Total Maximum Daily Load For:
Upper Alum Gulch, Sonoita Creek Basin,
Santa Cruz River Watershed,
Coronado National Forest
near Patagonia, Santa Cruz County, Arizona

HUC 15050301-561A
Parameters: Cadmium, Copper, Zinc, and Acidity

June 30, 2003

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<u>NOTE:</u> Since initial publication the contact information has been updated.
For more information please contact:

TMDL Unit Supervisor
602-771-4468
800-234-5677
TDD 602-771-4829

ARIZONA DEPARTMENT OF ENVIRONMENTAL QUALITY

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APPROVALS

Prepared & Submitted by: ________________________________ Date: __________

Robert Scalamera, Hydrologist, TMDL Unit

Approved by: ____________________________________ Date: _________

Nancy LaMascus, Supervisor, TMDL Unit

Approved by: ____________________________________ Date: _________

Linda Taunt, Manager, HSA Section

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Note: ADEQ has rewritten this report based on comments submitted in response to the previous (12/06/01 and 08/22/02) reports and to reflect changes in Arizona's Surface Water Quality Standards resulting from the 2002 triennial review.

Project Manager: Robert J. Scalamera, Hydrologist
Arizona Department of Environmental Quality
Water Quality Division
Hydrologic Support & Assessment Section, TMDL Unit
E-mail: scalamera.robert@ev.state.az.us
Telephone: (602) 771-4515

Mail Address: Arizona Department of Environmental Quality
Water Quality Division
Hydrologic Support & Assessment Section, TMDL Unit
Robert J. Scalamera / Mailstop 5415A-1
1110 W. Washington St.
Phoenix, Arizona 85007

ACRONYMS

ADEQ	Arizona Department of Environmental Quality
HEC-HMS	Hydrologic Modeling System produced by the U.S. Army Corps of Engineers, Hydrologic Engineering Center, Sacramento, California
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act, commonly known as Superfund
CWA	Clean Water Act
HUC	Hydrologic Unit Code
LA	Load Allocation (Non-Point Sources)
MOS	Margin of Safety
NPDES	National Pollutant Discharge Elimination Systems (CWA point source permits program)
TMDL	Total Maximum Daily Load
USEPA	United States Environmental Protection Agency (also EPA)
USGS	United States Geological Survey
USFS	United States Forest Service
WLA	Waste Load Allocation (Point Source)
WQS	Water Quality Standards
cfs	cubic feet per second (commonly used discharge measurement unit)
ft	feet
mg/L	milligrams per liter (pollutant concentration measurement unit)
µg/L	micrograms per liter (pollutant concentration measurement unit)
kg/day	kilograms per day (pollutant load measurement unit)

DEFINITIONS OF TERMS USED IN THIS REPORT

Bankfull (discharge)	The flow in the stream at the point of incipient flooding; i.e., the largest non-flood discharge.
Baseflow (discharge)	The perennial portion of the stream discharge; the flow not directly dependent on precipitation events. In the case of an ephemeral stream, baseflow equals zero.
Ephemeral	A stream that has a channel that is at all times above the water table and that flows only in direct response to precipitation
Intermittent	A stream or reach of a stream that flows continuously only at certain times of the year, as when it receives water from a spring or from another surface source, such as melting snow. (AAC R18-11-101(30))
Mining Residue	Residue that is a result of mine related activities and takes the form of waste material piles and spills.
Perennial	A surface water which flows continuously throughout the year. (A.A.C. R18-11-101(38))
Point source	Any discernible, confined, and discrete conveyance, including but not limited to any pipe, ditch, channel, tunnel, conduit, well, discrete fixture, container, rolling stock, concentrated animal feeding operation, landfill leachate collection system, vessel, or other floating craft from which pollutants are or may be discharged. (40 CFR 122.2)
Significant Mining	Mine related activities which result in an observable impact, such as adit drainage or a large volume of exposed mining residue.

NOTE: ADEQ uses USGS maps as the source of names for streams, mines, and other features. Where local usage varies, such differences are noted.

TABLE OF CONTENTS

1.0 PREFACE

1.1 The Clean Water Act (CWA) §303[d] and Its Significance

The CWA §303[d][1][A] requires that "each State shall identify those waters within its boundaries for which the effluent limitations...are not stringent enough to implement any water quality standard applicable to such waters." This act also requires states to establish Total Maximum Daily Loads (TMDLs) for such waters.

The CWA §303[d] requires states to submit to the United States Environmental Protection Agency (USEPA) a list of the surface waterbodies for which the designated use (e.g. irrigation, partial body contact, etc.) of that waterbody is impaired or "water quality limited". Surface water quality data are compared with water quality standards and other criteria to determine whether the waterbody is meeting its designated uses. ADEQ publishes a report on the status of surface water and groundwater quality in Arizona every two years (in accordance with the CWA §305(b)) and from this report derives the "Impaired Waters" or "303[d] List".

The TMDL process provides a flexible assessment and planning framework for identifying load reductions or other actions needed to attain surface water quality standards; i.e. water quality goals to protect aquatic life, drinking water, and other water uses. The CWA established the TMDL process to guide application of state surface water quality standards to individual waterbodies and their watersheds.

1.2 TMDL Defined

The requirements of a TMDL analysis are described in 40 CFR §130.2 & §130.7, based upon CWA §303[d]. A TMDL is described as "the sum of the individual wasteload allocations for point sources and load allocations for non-point sources and natural background" and a margin of safety such that the capacity of the waterbody to assimilate pollutant loadings is not exceeded. Represented as a mathematical equation:

$$TMDL = \sum WLA + \sum LA + MOS,$$

where WLA is the wasteload allocation consisting of loads from point sources, LA is the load allocation consisting of non-point source loads, and MOS is a Margin of Safety which serves to address uncertainties in the analysis and the natural system.

1.3 The TMDL Process

A TMDL analysis is a tool for implementing state surface water quality standards and is based on the relationship between pollution sources and in-stream water quality conditions. The TMDL process is a method used in balancing the pollution concerns for a waterbody and allocating the acceptable pollutant loads among the different point and non-point sources allowing the selection and implementation of suitable control measures to attain water quality standards.

In implementing TMDLs, certain criteria must be taken into account. These criteria include loading capacity, load allocation, wasteload allocation, natural background, and the margin of safety. The loading capacity is the greatest amount of loading that a waterbody can receive without violating water quality standards. Load allocation is the portion of a receiving water§s loading capacity that is attributed either to one of its existing non-point sources of pollution or to natural background sources. The portion of the receiving waters' loading capacity that is attributed to existing point sources of pollution is known as the wasteload allocation. Finally, the margin of safety is the factor that accounts for any uncertainty in the relationship between the pollutant loads and the quality of the receiving waterbody (40 CFR §130.2[f-g]). Total pollutant loads are determined by combining the point, non-point and background sources of pollution.

ADEQ has adopted a stakeholder process for many of its programs, including TMDLs. ADEQ works closely with affected stakeholders in developing the TMDL by holding meetings to solicit input on a variety of topics including background information; potential modeling scenarios; identifying possible pollutant sources for allocation; and discussing potential implementation strategies. Once TMDLs are developed for all the water quality problems, they are submitted to the EPA for review and approval.

The TMDL process is not complete once waste load allocations and load allocations have been determined. Assessment of the TMDL effectiveness must be made. Ideally, this would begin within two years after implementation and continue for the period necessary to measure effectiveness.

1.4 Project History

ADEQ performed this investigation of upper Alum Gulch in response to the stream being listed for violations of water quality standards on the 1996 and 1998 303[d] Lists. Because Alum Gulch is one of three stream segments in the Sonoita Basin that was listed on the State's 303[d] List of impaired waters, ADEQ decided to perform investigations of these segments simultaneously. The other waterbodies in this study are Harshaw Creek and Three R Canyon. This project was started in 1997 and site monitoring was performed between 1997 and 2000 by ADEQ staff.

In 2000, ADEQ hired Hydro Geo Chem (HGC) of Tucson, AZ to review available data, select an appropriate model, and conduct flow and load modeling for the three listed segments within the Sonoita Basin. HGC used ADEQ field measurements to support modeling. The first draft of this TMDL investigation was based solely on ADEQ field measurements and modeling performed by HGC. It was released for public review in December, 2001 and it received considerable public comment.

In the spring of 2002, the USGS completed a six year long study in the Sonoita Basin. USGS staff has made available to ADEQ staff all monitoring data and findings which would be considered pertinent to the three TMDL investigations. All references to their data and findings included herein were received through personal communication with USGS staff. Currently, results from their investigation are being synthesized into a draft report.

After the public review period, when the USGS data and findings from its investigation in the Sonoita basin, became available, ADEQ tasked HGC with reviewing the additional information and updating the model as necessary. HGC determined that the USGS data supported and enhanced ADEQ's understanding of pollutant sources and critical conditions; however, the USGS data did not offer new flow related events that could be used in the model. Additionally, USEPA approved ADEQ's proposed 2002 triennial review changes to the surface water quality standards. The TMDLs were recalculated using the new standards and revised designated uses for several of the listed segments. This draft of the report incorporates the additional data and changes to Arizona's water quality standards.

2.0 PHYSICAL SETTING

2.1 Overview

The Alum Gulch Basin is in Santa Cruz County, Arizona. The closest town is Patagonia, Arizona. The approximate center of the basin is, latitude: 31^{o} 29' N, longitude: 110^{o} 44' W. Basin elevation ranges from 6,300 ft. to 4,600 ft. The primary tributary to the listed portion of Alum Gulch is Humboldt Canyon, the mouth of which is between the January Adit and the World's Fair Mine. There are no active mines in the subject basin. Figures 1, 2, and 3 provide views of the project location, overall area, and the subject basin.

2.2 Climatology

The climate of the Alum Gulch basin varies from high desert in the Sonoita Valley to the steppe-like climate of the higher elevation grasslands and scrub forest. Below-freezing temperatures are to be expected during the winter months, and precipitation, both rain and snow, occurs most winters. Most summers bring "monsoon" thunderstorms. Snow may remain on the higher elevations for periods ranging from hours to weeks.

The closest weather stations to the subject basin, at Canelo Pass, Nogales, and San Rafael Ranch, have different climatic settings (e.g., elevation, position relative to mountains) and do not accurately reflect the conditions found in the Alum Gulch basin.

2.3 Hydrology

The two mile long subject reach is described in the Arizona surface water quality standards as:, "Headwaters to 31^{o} 28' 20"/110^{o} 43' 51" " and "31^{o} 28' 20"/110^{o} 43' 51" to 31^{o} 29' 17"/110^{o} 44' 25" ". These descriptions reference the same stream segment, Hydrologic Unit Code (HUC) #15050301-561A. Beginning at the January Adit, flow is intermittent, though primarily perennial due to the adit, to the downstream end of the listed reach. Based upon limited measurements and modeling at baseflow, groundwater (from springs and mine adits) is the sole source of flow in the perennial portion of the stream. Measured baseflow ranged from 0.001 to 3 cubic feet per second (cfs) at various points along the subject reach.

Upper Alum Gulch drains approximately 1900 acres and no known flow gaging stations are known to exist on the subject waterbody. Over the length of this investigation, observed flows varied from 0.001 to 50 cfs (estimated). This investigation appears to be the first hydrologic characterization of this basin. Field observations confirm that all of the tributaries to upper Alum Gulch are ephemeral.

During the 2002 ADEQ triennial review of standards, a flow-related designated use change, from perennial to ephemeral, was adopted for the portion of Alum Gulch upstream from the January Adit (within the listed reach) and downstream from a point approximately 800 meters downstream from the World's Fair Mine (below the listed reach).

2.4 Geology

The Alum Gulch Basin falls into the Basin and Range physiographic province. This province is typified by broad, gentle sloping valleys, such as the upper Sonoita Creek valley, separated by sharply rising mountain ranges. Upper Alum Gulch is a narrow, steep-walled valley which cuts into bedrock. Upon leaving the listed reach, lower Alum Gulch flows through a wider valley filled with alluvium.

The USGS map and sections of the Nogales and Lochiel quadrangles show the bedrock of Alum Gulch is comprised of greater than 4,500 ft. of igneous material. The headwaters of Alum Gulch, at the Trench Camp Mine, sits atop 500 to 1,500 ft. of Upper Cretaceous volcanics composed of trachyandesites, rhyolites, and dacites. Just south of the World's Fair Mine, this unit is juxtaposed by faulting to older Upper Cretaceous silicic volcanics, locally a biotite latite which is about 500 ft. thick. Both of these units rest unconformably on Upper Triassic/Lower Jurassic rhyolitic and latitic lavas, and tuffs. The western hills along Alum Gulch are capped by 25 to 75 ft. of Paleocene/Upper Cretaceous tuff, tuffaceous sandstone, and breccia which lie unconformably on the Upper Cretaceous trachyandesites.

In this watershed, ore deposition occurred during the Laramide Orogeny (probably Upper Cretaceous). The deposits are considered to be polymetallic vein replacements, such as the January vein. Associated skarns also host minerals of economic significance. An oxide rind, extending 30 ft. to 45 ft. subsurface, has developed in the vein deposits (personal comm, Floyd Gray, USGS, 07/25/02).

2.5 Vegetation/Wildlife

Upper Alum Gulch is a sparsely vegetated and lower Alum Gulch flows through a wider valley filled with alluvium and vegetated with the cottonwoods, sycamores, willows, and other plants typical of arid area riparian zones.

A review of the U.S. Fish and Wildlife Service web site did not reveal the presence of threatened or endangered species in the subject basin.

2.6 Land Use/Land Ownership

The Alum Gulch basin is almost wholly contained within the Coronado National Forest and is available for recreational usage.

The Alum Gulch basin contains areas of mineralization (primarily zinc, lead and copper) that have been mined since prior to the arrival of the first Spanish explorers, approximately 500 years ago (personal comm Arizona Department of Mines and Minerals; personal comm Sheila Dean, USFS) Large-scale mining, consisting of mainly sub-surface workings, began in the mid-1800s and continued for approximately 100 years. The region is covered with abandoned mine workings and mining residue. Alum Gulch has two privately owned mines, the Trench Camp Mine and the January Adit, both are owned by Asarco.

There is some privately owned land occupied by vacation cabins/homes in lower Alum Gulch (just outside the study area). Cattle grazing is also performed here.

2.7 Problem Statement

The segment was listed for impairments due to dissolved and total cadmium, copper, zinc, and acidity (pH). The overall purpose of this project was to provide an assessment of the sources of these pollutants and to calculate TMDLs for the listed pollutants on the affected reaches. Lower Alum Gulch, starting at the downstream end of the study reach and continuing approximately 4 ½ miles to its mouth on Sonoita Creek, is not included on the 303[d] List and, therefore, not addressed in this TMDL.

Flow in upper Alum Gulch carries measurable quantities of cadmium, copper, and zinc and has excessively low pH. The pollutants of concern result from the chemical weathering of sulfide-mineralized rock which produces sulfuric acid. Sulfuric acid acts to disassociate metals from the mineral matrix and make them available for transport, in the dissolved form, in the water column. Sulfide minerals are naturally occurring in the mining district. They can also be found in stockpiled mine materials.

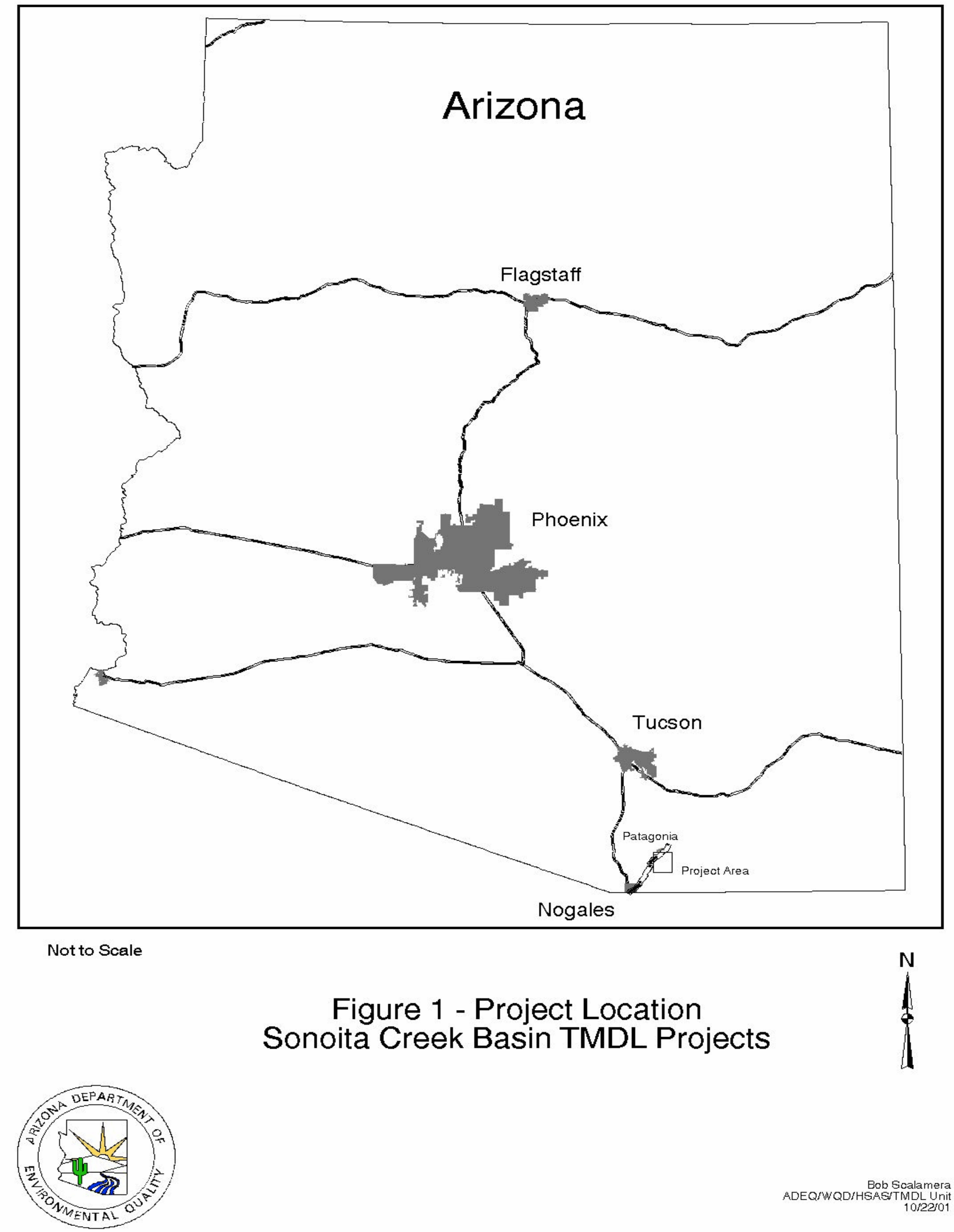
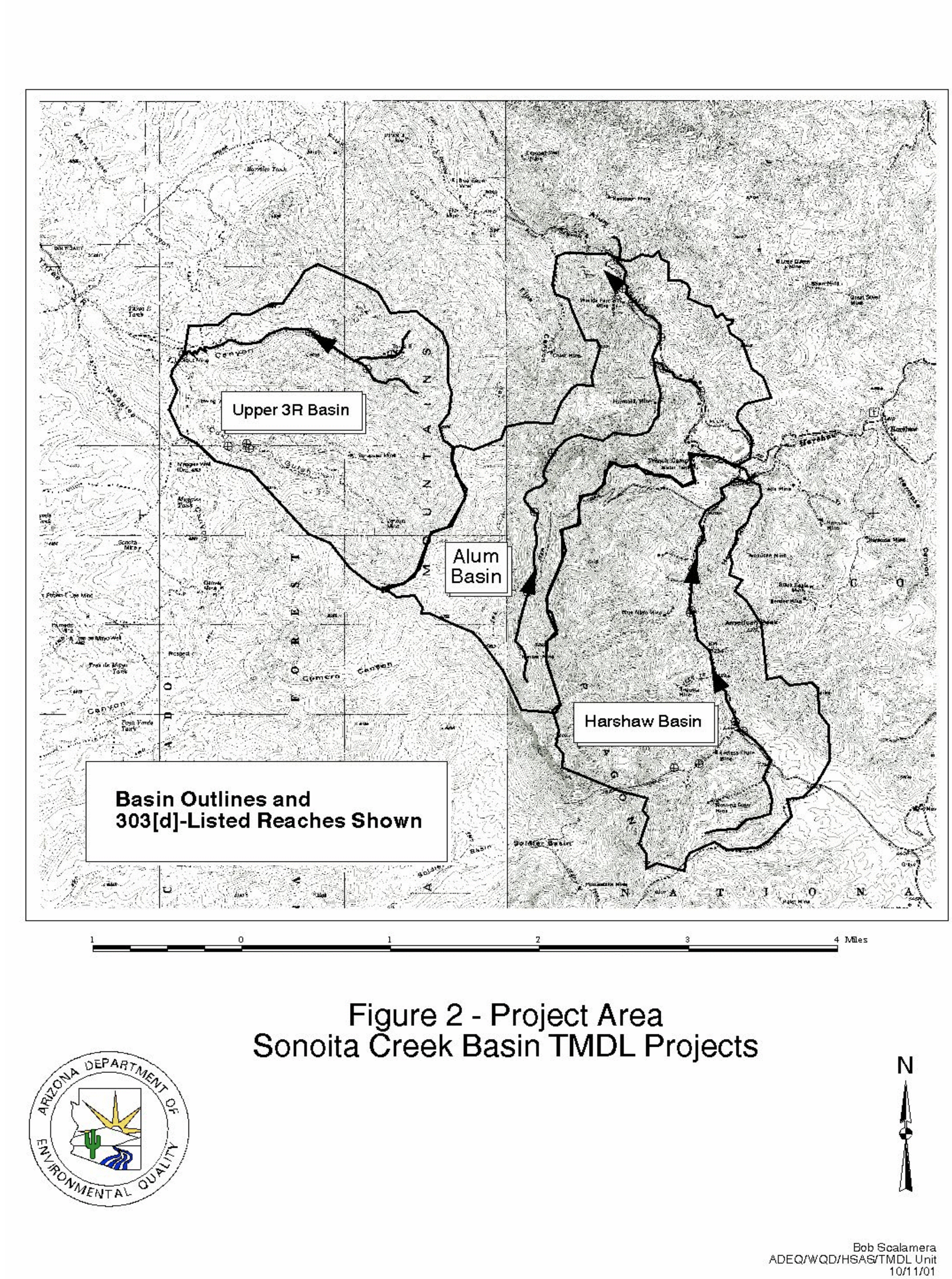


Figure 1 - Project Location
Sonoita Creek Basin TMDL Projects



Upper 3R Basin
Alum Basin
Harshaw Basin
Basin Outlines and 303[d]-Listed Reaches Shown
1 0 1 2 3 4 Miles
Figure 2 - Project Area
Sonoita Creek Basin TMDL Projects
ARIZONA DEPARTMENT OF ENVIRONMENTAL QUALITY
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Bob Scalamera
ADEQ/WQD/HSAS/TMDL Unit
10/11/01

3.0 NUMERIC TARGETS

3.1 Surface Water Quality Standards

The State of Arizona has adopted numeric water quality standards (Table 1) which protect the designated uses of each surface water. During the 2002 triennial review of surface water quality standards, ADEQ modified designated uses for several segments within the Alum Gulch study area. The State also repealed the chronic water quality standards on ephemeral waters; therefore only the acute standards apply to ephemeral waters. The revised standards were approved by the USEPA on October 22, 2002.

For Alum Gulch, from January Adit to 800 meters downstream of World's Fair Mine, the following designated uses apply:

- Aquatic and Wildlife, warm water (A&Ww),
- Full Body Contact (FBC),
- Fish Consumption (FC), and
- Agricultural Livestock Watering (AgL)

For Alum Gulch, upstream of January Adit and from 800 meters downstream of World's Fair Mine to its confluence with Sonoita Creek, the following designated uses apply:

- Aquatic and Wildlife ephemeral (A&We),
- Partial Body Contact (PBC), and
- Agricultural Livestock Watering (AgL)

For Humboldt Canyon, the following designated uses apply:

- Aquatic and Wildlife ephemeral (A&We) and
- Partial Body Contact (PBC)

The numeric target for each of the listed pollutants has been set so that the most stringent water quality standard for the supported designated uses can be supported. The cadmium, copper and zinc standards for the listed Aquatic and Wildlife uses vary with hardness (range of 25 to 400 mg/L as $CaCO_3$) (A.A.C. Title 18, Chapter 11, Article 1, App. A).

Table 1 Surface Water Quality Standards (basis for numeric targets)

Designated Use	pH	Cadmium (µg/l)		Copper (µg/l)		Zinc (µg/l)	
		Total	Dissolved	Total	Dissolved	Total	Dissolved
A&Ww (chronic)	6.5 - 9.0		0.8 - 6.2		2.7 - 29		36 - 379
A&Ww (acute)	6.5 - 9.0		0.95 - 19		3.6 - 50		36 - 379
A&We (acute)	6.5 - 9.0		14 - 290		6.3 - 86		344 - 3,599
AgL	6.5 - 9.0	50		500		25,000	
FBC/PBC	6.5 - 9.0	700		1,300		420,000	
FC	6.5 - 9.0	84				69,000	

The minimum applicable pH standard, as shown above, is 6.5. Since this is a unitless number, it was converted to H^+ ion concentration in µg/L for the load calculations. The formula is $10^{(-pH)}$ which results in a hydrogen concentration in moles and, since the atomic weight of hydrogen is one, this equates very closely to mg/L. Multiplying by 1,000 gives hydrogen ion concentration in µg/L Using this formula, the H^+ concentration of 0.00032 µg/L is equivalent to the standard of 6.5. The larger the H^+ concentration, the lower the pH.

Tables 2A-2D include a summary of measured concentrations in comparison to applicable standards. Figure 3 displays the relative locations of ADEQ and USGS sample sites.

3.2 In-stream Indicators

Reliable in-stream indicators that are solely related to water quality have not been observed in the subject watershed. The "normal" indicators (i.e., insects, fish, and vegetation) are also adversely affected by the huge variations in water quantity (dry to flood). The presence of evaporative salts (precipitates) on the dry portions of the streambed may be considered In-stream indicators, but much more data needs to be collected to determine and quantify the relationship to In-stream water quality. Attributing a cause to an in-stream indicator is therefore tenuous at best. Hillslope conditions hold some promise as indicators, but, again, much more data needs to be collected to determine and quantify the relationship to In-stream water quality. Therefore, for this phase of the TMDL, ADEQ has chosen to rely solely on In-stream concentrations of the pollutants of concern.

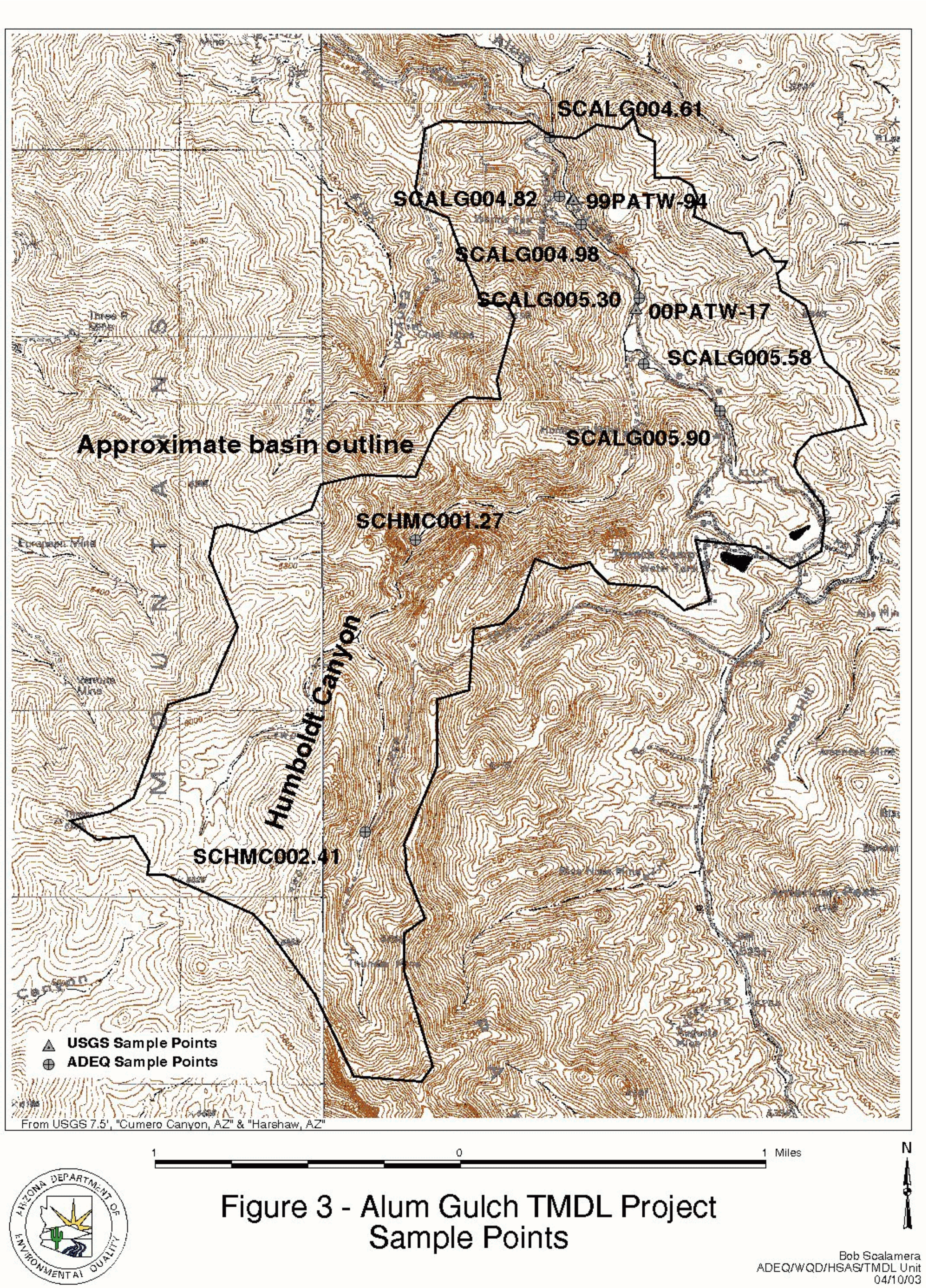


Figure 3 - Alum Gulch TMDL Project
Sample Points

POLLUTANT MONITORING DATA

Table 2A pH Data (standards exceedances in bold)

Site	Date	Discharge (cfs)	pH WQS	pH Data
SCHMC002.41	07/22/99	0.07	6.5 - 9.0	**3.3**
SCHMC001.27	07/20/99	50 (est)	6.5 - 9.0	**3.6**
SCALG005.90	07/20/99	15 (est)	6.5 - 9.0	**5.9**
SCALG005.58	07/20/99	0.07	6.5 - 9.0	**5.3**
SCALG005.58	01/11/00	0.001 (est)	6.5 - 9.0	**4.5**
SCALG005.30	07/20/99	0.06	6.5 - 9.0	**3.6**
00PATW-17 (nat. back.) (USGS)	02/07/00	not measured	6.5 - 9.0	**5.8**
SCALG004.98	07/20/99	0.05	6.5 - 9.0	**3.5**
SCALG004.82	12/04/97	0.01	6.5 - 9.0	**3.3**
SCALG004.82	02/10/98	6	6.5 - 9.0	**3.4**
SCALG004.82	03/31/98	2.9	6.5 - 9.0	**3.7**
SCALG004.82	06/02/98	0.01	6.5 - 9.0	**3.3**
99PATW-94 (nat. back.) (USGS)	07/27/99	not measured	6.5 - 9.0	not measured
SCALG004.61	07/20/99	0.36	6.5 - 9.0	**3.2**
SCALG004.61	01/11/00	0.001 (est)	6.5 - 9.0	**3.2**

Table 2B Cadmium data (standards exceedances in bold)

Site	Date	Discharge (cfs)	Hard [3] (mg/L) (calc/adj)	A & W WQS [3] (µg/L)	Data Cd diss [3] (µg/L)	AgL WQS (µg/L)	FC WQS (µg/L)	Data Cd total (µg/L)
SCHMC002.41 [1] (Humboldt Cyn)	07/22/99	0.07	36/36	21	2.8	--	--	2.4
SCHMC001.27 [1] (Humboldt Cyn)	07/20/99	50 (est)	20/25	14	ND [4, 5]	--	--	ND [4, 5]
SCALG005.90 [2]	07/20/99	15 (est)	110/110	72	10	50	--	10
SCALG005.58	07/20/99	0.07	2,269/400	6.2	**120**	50	84	**140**
SCALG005.58	01/11/00	0.001 (est)	2,666/400	6.2	**170**	50	84	**180**
SCALG005.30	07/20/99	0.06	1,830/400	6.2	**150**	50	84	**180**
00PATW-17 (nat. back.) (USGS)	02/07/00	not measured	15/25	14	0.18	50	84	not measured
SCALG004.98	07/20/99	0.05	1,581/400	6.2	**160**	50	84	**160**
SCALG004.82	12/04/97	0.01	1,522/400	6.2	**215**	50	84	**191**
SCALG004.82	02/10/98	6	188/188	3.6	**28**	50	84	29
SCALG004.82	03/31/98	2.9	2,08/208	3.8	**30**	50	84	27
SCALG004.82	06/02/98	0.01	1,597/400	6.2	**194**	50	84	**174**
99PATW-94 (nat. back.) (USGS)	07/27/99	not measured	19/25	14	0.09	50	84	not measured
SCALG004.61	07/20/99	0.36	1,424/400	6.2	**170**	50	84	**170**
SCALG004.61	01/11/00	0.001 (est)	1,880/400	6.2	**220**	50	84	**290**

Notes:
1 Ephemeral reach: A&We (acute) and PBC apply; all other reaches designated as perennial unless otherwise noted (see footnote 2).
2 Ephemeral reach: A&We (acute), PBC and AgL apply; all other reaches designated as perennial unless otherwise noted (see footnote 1).
3 Hardness values less than 25 mg/L were adjusted to 25 mg/L; values greater than 400 mg/L were adjusted to 400 mg/L. (A.A.C. Title 18, Chapter 11, Article 1, Appendix A)
4 Not Detected
5 Method Reporting Limit = 1 mg/L.

Table 2C Copper Data (standards exceedances in bold)

Site	Date	Discharge (cfs)	Hard [3] (mg/L) (calc/adj)	A &W WQS [3] (µg/L)	Data Cu diss [3] (µg/L)	AgL WQS (µg/L)	FBC/PBC WQS (µg/L)	Data Cu total (µg/L)
SCHMC002.41 [1] (Humboldt Cyn)	07/22/99	0.07	36/36	8.9	**540**	500	1,300	**550**
SCHMC001.27 [1] (Humboldt Cyn)	07/20/99	50 (est)	20/25	6.3	**140**	500	1,300	160
SCALG005.90 [2]	07/20/99	15 (est)	110/110	25	13	500	1,300	63
SCALG005.58	07/20/99	0.07	2,269/400	29	**110**	500	1,300	110
SCALG005.58	01/11/00	0.001 (est)	2,666/400	29	**400**	500	1,300	420
SCALG005.30	07/20/99	0.06	1,830/400	29	**1,200**	500	1,300	**1,200**
00PATW-17 (nat. back.) (USGS)	02/07/00	not measured	15/25	6.3	2	500	1,300	not measured
SCALG004.98	07/20/99	0.05	1,581/400	29	**1,500**	500	1,300	**1,400**
SCALG004.82	12/04/97	0.01	1,522/400	29	**2,080**	500	1,300	**1,890**
SCALG004.82	02/10/98	6	188/188	15	**966**	500	1,300	**917**
SCALG004.82	03/31/98	2.9	2,08/208	17	**881**	500	1,300	**799**
SCALG004.82	06/02/98	0.01	1,597/400	29	**2,110**	500	1,300	**2,140**
99PATW-94 (nat. back.) (USGS)	07/27/99	not measured	19/25	6.3	**8**	500	1,300	not measured
SCALG004.61	07/20/99	0.36	1,424/400	29	**1,600**	500	1,300	**1,900**
SCALG004.61	01/11/00	0.001 (est)	1,880/400	29	**2,000**	500	1,300	**2,100**

Notes:
1 Ephemeral reach: A&We (acute) and PBC apply; all other reaches designated as perennial unless otherwise noted (see footnote 2).
2 Ephemeral reach: A&We (acute), PBC and AgL apply; all other reaches designated as perennial unless otherwise noted (see footnote 1).
3 Hardness values less than 25 mg/L were adjusted to 25 mg/L; values greater than 400 mg/L were adjusted to 400 mg/L. (A.A.C. Title 18, Chapter 11, Article 1, Appendix A)

Table 2D Zinc Data (standards exceedances in bold)

Site	Date	Discharge (cfs)	Hard [3] (mg/L) (calc/adj)	A&W [3] WQS (µg/L)	Data Zn diss [3] (µg/L)	AgL WQS (µg/L)	FC WQS (µg/L)	Data Zn total (µg/L)
SCHMC002.41 [1] (Humboldt Cyn)	07/22/99	0.07	36/36	468	210	25,000	69,000	200
SCHMC001.27 [1] (Humboldt Cyn)	07/20/99	50 (est)	20/25	344	85	25,000	69,000	110
SCALG005.90 [2]	07/20/99	15 (est)	110/110	1206	**2500**	25,000	69,000	2,900
SCALG005.58	07/20/99	0.07	2,269/400	379	**39000**	25,000	69,000	**42,000**
SCALG005.58	01/11/00	0.001 (est)	2,666/400	379	**56000**	25,000	69,000	**56,000**
SCALG005.30	07/20/99	0.06	1,830/400	379	**44000**	25,000	69,000	**41,000**
00PATW-17 (nat. back.) (USGS)	02/07/00	not measured	15/25	344	32	25,000	69,000	not measured
SCALG004.98	07/20/99	0.05	1,581/400	379	**46000**	25,000	69,000	**49,000**
SCALG004.82	12/04/97	0.01	1,522/400	379	**54080**	25,000	69,000	**54,900**
SCALG004.82	02/10/98	6	188/188	200	**6110**	25,000	69,000	5,730
SCALG004.82	03/31/98	2.9	208/208	218	**8400**	25,000	69,000	7,680
SCALG004.82	06/02/98	0.01	1,597/400	379	**56200**	25,000	69,000	**50,600**
99PATW-94 (nat. back.) (USGS)	07/27/99	not measured	19/25	344	24	25,000	69,000	not measured
SCALG004.61	07/20/99	0.36	1,424/400	379	**49000**	25,000	69,000	**45,000**
SCALG004.61	01/11/00	0.001 (est)	1,880/400	379	**53000**	25,000	69,000	**54,000**

Notes:
1 Ephemeral reach: A&We (acute) and PBC apply; all other reaches designated as perennial unless otherwise noted (see footnote 2).
2 Ephemeral reach: A&We (acute), PBC and AgL apply; all other reaches designated as perennial unless otherwise noted (see footnote 1).
3 Hardness values less than 25 mg/ Were adjusted to 25 mg/L; values greater than 400 mg/L were adjusted to 400 mg/L. (A.A.C. Title 18, Chapter 11, Article 1, Appendix A)

4.0 SOURCE ANALYSIS

The primary project objective of this investigation was to collect data sufficient to isolate (geographically and temporally) and quantify, relative to each other, the primary pollutant load sources in the project area. All significant sources have been identified and linkages between these significant sources and loads are discussed in the Linkage Analysis Section 5.0.

The data used to determine impairment which resulted in the 303[d]-listing was collected during the 1980s and 1990s in support of the goals of other ADEQ programs and is insufficient to isolate sources or calculate loads. As part of this project, ADEQ collected data specific to the goals of source quantification and TMDL calculation. Lack of precipitation during the study period made a comprehensive analysis of all sources impossible.

There are no known NPDES-permitted point sources in the subject basin; however, a complete review of all sources may result in the classification of some as point source would require NPDES discharge permits.

4.1 Current Conditions

Verification sampling events were completed between December 1997 and June 1998 on Upper Alum Gulch at a sample point (SCALG004.82) near the downstream end of the listed reach. ADEQ conducted source identification monitoring of the subject waterbody during 1999 - 2000. In order to better monitor loads due to the World's Fair Mine, ADEQ replaced sample point SCALG004.82 with sample point SCALG004.61 further downstream. Four additional sample points in Alum Gulch and two sample points in Humboldt Canyon were also added and were located to allow determination of loads from known sources. Due to lower-than-normal precipitation during this period, ADEQ was able to collect only a limited number of samples. (Figure 3 displays the ADEQ sampling locations; Tables 2A-2D display the measured data.)

4.2 General Sources

4.2.1 Natural Background

With respect to the definition of a natural background source, HydroGeoChem, Inc. (HGC) concluded,

> ".. there are several areally-extensive zones of alteration and mineralization associated with the ore deposits in the subject watersheds. A field inspection verified that there are large portions of the subject watersheds containing naturally occurring disseminated pyrite and iron oxides due to weathering of pyrite." (HGC's Task 3 report, p. 4)

ADEQ staff initially selected a natural background sampling site in Humboldt Canyon which lies in the upper reaches of Alum Gulch. This area appears geologically and environmentally similar to Alum Gulch and it is in an area that has not been previously disturbed by mining or other human activities. However, because precipitation was never sufficient to result in flow, natural background samples could not be collected here as originally planned.

The USGS made natural background measurements (slope runoff) in Alum Gulch.

ADEQ's modeling contractor for this project, HGC, Inc., was tasked with determining the applicability of the USGS natural background data to the calculation of the TMDL. After review of the USGS data, field notes, conversations with USGS personnel (Floyd Gray and Laura Brady) and discussions with ADEQ, it was determined that two of the USGS measurement sets are usable as natural background for some of the ADEQ sample sites in the subject basin. This data is included in tables 2A-2D and was used to determine background metals concentration values for ADEQ sample sites: SCALG005.58, SCALG005.30, SCALG004.98, SCALG004.82 and SCALG004.61. Sample site SCALG005.90 consists solely of runoff from the Trench Camp Mine without natural background. Sample sites SCHMC001.27 and SCHMC002.41 are in an area where there are no USGS natural background sites.

Because there is no means of determining the discharge associated with the USGS natural background values, ADEQ has included these values only because no alternative exists. ADEQ will include more refined measurement of natural background runoff and associated discharges as part of the second phase of this TMDL.

The USGS measure dissolved fractions only. Because there are surface water quality standards for both, ADEQ measures both total and dissolved fractions. Review of the data however, indicates very little difference between the two in this watershed. Because it appears that metals tend to stay in the dissolved state, ADEQ considers USGS measurements representative of both total and dissolved natural background. The background concentrations displayed below were calculated by averaging the two USGS measurements. ADEQ will collect additional measurements of natural background runoff and associated discharges as part of the second phase of this TMDL.

Cadmium (diss & total): (0.09 + 0.18)/2 = 0.135 which is rounded to **0.14 µg/L**.

Copper (diss & total): (7.6 + 2.3)/2 = 4.95 which is rounded to **5 µg/L**.

Zinc (diss & total): (25 + 32)/2 = 28.5 which is rounded to **28 µg/L.**

The USGS pH measurements were more limited in scope than the metals and were not usable in determining the natural background load.

4.2.2 Adit drainage

The January Adit and World's Fair Mine have the only observed constant drainages in the subject basin. The January Adit does not discharge directly to the stream, but rather to constructed wetlands. The discharge evaporates or infiltrates, however, a portion of the infiltration then discharges to the stream.

The USGS (personal comm, Floyd Gray, USGS, 05/31/02) has concluded:

1) There are one or more springs beneath the World's Fair Mine.
2) These springs are a major source of acidity and metals, with equivalent concentrations and proportions as the World's Fair Adit drainage. This could be evidence that groundwater is impacted by the underground mine workings.

The adit drainage in the study area is usually very acidic, pH of 2 to 3, and carries a variety of metals. Corresponding flow rates into the stream fluctuated but generally were extremely low, barely a trickle. During dry periods all the drainage from the World's Fair Mine adit evaporated or entered the interstitial spaces of the waste dump before mixing with spring discharge and entering the stream.

As noted in the Hydrology Section, these sources define the perennial flow (baseflow) on Alum Gulch and thus, they are the only source of pollutant loadings during baseflow conditions. During bankfull flow, the drainage from mine works directly into streams is not a major source of pollutant loading due to dilution; i.e., the runoff flows are two or more orders of magnitude higher than the baseflow with corresponding lower loads as shown by modeling. The results of the modeling are displayed in tables 4A - 4L and comparison of bankfull loads to baseflow loads is easily made.

4.2.3 Mining residues

In addition to adit drainage, mining residues are a significant source of pollutants and consist of three major categories of material:

- Waste rock removed to gain access to the ore. (This material may or may not have leachable metals.)
- Low grade ore waste that has leachable metals in quantities that were uneconomical to extract at the time of mining.
- Mill tailings which are the finely ground waste after separation from the economically useful minerals. This material may or may not have leachable metals.

These materials are typically mixed (layered) in the same "dumps", dependent upon mine or mill activities at the time of dumping. The dumps are exposed to precipitation and are being slowly eroded and fed into the stream by runoff. ADEQ did not observe significant movement or erosion of this material after the low intensity (≈ two year) precipitation event that was sampled; however, gullies and rills were noticed during a sampling trip that occurred several days after a large localized precipitation event. It should be noted that these piles, which are in contact with the stream, are being constantly eroded and undercut creating a potential for collapse into the stream.

The USGS came to the following conclusions about mining residue:

> The mine sites of the watershed typically include numerous adits and shafts, waste rock, and relic tailings dumps, and the larger sites typically have the remains of mills or other ore-handling fixtures, all resting on the steep, rocky banks of the stream. These sites release concentrations of metals in the "high metal" (high concentrations) category relative to a large range of mine types compiled from world literature (see Plumlee et al, 1993) (personal comm, Floyd Gray, USGS, 05/31/02).

4.2.4 Streambeds

Streambed sediments result from the wasting of mining residue piles and evaporative deposits from groundwater discharges which vary in composition as do the waste piles. Findings from the USGS investigation suggest that streambed sediments are the primary source of pollutant loading (personal comm, Floyd Gray, USGS, 5/31/02). Streambed sediments are not directly addressed by this phase of the TMDL due to a lack of data that can be used to associate sediment concentrations with water column concentrations at various discharges. Arizona currently does not have standards for sediments, but this loading source will be further characterized in a later phase of the investigation.

4.3 Existing, Known Sources

Figure 4 displays the relative inputs in a graphical format. The sampling results shown in Tables 2A - 2D and the modeling results shown in Tables 4 - 6 were used to support the following conclusions.

4.3.1 Trench Camp Mine

The Trench Camp Mining residue material dumps Nos.1, 2, and 4 fill the upper portion of Alum Gulch, and dump No.3 is in the Harshaw Creek basin. Trench Camp Mine, formerly occupied by a mine, mill, and smelter, was largely remediated by Asarco, during the 1980’s and 1990’s. The remediation included the removal of structures, filling of the main shaft, and leveling and vegetating of the four waste material dumps. Asarco also removed stream bottom sediments from an approximately 400 meter reach of Alum Gulch running from the “bottom” of the Trench Camp Mine to below the created wetlands that capture the January Adit discharge. The sediments were replaced with crushed limestone intended to act as a neutralizing agent for acidic drainage that should reach it.

Sample point SCALG005.90 was used to measure runoff from the Trench Camp Mine. The stream is ephemeral at this point and was sampled during only one storm event. Sample results show that Trench Camp Mine contributes minor amounts of zinc and acidity to the water column; however, its load contribution is much less than that of the other unaddressed sources in the subject basin.

4.3.2 January Adit

The January Adit, 200 meters downstream from Trench Camp Mine, was plugged in the late 1990§s by Asarco. Its discharge was piped to a wetlands created for treatment. The artificial wetlands has not yet met treatment expectations and Asarco is currently researching alternative treatment methods. The portion of the flow from the wetlands that percolates into the stream is the most upstream perennial water source in Alum Gulch. Sample point SCALG005.58 is used to measure the contribution from the January Adit wetlands. January Adit is a minor contributor of cadmium, copper and acidity and a major contributor of zinc to the water column. Its load contributions of acid and copper are less than that of the World's Fair Mine and Humboldt Canyon.

4.33 Humboldt Canyon

For purposes of this project, Humboldt Canyon can be divided into an upper and lower segment. The density of mining activities in each of these precludes differentiating between individual mines as sources. The division between the upper and lower segments is the waterfall segment the downstream end of which is just upstream from the Humboldt Well. This waterfall segment is approximately 500 meters of very rugged terrain. There is no visually discernable (from the air or ground) sources of pollutant loading.

The headwaters of Humboldt Canyon, a one and a half mile reach, contains the Thunder Mine and several un-named mines of sufficient size with easily observable waste piles and spills. This material, if of proper composition, could be considered a pollutant source.

Below the waterfall segment, is the Humboldt Well, a 5,000 foot exploration hole which has been steel-cased to about 2,000 foot below ground surface (personal comm, Duane Yantorno, Asarco, 1997). Because this well is artesian, it has been capped and equipped with a small, garden-hose sized, valve. When the valve is opened, the water will arc to a height of approximately two feet. Measurements of the pH of this water ranged from 2.8 to 3.8. Metals were not sampled here.

The lower portion of Humboldt Canyon has many small prospect pits, several small adit or shaft mines with observable waste piles and spills, and the Humboldt Mine, a cluster of shafts and adits with waste piles large enough to occupy part of the stream channel.

Sample points SCALG005.30 (downstream from the Humboldt mouth, upstream from the Alum Gulch water fall) and SCALG004.98 (downstream from the Alum Gulch water fall, upstream from the World§s Fair Mine) were used to monitor the water quality between the mouth of Humboldt Canyon and the World's Fair Mine.

Data collected at sample point SCALG005.30 was also compared to data collected at sample point SCALG0005.58, located upstream from the mouth of Humboldt Canyon. Data comparison indicates that Humboldt Canyon is considered a major source of copper, zinc, and acidity.

4.3.4 World's Fair Mine

The World's Fair Mine, an abandoned claim within the Coronado National Forest, is a complex of shafts and adits and a former mill site. There is a constantly draining adit with very low flow and a spring or springs buried beneath the waste pile (personal comm, Floyd Gray, USGS, 2002). This waste pile is a large exposure of waste material which includes mill tailings that fill a tributary draw and a portion of Alum Gulch. The left stream bank of Alum Gulch is defined by the waste pile as evidenced through undercutting of the pile by the stream flow.

The World's Fair Mine site is a major contributor to loading of all the subject pollutants. The World's Fair mine is approximately 300 meters upstream from the bottom of the 303[d]-listed reach and there are no significant sources of pollutant loading in this lowest segment downstream of the mine.

Sample point SCALG004.82, only used during 1997-1998 sampling, is immediately downstream from the World's Fair Mine. This sample point was replaced for the 1999-2000 sampling by SCALG004.61 located approximately 200 meters downstream from the World's Fair Mine. These points were used to measure the contribution from the World's Fair Mine.

4.3.5 Source Summary

Upper Alum Gulch and Humboldt Canyon are narrow steep-walled canyons with limited horizontal space available to support mining activity, yet there are many small mines throughout the basin which have a potential impact. During this first phase of the TMDL project, ADEQ was able to quantify the contributions of a large number of mines on a segment/tributary basis (e.g., upper Humboldt Canyon, lower Humboldt Canyon).

Based upon the results of field measurements, the major portion of the loading originates from the World's Fair Mine area and Humboldt Canyon with relatively minor contributions from Trench Camp Mine and the January Adit. Modeling, described in section 6, also supports this conclusion. It appears that the remediation efforts at Trench Camp and the January Adit have been relatively successful. Contributions of acidity and copper are one to two orders of magnitude less than samples collected from Humboldt Canyon or the World's Fair Mine. There appears to be little change in cadmium levels amongst the various sites and all sites except Trench Camp (site SCALG005.90) are major contributors of zinc.

Lastly, except at World's Fair Mine, there appears to be an inverse relationship between discharge and loading between the mouth of Humboldt Canyon and the World's Fair Mine. At low flows the loadings increase dramatically and at higher flows, the loading decrease. Other than Humboldt Canyon or stream sediments, there are no other apparent sources of the subject pollutants between the created wetlands (at the January Adit) and the World's Fair Mine.

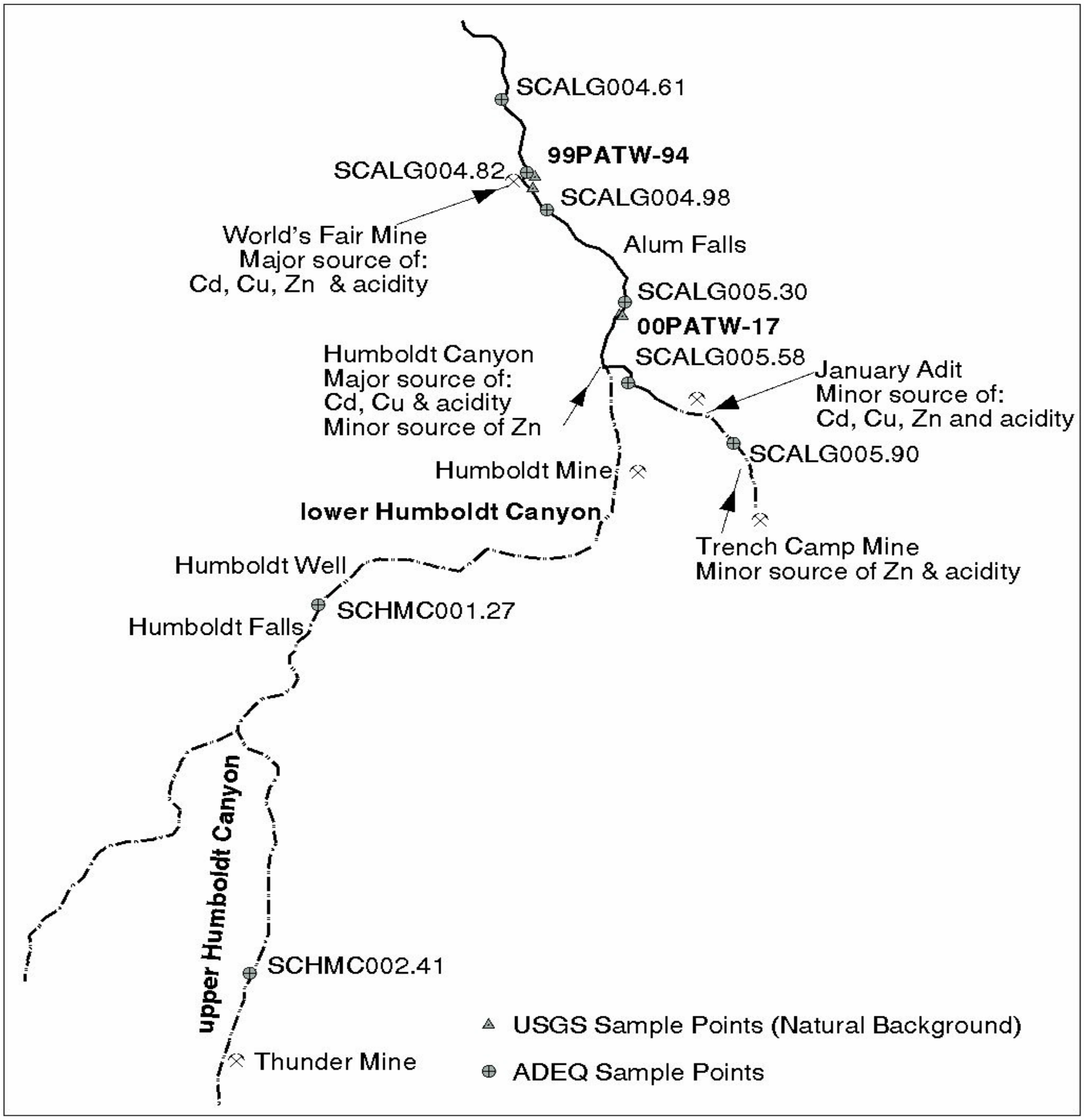


Figure 4 - Upper Alum Gulch TMDL Project
Loading Sources Schematic

Not to Scale

Bob Scalamera
ADEQ/WQD/HSAS/TMDL Unit
8/15/02

5.0 LINKAGE ANALYSIS

5.1 Linkage of Sample Sites and Sources

Table 3 and Figure 4 display the linkage between each sample site (point of compliance) and the pollutant load sources corresponding to each point. Figure 4 also displays the relative significance of the load sources.

Table 3 Linkage of Sample Sites (Points of Compliance) and Sources

Site ID	Pollutant Sources
SCHMC002.41	Humboldt Canyon headwaters, Thunder Mine and others plus natural background
SCHMC001.27	Humboldt Canyon, upstream load plus natural background
SCALG005.90	Alum Gulch headwaters plus Trench Camp Mine runoff
SCALG005.58	Alum Gulch upstream loads plus January Adit load
	Confluence of Humboldt Canyon and Alum Gulch
SCALG005.30	Upstream loads of Alum Gulch plus Humboldt Canyon load
00PATW-17	Slope runoff to Alum Gulch - natural background (USGS)
SCALG004.98	Upstream loads plus natural background
SCALG004.82	Bankfull = upstream loads plus World§s Fair Mine load plus natural background. Baseflow = World’s Fair Mine load plus negligible natural background (point source).
99PATW-94	Slope runoff to Alum Gulch - natural background (USGS)
SCALG004.61	Bankfull = upstream loads plus World§s Fair Mine load plus natural background. Baseflow = World’s Fair Mine load plus negligible natural background (point source).

The pollutants of concern are linked in that all result from the action of water and oxygen on sulfide minerals in mining residues, streambed sediments, and naturally occurring mineral deposits which produce sulfuric acid. The acid acts to disassociate metals from the mineral matrix and make them available for transport in the dissolved form in the water column.

5.2 Critical Conditions

Conclusions from the USGS investigation characterize the factors critical to loading in Alum Gulch:

> Periodically, almost seasonally, release of waste rock into the streams were observed with the subsequent release of metals to the water column. This metal release by waste rock movement is a significant component in low volume desert waterways.
>
> Waste material captured in the stream during storms is transported downstream and deposited preferentially in areas of shallow gradient where the velocity and suspended load capacity of the stream is diminished. The process by which storm water is degraded appears to be via interaction with reactive detritus (e.g. sulfide-bearing siliceous waste

rock, sulfate salts) from waste piles and from interaction with highly soluble salts accumulated in stream-bed sediment via evaporation. By the combined actions of these processes the acid generating potential of downstream areas typically resembles that of upstream mine sites and thus the water chemistry changes little during transport. Therefore these stream segments have the highest potential for the release of metals into the watershed.

Metal concentrations from water and sediment samples collected downstream from dump sites by the USGS during storm runoff are substantially higher than those measured in gullies and sheet flow above the primary streambed. The USGS has concluded that mine dump erosion and the accumulation of evaporative salts from acidic, metal-enriched discharge from abandoned mine sites are the largest contributors to degraded streamflow during storm events (personal comm, Floyd Gray, USGS, 5/31/02).

This TMDL provides for attainment of water quality standards under all flow regimes by using selected flow and/or loading conditions as critical modeling scenarios. Loads may be different within a hydrologic event (i.e., "first flush" versus later samples) and between sample events. As previously mentioned, the USGS considers sediment, including evaporative deposits, to be the major sources of pollutant load and contend that flows through the sediment and evaporative salt deposits will trigger loading, regardless of season.

The ADEQ-chosen critical flows to model were the 2 year, 24 hour event (approximately bankfull) and baseflow. The model is capable of calculating loads at flows other than these critical flows due to the use of the extrapolation factors. Input of the selected flow into the model will result in loads and TMDLs calculated for the selected flow. ADEQ collected samples/measurements in the subject streams during baseflow conditions and, in limited quantities, during higher flows which were used to calculate extrapolation factors as explained in Appendix B. At flows ranging from zero to bankfull, the loads calculated using baseflow discharges apply; at flows equal to and greater than bankfull, the loads calculated using bankfull discharges apply.

As mentioned in the Hydrology section, the baseflow or perennial portion of the stream is solely derived from the discharges of the January Adit and source/sources under the World's Fair Mine. Both of these discharges exceed surface water quality standards and therefore, this baseflow scenario is considered a critical modeling condition. (Note: Baseflow is not further defined as the commonly used design flow of "7Q10 flow" because of the lack of the necessary gage data and, in the case of an ephemeral stream, 7Q10 flows tend to equal zero.)

Because flow interaction with sediment is considered to be the primary source of loading (as confirmed by the USGS), bankfull was also chosen as a critical modeling condition as this is the flow during which the most sediment disturbance or movement occurs over time (Leopold, 1978). In Arizona, the bankfull event generally occurs at approximately the 1.1 to 1.8 year return interval; channels in mountainous regions (such as the subject stream) are close to the 1.4 year return interval (Moody, 1999). The 2 year return interval precipitation event is the closest to 1.4 year with sufficient data available to feed a hydrologic model.

(Note: Bankfull field estimations are based upon field observations and measurements in

"Regional Relationships For Bankfull Stage in Natural Channels of Central and Southern Arizona", Northern Arizona University, College of Engineering and Technology, Moody, T. O. & W. Odem, February, 1999.)

6.0 LOAD CALCULATIONS AND TMDL

6.1 Model Considerations

6.1.1 Data Sources and Limitations

Because there are no rain gauges or flow gauges within the subject reach of Alum Gulch, historic data was not available for model calibration. Additionally, drought conditions greatly reduced the opportunity for sample collection. ADEQ did measure stream cross-sections at or near many of the sample points for purposes of hydrologic model setup.

Because of the limited amount of precipitation, flow and water quality data, load modeling requires a number of assumptions be made. For example, assumptions such as initial loss and runoff transformation can be generalized/estimated as they have less impact on model outcomes. These assumptions are not unusual in water quality analysis, regulation and TMDL development. This lack of data is one of the reasons ADEQ considers this project to be a first phase of the TMDL.

In HGC's Model Selection Report, a succinct analysis of data limitations is made.

> With respect to runoff estimation, there is a good geomorphologic basis for constructing a runoff model, but calibration of the model will be difficult due to the lack of runoff hydrographs for measured precipitation events. The ephemeral nature of most flows and the lack of continuous runoff data argues for using an event-based model rather than a continuous model. The need for a simple method of rainfall runoff estimation is indicated by the inability to calibrate the model.
>
> To model mass loading, the water quality of runoff will need to be generalized to large areas and considered steady with respect to time and discharge. The limited spatial coverage of the water quality data and the lack of information on sediment dictates that chemical processes that may potentially transfer constituents between different phases and sources cannot be considered, and that simple mixing will have to be assumed. These factors indicate that a relatively simple method of tracking the mass balance such as a spreadsheet program would be sufficient. (HGC's Task 3 report, p. E-2)

HGC concluded the Model Findings Report by stating,

> Given the ephemeral nature of the subject watersheds and the limited flow and water quality data available, the runoff estimates and loading calculations reported herein are adequate as a first approximation for making water quality management decisions (HGC's Task 4 report, p. 36).

As mentioned in the Project History section, HGC and ADEQ recently reviewed USGS data that was not available for consideration during the first draft of this report. This data was helpful because it contained additional measurements of background concentration and it confirmed the primary source of pollutant loading is from stream sediment. However, ADEQ could not use it to calculate background loads due to lack of corresponding discharge measurements. Attempts by the modeling contractor, HGC, Inc., to match existing precipitation records for the closest weather stations with the dates of the USGS samples failed to provide sufficient linkage between precipitation and discharge. The USGS has limited measurements (without corresponding discharge measurements) of the impact of springs and direct adit drainage on the stream and this was used to form their conclusions.

6.1.2 Conceptual Model

The following is excerpted from Task 3 - Report of Model Selection Findings.

> "Based on the conceptual model and availability of data, an appropriate model for the Sonoita Basin simulates surface runoff and baseflow from a rural area at a watershed and subbasin scale, performs event-based simulations, requires no calibration, and allows prescription of runoff concentrations at a subbasin scale (e.g., as a function of land use) for load calculation.
>
> Guidance for model selection is provided in the EPA's Compendium of Tools for Watershed Assessment and TMDL Development (EPA, 1997). Watershed-scale loading models described by EPA (1997) are the most appropriate for Sonoita Basin project but were generally more complex than warranted due to the lack of calibration data. Based on the review of watershed-scale loading models and the constraints on modeling due to data availability, the most appropriate method to evaluate loading was determined to be use of the rainfall-runoff model HEC-HMS developed by the United States Corps of Engineers (sic) to estimate runoff and a spreadsheet calculation procedure to estimate subreach loading."(HGC's Task 3 report, p. E-2)

6.1.3 Flows

Event based rainfall-runoff simulations were performed using HEC-HMS. Precipitation events (2 year, 24 hour rainfalls) were determined from the isopluvial contour maps in NOAA (1973). Based upon field observations, this high-frequency, low volume rainfall is the most likely to have produced the conditions under which existing discharge and water quality measurements were made. The other critical flow, baseflow, used ADEQ-measured data.

> "The rainfall runoff model was constructed to represent the subject watershed to the best degree possible, although the accuracy of the predicted runoff rates and volumes cannot be quantitatively determined because there are no rainfall runoff measurements of actual storms with which to calibrate and validate the model." (HGC's Task 4 report)

6.1.4 Loads

> "Well mixed conditions and non-reactive transport of hydrogen ions and metals would be assumed so that resulting concentrations could be calculated by simple mixing. This approach to loading analysis is based on standard principles of load estimation." (HGC's Task 3 report, p. 22)

The HEC-HMS estimated stream flow and ADEQ measured baseflow were combined with the measured and estimated pollutant concentrations at various locations in a Quattro Pro spreadsheet (tables 4 - 6) to calculate loading estimates at each target site.

6.1.5 Modeling Scenarios

Several different flow scenarios were modeled to consider possible extremes. These scenarios were coupled with a synthetic rainfall distribution that is likely to occur in the Sonoita Basin.

The high-frequency precipitation events, the 2-, 5-, 10-year, and 24-hour rainfalls, were determined using isopluvial contour maps from NOAA (1973). High frequency, low volume rainfalls are the most likely to have produced the conditions during which existing discharge and water quality measurements were made. A low frequency event, the 100-year 24-hour rainfall was also evaluated. (From HGC's Task 3 report, p. E-3)

Because the critical condition for loading is flow dependent, the 2-year scenario and a baseflow scenario, developed by ADEQ, were used to develop load scenarios.

6.1.6 Calculation of Flow-extrapolated Concentrations

Due to the ephemeral nature of the majority of the subject streams and the lack of precipitation during the period of the investigation, very few monitoring points in the Alum Gulch basin were sampled more than once. With very few exceptions these were primarily measurements of streamflow resulting from groundwater discharge. The few measurements of runoff only approximately correspond with bankfull. Therefore, ADEQ determined a means of extrapolating the limited measured concentrations and flows was needed in order to model bankfull loads. The two methods for determining these extrapolation factors are described below and are explained in detail with examples in Appendix B.

Results from the monitoring point (SCALG004.82, downstream from World's Fair Mine) with measurements under both high and low flow conditions were used to calculate a "bankfull extrapolation factor". The bankfull concentrations calculated using the flow-weighted extrapolation factor were tested against the bankfull concentrations calculated using a factor created by taking an average of the arithmetic ratio of the measured concentrations. The factor which yielded the greatest accuracy is used to calculate the bankfull concentration estimates.

6.2 Load Capacity

The measured and modeled concentrations are used to calculate corresponding loads of the 303[d]-listed pollutants. These loads are based on the modeled hardness and flow.

Tables 4A - 4L display the Load Capacity values calculated according to the formula below and show the 20% explicit margin of safety (see section 6.3) which is based on the load capacity.

Load Capacity = 0.0024465 · Flow · Numeric Target (standard)

The loads and other values necessary to calculate load allocations and TMDLs (Tables 4 - 6) were calculated using the following:

The value 0.0024465 is a units conversion factor to get from µg/L and cubic feet per second (cfs) to kg/day:

[1.0 x 10^{-9} kg/µg · 28.316 L/ft^3· 86,400 sec/day] · conc (µg/L) · flow (ft^3/sec) · concentration extrapolation factor which works out to:

[0.0024465] · conc · flow · concentration extrapolation factor = ***load kg/day***

CALCULATING LOAD CAPACITY

Table 4A Trench Camp Mine runoff (point source) Sample point: SCALG005.90
Bankfull discharge = 8.7 cfs

Parameter	Hardness (mg/L)	WQS (µg/L)	Load Capacity (kg/day)	MOS (kg/day)
Cd (diss)	110	72	1.5	0.3
Cd (total)	n/a	50	1.1	0.21
Cu (diss)	110	25	0.54	0.11
Cu (total)	n/a	500	11	2.1
Zn (diss)	110	1,206	26	5.1
Zn (total)	n/a	25,000	532	106
H+ (pH)	n/a	0.00032	0.0000068	0.0000014

Table 4B January Adit (point source) Sample point: SCALG005.58
Baseflow discharge = 0.04 cfs

Parameter	Hardness (mg/L)	WQS (µg/L)	Load Capacity (kg/day)	MOS (kg/day)
Cd (diss)	400	6.2	0.00061	0.00012
Cd (total)	n/a	50	0.0049	0.00098
Cu (diss)	400	29	0.0029	0.00057
Cu (total)	n/a	500	0.049	0.0098
Zn (diss)	400	379	0.037	0.0074
Zn (total)	n/a	25,000	2.4	0.49
H+ (pH)	n/a	0.00032	0.000000031	0

Table 4C Basin containing the January Adit and Trench Camp Mine (non-point source)
Sample point: SCALG005.58
Bankfull discharge = 12.6 cfs

Parameter	Hardness (mg/L)	WQS (µg/L)	Load Capacity (kg/day)	MOS (kg/day)
Cd (diss)	313	5.2	0.16	0.032
Cd (total)	n/a	50	1.5	0.31
Cu (diss)	313	24	0.73	0.15
Cu (total)	n/a	500	15	3.1
Zn (diss)	313	308	9.5	1.9
Zn (total)	n/a	25,000	771	154
H+ (pH)	n/a	0.00032	0.0000099	0.0000020

Table 4D Upper Humboldt (headwaters) (non-point source) Sample point: SCHMC002.41
Bankfull discharge = 12.7 cfs

Parameter	Hardness (mg/L)	WQS (µg/L)	Load Capacity (kg/day)	MOS (kg/day)
Cd (diss)	100	65	2	0.4
Cd (total)	n/a	700	22	4.3
Cu (diss)	100	23	0.72	0.14
Cu (total)	n/a	1,300	40	8.1
Zn (diss)	100	1,112	35	6.9
Zn (total)	n/a	420,000	13,050	2,610
H+ (pH)	n/a	0.00032	0.0000099	0.0000020

Table 4E Upper Humboldt & un-named tributaries (non-point source)
Sample point: SCHMC001.27
Bankfull discharge = 38.6 cfs

Parameter	Hardness (mg/L)	WQS (µg/L)	Load Capacity (kg/day)	MOS (kg/day)
Cd (diss)	25	14.4	1.4	0.27
Cd (total)	n/a	700	66	13
Cu (diss)	25	6.3	0.59	0.12
Cu (total)	n/a	1,300	123	25
Zn (diss)	25	344	32	6.5
Zn (total)	n/a	420,000	39,663	7,933
H+ (pH)	n/a	0.00032	0.000030	0.0000060

Table 4F Basin containing the January Adit, Trench Camp Mine and Humboldt Canyon (non-point source) Sample point: SCALG005.30
Baseflow discharge = 0.06 cfs

Parameter	Hardness (mg/L)	WQS (µg/L)	Load Capacity (kg/day)	MOS (kg/day)
Cd (diss)	400	6.2	0.00091	0.00018
Cd (total)	n/a	50	0.0073	0.0015
Cu (diss)	400	29	0.0043	0.00086
Cu (total)	n/a	500	0.073	0.015
Zn (diss)	400	379	0.056	0.011
Zn (total)	n/a	25,000	3.7	0.73
H+ (pH)	n/a	0.00032	0.000000047	0

Table 4G Basin containing the January Adit, Trench Camp Mine and Humboldt Canyon (non-point source) Sample point: SCALG005.30
Bankfull discharge =68.5 cfs

Parameter	Hardness (mg/L)	WQS (µg/L)	Load Capacity (kg/day)	MOS (kg/day)
Cd (diss)	232	4.2	0.7	0.14
Cd (total)	n/a	50	8.4	1.7
Cu (diss)	232	18	3.1	0.62
Cu (total)	n/a	500	84	17
Zn (diss)	232	239	40	8
Zn (total)	n/a	25,000	4,190	838
H+ (pH)	n/a	0.00032	0.000054	0.000011

Table 4H Basin between SCALG005.30 and World's Fair (non-point source)
Sample point: SCALG004.98
Bankfull discharge = 74.8 cfs

Parameter	Hardness (mg/L)	WQS (µg/L)	Load Capacity (kg/day)	MOS (kg/day)
Cd (diss)	201	3.7	0.69	0.14
Cd (total)	n/a	50	9.1	1.8
Cu (diss)	201	16	3	0.6
Cu (total)	n/a	500	91	18
Zn (diss)	201	212	39	7.7
Zn (total)	n/a	25,000	4,575	915
H+ (pH)	n/a	0.00032	0.000059	0.000012

Table 4I World's Fair Mine (point source) Sample point: SCALG004.82.
Baseflow discharge = 0.01 cfs.

Parameter	Hardness (mg/L)	WQS (µg/L)	Load Capacity (kg/day)	MOS
Cd (diss)	400	6.2	0.00015	3.04E-05
Cd (total)	n/a	50	0.0012	0.00024
Cu (diss)	400	29	0.00072	0.00014
Cu (total)	n/a	500	0.012	0.0024
Zn (diss)	400	379	0.0093	0.0019
Zn (total)	n/a	25,000	0.61	0.12
H+ (pH)	n/a	0.00032	0.0000000080	0

Table 4J World's Fair Mine and surroundings (non-point source) Sample point: SCALG004.82
Bankfull discharge = 75.9 cfs

Parameter	Hardness (mg/L)	WQS (μg/L)	Load Capacity (kg/day)	MOS (kg/day)
Cd (diss)	389	6.1	1.1	0.23
Cd (total)	n/a	50	9.3	1.9
Cu (diss)	389	29	5.3	1.1
Cu (total)	n/a	500	93	19
Zn (diss)	389	370	69	14
Zn (total)	n/a	25,000	4,642	928
H+ (pH)	n/a	0.00032	0.000059	0.000012

Table 4K World's Fair Mine and basin downstream (point source) Sample point: SCALG004.61
Baseflow discharge = 0.19 cfs

Parameter	Hardness (mg/L)	WQS (μg/L))	Load Capacity (kg/day)	MOS (kg/day)
Cd (diss)	400	6.2	0.0029	0.00058
Cd (total)	n/a	50	0.023	0.0046
Cu (diss)	400	29	0.014	0.0027
Cu (total)	n/a	500	0.23	0.046
Zn (diss)	400	379	0.18	0.035
Zn (total)	n/a	25,000	12	2.3
H+ (pH)	n/a	0.00032	0.00000015	0

Table 4L World's Fair Mine and basin downstream (non-point source)
Sample point: SCALG004.61
Bankfull discharge = 93.2 cfs

Parameter	Hardness (mg/L)	WQS (μg/L)	Load Capacity (kg/day)	MOS (kg/day)
Cd (diss)	400	6.2	1.4	0.28
Cd (total)	n/a	50	11	2.3
Cu (diss)	400	29	6.7	1.3
Cu (total)	n/a	500	114	23
Zn (diss)	400	379	86	17
Zn (total)	n/a	25,000	5,700	1,140
H+ (pH)	n/a	0.00032	0.000073	0.000015

CALCULATING LOADS

Tables 5A - 5L display the Existing Load and its components: Natural Background and Human-caused calculated according to the formula:

Existing Load = 0.0024465 (unit conversion factor) · Flow · Existing Concentration

Natural Background Loading = 0.0024465 (unit conversion factor) · Flow · Natural Background Concentration

Human-caused Load = Existing Load - Natural Background Loading

Note: Loads resulting from runoff including a natural background load.

Table 5A Trench Camp Mine runoff (point source) Sample point: SCALG005.90
Bankfull discharge = 8.7 cfs

Parameter	Existing Conc (µg/L)	Existing Load (kg/day)	Nat Back Conc (µg/L)	Nat Back Load (kg/day)	Human-Caused Load (kg/day)
Cd (diss)	10	0.21		0	0.21
Cd (total)	10	0.21		0	0.21
Cu (diss)	13	0.28		0	0.28
Cu (total)	63	1.3		0	1.3
Zn (diss)	2,500	53		0	53
Zn (total)	2,900	62		0	62
H+ (pH)	0.00076	0.000016		0	0.000016

Table 5B January Adit (point source) Sample point: SCALG005.58
Baseflow discharge = 0.04 cfs

Parameter	Existing Conc (µg/L)	Existing Load (kg/day)	Nat Back Conc (µg/L)	Nat Back Load (kg/day)	Human-Caused Load (kg/day)
Cd (diss)	145	0.014		0	0.014
Cd (total)	160	0.016		0	0.016
Cu (diss)	112	0.011		0	0.011
Cu (total)	113	0.011		0	0.011
Zn (diss)	47,500	4.6		0	4.6
Zn (total)	49,000	4.8		0	4.8
H+ (pH)	0.02	0.0000020		0	0.0000020

Table 5C Basin containing the January Adit and Trench Camp Mine (non-point source)
Sample point: SCALG005.58
Bankfull discharge = 12.6 cfs

Parameter	Existing Conc (µg/L)	Existing Load (kg/day)	Nat Back Conc (µg/L)	Nat Back Load (kg/day)	Human-Caused Load (kg/day)
Cd (diss)	21	0.65	0.14	0.0043	0.64
Cd (total)	24	0.74	0.14	0.0043	0.74
Cu (diss)	112	3.5	5	0.15	3.3
Cu (total)	113	3.5	5	0.15	3.3
Zn (diss)	6,270	193	28	0.86	192
Zn (total)	6,223	192	28	0.86	191
H+ (pH)	0.012	0.00037		0	0.00037

Table 5D Upper Humboldt (headwaters) (non-point source) Sample point: SCHMC002.41
Bankfull discharge = 12.7 cfs

Parameter	Existing Conc (µg/L)	Existing Load (kg/day)	Nat Back Conc (µg/L)	Nat Back Load (kg/day)	Human-Caused Load (kg/day)
Cd (diss)	0.4	0.012		0	0.012
Cd (total)	0.4	0.012		0	0.012
Cu (diss)	238	7.4		0	7.4
Cu (total)	234	7.3		0	7.3
Zn (diss)	28	0.87		0	0.87
Zn (total)	25	0.78		0	0.78
H+ (pH)	0.3	0.0093		0	0.0093

Table 5E Upper Humboldt & un-named tributaries (non-point source) Sample point: SCHMC001.27
Bankfull discharge = 38.6 cfs

Parameter	Existing Conc (µg/L)	Existing Load (kg/day)	Nat Back Conc (µg/L)	Nat Back Load (kg/day)	Human-Caused Load (kg/day)
Cd (diss)	0.5	0.047		0	0.047
Cd (total)	0.5	0.047		0	0.047
Cu (diss)	62	5.9		0	5.9
Cu (total)	68	6.4		0	6.4
Zn (diss)	85	8		0	8
Zn (total)	110	10		0	10
H+ (pH)	0.15	0.014		0	0.014

Table 5F Basin containing the January Adit, Trench Camp Mine and Humboldt Canyon (non-point source) Sample point: SCALG005.30
Baseflow discharge = 0.06 cfs

Parameter	Existing Conc (µg/L)	Existing Load (kg/day)	Nat Back Conc (µg/L)	Nat Back Load (kg/day)	Human-Caused Load (kg/day)
Cd (diss)	150	0.022		0	0.022
Cd (total)	180	0.026		0	0.026
Cu (diss)	1,200	0.18		0	0.18
Cu (total)	1,200	0.18		0	0.18
Zn (diss)	44,000	6.5		0	6.5
Zn (total)	41,000	6		0	6
H+ (pH)	0.25	0.000037		0	0.000037

Table 5G Basin containing the January Adit, Trench Camp Mine and Humboldt Canyon (non-point source) Sample point: SCALG005.30
Bankfull discharge =68.5 cfs

Parameter	Existing Conc (µg/L)	Existing Load (kg/day)	Nat Back Conc (µg/L)	Nat Back Load (kg/day)	Human-Caused Load (kg/day)
Cd (diss)	21	3.5	0.14	0.023	3.5
Cd (total)	28	4.7	0.14	0.023	4.7
Cu (diss)	529	89	5	0.84	88
Cu (total)	511	86	5	0.84	85
Zn (diss)	5,808	973	28	4.7	969
Zn (total)	5,207	873	28	4.7	868
H+ (pH)	0.15	0.025		0	0.025

Table 5H Basin between SCALG005.30 and World's Fair (non-point source)
Sample point: SCALG004.98
Bankfull discharge = 74.8 cfs

Parameter	Existing Conc (µg/L)	Existing Load (kg/day)	Nat Back Conc (µg/L)	Nat Back Load (kg/day)	Human-Caused Load (kg/day)
Cd (diss)	23	4.2	0.14	0.026	4.2
Cd (total)	24	4.4	0.14	0.026	4.4
Cu (diss)	661	121	5	0.91	120
Cu (total)	596	109	5	0.91	108
Zn (diss)	6,072	1,111	28	5.1	1,106
Zn (total)	6,223	1,139	28	5.1	1,134
H+ (pH)	0.19	0.035		0	0.035

Table 5I World's Fair Mine (point source) Sample point: SCALG004.82
Baseflow discharge = 0.01 cfs.

Parameter	Existing Conc (µg/L)	Existing Load (kg/day)	Nat Back Conc (µg/L)	Nat Back Load (kg/day)	Human-Caused Load (kg/day)
Cd (diss)	204	0.005		0	0.005
Cd (total)	182	0.0045		0	0.0045
Cu (diss)	2,095	0.051		0	0.051
Cu (total)	2,015	0.049		0	0.049
Zn (diss)	55,140	1.3		0	1.3
Zn (total)	52,750	1.3		0	1.3
H+ (pH)	0.51	0.000012		0	0.000012

Table 5J World's Fair Mine and surroundings (non-point source) Sample point: SCALG004.82
Bankfull discharge = 75.9 cfs

Parameter	Existing Conc (µg/L)	Existing Load (kg/day)	Nat Back Conc (µg/L)	Nat Back Load (kg/day)	Human-Caused Load (kg/day)
Cd (diss)	29	5.4	0.14	0.026	5.4
Cd (total)	28	5.2	0.14	0.026	5.2
Cu (diss)	924	172	5	0.93	171
Cu (total)	858	159	5	0.93	158
Zn (diss)	7,255	1,347	28	5.2	1,342
Zn (total)	6,705	1,245	28	5.2	1,240
H+ (pH)	0.32	0.059		0	0.059

Table 5K World's Fair Mine and basin downstream (point source) Sample point: SCALG004.61
Baseflow discharge = 0.19 cfs

Parameter	Existing Conc (µg/L)	Existing Load (kg/day)	Nat Back Conc (µg/L)	Nat Back Load (kg/day)	Human-Caused Load (kg/day)
Cd (diss)	220	0.1		0	0.1
Cd (total)	290	0.13		0	0.13
Cu (diss)	2,000	0.93		0	0.93
Cu (total)	2,100	0.98		0	0.98
Zn (diss)	53,000	25		0	25
Zn (total)	54,000	25		0	25
H+ (pH)	0.64	0.0003		0	0.0003

Table 5L World's Fair Mine and basin downstream (non-point source) Sample point: SCALG004.61
Bankfull discharge = 93.2 cfs

Parameter	Existing Conc (µg/L)	Existing Load (kg/day)	Nat Back Conc (µg/L)	Nat Back Load (kg/day)	Human-Caused Load (kg/day)
Cd (diss)	170	39	0.14	0.032	39
Cd (total)	170	39	0.14	0.032	39
Cu (diss)	1,100	251	5	1.1	250
Cu (total)	1,900	433	5	1.1	432
Zn (diss)	49,000	11,173	28	6.4	11,166
Zn (total)	45,000	10,261	28	6.4	10,254
H+ (pH)	0.38	0.087		0	0.087

6.3 Margin of Safety

6.3.1 Explicit Margin of Safety

This TMDL has been calculated based on real loads at baseflow and simulated loads at a higher flow with a return interval of two years.

The precision of measurement of the parameters of concern is plus or minus 5% (personal comm, State Laboratory, Arizona Department of Health Services). An explicit margin of safety of 5% was applied to the TMDL to account for this error.

An additional explicit margin of safety of 15% was applied to account for:

- The lack of characterization of many of the minor sources in the subject basin.
- The potential for unidentified sources to contribute pollutant loads or identified sources to provide larger loads than anticipated.
- The modeling for the project assumes homogeneous rainfall across the entire subject basin. However, precipitation events can occur in portions of the watershed with other portions receiving none and thereby resulting in runoff patterns and stream discharges different from those modeled.

The total explicit margin of safety used is 20% of the load capacity.

6.3.2 Implicit Margin of Safety

A non-quantifiable implicit margin of safety was applied by:

Not allocating additional loading when capacity was available. When the existing load for a stream segment was less than the load capacity, (e.g., standards are not being exceeded) instead of using the difference between load capacity and existing loading as additional allowable load, ADEQ instead chose not to allow any additional loading. This was done for several reasons:

- Even if one or more segments meet standards, the stream reach as a whole does not and therefore additional loading shall not be allocated.

- To allow for non-quantifiable errors in modeling methodology.
- To allow for future sources. This allowance is not required by law, but neither is it prohibited. (Future sources are most likely to take the form of additional loading caused by the exposure of "fresh" mineralized material to runoff.)

Use of conservative modeling assumptions, for example:

- "The assumption of steady concentrations may overestimate loading because most chemical analyses are for samples collected at relatively low flows, and thus potentially represent higher concentrations, compared to the event average flows used to calculate loading." (HGC Task 4 report, p. 35).
- The model assumes conservative mixing and does not account for physical and chemical processes occurring In-stream that may reduce concentrations between sample points.

6.4 Allocations and TMDL

The In-stream water quality in the subject waterbodies is such that loads need to be reduced in order to meet standards. The following TMDLs and associated allocations are set at levels adequate to result in the attainment of applicable water quality standards.

6.4.1 TMDL Calculations

The TMDL is represented by the mathematical equation:

TMDL = ∑WLA + ∑LA + MOS + Natural Background, where:

WLA is the wasteload allocation consisting of loads from point sources (not used in this phase of the TMDL),

LA is the load allocation consisting of non-point source loads, and

MOS is a Margin of Safety which serves to address uncertainties in the analysis and the natural system.

In order to increase clarity, ADEQ has chosen to break out **Natural Background** from the LA as the loading due to natural background sources.

There are currently no NPDES permitted point sources identified in the subject watershed; however, ADEQ has determined the January Adit, Trench Camp Mine and the World's Fair Mine meet the definition of point sources. ADEQ plans to conduct a detailed survey to determine if any point sources exist as part of a later phase of the subject TMDL. The final TMDLs set for the pollutants in the listed portion of Alum Gulch will not change solely if a source currently considered to be nonpoint source is later determined to be a point source. With respect to the TMDL equation, the only change that would be made in this event would be the movement of a load from the load allocation column to the wasteload allocation column.

In this first phase of the TMDL, loads at each sample point include the upstream loads. In later phases of this TMDL, ADEQ may elect to break out the upstream load from each load when enough data has been collected to allow more accurate accounting for In-stream physical and chemical processes such as: dilution; reactions with other inputs;

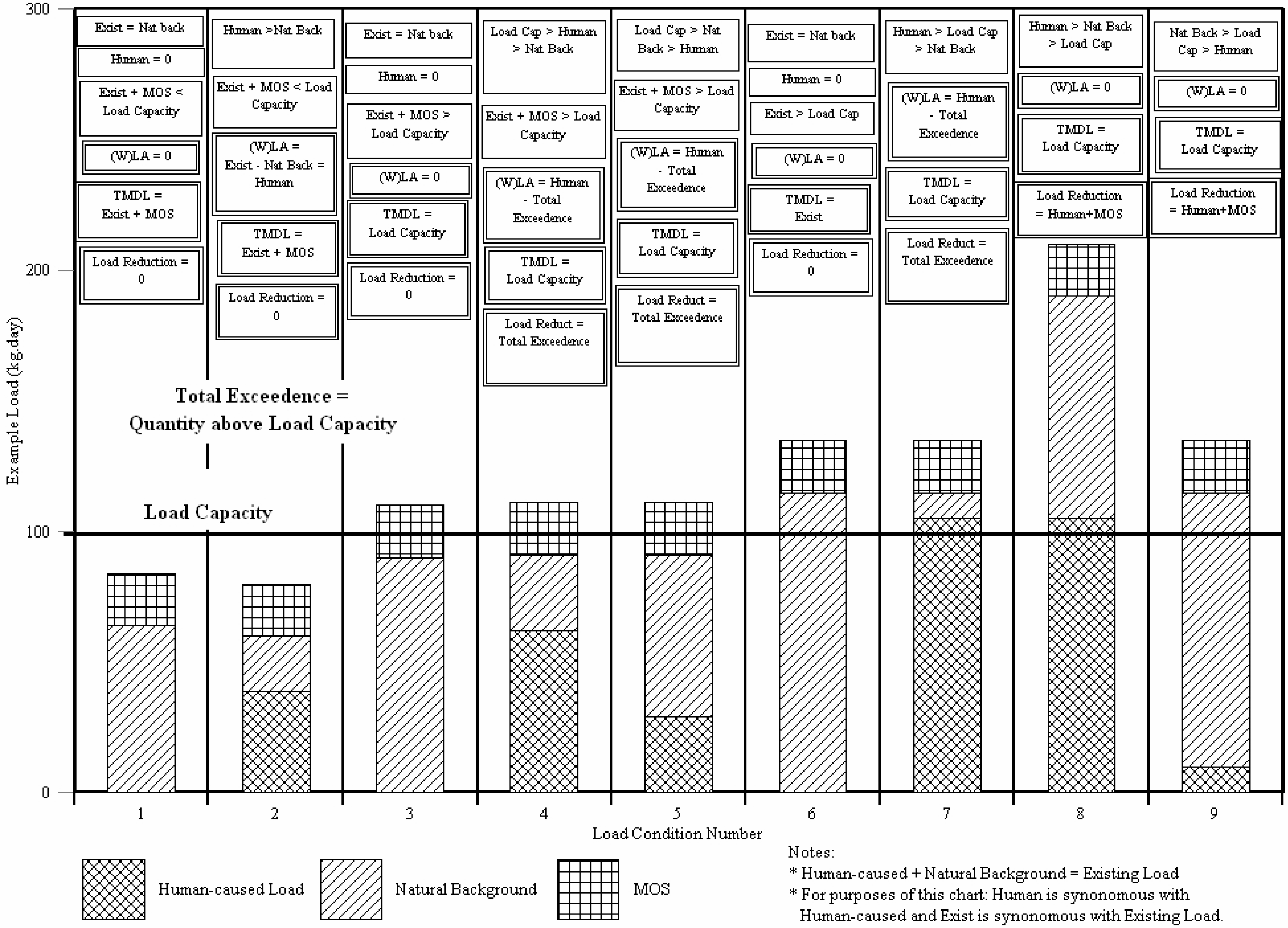
precipitation; binding or reacting with sediments. Additionally, load allocations might be calculated for discrete sources.

The application of the extrapolation factor to the natural background measurements is most accurate at the point of collection. When the natural background load calculated at the point of collection is applied to other sample points, apparent inconsistencies in mass balance may occur, such as the measured load being less than the estimated background load. This occurs because the model assumes conservative mixing and does not account for physical and chemical processes that reduce In-stream concentrations between the background and the downstream sample points. These processes, which include dilution with discharging ground water or other surface flows, precipitation of metal hydroxides from streamflow, and metal adsorption to stream sediment, are too complicated to be practically modeled at the watershed scale without detailed flow measurements and chemical information for water and sediment.

ADEQ does not consider this prima facie evidence of a need for site specific standards. In later phases of this TMDL, ADEQ will collect the necessary data to further characterize natural background.

Tables 6A - 6L summarize the values needed to calculate the load allocations and display the load allocations, wasteload allocations and the load reductions necessary to meet the TMDLs. The calculation of the load and wasteload allocations and any load reductions are completed in accordance with the conditions displayed in Figure 5. The "load condition" column in tables 6A - 6L corresponds to the numbers along the bottom of Figure 5. Unless otherwise specified, the tables are ordered by source. All units are kg/day.

Figure 5
Possible Load Conditions Chart



CALCULATING LOAD ALLOCATIONS AND TMDLs

Table 6A Trench Camp Mine runoff (point source) Sample point: SCALG005.90
Bankfull discharge = 8.7 cfs No natural background load applicable at this sample point.

Parameter	Load Cond. (Fig. 5)	Load Capacity (kg/day)	MOS (kg/day)	Nat Back Load (kg/day)	Human-Caused Load (kg/day)	Load Allocation (kg/day)	Waste Load Allocation (kg/day)	TMDL (kg/day)	Load Reduction (kg/day)
Cd (diss)	2	1.5	0.3	N/A	0.21	N/A	0.21	0.51	0
Cd (total)	2	1.1	0.21	N/A	0.21	N/A	0.21	0.42	0
Cu (diss)	2	0.54	0.11	N/A	0.28	N/A	0.28	0.39	0
Cu (total)	2	11	2.1	N/A	1.3	N/A	1.3	3.4	0
Zn (diss)	7	26	5.1	N/A	53	N/A	21	26	33
Zn (total)	2	532	106	N/A	62	N/A	62	168	0
H+ (pH)	7	0.0000068	0.0000014	N/A	0.000016	N/A	0.0000054	0.0000068	0.000011

Table 6B January Adit (point source) Sample point: SCALG005.58
Baseflow discharge = 0.04 cfs No natural background load applicable at this sample point at this discharge.

Parameter	Load Cond. (Fig. 5)	Load Capacity (kg/day)	MOS (kg/day)	Nat Back Load (kg/day)	Human-Caused Load (kg/day)	Load Allocation (kg/day)	Waste Load Allocation (kg/day)	TMDL (kg/day)	Load Reduction (kg/day)
Cd (diss)	7	0.00061	0.00012	N/A	0.014	N/A	0.00049	0.00061	0.014
Cd (total)	7	0.0049	0.00098	N/A	0.016	N/A	0.0039	0.0049	0.012
Cu (diss)	7	0.0029	0.00057	N/A	0.011	N/A	0.0023	0.0029	0.0087
Cu (total)	2	0.049	0.0098	N/A	0.011	N/A	0.011	0.021	0
Zn (diss)	7	0.037	0.0074	N/A	4.6	N/A	0.03	0.037	4.6
Zn (total)	7	2.4	0.49	N/A	4.8	N/A	2	2.4	2.9
H+ (pH)	7	0.000000031	0.0000000062	N/A	0.000002	N/A	0.000000025	0.000000031	0.000002

Table 6C Basin containing the January Adit and Trench Camp Mine (non-point source). Sample point: SCALG005.58
Bankfull discharge = 12.6 cfs No H+ natural background available.

Parameter	Load Cond. (Fig. 5)	Load Capacity (kg/day)	MOS (kg/day)	Nat Back Load (kg/day)	Human-Caused Load (kg/day)	Load Allocation (kg/day)	Waste Load Allocation (kg/day)	TMDL (kg/day)	Load Reduction (kg/day)
Cd (diss)	7	0.16	0.032	0.0043	0.64	0.12	N/A	0.16	0.52
Cd (total)	2	1.5	0.31	0.0043	0.74	0.74	N/A	1	0
Cu (diss)	7	0.73	0.15	0.15	3.3	0.43	N/A	0.73	2.9
Cu (total)	2	15	3.1	0.15	3.3	3.3	N/A	6.6	0
Zn (diss)	7	9.5	1.9	0.86	192	6.7	N/A	9.5	186
Zn (total)	2	771	154	0.86	191	191	N/A	346	0
H+ (pH)	7	0.0000099	0.000002	N/A	0.00037	0.0000079	N/A	0.0000099	0.00036

Table 6D Upper Humboldt Canyon (headwaters) (non-point source) Sample point: SCHMC002.41
Bankfull discharge = 12.7 cfs No natural background load available at this sample point.

Parameter	Load Cond. (Fig. 5)	Load Capacity (kg/day)	MOS (kg/day)	Nat Back Load (kg/day)	Human-Caused Load (kg/day)	Load Allocation (kg/day)	Waste Load Allocation (kg/day)	TMDL (kg/day)	Load Reduction (kg/day)
Cd (diss)	2	2	0.4	N/A	0.012	0.012	N/A	0.41	0
Cd (total)	2	22	4.3	N/A	0.012	0.012	N/A	4.4	0
Cu (diss)	7	0.72	0.14	N/A	7.4	0.58	N/A	0.72	6.8
Cu (total)	2	40	8.1	N/A	7.3	7.3	N/A	15	0
Zn (diss)	2	35	6.9	N/A	0.87	0.87	N/A	7.8	0
Zn (total)	2	13,050	2,610	N/A	0.78	0.78	N/A	2,611	0
H+ (pH)	7	0.0000099	0.000002	N/A	0.0093	0.000008	N/A	0.0000099	0.0093

Table 6E Upper Humboldt & un-named tributaries (non-point source) Sample point: SCHMC001.27
Bankfull discharge = 38.6 cfs No natural background load available at this sample point.

Parameter	Load Cond. (Fig. 5)	Load Capacity (kg/day)	MOS (kg/day)	Nat Back Load (kg/day)	Human-Caused Load (kg/day)	Load Allocation (kg/day)	Waste Load Allocation (kg/day)	TMDL (kg/day)	Load Reduction (kg/day)
Cd (diss)	2	1.4	0.27	N/A	0.047	0.047	N/A	0.32	0
Cd (total)	2	66	13	N/A	0.047	0.047	N/A	13	0
Cu (diss)	2	0.59	0.12	N/A	5.9	0.48	N/A	0.59	5.4
Cu (total)	2	123	25	N/A	6.4	6.4	N/A	31	0
Zn (diss)	2	32	6.5	N/A	8	8	N/A	15	0
Zn (total)	2	39,663	7,933	N/A	10	10	N/A	7,943	0
H+ (pH)	7	0.00003	0.000006	N/A	0.014	0.000024	N/A	0.00003	0.014

Table 6F Basin containing the January Adit, Trench Camp Mine and Humboldt Canyon (non-point source). Sample point: SCALG005.30
Baseflow discharge = 0.06 cfs No natural background load applicable at this sample point at this discharge.

Parameter	Load Cond. (Fig. 5)	Load Capacity (kg/day)	MOS (kg/day)	Nat Back Load (kg/day)	Human-Caused Load (kg/day)	Load Allocation (kg/day)	Waste Load Allocation (kg/day)	TMDL (kg/day)	Load Reduction (kg/day)
Cd (diss)	7	0.00091	0.00018	N/A	0.022	0.00073	N/A	0.00091	0.021
Cd (total)	7	0.0073	0.0015	N/A	0.026	0.0059	N/A	0.0073	0.021
Cu (diss)	7	0.0043	0.00086	N/A	0.18	0.0034	N/A	0.0043	0.17
Cu (total)	7	0.073	0.015	N/A	0.18	0.059	N/A	0.073	0.12
Zn (diss)	7	0.056	0.011	N/A	6.5	0.045	N/A	0.056	6.4
Zn (total)	7	3.7	0.73	N/A	6	2.9	N/A	3.7	3.1
H+ (pH)	7	0.000000047	0.0000000094	N/A	0.000037	0.000000038	N/A	0.000000047	0.000037

Table 6G Basin containing the January Adit, Trench Camp Mine and Humboldt Canyon (non-point source). Sample point: SCALG005.30
Bankfull discharge = 68.5 cfs No H+ natural background available.

Parameter	Load Cond. (Fig. 5)	Load Capacity (kg/day)	MOS (kg/day)	Nat Back Load (kg/day)	Human-Caused Load (kg/day)	Load Allocation (kg/day)	Waste Load Allocation (kg/day)	TMDL (kg/day)	Load Reduction (kg/day)
Cd (diss)	7	0.7	0.14	0.023	3.5	0.54	N/A	0.7	3
Cd (total)	2	8.4	1.7	0.023	4.7	4.7	N/A	6.4	0
Cu (diss)	7	3.1	0.62	0.84	88	1.6	N/A	3.1	86
Cu (total)	7	84	17	0.84	85	66	N/A	84	19
Zn (diss)	7	40	8	4.7	969	27	N/A	40	941
Zn (total)	2	4,190	838	4.7	868	868	N/A	1,711	0
H+ (pH)	7	0.000054	0.000011	N/A	0.025	0.000043	N/A	0.000054	0.025

Table 6H Basin between SCALG005.30 and World's Fair (non-point source) Sample point: SCALG004.98
Bankfull discharge = 74.8 cfs No H+ natural background available.

Parameter	Load Cond. (Fig. 5)	Load Capacity (kg/day)	MOS (kg/day)	Nat Back Load (kg/day)	Human-Caused Load (kg/day)	Load Allocation (kg/day)	Waste Load Allocation (kg/day)	TMDL (kg/day)	Load Reduction (kg/day)
Cd (diss)	7	0.69	0.14	0.026	4.2	0.52	N/A	0.69	3.7
Cd (total)	2	9.1	1.8	0.026	4.4	4.4	N/A	6.2	0
Cu (diss)	7	3	0.6	0.91	120	1.5	N/A	3	119
Cu (total)	7	91	18	0.91	108	72	N/A	91	36
Zn (diss)	7	39	7.7	5.1	1,106	26	N/A	39	1,080
Zn (total)	2	4,575	915	5.1	1,134	1,134	N/A	2,054	0
H+ (pH)	7	0.000059	0.000012	N/A	0.035	0.000047	N/A	0.000059	0.035

Table 6I World's Fair Mine (point source) Sample point: SCALG004.82
Baseflow discharge = 0.01 cfs No natural background load applicable at this sample point at this discharge.

Parameter	Load Cond. (Fig. 5)	Load Capacity (kg/day)	MOS (kg/day)	Nat Back Load (kg/day)	Human-Caused Load (kg/day)	Load Allocation (kg/day)	Waste Load Allocation (kg/day)	TMDL (kg/day)	Load Reduction (kg/day)
Cd (diss)	7	0.00015	3.04E-05	N/A	0.005	N/A	0.00012	0.00015	0.0049
Cd (total)	7	0.0012	0.00024	N/A	0.0045	N/A	0.00098	0.0012	0.0035
Cu (diss)	7	0.00072	0.00014	N/A	0.051	N/A	0.00057	0.00072	0.051
Cu (total)	7	0.012	0.0024	N/A	0.049	N/A	0.0098	0.012	0.04
Zn (diss)	7	0.0093	0.0019	N/A	1.3	N/A	0.0074	0.0093	1.3
Zn (total)	7	0.61	0.12	N/A	1.3	N/A	0.49	0.61	0.8
H+ (pH)	7	0.000000008	0.0000000016	N/A	0.000012	N/A	0.000000006	0.000000008	0.000012

Table 6J World's Fair Mine and surroundings (non-point source) Sample point: SCALG004.82
Bankfull discharge = 75.9 cfs No H+ natural background available.

Parameter	Load Cond. (Fig. 5)	Load Capacity (kg/day)	MOS (kg/day)	Nat Back Load (kg/day)	Human-Caused Load (kg/day)	Load Allocation (kg/day)	Waste Load Allocation (kg/day)	TMDL (kg/day)	Load Reduction (kg/day)
Cd (diss)	7	1.1	0.23	0.026	5.4	0.88	N/A	1.1	4.5
Cd (total)	2	9.3	1.9	0.026	5.2	5.2	N/A	7.1	0
Cu (diss)	7	5.3	1.1	0.93	171	3.3	N/A	5.3	167
Cu (total)	7	93	19	0.93	158	73	N/A	93	85
Zn (diss)	7	69	14	5.2	1,342	50	N/A	69	1,292
Zn (total)	2	4,642	928	5.2	1,240	1,240	N/A	2,173	0
H+ (pH)	7	0.000059	0.000012	N/A	0.059	0.000048	N/A	0.000059	0.059

Table 6K World's Fair Mine and basin downstream (point source) Sample point: SCALG004.61
Baseflow discharge = 0.19 cfs No natural background load applicable at this sample point at this discharge.

Parameter	Load Cond. (Fig. 5)	Load Capacity (kg/day)	MOS (kg/day)	Nat Back Load (kg/day)	Human-Caused Load (kg/day)	Load Allocation (kg/day)	Waste Load Allocation (kg/day)	TMDL (kg/day)	Load Reduction (kg/day)
Cd (diss)	7	0.0029	0.00058	N/A	0.1	N/A	0.0023	0.0029	0.1
Cd (total)	7	0.023	0.0046	N/A	0.13	N/A	0.019	0.023	0.12
Cu (diss)	7	0.014	0.0027	N/A	0.93	N/A	0.011	0.014	0.92
Cu (total)	7	0.23	0.046	N/A	0.98	N/A	0.19	0.23	0.79
Zn (diss)	7	0.18	0.035	N/A	25	N/A	0.14	0.18	24
Zn (total)	7	12	2.3	N/A	25	N/A	9.3	12	16
H+ (pH)	7	0.00000015	0.00000003	N/A	0.0003	N/A	0.00000012	0.00000015	0.0003

Table 6L World's Fair Mine and basin downstream (non-point source) Sample point: SCALG004.61
Bankfull discharge = 93.2 cfs No H+ natural background available.

Parameter	Load Cond. (Fig. 5)	Load Capacity (kg/day)	MOS (kg/day)	Nat Back Load (kg/day)	Human-Caused Load (kg/day)	Load Allocation (kg/day)	Waste Load Allocation (kg/day)	TMDL (kg/day)	Load Reduction (kg/day)
Cd (diss)	7	1.4	0.28	0.032	39	1.1	N/A	1.4	38
Cd (total)	7	11	2.3	0.032	39	9.1	N/A	11	30
Cu (diss)	7	6.7	1.3	1.1	250	4.2	N/A	6.7	245
Cu (total)	7	114	23	1.1	432	90	N/A	114	342
Zn (diss)	7	86	17	6.4	11,166	63	N/A	86	11,103
Zn (total)	7	5,700	1,140	6.4	10,254	4,554	N/A	5,700	5,700
H+ (pH)	7	0.000073	0.000015	N/A	0.087	0.000058	N/A	0.000073	0.087

7.0 IMPLEMENTATION

This investigation shows that water quality standards will be met when the load reductions are achieved. The first phase investigation has identified the major sources of pollutant loading and quantified contributions so that management decisions can be made.

The target conditions for Alum Gulch are the removal of all mining residue dumps from the streambanks, the removal of all mine-waste originated sediments from the streambed and the isolation and treatment of all mining-impacted groundwater discharges (springs and adit drainage). While TMDL calculations and values may be different between pollutants, controlling the exposure of the source material to weathering, treating the runoff and removing stream sediments from segments where needed, will reduce all the 303[d]-listed pollutants to within standards or natural background levels.

With the exception of Trench Camp Mine and the January Adit, both owned by Asarco, the pollutant sources in the subject basin are all on Coronado National Forest land. Asarco is designing methods of passive treatment of the January Adit drainage. As a result of this project, ADEQ has determined that both the January Adit and the Trench Camp Mine (runoff) meet the definition of a point source and NPDES permits will be required. The load allocations presented in this report will be used to determine permit limits.

Abandoned mines represent significant technical, legal, and monetary challenges in designing and implementing remedial measures. USFS has a duty to apply for NPDES permits for both active and abandoned mines, on lands under their control, with potential to discharge to surface waters. Such permits would address discharges to surface water from mining haul roads, mine tailing and waste rock piles, and other mining-related facilities. The U.S. Forest Service has a program using CERCLA-driven actions to support remediation of sites causing harm to the ecosystem. This has not been instituted in the subject basin, but is being considered by the Coronado National Forest. If USFS addresses problems at any of these sites through CERCLA, or any other remediation program, specific permits may not be necessary; however, the requirements normally established through a permit are still required to be met.

ADEQ has divided the pollutant sources into categories based upon possible remediation strategies. These suggested strategies are general. These suggested strategies are general responsible parties must undertake site specific studies before selection, design, and implementation of a remediation method can be accomplished.

1. Mining residue dumps can be remediated by
    a. Removing the material and either hauling to an active mine for processing with ore, or using the material to fill the abandoned mine works.

    b. Leaving the material in place and preventing impacted runoff from reaching the stream. (This has been accomplished fairly successfully by Asarco at Trench Camp Mine.)
2. Combining impacted stream sediments with the mining residue dump material, and an acid neutralizing material; e.g., limestone or portland cement, for remediation.

As previously stated, the USGS (personal comm, Floyd Gray, USGS, 05/31/02) has concluded that in addition to mine dump erosion, the accumulation of deposits in the streambed resulting from the evaporation of discharge from abandoned mine sites and mining-impacted springs is another large contributor to degraded streamflow when re-dissolved during storm events.

ADEQ has not made linkages between the water discharged into the subject stream and a specific mine, but treatment of discharges (perhaps in an artificial wetlands as has been successfully done elsewhere) would reduce the pollutant loading.

The second phase investigation will:

- Further develop the characterization of natural background versus human-caused loads;
- Further characterize sources;
- Require NPDES permits for point source dischargers;
- Refine load allocations, possibly reclassifying some of the load allocations to wasteload allocations; and
- Initiate formation of a watershed group focused towards implementation.

ADEQ will pursue collaboration with the USGS to continue its watershed studies in this area, including support for flow and pollutant sampling. ADEQ may conduct additional sampling when climate conditions change from drought to a wetter pattern.

HGC's Model Development Report summary includes several suggestions that should be performed as part of a second phase investigation: "[W]ork that could be undertaken to improve the basis for modeling includes the following::

- Installation and monitoring of precipitation gauges to determine rainfall intensities and site-specific daily rainfall for comparison with National Weather Service data,

- Development and continuous monitoring of stream gauging stations for measuring complete runoff hydrographs, and

- Synchronous collection of water quality samples at several locations over the duration of a complete runoff event to determine concentration as a function of location and discharge."

In sum, achieving the target conditions will reduce the human-caused loads to within standards. Additional monitoring and investigation will further develop ADEQ's understanding of loading due to natural background causing exceedances and where and when this might happen.

8.0 PUBLIC PARTICIPATION AND RESPONSIVENESS SUMMARY

Development of the Alum Gulch TMDL included public participation in accordance with 40 CFR Parts 25 & 130.7. Public participation included review and input from stakeholder groups. Multiple presentations and meetings were held by the ADEQ in 1997 and 2001. These meetings were attended by owners/operators of mining sites, property owners; environmental groups; representatives of local, state, and federal agencies; and other interested members of the public.

Written documentation of public participation is on file with ADEQ's Hydrologic Support and Assessment Section, located at 1110 W. Washington Street, 5th Floor, Phoenix, Arizona 85007.

Additionally, ADEQ released a draft of this report in December, 2001. Response to this document revealed ADEQ should:

- More clearly explain the concentration extrapolation methodology
- Clarify its understanding of natural background conditions
- Clearly show the linkages between sample sites and sources.

Considering these concerns and the fact that recently approved changes to the surface water quality standards would affect this study, ADEQ rewrote the TMDL report and is releasing this second draft for comments.

9.0 BIBLIOGRAPHY AND REFERENCES

For availability and price information of ADEQ documents, call (602) 207-2202.

ADEQ, “Analysis of Water Quality Limited Waters in the Sonoita Creek Watershed near Patagonia, Santa Cruz County, Arizona Phase I - Confirmatory Sampling of 303[d]-Listed Parameters”, October, 1998, Phoenix, Arizona.

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Schrader, C. Frank, USGS Bulletin 582, “Mineral Deposits of the Santa Rita and Patagonia Mountains”, 1915.

U.S. Environmental Protection Agency, “Compendium of ERT Surface Water and Sediment Sampling Procedures”, 1991. Washington, D.C.

U.S. Geological Survey Administrative Report “Preliminary Assessment/Site Inspection of the Alum Gulch - Flux Canyon Watershed, Northern Patagonia Mountains", Floyd Gray, Laura Norman, Oscar Duarte, Ailiang Goo, and Maurice Chafee, July 2002 (in press).

U.S. Geological Survey “Study and Interpretation of the Chemical Characteristics of Natural Water”, Water-Supply Paper 2254, John D. Hem, 1989.

Personal communications with personnel of the Arizona Department of Mines and Minerals, Phoenix, Arizona. Various dates over the course of the project.

Contractor reports are available at the Hydrologic Support and Assessment Section, 3rd floor, ADEQ, 3033 N. Central, Phoenix. Copies can be made and are subject to a State-required copying fee.

APPENDIX A - Data Collection

Sample Sites

Figure 3 is a map of the subject basin with sample site locations. Sample sites were selected to permit meeting of project goals. ADEQ has developed a system of surface water sample point I.D.s:

Site ID: bbsssddd.d **bb** = basin ("SC" is the Santa Cruz River); **sss** = stream code (e.g.: "ALG" for Alum Gulch); **ddd.dd** = distance from stream mouth in stream miles along the stream channel as measured on U. S. Geological Survey maps in a scale of 1:24,000.

Sample points are listed in order from most upstream to most downstream. Where appropriate, tributary sample points are inserted between the sample points bracketing the mouth of the tributary. Complete locational data including latitude, longitude, UTM, or HUC, is stored in the project files in tabular format and available for the cost of copying from ADEQ.

SCALG005.90: Alum Gulch - Downstream from Trench Camp mine. The flow is runoff from the Trench Camp Mine. The stream is ephemeral at this point and therefore was only sampled during storm events.

SCALG005.58: Alum Gulch - Downstream from the January Adit treatment system wetlands and above the mouth of Humboldt Canyon. (Perennial reach)

SCHMC002.41: allows measurement of upper Humboldt Canyon (tributary of Alum Gulch) - intersection of creek & jeep road. (Ephemeral)

SCHMC001.27: (lower Humboldt Canyon) Base of falls upstream from Humboldt Well. (Ephemeral)

SCALG005.30: Alum Gulch downstream from the Humboldt mouth, upstream from the water fall. (Perennial)

SCALG004.98: Alum Gulch - Downstream from the water fall, upstream from the World's Fair Mine. (Perennial)

SCALG004.82: Alum Gulch - Immediately downstream from the World's Fair Mine, only used during 1997-1998 sampling, replaced with SCALG004.61 further downstream for later sampling events. (Perennial)

SCALG004.61: Alum Gulch - approximately 200 meters downstream from the World's Fair Mine. (Perennial)

Sample Collection Procedures and Equipment

The targeted parameters are those for which each stream is considered impaired as reported on the 303[d] list. Tributaries were monitored for the listed parameters of the downstream waters.

ADEQ followed the current USEPA-approved Quality Assurance Project Plan (QAPP) (May, 1991) and the ADEQ Fixed Station Network Procedures Manual derived from the QAPP. These contain the sampling techniques ADEQ is required to follow and which were followed as part of this project.

Commentors have suggested that ADEQ should follow EPA Method 1669, "Sampling Ambient

Water for Determination of Trace Metals at EPA Water Quality Criteria Levels", EPA 821-R-95034 (1995) when collecting metals data. Method 1669 states: "This method is not intended for determination of metals at concentrations normally found in treated and untreated discharges from industrial facilities. Existing regulations (40 CFR parts 400-500) typically limit concentrations to the mid to high part-per-billion (ppb) range, whereas ambient metals concentrations are normally in the low part-per-trillion (ppt) to low ppb range."

Due to the heavy mining and ore processing activity in the subject basins, the concentrations of the listed metals are in the high part-per-billion and part-per-million ranges rather than the suggested low part-per-billion range. The relevant standards for the subject streams are within the detection limits for standard EPA methods as opposed to the specialized 1600-series methods.

There were instances where results for dissolved metals were greater than those for total metals which raised questions about the validity of the reported data. The dissolved concentrations are due to larger than the total concentrations due to rounding in reporting and because some samples were diluted due to matrix interference (personal comm, Carie Wilson, Bolin Laboratories, 01/23/98). Conversations with ADEQ QA/QC Unit and Bolin staff determined that the data is still valid.

Field Measurements and Equipment

Field water quality data was obtained with a Hydrolab Surveyor. These measurements are:

- water temperature (C)
- dissolved oxygen (mg/L and % saturation)
- specific conductance (μmhos)
- pH (a field measurement due to holding time of 15 minutes)

Other measurements are:

- Air temperature (C)
- Flow with either a Marsh-McBirney current velocity meter or, in cases of very low or very high discharge, a flow measurement was not possible and an estimate was made by field personnel.
- A hand-held Global Positioning System (GPS) receiver was used to locate sample sites.

All field measurements and observations were recorded on field sheets. All sites were photographed during each visit.

Laboratories and Analytical Methods

ADEQ is required (A.A.C. R18-11-111) to use an approved analytical methods and a laboratory that is licensed by the Arizona Department of Health Services (ADHS). For the subject waterbodies, ADEQ used the ADHS State laboratory and Bolin Laboratories, a DHS-licensed laboratory.

Bolin Laboratories, Inc.	Arizona State Health Laboratory
1763 N. 25th Avenue	1520 W. Adams
Phoenix, Arizona 85023	Phoenix, Arizona 85007

Hardness data is necessary to evaluate the metals data because surface water quality standards for certain parameters change because toxicity varies with hardness. The higher the hardness value, the lower the toxicity. EPA guidance and Arizona's surface water quality standards bracket the hardness values from 25 mg/L to 400 mg/L as $CaCO_3$. Further study is needed to determine whether the hardness equations for these metals holds for hardnesses exceeding 400 mg/L as $CaCO_3$. Hardness was calculated from the calcium and magnesium concentrations in accordance with the "Standard Methods for the Examination of Water and Wastewater", 19th Edition, 1995.

The laboratory analytical methods were used in this project were:

Total Ca, Fe, Mg and Zn (total & dissolved): USEPA method 200.7

Copper (total & dissolved): USEPA method 200.9

Quality Control

At least one set of quality control blanks and split samples were collected during each sample event. Split samples were collected (using an USGS-designed churn splitter) as a check on laboratory accuracy. This is a sample split between two bottle sets which can reasonably be assumed to be identical (within 10%) of each other. All splits were within acceptable tolerances. "Blanks" were collected to verify the efficacy of field decontamination and equipment cleanliness.

ADEQ also split some samples with Asarco as a courtesy to Asarco. These were not part of the project quality assurance splits and blanks which were collected at other sample points. In one instance, zinc was detected in a blank collected at Asarco's request and was determined to be a result of contamination of the rinse water supplied by DHS. The detected concentrations (in the rinse water) were 20 to 40 µg/L while the stream concentration was over an order of magnitude higher at 470 µg/L.

Checking of all calculations and data entry was done by ADEQ staff. All ADEQ field equipment is maintained and calibrated on a regular basis to ensure valid field measurements. Calibration information was logged in the record book for each individual instrument.

APPENDIX B - Calculation of Concentration Extrapolation Factors

Due to the lack of precipitation and the ephemeral nature of the subject stream system, very few sample points were sampled more than once and most measurements were made under baseflow conditions in the spring-fed (groundwater) portion of these streams. These limited measurements were used as the basis for calculating (extrapolating) concentrations at higher (bankfull) flow. In order to model loads under the identified critical flows of baseflow and bankfull (high) flow, a means was established to calculate an estimated bankfull flow concentration from the measured low flow concentration at each sample point.

The sample points in each stream with measurements under both high and low flow conditions were identified and those measurements used to calculate a bankfull concentration extrapolation factor. Two methods of deriving this factor were tested: a flow-weighted factor and an average ratio factor.

The bankfull concentration calculated by each method was tested against the measured bankfull concentrations at that sample point. The factor which yielded the greatest overall accuracy for each stream is used to calculate the bankfull concentration estimates. This accompanying tables, formulas and examples explain the logic behind the selection of each factor .

The bankfull concentration for each sample point was calculated by multiplying the selected factor by the measured baseflow concentration. This extrapolated bankfull concentration is then inserted into the loading model.

The value 0.0024465 is a units conversion factor to go from µg/L and cubic feet per second (cfs) to kg/day:

[1.0 x 10^{-9} kg/µg · 28.316 L/ft^3 · 86,400 sec/day] · conc (µg/L) · flow (ft^3/sec) · concentration extrapolation factor which works out to:

[0.0024465] · conc · flow · concentration extrapolation factor = ***load kg/day***

The general relationship, or trend, of the concentrations of each parameter with changes in flow was determined using linear regression. Due to insufficient data, the resulting "best-fit" line was used solely as an indicator of general direction of change; i.e., increasing or decreasing, with increasing discharge. ADEQ intends to conduct additional monitoring in the subject basins and will adjust the TMDL as needed when the additional data is considered.

The following extrapolation factors were calculated for Alum Gulch; an explanation and example of the methodology for each follows.

Hard:	0.127
H+:	0.597
Cd (dissolved):	0.142
Cd (total):	0.153
Cu (dissolved):	0.441
Cu (total):	0.426
Zn (dissolved):	0.132
Zn (total):	0.127

Hardness

Hardness is calculated from calcium and magnesium in units of mg/L as $CaCO_3$. When hardness is used to calculate standards for certain metals, the hardness is always the calculated value or 400 mg/L, whichever is less. For example, a calculated hardness of 2666 is **not** used to calculate a standard, instead 400 is used to calculate the standard, but a calculated hardness of 208 **is** used to calculate the standard. (A.A.C. Title 18, Chapter 11, Article 1, Appendix A).

In the Alum basin, hardness tends to decrease as discharge increases. Due to the lack of data, it is difficult to determine the accuracy of the extrapolation from baseflow to high flow. The following tables and formulae were developed to determine the concentration extrapolation factor.

Flow Weighting

Site ID	Date	Discharge (cfs)	Flow	Hard	Hard (weighted factor)	Hard (weighted calc)	Hard (weighted error)
SCALG005.58	1/11/00	0.001	base	2,666			
SCALG005.58	7/20/99	0.07	low	2,269		2,333	3%
SCALG004.82	12/4/97	0.01	base	1,522	0.875	1,365	
SCALG004.82	6/2/98	0.01	base	1,597			
SCALG004.82	3/31/98	2.87	high	208			556%
SCALG004.82	2/10/98	6.00	high	188			626%
SCALG004.61	1/11/00	0.001	base	1,880			
SCALG004.61	7/20/99	0.36	high	1,424		1,645	16%
						Average Error:	300%

Average Ratio

Site ID	Date	Discharge (cfs)	Flow	Hard	Hard (avg factor)	Hard (avg calc)	Hard (avg error)
SCALG005.58	1/11/00	0.001	base	2,666			
SCALG005.58	7/20/99	0.07	low	2,269		339	85%
SCALG004.82	12/4/97	0.01	base	1,522	0.127	198	
SCALG004.82	6/2/98	0.01	base	1,597			
SCALG004.82	3/31/98	2.87	high	208			5%
SCALG004.82	2/10/98	6.00	high	188			5%
SCALG004.61	1/11/00	0.001	base	1,880			
SCALG004.61	7/20/99	0.36	high	1,424		239	83%
						Average Error:	45%

Hard(weightedfactor) =

$$\frac{\dfrac{\sum(\text{High Flow Concentration x High Flow Discharge})}{\sum \text{High Flow Discharge}} - \dfrac{\sum(\text{Low Flow Concentration x Low Flow Discharge})}{\sum \text{Low Flow Discharge}}}{\dfrac{\sum(\text{Low Flow Concentration x Low Flow Discharge})}{\sum \text{Low Flow Discharge}}}$$

example: Hard(weightedfactor) =

$$\frac{\dfrac{((208 \times 2.87) + (188 \times 6.00))}{(2.87 + 6.00)} - \dfrac{((1{,}522 \times 0.01) + (1{,}597 \times 0.01))}{(0.01 + 0.01)}}{\dfrac{((1{,}522 \times 0.01) + (1{,}597 \times 0.01))}{(0.01 + 0.01)}} = \underline{\mathbf{0.876}}$$

= **0.876** = concentration adjustment factor. (diff. due to rounding.)

Hard(weightedcalc) = Hard(weightedfactor) * Hard(low flow average) = 0.876 x {(1522+1597) / 2} = **1,365** mg/L
Hard(weightederror) = (Hard - Hard(weightedtest)) / Hard = (208 - 1365) / 208 = **556 % error**

Hard(avgfactor) = average of Hard(high flow) / average of Hard(low flow)
example: Hard(avgfactor) = { (208 + 188) /2} / { (1522 + 1597) / 2} = **0.127** = concentration adjustment factor.
Hard(avgcalc) = Hard(avgfactor) * Hard(low flow average) = 0.127 x {(1522 + 1597) / 2} = **198** mg/L
Hard(avgerror) = (Hard - Hard(weightedtest)) / Hard = (208 - 198) / 208 = **5% error**

If error is less than 0, then calculated concentration is less than measured; If error is greater than 0, then calculated concentration is greater than measured.
Average Error of each stream is calculated using the absolute value of each individual error.

Alum Gulch exhibits a tendency towards a slight decrease in hardness with a large increase in flow. Based upon these calculations, using the average ratio is a better choice as borne out by the comparison of the two methods of calculating the extrapolation factor as displayed in the tables above. When all, including extrapolated, data is plotted against flow, the general data trend is maintained by the extrapolated data. Therefore, the average ratio extrapolation factor of 0.127 is acceptable.

pH (as H^+)

$10^{(-pH)} \cdot 1000 = H^+$ concentration in mg/L

Alum Gulch exhibits a very slight tendency towards an increase in pH with a large increase in flow. The baseflow source is groundwater (from springs) and the high flow acidity results from groundwater and from runoff water reacting with surface material or streambed sediments or both.

The average ratio extrapolation factor of 0.597 is the more accurate choice and provides a decrease in H^+ concentration which results in a slight increase in pH with increasing flow. When all, including extrapolated, data is plotted against flow, the general data trend is maintained by the extrapolated data.

Cadmium

Based upon the available data, cadmium concentration generally tends to decrease as discharge increases in the subject basin.

The Alum Gulch cadmium data would be most accurately extrapolated by using the average ratio extrapolation factors of 0.142 (dissolved) and 0.153 (total). When all, including extrapolated, data is plotted against flow, the general data trend is maintained by the extrapolated data.

Copper

Based upon the available data, copper concentration generally tends to decrease as discharge increases in the subject basin.

The Alum Gulch copper data would be most accurately extrapolated by using the average ratio extrapolation factors of 0.441 (dissolved) and 0.426 (total). When all, including extrapolated, data is plotted against flow, the general data trend is maintained by the extrapolated data.

Zinc

Based upon the available data, zinc concentration generally tends to decrease as discharge increases in the subject basin.

The Alum Gulch zinc data would be most accurately extrapolated by using the average ratio extrapolation factors of 0.132 (dissolved) and 0.127 (total). When all, including extrapolated, data is plotted against flow, the general data trend is maintained by the extrapolated data.