the river's upper basin. Flow between the lowermost reservoir (Two-Mile) and the Santa Fe Wastewater Treatment Plant (WWTP) occurs only during spring runoff and storm events. Thus, the channel is usually dry in this reach and, consequently, the discharge from the Santa Fe WWTP is a major source of flow in the channel. About 10 miles downstream of Santa Fe the river begins to cut a deep canyon as it flows to the Rio Grande. In this reach the flow is enhanced by some flow from Cienega Creek and upwelling groundwater.

Figure 3-5
Santa Fe River, upstream of the Santa Fe WWTP discharge (2000).

Figure 3-5 illustrates the reach of the Santa Fe River immediately upstream of the Santa Fe WWTP discharge. The lack of riparian vegetation demonstrates well the infrequency of flow in this reach. Figure 3-6 shows where the WWTP effluent first enters the river channel and highlights the demarcation between ephemeral and effluent-dependent reaches. Figure 3-7 illustrates the Santa Fe River downstream in the reach that cuts through the canyon. Note the well-developed riparian zone located in this reach.

Figure 3-6
Santa Fe River at the location where effluent first enters the river channel (2000).

Figure 3-7
Reach of the Santa Fe River flowing through a canyon (2000).

Santa Cruz River, Tucson, Arizona

The Santa Cruz River originates as a small stream in Arizona's San Rafael Valley, flows south into Mexico, and then north into the United States near Nogales, Arizona. Historically, the Santa Cruz was a perennial stream until it reached Tubac, Arizona, where it went subsurface. Downstream in the Tucson area, the river re-emerged where the groundwater table again intersected the surface. Historically, perennial flow in this portion of the Santa Cruz River consisted primarily of marshes or cienegas interspersed with reaches that were often dry.

Today, much of the Santa Cruz River downstream of Nogales (near the Mexican border) is either effluent-dependent or ephemeral. Upstream of Tucson, the City of Nogales discharges effluent creating an effluent-dependent reach stretching approximately 20 miles from Nogales to Tubac. In the Tucson area, the Santa Cruz River is ephemeral through most of the city and much of the river has been modified for flood control purposes. Downstream of the Roger Road WWTP (western part of the Tucson area) the river becomes effluent-dependent as a result of the discharge. Downstream of the Roger Road WWTP the flow is augmented by the effluent discharged from the Ina Road WWTP. Effluent-dependent flow continues downstream of Tucson for approximately 20 to 40 river miles, where the river again becomes ephemeral.

Figure 3-8
Santa Cruz River upstream of the Roger Road WWTP outfall (2000).

Figure 3-8 illustrates the Santa Cruz River upstream of the Roger Road WWTP outfall. The growth of arid vegetation is apparent as well as the modification of the river channel for flood control. Figure 3-9 illustrates the demarcation between a dry and wet channel at the Roger Road WWTP outfall. Finally, Figure 3-10 shows the river downstream of the Ina Road WWTP discharge where dense vegetation creates a beneficial ribbon of wetlands/riparian habitat.

Figure 3-9
Roger Road WWTP discharge into Santa Cruz River (2000).

Figure 3-10
Santa Cruz River, downstream of Ina Road WWTP discharge (2000).

Salt and Gila Rivers, Phoenix, Arizona

The Salt River originates in the White Mountains of eastern Arizona where it flows westward through steep canyons before entering the Salt River Valley, a broad floodplain where the Phoenix metropolitan area is located. In the western portion of the Phoenix metropolitan area, the Salt River joins the Gila River. During the early 1900s, dams were constructed on the Salt and Gila Rivers for water supply, diversion, and flood control. By changing the way water flowed downstream, the dams completely changed the character of the two rivers.

Before 1900, the Salt River was a perennial river with the heaviest flows in spring and early summer and lower flows in the fall and during droughts. Today, downstream of the dams and diversions the Salt River through much of the Phoenix area is an ephemeral watercourse, which experiences high flows only during unusually rainy years or extreme stormwater runoff events. Downstream of the 91st Avenue River crossing and upstream of the Salt and Gila River confluence, the City of Phoenix 91st Avenue WWTP discharges effluent to the Salt River creating an effluent-dependent water.

Figure 3-11
Salt River upstream of the 91st Avenue WWTP discharge (2000).

Figure 3-11 illustrates the Salt River upstream of the 91st Avenue WWTP discharge. The growth of arid vegetation illustrates the ephemeral nature of this portion of the river channel. Figure 3-12 shows the side channel that carries effluent from the WWTP to the mainstem Salt River. Flow has occurred in this channel for many years and it now has a well developed riparian area. Figure 3-13 shows the effluent-dependent river downstream of the Salt and Gila River confluence in a low gradient area where flows are slow and wetlands vegetation has developed.

Figure 3-12
Effluent channel carrying effluent from 91st Avenue WWTP to the mainstem Salt River (2000).

Figure 3-13
Effluent-dependent Gila River below Salt and Gila River confluence (2000).

Section 4
Project Research

The AWWQRP has provided funding for the following research projects for which fact sheets are provided on the following pages:

- Discharger Survey
- Habitat Characterization Study
- Extant Criteria Evaluation
- Evaluation of the Reliability of Biotic Ligand Model (BLM) Predictions for Copper Toxicity in Waters Characteristic of the Arid West
- Evaluation of the EPA Recalculation Procedure in the Arid West and Preparation of the Recalculation Procedure User's Guide
- Hardness-Dependent Ammonia Toxicity and the Potential Use of the Water-Effect Ratio
- Aquatic Communities of Ephemeral Streams
- AWWQRP Special Studies Report: Use of the EPA Recalculation Procedure with the Copper Biotic Ligand Model, and the Relative Role of Sodium and Alkalinity vs. Hardness in Controlling Acute Ammonia Toxicity
- Arid West Water Quality Research Project User's Guide

The AWWQRP also jointly funded a project administered by the Water Environment Research Foundation (WERF). This project, *Evaluation of Whole Effluent Toxicity Testing as an Indicator of Aquatic Health in Effluent-Dominated Streams: A Pilot Study*, evaluated the quality of data needed to determine relationships between chronic WET test results in treated effluent and the condition of the biological community in the receiving water. Two of the six study sites were arid west effluent-dominated waters. WERF published its final report in 2007.

Discharger Survey

Project Purpose and Objectives

Prior to implementing specific research projects to support the purpose of the AWWQRP, Project advisors recommended that additional information be gathered to identify the nature of existing arid west receiving waters and the species or habitats that are affected by discharges to these waters. Accordingly, a survey of dischargers (the "WQRP Pre-Research Survey of Municipal National Pollutant Discharge Elimination System (NPDES) Dischargers in the Arid and Semi-Arid West" or "Discharger Survey") was to be conducted to gather basic data on each of their discharges. Examples of basic data include discharge rates; beneficial uses; and the physical, chemical, and biological characteristics associated with each discharge. In addition, dischargers were asked to identify key water quality issues of concern.

Survey Data

The EPA database Basins for EPA Regions 6, 7, 8, 9, and 10 was queried in 1998 to identify all NPDES permit holders in the arid west. Identified NPDES dischargers were separated into "major" (discharge > 1 million gallon per day [mgd]) and "minor" discharges (discharge <1 mgd). Questionnaires were sent to all major dischargers to gather basic data on the wastewater facility, effluent discharge, and characteristics of the receiving water. Phone calls were made as needed to follow-up on the questionnaires. Based on the survey results, the project identified a core set of dischargers consisting of locations where the effluent discharge creates an effluent-dependent or effluent-dominated water in an otherwise dry watercourse.

Project Results

Survey results demonstrated that effluent-created waters are a common phenomenon of the arid west. The EPA database query identified 4,515 NPDES permits within the 17 western states with portions classified as arid or semi-arid. Of these permits, 1,001 were classified as major municipal dischargers; of the 1,001 major dischargers, 251 were specifically located in areas considered part of the arid west. Within these 251 permitted discharges, there were 71 permit holders that resulted in 78 wastewater discharge sites that created effluent-dependent or effluent-dominated waters in what would otherwise be ephemeral or intermittent watercourses (Note: Additional information obtained since 1998, the year the Discharger Survey was conducted, suggests that currently the number of effluent-dependent and effluent-dominated waters is somewhat greater than 78).

Table 4-1 Distribution by State and Discharge Volume of Discharges Creating Effluent Dependent Waters (from Discharger Survey Report)

State	1-25 mgd	25-49 mgd	50-200 mgd	>200 mgd
Arizona	12	—	4	—
California	11	2	—	—
Colorado	2	—	1	—
Kansas	2	—	—	—
Montana	2	—	—	—
North Dakota	—	1	1	—
Nebraska	1	—	—	—
New Mexico	10	—	—	—
Nevada	1	—	2	1
South Dakota	2	—	—	—
Texas	12	—	—	—
Utah	5	1	—	—
Washington	1	—	—	—
Wyoming	4	—	—	—

The majority of wastewater treatment facilities in the arid west that discharge to ephemeral or intermittent watercourses are located in eastern California, Arizona, New Mexico, and west Texas (Table 4-1). These four states are collectively home to 65 percent of the discharge sites. The largest dischargers by volume are located in Arizona, Colorado, and Nevada. The issues of concern identified by dischargers ranged widely from specific chemical criteria to endangered species; however, three key areas were identified as common concerns: nutrient criteria, especially ammonia, chlorine, and pesticides. Dischargers also noted that potential future water quality concerns included nitrogen, metals, dissolved solids, and toxicity.

Project Outcome and Final Report

The Discharger Survey showed that dischargers have a firm understanding of effluent characteristics associated with their respective wastewater facilities. In contrast, the physical, chemical, and biological attributes of the receiving waters were not well known. This key finding provided the stimulus for the AWWQRP-funded Habitat Characterization Study that focused research efforts on 10 of the core discharges identified by the Discharger Survey. These 10 discharges have served as case studies to provide greater understanding of the physical, chemical, and biological characteristics of effluent-driven ecosystems.

Habitat Characterization Study

Project Purpose and Objectives

The Habitat Characterization Study was commissioned to document the physical, chemical, and biological characteristics of 10 effluent-dependent waters in the arid west. Effluent-dependent waters are created by the discharge of treated effluent into normally dry streambeds or streams that would have minimal flow during part of the year in the absence of effluent discharge. These 10 sites represent case studies, and as such, the study was not conducted to scientifically verify any particular hypothesis, but to collect data to objectively describe and characterize effluent-dependent ecosystems. The need for this activity was generated by the frequently asked question: When we implement water quality programs in effluent-dependent waters, what are we trying to protect?

The physical, chemical, and biological characteristics of habitats at each of the 10 case study sites were documented upstream and downstream of the WWTP discharge point. The objectives of this effort were to (1) review existing physical, chemical, and biological data; (2) conduct a site reconnaissance level survey to characterize habitats using established protocols and protocols adapted for arid west conditions; (3) identify similarities and differences among sites; (4) discuss potential approaches to protect these habitats in the context of existing regulatory programs; and (5) recommend areas for additional study.

Compilation and Evaluation of Case Study Data

Historical and site reconnaissance data were collected at the following 10 case study sites: Santa Cruz River below Nogales and Tucson, Arizona; Salt River below Phoenix, Arizona; Santa Ana River below San Bernardino, California; Fountain Creek below Colorado Springs, Colorado; South Platte River below Denver, Colorado; Las Vegas Wash below Las Vegas, Nevada; Santa Fe River below Santa Fe, New Mexico; Carrizo Creek below Carrizo Springs, Texas; and Crow Creek below Cheyenne, Wyoming.

Physical Data Summary—Historical physical data included electronic records of streamflow upstream and downstream of WWTP outfalls, and climate and stage-discharge relationship data. If available, results from site-specific hydrology and geomorphology studies were incorporated, and a reconnaissance level field geomorphology assessment was conducted at each site.

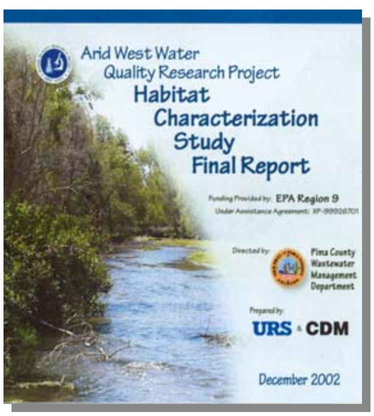
Chemical Data Summary—Historical water quality data included EPA, U.S. Geological Survey, and discharger records collected upstream and downstream of each WWTP outfall. If available, results from site-specific water quality studies were also incorporated.

Biological Data Summary—Where available, site-specific historical aquatic and terrestrial species data from fish and wildlife agencies, state environmental departments, and other historical studies were evaluated. In addition, a site reconnaissance level field assessment of aquatic habitat, aquatic species, terrestrial habitat, and terrestrial species was conducted at each site.

Project Results

The project team utilized the available historical and site reconnaissance data to characterize the aquatic and terrestrial habitats of the 10 case study sites. Commonalities as well as differences among sites were identified and these findings were used to develop an effluent-dependent stream ecosystem model based on accepted riverine ecological models. A review of the data also identified the following:

- Effluent-dependent waters are sufficiently different from other waterbody types to represent a distinct waterbody class
- Physical habitat of an effluent-dependent water results from a combination of several factors, most significant of which are the physical dynamics associated with the discharge itself and channel modifications associated with development of urban areas
- Differences exist between the chemical composition of waters at the study sites and laboratory water used for WET testing and pollutant-specific laboratory toxicity studies
- Aquatic and terrestrial biological communities are a reflection of the physical and chemical template resulting from instream flow characteristics (natural and effluent-driven)
- Increased levels of wastewater treatment may not be the most cost-effective approach for improving the aquatic communities of waters receiving discharges of treated effluent



Final Report

The Habitat Characterization Study final report represents the results of a comprehensive review from AWWQRP scientific and regulatory advisors and other interested stakeholders. The finding that effluent-dependent waters represent a distinct waterbody class has significant implications for the implementation of water quality programs in these created ecosystems. Implications range from potential limitations on what is biologically attainable in the aquatic community to the economics of wastewater treatment. Accordingly, the final report presents results and findings, from not only a technical perspective, but also from a regulatory and economic perspective.

Extant Criteria Evaluation

EPA's National Ambient Water Quality Criteria (AWQC) are used as the basis for state water quality regulations, including protection of beneficial uses and derivation of NPDES discharge permit levels. These set maximum threshold concentrations of contaminants for both freshwater and marine environments. Numeric AWQC are derived using a well-defined process that relies on the collection of mostly laboratory-derived toxicity data that are then used to calculate both an acute and a chronic criterion. Narrative AWQC criteria are created for constituents that are not appropriate to this process (e.g., pH, temperature, total dissolved solids).

Project Purpose and Objectives

One major difficulty in applying AWQC to surface waters in the arid west is that they are derived chiefly from standardized toxicity tests using aquatic species that may not be representative of aquatic biota in this region. Furthermore, the physical and chemical characteristics of surface waters in the arid west differ substantially from those in more mesic regions. AWQC thus may not provide an appropriate or consistent level of protection for aquatic ecosystems in arid regions, which are subject to these unique environmental conditions.

The objectives of the Extant Criteria Evaluation (ECE) project were to (1) examine the appropriateness of AWQC for arid western ecosystems, (2) identify potential weaknesses in the AWQC (or their derivation methods) for these systems, and (3) recommend future research to address any identified potential weaknesses.

Project Results

The goal of the ECE was to evaluate the relevance of selected EPA AWQC to ephemeral and effluent-dependent watercourses in the arid west. More emphasis was placed on considering modifications to AWQC duration and frequency periods to better reflect the biotic and hydrologic conditions encountered in these systems. To test this approach, four AWQC were evaluated as "models" for several important contaminant classes of interest to dischargers in the arid west:

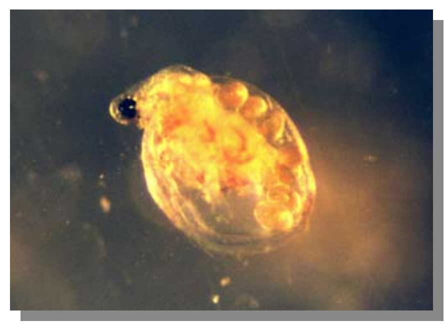
- *Copper* represents metals for which accumulation at the biotic ligand best predicts toxicity. Other important metals in this category include silver, zinc, nickel, and cadmium.
- *Selenium* is an example of an inorganic element for which bioaccumulation or dietary intake are important to toxicity. Another example in this category is mercury.
- *Diazinon*, an organic insecticide, represents contaminants that are primarily toxic to invertebrates, rather than fishes.
- *Ammonia* is an example of a constituent for which criteria are derived on the basis of pH and water temperature.

AWQC Magnitudes—Changes in default national AWQC magnitudes are probably warranted to maximize the accuracy by which they represent concentrations that are protective of aquatic life in these systems. For the most part, existing site-specific criteria modification methods (i.e., recalculation procedure, water-effect ratio procedure, and resident species procedure) may adequately address these changes, and so a "regional" approach may not be necessary in many cases. The extent to which methods for site-specific magnitude modification may be applied on a regional scale depends mostly upon the ability to generalize the composition of biotic assemblages for use with a Recalculation

Procedure. In particular, the presence vs. absence of planktonic cladocerans needs better confirmation owing to the importance of these taxa to criteria derivation for many criteria chemicals.

AWQC Duration and Frequency—Criteria implementation also depends upon the duration (i.e., averaging period) and frequency (i.e., period between criteria excursions that still allows for recovery of aquatic communities) components of an AWQC. Because default duration values are based entirely on laboratory toxicology and toxicokinetics data, it is not possible to suggest modifications on the basis of conditions unique to the arid west. However, recent laboratory evidence suggests that these default duration values may be overly conservative (i.e., too short) in some cases. Increasing duration values would significantly increase design flows for NPDES permit calculations, and so is an important avenue of future study.

The relevance of the default 3-year recovery period to arid west biotic assemblages was evaluated not only as a function of community recovery from disturbance, but also as a function of hydrologic disturbance frequency. The analysis suggests that the frequency and duration of hydrologic events in ephemeral streams of the arid west have the potential to be of similar importance to biotic communities as is exposure to toxics. The frequency of hydrologic disturbance to ephemeral and effluent-dependent streams certainly is high enough to suggest that these ecosystems could be disturbed more frequently than once every 3 years. In contrast, the biotic assemblages of ephemeral and effluent-dependent streams may still require longer time periods (e.g., 3 years) to recover from disturbance even if a substantial number of endemic species still remain. This suggests that it may be environmentally conservative to retain the default 3-year frequency of allowed excursions except, perhaps, for relatively unmodified ephemeral streams. Frequency values also can have a significant impact on derivation of NPDES permit design flows, and so a closer examination of the 3-year default frequency—at least in the case of ephemeral streams—deserves closer attention.



***Ceriodaphnia dubia,* a commonly used test organism for conducting toxicity tests.**

Copper Hardness-Toxicity Study—The mitigating effect of increasing hardness on metal toxicity is reflected in EPA water quality criteria, but are limited to a hardness range of 25 to 400 milligrams per liter (mg/L) (as $CaCO_3$). However, waters in the arid west frequently exceed 400 mg/L hardness, and the applicability of hardness-toxicity relationships in these waters is unknown. Thus in a companion study to the copper AWQC evaluation, acute toxicity tests with *Ceriodaphnia dubia* were conducted at hardness levels ranging from ca. 300 to 1,000 mg/L using reconstituted waters that mimic two kinds of natural waters with elevated hardness (Las Vegas Wash, Nevada, and a $CaSO_4$-treated mining effluent in Colorado). The moderately-alkaline EPA synthetic hard water was also included for comparison. Although copper toxicity still decreased with increasing hardness at levels >400 mg/L, the hardness-toxicity relationships differed with ion composition. In particular, increasing alkalinity, magnesium, or sodium concentrations explained decreases in copper toxicity better than did either hardness or calcium concentrations. Therefore, further study is needed to determine whether simple hardness-based metals criteria are appropriate for use in the arid west, or whether more complex approaches are warranted.

Final Report

A limited number of final report copies were distributed by Pima County. In 2007, the report will be published as a book by the Society of Environmental Toxicology and Chemistry.

Evaluation of the Reliability of the Biotic Ligand Model Predictions for Copper Toxicity in Waters Characteristic of the Arid West

As part of the ECE for the AWWQRP, copper was evaluated to represent a metal for which aquatic impacts depend strongly on site-specific water quality characteristics such as hardness, alkalinity, and pH. Metal toxicity often varies as a function of hardness, and so AWQC for metals—including copper — are typically derived as a mathematical function of hardness. In contrast, hardness may not be the best predictor of copper toxicity in arid west streams. As a result, simple hardness equations typically used to adjust copper AWQC may not accurately represent the more realistic and complex factors that may control metal toxicity in very hard waters.

To further evaluate these more complex factors controlling copper toxicity, the ECE evaluated the relevance of the Biotic Ligand Model (BLM) for use in site-specific AWQC modification in arid west watercourses. The BLM is a mechanistic model of metal bioavailability that simulates metal interactions with specific receptors (the "biotic ligand") in aquatic organisms associated with metal toxicity. Even though this model was developed using data from relatively soft to moderately hard waters, ECE studies suggested that model predictions are still accurate in very hard waters characteristic of the arid west.

Project Objectives and General Approach

Even though the results of the initial BLM tests in the ECE were promising, they were based on the outcome of a single study of copper toxicity using the cladoceran *Ceriodaphnia dubia*. It was determined that evaluating the generality of this conclusion for copper would require testing with additional species (e.g., fathead minnows or *Daphnia magna*), and using waters characteristic of a wider range of natural waters in the arid west. Therefore, this project entailed a series of studies designed to further evaluate the reliability of the BLM to predict copper toxicity in arid west waters. Primary project objectives included:

Toxicity tests being conducted with fathead minnows, *Pimephales promelas*.

- Conduct acute copper toxicity tests with three different aquatic test species under a range of water quality conditions (e.g., cations, anions, and dissolved organic carbon) that are representative of waters in the arid west. This range of water quality conditions was generated by testing in natural waters from sites already studied in the AWWQRP ECE and Habitat Characterization Study projects under both low- and high-flow conditions. Samples for testing were obtained from seven effluent-dependent waters throughout the arid west to represent the widest possible range of water quality conditions that could be encountered in the region. Our general approach was to conduct a series of WER-style studies to compare copper toxicity in a particular "natural site water" to that of a laboratory reconstituted water designed to mimic the major ion composition of that site water.

- Based on the water quality data obtained from these studies, a statistical evaluation of the predictive capabilities of the BLM was conducted for these waters. Modifications were also suggested where appropriate to improve model predictions.

Project Results

The unmodified version of the BLM only predicted 61 percent of the copper toxicity values in the present study with reasonable accuracy (i.e., within two-fold of empirical toxicity values). While the majority of the unacceptable predictions were for the fathead minnow, the model performed remarkably well for the two invertebrates whose sensitivity to copper were closest to the acute criterion concentration. Further investigations revealed that carbonate precipitation was likely occurring in site and laboratory waters due to elevated concentrations of calcium and magnesium. Consideration of carbonate precipitation and interactions between magnesium and the biotic ligand of fish and invertebrates improved model predictions by 40 percent. Therefore, the present study demonstrated the utility of considering the influence of all water quality variables when deriving site-specific criteria for waters with elevated hardness.

Conclusions and Regulatory Implications

Conclusions from this study further suggested that the BLM generates more appropriate and protective copper standards for waters with elevated hardness when compared to the hardness-based equation or WER approaches. Although the historical site-specific methods (hardness equation and WER) are useful for surface waters with low to moderate levels of hardness, the unique chemical conditions of arid west streams require site-specific methods that account for the influences of all water quality variables (i.e., pH, dissolved organic carbon, alkalinity, and major ions). Therefore, the BLM offers an improved alternative to the hardness-based and WER approach for modifying copper criteria, particularly for situations where the current methods would be under-protective of sensitive aquatic life.

Hardness-Dependent Ammonia Toxicity and the Potential Use of the Water-Effect Ratio

Ammonia is unique among regulated toxicants, as it is an endogenously produced compound that organisms must either excrete or detoxify for survival. In aqueous solution, total ammonia nitrogen (TA-N) exists in two forms, the ammonium ion (NH_4^+) and un-ionized ammonia (NH_3), and their relative chemical abundance is primarily dependent upon the pH and temperature of the solution. Accordingly, ammonia toxicity to aquatic organisms is also largely a function of pH and temperature, with toxicity increasing with increasing pH. As a result, EPA's most recent (1999) national recommended acute AWQC for ammonia depend directly on pH (in addition to the presence or absence of salmonid fish). The 1999 AWQC also mentions that ions other than pH (e.g., hardness cations such as calcium or magnesium) may also affect acute ammonia toxicity, but this was not considered significant enough to base criteria calculation on hardness.

Project Objectives and General Approach

Although the 1999 AWQC is not expressed as a function of hardness, some toxicity studies have suggested that ammonia toxicity may vary with hardness for both invertebrates and fish. This clearly could be a significant issue for ephemeral and effluent-dependent waters in the arid west with elevated hardness, because if ammonia/hardness relationships can be confirmed, it may be possible to consider WER-based studies to derive site-specific water quality standards for these waters. However, additional scientific study is needed to further evaluate empirical relationships between hardness and acute ammonia toxicity. Therefore, a simple empirical study was conducted as a "proof of concept" to determine whether hardness exerts a significant enough effect on acute ammonia toxicity to be used as a basis for deriving site-specific ammonia standards in hard, effluent-dependent waters. This study consisted of three general components:

- ♦ A literature review for scientific studies conducted since publication of the 1999 AWQC to evaluate whether any new studies support or reject the hardness-ammonia toxicity relationships mentioned above
- ♦ A series of acute toxicity tests that independently varied hardness and pH to further evaluate the significance of hardness-ammonia toxicity relationships for both freshwater fish and invertebrates
- ♦ A limited set of confirmatory WER studies in effluent-dependent waters of varying hardness to determine whether WER magnitudes were a function of hardness

Project Results

No significant relationships were observed between hardness and the toxicity of ammonia to either of the fish species examined. These findings contradict the conclusions of several physiological studies that suggested an ammonia/hardness relationship might exist owing to an increase in ammonia excretion with increasing hardness. For the invertebrate species tested, the only significant hardness/ ammonia toxicity relationships observed were that at pH 8, ammonia toxicity increased with increasing hardness for *H. azteca* and decreased with increasing hardness for *C. dubia* when expressed on the basis of total ammonia-N. These results were not in agreement with previous studies that found the toxicity of total ammonia to *H. azteca* decreased with increasing hardness and the toxicity of total ammonia to *C. dubia* increased with hardness. However, the previous *H. azteca* studies were confounded by the fact that alkalinity (and, likely, sodium) co-varied with hardness, while alkalinity was held constant in the acute toxicity tests conducted in the present study. To determine whether or not this discrepancy in experimental design could explain the inconsistency in study results, a series of additional acute *H. azteca* studies were conducted wherein sodium was independently manipulated in conjunction with hardness and alkalinity. The results of these studies confirmed that allowing alkalinity to fluctuate with hardness likely had a significant effect on the results previously observed, and that elevated sodium levels offer considerable protection to *H. azteca* against ammonia toxicity, especially when coupled with elevated hardness.

Culture room for laboratory toxicity testing.

WERs, expressed as total ammonia, were fairly consistent among species. In particular, fathead minnow WERs generally ranged from 0.5 to 2 among all sites, WERs were consistently highest for *C. tentans* among all sites (0.5 to 3), and WERs for *C. dubia* were ≤ 1 for all sites. WERs, expressed as total ammonia, were also fairly consistent among sites. The highest WERs were generally found in the South Platte River, the lowest WERs were generally found in the Santa Ana River, and the Salt River and Las Vegas Wash WERs were intermediate. WER magnitudes at these sites, however, were not a function of hardness. As previously discussed, other water quality parameters (i.e., alkalinity and sodium) may affect the toxicity of ammonia in natural waters; thus, the lack of a clear relationship between hardness and the WERs measured at these sites may be due to the fact that other factor(s) was contributing more heavily to the toxicity of ammonia to the species tested.

Conclusions

This study has supported the limited toxicity literature available, which suggests that hardness (and/or related cations) may influence acute ammonia toxicity. However, these effects have been shown to be species-specific, (i.e., no one ion composition will exert the same influence) and only valid for invertebrates, not fish. To further elucidate the mechanisms governing these effects, however, major ion composition other than hardness (sodium is of particular interest) needs additional independent experimental manipulation. This study has also shown that WERs >1 can be observed in effluent-dependent waters for both fish and invertebrates. The WERs found to be >1 may have been the result of a difference in ionic composition between the site and laboratory waters, but it is clear that the protective effect associated with these significant WERs was not due to hardness alone. Therefore, until these potential ion effects and/or mechanisms are better understood, it is difficult to predict whether a positive WER could be achieved for a given site without first conducting empirical tests.

Evaluation of EPA Recalculation Procedure

Although AWQC are designed to protect most species nationwide, criteria are derived from toxicity tests primarily with surrogate laboratory organisms. These surrogates are usually those species encountered in perennial streams in mesic environments, e.g., the eastern U.S., the Pacific Northwest, and the intermountain Rocky Mountains, such as rainbow trout. A much smaller body of toxicological knowledge exists for stream biota characteristic of the arid parts of the West. The responses of species adapted to effluent-dependent waters to discharged pollutants are even less well understood.

EPA regulations and guidance documents provide a procedure to recalculate site-specific water quality criteria that reflect local, unique conditions, or exposed populations. But, because of the paucity of toxicological data on arid west species in their native habitats, it is difficult for state regulators to fully utilize the recalculation methodology. The EPA Recalculation Procedure study is intended to make the first steps to alleviate barriers to using these tools in Western streams and to more fully, and more appropriately, protect these ecosystems.

Project Objectives and General Approach

The project used fundamental insights from previous AWWQRP efforts to evaluate the potential use and/or modification of the recalculation procedure with five chosen AWQCs based on resident species data from five pilot study streams. The Recalculation Procedure was used as a basis for comparing resident aquatic species lists to toxicity databases for ammonia, copper, zinc, aluminum, and diazinon.

The resident species data from five pilot study streams (see map) were collected. Where possible, data were accumulated from the scientific literature to ensure that the resident species included existing, as well as potentially existing, biota. The resulting databases provide a reliable resident species list for each pilot study stream.

Using EPA methods, species from the toxicity databases for the five criteria under study (ammonia, copper, zinc, aluminum, and diazinon) were added and deleted. This portion of the study included a sensitivity analysis on the effects of modifications of toxicity database size on the resulting recalculated criteria values.

A list of resident species common to the case study sites was compiled, including species common to arid west streams that would potentially be useful for new toxicity data development. These included genera often found in EDWs, for example: *Cyprinidae* (minnows, carps), *Centrarchidae* (sunfish, bass, etc.), Multiple midge genera, *Callibaetis*, *Tricorhythodes* (mayflies), and *Argia* (damselfly).

The possibility of generating a new minimum data requirement for toxicity database evaluation that is functionally equivalent to the current, nationwide, 8-family database "rule," but more appropriate to protection of aquatic communities in arid west streams was evaluated.

Project Results

Resident species lists from the five sites had several similarities. Cluster analysis of the data produced two regional groupings, representing the High Plains and Southwest (Chihuahuan & Sonoran) geographical localities. *Cyprinidae* (minnow) represent 22 to 40 percent of fish taxa and the second most diverse family is *Centrarchidae* (sunfish) – although mostly comprised of non-native species. 58 to 85 percent of invertebrate taxa are aquatic insects, with midge genera common to all streams and *Callibaetis*, *Tricorhythodes* (mayflies), and *Argia* (damselfly) also common. No resident salmonids or zooplankters were found.

Based upon these data and other literature studies, we are suggesting that the EPA 8-family rule used in water quality criteria be modified for common trends in arid west species composition. *Cyrinids*, *Centrarchids*, and aquatic insects are more critical for food web functionality in arid environments than coldwater game fish and zooplankton; therefore, we propose a modified 8-family rule that would better represent these species in the development of water quality criteria.

Work on the toxicity database for the five subject pollutants has also produced results that could impact regional criteria. Both the acute and chronic databases for the five criteria have been updated. For aluminum, this has resulted in new hardness based acute and chronic criteria equations. Ammonia criteria were modified based on "cold" and "warm" water biota for both acute and chronic equations, simplifying current criteria. The copper update resulted in new equations for both acute and chronic, including a new hardness relationship based on chronic data. The zinc update resulted in a new acute-chronic ratio, with subsequent updated equations.

When applied to the various study sites, the recalculation procedure and development of site-specific criteria using these new data were generally less restrictive than the national criteria, especially for zinc and copper. Ammonia was the only compound not greatly affected by derivation of site-specific criteria since national criteria were derived from cold and warmwater specific databases. Furthermore, in most cases regional criteria are less restrictive than the national criteria.

Calculation Findings Decision Matrix

	Santa Ana River	Santa Cruz near Nogales	Santa Cruz near Tucson	Salt/Gila Rivers	Fountain Creek	South Platte River	Southwest Region	High Plains Region
Aluminum	-	+	NA	=	-	-	-	-
Ammonia	=	=	=	=	=	=	=	=
Copper	+	+	+	+	+	+	+	+
Diazinon	+	+	+	+	+	+	+	+
Zinc	+	+	+	+	+	+	=	+

NOTES:
"+" = Recalculated criteria are less restrictive than national updated criteria.
"-" = Recalculated criteria are more restrictive than national updated criteria.
"=" = Less than 10% change in recalculated criteria from national updated criteria.
NA = Data were not available to conduct the analysis.

Recalculation Procedure User's Guide

To assist in the possible application of these methods, a User's Guide was prepared for the Recalculation Procedure to aid dischargers and permit holders in applying a Recalculation Procedure given the unique biological conditions often present in effluent-dependent waters. This document includes a discussion of the derivation of national AWQC and evaluation of the use of the WER method versus the Recalculation Procedure and Resident Species Procedure in effluent-dependent waters. In addition, the User's Guide includes a discussion on the role AWQC in regulating water quality via the NPDES program of the Clean Water Act. A rough cost-benefit analysis for the resulting modified criterion is also provided.

Aquatic Communities of Ephemeral Streams

National water quality criteria for aquatic life may be under- or over-protective if (1) the aquatic species resident in a waterbody are more or less sensitive than the species included in the national dataset used to calculate the water quality criteria; or (2) physical and/or chemical characteristics at the site alter the biological availability and/or toxicity of the chemical. To determine if the resident species are more or less sensitive, it is necessary to have an appropriate aquatic species list.

Research on the aquatic community that inhabits an ephemeral stream (defined as a surface water that has a channel that is at all times above the water table and flows only in direct response to precipitation or snowmelt) of the arid west is limited. Most of the aquatic species lists have been developed from studies on "intermittent" streams, which typically flow only seasonally, or "interrupted" streams, waterbodies that have reaches that flow year-round separated by reaches that remain dry. Typically, both intermittent and interrupted streams have diverse aquatic communities in the flowing reaches and there have been a number of studies documenting the aquatic communities of these types of water. In contrast, aquatic species lists from ephemeral streams are few.

Project Objectives and General Approach

To address this lack of information, a study was commissioned to collect aquatic species data from ephemeral streams following precipitation events. Potential waterbodies for data collection were selected from arid regions with distinct patterns of rainfall, temperature, stream flow, and ecology: High plains, cool desert, and hot desert.

Water column, benthic, and vertebrate samples were collected to account for the potential for transient microinvertebrates (i.e., zooplankton), presence of macroinvertebrates (e.g., aquatic insects, amphipods, and isopods), and the presence of fishes and amphibians, respectively. The research team also attempted to evaluate the "succession" of the fauna within each stream as related to the duration of the flow events by sampling daily after peak flows began to subside until no surface water remained.

Two views of Ephemeral Mescal Arroyo upstream of Cienega Creek.

Benthic macroinvertebrate samples were collected using methods consistent with EPA Rapid Bioassessment Protocols. Microinvertebrate samples were gathered by filtering a known volume of stream water through a 68 μm mesh zooplankton. Vertebrate sampling was conducted by targeting appropriate habitats (e.g., pools, snags, or other instream cover).

In the arid west, flow events in ephemeral streams are generally characterized by a sharp increase, followed by a gradual decrease in flow, making aquatic biological collections difficult. Enough time needed to pass to allow the recently wetted stream channel the potential to be colonized, yet sampling was not delayed too long, since flow could cease and the channel become quickly dry. Sampling was not conducted on the rising limb of the hydrograph, when the system is "flushing" and restricting movement of potential colonizers (therefore posing safety hazards to field personnel). Rather, sampling began on the declining limb when flows lessen to levels at which biota movement is not restricted. In addition, significant habitat is created well after the peak has passed in most desert streams, as ephemeral ponds and other short-lived aquatic environments persist.

Project Findings

- A total of 21 distinct taxa of microinvertebrates were collected; most of the taxa and individuals within this group were from terrestrial sources or were the immature stages of aquatic macroinvertebrates.

- A total of 86 distinct taxa of aquatic macroinvertebrates were collected, including *Insecta, Hydracarina, Crustacea, Oligochaeta, Hirudinea*, and *Gastropoda*. Most of the taxa had aerially dispersing life stages and were present either in that form or as immature larvae recently hatched from eggs deposited by the aerial life stage. The remaining taxa likely came from upstream perennial water sources, terrestrial sources, and or cryptobiotic life stages. Succession patterns of the aquatic macroinvertebrates, at sites with and without known or likely upstream sources of potential colonizers, were typical of succession patterns on ephemeral habitats. Although many taxa were collected repeatedly throughout succession, some taxa were collected only once or a few times, suggesting that they were using the ephemeral habitat resource only as a "stop-over" between other aquatic habitats. Generally, taxa richness was highest in the first few days after flows began to recede, and decreased as available habitat diminished.

- Four species of fish were collected; two of these species were nonnative, collected only as desiccated specimens from the middle of a dry streambed. The native species were collected in small numbers at only a few sites, apparently arriving within 1 day (longfin dace) to 3 to 5 days (fathead minnows) after high flows begin to recede.

- Six species of amphibians were collected, including one *Salientia* and five species of *Anura*. Both adult and tadpole life stages of the anurans were collected, with many individuals in the process of metamorphosis from tadpole to adult. Amphibians were collected throughout succession and apparently can remain in the streams until they reach adulthood, if surface water persists.

- Very little similarity was observed between the communities collected in the three study areas. Overall similarity between watersheds was about 5 percent. Based on the aquatic macroinvertebrate data, the closest similarity between any two individual sites was only 25 percent. Such a low similarity value is likely the result of biogeographic patterns and differences in latitude, substrate, riparian vegetation, and the apparently random pattern of colonization.

- Areal extent of aquatic habitat tended to decrease with time after high flows began to recede. Similarly, the number of taxa tended to decrease as available aquatic habitat diminished.

- Representative resident taxa lists from the arid west region, as compiled from previous AWWQRP projects, were supplemented by an additional 50 taxa collected in this study. The lack of resident fish (particularly centrarchids) and elimination of key water quality indicator organisms such as cladocerans and isopods from the resident species lists could have a considerable effect on the development of water quality criteria as applied to ephemeral streams.

AWWQRP Special Studies Report: Use of the EPA Recalculation Procedure with the Copper Biotic Ligand Model, and Relative Role of Sodium and Alkalinity vs. Hardness in Controlling Acute Ammonia Toxicity

The purpose of this report was to build upon knowledge gained from past studies conducted as part of the Arid West Water Quality Research Project (AWWQRP), and apply them to the newest regulatory guidance from EPA. This report was organized into three chapters, the first two of which addressed implementation of the Biotic Ligand Model for regulatory protection of aquatic life from copper, and the third addressed the relative roles of sodium and hardness in controlling acute ammonia toxicity to aquatic organisms.

Evaluation of Site-Specific Standards Using Biotic Ligand Model (BLM) Adjusted Copper Ambient Water Quality Criteria/Use of the EPA Recalculation Procedure to Develop Site-Specific BLM-Based Copper Criteria

We evaluated the applicability of the EPA recalculation procedure to the recently released (2007) BLM-based copper (Cu) Ambient Water Quality Criteria (AWQC), using the findings and arid west specific methodology developed in the Pima County AWWQRP *Evaluation of the EPA Recalculation Procedure in the Arid West* Technical Report.

To generate BLM-based site-specific AWQC for Cu, non-resident taxa were first deleted from the national BLM adjusted Cu database for each study stream and two regions representing major trends in aquatic life community structure (Southwest and High Plains). The total number of species represented in the resulting site-specific BLM adjusted databases ranged from 7 for the Santa Cruz near Tucson to 29 for the High Plains regional database. The recalculated BLM final acute values (FAVs; before adjusting to site water chemistry) were very similar between sites and regions. Next, mean site water chemistry and recalculated FAVs were run with the BLM to generate median lethal accumulation values (LA50s) and site-specific FAVs. Resulting BLM-based site specific acute and chronic Cu criteria ranged from 32.4 to 209.2 μg/L and 20.1 to 130.0 μg/L, respectively. These site-specific BLM-based criteria reflect both the sensitivity of species that are expected to be resident to arid west effluent-dependent/dominated streams, and expected copper complexing due to site-specific water quality characteristics.

Although the recalculated BLM-FAVs were very similar among sites, all BLM-based site-specific criteria were substantially greater than hardness modified site-specific criteria. These results suggest that Cu complexing resulting from site water characteristics other than hardness has a greater effect on criteria when using the BLM than the site-specific toxicity databases generated with the step-wise deletion process. For the arid west sites, the complexing reduces Cu toxicity and results in water quality criteria that are less stringent than hardness modified site-specific criteria, but still protective of aquatic life.

Current Status and Future Trends in Biotic Ligand Models for Derivation of Aquatic Life Protection Criteria for Metals

The development of computational models which can be used to predict the influence of environmental concentrations of metals on aquatic organisms has received considerable attention by researchers and regulators worldwide. Currently, advancements in predictive models that can account for biological effects from acute (short-term, high magnitude) and chronic (long-term, low level) exposures to metals have provided regulators in the United States and Europe with tools for confidently implementing site-specific water quality standards. In this report, the current status of the BLM is presented with respect to the various metals, organisms, and test endpoints for which models have been validated.

To date, copper has received the most attention and there are currently BLMs representing several trophic levels (plants, invertebrates, and fish) and a variety of test endpoints (survival, reproduction, growth, etc.). As such, the EPA has recently released a revised Cu criteria guidance document for a copper ambient water quality criterion which utilizes a BLM for criterion derivation purposes. In addition, the roles of BLMs for deriving additional acute and chronic water quality standards and as tools for identifying "at risk" aquatic habitats are discussed in detail. Future trends in BLM development, such as accounting for the influence of metal mixtures, effects in sediment and terrestrial habitats, and dietary exposures, are discussed relative to their use in a regulatory context and enhancing our ability to predict the effects of metals on environmental systems. In general, the use of BLMs to predict the influence of environmental concentrations of metals on aquatic organisms represents a significant departure from the current methodologies and should provide a more scientifically-defensible means of regulating effluent discharges based on site-specific water quality conditions.

Relative Role of Sodium and Alkalinity Versus Hardness Cations in Controlling Acute Ammonia Toxicity to Aquatic Organisms

The objective of this project was to build upon the hardness-ammonia studies conducted in 2006 for AWWQRP, which supported the limited toxicity literature available suggesting that hardness (and/or related cations) may influence acute ammonia toxicity. To further elucidate the mechanisms governing these relationships, sodium was independently manipulated in conjunction with hardness and alkalinity in a series of acute *Hyalella azteca, Ceriodaphnia dubia*, and *Pimephales promelas* toxicity tests. For each species, four reconstituted waters were made in which hardness was varied and sodium concentrations were manipulated, either by direct addition of sodium chloride (NaCl), or as a result of increasing alkalinity (sodium addition as sodium bicarbonate – $NaHCO_3$).

For the amphipod, *H. azteca*, the cladoceran, *C. dubia*, and the fathead minnow, *P. promelas*, increasing hardness ameliorated the acute toxicity of ammonia only when coupled with an increase in sodium as alkalinity. Increasing sodium alone (as either NaCl or alkalinity), without also increasing hardness, had variable effects on the acute toxicity of ammonia to these species. For example, increasing sodium alone as NaCl only resulted in a decrease in toxicity to *H. azteca* and, while for *H. azteca*, increasing sodium alone as alkalinity did not affect ammonia toxicity. For both *C. dubia* and *P. promelas*, this treatment caused the highest level of toxicity observed across all tests.

Based on these conclusions, hardness does exert a significant effect on acute ammonia toxicity, but only in hard waters where sodium (as alkalinity) is also elevated. These studies, as well as those found in the literature, which were the basis for this research, corroborate the current suggestion from the latest AWQC for ammonia that water-effect-ratios (WERs) greater than 1 may be expected when a difference in ionic composition, in conjunction with pH or hardness, is present between site and laboratory waters.

Arid West Water Quality Research Project User's Guide

Purpose

The AWWQRP User's Guide was developed to provide one source for all AWWQRP-funded research activities. The Guide not only provides concise summaries of each research project, but it also includes a complete copy of each research report on an attached CD. In addition to providing one source for all research findings, the User's Guide presents and discusses AWWQRP program results in the context of the water quality standards program implemented under the federal Clean Water Act (CWA).

To a large degree, the simple problems of water quality control have been addressed. Today, more than 30 years after establishment of the CWA, the remaining water quality issues are typically complex. To address these new challenges, water quality standards practitioners have had to identify new and innovative ways to develop and implement water quality standards. Often such innovation is found right next door in a neighboring state or in states that are not part of the arid west. Unfortunately, what has occurred in these other states is not always readily known. Accordingly, the User's Guide was developed with all water quality standards practitioners in mind; not just dischargers who must comply with the myriad of state and federal water quality standards regulations, but also state regulators who are often searching for practical and innovative ways to develop and implement water quality standards within the bounds of the CWA and its implementing regulations, especially for the protection of aquatic life and recreational uses in arid west waters.

Perspective of the User's Guide

Significant challenges exist regarding how water quality standards regulations should be applied to ecosystems modified by the discharge of effluent, especially for aquatic life uses. There are numerous opinions regarding the appropriateness of discharging effluent where the result is converting naturally ephemeral or intermittent streams into effluent-dependent or effluent-dominated waters, respectively. Completely opposite viewpoints exist. On the one hand, some view the act of discharging any treated effluent into ephemeral or intermittent waters as causing damage to the environment, while on the other hand others view the discharge of treated effluent as providing a valuable resource with multiple benefits. There are a number of permutations of these viewpointss that fall somewhere in between these two opposing views. Given the difference of opinion the User's Guide does not make any judgments regarding the appropriateness of point source discharges. Instead the focus is on the recognition that such discharges are common, they are being studied, and present a challenge for how to best regulate them under the water quality standards regulation. In addition, the User's Guide recognizes that given the increased competition for water resources that will occur in the future—especially in the arid west—this challenge will not disappear any time soon.

Users Guide Content

The User's Guide contains seven sections that illustrate key arid west water quality issues in a relatively brief, readable format. However, for those who wish to see the more substantive information behind what is presented, a CD was included that contains extensive supporting documentation, including final reports of all AWWQRP research projects. Following is a summary of the content of each section of the User's Guide:

Foreword—Provides a brief summary of the purpose of the AWWQRP and acknowledges the many organizations and individuals that made the project a success.

Section 1 – Introduction—This section describes the origins of the AWWQRP and summarizes the purpose and content of the User's Guide.

Section 2 – Arid West Framework—Section 2 presents a basic overview of the water quality standards program for the new water quality standards practitioner and provides an overview of arid west ecosystems and the challenges ahead in these waters.

Section 3 – Arid West Research—This section provides an overview of the research conducted by the AWWQRP on arid west waters, as well as a brief overview of relevant research carried out by other organizations, especially the Water Environment Research Foundation (WERF).

Section 4 – Available and Emerging Regulatory Tools—Concerns regarding water quality standards applicability often arise through one of two paths: Issuance of a point source discharge permit or implementation of a Total Maximum Daily Load. This section reviews a variety of tools currently in use to address water quality standards concerns and presents a number of emerging tools.

Section 5 – Implementing the Regulatory Process—The regulatory process that must be implemented to modify a use or criterion can be difficult. Why do some processes achieve success, while others result in either outright failure or, possibly worse, no action? This section explores this issue and provides some recommendations for increasing the likelihood of achieving success when seeking to establish alternative water quality standards.

Section 6 – Water Quality Standards Implementation – Case Studies—Often it is heard that the Clean Water Act and its implementing regulations are inflexible, providing no opportunity for states to tailor water quality standards to unique types of aquatic ecosystems. While issues arise all the time that require new approaches to water quality standards development, numerous opportunities already exist to use innovative approaches to solve problems. This section documents, in the form of case study examples, how some states have seized the initiative to develop innovative approaches.

Section 7 – Finding the Best Regulatory Solution—Identifying the best approach to address a water quality standards concern involves many factors. What is the waterbody type? What kind of scientific studies are needed? Is there consensus among stakeholders regarding the proposed solution? These are just some of the many questions that need to be considered when looking for a solution. This final chapter explores these ideas to help practitioners decide on a framework for finding the best regulatory solution.

Section 5
Project Outreach

Presentations

AWWQRP representatives and members of the AWWQRP research teams have participated in numerous public outreach activities involving scientific societies, public interest groups, trade organizations, and government agencies. To encourage this activity, public outreach has been a required element in all research project and research management contracts. Table 5-1 presents a summary of all presentation, poster, and workshop participation activities conducted by AWWQRP participants. Several of these activities were organized as special sessions at professional meetings.

Table 5-1 Arid West Water Quality Research Project Presentations

Organization	Year/Event	Presentation Title/Topic
American Fisheries Society	2001 Annual Meeting	• Water Resource Conflicts: The Need for Alternative Performance Measures for Effluent-Dominated Waters • New Tools for Investigating the Relationships of Water Quality and Habitat • Arid West Water Quality Research Project
American Geophysical Union	2001 Annual Meeting	• A Conceptual Model for Effluent-Dependent Riverine Environments (Poster)
American Institute of Hydrology	2007 Annual Meeting	• Aquatic Communities of Arid-West Ephemeral-Stream Ecosystems - Initial Results
American Water Resource Association	2001 Annual Meeting	Special Session: Ecological Benefits of Effluent-Dependent Waters • The Arid West Water Quality Research Project • Water Resource Conflicts: The Need for Alternative Performance Measures for Effluent-Dominated Waters • Potential Influence of Hydrological Flow Regimes in the Arid West on Aquatic Biological Communities: A Review • New Tools for Investigating the Relationships of Water Quality and Habitat in Structuring Aquatic Biological Communities in Western Streams • On the Importance of Fluvial Process to Habitat Function in Effluent-Dependent Environments • Ionic Strength of Western Waters Compared to Standard Toxicity Test Waters and Discussion of Potential Impacts on Biota From Natural Water Quality in Western Streams
	2005 Annual Meeting	• Alternatives for Deriving Site-Specific Water Quality Criteria for Effluent-Dependent Waters in the Arid Western U.S.
Arizona Hydrological Society	2000	• Arid West Water Quality Research Project
	2001	• Habitat Characterization Study
	2005 Annual Meeting	• Arid West Water Quality Research Project: Three New Investigations of Site-Specific Criteria Methodology for Southwestern Streams

Table 5-1 Arid West Water Quality Research Project Presentations (cont.)

Organization	Event	Presentation Title/Topic
Arizona Mining Association	2002	• Habitat Characterization Project Update
Arizona Municipal Utilities Leadership Institute	2002	• Arid West Water Quality Research Project
Arizona Riparian Council	2002 Annual Meeting	• Riparian Resources and Water Quality in the Arid West? Conflicts, Uses, and Innovation
Arizona Water Pollution Control Association	2000 Annual Meeting	• Arid West Water Quality Research Project
	2001 Annual Meeting	• Arid West Water Quality Research Project Update
	2002 Annual Meeting	• Arid West Water Quality Research Project Update
	2003 Annual Meeting	• Arid West Water Quality Research Project Update
	2004 Annual Meeting	• Arid West Water Quality Research Project Update
	2005 Annual Meeting	• Arid West Water Quality Research Project Update
	2006 Annual Meeting	• Arid West Water Quality Research Project Update
	2007 Annual Meeting	• Arid West Water Quality Research Project Accomplishments and Impacts
Arizona Water Quality Management Working Group	2005	• Arid West Water Quality Research Project
California Stormwater Quality Task Force	2000	• Briefing on the Arid West Water Quality Research Project and Habitat Characterization Study
City of Tucson Water Advisory Meeting	2003	• Arid West Water Quality Research Project
Colorado Wastewater Utilities Council	2001	• Arid West Water Quality Research Project
	2002	• Arid West Water Quality Research Project Update
Colorado Water Quality Control Commission	2001	• Arid West Water Quality Research Project
Colorado Water Quality Division	2003 309 Study Symposia	• Characteristics of Western Effluent-Dependent and Effluent-Dominated Ecosystems • Application of Ambient Water Quality Criteria to Ephemeral and Effluent-Dependent Waters in the Arid West

Table 5-1 Arid West Water Quality Research Project Presentations (cont.)

Organization	Event	Presentation Title/Topic
Colorado Water Quality Forum	2000	• Arid West Water Quality Research Project
	2001	• Arid West Water Quality Research Project Update
	2002	• Arid West Water Quality Research Project Update
	2005	• Arid West Water Quality Research Project Update
	2006	• Arid West Water Quality Research Project Update
Environmental Protection Agency	1999	• Briefing with EPA Region 9 Staff
	2000	• Briefing with EPA Region 8 Staff • Briefing with EPA Region 9 Staff • Briefing with EPA Headquarters Staff
	2001	• Briefing with EPA Region 9 Staff
	2002	• Briefing with EPA Headquarters Staff
	2002 National Symposium on Designated Uses	• Evaluating Water Quality Criteria for Designated Uses in Ephemeral and Effluent-Dependent Watercourses of the Arid West • Evaluating Use Attainment in an Effluent-Dependent Water
	2005	• Briefing with EPA Region 9 Staff (teleconference)
	2006 Designated Uses Conference (Chicago, Seattle)	• No formal presentation; shared Arid West Water Quality Research Project information
	2006 Effluent Dependent Waters Water Quality Standards Workshop	• No formal presentation; shared Arid West Water Quality Research Project information
	2007	• Briefing with EPA Headquarters Staff
Hawaiian Water Environment Association	2003	• Arid West Water Quality Research Project
Las Vegas Wash Study Subcommittee	2000	• Briefing on the Habitat Characterization Study
Maricopa County Bar Association	2004	• Developing Water Quality Standards in the Arid West
National Association of Clean Water Agencies (formerly Association of Metropolitan Sewerage Agencies (AMSA))	2002	• Briefing on Arid West Water Quality Research Project
	2004 Summer Meeting	• Arid West Water Quality Research Project
	2006 Winter Meeting	• Arid West Water Quality Research Project Update
	2006 Summer Meeting	• Conflict and Cooperation: Arid West Water Resource Issues
National Water Resources Association	2001	• Arid West Water Quality Research Project
	2002	• Arid West Water Quality Research Project: Developing Sound Science
Nature Conservancy, The	2001	• Arid West Water Quality Research Project and Habitat Characterization Study (Poster)
Navajo Nation EPA Symposium	2004	• Arid West Water Quality Research Project

Table 5-1 Arid West Water Quality Research Project Presentations (cont.)

Organization	Event	Presentation Title/Topic
Nevada Water Resources Association	2004 Annual Meeting	• Characteristics of Arid West Effluent-Dependent Waters • Impact of Hardness and Other Constituents on the Toxicity of Copper, Silver, and Cadmium in Ephemeral and Effluent Watercourses in the West
North American Benthological Society	2007 Annual Meeting	• Aquatic Community Composition of Ephemeral Stream Ecosystems of the Southwestern United States • Succession Patterns in Aquatic Communities of Ephemeral Stream Ecosystems of the Southwestern United States
Pima Association of Governments	1999	• Arid West Water Quality Research Project
	2003	• Arid West Water Quality Research Project
Pima Environmental Planning Advisory Committee, Water Quality Subcommittee	2000	• Briefing on the Arid West Water Quality Research Project
	2001	• Arid West Water Quality Research Project Update
Pima County Wastewater Management Advisory Committee	2000	• Briefing on the Arid West Water Quality Research Project
	2001	• Arid West Water Quality Research Project Update
	2002	• Arid West Water Quality Research Project Update
	2005	• Arid West Water Quality Research Project Update
	2007	• Arid West Water Quality Research Project Update
Rocky Mountain Water Environment Association	2000	• Arid West Water Quality Research Project
Society for Environmental Toxicology and Chemistry	2002 Annual Meeting	Special Session: Arid Ecosystems: Unique Considerations • Arid West Water Quality Research Project: Understanding Arid West Ecosystems • Effluent-Dependent Water Ecosystems • What Defines the Aquatic Life Use in Effluent-Dependent Waters? • Application of Ambient Water Quality Criteria to Ephemeral and Effluent-Dependent Waters • The Recovery of Arid Western Stream Assemblages from Disturbance, and its Relevance to the Frequency of Allowed AWQC Excursions • Relevance and Applicability of Ambient Water Quality Criteria for Selenium in Arid West Streams
	2003 Annual Meeting	• Workshop - Ecological Effects Assessment for Arid Environments (incorporated findings from Arid Water Quality Research Project)
	2005 Annual Meeting	• Validation of Biotic Ligand Model Performance in Extremely Hard Surface Waters

Table 5-1 Arid West Water Quality Research Project Presentations (cont.)

Organization	Event	Presentation Title/Topic
Society for Environmental Toxicology and Chemistry (cont.)	2006 Annual Meeting	• Evaluation of Copper Criteria in Very Hard Water • National Ambient Water Quality Criteria Updates Resulting From an Evaluation of the Recalculation Procedure in Arid West Effluent-Dependent Waters • Evaluation of USEPA Recalculation Procedure in Arid West Effluent-Dependent/Dominated Waters – Potential Regional Method Adjustments • Evaluation of the USEPA Recalculation Procedure to Derive Site-Specific Criteria in Arid West Effluent-Dependent/ Dominated Waters - Is it Worth the Effort? • Research Needs to Address Conflicts between Water Quality and Water Supply in Arid Urban Environments • Influence of Elevated Hardness on Ammonia Toxicity to Fish and Aquatic Invertebrates (Poster)
Society for Risk Analysis, Annual Meeting	2004 Annual Meeting	• Workshop - Ecological Risk Assessment Methods for Arid Environments (incorporated findings from Arid Water Quality Research Project)
Sonoran Desert Conservation Plan, Science Technical Advisory Team	2000	• Briefing on the Habitat Characterization Study
Tucson Symposium for Water	2001	• Arid West Water Quality Research Project
University of Arizona/ Arizona State University Water Quality Center Meeting	2002	• Arid West Water Quality Research Project
U.S. Army Corps of Engineers	2001	• Arid West Water Quality Research Project
U.S. Committee on Irrigation and Drainage	2002 Annual Meeting	• Water Resource Conflicts: The Need for an Alternative Approach to Permitting in Effluent-Dependent Ecosystems
U.S. Department of Agriculture, Agricultural Research Service	2002	• Arid West Water Quality Research Project: Physical, Chemical and Biological Characteristics of Effluent-Dependent Waters
Water Environment Federation Technology Meeting	2001 Annual Meeting	• Ionic Strength of Western Waters Compared to Standard Toxicity Test Waters and Discussion of Potential Impacts on Biota from Natural Water Quality in Western Streams • Potential Influence of Hydrological Flow Regimes in the Arid West on Aquatic Biological Communities – A Review • Water Resource Conflicts: The Need for an Alternative Approach to Permitting in Effluent-Dependent Ecosystems • New Tools for Investigating the Relationships of Water Quality and Habitat in Structuring Aquatic Biological Communities in Western Streams
	2005 Annual Meeting	• Arid West Aquatic Life Uses

Table 5-1 Arid West Water Quality Research Project Presentations (cont.)

Organization	Event	Presentation Title/Topic
Water Environment Federation TMDL Conference	2001 Specialty Conference	• Arid West Water Quality Research Project
	2007 Specialty Conference	• Updates to National Ambient Water Quality Criteria as part of an Evaluation of the USEPA Recalculation Procedure in Arid West Waters • Evaluation of the USEPA Recalculation Procedure to Derive Site-Specific Criteria in Arid West Effluent-Dependent/Dominated Waters – An Integral Step in TMDL Development
Water Environment Research Foundation	2000	• Briefing on the Arid West Water Quality Research Project
	2002	• Briefing on the Arid West Water Quality Research Project
	2007	• Briefing on the Arid West Water Quality Research Project
Western Coalition of Arid States	2000 Fall Meeting	• Arid West Water Quality Research Project Update
	2001 Fall Meeting	• Arid West Water Quality Research Project Overview • Habitat Characterization Study • Regulatory Implications Habitat Characterization Study • Extant Criteria Evaluation
	2001 Spring Meeting	• Arid West Water Quality Research Project Update
	2001 Summer Meeting	• Habitat Characterization Study
	2002 Spring Meeting	• Habitat Characterization Study • Arid West Water Quality Research Project Update
	2002 Summer Meeting	• Arid West Water Quality Research Project: Project Update • Extant Criteria Evaluation: Project Summary
	2003 Spring Meeting	• Arid West Water Quality Research Project Update
	2003 Summer Meeting	• Arid West Water Quality Research Project Update
	2004 Summer Meeting	• Arid West Water Quality Research Project Update
	2005 Spring Meeting	• Arid West Water Quality Research Project Update
	2005 Summer Meeting	• Arid West Water Quality Research Project Update
	2005 Fall Meeting	• Arid West Water Quality Research Project User's Guide
	2005 Winter Meeting	• Arid West Water Quality Research Project, Update on Ongoing Research Projects
	2006 Fall Meeting	• Arid West Water Quality Research Project - Opportunities
	2007 Winter Meeting	• Arid West Water Quality Research Project briefings/discussions and materials/reports distribution

Table 5-1 Arid West Water Quality Research Project Presentations (cont.)

Organization	Event	Presentation Title/Topic
Western Governors Association, Western States Water Council	2000	• Arid West Water Quality Research Project Update
	2001	• Arid West Water Quality Research Project
	2002 Symposium on Arid Areas Issues	• Habitat Characterization Study • Extant Criteria Evaluation
	2006 Workshop	• Participation in stakeholder meeting, *Effluent Dependent Waters in the Arid West*
Western States	Periodic	• Briefings/discussions/testimonies have been provided to state agencies as needed or as requested.
Western Water Law, CLE International, Denver	2002	• Arid West Water Quality Research Project

Publications

Table 5-2 presents a summary of all publications associated with the project.

Table 5-2 Arid West Water Quality Research Project Publications

Habitat Characterization Study

- Meyerhoff, R.D., T. Moore, S. Morea, E. Curley, T. Foster, K Sierra, M. Murphy and L. Smith. 2002. *New Permit Approach Needed for Effluent-Dependent Waterbodies*. Watershed & Wet Weather Technical Bulletin 7: 7-12.
- Murphy, M., R. Meyerhoff, E. Curley and K. Ramage. 2008. Proposed title: *Characterizing the Habitat of Effluent-Dependent Waters*. In Prep.

Extant Criteria Evaluation

- Gensemer, R.W., R.B. Naddy, W.A. Stubblefield, J.R. Hockett, R. Santore and P. Paquin. 2002. *Evaluating the role of ion composition on the toxicity of copper to Ceriodaphnia dubia in very hard waters*. Pages 87-98, in: J.W. Gorsuch, C.R. Janssen, C.M. Lee and M.C. Reiley, editors. Special Issue: The Biotic Ligand Model for Metals—Current research, Future directions, Regulatory implications. Comparative Biochemistry and Physiology, Volume 133C, Numbers 1-2, September 2002.
- Naddy, R. B., G. R. Stern, and R. W. Gensemer. 2003. *Effect of culture water hardness on the sensitivity of Ceriodaphnia dubia to copper toxicity*. Environmental Toxicology and Chemistry 22:1269-1271.
- SETAC. 2007, In Press. *Relevance of Ambient Water Quality Criteria for Ephemeral and Effluent-Dependent Watercourses of the Arid Western United States* (with co-editors, Robert Gensemer, Parametrix; Ed Curley and Karen Ramage, Pima County Wastewater Management Department), Society for Environmental Toxicology and Chemistry (SETAC) Press, ISBN #978-1-880611-91-3.

Evaluation of the Reliability of Biotic Ligand Model Predictions for Copper Toxicity in Waters Characteristic of the Arid West

- Van Genderen, E., R. Gensemer, C. Smith, R. Santore, A. Ryan. 2007. *Evaluation of the Biotic Ligand Model relative to other site-specific criteria derivation methods for copper in surface waters with elevated hardness.* Aquatic Toxicology: Special issue in celebration of Rick Playle. Manuscript Accepted.

Table 5-2 Arid West Water Quality Research Project Publications (cont.)

Evaluation of the EPA Recalculation Procedure In The Arid West
(Working with editor of Integrated Environmental Assessment - SETAC journal - to publish these papers as a series)

- Canton, S.P., L.G. Wall, R. Gensemer, and M. Murphy. 2007. *Evaluation of the U.S. EPA Recalculation Procedure in Arid West Effluent Dependent Waters: 1. Introduction to the Study*. In Prep.
- Lynch, J., S.P. Canton, G.D. DeJong, R. Gensemer, and M. Murphy. 2007. *Evaluation of the U.S. EPA Recalculation Procedure in Arid West Effluent Dependent Waters: 2. Development of the resident species lists.* In Prep.
- Carney, M, L.G. Wall, S. P. Canton, R. Gensemer, and M. Murphy. 2007b. *Evaluation of the U.S. EPA Recalculation Procedure in Arid West Effluent Dependent Waters: 3. Updates to the ambient water quality criteria for aluminum.* In Prep.
- Wolf, C., L.G. Wall, M. Carney, S. P. Canton, R. Gensemer, and M. Murphy. 2007. *Evaluation of the U.S. EPA Recalculation Procedure in Arid West Effluent Dependent Waters: 4. Updates to the ambient water quality criteria for ammonia.* In Prep.
- Wall, L.G. S. P. Canton, M. Carney, R. Gensemer, and M. Murphy. 2007a. *Evaluation of the U.S. EPA Recalculation Procedure in Arid West Effluent Dependent Waters: 5. Updates to the ambient water quality criteria for copper.* In Prep.
- Canton, S.P., L.G. Wall, M. Carney, R. Gensemer, and M. Murphy. 2007. *Evaluation of the U.S. EPA Recalculation Procedure in Arid West Effluent Dependent Waters: 6. Updates to the ambient water quality criteria for zinc.* In Prep.
- Wall, L.G. S. P. Canton, M. Carney, C. Wolf, R. Gensemer, and M. Murphy. 2007b. *Evaluation of the U.S. EPA Recalculation Procedure in Arid West Effluent Dependent Waters: 7. Modifications to the method for the arid West.* In Prep.
- Carney, M., S.P. Canton, L.G. Wall, R. Gensemer, and M. Murphy. 2007a. *Evaluation of the U.S. EPA Recalculation Procedure in Arid West Effluent Dependent Waters: 8. Case Studies*. In Prep.
- Canton, S.P., L.G. Wall, M. Carney, R. Gensemer, and M. Murphy. 2007. *Evaluation of the U.S. EPA Recalculation Procedure in Arid West Effluent Dependent Waters: 9. Recalculation Findings and Study Conclusions.* In Prep.

Hardness-Dependent Ammonia Toxicity and the Potential Use of the Water-Effect Ratio

- Smith CA, Gensemer RW, Van Genderen EJ, Canton SP, Wolf CF, Wall L. 2007. *Hardness-dependent ammonia toxicity and the potential use of the water-effect ratio.* In Prep.

Aquatic Communities of Ephemeral Streams
(Intent is to publish these manuscripts as a series)

- De Jong, G. D., S P. Canton, J. Lynch, and M. Murphy. 2007. *Aquatic Communities of Ephemeral Stream Ecosystems in the Southwestern United States: 1. Community Composition*. In Prep.
- De Jong, G. D., S. P. Canton, and M. Murphy. 2007. *Aquatic Communities of Ephemeral Stream Ecosystems in the Southwestern United States: 2. Biotic Succession.* In Prep.
- Canton, S. P., L. G. Wall, G. D. De Jong, and M. Murphy. 2007. *Aquatic Communities of Ephemeral Stream Ecosystems in the Southwestern United States: 3. Implications for the Recalculation Procedure for Site-Specific Water Quality Standards.* In Prep.

Other Publications

- American Fisheries Society. 2000. *Water Quality Matters.* American Fisheries Society, Water Quality Section Newsletter.
- Arizona Floodplain Management Association. 2002. *Arid West Water Quality Research Project: Ephemeral and Effluent-Dependent Streams Issues.* Floods Happen! Arizona Floodplain Management Association Newsletter.
- CDM. 2003. *Ensuring Sound Science in the Arid West*. CDM News, periodic publication of CDM.
- Curley E. and R. Meyerhoff. 2003. *Update: Arid West Water Quality Research Project.* Western Coalition of Arid States (WESTCAS) Newsletter, Volume 13, Spring 2003.
- Curley, E., K. Ramage, and R. Meyerhoff. 2007. *Focus on Arid West Water Quality Research Project.* WESTCAS Newsletter, February 2007.
- Pima County Wastewater Management Department. 2007. *Arid West Water Quality Research Project Users Guide.* Prepared for the Arid West Water Quality Research Project by CDM and Risk Sciences.
- Ramage, K., E. Curley, and R. Meyerhoff. 2007. *Arid West Water Quality Research Project.* Arizona Water Pollution Control Association. January 2007.
- Southwest Hydrology. 2002. *WQRP Looking at Appropriateness of National Ambient Water Quality Criteria.* Southwest Hydrology, May/June 2002.
- Water Environment Research Foundation. 2000. *Arid West Water Quality Research Project.* Progress Newsletter, Summer 2000.

Section 6
AWWQRP Model for Success

Establish a Functional Structure

The primary contributor to the success of the AWWQRP has been the project structure, which was established in accordance with the first EPA workplan. While there was agreement early in the project that this structure would support project goals, ultimately, this anticipated support exceeded expectations and enhanced efforts to conduct peer-reviewed research and outreach. Figure 6-1 provides a graphical representation of the process established to manage research efforts under the AWWQRP. Key elements include:

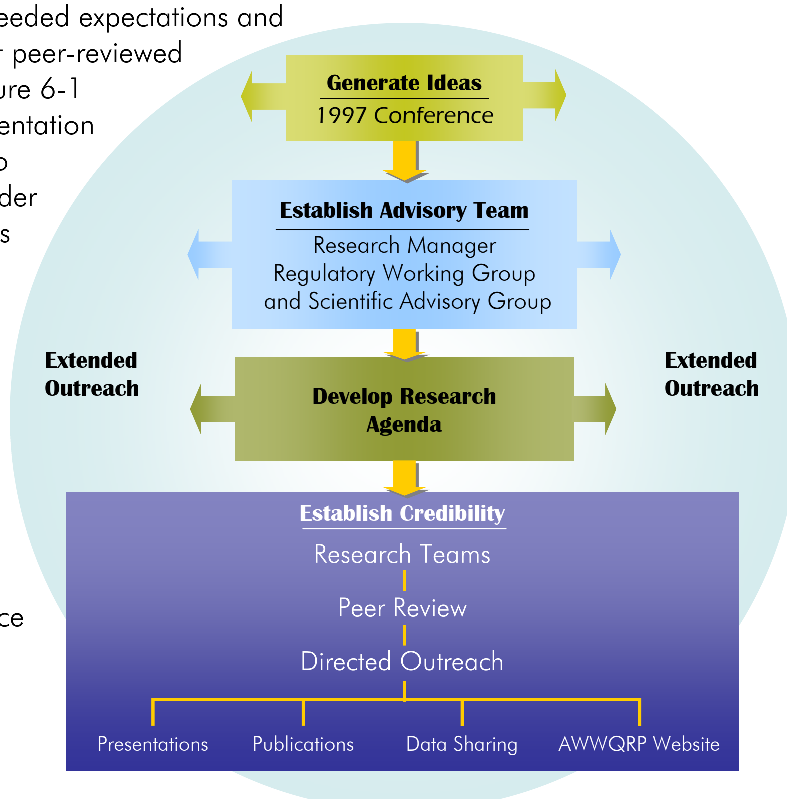


Figure 6-1
AWWQRP Model for Success

- Generate Research Ideas—The AWWQRP kicked-off its research effort by gathering interested stakeholders together at a regional conference in Tucson, Arizona in April 1997. More than 100 conference participants generated research ideas in four general areas:
  - Chemicals of Concern
  - Habitats of Concern
  - Biological Criteria
  - Whole Effluent Toxicity
- Establish Advisory Teams—Pima County Wastewater Management Department working closely with EPA Region 9 identified potential candidates to serve on the RWG and SAG. Many of the selected members participated in the 1997 conference.
- Develop Research Agenda—Working with the RWG, a Research Manager was appointed to provide overall scientific direction, including developing and maintaining a Research Agenda, preparing scopes of work for research efforts, and conducting technical outreach.

Establish Credibility

With a structure in place to guide the process and key personnel identified to advise, manage, and execute research activities, the next key step was to establish credibility with the stakeholders. This need was met through the following activities:

- Research Teams—Credible research teams were selected based on their qualified expertise and understanding of arid west regulatory issues.
- Peer Reviewed Research—SAG provided peer review; level of review was sufficient in some cases to augment peer review by publications.
- Directed Outreach—Research teams were required to participate in outreach activities in multiple venues, including professional societies, trade, and government agency meetings (see Section 5). In many cases, the researchers took the lead in organizing special sessions focused on the project. A project website was established at www.pima.gov/wwm/wqrp/index.htm.
- Extended Outreach—All project participants regardless of their role in the project, facilitated outreach through their own professional networks. In the end, this extended outreach provided many more opportunities for sharing project information than would have been possible through directed outreach alone. Both directed and extended outreach efforts have resulted in a number of accomplishments where AWWQRP-developed data have been used to support regional and national water quality issues:
  - *Selenium Criteria Development* – Selenium information from the ECE project were incorporated into formal comments submitted to EPA during the development of the recently revised draft selenium criteria document.
  - *Copper BLM Development* – The ECE and Copper BLM studies provided data on the role of magnesium and characteristics of very hard waters in the BLM model.
  - *Colorado 309 Symposium* – During the State of Colorado process to evaluate potential revisions to aquatic life uses and criteria in effluent-dominated, effluent-dependent, and ephemeral types of waters, the AWWQRP participated in state-organized workshops to share research findings.
  - *Colorado Wastewater Utility Council* – Ammonia data developed by the Recalculation Procedure Evaluation provided support to the Council's efforts to work with State of Colorado on the establishment of ammonia criteria.
  - *California, Santa Ana Region* – Stakeholders are working with Santa Ana Regional Water Quality Control Board to use the findings of the aluminum criteria research (Recalculation Procedure Evaluation) to revise the regional aluminum criteria.
  - *Environment Canada* – Canada's national environmental agency requested the aluminum criteria research findings developed for the Recalculation Procedure Evaluation for use in their efforts to revise national aluminum criteria recommendations.
  - *Western States Water Council* – The Council has been working with EPA since 2002 on the development of policy for the implementation of water quality standards in effluent-dependent waters. To support this effort, the AWWQRP has provided the Council with project data, participated in technical and policy workshops, and made presentations on project results.
  - *EPA Water Quality Standards Workshop on Effluent-Dependent Waters* – Project information has been shared with EPA during workshops and as written comments.
  - *State Regulatory Activities* – Project information has been made available to state water quality regulatory agencies through a number of venues – both directly through meetings and workshops and indirectly when provided as a basis for testimony on proposed regulations.

Section 7
Summary and Conclusions

Project Summary

As noted in Section 1, the purpose of the AWWQRP was to conduct scientific research and disseminate scientific information on western ephemeral and effluent-dependent waters to help resolve issues of significance to both the regulated community and regulators at state, tribal, and federal levels. To accomplish this purpose, research was to be conducted in five key areas. These key areas and the projects implemented to support them are summarized in Table 7-1.

Table 7-1 Research Summary

Area of Research	Supporting Research Projects
Water Quality Criteria and Standards for Arid West habitats	■ Habitat Characterization Study ■ Extant Criteria Evaluation ■ Evaluation of the EPA Recalculation Procedure in the Arid West and Recalculation Procedure User's Guide ■ AWWQRP User's Guide
Water Quality Criteria for Chemicals of Concern	■ Extant Criteria Evaluation ■ Evaluation of the Reliability of the Biotic Ligand Model Predictions for Copper Toxicity in Waters Characteristic of the Arid West ■ Evaluation of the EPA Recalculation Procedure in the Arid West and Recalculation Procedure User's Guide ■ Hardness-Dependent Ammonia Toxicity and the Potential Use of the Water-Effect Ratio ■ AWWQRP Special Studies Report: Use of the EPA Recalculation Procedure with the Copper Biotic Ligand Model, and the Relative Role of Sodium and Alkalinity vs. Hardness in Controlling Acute Ammonia Toxicity
Biological and Ecological Criteria and Standards for Arid West Ecosystems	■ Habitat Characterization Study ■ Aquatic Communities of Ephemeral Streams
Whole Effluent Toxicity (WET) Testing Guidance for Arid West Waters	■ Evaluation of Whole Effluent Toxicity Testing as an Indicator of Aquatic Health in Effluent-Dominated Streams: A Pilot Study (joint project with WERF)
Arid West Water Quality Policy and Implementation Issues	■ Discharger Survey ■ AWWQRP User's Guide

An important element of the workplan established with EPA to manage this project was the requirement to conduct research in an environment where regulatory and technical peer review of research products openly occurred throughout the process. Sections 2 and 6 of this final report demonstrate success in fulfilling this project element.

Finally, a key to the success of any project is the timely dissemination of information. From its beginning the project team has made a significant effort to share project results and their implications in a variety of technical, regulatory, industry, and public interest forums, including publication in the primary scientific literature. Section 5 summarizes the more than one hundred formal outreach activities that occurred during the course of the project. This summary does not include the countless informal meetings that occurred where various project participants shared information to their colleagues regarding AWWQRP activities. Section 5 also summarizes the already published research papers and the many additional papers that are in preparation that will be published after the project has ended.

Conclusions

The AWWQRP was designed to create a broader understanding of water quality issues unique to the arid west and provide scientific and regulatory data in support of a regional approach to the development of water quality criteria and designated uses. Heightened interest in arid west water quality issues continues to be fueled by the recognition that treated effluent is a valuable water resource.

Nowhere is the competition for scarce water resources more fierce than in the arid west. And, nowhere are effluent limits likely to be more stringent. Wastewater facilities must routinely meet discharge limits at the end-of-pipe owing to an absence of dilution in the receiving waters. Where the discharge is to an ephemeral stream, aquatic ecosystems often arise as a direct result of the perennial flow provided by wastewater discharges. However, such effluent-dependent habitats may be lost if more stringent permit limits result in a superior quality effluent that is too valuable to simply discharge to the nearest waterbody. Consequently, where there are multiple competing demands for the same resource, supporting all of the uses simultaneously often requires some consideration and compromise.

In these situations, finding that compromise may require research to generate the data needed to find a common solution. However, as this project has demonstrated, such research cannot take place in a vacuum. Instead, research must be conducted openly with appropriate oversight. As a result of collaborative participation by the RWG and SAG for this project, research outcomes with broad appeal resulted. Similarly, as was noted in the case study summaries prepared for the User's Guide, the underlying key factor associated with the achievement of a successful resolution to a regulatory noncompliance issue was stakeholder collaboration.

The AWWQRP has been pleased to have fulfilled part of the need for research to support regulatory decisions in arid west waters. Section 6 highlighted some of the areas where research results have provided important information to address local and regional regulatory issues. However, even though this project has ended, the interest in additional research on arid waters continues. We believe that the AWWQRP model can be used again as a successful approach for conducting more research to find innovative and scientifically acceptable ways to address increasingly complex, difficult regulatory questions.