Pinto Creek
Site-Specific Water Quality Standard for Dissolved Copper

Salt River Watershed – HUC# 15060103-018
Gila, Maricopa and Pinal Counties, Arizona

October 2016

Open File Report 16-04

Acknowledgements

This report is the result of extraordinary efforts by numerous individuals, the foremost being the capable staff of the Arizona Department of Environmental Quality (ADEQ), Water Quality Division, Surface Water Section. Without their dedicated assistance, this study of Pinto Creek would not have been possible.

The following Arizona Department of Environmental Quality staff assisted Greg Olsen in collecting more than 670 water samples in the Pinto Creek watershed. Many of these staff worked very long hours thru day and night, frequently in very challenging field conditions: Shad Bowman, Joe Cosgrove, Jalyn Cummings, Steve Franchuck, Lee Johnson, Sara Konrad, Doug McCarty, Frank Metzler, Chris Notgrass, Matt Oller, Patsy Olsen, Kyle Palmer, Steve Pawlowski, Sam Rector, Bob Scalamera, Patti Spindler, Jason Sutter, Linda Taunt, and Roland Williams.

Administrative and Technical Support Staff provided invaluable project assistance and include: Karla Burnley, Karen Black, Danese Cameron, Julie Finke, Melanie Ford, Victor Gass, Ruth Hall, Mel Hessel, BJ Kenyon, Nancy LaMascus, Diana Marsh, Lisa Rowe, Larry Stevenson, Patti Tuve, Debra Daniel, Steve Vogel, Linda Wright, Yan Zhao, the inorganics analysis staff of the Arizona Department of Health Services Laboratory, and EPA Region IX.

ADEQ would like to express sincerest appreciation to the talented modeling team from Malcolm Pirnie Inc. including: Clifton Bell, Tom Gallo, Jeff Manuszak, and Steve Stacy.

ADEQ would also like to recognize the cooperation of the residents and land owners of the MF Ranch area as well as the contributions of helpful information and insight from participants of Pinto Creek Watershed Group members including: governmental agencies (Arizona Fish & Game Department, US Forest Service - Tonto National Forest), citizen groups (Arizona Center for Law in the Public Interest, Citizens for the Preservation of Powers Gulch and Pinto Creek, Friends of Pinto Creek, Maricopa Audubon Society, Mineral Policy Center, National Wildlife Federation, People for the West, Grand Canyon Chapter of the Sierra Club, Sun City Hikers, Western Mining Action Project), mining companies and their representatives (Capstone (formerly BHP) Copper Inc., Bryan Cave, Carlota Copper Co., Haley & Aldrich, Freeport McMoRan Corporation (formerly Phelps Dodge), and other interested parties and land owners.

Table of Contents

List of Tables

List of Figures

List of Acronyms

A.A.C.	Arizona Administrative Code
A&Ww	Aquatic and Wildlife, warm water
A&Wc	Aquatic and Wildlife, cold water
ADEQ	Arizona Department of Environmental Quality
AgI	Agricultural Irrigation
AgL	Agricultural Livestock Watering
Capstone-PVO	Capstone - Pinto Valley Operations
CFR	Code of Federal Regulations
CFS	Cubic Feet per Second
CWA	Clean Water Act
EIS	Environmental Impact Statement
EPA	Environmental Protection Agency
FBC	Full Body Contact
FC	Fish Consumption
HSPF	Hydrologic Simulation Program Fortran
HUC	Hydrologic Unit Code
LA	Load Allocation
MPI	Malcolm Pirnie, Inc.
mg/L	milligrams per liter, equivalent to parts per million
NPDES	National Pollutant Discharge Elimination System
PERLND	Pervious Land Segments
PLS	Pregnant Leachate Solution
SSS	Site-Specific Standard
TMDL	Total Maximum Daily Load
T&E	Threatened and Endangered Species
µg/L	micrograms per liter, equivalent to parts per billion
USFS	United States Forest Service
USGS	United States Geological Survey
WLA	Wasteload Allocation

1.0 INTRODUCTION

This document describes the data and methodology used to derive a Site-Specific Standard (SSS) for dissolved copper in Pinto Creek. The proposed SSS is geographically limited to a 15.55 mile reach of Pinto Creek (Ellis Ranch Tributary at latitude 33º19'26.7", longitude 110º54'57.5" to West Fork Pinto Creek), and the dissolved copper concentration is calculated to be 34 µg/L, which is equal to natural background conditions. The proposed SSS criterion replaces the default chronic dissolved copper standard under all hardness values and the acute dissolved copper standard for hardness values less than 268 mg/L. At hardness values equal to or above 268 mg/L the acute dissolved copper standard will be based on the hardness dependent formula listed in Arizona Administrative Code (A.A.C.), Title18, Chapter 11, Appendix A.

The data used to derive the SSS were obtained from 670 water quality samples collected at 48 sites by the Arizona Department of Environmental Quality (ADEQ) between the years 2000 and 2005. Of these water samples, approximately 126 were obtained from 21 sites in sub-watersheds judged to be representative of natural, pre-anthropogenic conditions. This information combined with numerous other environmental data was used to construct a dynamic watershed water quality model of Pinto Creek. This model provided a tool by which pre-anthropogenic water quality for all of Pinto Creek could be estimated with a reasonable degree of confidence.

This document was originally circulated in 2008 as a draft for informal public review and comment. The study and report has been revised on the basis of the comments received, and results of subsequent revisions to the watershed model. The SSS proposed herein has been recalculated using the same methodologies used in the prior draft report, but with a revised background data set, more conservative assumptions and new results generated by the revised watershed model. The previously proposed SSS for dissolved copper was 42 µg/L and has been revised downward, as described herein, to 34 µg/L. The specific reach of Pinto Creek to apply the SSS remains unchanged in this report.

2.0 PROJECT BACKGROUND

Pinto Creek (HUC 15060103-018) first appeared on the 1998 State of Arizona's Clean Water Act (CWA) Section 303(d) list of impaired waters, for exceeding the water quality standard for dissolved copper. Much of the data used for the listing was derived from field investigations conducted by ADEQ (circa 1990) of unauthorized discharges originating from the Gibson copper mine.

In 2001, the United States Environmental Protection Agency (EPA) completed a Phase I Total Maximum Daily Load (TMDL) analysis of Pinto Creek (EPA, 2001). This TMDL analysis appropriately attributed much of the copper load in Pinto Creek to discharges originating from the inactive Gibson mine facilities. Other specifically itemized load allocations included in the Phase I TMDL analysis were; Henderson Ranch mines

(Figure 1), unknown sources below old Highway US 60, the Cactus Breccia formation, the proposed Carlota mine facilities, and the Capstone-Pinto Valley Operations (PVO) National Pollutant Discharge Elimination System (NPDES) outfalls. In the Phase I model, EPA set the natural background concentration at a uniform 10 µg/L (0.010 mg/L) dissolved copper for the entire Pinto Creek watershed. The hardness, by which the Aquatic & Wildlife (A&W) dissolved copper criteria are based, was assumed to be 400 mg/L (EPA, 2001).

Figure 1. Waste Rock at Henderson Ranch Mines

Due to the limited available data on which the Phase I TMDL was based, ADEQ began a comprehensive field data collection program to provide information for a refined Phase II TMDL analysis. Early in the data collection phase, it was observed that copper was ubiquitous in the surface waters of the watershed. Many human-caused sources, predominantly from abandoned or inactive mines, were readily identified. Copper concentrations associated with these sources were found to be orders of magnitude greater than applicable water quality standards. Remarkably, elevated copper concentrations also persisted in several tributaries where no known sources of copper existed. Also observed in the data were substantial spatial and temporal variations in hardness levels on which the A&W water quality criteria for dissolved copper are based (A.A.C. R18-11, Appendix A).

A majority of the surface waters with very low hardness values were observed in the upper portions of the watershed, resulting in correspondingly low dissolved copper criteria values in these areas. These areas of low hardness waters occurred coincidently with some of the copper-laden tributaries with no apparent anthropogenic sources of copper. This combination of elevated background copper levels and low

hardness is a considerably different condition than the assumed environment modeled in the Phase I TMDL. During the early Phase II TMDL project, ADEQ began to hypothesize that natural background conditions alone may be exceeding the dissolved copper criteria in certain areas. Thus, deriving a TMDL that would meet the default copper criterion would not be realistically achievable in portions of Pinto Creek.

In 2003, ADEQ conducted water quality monitoring of additional tributaries with no apparent, or at least very minimal, disturbances to confirm these findings. An initial attempt at watershed modeling in 2004 concluded that portions of Pinto Creek would exceed the default copper criteria, even if all human-caused sources were removed from the analysis.

In 2004, ADEQ reviewed additional data on land use, geology, as well as known abandoned mines to target and monitor sub-watersheds thought to represent undisturbed natural background conditions. ADEQ also attempted to obtain surface water samples specific to individual geologic units to derive a range of dissolved copper values in runoff from these lithologies. In 2004 and 2005, ADEQ collected samples from these tributaries during several moderately large precipitation events.

At this point, the watershed modeling effort took on two major objectives; 1) to perform the analysis needed for TMDL development, and 2) to generate a model scenario that estimated water quality in terms of pre-anthropogenic or natural background conditions.

This report summarizes the results of the data collection and modeling effort, and documents the process of deriving a recommended SSS for dissolved copper in Pinto Creek. Acknowledgment of the natural background condition and establishment of the SSS has been found to be a prerequisite in order to complete the pending Phase II TMDL analysis of Pinto Creek.

3.0 GENERAL WATERSHED INFORMATION

3.1 Physical Characteristics

Pinto Creek is a predominately intermittent stream that drains approximately 183 square miles in portions of Gila, Pinal, and Maricopa counties in east central Arizona (Figure 2). The stream extends approximately 33 miles from its headwaters in the Pinal Mountains to Roosevelt Lake. Although much of the creek length is intermittent, it contains several perennial reaches where groundwater is forced to the surface by bedrock constrictions (MPI, 2006). Pinto Creek flows perennially in at least three reaches: from the confluence with Miller Gulch to a point downstream of the Haunted Canyon confluence; from a point below the Iron Bridge to a point above the West Fork of Pinto Creek confluence; and from the Pinto Valley weir to a point upstream from the Blevens Wash confluence (EPA, 2001).

The Pinto Creek basin is generally characterized by thin soils and steep rugged hills with surface elevations that range between 2100 and 6400 feet above mean sea level (Figure 3) (MPI, 2006). The character of Pinto Creek changes significantly along the stream course. From its uppermost reaches to the Pinto Valley Weir, Pinto Creek and

its tributaries have the characteristics of mountain stream channels, with relatively steep gradients, small flood plains, and coarse stream bed materials. In these areas, the stream is enclosed by steep, rugged terrain possessing only a thin soil cover. Due to the steep topography, thin soils and high stream gradient, the Pinto Creek is hydrologically flashy in nature. Below the Pinto Valley Weir, Pinto Creek transitions to flatter gradients, with wider floodplains as it continues toward the mouth of Pinto Creek at Roosevelt Lake (EPA, 2001).

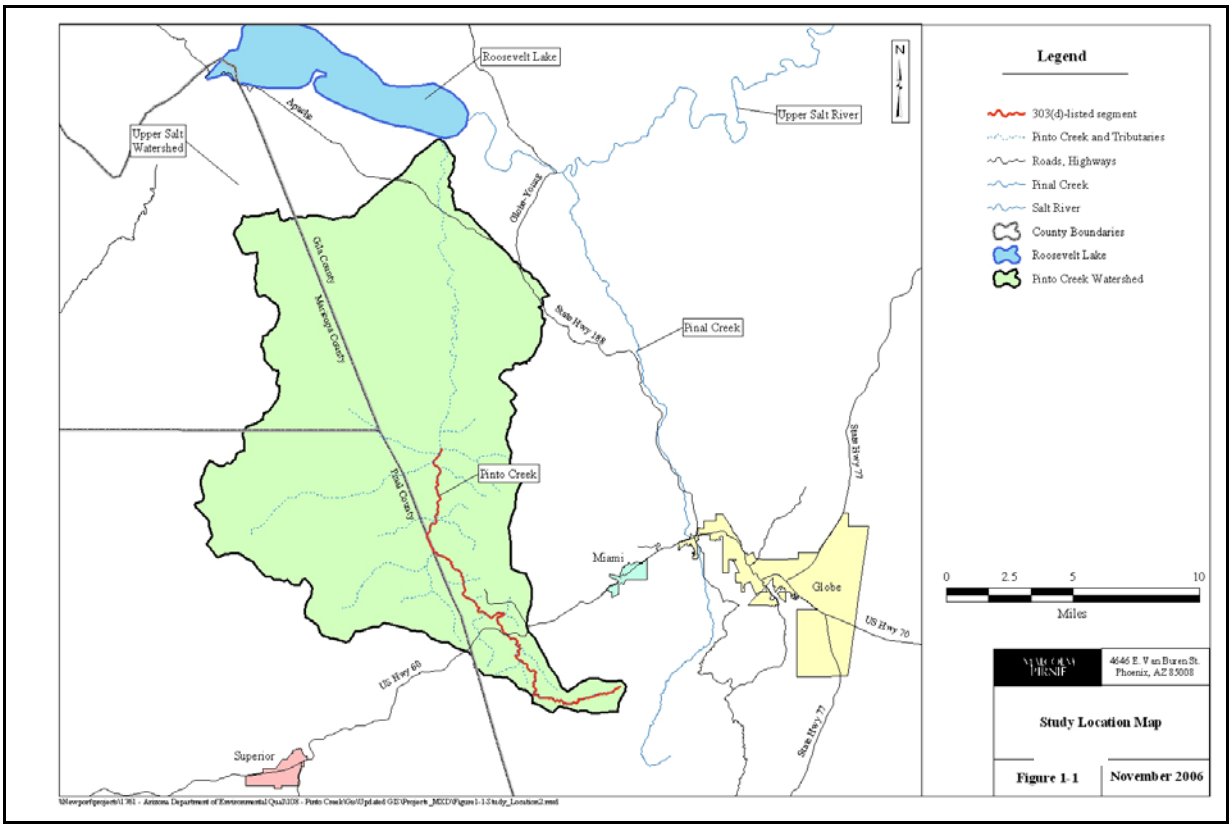

Figure 2. Study Location Map (MPI, 2006)

3.2 Land Use

Based on a GIS analysis, most of the Pinto Creek Basin (95 percent) consists of undisturbed land that is covered by a mixture of shrub and brush rangeland and evergreen forest, including portions of the Tonto National Forest. The other major land cover is stockpile material from mining facilities, which covers about 5 percent of the Pinto Creek Basin. Buildings, roads, and paved areas represent a minimal portion of the watershed (MPI, 2006).

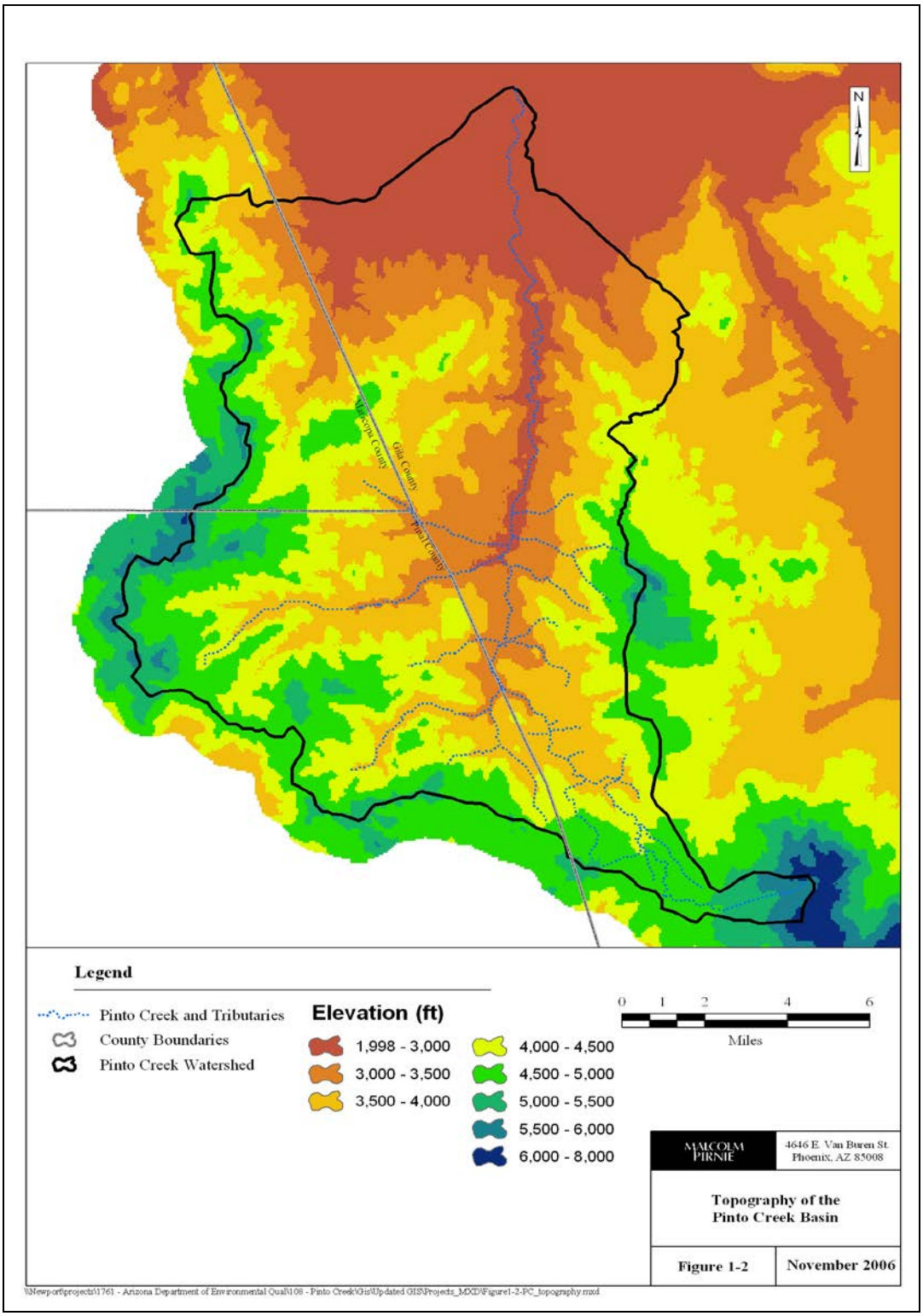

Figure 3. Watershed Elevation Map (MPI, 2006)

3.3 Physiographic Setting

Pinto Creek is located on the northern margin of the Basin and Range physiographic province which is typified by alluvium-filled valleys separated by elongated fault-blocked mountain ranges (Hunt, 1974). Pinto Creek originates in the Pinal Mountains, and flows northerly toward Roosevelt Lake, a man-made reservoir located in the Salt River valley.

3.4 Mining History

Pinto Creek flows across the western margin of the historic Globe-Miami mining district, one of the major porphyry copper districts in the southwestern United States (EPA, 2001). Due to the natural copper mineralization, the basin contains numerous historical mining-related disturbances including open pits, tunnels, waste rock and tailings piles, leach dumps, and milling facilities. The largest mining operation in the watershed is the Capstone-PVO, many of the Capstone operations have been impounded to prevent surface discharge to Pinto Creek during storms smaller than the 100-year, 24-hour events (MPI, 2006). Carlota Copper is also actively mining within the watershed. A more detailed synopsis of historic mining activities is available in the Phase I TMDL for Pinto Creek (EPA, 2001).

3.5 Geologic Setting

The headwaters of the Pinto Creek basin are primarily underlain by schist and granite (Figure 4). Various other lithologies outcrop throughout the basin, including dacite, diabase, and the sedimentary rocks of the Apache Group that includes sandstones, shales, and limestones. The Cactus Breccia copper ore body crops out in a small area in and near the Pinto Creek channel. This ore body has been extensively mined on the east side of Pinto Creek by Capstone with the western side being the objective of Carlota Copper (Figure 5). Other portions of the creek channel are underlain by alluvial sediments (MPI, 2006).

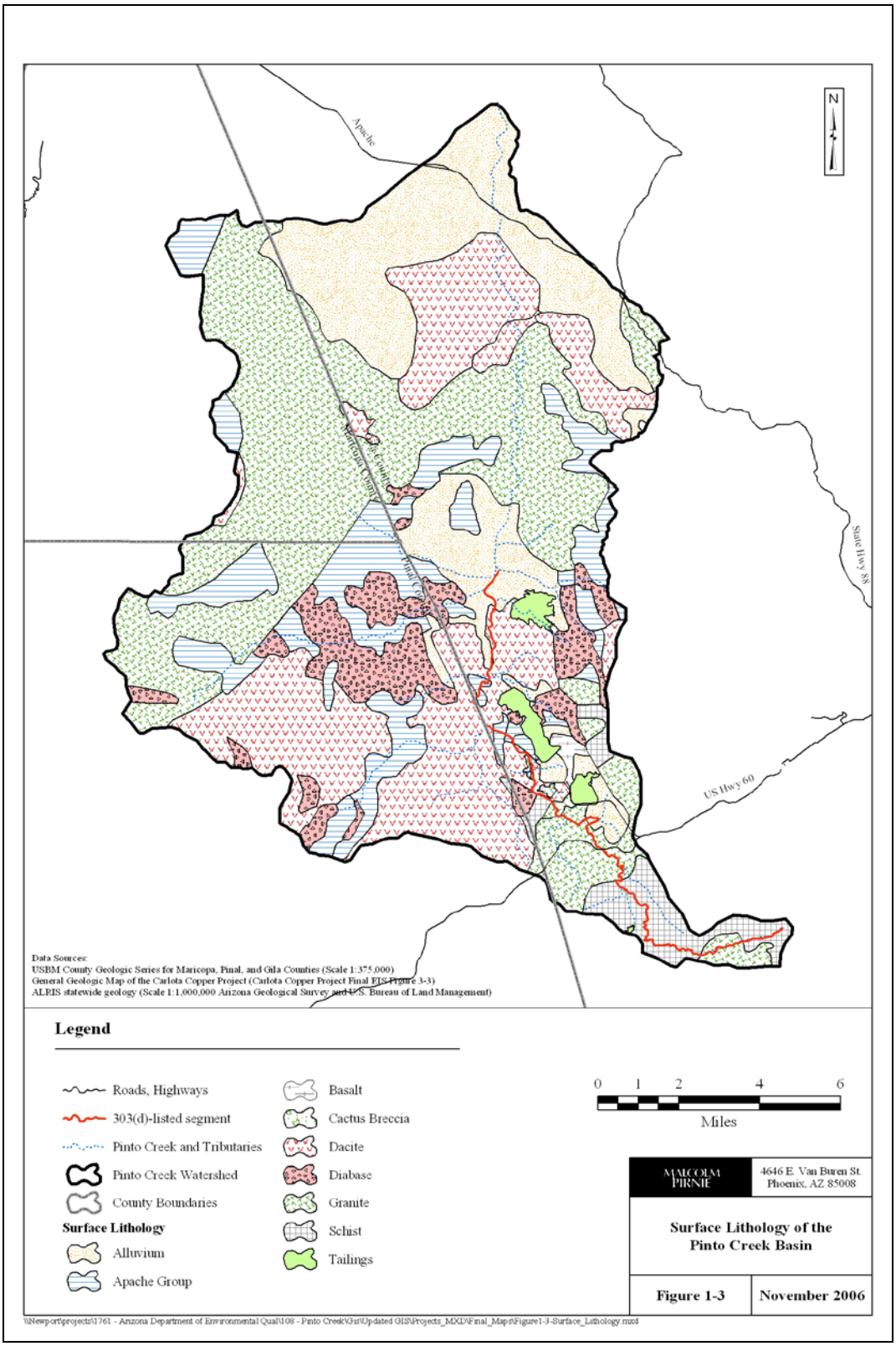

Figure 4. Surface Lithology of the Pinto Creek Basin (MPI, 2006)

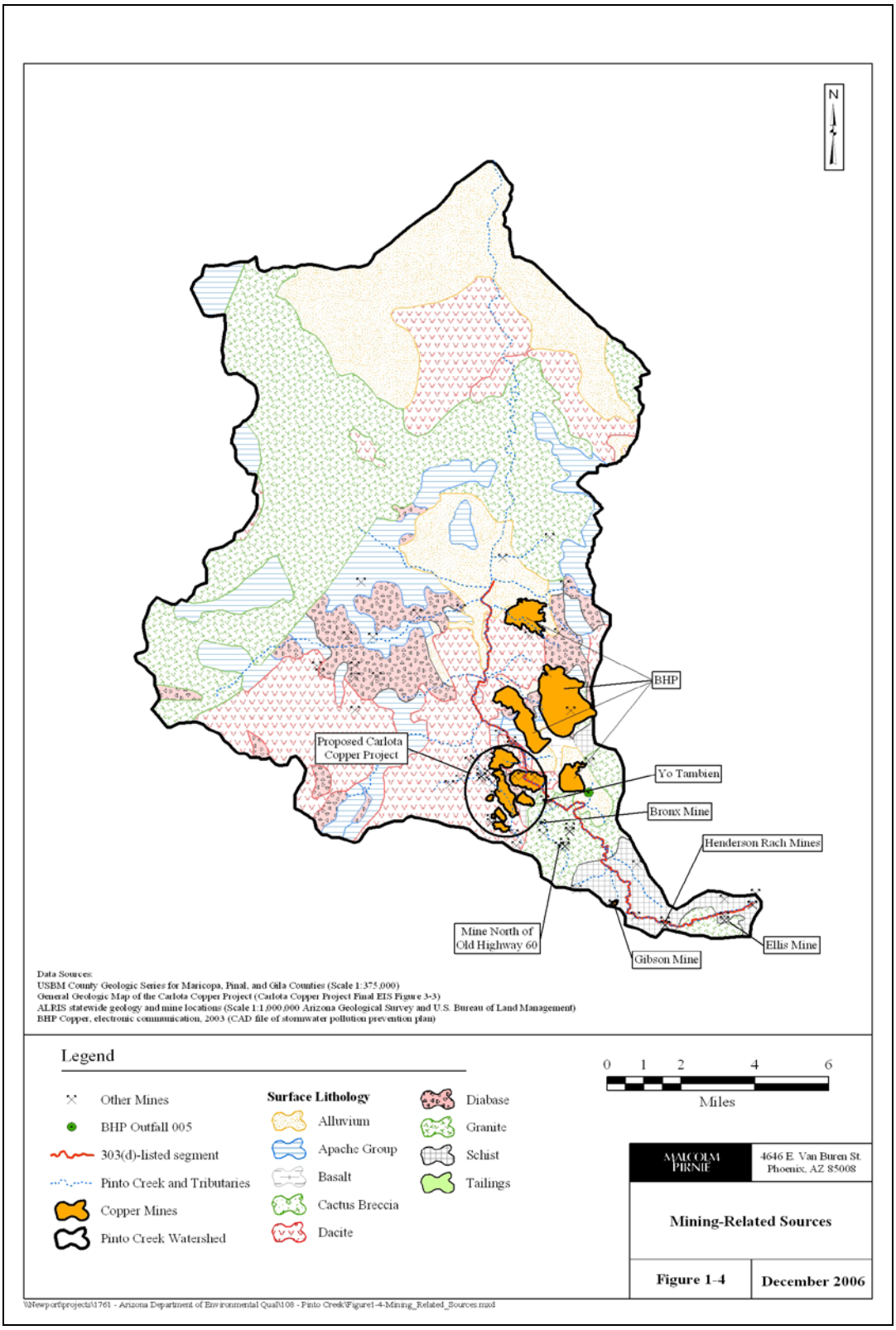

Figure 5. Mining Related Sources in the Pinto Creek Basin (MPI, 2006)

3.6 Climatic Setting

The climate of the Pinto Creek watershed is characterized by warm summers and mild winters. Average annual precipitation measured at the Capstone-PVO mine from 1973 thru 1995 is approximately 23.8 inches, and has ranged from 10.2 to 41.2 inches annually (USFS, 1997). Increased precipitation is received in July and August as the result of convective, short duration, monsoon thunderstorms. A second rainy season occurs in winter (December through March), and is associated with low pressure storm fronts moving into Arizona from the Pacific Ocean. (Sellers, W.D., Hill, R.H, 1974). Snowfall is common in the higher elevations of the watershed during the winter months.

3.7 Water Quality Standards

Pinto Creek has been divided into three reaches within HUC 15060103:

- 15060103-018A (Headwaters to Ellis Ranch Tributary at 33º19'26.7" / 110º54'57.5")
- 15060103-018B (Ellis Ranch Tributary to West Fork Pinto Creek)
- 15060103-018C (West Fork Pinto Creek to Roosevelt Lake)

Each of these reaches were assessed as not attaining the Aquatic and Wildlife (A&W) dissolved water quality standard in the draft 2016 305(b) Assessment Report. The A&W designated use changes from cold to warm water at an elevation of 5000', see Table 1 for the designated uses applicable to Pinto Creek.

Table 1. Designated Uses applicable to Pinto Creek

Reach	Designated Uses
-018A	A&W coldwater, Fish Consumption (FC), Full Body Contact (FBC), Agricultural Irrigation (AgI), and Agricultural Livestock Watering (AgL)
-018B and -018C	A&W warmwater, FC, FBC, AgI, and AgL

Surface water quality standards are based in the designated uses assigned to a particular waterbody or reach. Although Pinto Creek carries the FC designated use there is no numeric standard for dissolved copper to protect the FC designated use. Table 2 summarizes the current standards applicable to Pinto Creek; all values are expressed as µg/L. The current A&W dissolved copper standards are hardness dependent meaning as hardness increases the dissolved copper standard increases (A.A.C. R18-11, Appendix A). The proposed SSS will only apply to reach -018B.

Table 2. Current Numeric Water Quality Criteria for Copper Applicable to Pinto Creek

A&W cold and warm water (dissolved copper)	FBC (total copper)	AgI (total copper)	AgL (total copper)
<u>Acute</u> 0.18 – 49.62 <u>Chronic</u> 0.18 – 29.28	1,300	5000	500

4.0 REGULATORY FRAMEWORK FOR DEVELOPING A SITE-SPECIFIC STANDARD

EPA policy acknowledges that natural background conditions may in some instances exceed default numeric standards, and thus warrant establishment of site-specific aquatic life criteria (EPA, 1997). This policy requires that States define the meaning of "natural background", and specify or reference the procedures for determining natural background. The policy also states that site-specific criteria may be set equal to the natural background condition.

Pursuant to the EPA policy, ADEQ has promulgated rules for adopting site-specific water quality standards based on the natural background condition. The specific rule can be found in the A.A.C. R18-11-115. The statute states that the director may adopt a SSS when "the natural background concentration of a pollutant is greater than the numeric water quality standard to protect aquatic life prescribed in A.A.C. R18-11, Appendix A." It also discusses the process to follow in order to develop a SSS based on natural background conditions:

> *Natural background.*
> *a. A person seeking to develop a site-specific standard based on natural background shall provide a study outline to the Director and obtain the Director's approval before conducting the study.*
>
> > *i. The person may use statistical or modeling approaches to determine natural background concentration.*
> > *ii. Modeling approaches include Better Assessment Science Integrating Source and Nonpoint Sources (Basins), Hydrologic Simulation Program-Fortran (HSPF), and Hydrologic Engineering Center (HEC) programs developed by the U.S. Army Corps of Engineers.*
>
> *b. The Director may establish a site-specific standard at a concentration equal to the natural background concentration.*
> *c. For purposes of this subsection, "natural background" means the concentration of a pollutant in a surface water due only to non-anthropogenic sources.*

EPA policy and support documentation stresses that site-specific criteria must be based on sound scientific rationale (EPA, 1997 and EPA, 2005). However, there is little published guidance available on the specific methodologies or procedures for determining natural background conditions. One document *"EPA Region 10 Natural Conditions Workgroup Report on Principles to Consider When Reviewing and Using Natural Conditions Provisions"* (EPA, 2005), lists the following key principles of natural background determinations:

- geographically specific;
- scientifically defensible;
- well-documented and supported with data and information;

- highlighted in a process that provides the public an opportunity for review and comment when natural condition provisions are applied;
- tracked and accessible to the public.

5.0 GENERALIZED TECHNICAL APPROACH

The EPA document referenced above suggests two fundamental approaches to determination of natural conditions; 1) measurement approach, and 2) modeling approach (EPA, 2005).

The measurement approach assumes that the watershed is already free of anthropogenic sources. Further, the measurement approach requires water quality data sufficient to statistically characterize the stream under a range of flow and seasonal conditions.

The modeling approach requires a model code and input data commensurate with the complexity of the watershed hydraulics and pollutant being analyzed. Typically the model is calibrated to the available current condition data, and then modified to estimate eventual conditions. This process is also called “negative elimination” - estimating eventual conditions after quantifying and eliminating anthropogenic inputs (i.e., removing human impacts and then setting what remains as a “natural condition”) (EPA, 2005).

ADEQ’s method for estimating natural background for Pinto Creek is the modeling approach, supplemented with a substantial set of water quality data judged to be representative of natural background conditions.

A dynamic non-point source model, HSPF (Hydrologic Simulation Program Fortran) version 12 (Aqua Terra Consultants, 1997), was employed to calculate existing loads, predict future conditions under various storm events, and evaluate potential remedial or new source scenarios. The HSPF model is well known and supported by EPA for TMDL development and is included in EPA’s BASINS version 3.x (Better Assessment Science Integrating Point and Nonpoint Sources) (EPA, 2001) HSPF is arguably the most robust dynamic watershed model available. The HSPF model also offers the ability to simulate pre-anthropogenic watershed conditions, by removing all human-caused pollutant sources from the current conditions model. The resulting model is representative of natural background conditions.

After changing the current calibrated HSPF model to a natural background model, the basic steps to arriving at the SSS are:

1. Comparing the default water quality criteria and model predicted natural condition water quality,
2. Determining the length of the SSS reach by identifying the specific reach which is “naturally” greater than the default standard, and

3. Determining the new criterion for the reach by estimating the peak natural condition concentration.

6.0 WATER QUALITY DATA

The data used to derive the SSS includes 670 stream water quality samples collected at 48 sites by the Arizona Department of Environmental Quality (ADEQ), predominantly, between the years 2000 thru 2005. Of these water samples, approximately 126 were obtained from 21 sites in sub-watersheds judged to be representative of natural, pre-anthropogenic conditions.

6.1 Natural Background Lithologies

6.1.1 Pinal Schist

The quality of surface water runoff from the Pinal Schist bedrock lithology (Figure 6) was assessed in six locations (ADEQ Site Numbers: 102650, 102651, 102652, 102653, 102654 and 102656). A minor unit of non-schist granodiorite outcrops in the headwaters of the “Ellis Ranch” tributary and is not included in this grouping of natural background conditions of the schist lithology. A total of 35 samples were collected by manual grab and automatic sampler methods. The observed minimum and maximum concentrations were 18 µg/L and 45 µg/L, respectively. On a single-mean-value-per-site basis, the average dissolved copper concentration is 27.8 µg/L, with a standard deviation of 3.3 µg/L.

Figure 6. Pinal Schist along Pinto Creek

6.1.2 Schultz Granite

Surface waters originating from the Schultz Granite bedrock lithology (Figure 7) were assessed in four locations. (ADEQ Site Numbers: 102657, 102687, 102688, and 102609). A total of 13 samples were collected by manual grab methods. The observed minimum and maximum concentrations were 19 µg/L and 72 µg/L respectively. On a single-mean-value-per-site basis, the average dissolved copper concentration is 35.1 µg/L, with a standard deviation of 10 µg/L.

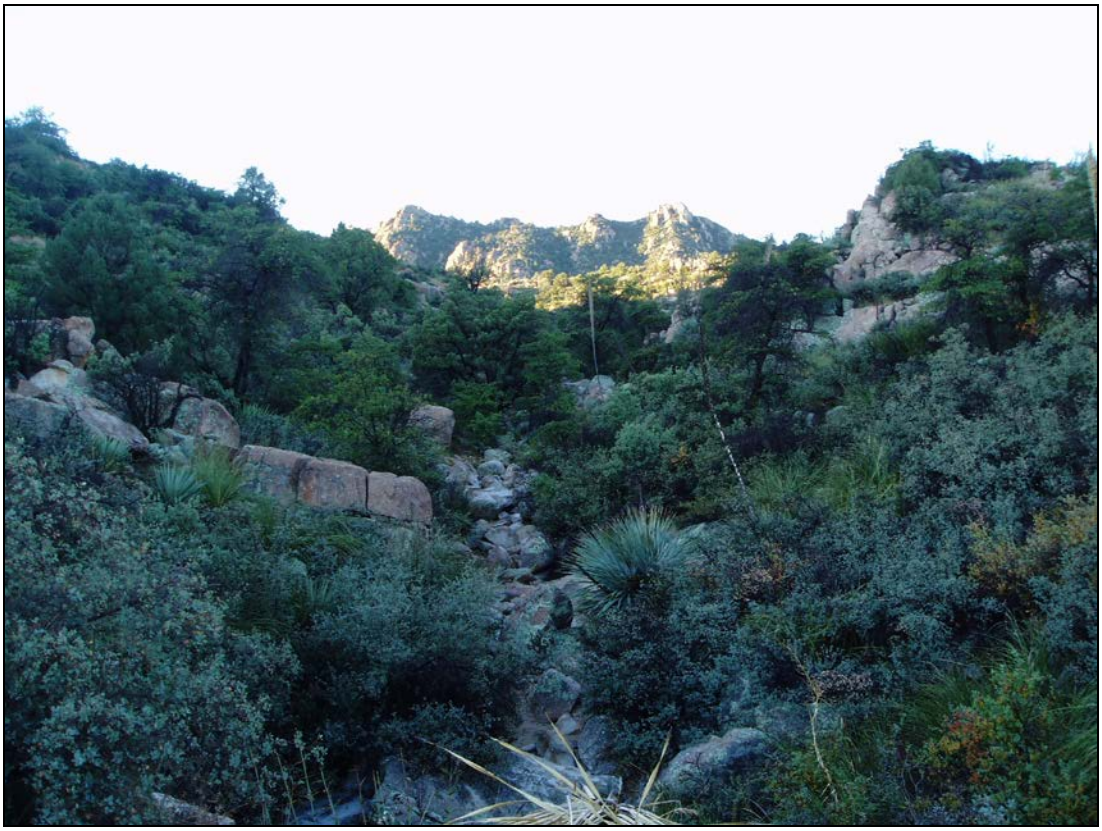

Figure 7. Schultz Granite with 5-Point Mountain in Background

6.1.3 Other Bedrock Lithologies

The remaining data used for the natural background condition modeling includes sample sites on major tributaries in the middle portions of the Pinto Creek basin below US Highway 60 including; Powers Gulch, Haunted Canyon, “Mowing Machine” Basin, and West Fork Pinto Creek. Most of these sites characterize sub-basins with mixed bedrock lithologies including; the sedimentary Apache Group, basalt, dacite, diabase, and surficial alluvium (MPI, 2006).

On the basis of mapping of known mines, there is the potential for anthropogenic copper sources to influence some of the background data, especially the Powers Gulch sub-basin. ADEQ would have preferred to obtain more samples from this

area, however access to this area is difficult in dry conditions, and practically impossible during stormflow conditions. While there is the potential for some limited anthropogenic bias in this data, it is assumed to be restricted to a few sub-basins such as Powers and Gold Gulch basins. These tributaries do not enter Pinto Creek until points below the projected maximum copper concentrations (i.e., below the Cactus / Carlota ore body). Thus, the only potential effect on the SSS that could be anticipated by collecting additional data would be to slightly reduce the distance downstream at which the default dissolved copper standard is met.

The analytical results for several locations in this group reported values as "not-detected" by the laboratory. For purposes of this analysis, a value of ½ of the detection limit (e.g., detection, reporting, or method) is used to calculate the statistics.

The water quality of runoff from the various mixed bedrock lithologies was assessed in eleven locations (ADEQ Site Numbers: 101072, 101131, 102433, 102434, 102665, 102667, 102668, 102941, 102663, 102664, and 102666). A total of 78 samples were collected by manual grab and automatic sampler methods. The observed minimum concentration was not-detected (ND) (i.e., less than 10 µg/L), in 17 samples. The maximum observed concentration was 43 µg/L. On a single-mean-value-per-site basis, the average dissolved copper concentration is 17.7 µg/L, with a standard deviation of 8.6 µg/L.

The final natural background values assigned in the model are listed in Table 1 of the 2009 MPI technical memorandum.

7.0 MODEL APPLICATION TO THE PINTO CREEK WATERSHED

The Pinto Creek watershed is predominantly mountainous in nature, and requires a dynamic watershed model with a relatively short time-step to simulate the complex and flashy nature of Pinto Creek's flow and copper loading. The model needed to simulate the different hydrologic characteristics and metals loading associated with different land covers and lithologies, as well as in-stream transport processes. The HSPF model code is well suited for this type of analysis.

The complexity of the Pinto Creek watershed required subdividing it into 41 subbasins. These subbasins were further divided into nine land cover types based on geology or land use, resulting in 149 pervious land segments (PERLND's). These PERLND's each have various acreage, physical and chemical characteristics assigned.

The HSPF model is a data intensive model requiring extensive time-series data on weather conditions, streamflow and water quality to be used successfully. These data sets were largely populated by automated weather stations, water samplers and stream

gage equipment deployed by ADEQ and two stream gages maintained by the United Stated Geological Survey (USGS).

Numerous other input parameters are required to be set in the runoff, pollutant loading, channel hydraulics, and in-stream transport modules of the HSPF model. These input parameters are adjusted during the calibration phase of model construction.

A detailed discussion on the data sources, conceptual model, model selection, model design, calibration and results are summarized on the Pinto Creek Phase II Modeling Report (MPI, 2006).

8.0 MODEL ASSUMPTIONS

8.1 Potential Non-Reversible Human Induced Copper Loading Sources

ADEQ has considered the potential for several human-caused sources of copper in the sub-watersheds that have been sampled and deemed representative of natural background. These potential influences include roads, road cuts (section 8.1.1) and aerial deposition (section 8.1.2).

8.1.1 Roads and Road Cuts

ADEQ has observed in some other TMDL studies that roads and road cuts into acid generating bedrock can cause significant water quality issues. It is acknowledged that several watersheds where ADEQ obtained natural background samples have some minimal land disturbance from roads or jeep trails. However, ADEQ does not believe that these minor land disturbances have influenced the natural background data to any detectable degree, because there are examples of data from sub-watersheds with roads with appreciably lower copper levels than other sub-watersheds with no known road disturbances.

Consider the following three natural background sites all within the schist bedrock lithology. Site 102654 has a dirt road with road cuts along the entire watercourse and a mean dissolved copper level of 24 µg/L; whereas roadless site 102653 was 45 µg/L and roadless site 102650 was 34 µg/L. On the basis of examples like these, ADEQ concludes that although a few of the natural background sample sites have some minor roads or jeep trails within their sub-watershed, there is no discernable increase in dissolved copper as a result of these disturbances.

8.1.2 Aerial Deposition

Aerial deposition of copper from active or historical mine facilities and smelters was considered as a potential non-reversible, human induced, source of copper

loading. Particulate deposition from mine facilities would reasonably be possible from the Capstone-PVO mine located within the Pinto Creek watershed. Other potential sources outside of the watershed include open pit mining and smelting facilities in the Globe-Miami area approximately 5 miles easterly, Ray-Hayden area approximately 30 miles southerly, and in Superior approximately 10 miles westerly of the Pinto Creek watershed. Metropolitan Phoenix is another potential source of copper containing particulates located approximately 60 miles westerly of the Pinto Creek watershed.

Locally, the prevailing surface wind direction in the watershed is predominantly from a southeasterly direction (USFS, 1997, EIS, p3-8). If aerial deposition were a significant source of copper from the Capstone-PVO mine or other regional sources, it might be expected that monitoring sites located northwesterly of the Capstone-PVO mine would exhibit elevated copper values. Considering that sites such as the long-term ADEQ monitoring site 100346, as well as sites 102435 and 102434 typically exhibit some of the lowest copper levels the watershed and are frequently below detection limits, ADEQ concludes that the impact of aerial deposition of copper from local or regional sources is not a measurable factor in this analysis of watershed conditions.

8.2 Other Assumptions

Assumption #1 - Abandoned/inactive mines were modeled as non-point sources and assigned uniform areas of 5 acres (except Gibson mine which is approximately 15 acres).
Rationale: The HSPF model is a dynamic watershed model by which "non-point sources" rely on precipitation to generate runoff. Therefore, some surface area is required in order for the model to generate a pollutant discharge. It is acknowledged that several of the mine facilities (i.e., Yo Tambien, Bronx mines) are primarily known for having direct discharge from their adits. These adits could potentially be modeled as "point sources", as opposed to mine dumps or tailings (which are normally modeled as non-point sources). However, while precipitate copper stains were observed on the ground at the adit exits, no active flow was observed, even after relatively large storm events. This is likely due to the drought conditions of the past few years, and as a result, groundwater elevations have likely declined. Therefore, in order to include a "source" in the model that would respond to precipitation events, and to facilitate various changes in model scenarios, the minimal 5 acre surface areas were assigned.
Implications: In general, ADEQ considers this is an environmentally conservative assumption.

Assumption #2 - Permanent hydrologic alterations in the "Current/Calibration" model are retained in the ambient/background model. Specifically, these consist of those portions of the basin occupied by Carlota and Capstone- PVO which are effectively hydraulically isolated from Pinto Creek.
Rationale: Capstone-PVO are medium sized open pit mine with associated tailings piles and leach dumps. Stormwater from the mine site is retained and managed on-site

in retention ponds which do not normally discharge to Pinto Creek. This stormwater retention is expected to continue in perpetuity. If the area of the Capstone-PVO mine were to be included in the ambient/background model, it would have required additional assumptions on hydraulic and pollutant fluxes over a substantial area in the middle Pinto Creek basin, which could not be readily be measured or verified.
Implications: In general, ADEQ considers this is an environmentally conservative approach. It could be argued that by including the Capstone-PVO area in the model, more dilution would occur from additional stormwater contribution. This in turn could potentially have the effect of reducing the required length of the SSS reach. However, because the mine is located on an extensive copper ore body, in all likelihood this additional flow would contribute even more copper per unit area to the stream than is currently included in the ambient/background model.

Assumption #3 – When comparing the model predictions at the USGS Gage on Pinto Creek below Haunted Canyon to the A&W chronic standard, a hardness of 150 mg/L was used to calculate the criterion, instead of the mean of all samples (477 mg/L). The A&W chronic standard for dissolved copper is 12.66 µg/L at a hardness of 150 mg/L.
Rationale: An analysis of the variability of hardness at this location indicates substantially lower hardness levels of approximately 150 mg/L during stream flows greater than 10 cfs (cubic feet per second). Since the model was designed and calibrated to predict the copper concentrations under the critical (storm) flow conditions, it is more appropriate to use hardness data representative of those conditions. ***Implications:*** This is an environmentally conservative approach, as the assumption results in a more stringent standard for comparison with the model predicted water quality.

9.0 MODEL RESULTS

9.1 Field Observed Existing Conditions

In Figure 8, the mean dissolved copper values of field samples obtained from Pinto Creek are plotted (green line with diamonds) by the river mile distance from the river's mouth at Lake Roosevelt. The "+" and "-" symbol situated above and below each sampling site (diamond), indicates the range of dissolved copper values in the analytical data for that site. The magenta squares, shows the chronic Aquatic & Wildlife standard based on the mean hardness observed at that sampling site (with the exception of the USGS gage below Haunted Canyon where the criteria was based on a "storm flow" hardness of 150 mg/L). All observed data (green line with diamonds) above the magenta line exceed the chronic criteria. It should be noted that the "y" axis is plotted on a logarithmic scale to improve legibility at lower concentrations, while still depicting the very high values. Figure 9 depicts the sampling locations plotted in Figures 8 and 10-13.

Initial water quality in the headwaters (mile 33+), continuing downstream past the "Ellis Ranch" tributary (mile 32.31), and continuing to the sample site above the Henderson Mines (mile 32.25), frequently appears to meet the existing chronic criteria. Beginning at the Henderson Mines, increased copper concentrations combined with decreased

hardness levels cause the stream to exceed the default chronic A&W water quality standard. Dissolved copper increases markedly below the confluence with the Gibson tributary (mile 28.8), with peak observed mean concentration occurring at the sample site located at the old US Highway 60 crossing (mile 27.51). From this point downstream, observed dissolved copper concentrations gradually decrease, with the exception of a slight increase thru the Carlota / Cactus Breccia copper ore deposit. Hardness, and thus chronic criteria, generally increases through this reach as well. Mean copper concentrations are generally low and normally meet the chronic standard from the USGS Pinto Valley weir (mile 14.51) to Lake Roosevelt. The apparent increase in copper from the Henderson Ford site (mile 8.48) to the site at the Arizona State Route 188 Highway (mile 4.37) is an artifact of stream flow condition sampling bias. Data collected from the Henderson Ford site represents generally low-flow conditions when little copper was being delivered to the stream; whereas the SR 188 site is exclusively representative of higher storm-flow conditions when copper delivery and transport to the stream is significantly higher.

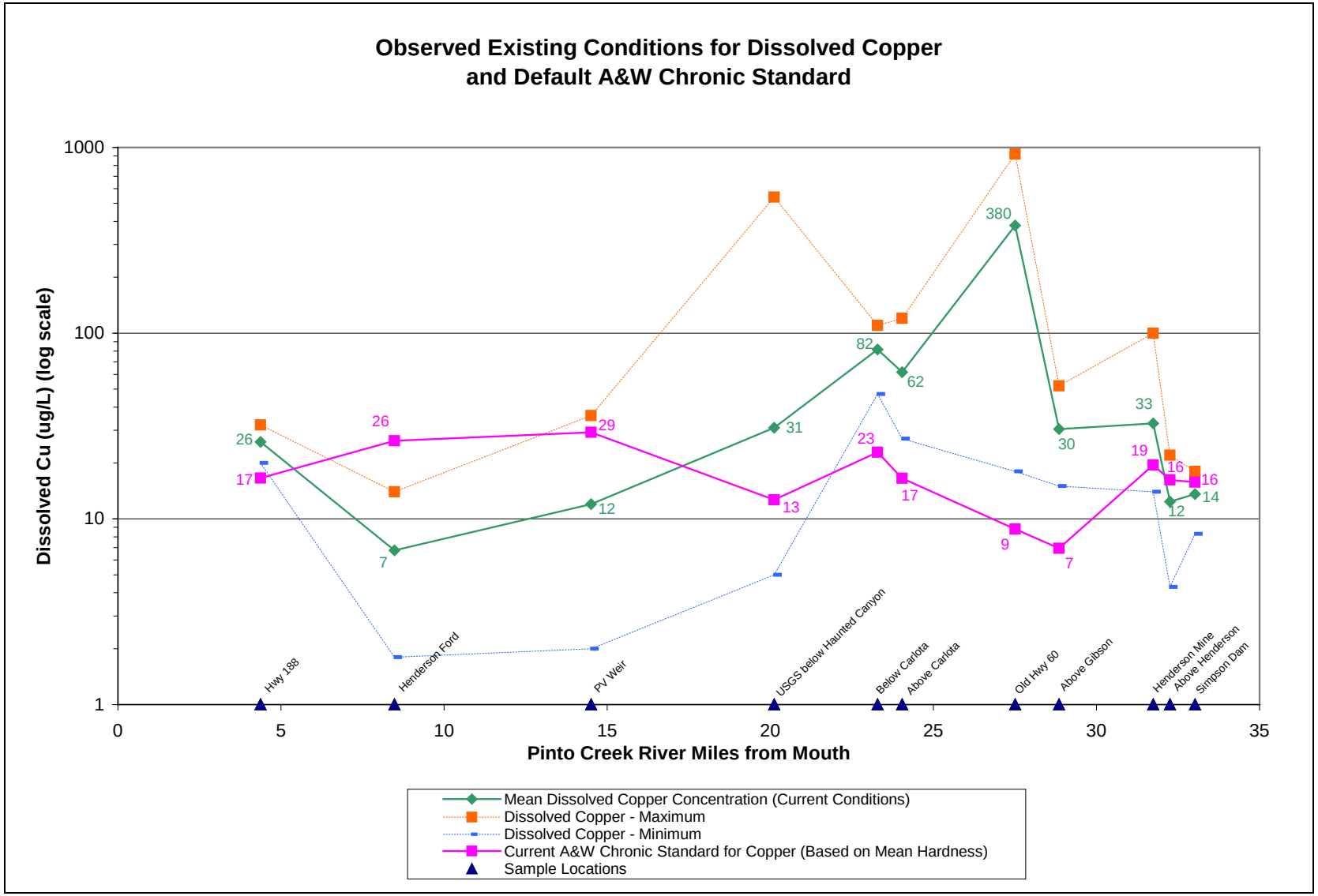

Figure 8. Observed Conditions Versus Default A&W Chronic Standard

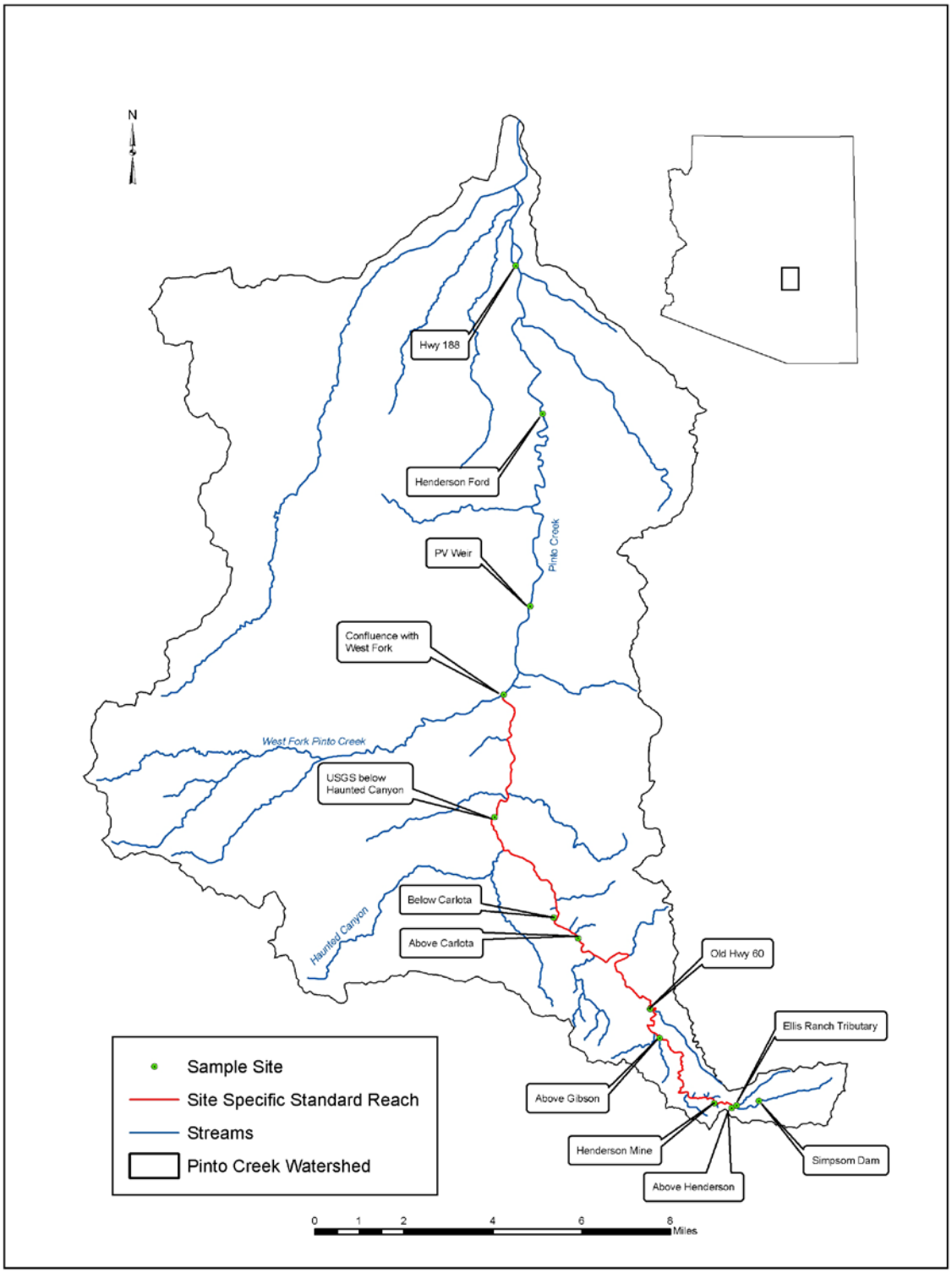

Figure 9. Sample sites and site specific standard reach

9.2 Model Calibration to Current Conditions

In Figure 10, the HSPF model output for current watershed conditions (with all known human and natural sources of copper contributing today), has been added to the previous exhibit. The predicted copper concentration for the 2-year, 1-hour (brown line with triangles) is depicted here. This graphic illustrates that the HSPF model exhibits a good calibration to the range of field data collected during storm-flow conditions. The departure of the model results to observed data in the area below Henderson Mines is primarily due to fact that no model output was available to plot data in that area. The modeled departures in the vicinity of the Pinto Valley weir and Henderson Ford are largely a result of field data collected under lower flow conditions than the modeled storm runs. Additional detailed information on hydraulic and chemical calibrations is included in the MPI modeling report and technical memorandums.

9.3 Modeling Natural Background Conditions

The calibrated model was then used to simulate a natural condition scenario by reverting the mine sites to assumed pre-anthropogenic conditions, as discussed in further detail in the MPI modeling report and technical memorandums. The pre-anthropogenic, natural condition model output for the most frequent precipitation event (2-year, 1-hour) is shown in Figure 11(purple line with circles). It can also be noted from this chart, the model predicts that the actual dissolved copper concentrations observed today (green line with diamonds) can be substantially reduced by remediation of the abandoned/inactive mines.

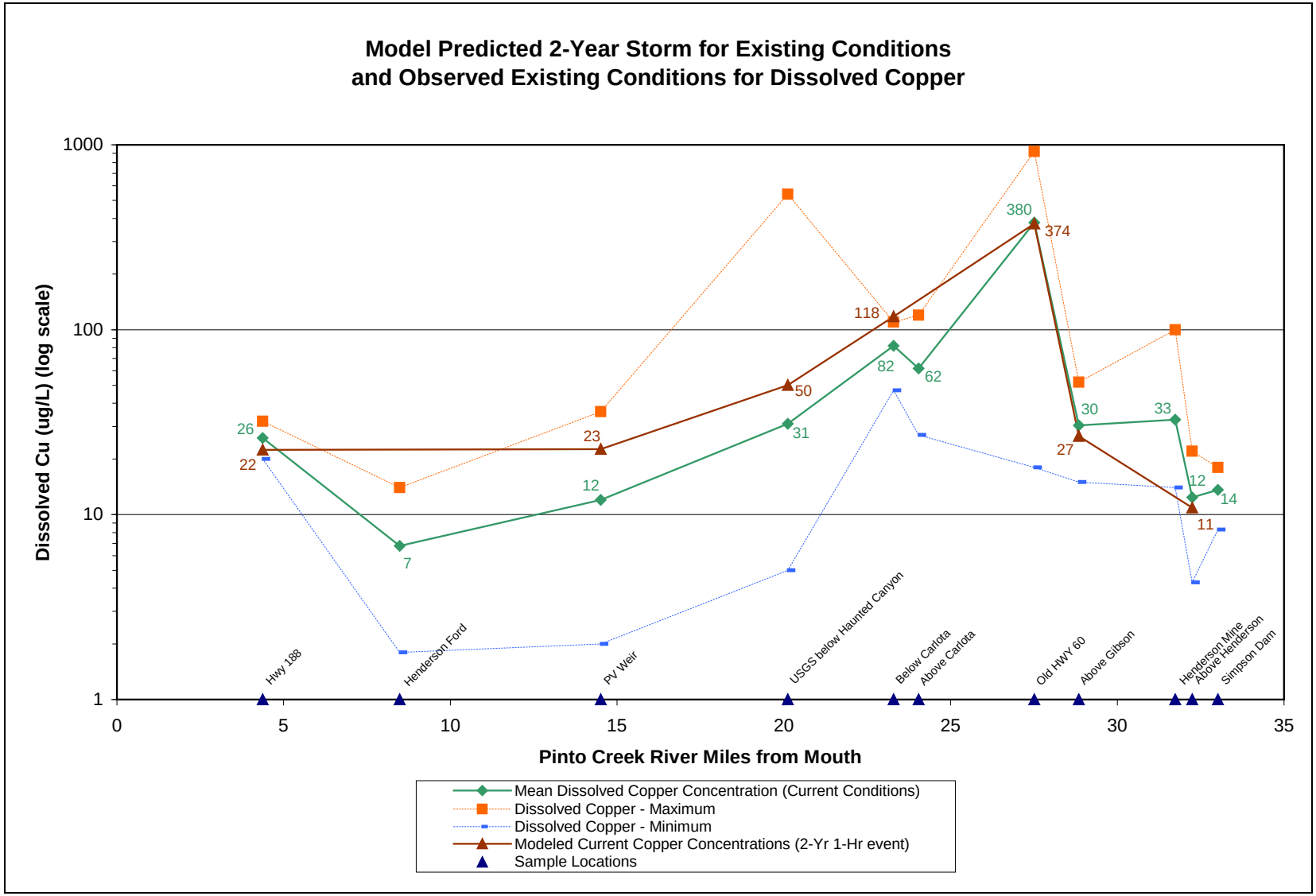

Figure 10. Modeled 2-Year Storm Events Versus Current Conditions

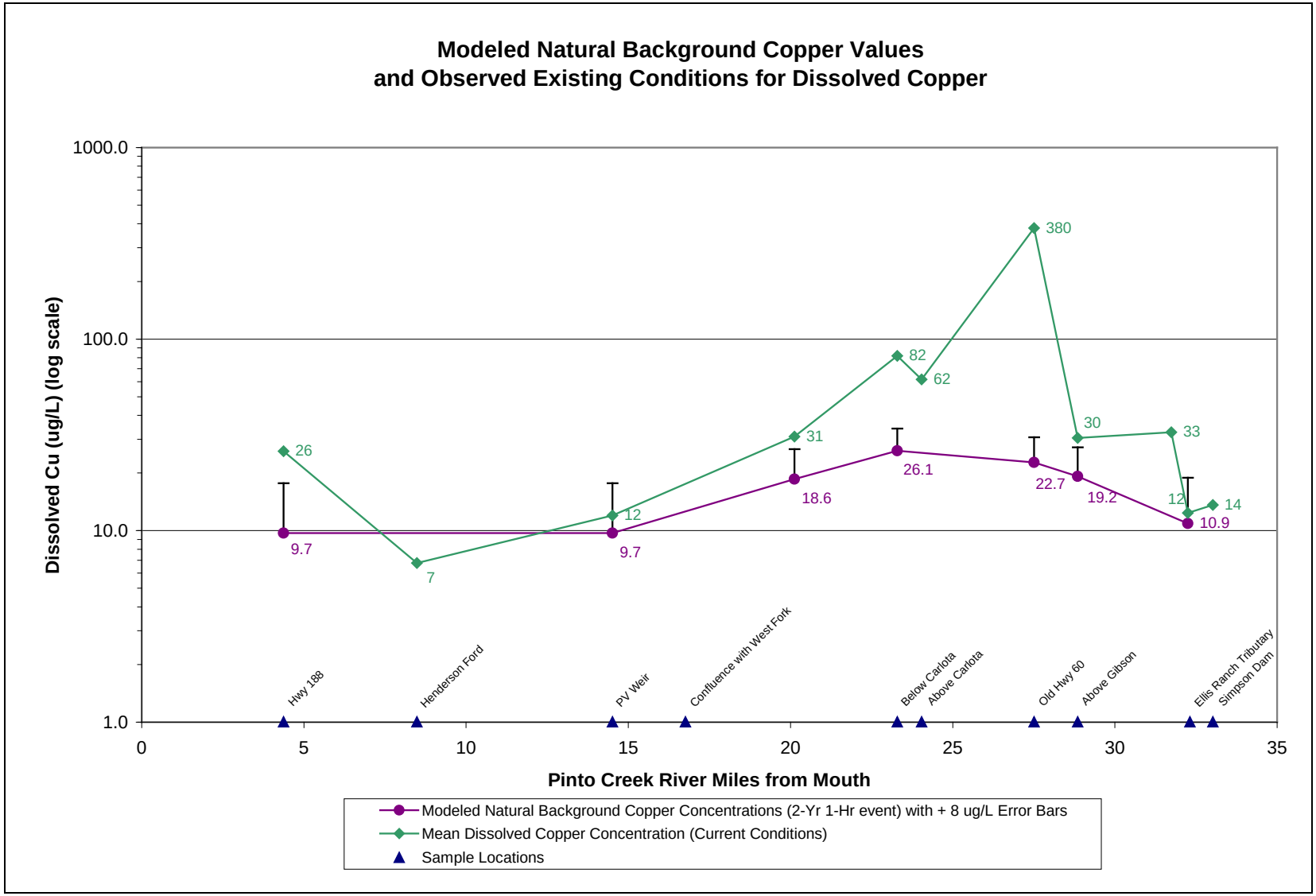

Figure 11. Modeled Natural Background Conditions Versus Existing Conditions

10.0 DERIVATION OF THE SITE-SPECIFIC STANDARD FOR PINTO CREEK

SSS Determination Step 1 – Compare the Default Water Quality Criteria to the Model Predicted Natural Water Quality

The model prediction of natural background dissolved copper concentration for the most frequent event modeled, which is 2-yr, 1-hr event (refer to Table 4 in the 2009 MPI technical memorandum) is plotted on the chart below versus the river mile location (Figure 12). Also plotted are the default chronic A&W copper criteria for each location based on the mean hardness observed at each location (magenta line with squares). The red line indicates the stream segment that the proposed 34 µg/L SSS will be applied to (reach -018B).

SSS Determination Step 2 – Define the length of the SSS reach by identifying the specific reach which is "naturally" greater than the default standard

Referring to Figure 12, the model predicted natural background concentration (purple line) starts to exceed the default standard (magenta line) at approximately river mile 32. The natural background concentration continues to exceed the default standard flowing downstream until approximately river mile 17. Downstream of river mile 17 to Lake Roosevelt, the default chronic A&W standard is predicted to be met in natural conditions.

SSS Determination Step 3 – Define the new SSS criterion for the reach by estimating the peak natural condition concentration.

Determine the level for the SSS by selecting the copper concentration from the station with the maximum predicted natural background concentration. To this value add the average standard deviation of copper from sites identified as representing natural background.

This value is also derived from the pre-anthropogenic, natural condition HSPF model output for the 2-year, 1-hour precipitation event and is depicted in Figure 11 above (purple line). As can be noted from this chart, the maximum natural background concentration is predicted to occur just downstream of the Cactus / Carlota ore body. Downstream of this point, copper concentrations decrease primarily due to dilution from major tributaries with low natural copper levels such as Powers Gulch, Haunted Canyon, Mowing Machine Basin, and the West Fork Pinto Creek.

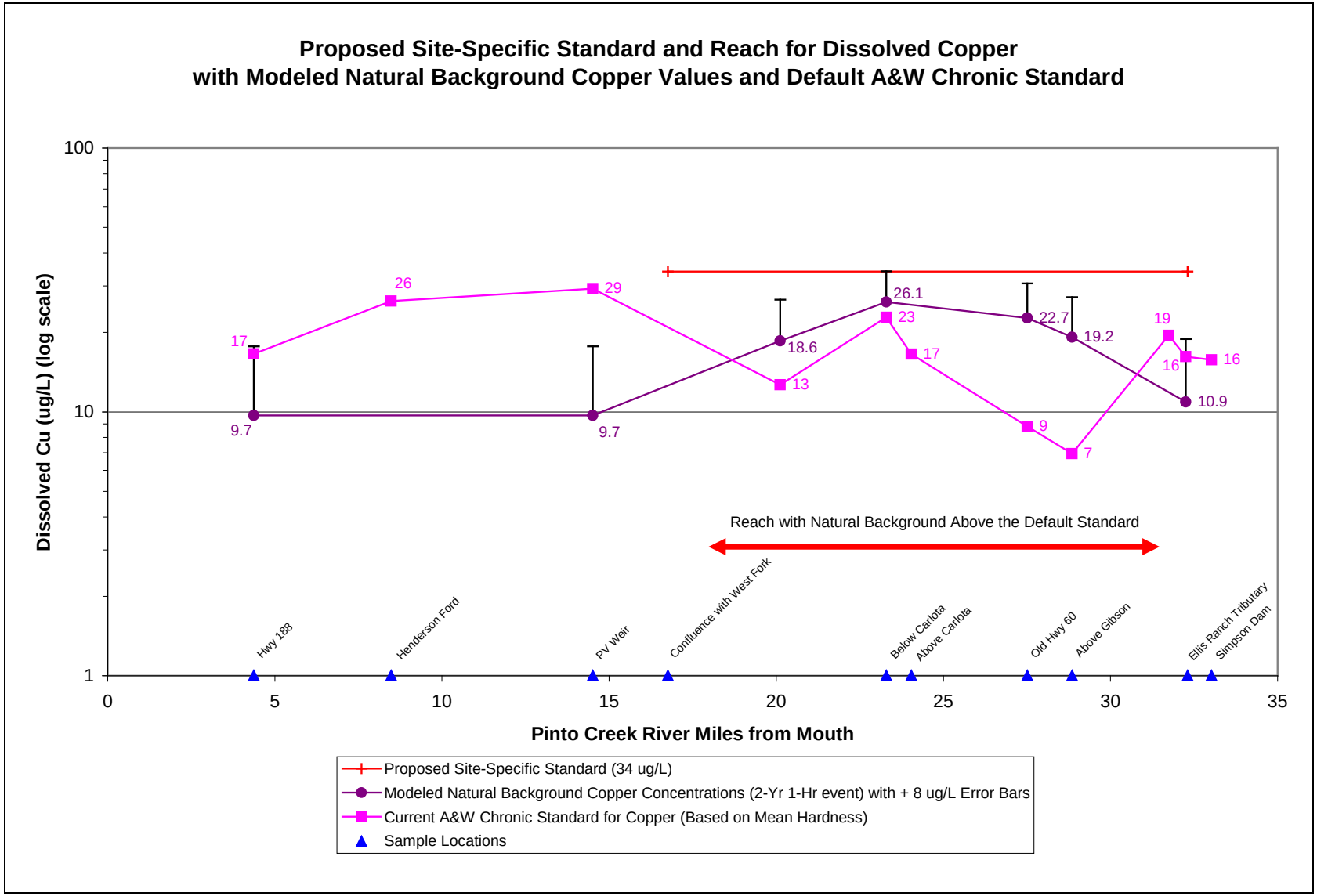

Figure 12. Proposed SSS Standard versus Natural Background and Current Standard

ADEQ has reasonably high confidence in the model predictions. However, it must be recognized that all models are necessarily simplified datasets and algorithms simulating the real world. Therefore, all models are in error to some degree. Since the runoff concentration input data had to be reduced to a single value for each land segment in the model, the true real-world variability is not accounted for in the raw model output.

One of the most tangible examples of input variability is in the water quality samples judged to be representative of natural background conditions. In Table 3 below, those sites deemed as background and having more than one sample are tabulated. Based on analysis of this data, an average standard deviation of the natural background copper data is 8.00 µg/L.

Table 3. Calculation of Average Standard Deviation from Natural Background Sampling Sites with Multiple Sample Events

ADEQ Site Number	Site Name	Bedrock Type	Samples (n)	Min µg/L	Max µg/L	Mean µg/L	Standard Deviation µg/L
102655	Mead Canyon below MF Ranch	Schist	19	23	67	37.84	8.66
102654	Unnamed trib to Pinto Creek- at FR #2	Schist	30	18	32	24	3.30
101072	Haunted Canyon Weir HC-4	Mixed	47	5.4	23	13.29	7.42
102667	Mowing Machine Basin near Pinto Creek	Mixed	3	12	27	19	7.55
102668	JK Mountain Trib above West Fork Pinto Creek	Mixed	2	18	28	23	7.07
102657	Five Point Mountain Trib	Granite	4	46	72	59.25	10.81
102687	Unnamed Trib to UF1	Granite	4	22	50	30.5	13.18
102688	Unnamed Trib to 5-Point Mountain Trib	Granite	4	19	33	24.5	6.03
			113	5.4	72	28.92	8.00

A model cannot be more accurate than the data input to the model. While there are many model input variables whose absolute values are unknown, this straightforward analysis of the above data set is a measured and conservative estimate of the maximum model accuracy. In other words, the output of estimated copper concentrations from the model should be assumed to have and error of at least ± 8.00 µg/L.

In arriving at a final recommended copper criterion for the SSS reach, ADEQ considers it prudent and reasonable to account for natural variation in the input data by adding this value to model output. Therefore ADEQ has elected to add 8 µg/L to the maximum predicted model output of 26 µg/L to arrive at the recommended dissolved copper SSS numeric criterion of 34 µg/L.

11.0 RECOMMENDED SITE-SPECIFIC STANDARD FOR PINTO CREEK

The recommended dissolved copper criteria applicable to the SSS reach of Pinto Creek is 34 µg/L (or 0.034 mg/L). The proposed SSS criterion replaces the default chronic dissolved copper standard under all hardness values and the acute dissolved copper standard for hardness values less than 268 mg/L. At hardness values equal to or above 268 mg/L the acute dissolved copper standard will be based on the hardness dependent formula listed in Arizona Administrative Code (A.A.C.), Title18, Chapter 11, Appendix A.

The recommended stream reach to apply the SSS begins on Pinto Creek at the confluence with the “Ellis Ranch” tributary (river mile 32.31) located at latitude 33º19’26.7”, longitude 110º54’57.5”, continuing downstream 15.55 river miles to the confluence with the West Fork Pinto Creek (river mile 16.76) located at latitude 33º27’32.3”, longitude 111º0’19.7”, see Figure 12.

12.0 IMPLEMENTATION ISSUES

12.1 Non-point and unpermitted sources

ADEQ will prepare an implementation plan following or concurrent with the Phase II TMDL for Pinto Creek. This plan will detail specific recommendations and actions needed to restore the natural water quality in Pinto Creek. Assuming the proposed SSS is implemented at the level of 34 µg/L, a reduction in copper loading exceeding 90 percent will be required to achieve this goal (refer to Figure 13).

A majority of the needed copper loading reductions will have to come from remediaton of non-point or unpermitted sources. Some significant improvements are already underway in the watershed. The Gibson mine is the single largest copper source in the watershed impacting Pinto Creek (Figure 14). It is estimated that the Gibson mine represents over 90 percent of the dissolved copper load in the upper portion of the watershed. In recognition of this, ADEQ has awarded two Water Quality Improvement (Section 319) grants to reduce pollutant loads from the Gibson mine site.

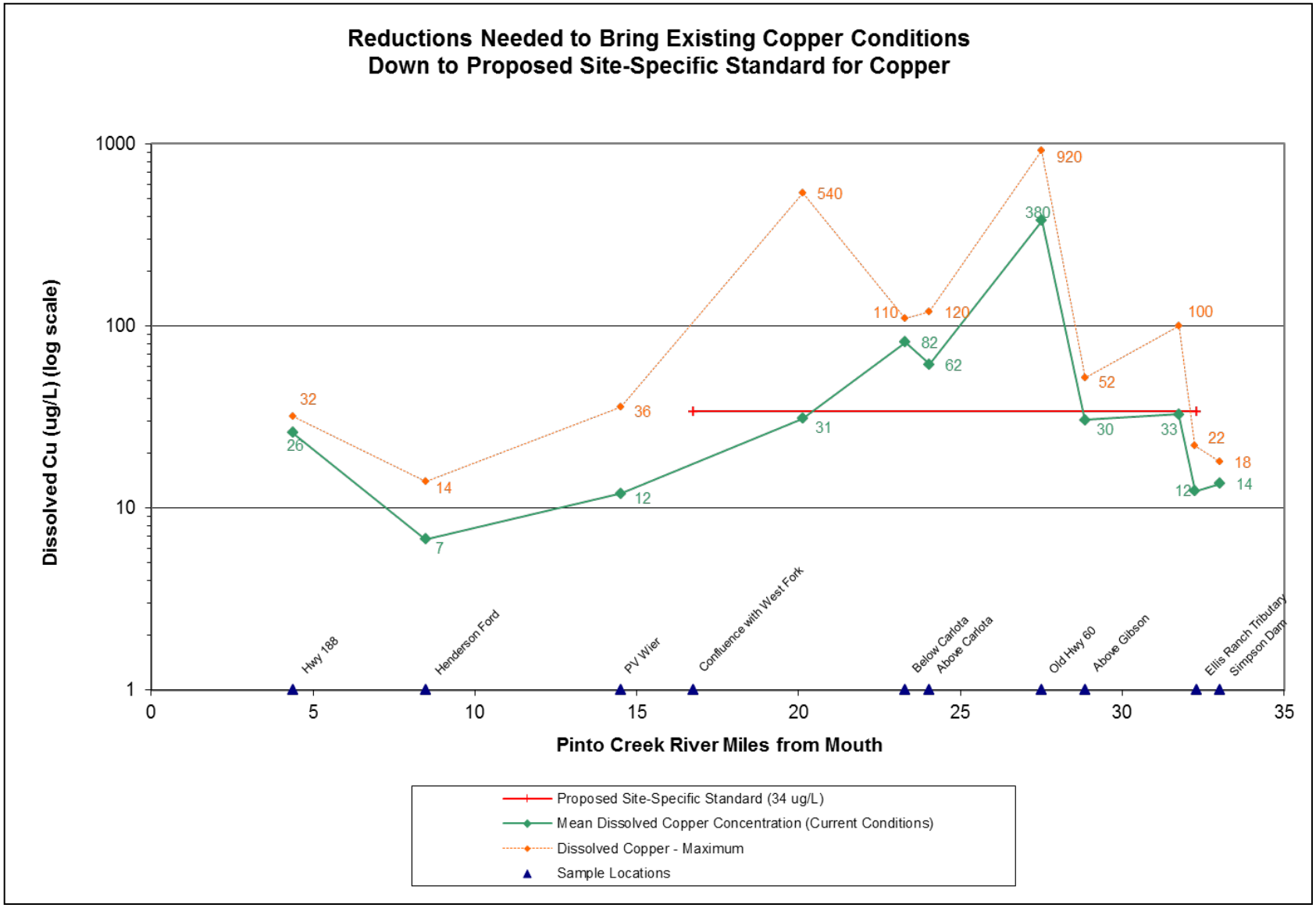

Figure 13. Reductions Needed to Meet SSS

In addition to the remedial activities funded by the 319 grants, the Gibson mine owners are addressing other sources on the site thru Arizona's Aquifer Protection Program. These include closure of several pregnant leach solution (PLS) ponds and assessing the impact of former in-situ underground leaching facilities. Effectiveness monitoring is ongoing and will determine the reduction in copper loading to Pinto Creek resulting from these actions.

Other known human-caused sources of copper in the watershed include at least five other inactive/abandoned copper mines including; Ellis, Henderson, Bronx, Blue Gate, and Old Highway 60 mines. The ownership of these historic mines has not been determined conclusively, however it is currently believed that most are located on US Forest Service lands. Regardless of ownership, remediation of these sites will need to be implemented in order for water quality improvements to occur.

Figure 14. Gibson Mine Pre-remediation Conditions of Lower PLS Pond and Stock Piles

12.2 Point sources

The only current individually permitted AZPDES point-source to Pinto Creek is the Capstone-PVO mine. Of the Capstone-PVO facilities, only outfall 005 (Figure 15) discharges continuously. All other Capstone-PVO facilities are intended to be non-discharging below the 100-yr/24-hr storm event. The former individual NPDES (EPA issued) permit for the Carlota mining project was vacated by the 9th Circuit Court but they maintain Multi-Sector General Permit coverage. The need for any changes to the

AZPDES permits for these facilities as a result of implementing the SSS will be evaluated during the permit renewal processes. Monitoring data suggests that AZPDES permited outfalls for both Carlota and Capstone are insiginificant sources of copper.

Figure 15. Capstone-PVO Outfall 005

12.3 Protection of Designated Uses

EPA guidance suggests that an SSS should address the question of whether the SSS is protective of all designated uses (EPA, 2005). As shown previously in Table 2, the proposed SSS of 34 µg/L dissolved copper is substantially lower than the applicable standards for the FBC, AgI, and AgL uses. Therefore the SSS is fully protective of these designated uses.

The Aquatic and Wildlife criterion is the only designated use with a water quality standard more stringent than the proposed SSS. However, EPA guidance suggests that "Criteria which are based on truly natural conditions (i.e., conditions absent human impacts) inherently protect the aquatic life uses that have "naturally" existed in the waterbody" (EPA, 2005, p9). Therefore the SSS is fully protective of the aquatic life use as well.

12.4 Threatened and Endangered Species

According to the EIS for the Carlota Project (USFS, 1997, pF-3), two endangered species are listed for the Pinto Creek area, the Arizona Hedgehog Cactus, and the Lesser Long-nosed Bat (Figure 16). ADEQ has not evaluated what, if any, impacts the modest change in dissolved copper criteria for Pinto Creek may have on any Threatened and Endangered (T&E) Species. ADEQ believes that the rationale applied to aquatic life (i.e., that naturally occurring levels of pollutants are adequately protective), is reasonably extended to other wildlife uses as well. For that reason,

ADEQ believes that uses by these T&E species are inherently protected by the proposed SSS.

Figure 16. Lesser Long-nosed Bat (US Fish & Wildlife Service)

13.0 PUBLIC PARTICIPATION

13.1 Public Meetings

Public participation has been an important factor in the development of the Pinto Creek Phase II TMDL and this SSS. Since the conclusion of EPA's Phase I TMDL ADEQ has held four public meetings to disseminate information, discuss issues and receive questions, comments and suggestions from the public.

The meetings were held: February 1, 2001 and December 15, 2003, at the Capstone-PVO Training Facility, July 22, 2004 at City Hall, Globe AZ, and June 12, 2007 at the Bullion Plaza Cultural Center & Museum, Miami, Arizona.

All meetings were well attended and the audience comprised a broad range of interests. Groups in attendance generally included: Arizona Center for Law in the Public Interest, Arizona Department of Environmental Quality, Arizona Fish & Game Department, Capstone Copper Inc, Bryan Cave, Carlota Copper Co, Citizens for the Preservation of Powers Gulch and Pinto Creek, Friends of Pinto Creek, Grand Canyon Chapter of the Sierra Club, Haley & Aldrich, Maricopa Audubon Society, Mineral Policy Center, National Wildlife Federation, People for the West, Freeport McMoRan Corporation (formerly Phelps Dodge), Sun City Hikers, Tonto National Forest, Western Mining Action Project and other local parties and land owners.

13.2 Opportunity to Comment

The Pinto Creek SSS was incorporated into the 2016 Triennial Review of Surface Water Quality Standards rule package. A public comment period began on February 19, 2016 and ended on April 6, 20016. A public hearing was held on April 6, 2016. No comments regarding the Pinto Creek SSS were received.

14.0 REFERENCES

Arizona Department of Environmental Quality (ADEQ), 1991. *Investigation of the Gibson Mine Discharges into Pinto Creek (October 1 & 16, 1990),* Report by Peter Hyde, Office of Water Quality, Water Assessment Section, Report WQMS-212.155, January 15, 1991.

Arizona Department of Environmental Quality (ADEQ), 1998. *Arizona Water Quality Assessment 1998, Volume II -- Assessment Data and Standards,* Arizona Department of Environmental Quality Report EQR-98-14, November 1998.

Arizona Department of Environmental Quality (ADEQ), 2000a. *Quality Assurance Program Plan Total Maximum Daily Load (TMDL) Program*, October 26, 2000.

Arizona Department of Environmental Quality (ADEQ), 2000b. *ADEQ TMDL Program Procedures Manual for Surface Water Monitoring*, October 26, 2000.

Aqua Terra Consultants, 1997. *Hydrologic Simulation Program – Fortran, User's Manual for Version 11.*

Hunt, C.B., 1974. *Natural Regions of the United States and Canada*, Charles B. Hunt, W.H. Freeman & Co., San Francisco, CA, 1974.

Malcolm Pirnie Inc, (MPI) 2006. *Pinto Creek Phase II TMDL Modeling Report*, Report prepared for the Arizona Department of Environmental Quality, February, 2006.

Malcolm Pirnie Inc, (MPI) 2008. Technical Memorandum - Project No. 1761-117, September 9, 2008

Malcolm Pirnie Inc, (MPI) 2009. Technical Memorandum - Project No. 1761-117, Rev. November 17, 2009

Peterson, N.P., 1962. *Geology and Ore Deposits of the Globe-Miami District, Arizona,* U.S. Geological Survey Professional Paper 3, 151 pp. plus 8 plates.

Sellers, W.D., and Hill, R.H.,1974. *Arizona Climate 1931-1972*, The University of Arizona Press, Tucson, AZ, 1974.

U.S. Environmental Protection Agency, 2001. *Total Maximum Daily Load for Copper in Pinto Creek, Arizona,* U.S. EPA Region 9, April 2001.

U.S. Environmental Protection Agency - Region 10. 2001. *Natural Conditions Workgroup Report on Principles to Consider When Reviewing and Using Natural Conditions Provisions*

U.S. Forest Service (USFS), 1997. *Final Environmental Impact Statement for Carlota Copper Project,* Tonto National Forest, Phoenix, AZ, Record of Decision and 3 volumes, July, 1997.