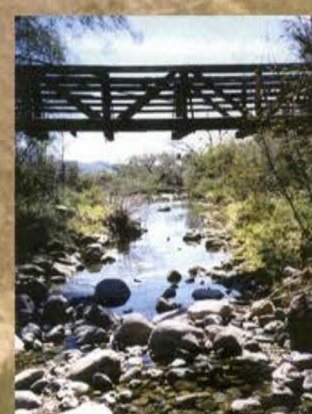
Restoration and Management Plan for Queen Creek Near Superior, Arizona



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Prepared for:

Town of Superior

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Chapter 1. Introduction

PURPOSE

For nearly a century, copper was the natural resource that defined the identity of the Town of Superior, Arizona (Superior). With the cessation of active mining in 1982, followed by a plunge in population, a shaky economy, and continued uncertainty regarding the future of mining operations, the town has taken a fresh look at its natural resources. Queen Creek emerged from this introspection as a new kind of treasure whose many riches could be obtained through restoration rather than exploitation. Restoring flow, native vegetation, and wildlife along the creek holds the promise of meeting a long-standing local need for more recreational opportunities, enhancing the aesthetic beauty of the town, and helping reverse the statewide decline of riparian habitats. These enhancements would transform the image of Superior not only for residents but also for visitors, thereby opening the possibility of creating an economic revival based on tourism. With so many regards to be reaped by taking care of the long-neglected creek, the townspeople initiated the process of developing this restoration and management plan. It is an important step toward fulfilling the vision of Queen Creek as the literal and figurative centerpiece of a revitalized Town of Superior.

APPROACH

A primary objective of this restoration and management plan is to address public issues and concerns, gain public support, and encourage stewardship of the creek by involving the community in the planning process. The planning process has been designed to provide opportunities for interested parties to express their interests and concerns at various stages of the plan development. We anticipate that initiating community involvement early in the restoration process will help to facilitate a sense of community ownership and pride for the duration of the project and beyond. We hope that the development of the restoration and management plan will be seen as first step in raising public awareness of the importance of the creek and riparian habitat and the need to protect them.

Chapter 2. Inventory and Assessment of Existing and Historical Conditions

This chapter summarizes a reconnaissance-level inventory and assessment of resources and conditions along the Queen Creek riparian corridor. Important natural and cultural features are described, including the history and cultural resources of the area, physiography, soils, hydrology, water quality, and biological resources. The description will provide the context and basis for developing recommendations for habitat restoration and management along the riparian corridor and development of associated recreational opportunities.

LOCATION

The 5-mile reach of Queen Creek addressed in this plan is located in and around the Town of Superior, Arizona, about 63 miles east of Phoenix, 18 miles west of Globe and Miami, and 31 miles northeast of Florence Junction at the intersection of U.S. Highway 60 and State Highway 177 (Figure 2-1). Superior is located near the headwaters of Queen Creek, which drains the western slopes of Fortuna Peak and Kings Crown Peak (Figure 2-2). These two prominences are in one of the westernmost ridges of Arizona's Central Highlands geomorphic province. The creek flows westward from its headwaters, draining an area midway between the Salt and Gila Rivers. The creek formerly entered the Gila River but now ends at the Roosevelt Water Conservation District Canal near the City of Queen Creek, about 25 miles southeast of Phoenix. About 10 miles downstream of Superior, Queen Creek is regulated by Whitlow Dam, an earthen flood-control structure.

The plan focuses on the segment of Queen Creek between the bridge on U.S. Highway 60 about 2 miles northeast of Superior to the Boyce Thompson Arboretum (Arboretum) about 2 miles southwest of Superior (Figure 2-2). The principal developments in the vicinity of the plan area are the Broken Hills Properties Company (BHP) copper mine, Superior, and the Arboretum.

Based on creek characteristics and land use, the plan area has been divided into the five reaches shown on Figure 2-3 and presented in the following descriptions.

Reach 1

The uppermost reach considered in detail in this plan begins where Queen Creek flows under the upper U.S. Highway 60 bridge, about 2 miles upstream of Superior. Through this reach, the creek flows through a deep canyon on BHP property.

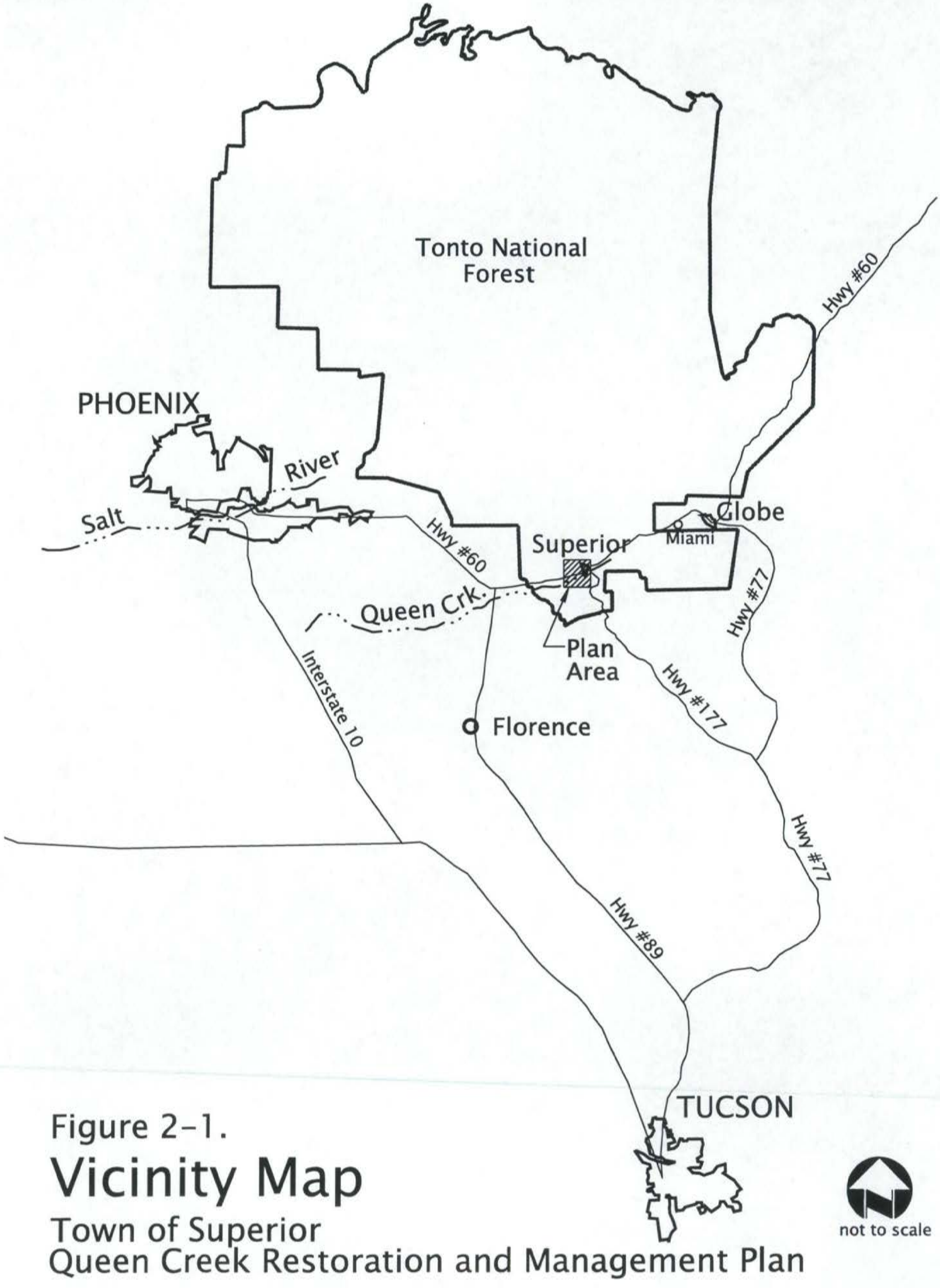
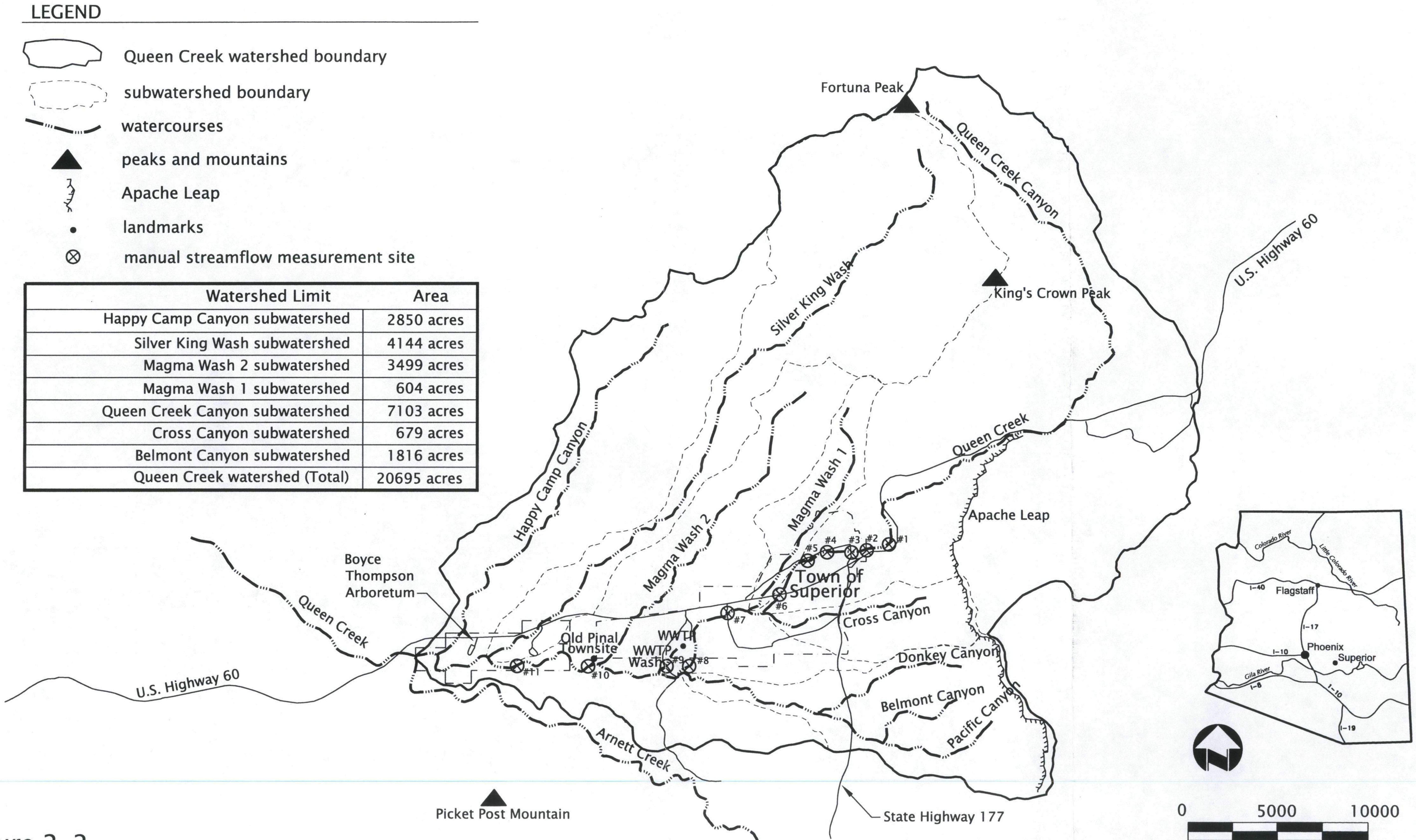


Figure 2-1.

Vicinity Map

Town of Superior
Queen Creek Restoration and Management Plan



Watershed Limit	Area
Happy Camp Canyon subwatershed	2850 acres
Silver King Wash subwatershed	4144 acres
Magma Wash 2 subwatershed	3499 acres
Magma Wash 1 subwatershed	604 acres
Queen Creek Canyon subwatershed	7103 acres
Cross Canyon subwatershed	679 acres
Belmont Canyon subwatershed	1816 acres
Queen Creek watershed (Total)	20695 acres

Figure 2-2.

Queen Creek Watershed Map

Town of Superior Queen Creek Restoration and Management Plan

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Phoenix, AZ 85004

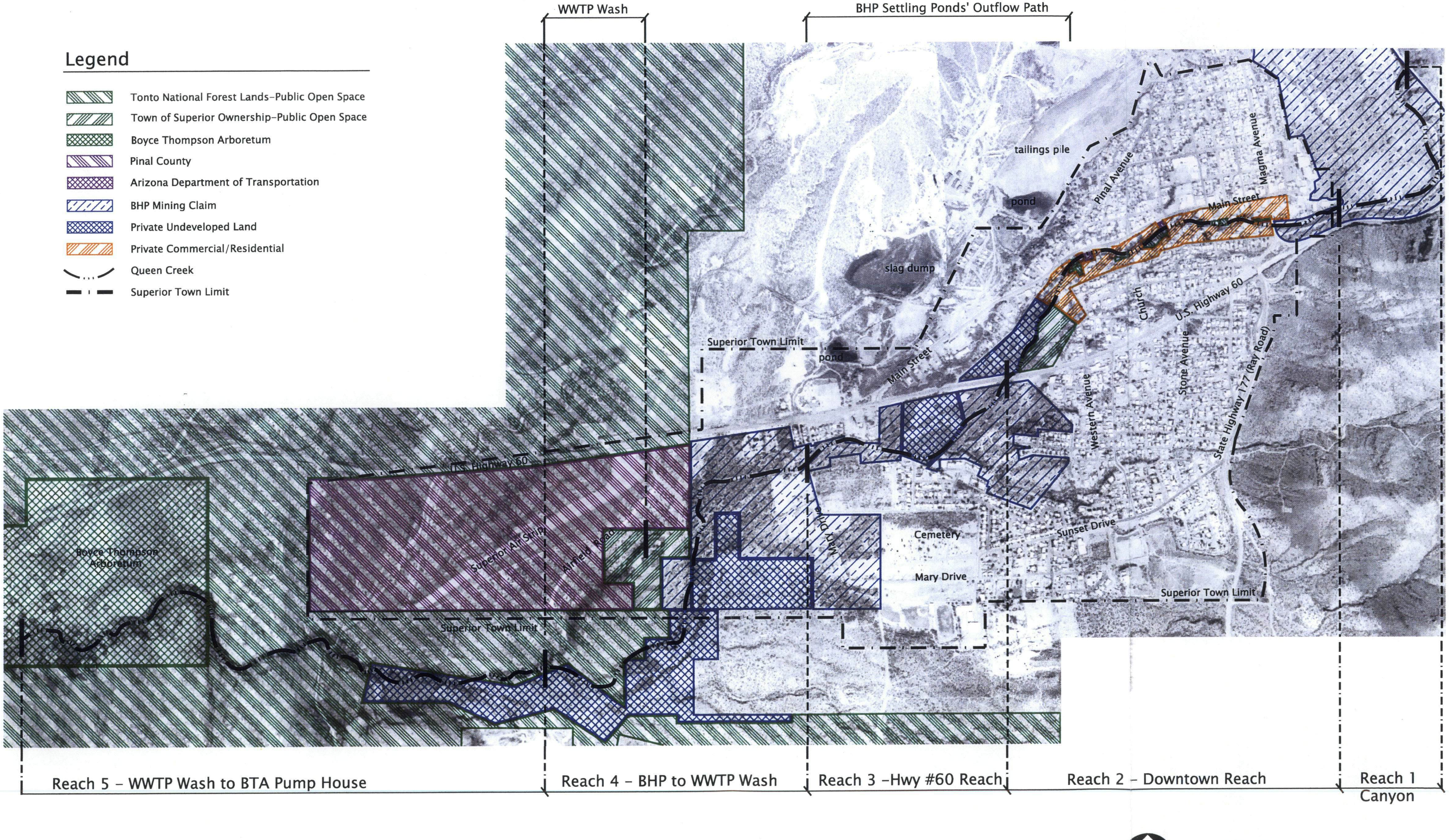

Figure 2-3.

Reach Boundaries and Property Ownership along Queen Creek

Town of Superior Queen Creek Restoration and Management Plan

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Reach 2

Superior straddles Queen Creek where the creek first leaves the steep mountain canyons and flows out onto the desert floor. The creek passes through downtown Superior on private properties devoted primarily to commercial and residential uses. Leaving downtown Superior, before passing under the lower U.S. Highway 60 bridge, the creek passes through an existing park (Community Park) and privately owned, undeveloped properties.

Reach 3

Between the lower U.S. Highway 60 bridge and Mary Drive, the creek passes through a low, mesquite-covered floodplain owned by private landowners, including BHP. In this area, lands adjacent to the creek are undeveloped open space.

Reach 4

Below Mary Drive, the creek bends south around the bluff on which the Superior Municipal Wastewater Treatment Plant (WWTP) is located before continuing across Airport Road to reach the tributary wash that conveys discharges from the WWTP (WWTP wash). Tonto National Forest lands abut the right bank of the creek along much of this reach, while BHP and other private landowners own the land along the left bank.

Reach 5

After the confluence with the WWTP wash, the creek runs through a 1.5-mile stretch of Tonto National Forest land and the Arboretum. The plan area ends at the Arboretum pump house.

HISTORY AND CULTURAL RESOURCES

This section of the report describes in general the prehistoric, ethnographic, and historical context of the plan area, as well as known and potential cultural resources in the vicinity of Queen Creek near Superior. A more thorough discussion of cultural and historical resources is included in Appendix A.

Prehistory

The Archaic period of prehistory in the Desert Southwest is defined by the end of the Pleistocene (circa 8000 B.C.) and the earliest Hohokam evidence (circa 1–500 A.D.). The Southwest was probably occupied by a number of groups with distinctive cultural traditions in the Archaic period, one of which, the Cochise, is recognized in southeastern and east-central Arizona. The Cochise tradition includes three distinct phases: Sulphur Springs (7000–5000 B.C.); Chiricahua (5000–2000 B.C.); and San Pedro (2000–100 B.C.). The last phase includes evidence suggesting the beginning of agriculture and artifact assemblages similar to both the Hohokam and Mogollon cultures (Irwin-Williams 1979, Gumerman and Haury 1979, Gumerman 1991).

The Hohokam occupied the middle Gila and Salt Rivers drainage basins in the Sonoran Desert of Southern Arizona. Haury (1976) proposes the following chronology for the central Gila-Salt drainage system: the Pioneer Period (1–550 A.D.), the Colonial Period (550–900 A.D.), the Sedentary Period (900–1100 A.D.), and the Classic Period (1100–1450 A.D.) Changes in Hohokam culture during the last period suggest an intrusion of Salado people from the north, a Salado influence, an infusion of ideas or people from Mexico, or simply developments from the previous Sedentary phase (Gumerman and Haury 1979, Gumerman 1991).

Ethnography

Unless otherwise cited, the following discussion regarding the Western Apache is adapted from Basso (1983).

Superior lies within land once occupied by the San Carlos Apache, one of five major groups occupying contiguous territories in east-central Arizona known collectively as the Western Apache. Spanish accounts and Western Apache clan legends indicate that Western Apaches occupied the area from the Mogollon Rim to the Gila River by the 1700s. The San Carlos Apache consisted of four bands, one of which was the Pinal band. By the 1700s, the Western Apache had acquired the technique of farming; however, because they were dependent upon hunting and gathering for 75% of their food, they did not permanently locate their residences. By the middle of the 1700s, the Western Apache had established an intricate network of trading and raiding relationships that involved at least a dozen other cultural groups and reached all the way from the Hopi villages in northern Arizona to Spanish settlements in central Sonora.

Historical Context

Although Coronado explored this region of Arizona in 1542, little other Spanish exploration took place thereafter. Spanish travelers into the region were mainly Jesuit priests whose mission was to convert the indigenous population to Catholicism. Spanish settlements were eventually established in the larger region in which the Apache raided. Spanish attempts to combat the Apache raiding were not successful, and hostilities intensified. In the late 1700s, a peace agreement was reached with the Apaches, and a food-ration system was established, which decreased raiding activities. This situation deteriorated after Mexico won independence from Spain in 1821, and by 1831, Apache raiding had recommenced with intensity. This was met with a Mexican policy of extermination, and as a result, from 1831 to 1853, the Apache population of Sonora drastically declined.

After Arizona came under the control of the United States in 1853, Euroamericans began immigrating to the area, many intent on making their fortune in mining. Hostilities ensued between the new immigrants and the Apaches and resulted in warfare that lasted for almost 40 years. In 1870, the Western Apache were removed to the San Carlos Reservation. Today, the first and preferred language of many Apache is their native language, and although many Apaches have converted quite devoutly to Christianity, native ceremonies are still conducted by shamans, and many native spiritual beliefs are still maintained and passed on.

The Silver King and the Pioneer Mining Districts were established after the discovery of silver in the 1870s. In 1878, the mill town of Pinal (originally known as Picket Post) was established and quickly began processing the ore of the Silver King Mine. Pinal soon became a town with a population of over 2,000 (Bernard Deutsch Associates 1988). Another mining camp that developed around Silver Queen became known as Queen. The economic depression of the 1890s and the discontinuation of silver coinage in 1893 led to the decline of silver mining and the cessation of production by the Silver Queen. In 1902, the Lake Superior and Arizona Mining Company was established; the company purchased the Golden Eagle Mine and laid out the townsite of Hastings at the Queen mining camp. The town was eventually renamed Superior, prospered with the growth of mining companies, and had a peak population of over 5,000 (Bernard Deutsch Associates 1988).

In 1910, William Boyce Thompson purchased the Silver Queen Mine and constructed a mill and smelter and the Magma Arizona Railroad to transport the ore. Over the following years, many structures were built to serve the needs of the company employees. In 1924, Thompson built an arboretum along Queen Creek west of Superior. Today, the arboretum is both a National Historic District and an Arizona State Park. Figure 2-4 shows Superior around 1908, Figure 2-5 shows Queen Creek Canyon around 1920, and Figure 2-6 shows Superior across Queen Creek around 1920.

Recorded Sites

A search of cultural-resources records was conducted at the Arizona State Historic Preservation Office, the Tonto National Forest, and the Arizona State Museum. Within the plan area, recorded sites were identified within an 800-foot-wide corridor along Queen Creek. The search indicates that a total of nine sites have been previously recorded. Two of the nine sites are prehistoric in nature, and seven are historical. The prehistoric sites include two ceramic sherd areas, one ascribed to the Salado culture, the other to Hohokam. One of the prehistoric sites has been evaluated and recommended for nomination to the National Register of Historic Places (NRHP). The seven recorded historical resources within the 800-foot-wide creek corridor are mostly associated with mining in the area. One of these sites is the historic Pinal City and Silver King Mine.

Figure 2-4. Photo of Superior Looking North across Queen Creek, Circa 1908 (?). Circular mark near center is damage to the original photograph.

Figure 2-5. Photo of Queen Creek Canyon from Magma Avenue Bridge, circa 1920 (?).

Figure 2-6. Photo of Superior Looking Northwest across Queen Creek, circa 1920 (?).

The remaining six historic sites include four roads, a bridge, and mining features, such as tailings, tunnels, and prospect pits. Six of the seven historic sites have been evaluated for eligibility for listing on the NRHP. All but one of these were recommended as eligible for listing on the NRHP. According to the records search, it does not appear that any of the nine sites have been evaluated for eligibility to the Arizona Register of Historic Places (ARHP).

Potential Sites

The review of the records-search information indicates that certain types of cultural resources seem to be prevalent in the vicinity of the plan area. Therefore, it is reasonable to assume that the same types of cultural resources may be found in future surveys for cultural resources. These cultural resources might include prehistoric villages, habitation sites, and ceramic sherd areas attributable to either Salado or Hohokam cultures; historical features associated with mining, including tunnels, prospecting pits, tailings, roads, camps, and towns; and historical roadways, including wagon, dirt, and paved roads.

LANDFORM AND SOILS

The part of the overall Queen Creek watershed that is of interest for this plan is the uppermost part, which extends from the headwaters of Queen Creek to the confluence with Arnett Creek at the downstream end of the Arboretum (Figure 2-2). This part of the watershed has a total area of 20,694 acres. Elevations range from 2,350 feet at the confluence with Arnett Creek to 5,541 feet at the summit of Kings Crown Peak. Arnett Creek drains the northern and eastern slopes of Picketpost Mountain, which is another prominent fault-block mountain south of Queen Creek near the Arboretum. Small tributaries to Queen Creek include several canyons draining the toe of Apache Leap (Pacific, Belmont, Donkey, and Cross Canyons), an unnamed wash that flows between Superior and the mine buildings on the north side of Queen Creek, Silver King Wash, and Happy Camp Canyon. The subwatersheds of each of these tributaries are also shown in Figure 2-2.

The surficial geologic formation in the Queen Creek plan area is the Gila Formation, which consists of fairly well-consolidated and cemented sediments in most of the area (Anderson pers. comm.). Queen Creek flows through a deep canyon as it descends from the slopes of Apache Leap and Kings Crown Peak above the plan area. Cemented sandstones and conglomerates of the Gila Formation are visible at many locations along Reaches 1, 2, and 5 of the Queen Creek channel (Figure 2-7). In other areas, they are covered by a layer of unconsolidated sediments ranging from silts and sands to large boulders. In general, the texture of unconsolidated channel sediments decreases from large boulders in Reach 1 to smaller cobbles intermixed with gravel, sand, and occasional clay or silt in Reaches 4 and 5.

In the plan area, the creek channel from Reach 1 to about the middle of Reach 2 is lined with many large boulders and occasional bedrock outcrops. Channel sediments become finer as the creek leaves the canyon above Superior and flows southwest across the desert floor. By Reach 4, the

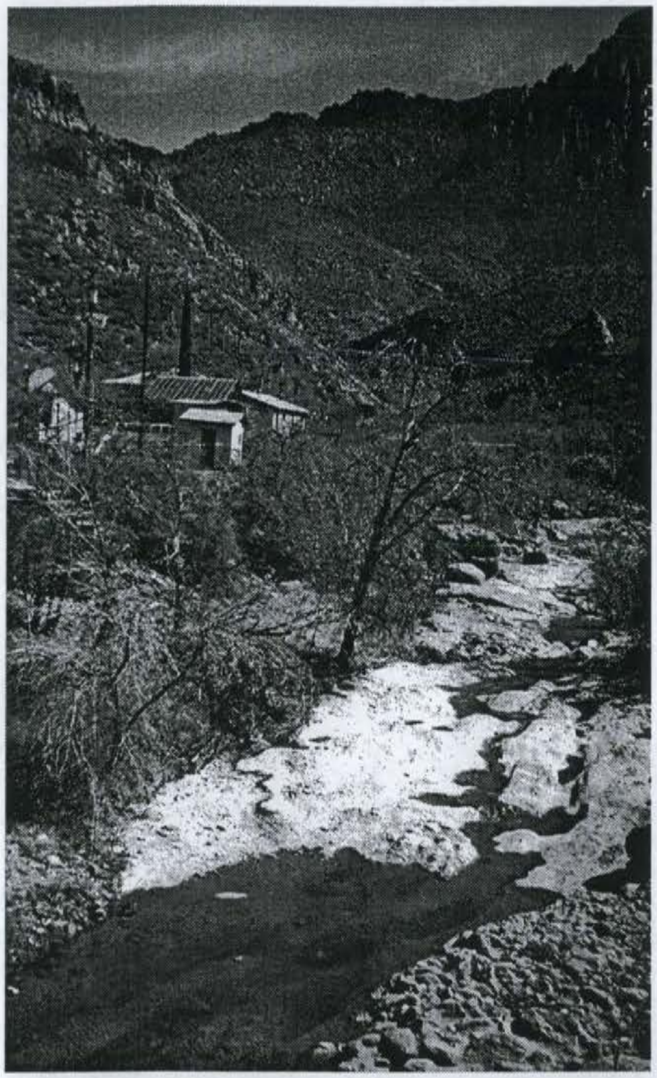


Figure 2-7. Gila Formation Bedrock Exposed in Creek Bed near the Magma Avenue Bridge.

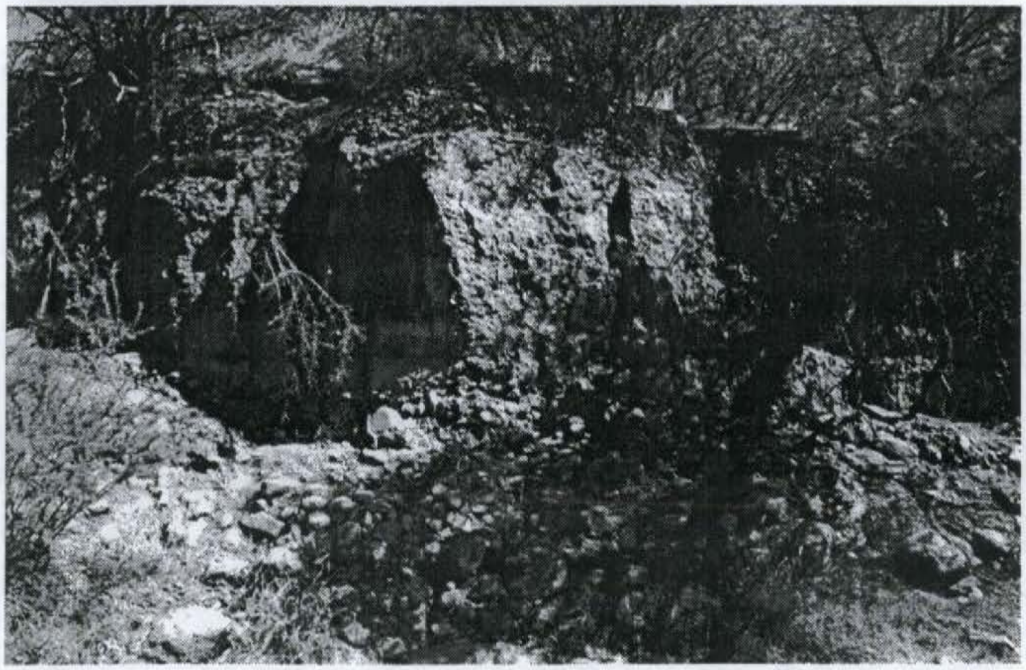


Figure 2-8. Highly Variable Subsurface Soil Textures Exposed in Creek Bank along Reach 3.

sediment texture in the channel includes a high percentage of organic matter, sand, silts and clay, and gravel along with cobbles and small rocks (Myers 1993).

The General Soil Map of Pinal County, Arizona, (U.S. Soil Conservation Service 1971) maps the soils in the plan area as Caralampi–White House association. This soil is associated with valley slopes, occurring largely on moderately dissected old alluvial fans with slopes of 5-30%. Caralampi soils make up about 65% and White House soils about 20% of the association. About 10% is medium-textured alluvial soils associated with the Queen Creek channel and adjacent drainageways. These alluvial soils support the riparian-vegetation associations of the creek. The high variability of soil textures in the floodplain along Reach 3 is shown in Figure 2-8.

PRECIPITATION AND TEMPERATURE

Climate data for Superior have been recorded since 1948 (Western Regional Climate Center 1998). Average annual precipitation is 18.59 inches. Precipitation commonly occurs in all months, but there are two distinct precipitation seasons, as indicated in Figure 2-9. Most of the annual precipitation falls in winter, when large frontal-storm systems originating from the Pacific Ocean create storms of generally moderate intensity that last for several days. A small amount of winter precipitation falls as snow, but the snow generally melts within a few days or weeks. In summer, intense but brief and localized thunderstorms occasionally drop significant amounts of rainfall derived from moist air masses originating in the Gulf of Mexico. May and June are the months of least precipitation.

Average daily maximum air temperatures (Figure 2-9) range from 60°F in January to 99°F in June. Corresponding average daily minimum temperatures are 41°F in January and 77°F in June.

HYDROLOGY

This section describes available streamflow, groundwater, water-use, wastewater-generation, and water-quality data for Queen Creek and Superior. Available streamflow data are not adequate for completing water-balance calculations needed for vegetation planning, and no local measurements of evapotranspiration (ET) are available. Accordingly, estimates of daily streamflow and monthly ET were developed by adjusting data from similar nearby watersheds.

Daily basic data sufficient to provide a general overview of hydrology and water use are shown in the graphs and tables in this section. Additional graphs and tables and documentation of the method used to estimate daily streamflows are presented in Appendix B.

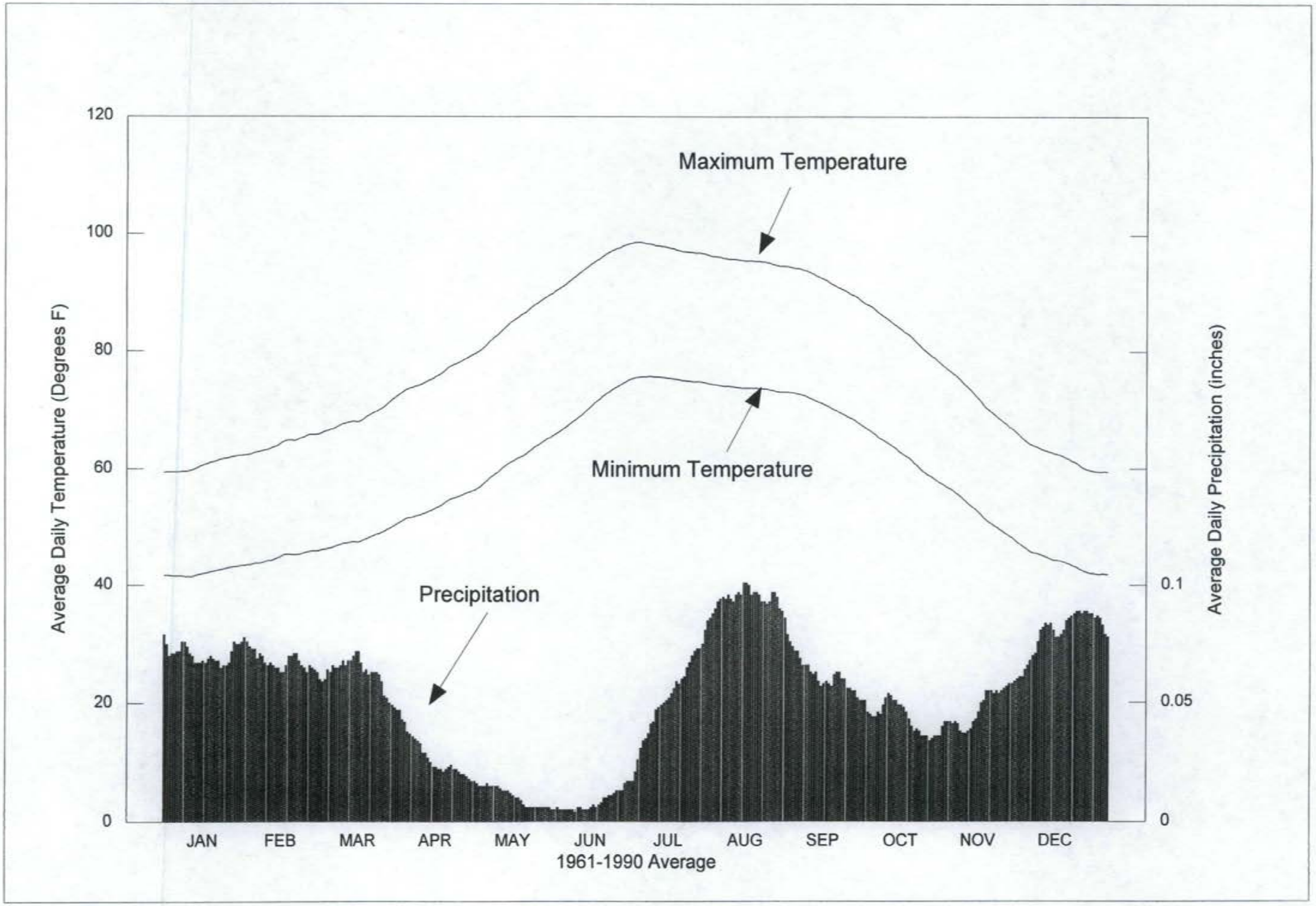


Figure 2-9. Average Daily Maximum and Minimum Temperatures and Precipitation at Superior, 1961-1990

Streamflow

Streamflow data for Queen Creek are available only for limited periods of time and only at a few locations. Continuous records of streamflow are available for the following gages:

- a gage operated by the U.S. Geological Survey near Florence Junction from August 1940 to May 1941,
- a gage at Whitlow Dam (also near Florence Junction) from 1949–1958,
- a BHP gage on the ephemeral wash parallel to Pinal Street, and
- a gage on Queen Creek at the Arboretum.

The period of record for the U.S. Geological Survey gage near Florence Junction is too short to evaluate the frequency and duration of high flows, and the location (15 miles downstream of Superior) is too distant for low-flow data to be useful for characterizing conditions near Superior. The average-annual discharge for the gage at Whitlow Dam, which regulates a large flood-detention basin, was 2,970 acre-feet (af). The minimum and maximum annual discharges were 940 af and 10,130 af, respectively (Arizona Department of Water Resources 1994, Vol. II).

BHP operates a gage on an ephemeral wash (Magma Wash 1 in Figure 2-2) next to one of its water-treatment ponds as a requirement of their National Pollution Discharge Elimination System (NPDES) permit. The wash flows along Pinal Avenue and empties into Queen Creek between the U.S. Highway 60 bridge and Mary Drive. Surface flow is present only in response to major storms. The most recent flow event was in January 1993 (Lira pers. comm.). The amount of rainfall measured at the Arboretum that month was 8.62 inches, or four times the average amount and more than in any other month during 1988–1997. The wash drains an area of about 604 square miles on the lower flanks of Apache Leap. The infrequent occurrence of flow in this wash indicates that surface inflow to Queen Creek from most tributaries between Apache Leap and the Arboretum is probably minimal.

A manometer-type stream gage, which was installed on Queen Creek at the Arboretum in September 1994, records stream stage every 15 minutes. Stage measurements are converted to flow using a 7-point rating curve calibrated for low flows only. Daily average flow at the gage during 1995–1997 is shown in Appendix B. Flow is typically absent during May–October. A small base flow of 1,000-2,000 gallons per minute (gpm) or 2-5 cubic feet per second (cfs) in winter is punctuated by brief flow peaks in response to rainfall (1 cfs is equal to 448.8 gpm). The peaks (average flow over 24 hours) are commonly 30,000-40,000 gpm (70-90 cfs). The magnitude of base flow experiences abrupt shifts (e.g., January 1996, January 1997), which may indicate inaccurate measurement. Abrupt shifts can result from changes in the streambed configuration (e.g., during storms, as a result of human activity), clogging of orifices on the gage apparatus, and seizing or malfunctioning of mechanical components of the gage apparatus. In addition, recorded low flows at the gage have not appeared consistent enough with occasional flow measurements made for this study (see below) to allow the two sources of data to be merged for the purpose of calculating seepage losses. Thus, for the purpose of the water-balance analysis developed for this plan, the gage records are principally useful as an indicator of the presence or absence of flow (i.e., the season during which base flow is present).

In addition to the gage records, miscellaneous streamflow measurements have been made for this plan using current-meter, bucket-and-stopwatch, and salt-dilution methods. The locations of the measurement sites are shown in Figure 2-2, and the flow data are shown in Appendix B. Only a few sites were measured on most of the dates. During some site visits, the creek was dry at a number of the measurement stations, which precluded calculation of seepage losses. On other occasions, logistical considerations prevented the measurement of flow at all the targeted sites. However, the data that was collected clearly showed that seepage losses were very small during spring 1998. This information was sufficient to prepare a water balance model for evaluating restoration opportunities.

A long-term record of daily or monthly streamflow at the upstream end of Reach 1 is needed to identify any changes that may have occurred in the streamflow regime and to evaluate its suitability for restoration. None of the available gage records for Queen Creek provide an adequate basis for estimating Reach 1 flows because the gage locations are too far downstream, the periods of record are too short, and/or the accuracy of the low-flow data are questionable.

As an alternative, natural streamflow in Reach 1 was estimated by correlation with gaged flows in Wetbottom Creek and West Fork Sycamore Creek, which are two watersheds of similar size and terrain in Arizona's Central Highlands province. Because daily flow-duration characteristics of these two streams are not unusual, monthly flows entering Reach 1 during 1961–1974 (the period of record for West Fork Sycamore Creek) were estimated from these predictor gages by correcting for the differences in drainage-area size and average-annual precipitation. The details of the streamflow estimation procedure are described in Appendix B. The resulting monthly flows in dry, normal, and wet years at the top of Reach 1 are shown in Table 2-1. Average monthly flows are particularly useful as an indicator of the season of live flow in different year types for this intermittent reach of Queen Creek. Note that each month of the year was calculated independently and that it is very unlikely that all months of the year would be either wet or dry.

High Flows and Flooding

Changes in vegetation along the Queen Creek channel will affect flood levels during large storms. The Federal Emergency Management Agency (FEMA) completed a flood-insurance study and a flood-boundary and floodway map of Superior in 1981 (Federal Emergency Management Agency 1981a, 1981b). FEMA used the U.S. Soil Conservation Service's TR-20 model with precipitation intensity-duration-frequency data from the National Oceanic and Atmospheric Administration to estimate flood magnitudes for the flood-insurance study. Estimated peak flows for floods of various recurrence intervals are shown in Table 2-2.

The flood-boundary map shows that a number of residences along Heiner Drive would be inundated in a 100-year storm. (A 100-year flood is the peak flow that has a 1% probability of occurring in any year.) The FEMA 100-year floodplain map is shown in Figure 2-10; it was

Table 2-1. Estimated Average Monthly Flows in Queen Creek at the Top of Reach 1 in Wet, Normal, and Dry Years

Wet	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Wetbottom Creek	0.00477	0.03065	0.06608	0.09500	0.10772	0.12247	0.02198	0.00174	0.00029	0.00130	0.00737	0.00824
W. Sycamore Creek	0.00043	0.00128	0.04039	0.01913	0.01786	0.03827	0.00638	0.00213	0.00043	0.00000	0.00043	0.00085
Average	**0.00260**	0.01596	0.05323	0.05706	0.06279	0.08037	0.01418	0.00193	0.00036	0.00065	0.00390	0.00455
Estimated Queen Creek flow above Magma Club (cfs)	0.58879	3.61756	12.06303	12.93090	14.22803	18.21127	3.21269	0.43745	0.08094	0.14744	0.88367	1.03013

Normal	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Wetbottom Creek	0.00058	0.00072	0.00810	0.03962	0.03181	0.02906	0.00622	0.00058	0.00014	0.00000	0.00072	0.00043
W. Sycamore Creek	0.00000	0.00000	0.00085	0.00850	0.01361	0.00808	0.00255	0.00085	0.00000	0.00000	0.00000	0.00000
Average	0.00029	0.00036	0.00447	0.02406	0.02271	0.01857	0.00438	0.00071	0.00007	0.00000	0.00036	0.00022
Estimated Queen Creek flow above Magma Club (cfs)	0.06553	0.08191	1.01375	5.45219	5.14560	4.20811	0.99347	0.16187	0.01638	0.00000	0.08191	0.04915

Dry	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Wetbottom Creek	0.00000	0.00000	0.00043	0.00085	0.00085	0.00255	0.00128	0.00043	0.00000	0.00000	0.00000	0.00000
W. Sycamore Creek	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00043	0.00085	0.00085	0.00128	0.00043	0.00000
Average	0.00000	0.00000	0.00021	0.00043	0.00043	0.00128	0.00085	0.00064	0.00043	0.00064	0.00021	0.00000
Estimated Queen Creek flow above Magma Club (cfs)	0.00000	0.00000	0.04817	0.09634	0.09634	0.28903	0.19269	0.14452	0.09634	0.14452	0.04817	0.00000

Note: Values are accurate to at most 2 significant digits. Additional digits are retained throughout the table to avoid rounding small entries to zero.

Table 2-2. Flood Magnitudes and Peak Flows in Queen Creek at Mary Drive

Flood Magnitude		
Annual Probability (rate)	Recurrence Interval (years)	Peak Flow (cfs)[a]
0.10	10	4,600
0.02	50	9,800
0.01	100	11,400
0.002	500	14,200

[a] cfs = cubic feet per second

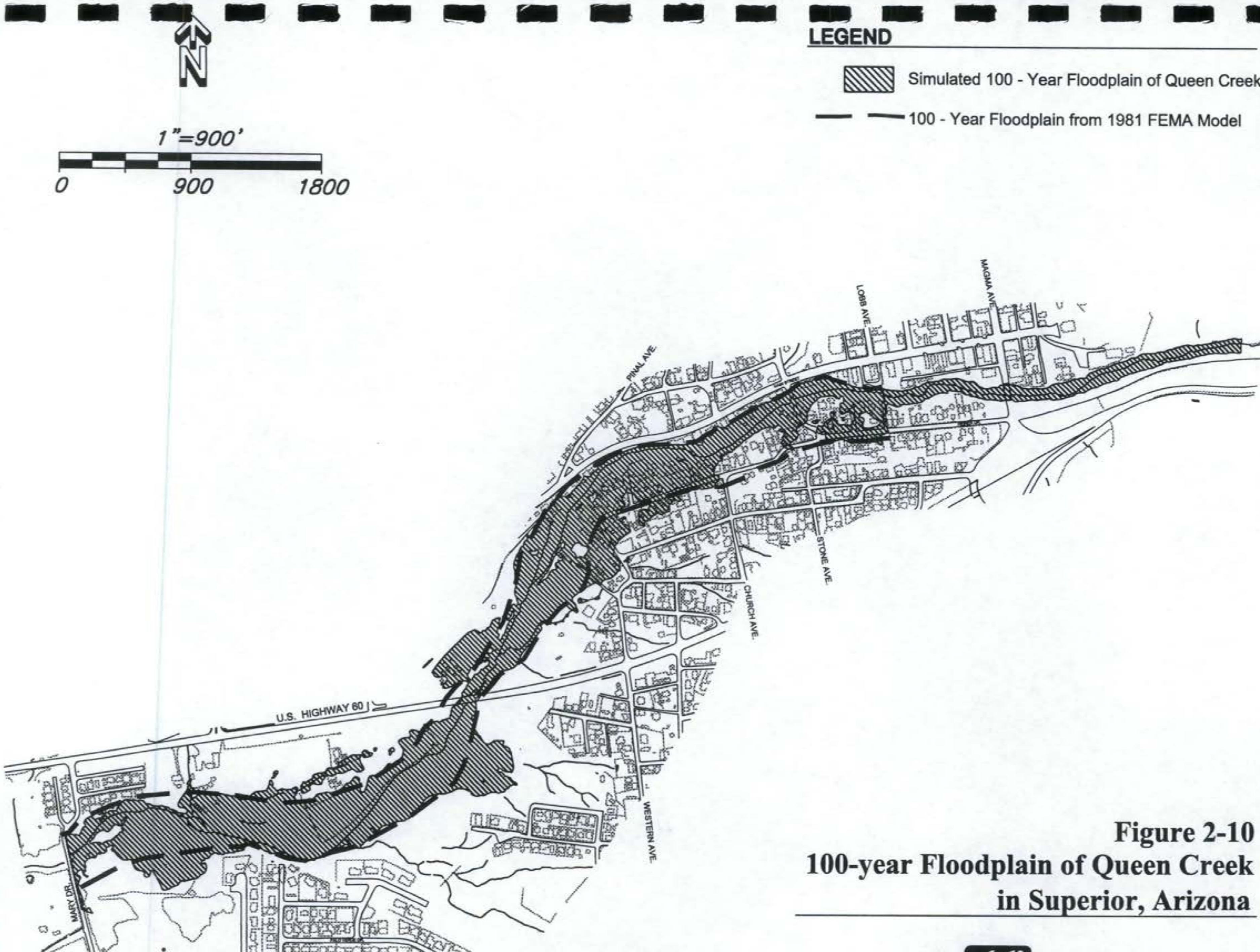


Figure 2-10
100-year Floodplain of Queen Creek in Superior, Arizona

Jones & Stokes Associates, Inc.

calculated using the HEC-2 flood-hydraulics modeling software developed by the U.S. Army Corps of Engineers (USACE).

Flooding is not perceived as a major problem by local residents because all floods that have occurred in about the last 60-70 years have been contained within the channel and have not inundated buildings along the creek. Harold Smith, who has lived in Superior nearly continuously for 73 years, does not recall a single flood that inundated homes along the creek (Smith pers. comm.). The largest flood he remembers in the last 45 years resulted from a thunderstorm in 1967 that dropped 3.5 inches of rain near King's Crown Peak (Figure 2-2). The water reached the third step of the Lobb Avenue footbridge but receded quickly without inundating any buildings. If the storm, however, had been centered more directly in the upper Queen Creek watershed, he suspected that the peak floodflow in Superior would have been considerably larger.

Mary Palacio, another resident who has lived in Superior since approximately the 1930s, also does not recall any flood that inundated buildings. Her aunt, however, remembers that some residences along Heiner Drive were inundated in a flood in the 1920s (Palacio pers. comm.). According to Mr. Smith and Ms. Palacio, the FEMA floodplain-mapping study in 1981 was not prompted by any real or perceived flood problem, and the study was not followed by any flood-control projects. Mr. Smith understood that the principal purpose of the study was to define a floodplain so that residents could obtain flood insurance. Recurring flood damage in other Arizona towns where floodplains had not been mapped may have motivated FEMA to develop the Superior map in anticipation of potential problems. This was not confirmed by FEMA, who was contacted by Jones & Stokes to determine what prompted the FEMA flood mapping in Superior.

Ironically, a week before the final public meeting for the planning process (i.e. in early August 1999) a moderate flood event occurred. Rainfall intensity reached a maximum of 1.75 inches in 1 hour in Superior. The ensuing flood flow reached the top of the low-flow channel bank and inundated the margins of some back yards of residences along Sonora Street (the westward extension of Heiner Drive). At the Arboretum, the flood destroyed the footbridge located next to the stream gage and Canyon Well. The bridge had cost $65,000 to construct. This was the only reported property damage from the flood event.

It is not clear whether a 100-year flood has simply not occurred in the last 70 years or whether the magnitude of the event was overestimated in the FEMA flood study. Notwithstanding the lack of frequent flood damage, there are a few signs of channel modifications that appear to have been ad-hoc efforts to manage flooding. Numerous willow trees in the channel along the lower end of the downtown reach (Reach 2) were cut down sometime after the January 1993 flood. Unfortunately, the tree removal may have increased rather than decreased the flood risk along that reach. The willow stumps have resprouted into dense, multi-stemmed shrubs that have a higher flow resistance than the individual tree trunks they replaced. Sediment deposition and vegetation growth have reportedly decreased the channel capacity in this area, so that this creek segment would be the most likely to experience overbank flooding (Smith pers. comm.).

The flood-hydraulics model developed by FEMA was updated for this study to provide quantitative estimates of the potential flood impacts of actions proposed in this plan and to identify potential mitigation strategies for any adverse impacts. The original input data were obtained from the FEMA archives and reactivated using the USACE's HEC-RAS software, which has largely replaced the original HEC-2 software. The simulated 100-year floodplain closely matched the FEMA floodplain. Simulations of a channel fully vegetated with shrubs and trees resulted in a floodplain that was only slightly larger than the existing floodplain in certain areas. Further simulations demonstrated that low levees along the top of the creek bank would be capable of preventing flooding along most of Heiner Drive and Sonora Street, but that levees up to 6 feet high would be needed in a few locations near Lobb Avenue. The model also confirmed that the floodplain terrace on the left bank of Queen Creek downstream of the Highway 60 bridge—which is the proposed location for an artificial lake (see Chapter 5)—is an area of ineffective flow under flood conditions. Complete details regarding model input, calibration, and results are provided in Appendix B.

Low Flows

Low flows are more persistent than high flows, and unless shallow groundwater is present, riparian vegetation along the creek channel depends on this persistent flow as its principal water supply in many months.

The estimated normal and wet-year monthly flows in Reach 1 (Table 2-1) indicate that a solid base flow of 1 cfs or more would normally be present from December through April, decreasing to a negligible in June and July. In wet years, significant amounts of base flow can be expected from August through early May. Under dry conditions average monthly flow could be less than 0.3 cfs in any month and is likely to be less than 0.15 cfs in most months.

Existing base flow in Queen Creek does not appear to be as persistent as indicated by the flows listed in Table 2-1, which were estimated by correlation with gaged flows in undisturbed watersheds. Many Superior residents stated during the planning process that flow in Queen Creek in the downtown area (Reach 2) is not nearly as persistent as it was in their childhood (Zapata pers. comm., Smith pers. comm., Lira pers. comm.). Specifically, pools in the creek a short distance upstream of the Magma Avenue bridge used to remain full of water all summer and served as popular swimming holes. The drought stress and mortality evident in cottonwood trees along Reach 2 also suggest that the flow regime has become drier.

The most likely cause of the decrease in base flow is seepage into underground mine workings. Discharge from the dewatering pumps in the BHP copper mine increases noticeably for several weeks following rain storms (Lira pers. comm., Anderson pers. comm.), and the increased flow is either groundwater that would have seeped into the creek or streamflow that leaked out of the creek. Large amounts of Queen Creek flow reportedly leak into mine workings along the creek about 0.2 mile upstream of the Magma Club (Lira pers. comm.). Another leaky spot is located near the upper end of Reach 1, where the creek crosses exposed, steeply dipping limestone beds. Mine workers built a berm isolating one-half of the creek channel to shunt flow away from the leakiest spots (Smith pers. comm.). In addition, mine operators have attempted to decrease seepage from the creek into the mine at least twice during the mine's 100-year history, once by sealing the creekbed and once by grouting the walls of selected mine tunnels. Neither of these efforts met with much success because the water was able to flow around the seals through other fractures (see additional description under "Actions Not Recommended for Implementation at This Time" in Chapter 5).

The miscellaneous flow measurements made for this plan indicate that the downtown reach was completely dry during summer 1997 and that the cobbly streambed in that reach is sufficiently permeable at some locations to transmit flows of up to 0.2 cfs (100 gpm) entirely as subsurface underflow.

Seepage into mine workings is not the only human influence on base flow in the creek. Low flows in Queen Creek also are augmented by municipal wastewater and mine-dewatering discharges.

Superior Municipal Wastewater Treatment Plant Discharge

The WWTP is located between U.S. Highway 60 and Queen Creek west of Mary Drive (Figure 2-2). The WWTP was built in 1976 and has a capacity of 750,000 gallons per day (gpd). Tertiary-treated wastewater is discharged to the WWTP wash and flows 2,200 feet south to the confluence with Queen Creek. The discharge to the creek is not metered directly. However, the inflow to the plant is metered, and outflow is essentially equal to inflow because fluctuations in storage at the WWTP are minimal (Real pers. comm.). Daily inflows to the WWTP during May 1996 through October 1997 were remarkably constant (as shown in Figure 2-11). The dry-weather inflow averaged 160 gpm (equal to 230,000 gpd, 0.36 cfs, or 258 acre-feet per year [af/yr]) and showed no seasonal variation. Occasional periods of increased inflow occur during periods of heavy rainfall. Total inflow during May 1996 through April 1997 was 86.4 million gallons.

Reclaimed water from the WWTP has also been delivered by pipeline for irrigation at several municipal facilities since 1984. Presently, about 3-6 million gallons per year (mgal/yr) are used at Murchison baseball field. Other facilities that use or historically have used reclaimed water for irrigation include Kennedy Elementary School (about 0.6 mgal/yr), the Superior High School memorial field (2-3 mgal/yr), and the cemetery (Real pers. comm.). If all these facilities received their maximum historical delivery in 1 year, the amount of reclaimed water used would be only 11% of the amount presently produced at the WWTP.

Wastewater inflow fluctuates regularly and substantially on an hourly basis (see Appendix B). On weekdays, there is a pronounced period of peak water use between 6:00 a.m. and 8:00 a.m. and a smaller peak in the late afternoon and evening. Inflow plummets during the late night hours to only 25% of the typical daytime inflow. On weekends, the morning peak inflow period is later and longer. Morning and evening measurements of flow in the ephemeral wash in July 1997 confirmed that the effluent discharge fluctuates substantially in a similar diurnal pattern.

BHP Mine Dewatering Discharge

Discharge from BHP's dewatering water-treatment ponds was fairly large but contributed infrequently to low flows in Queen Creek. When the mine was in operation, dewatering pumps removed water from a central sump at one of the deepest shafts to keep the underground workings

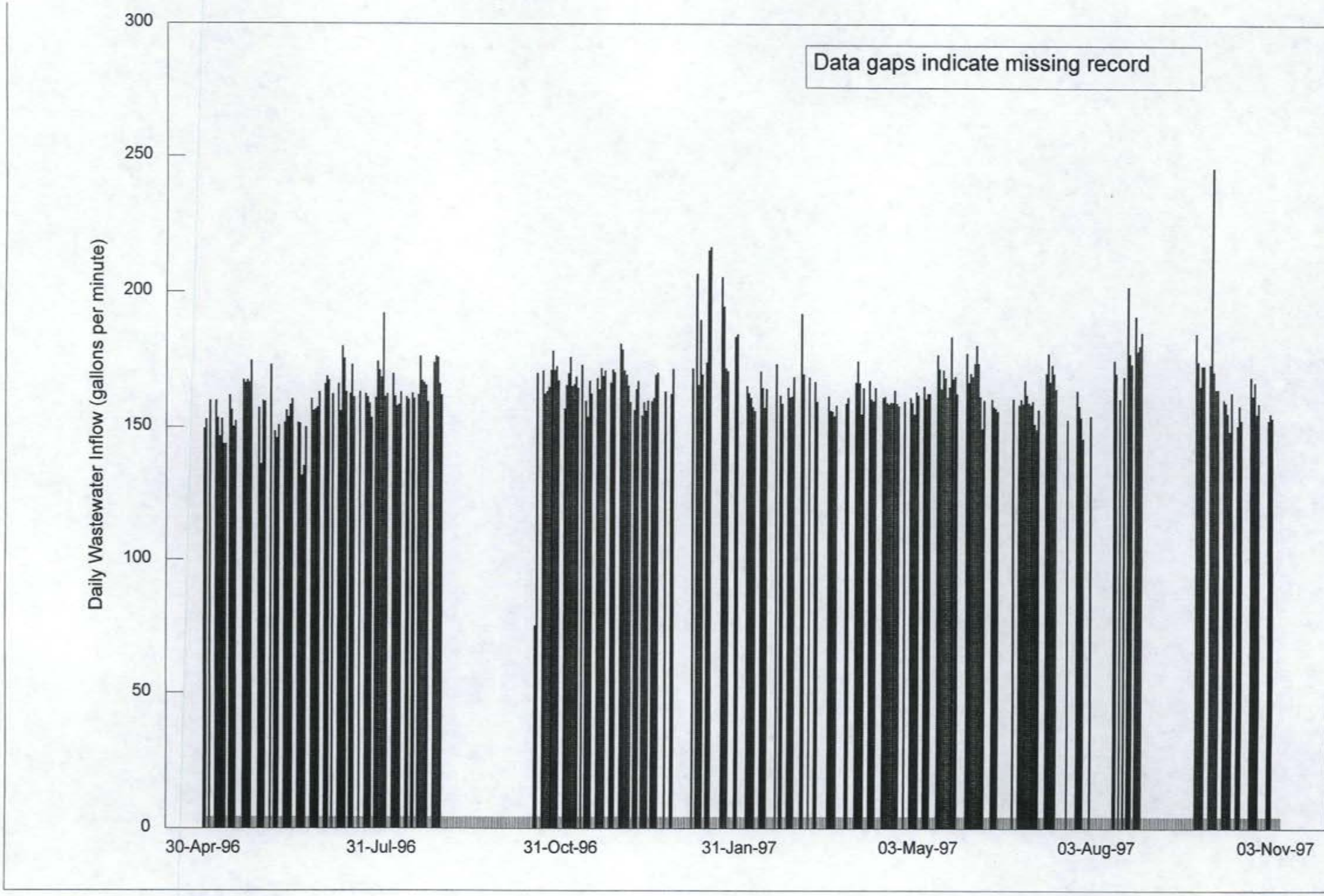


Figure 2-11. Daily Inflow to Superior Municipal Wastewater Treatment Plant during May 1996-October1997

dry. The pumps operated continuously at a rate of about 500 gpm and discharged into ponds where metals are removed by addition of lime, flocculation, and settling (Lira pers. comm.). The ponds have a large surface area, and losses to seepage and evaporation equaled or exceeded the inflow of dewatering water most of the time. When the pond storage capacity was exceeded, excess treated water was discharged into an unnamed ephemeral wash that enters Queen Creek near Mary Drive. Historically, discharges were quite sporadic. Monthly average dewatering discharges during 1978–1998 are shown in Figure 2-12. Although the number of days of discharge in each month was highly variable, the discharge rates were usually about 800-1,000 gpm in months when discharge occurred. Relatively continuous, high rates of discharge occurred in 1989–1990, when dewatering was resumed after a 3-year hiatus. Dewatering was again discontinued indefinitely in May 1998.

Evaporative Demand

Evaporative demand is the driving force that causes ET, which is the consumptive use of water by plants. Reference evapotranspiration (ET_0) is the ET rate of short-cropped, well-watered grass and is used as the basis for comparing ET rates between regions and among different crops and vegetation types. Evaporative demand can be measured directly using Class A standard evaporation pans, one of which has been operated at the Arboretum since the 1920s. ET_0 can be estimated from evaporation-pan data or calculated from hourly meteorological data collected at microclimate stations, such as the ones operated throughout the state by the Arizona Meteorological Network (AZMET). The AZMET stations closest to Superior are in the towns of Queen Creek and Safford. AZMET has prepared contour maps of average monthly ET_0 in Arizona (Arizona Meteorological Network 1998). Monthly ET_0 estimated from the Arboretum evaporation-pan data during 1996–1997 and average monthly AZMET ET_0 for Superior are shown in Appendix B and are similar to each other. Thus, the Arboretum evaporation-pan data can be used to provide a reasonably accurate timeseries of ET_0 data. Average-annual ET_0 for Superior based on AZMET data is 60 inches, and estimated annual ET_0 for the Arboretum in1997 is 59 inches.

Groundwater

Regional Groundwater Management

Superior is located at the far eastern end of the East Salt River Valley subbasin of the Phoenix Active Management Area (AMA). The Phoenix AMA is one of the four (there are now five) original overdrafted groundwater basins established by the Arizona Groundwater Management Code (Code) of 1980, and as such, it is subject to intensive management. The primary management goal of the Phoenix AMA is to achieve safe-yield by 2025 (defined as a long-term balance between the annual amount of groundwater withdrawn in the AMA and the annual amount of natural and artificial recharge). The East Salt River Valley subbasin covers an area of 1,710 square miles east and northeast of Phoenix, including the Cities of Tempe and Mesa. Groundwater pumping began in the late 1800s and peaked in the 1950s at an average annual rate of 2,300,000 af/yr. Groundwater pumping had decreased to only 305,000 af/yr in 1990, but cumulative overdraft during the preceding

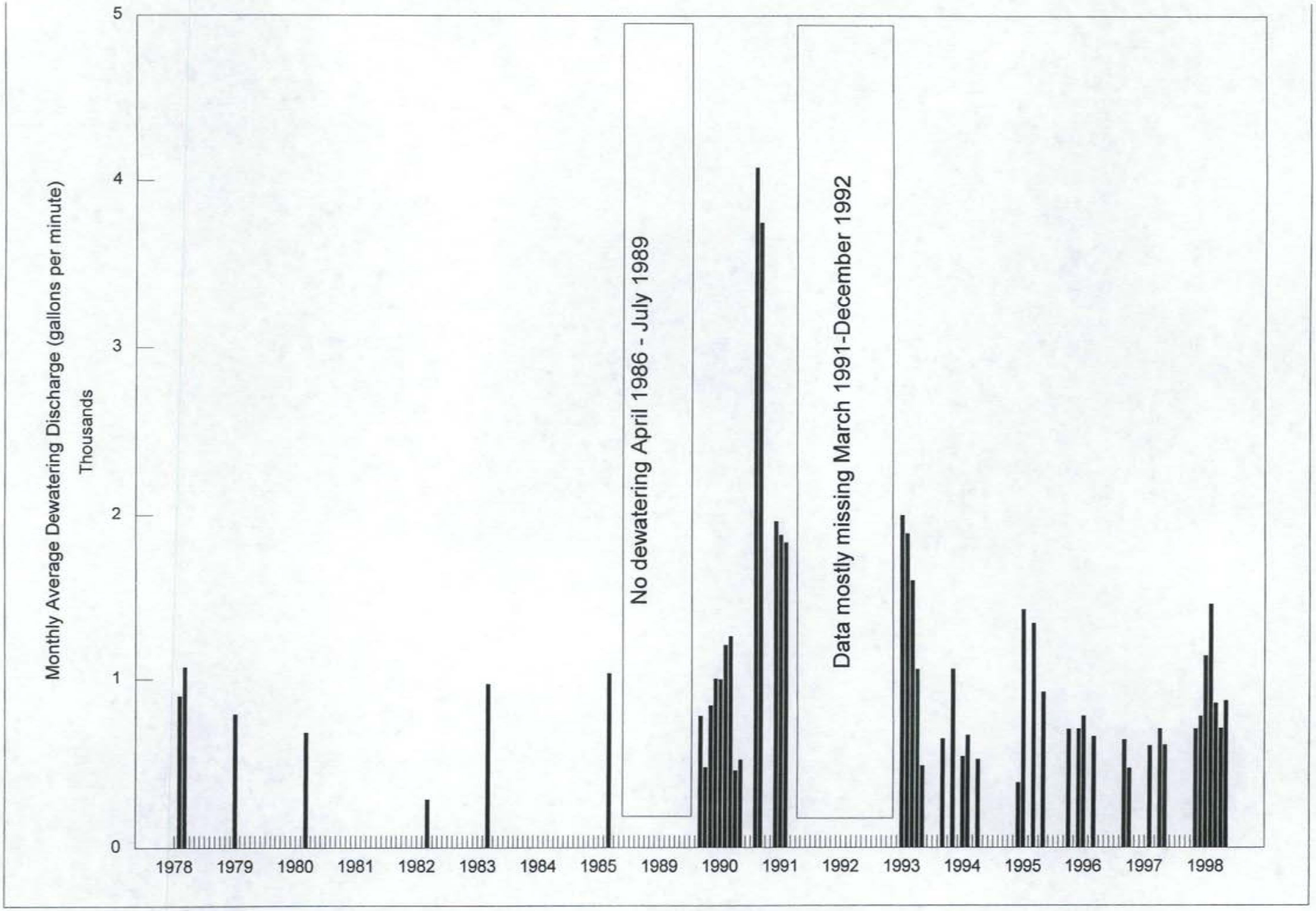


Figure 2-12. Discharge Rate from BHP Treatment Ponds for Dewatering Water during 1978-1998.

century had lowered groundwater levels by 350-400 feet in some areas. Overdraft also caused land subsidence of up to 5 feet in the western part of the East Salt River Valley (Arizona Department of Water Resources 1994, Vol. II).

Municipal water suppliers in Active Management Areas have "service area rights" to pump groundwater as needed for residents of their legally defined service area. However, the amount of pumping is subject to state-mandated conservation requirements, and the maximum amount of annual pumping is limited accordingly (Arizona Department of Water Resources 1994, Vol. I).

Local Hydrogeology

Groundwater in the vicinity of Superior appears to be divided functionally into shallow and deep-flow systems that share a certain amount of interconnection. Information regarding the deep-flow system comes from observations of groundwater flow and levels in the mine workings, and information regarding the shallow system comes from domestic water wells and flow gains and losses in Queen Creek.

Apache Leap consists of a highly fractured dacite tuff. It is underlain by Paleozoic carbonate deposits that form conspicuous tilted bedrock strata in the lower part of the Queen Creek canyon immediately upstream of Superior (Anderson pers. comm.). The fractures in the tuff allow a small amount of rainfall infiltration. Under predevelopment conditions, infiltrated water would percolate through the bluff and gradually emerge as base flow in springs and Queen Creek. A spring near U.S. Highway 60 at the top of the bluff still responds noticeably to rainfall. The extensive network of tunnels and shafts in the Magma Mine intercept part of the natural groundwater flow. Dewatering pumps at the bottom of the mine—4,100 feet below the ground surface—removed groundwater that infiltrated into the mine and discharged it into large treatment ponds, where most of the water was lost to evaporation and seepage. Because of the dewatering pumping, the effective depth to water in the deep groundwater system near the mine was about 4,100 feet. The dewatering rate commonly increased from its usual rate of about 500 gpm to as much as 800 gpm for several weeks following large rainstorms (Lira pers. comm.), which confirms that the deep groundwater system is at least partially connected to the shallow system.

West of Apache Leap, the older sediments are overlain by the Gila Formation, which is a mixture of sedimentary rocks ranging from a hard, uniform sandstone to a conglomerate containing large boulders in a sand matrix. Because domestic wells in Superior are able to produce water from relatively shallow depths (<300 feet), there clearly is a shallow groundwater system associated with the Gila Formation. Because of its variable texture and degree of cementation, the primary permeability of the Gila Formation is probably quite variable but generally low. This level of permeability is consistent with the reportedly low yields of domestic wells that are completed in the formation (Anderson pers. comm., Zapata pers. comm.). Water levels in two wells at the south edge of town and one well northeast of the Arboretum (Figure 2-3) were measured in conjunction with a landfill investigation (Lomas pers. comm.). The wells are 200-300 feet deep, and a single set of measurements is available from November 1992. Although the water table varied substantially in depth below the ground surface (47-95 feet) and elevation above sea level (2,473-2,625 feet), it was within a few feet of adjacent creekbed elevation for all three wells, even though the wells are located

1,800-2,700 feet from the creek. These observations suggest that the water table is fairly flat and slopes westward at the same gradient as the creekbed, and that the shallow groundwater system is hydraulically connected with the creek along most of its length.

Wherever the water table is lower than the level of the creekbed, Queen Creek will tend to lose flow to seepage. Conversely, the creek may gain flow along reaches where the adjacent water table is higher than the creekbed. The lack of pronounced flow losses along Reaches 2 and 5 during periods of continuous low flow in spring 1998 indicates either that sediments immediately underlying the streambed along these reaches are relatively impermeable or that the shallow groundwater system had filled to capacity and was rejecting further recharge after prolonged winter flows. Subsurface flow is often present at the Arboretum, where the main irrigation well, a shallow infiltration gallery located on the bank of the creek, continues to produce water after surface streamflow has ceased (Dion pers. comm.).

An abrupt transition in geology between Reach 2 and Reach 3 is marked by a change in vegetation that is probably associated with a change in water-table depth and seepage loss rate. Reach 3 and the upper part of Reach 4 are located in a broad, low area between bluffs of the Gila Formation. Several tributary washes enter Queen Creek in this area, and the relatively flat floodplain between the bluffs appears to consist of unconsolidated alluvium deposited by the streams. The alluvium is sandy at the surface and probably consistently more permeable than the Gila Formation. Small amounts of base flow that do not percolate rapidly into the Gila Formation along Reach 2 are suddenly able to percolate rapidly, presumably resulting in high seepage loss rates. The highly permeable alluvium also allows groundwater to flow rapidly downvalley to the next low-permeability obstruction, the bluff on which the WWTP is located. The water table in the alluvium is probably relatively flat, while the land surface and creekbed slope substantially down the valley. This slope would result in a deeper water table at the upstream end of the alluvium (near the Highway 60 bridge) than at the downstream end. The distribution of vegetation along the alluvium supports this hypothesis. The upstream two-thirds of the alluvial area (most of Reach 3) is covered somewhat sparsely with mesquite. Broadleaf phreatophytic riparian vegetation, such as willows and cottonwoods, are absent. Near the lower end of Reach 3, the first tamarisk plants appear, and by the middle of Reach 4 the creek banks support a dense mixture of tamarisk and cottonwood.

WATER SUPPLY AND DEMAND

The mine obtained all of its process water from the discharge of the mine dewatering pumps. Potable water for domestic and office needs of the onsite mine employees is obtained from freshwater inflow to the Neversweat Tunnel, which is the main tunnel connecting the western and eastern mine workings. Total inflow averages about 150 gpm, of which about 50 gpm has historically been diverted for potable supply in the mine buildings. BHP owned four water wells near Florence Junction, 23 miles west of Superior, but sold two of them in the 1980s. BHP occasionally bought potable water from Superior (Lira pers. comm.).

The Arizona Water Company (AWC) provides service for Superior's municipal water customers from wells near Florence Junction. AWC participates in the gallons per capita per day

(GPCD) program, which establishes a maximum GPCD based on a 3-year running average of municipal water use. The total amount withdrawn from AWC wells for use in Superior for the year 1999 was 488.8 af/yr. (Pogorzelski pers. comm.). At this time, the Town of Superior has no water rights; however, the Town has applied for a Central Arizona Project (CAP) allocation of 271 af/yr. Approval for this allocation is pending (Zapata pers. comm.). Approximately 25 residents have domestic wells, but yields are typically low (Zapata pers. comm.). The WWTP discharges water at a fairly constant rate of about 240,000 gpd. Over the course of a year, total wastewater discharge is about 270 af, or about 55% of total annual municipal water use.

The Arboretum used an average of 12.9 million gallons (40 af) per year for irrigation during 1986–1994. Records of weekly pumping amounts are available (see Appendix B). Water use is substantial in all months but is greatest in months with low rainfall and relatively high ET demand. In any given year, pumping fluctuates substantially in response to the influence of weather on ET demand.

Until 1998, all irrigation water at the Arboretum was obtained from the Canyon Well, which is an underground vault that functions as an infiltration gallery on the north bank of Queen Creek at the western end of the developed part of the Arboretum (at the stream gage and footbridge). Water is pumped from the vault into Ayer Lake, from which it is pumped into the irrigation distribution system. In summer, demand exceeds the rate at which the well can obtain water from the creek (surface or subsurface flow), and the lake level progressively declines. During these periods, the pump empties the vault as soon as it fills and intercepts virtually all subsurface flow associated with the creek.

The yield of the Canyon Well is considered slightly inadequate for existing irrigation demand and clearly insufficient to meet increased demands associated with future expansion of the Arboretum plantings. In 1997, a new well was drilled adjacent to the creek channel near the confluence of Arnett Creek and Queen Creek at the western end of the Arboretum. Pumping from this well commenced in 1998. Water supplied from the new well is slightly more expensive than water from the Canyon Well because it must be pumped further uphill to the point of use. Consequently, it has been used only sparingly to supplement the Canyon Well. As irrigation demand increases, use of the new well will increase commensurately. Arboretum has obtained water-rights permits from the Phoenix AMA for up to 112 af/yr of groundwater pumping.

Potable water at the Arboretum is supplied by a connection to the pipeline that delivers municipal water to Superior from wells near Florence Junction.

WATER QUALITY

The only available routine measurements of water quality in Queen Creek are weekly measurements of electrical conductivity at the Arboretum. Conductivity is a general indication of the total concentration of dissolved minerals in the water, which typically consist primarily of calcium, magnesium, sodium, bicarbonate, and chloride. Data for 1994 indicate that conductivity fluctuated widely and frequently over a range from 550 to 1,200 micromhos per centimeter (μmho/cm) (see Appendix B). This conductivity range corresponds to a total dissolved-solids concentration of 360-780 milligrams per liter (mg/l). For comparison, the maximum recommended dissolved-solids concentration for long-term consumption under federal drinking water standards is 500 mg/l (California Department of Water Resources 1993). Arboretum staff reported that conductivity increases noticeably when BHP discharges dewatering water from the storage ponds (Dion pers. comm.). The variations in conductivity during 1994, however, do not conform to this pattern. The only pronounced increase in conductivity was in September, and there were no BHP discharges between April and December.

The electrical conductivity of Queen Creek was measured at several locations on March 4, 1998, in conjunction with streamflow measurements using the salt-dilution method. A longitudinal profile of conductivity (see Appendix B) shows that conductivity increased steadily from 101 μmho/cm upstream of the Magma Avenue bridge to 540 μmho/cm at the U.S. Highway 60 bridge. There are no known discharges along this reach. Some of the increase in conductivity could be the result of streamflow depletion by evaporation, because the approximately fivefold increase in conductivity was accompanied by a fourfold decrease in flow. Conductivity increased substantially (to 2,200 μmho/cm) at site 8, which is downstream of the BHP discharge point and upstream of the WWTP discharge point (Figure 2-3). BHP discharged dewatering water on 9 days in March 1998, and some of the increase in measured conductivity could be the result of a concurrent or recent BHP discharge.

Selected water-quality constituents are measured in the effluent from the WWTP. The constituents include 11 metals, total suspended solids, and several nitrogen compounds (Real pers. comm.). In samples collected on July 6, 1998, the metal concentrations were all below the detection limits, the concentration of total suspended solids was 180 mg/l, and the concentration of nitrate was 10 mg/l (as nitrogen). The nitrate concentration coincidentally equaled the maximum concentration allowed in drinking water under state and federal regulations. Unfortunately, the electrical conductivity of the effluent is not routinely measured.

Water quality in Queen Creek immediately above and below the BHP dewatering water-discharge point is sampled annually as a condition of BHP's NPDES permit. In 1997, sampling was done on May 7 at a time when the only flow in the creek at the discharge location was from the discharge itself (Cadmus Group 1997). Thus, the reported water quality characterizes the discharge. The electrical conductivity was 2,860 μmho/cm, which corresponds to a dissolved-solids concentration of about 1,860 mg/l. Hardness was extremely high (1,600 mg/l as CaCO3), pH was slightly alkaline (8.0), and the only metal reported above its detection limit was copper (28 grams per liter). This concentration was reported to have negligible toxicity because of the high hardness level of the water.

VEGETATION COMMUNITIES AND WILDLIFE HABITATS

The plan area encompasses a number of vegetation communities that provide value for wildlife, including special-status species known or potentially occurring in the area. Riparian plant associations described by Brown (1982), Szaro (1989), and Myers (1993) were reviewed to classify the riparian communities in the plan area. Szaro's (1989) classifications were the most comprehensive and provided a basis from which to describe communities within the plan area; however, the specific riparian communities occurring along Queen Creek reflect minor differences from those observed in classifications described by Szaro.

The general condition of riparian vegetation along the creek was observed during field reconnaissance in March and May 1998 and June and September 1999, and vegetation communities were mapped onto the aerial photograph as shown in Figure 2-13. The vegetation of the drainages below the BHP settling ponds and the WWTP, where augmented water flows have resulted in the establishment of riparian vegetation, were also mapped and described. In addition, locations of non-native, invasive species populations (e.g., tamarisk, tree of heaven, and giant reed) that could potentially compete with native riparian species within the plan area were mapped. Table 2-3 is a list of plant species observed in the plan area or mentioned in the text.

The value of riparian vegetation communities to wildlife were assessed by conducting breeding-bird point-count surveys in May 1998 and September 1999. Because riparian habitats in the desert southwest are known to provide high-value habitat to a variety of migratory and resident birds, breeding birds were chosen as an indicator of habitat value. Specifically, vegetation associations with greater species diversity or larger populations were used as an indication of potentially higher habitat value. Because the point-count survey was a limited, one-time survey, the results are an indicator of wildlife-habitat associations but are not a statistically robust evaluation of populations or habitat associations of individual species. The results of the survey are presented in detail in Appendix C; the following sections summarize the results for each vegetation community. Habitat attributes that may account for the higher habitat value are also described. Table 2-4 is a list of wildlife observed in the plan area during field surveys or mentioned in the following sections.

Vegetation Categories

Cottonwood–Willow Riparian Woodland

Cottonwood–willow riparian woodland occupies about 26 acres of the plan area in the low floodplain of Queen Creek. Fremont cottonwoods and Gooding's willows are well represented in the canopy. Velvet ash is also present but less common in this community. The understory includes young willows, ash, and seepwillow, and the lush herbaceous layer contains a variety of grasses and forbs, including Bermuda grass, rabbitsfoot grass, deer grass, spikerush, wild rhubarb, and flat sedge. Adjoining high floodplain and terrace areas support dense stands of shrubby velvet mesquite that grade laterally to Sonoran desert scrub. Collectively, these zones form broad, well-developed, structurally diverse riparian woodland. A photograph of these adjoining vegetation types is shown in Figure 2-14.

The cottonwood–willow riparian community is among the richest habitats in the desert southwest for bird diversity and abundance (Rosenberg et al. 1991). One important feature that separates mature cottonwood–willow habitats from other riparian vegetation is their structural

Table 2-3. Plant Species Observed near the Queen Creek Plan Area during Field Reconnaissance Surveys or Mentioned in the Inventory and Assessment of Historical Conditions

Common Name	Scientific Name
Riparian Species	
Arizona black walnut	*Jugllans major*
Arizona rosewood	*Vauquelinia californica*
Arizona sycamore	*Platanus wrightii*
Bermuda grass[a]	*Cynodon dactylon*
Blue palo verde	*Cercidium floridium*
Canyon grape	*Vitis arizonica*
Canyon ragweed	*Ambrosia ambrosioides*
Cattail	*Typha domingensis*
Coyote willow	*Salix exigua*
Creeping barberry	*Berberis repens*
Deer grass	*Muhlenbergia rigens*
Desert broom	*Baccharis sarothroides*
Desert hackberry	*Celtis spinosa* var. *pallida*
Desert honeysuckle	*Anisacanthus thurberi*
Desert mock-orange	*Crossosoma bigelovvii*
Dock species	*Rumex hymenosepalus*
Fremont cottonwood	*Populus fremontii*
Gooding's willow	*Salix gooddingii* var. *varabilis*
Horsetail	*Equisetum* sp.
Netleaf hackberry	*Celtis laevigata*
Oleander[a]	*Nerium oleander*
Rabbitfoot grass[a]	*Polypogon monspeliensis*
Salt cedar[a]	*Tamarix* sp.
Sedge	*Cyperus acuminatus*
Seepwillow	*Baccharis salicifolia*

Table 2-3. Continued.

Common Name	Scientific Name
Spikerush	*Eleocharis* sp.
Tree of heaven[a]	*Ailanthus altissima*
Velvet ash	*Fraxinus velutina*
Velvet mesquite	*Prosopis velutina*
Sonoran Desert Species	
Arizona hedgehog cactus[b, c]	*Echinocereus triglochidiatus arizonicus*
Barrel cactus	*Ferocactus wislizenii*
Brittlebush	*Encelia farinosa*
Broom snakeweed	*Gutierrezia sarothrae*
Catclaw acacia	*Acacia greggii*
Cockleburr[a]	*Xanthium strumarium*
Creosote bush	*Larrea tridentata*
Cudweed sagewort	*Artemisia ludoviciana*
Desert agave	*Agave deserti*
Desert broom	*Baccharis sarothroides*
Engelmann prickly pear	*Opuntia engelmannii*
Fairy duster	*Calliandra eriophylla*
Foothill palo verde	*Cercidium microphyllum*
Globe mallow	*Sphaeralcea* sp.
Hohokum agave[b, c]	*Agave murpheyi*
Jojoba	*Simmondsia chinensis*
Jumping cholla	*Opuntia fulgida*
Ocotillo	*Fouquieria splendens*
Russian thistle[a]	*Salsola iberica*
Saguaro	*Carnegiea gigantea*

Table 2-3. Continued.

Common Name	Scientific Name
Saltbush	*Atriplex polycarpa*
Thistle[a]	*Cirsium* sp.
Triangleleaf bursage	*Ambrosia deltoidea*
Banana yucca	*Yucca baccata*
Varied fishhook cactus[b, c]	*Mammillaria viridiflora*

a Introduced species.
b Special-status species (see Table 2-5).
c Not observed.

Table 2-4. Wildlife Species observed near Queen Creek during Field Reconnaissance Surveys, or mentioned in the Inventory and Assessment of Historical Conditions

Common Name	Scientific Name
Fish	
Desert pupfish[a,b]	*Cyprinodon macularius macularius*
Gila topminnow[a,b]	*Poeciliopsis occidentalis occidentalis*
Reptiles	
Fence lizard	*Sceloporus sp.*
Long-nosed leopard lizard[a,b]	*Gambelia wiselezenii*
Lowland leopard frog[a,b]	*Rana yavapaiensis*
Sonoran desert tortoise[a,b]	*Gopherus agassizii*
Birds	
Turkey vulture	*Cathartes aura*
Red-tailed hawk	*Buteo jamaicensis*
Gambel's quail	*Callipepla gambelii*
Killdeer	*Charadrius vociferus*
Rock dove	*Columba livia*
White-winged dove	*Zenaida asiatica*
Mourning dove	*Zenaida macroura*
Inca dove	*Columbina inca*
Greater roadrunner	*Geococcyx californianus*
Great horned owl	*Bubo virginianus*
Vaux's swift	*Chaetura vauxi*
White-throated swift	*Aeronautes saxatalis*
Black-chinned hummingbird	*Archilochus alexandri*
Anna's hummingbird	*Calypte anna*
Costa's hummingbird	*Calypte costae*
Gila woodpecker	*Melanerpes uropygialis*
Ladder-backed woodpecker	*Picoides scalaris*
Black phoebe	*Sayornis nigricans*
Say's phoebe	*Sayornis saya*
Vermillion flycatcher	*Pyrocephalus rubinus*
Ash-throated flycatcher	*Myiarchus cinerascens*
Western kingbird	*Tyrannus verticalis*
Violet-green swallow	*Tachycineta thalassina*
Northern Rough-winged swallow	*Stelgidopteryx serripennis*

Table 2-4. Continued

Common Name	Scientific Name
Birds (continued)	
Verdin	*Auriparus flaviceps*
Cactus wren	*Campylorhynchus brunneicapillus*
Rock wren	*Salpinctes obsoletus*
Canyon wren	*Catherpes mexicanus*
Bewick's wren	*thryomanes bewickii*
House wren	*Troglopdytes aedon*
Ruby-crowned kinglet	*Regulus calendula*
Black-tailed gnatcatcher	*Polioptila melanura*
Northern mockingbird	*Mimus polyglottos*
Curve-billed thrasher	*Toxostoma curvirostre*
Phainopepla	*Phainopepla nitens*
European starling	*Sturnus vulgaris*
Bell's vireo	*Vireo bellii*
Lucy's warbler	*Vermivora luciae*
Yellow warbler	*Dendroica petechia*
Yellow-rumped warbler	*Dendroica coronata*
Black-throated gray warbler	*Dendroica nigrescens*
Yellow-breasted chat	*Icteria virens*
Summer tanager	*Piranga rubra*
Northern cardinal	*Cardinalis cardinalis*
Pyrrhuloxia	*Cardinalis sinuatus*
Blue grosbeak	*Guiraca caerulea*
Abert's towhee	*Pipilo aberti*
Spotted towhee	*Pipilo erythrophthalmus*
Canyon towhee	*Pipilo fuscus*
Song sparrow	*Melospiza melodia*
Lincoln's sparrow	*Melospiza lincolnii*
White-crowned sparrow	*Zonotrichia leucophyrs*
Dark-eyed junco	*Junco hyemalis*
Great-tailed grackle	*Quiscalus mexicanus*
Bronzed cowbird	*Molothrus aeneus*
Brown-headed cowbird	*Molothrus ater*
Northern oriole	*Icterus galbula*
Hooded oriole	*Icetrus cucullatus*
House finch	*Carpodacus mexicanus*
Lesser goldfinch	*Carduelis psaltria*
House sparrow	*Passer domesticus*

Table 2-4. Continued

Common Name	Scientific Name
Mammals	
Beechey ground-squirrel	*Spermophilus beecheyi*
Desert cottontail	*Sylvilagus audubonii*
Black-tailed jackrabbit	*Lepus californicus*
Raccoon	*Procyon lotor*
Gray fox	*Urocyon cineroargenteus*
Stripped skunk	*Mephitis mephitis*
Javelina	*Tayassu tajaca sonoriensis*

[a] Special-status species (see Table 4).
[b] Not observed.

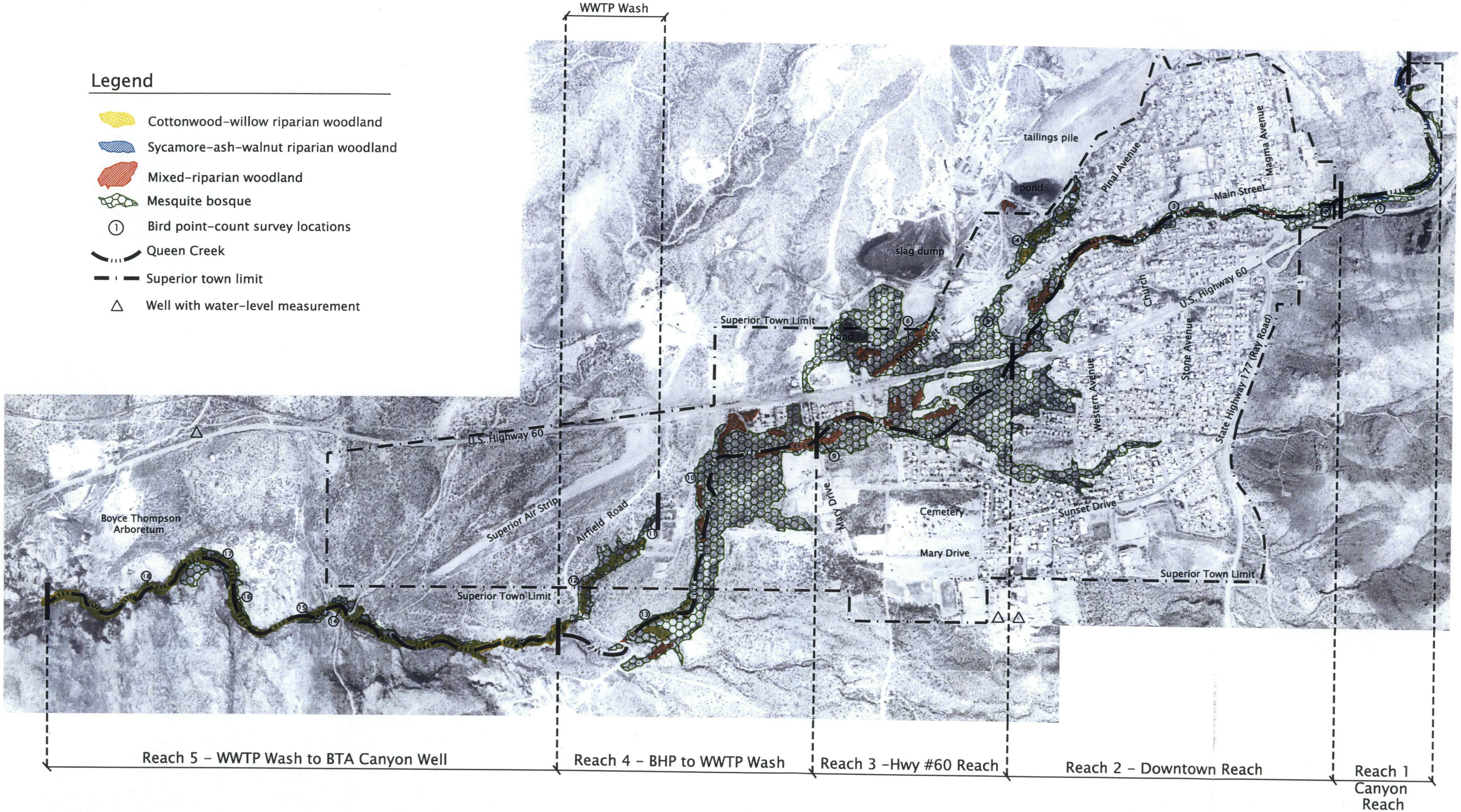


Figure 2-13.

Map of Vegetation along Queen Creek

Town of Superior Queen Creek Restoration and Management Plan

Jones & Stokes Associates
340 East Palm Lane No. A275
Phoenix, AZ 85004

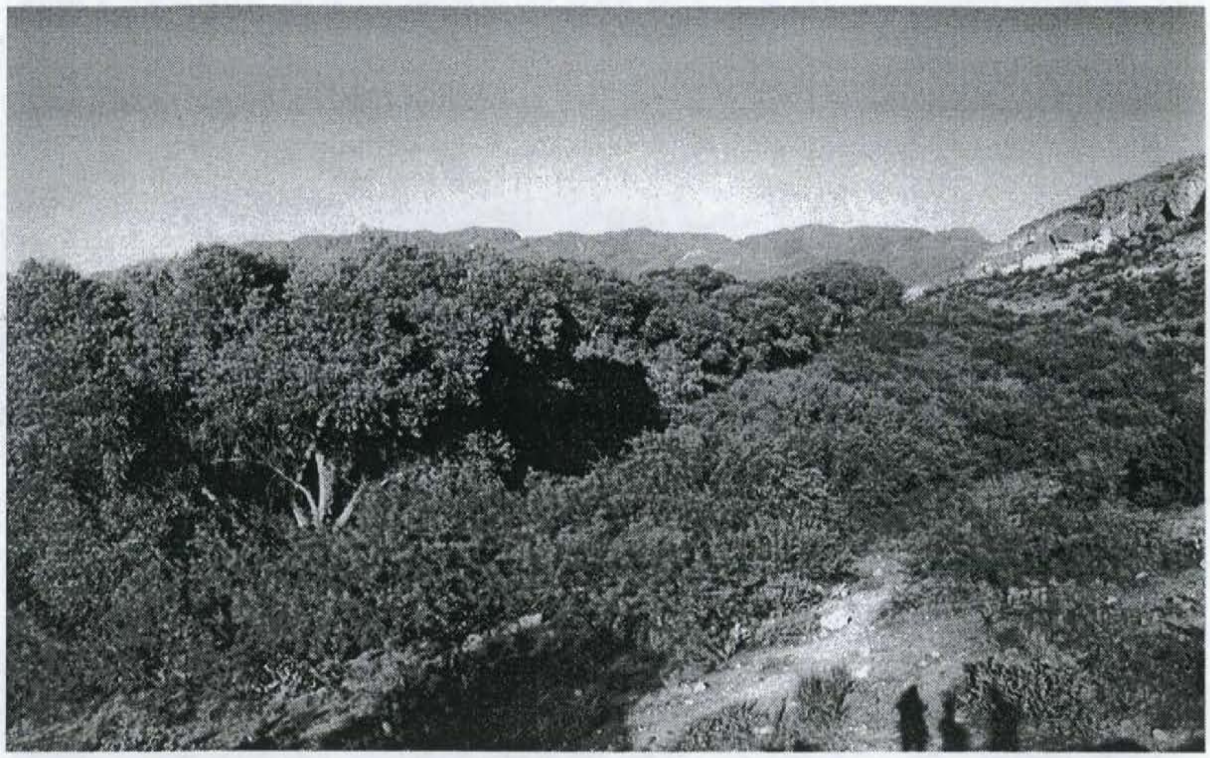


Figure 2-14. Cottonwood/Willow Riparian Forest and Adjacent Sonoran Desert Scrub in Reach 5.

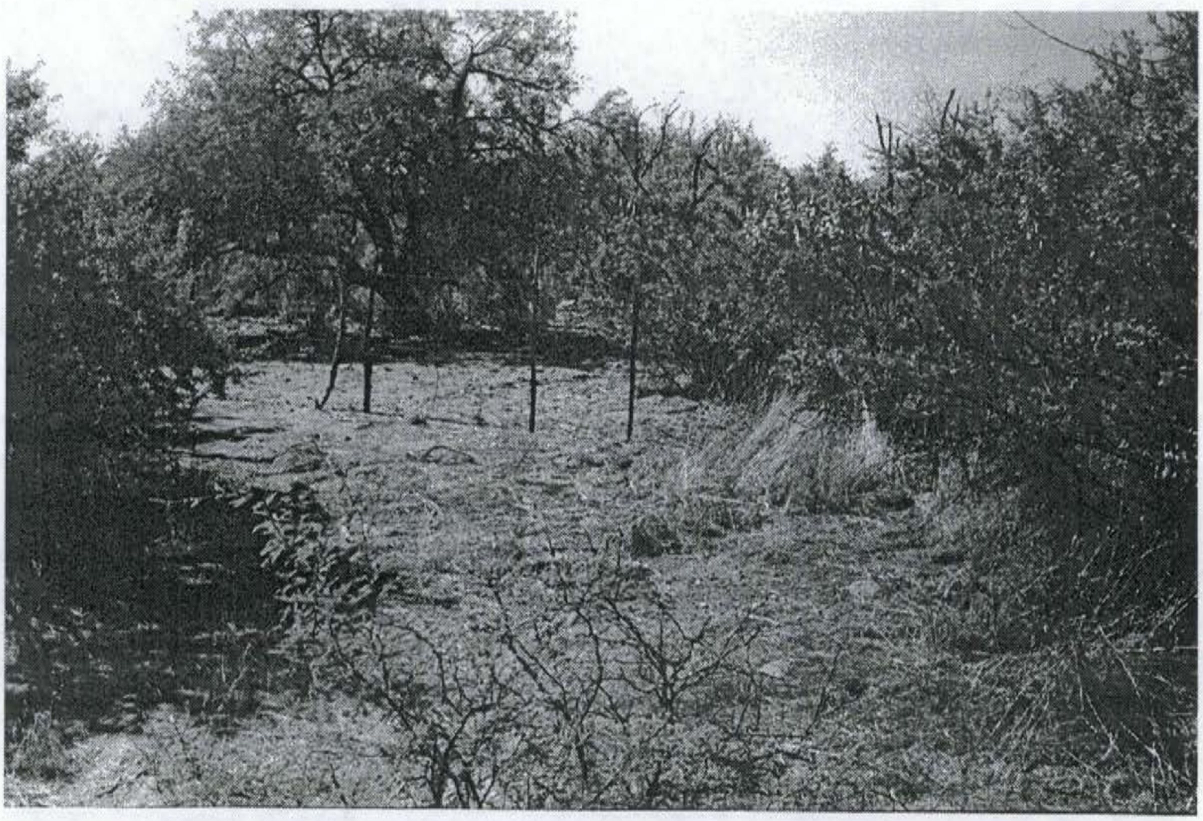


Figure 2-15. Mesquite Bosque on the Queen Creek Floodplain in Reach 3.

complexity (Rosenberg et al. 1991). Cottonwoods and willows typically grow to be the tallest trees in creek or river valleys, forming a strip of green vegetation within an extremely dry landscape. Mature stands, with trees often over 70 feet tall, provide both vertical and horizontal foliage layers that are absent in most of the other valley habitats (Rosenberg et al. 1991), and birds that breed or winter in the Arizona desert riparian habitats prefer tall willows and cottonwoods over shorter, shrubby, or open vegetation patches. Areas with perennial water flow are particularly valuable habitat within this arid landscape because they provide a drinking-water source, provide shade and cover, and support numerous insects and other invertebrates, which are prey for wildlife.

Breeding-bird point-count surveys conducted in May 1998 at Queen Creek indicate that cottonwood–willow riparian habitat supported a slightly greater species diversity than mixed riparian and velvet mesquite communities (Appendix C). Birds occurring in cottonwood–willow riparian habitat during the surveys included summer resident, riparian-associated species, as well as migrants. Yellow-breasted chats, Bell's vireos, and Lucy's and yellow warblers were common in this riparian habitat. Song sparrow, summer tanager, vermilion flycatcher, and northern oriole also were present but in lower numbers. These occurrences are consistent with the general bird-habitat relationships reported by Rosenberg et al. (1991) for the Colorado River Valley.

The vertical structure of riparian vegetation formed by cottonwoods and willows appears to be important for canopy nesting wildlife, such as yellow warbler, summer tanager, and northern oriole. These species are largely restricted to areas with tall cottonwoods and willows. Yellow warblers also were observed in small or structurally uncomplex riparian patches, as long as a tall cottonwood or willow was present. Signs of raccoon, striped skunk, and gray fox were observed in this habitat, and a number of other mammals, snakes, and lizards are also expected to occur here. Local residents have also reported common sightings of javelina (i.e., wild pig) (Chavez pers. comm.).

Sycamore–Ash–Walnut Riparian Woodland

Sycamore–ash–walnut riparian woodland is the main vegetation community along Queen Creek at the upper end of Reach 1 and continuing further up into the Canyon. As a result of the steep slopes characteristic of the canyon, the Arizona sycamore, velvet ash, and Arizona walnut trees form a narrow corridor along the creek channel. The adjoining upland slopes are vegetated with velvet mesquite, jojoba, and acacia. The structure of the woodland habitat is much less layered than the cottonwood–willow community and features a relatively open canopy, large leaves, and a sparse understory layer. Herbaceous species such as seepwillow, Arizona ragweed, and Arizona grape occupy the sparse understory of the sycamore–ash–walnut riparian woodland.

The canopy structure of this habitat is much more open. The scattered groupings of large sycamore, walnut, and ash trees probably occur where groundwater is closer to the surface and spaces between the boulders have enabled stoloniferous (stem-supporting and root-supporting) reproduction. There are very few willow, cottonwood, or salt-cedar trees in the canyon area, possibly because these species use seed dispersal as their dominant reproduction method, and seedlings are more prone to mortality by scour in the canyon during spring and summer floods (Brown 1991).

Although no point-count bird censuses were done in the upper part of Reach 1, this vegetation type is expected to provide habitat for the same suite of bird species found in the cottonwood-willow riparian forests further downstream. These species include riparian-canopy dwellers such as summer tanager, yellow warbler, and yellow-billed cuckoo as well as raptors such as the red-tailed and Harris hawk who may prefer the cliff habitats. Other wildlife species associated with this habitat are bats (*Myotis* sp.), the Arizona gray squirrel, and javelina.

Mixed-Riparian Woodland

Mixed-riparian woodland occupies about 14 acres at various locations along Queen Creek. The canopy of the mixed riparian community is typically a sparse mixture of Fremont cottonwood, Gooding's willow, velvet ash, and/or velvet mesquite. The understory includes young seepwillow, and the herbaceous layer is absent in this community. Mesquite, netleaf hackberry, and palo verde occur on the high floodplain and adjacent terrace areas. This community appears to occupy areas were water availability limits the development of dense stands of obligate riparian species and an herbaceous layer as in the cottonwood–willow community. Therefore, obligate riparian species, such as willows and cottonwoods, occur sporadically in areas where sediments have accumulated and soil moisture is more available, such as in the creek bottom and lower floodplain, where germination and growth of these species can be supported.

During the breeding-bird point-count surveys conducted in May 1998, commonly observed mixed riparian associated species were Lucy's and yellow warbler, yellow-breasted chat, and Bell's vireo. White-winged doves, house sparrows, and northern cardinal also were common. A variety of mammals, including desert cottontail, occur in this habitat along with an assortment of lizards and snakes.

Mesquite Bosque

Mesquite bosques are open woodlands dominated by velvet mesquite, and they often contain a scrub understory of salt bush, hackberry, and other species. Mesquite bosques occupy about 199 acres along Queen Creek and occur in areas that have greater water availability than in upland areas but where the water table is too deep or streamflow is too intermittent to support cottonwood–willow and mixed-riparian communities. Mesquite is a facultative phreatophyte, and the height and density of mesquite shrubs is inversely correlated with depth to the water table. In areas mapped as mesquite bosque in Figure 2-13, the mesquite plants are distinctly larger and have a denser canopy than in surrounding upland areas. In several groves along Reach 5, the mesquite plants are large enough to be considered trees because they have single trunks and canopies that reach heights of about 30 feet. Typical mesquite bosque along Reach 3 is shown in Figure 2-15.

Next to cottonwood–willow and mixed-riparian habitat, mesquite bosque habitats in Arizona have been found to be the most important habitat for abundance and variety of birds (Rosenberg et al. 1991). Mesquite bosques generally dominate the upper floodplains and adjacent terraces. These areas often support resident populations of curve-billed thrashers, cactus wrens, verdins, and black-tailed gnatcatchers. High densities of Lucy's warbler can be found in mesquite-bosque habitat during the breeding season (Rosenberg et al. 1991). In winter, mistletoe, which parasitizes mesquite, produces an abundance of berries that attracts large numbers of phainopeplas, cedar waxwings, American robins, western and mountain bluebirds, and northern mockingbirds. The presence of saltbush and other seed-producing shrubs that occur in association with mesquite provide foraging habitat and cover for a number of wintering sparrows and resident quail and towhees.

During the breeding-bird point-count surveys conducted in May 1998, mesquite-bosque habitats were found to support high densities of certain summer-resident, riparian-associated species, including migratory yellow-breasted chat and Lucy's warbler. Mesquite-bosque habitats also supported a high density of resident phainopeplas and resident populations of white-winged and mourning doves, curve-billed thrashers, cactus wrens, verdins, northern cardinals, and house sparrows. Desert cottontails, black-tailed jack rabbits, and fence lizards were observed in the mesquite-bosque habitat. A variety of other mammals, lizards, and snakes also commonly inhabit mesquite bosque.

Sonoran Desert Scrub

Except for the bare cliffs of Apache Leap and the riparian vegetation along Queen Creek, the Queen Creek watershed is covered with Sonoran desert scrub vegetation typical of high desert areas in central Arizona. This plant community is characterized by open-desert scrub on sloped landforms dotted with occasional cacti. Shallow-to-steep slopes rising from the creek are too high above the water table to support riparian plants, which cannot survive on rainfall alone. The plants most commonly found in the Sonoran community include catclaw, yucca, creosote, ocotilla, and foothill palo verde. Some of the cacti interspersed within these plants are cholla, barrel cactus, and saguaro.

Wildlife occurring in this habitat include rock, cactus, and canyon wrens, verdins, gnatcatchers, and white-winged and mourning doves.

Invasive Exotic Vegetation

Field reconnaissance observations from May–June 1998 demonstrated a need for exotic-plant management in several areas of the creek corridor. Invasive exotic species that have been noted include tamarisk (salt cedar), ailanthus (Chinese tree-of-heaven), and arundo. Domestic landscape migrants, such as oleander, were also observed, but at that time did not appear invasive. When field reconnaissance was continued in summer 1999, it became apparent that exotic plants are more widespread than was initially apparent in 1998. Common invasive plants at the arboretum also include Chinese pistachio, African sumac, and Chinese date palm (Petrie pers. comm.).

Ailanthus

Ailanthus (Chinese tree-of-heaven) appears to have increased in population along Reach 2 between June 1998 and June 1999 and is now very common. It is also present at lower densities in Reaches 3-5. Ailanthus seedlings surrounding a dead cottonwood sapling are shown in Figure 2-16. This species should be a priority for managed removal in the downtown area.

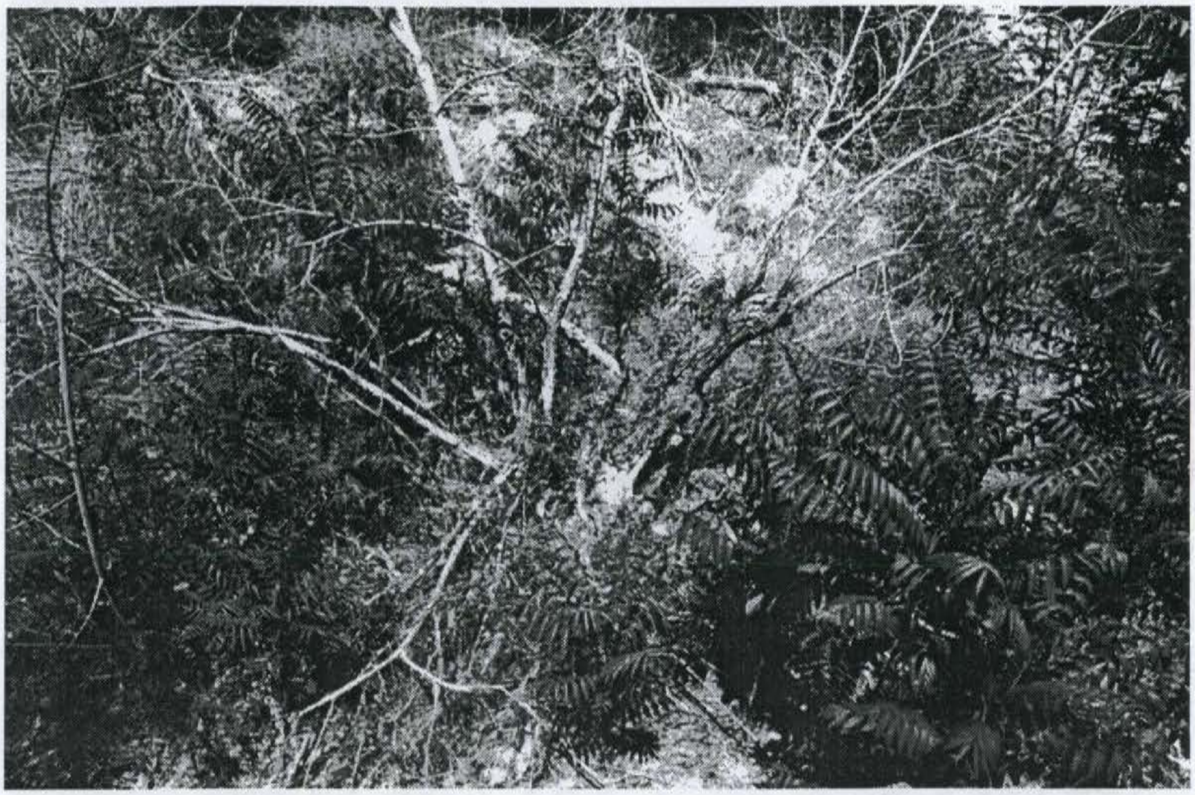


Figure 2-16. Tree of Heaven Seedlings around a Drought-Killed Cottonwood.

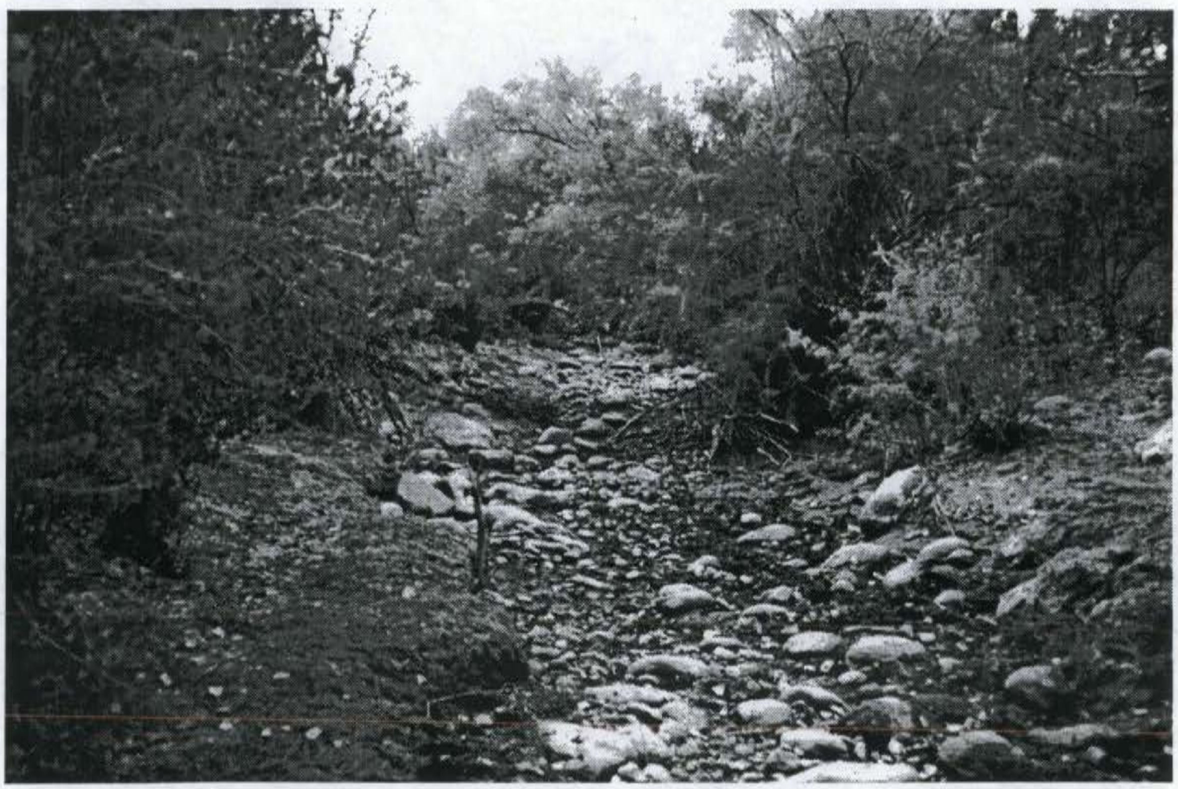


Figure 2-17. Young Cottonwoods Competing with Tamarisk in Reach 4.

Tamarisk

Tamarisk appears in the creek corridor mixed with mesquite-bosque habitat and the mixed-riparian communities in Reaches 2-5. Tamarisk seedlings are moderately common along the lower part of Reach 2. A large, dense stand of tamarisk is present in Magma Wash 1 near the upper dewatering water-storage ponds. Conditions along the channel in the upper part of Reach 3 appear to be too xeric to support tamarisk, but it begins to reappear 0.2 mile above Mary Drive. It is abundant from the Mary Drive location to the lower end of Reach 4 and clearly is competing with cottonwood–willow habitat, as shown in Figure 2-17. The shade created by the existing tree canopy along most of Reach 5 and the presence of nearly perennial streamflow favors cottonwood–willow vegetation over tamarisk, but the tamarisk is still present in scattered locations.

Arundo

Arundo appears in only two downtown locations. These existing clumps could increase and should be managed.

Oleander

Oleander is an ornamental plant that has begun establishing itself in the creek channel along Reach 2. Although it is not as common as tamarisk or tree-of-heaven, its population appears to be increasing. In addition to having poisonous sap, it competes with native riparian vegetation communities and should be targeted for removal.

Existing Vegetation Distribution

The plan area has been divided into reaches for analysis and planning purposes. Vegetation along each of the plan area reaches is described below and generally reflects differences in substrate and flow regime. The general plant associations and vegetative structure are shown in a series of three representative cross sections along the Queen Creek plan area.

Reach 1 of Queen Creek

In the canyon upstream of the Magma Club (Reach 1), the riparian plant community is sparse, consisting primarily of scattered Arizona sycamore, Arizona walnut, and velvet ash along the edge of the low-flow channel; and on the higher floodplain and terraces, velvet mesquite, netleaf hackberry, palo verde, and Sonoran desert scrub. The substrate in the stream channel is bedrock or boulders, with only occasional pockets of sand and gravel. The lack of vegetation in the channel probably results from scouring floodflows along this confined reach, lack of year-round flow, and a water table that is too deep in most locations to foster establishment of dense riparian vegetation. The sycamore, walnut, and velvet ash trees occur sporadically in areas where sediments have accumulated and soil moisture is available, or where subsurface flow obstructions cause groundwater to back up and rise to near the land surface. Subsurface baseflow or shallow groundwater through this reach during the summer months probably sustains established trees.

Reach 2 of Queen Creek

Mixed-riparian woodland and mesquite bosque occur in Reach 2. The mixed-riparian woodland occurs in a patchy distribution. Bedrock of the Gila Formation is exposed or at shallow depth along the upper part of Reach 2 between Magma Avenue and the Lobb Avenue footbridge. This hard substrate and the limited soil moisture capacity of the thin veneer of stream sediments and soil have prevented trees from becoming established except in isolated pockets of higher-quality substrate. Many of the individual cottonwood, willow, and ash trees in this reach also show moisture stress, as shown in Figure 2-18. The riparian canopy, composed primarily of Fremont cottonwood, is not continuous. The open understory in this reach of the creek is composed predominantly of seepwillow, desert broom, netleaf hackberry, and mesquite. The general character of the channel and vegetation is represented in Figure 2-19.

In ideal conditions, cottonwoods can grow to about 80 feet tall and contain broad, open canopies. However, in this reach mature trees average 30-40 feet tall and have smaller canopies. In addition, velvet ash and Gooding's willow trees in this reach are generally between 15-30 feet tall, which is smaller than typical trees of these species. The small stature suggests that the trees are frequently exposed to drought stress. Regeneration of riparian trees is also limited throughout this reach, which suggests that conditions have generally become more xeric since the mature trees became established. Rainfall is not known to have changed, so that the most likely cause of decreased moisture available is decreased streamflow, underflow, or groundwater levels.

Reach 3 of Queen Creek

Riparian vegetation transitions abruptly from mixed riparian woodland to a shrubby mesquite bosque at the top of Reach 3, where Queen Creek flows under the Highway 60 bridge and enters a relatively broad, flat floodplain consisting of unconsolidated alluvial deposits. The relatively high permeability of the alluvial deposits appears to result in a deep water table in the upper part of Reach 3, which would explain why tamarisk and broadleaf riparian vegetation is absent in that area. Willows and tamarisk begin reappearing near the lower end of the reach, where the water table is thought to be shallower.

Reach 4 of Queen Creek

The mesquite bosque in Reach 3 continues into Reach 4, following the Queen Creek floodplain down to Airfield Road (Figure 2-13). In the upper portion of Reach 4, the bosque is wide, but it becomes progressively narrower in the downstream portions of the creek corridor. A narrow band of cottonwood–willow riparian habitat occurs along the creek channel in Reach 4. Near Airfield Road, the cottonwood–willow habitat widens and contains a number of old, larger cottonwoods and willows with well-developed canopies, reflecting the reliable presence of shallow

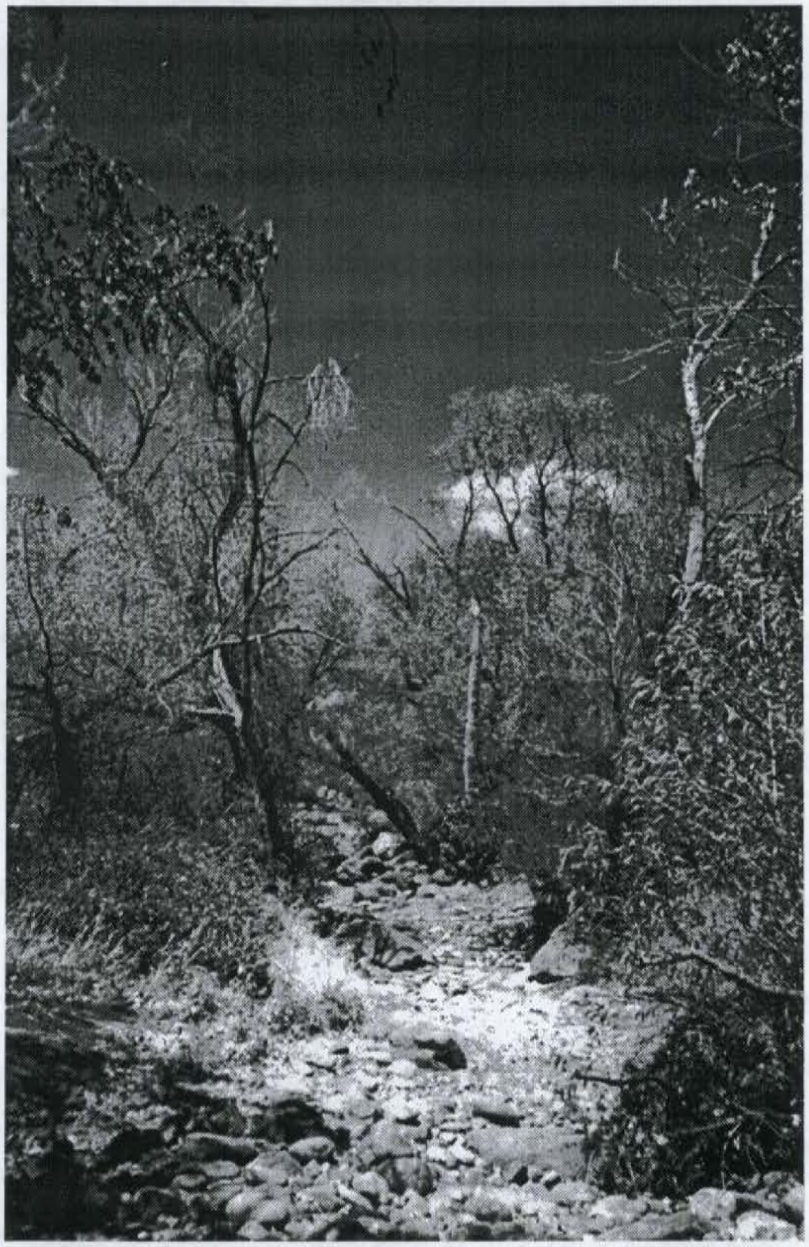


Figure 2-18. Cottonwood Mortality due to Drought Stress along Reach 2.

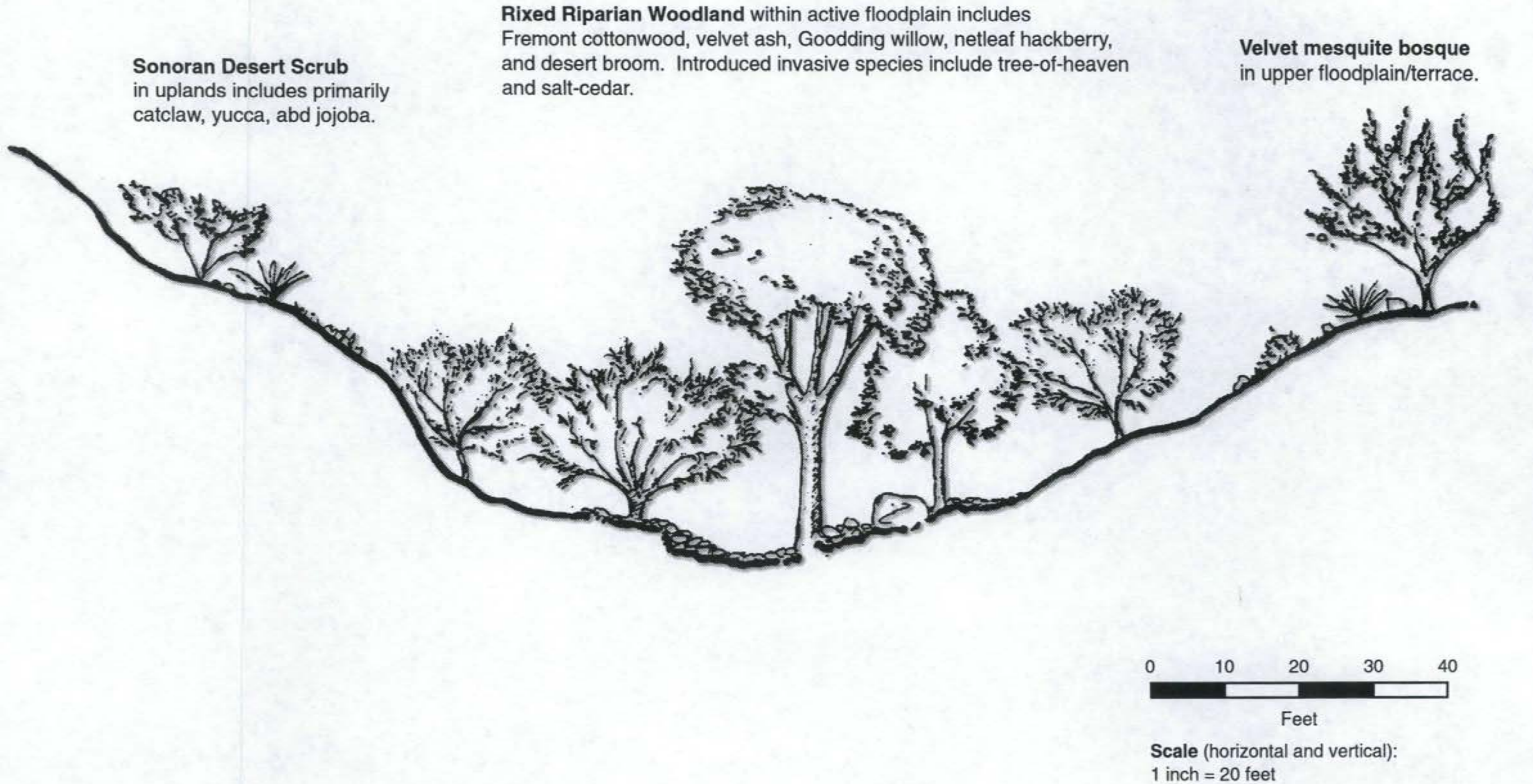


Figure 2-19. Representative Vegetation Cross-Section along Reaches 2 and 4

groundwater at the downstream end of the unconsolidated alluvial deposits. Immediately below Airfield Road, tamarisk and the mesquite bosque has been thinned and pruned to promote growth of grass for pasture.

Reach 5 of Queen Creek

Dense stands of Fremont cottonwood, Gooding's willow, and occasional sycamores occur along the reach between Old Pinal Townsite and the Arboretum stream gage. A slow transition occurs along this reach of the creek from vegetation dominated by Fremont cottonwood in the upstream portion to Gooding's willow in the downstream portions. During 1991, Tonto National Forest biologists inventoried portions of the riparian forest that occur on U.S. Forest Service lands within Reach 5 (Myers 1993). Because the occurrence of willows was three times greater than cottonwood, the riparian community was described as a Gooding's willow–Fremont cottonwood community (Myers 1993).

Besides the gallery riparian forest that occurs in the low floodplain, well-developed stands of velvet mesquite occur on the adjacent high floodplain and terrace, resulting in a broad, well-developed, structurally diverse riparian woodland. WWTP discharges provide perennial inflow to the reach that has fostered more luxuriant growth of riparian vegetation. Between Airfield Road and the Old Pinal Townsite, the creek flows through private property that is actively grazed. Riparian vegetation includes older cottonwoods, willows, and some mesquite. The herbaceous layer and subcanopy are not well developed as a result of grazing. Grazing stress is less along Reach 5, however, which has resulted in a better development of herbaceous and subcanopy layers that complement the gallery forest canopy, as shown in Figure 2-20.

Queen Creek Tributaries

The introduction of a perennial water source in intermittent tributaries to Queen Creek has resulted in the colonization of cottonwoods, willows, and tamarisk. This colonization has occurred along Magma Wash 1, next to Pinal Avenue (Figure 2-2), and in the WWTP wash. Whereas these areas naturally would have supported desert-wash vegetation such as mesquite and palo verde, they now support mature cottonwoods and willows as well as mesquite and tamarisk.

The riparian vegetation along Magma Wash 1 is supported by shallow groundwater seeping from the BHP ponds. The vegetation has a well-developed but somewhat open upper canopy; the subcanopy and herbaceous layers are not well developed, probably resulting from an inconsistent availability of surface water. Several dense mesquite and tamarisk thickets with scattered cottonwoods are also present. The cottonwoods provide some vertical canopy structure and diversity.

The WWTP wash supports a riparian community composed of mature cottonwoods, willows, and mesquite with structurally diverse canopy, subcanopy, and herbaceous layers. Aerial photos from 1979 show a mesquite woodland lining the wash and continuing onto the Queen Creek

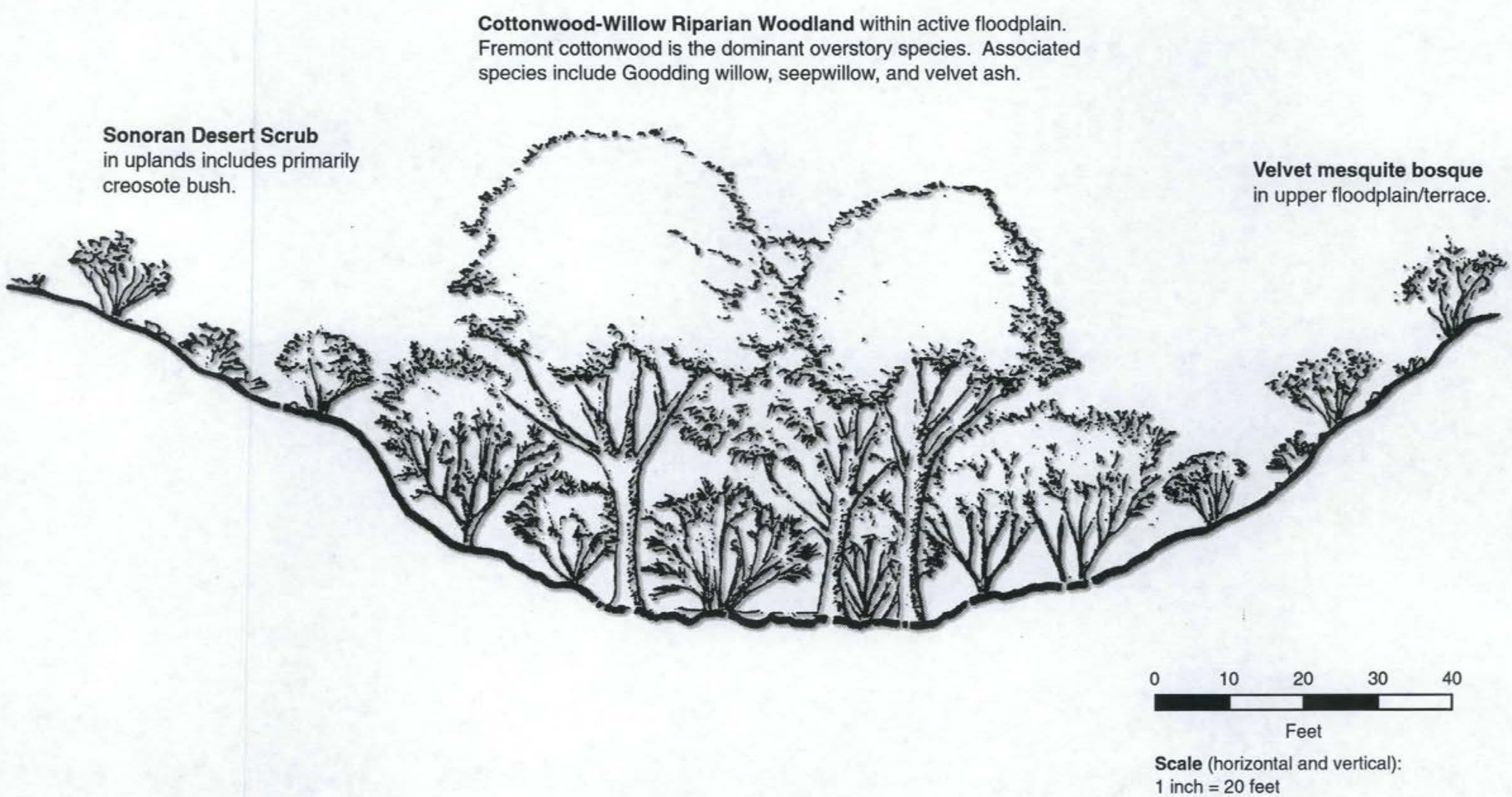


Figure 2-20. Representative Vegetation Cross-Section along Reach 5 near Old Pinal Townsite

floodplain. Currently, the wash still supports mesquite, but introduction of a perennial water source following the construction of the WWTP in 1974 has increased the height and density of the mesquite and allowed colonization by cottonwoods and willows.

Special-Status Species

Special-status species are plants and animals that are listed, proposed for listing, or are candidates for listing under the federal Endangered Species Act (ESA); species of special concern to state and federal resource agencies; and plants covered by the Arizona Native Plant Law of 1993. The Arizona Game and Fish Department (AGFD) provided a list from their Heritage Data Management System of seven special-status species (two fish, one reptile, one amphibian, and three plant species) known to occur in the general vicinity of the plan area, but not definitely known to occur in the Queen Creek riparian corridor. Table 2-5 contains a list of these species and summarizes their status, habitat requirements, potential for occurrence in the plan area, and potential effects to these species as a result of riparian restoration.

Wildlife

The potential for occurrence of the four special-status wildlife species (desert pupfish, gila topminnow, lowland leopard frog, and Sonoran tortoise) in the plan area was further assessed based on information contained in Wildlife of Special Concern in Arizona (Arizona Game and Fish Department in prep.) regarding the rangewide distributions of these species and the habitat suitability of the plan area for these animal species. The aquatic habitat in the plan area from the WWTP drainage to the Arboretum may provide potential habitat for the lowland leopard frog. The aquatic habitat in the same reach of the creek may provide habitat for the desert pupfish and gila topminnow, but because the habitat conditions (e.g., ponded water, presence of predators) are not ideal for these species, the potential for occurrence is low. Gila topminnow is reportedly present in Ayres Lake at the Arboretum, where predators may be absent (Petrie pers. comm.). Because the Sonoran desert tortoise occurs in upland habitats, the potential for this species to occur in the riparian corridor of Queen Creek within the plan area is also low.

Plants

The potential for the three special-status plants (Arizona hedgehog cactus, Hohokam agave, and varied fishhook cactus) to occur in the plan area was further assessed from information contained in the Handbook of Arizona's Endangered, Threatened, and Candidate Plants (U.S. Fish and Wildlife Service 1992) regarding the general habitat requirements of these plant species compared to the actual habitat conditions in the plan area. Given that these plant species occur in upland habitats, the potential for these plant species to occur in the riparian corridor of Queen Creek within the plan area is low. Discussions with the Tonto Forest riparian ecologist (Johnson pers. comm.) and the Arboretum horticultural specialist (Petrie pers. comm.) confirmed that Arizona

Table 2-5. Special-Status Species with Potential to Occur near Queen Creek

Species	Status*	Habitat Requirements	Potential for Occurrence under Existing Conditions	Potential Effects of Riparian Habitat Restoration
ANIMALS				
Desert pupfish *(Cyprinodon macularius macularius)*	LE, WC, S	Historically inhabited marshes, springs, backwaters, and slow flowing rivers and streams, of the Gila River Basin below 5,000 feet, before being extirpated from Arizona. Has been reintroduced in a number of sites in Arizona.	Low; although Queen Creek between the WWTP drainage and the arboretum supports perennial stream conditions that could support the fish, the presence of non-native predatory sunfishes would hinder establishment of a pupfish population.	Activities that would result in the reduction of flows in the currently perennial reach of the creek could aversely affect this species, if present.
Gila topminnow *(Poeciliopsis occidentalis occidentalis)*	LE, WC, S	Historically, was the most abundant native fish in the Gila River Basin. Currently occurs in 11 natural localities in southern Arizona, in warm water with moderate current in portions of the stream containing dense aquatic vegetation and algal mats.	Low; although Queen Creek between the WWTP drainage and the arboretum supports perennial stream conditions with dense algal mats, the lack of current and the presence of non-native predatory sunfishes and mosquitofish would hinder establishment of a topminnow population.	Activites that would result in the reduction of flows in the currently perennial reach of the creek could aversely affect this species, if present.
Lowland leopard frog *(Rana yavapaiensis)*	WC, S	Generally restricted to permanent waters, apparently preferring streams over ponds or other aquatic habitats within 0.25 mile of water.	Moderate to high; suitable aquatic habitat appears to be present in Queen Creek from the WWTP drainage to the arboretum. Non-native predaceous fishes and bullfrogs (if present) could negatively affect the frog.	Creation of new areas of perennial or near-perennial stream and additional riparian vegetation could provide improved habitat, including movement and dispersal corridor as well as potentially improved foraging and breeding opportunities.
Sonoran desert tortoise *(Gopherus agassizii)*	WC, S	Occurs across much of southwestern Arizona's Sonoran Desert, principally in rocky foothills, and less often on lower bajadas and in semidesert grassland.	Low; because suitable habitat for this species does not occur within the riparian corridor of Queen Creek the potential for occurrence of this rare species is low.	None.
PLANTS				
Arizona hedgehog cactus (*Echinocereus triglochidiatus arizonicus*)	LE, S, HS	Occurs on open slopes, in narrow cracks between boulders, and in the understory of shrubs in the ecotone between Madrean Evergreen Woodland and interior Chaparral, generally between 3,700 - 5,200 feet.	Low; because suitable habitat for this species does not occur within the riparian corridor of Queen Creek, the potential for occurrence of this rare species is low. Also, the plan area elevation , which ranges between about 2,350 - 3,000 feet, is slightly below the margin of the species' range.	None.

Table 2-5. Continued.

Species	Status*	Habitat Requirements	Potential for Occurrence under Existing Conditions	Potential Effects of Riparian Habitat Restoration
Hohokam agave (*Agave murpheyi*)	S, HS	Found in Sonoran desert scrub in central Arizona south to Sonora, between 1,300 - 2,400 feet, usually associated with prehistoric and historic human habitation.	Low; because suitable habitat for this species does not occur within the riparian corridor of Queen Creek, the potential for occurrence of this species is low. However, species could occur in the vicinity of the historic Old Pinal townsite adjacent to the plan area, because of the presence of historic and prehistoric habitations.	None.
Varied fishhook cactus *(Mammillaria viridiflora)*	SR	Found in several different habitats from Upper Sonoran zone in association with Quercus, Acrtostaphylos, and Juniperus to the Lower Sonoran zone in association with Carngiea, Fouquieria, and Larrea. Typically it grows on granite outcrops where terrain is very rugged and associated vegetation is very dense.	Low; because suitable habitat for this species does not occur within the riparian corridor of Queen Creek, the potential for occurrence of this species is low. This species has been found in Superior area; however, it is likely to occur on the steep slopes adjacent to the riparian corridor where the terrain is rugged but the incline supports dense vegetation.	None.

*Status explanations

LE = Listed endangered. Species identified by the U.S. Fish and Wildlife Service under the Endangered Species Act as being in imminent jeopardy of extinction.

WC = Wildlife of Special Concern in Arizona. Species whose occurrence in Arizona is or may be in jeopardy, or with known or perceived threats or population declines, as described by the Arizona Game and Fish Department's listing of Wildlife of Special Concern in Arizona (in prep.).

S = Species classified as "sensitive" by the Regional Forester when occurring on lands managed by the U.S. Forest Service.

HS = Highly safeguarded. Those Arizona native plants whose prospects for survival in this state are in jeopardy or that are in danger of extinction, or are likely to become so in the foreseeable future, as described by the Arizona Native Plant Law (1993).

SR = Salvage restricted. Those Arizona native plants not included in the Highly Safeguarded category, but have a high potential for theft or vandalism, as described by the Arizona Native Plant Law (1993).

hedgehog cactus and Hohokam agave could occur in the general vicinity of the plan area, but they would occupy upland Sonoran desert, not riparian habitats.

Chapter 3. Regulatory Environment

This section provides a brief overview of federal, state, and local regulations and permit requirements that may apply to the implementation of restoration activities or projects along Queen Creek. The specific applicability or rationale for inapplicability to each of the proposed management actions is included in the description of each action (see Chapter 5, "Elements of the Restoration and Management Plan"). Federal regulations and permits that are administered by state agencies are grouped with the state regulations.

FEDERAL REGULATIONS

National Environmental Policy Act

Compliance with the National Environmental Policy Act (NEPA) (42 USC 4321, 40 CFR 1500.1) applies to any activity or project that requires permits (e.g., federal Clean Water Act [CWA] Section 404 permit), entitlements, or funding from a federal agency; is jointly undertaken with a federal agency (e.g., U.S. Forest Service); or is proposed on federal land (e.g., Tonto National Forest). NEPA requires every federal agency to disclose the environmental effects of its actions for public review purposes and for assisting the federal agency in assessing alternatives to and consequences of the proposed actions. Some actions that involve minor or routine activities (e.g., small road culverts, hand clearing of vegetation, minor ground disturbance) are covered under blanket permits and do not require individual NEPA documentation.

Section 404 of the Federal Clean Water Act

Compliance with Section 404 of the federal CWA would be required for any activity that involves the discharge of dredged or fill material into jurisdictional waters of the United States, including wetlands and almost any streambed or drainage. Removal of vegetation by hand clearing is not regulated under Section 404. Ground disturbance involving excavation only is also unregulated, but grading activities that redistribute soil in a creek channel are regulated. Selected minor or routine activities are covered under nationwide permits with streamlined application procedures. Nationwide permits relevant to restoration activities along Queen Creek include:

- nationwide permit 14, which covers installation of culverts at minor road crossings,

- nationwide permit 26, which allows fill in small headwaters streams in which the average annual flow is <5 cfs (Queen Creek is included under this permit), and

- nationwide permit 27, which allows fill by private landowners in altered nontidal wetlands for the purpose of restoration.

Nationwide permits 14 and 26 require notification of the USACE, which administers Section 404. USACE will not issue a regular Section 404 permit until the state issues a certification (or waiver of certification) of compliance with state water-quality standards under Section 401 of the CWA (see "State Regulations") and the National Historic Preservation Act (NHPA).

Section 402 of the Federal Clean Water Act

Section 402 of the CWA requires that an NPDES permit be obtained by private or public entities proposing to discharge pollutants from a point source into waters of the United States. Point source usually refers to such things as a pipe, ditch, channel, tunnel, conduit, or well. NPDES permits are a federal requirement handled by the U.S. Environmental Protection Agency (EPA), but the Arizona Department of Environmental Quality (ADEQ) processes the applications within the state and passes the information on to the EPA.

Section 106 of the National Historic Preservation Act

Activities that are on lands owned by a federal agency (e.g., U.S. Forest Service), are considered a federal undertaking, or require a federal action (e.g., permit under Section 404 of the CWA) require compliance with Section 106 of the NHPA. This section requires that, before beginning any undertaking, a federal agency must take into account the effects of the undertaking on historic properties and afford the Advisory Council on Historic Preservation (ACHP) an opportunity to comment on these actions. The Section 106 process has five basic steps:

- identify and evaluate historic properties;

- assess effects of the project on historic properties;

- consult with the State Historic Preservation Officer (SHPO) regarding adverse effects on historic properties, resulting in a Memorandum of Agreement (MOA);

- submit the MOA to the ACHP; and

- proceed in accordance with the MOA.

Specific regulations regarding compliance with Section 106 state that, although the tasks necessary to comply with Section 106 may be delegated to others, the federal agency is ultimately responsible for ensuring that the Section 106 process is completed according to statute.

Sections 7 and 10 of the Federal Endangered Species Act

Activities or projects in areas where species listed as threatened or endangered under the federal ESA must comply with Section 7 of the ESA of 1973 (16 USC 1531 et seq.). Section 7 of the ESA requires federal agencies consult with the U.S. Fish and Wildlife Service (USFWS) to ensure that their actions do not jeopardize the continued existence of endangered or threatened species or result in the destruction or adverse modification of the critical habitat of these species. Section 10 of the ESA applies to those projects with no federal involvement that require an "incidental take" permit.

Restoration of habitat for a threatened or endangered species often raises concerns among landowners in or near the project that the use of their land will become highly restricted if the listed species eventually occupies the new habitat. "Safe harbor" agreements have been proposed as a means of allaying these fears. Under these agreements, landowners are exonerated from potential ESA liability when a listed species occupies newly created habitat and is later killed or harmed if the landowner subsequently decides to remove the habitat. Although much discussed at a conceptual level, safe harbor agreements can be difficult to implement in practice because regulations codifying the procedures are still quite new (adopted in 1998).

The species for which actions proposed in this plan are most likely to create potential habitat is the Gila topminnow. Several actions would create perennial flow or pools in Reach 2, which would thereby become reasonably suitable habitat for the topminnow. Topminnow are present in Ayers Lake at the Arboretum, and a few individuals topminnows occasionally escape the lake and reach Queen Creek during overflow events. However, they currently survive only a few days in the creek because of the abundance of predatory fish such as green sunfish. There is a possibility that Gila topminnow could migrate from Ayers Lake to the new habitat in Reach 2, but this would require that floodflow velocities be high enough to flush most of the predatory fish out of the creek but not so high that topminnow are prevented from swimming 2 miles upstream to the new habitat.

If reintroduction of Gila topminnow to Reach 2 is considered desirable, it could be achieved more promptly and reliably by actively transporting the fish to the new location. The possibility of including Gila topminnow restoration as part of the overall riparian restoration program is discussed in chapter 5 for the three potential actions that would create sufficient aquatic habitat to potentially support the fish (Actions 3, 4, and 6). This deliberate introduction of the Gila topminnow would require a safe-harbor agreement with local landowners in proximity of the creek and any proposed "lake". Gila topminnow introduction by stocking would need to be coordinated through Dave Weedman with AGFD (working out of the Phoenix office). The necessary safe-harbor agreements for an introduction of Gila topminnow would need to be coordinated with Lesley Deeroff with the U.S. Fish and Wildlife Service (working out of the Albuquerque Regional Office).

Special Use Permit

Tonto National Forest may require a special-use permit for restoration activities on national forest land.

STATE REGULATIONS

Water Quality Certification

Compliance with Section 401 of the federal CWA is required for any activity or project with federal involvement that result in discharge into waters of the United States. The ADEQ is responsible for reviewing water-quality certification applications and issuing a certification or waiver.

Aquifer Protection Permits

Aquifer Protection Permits are required for any "discharging facilities", where "discharge" means a direct or indirect addition of any pollutant (defined broadly) from a facility either directly to an aquifer or to the land surface in such a manner that there is reasonable probability that the pollutant will reach an aquifer. "Facilities" may include surface impoundments (e.g., ponds, lagoons), injection wells, and groundwater-recharge projects. The ADEQ is responsible for reviewing and issuing the aquifer-protection permit.

Wastewater Reuse Permits

Wastewater Reuse Permits are required for the operators of wastewater-treatment facilities, so that the reclaimed and treated water can be reused for such activities as irrigation or artificial recharge. The ADEQ is responsible for reviewing and issuing the wastewater-reuse permit.

State Historic Preservation Act

Activities on lands owned or controlled by an agency of the State of Arizona must comply with the Arizona State Historic Preservation Act (ASHPA) (A.R.S. 41-861 et. seq.). ASHPA mandates that all state agencies consider the potential of activities or projects to affect significant cultural resources. ASHPA states that each state agency is responsible for preservation of historic properties owned or controlled by the agency, and it dictates that each agency shall establish a program to locate, inventory, and nominate properties to the ARHP, the state's list of significant properties. Subsequently, each state agency involved in potential restoration projects must be contacted regarding specific procedures for cultural-resource studies conducted on lands in their ownership or control. The state agency is required to consult with the SHPO with regard to those activities or projects, especially those that have the potential to disturb the surface or subsurface of the ground, that may affect prehistoric or historical archaeological sites, or that may affect any buildings or structures that are 50 years old or older.

Arizona Native Plant Law

The Arizona Department of Agriculture (ADA) has compiled a list of protected plants and placed them in one of five categories of varying degrees of protection. Depending on the category, there are certain restrictions on the removal, transfer, or destruction of the plant. This law applies both to privately and state-owned lands. The only plant species protected under the law that occurs in the Queen Creek riparian corridor and that would potentially be harvested under actions proposed in this plan is velvet mesquite. Harvesting of mesquite requires that the landowner and harvest operator jointly apply for a harvest permit from the ADA.

Surface Water Use Permit

Activities or projects involving the diversion of surface water require an appropriative water right from the Arizona Department of Water Resources (ADWR). The appropriation must be for an officially recognized beneficial use. A reservoir permit would be required for projects involving the creation of a reservoir off an existing water course. This permit application requires listing the beneficial uses of the "reservoir". Habitat restoration is not considered a beneficial use. However, recreation and water supply for wildlife, including fish, are considered beneficial uses. ADWR does not designate streams as "fully appropriated", but for practical purposes many of them are. Downstream water users may protest a new application. If there is a protest to an application, ADWR may be involved in facilitating meetings between the applicant and the protesters. Resolution of the protest is the responsibility of the applicant and must be done within 450 days of the licensing period (Wildeman pers. comm.).

Groundwater Use Permit

Superior is located within the Phoenix AMA. Within an AMA, a person must have a groundwater right or permit to pump groundwater legally, unless the person is withdrawing groundwater from an exempt well. (As defined by the Code, an exempt well is a well with a maximum pump capacity of 35 gpm, which may be used to withdraw groundwater only for non-irrigation purposes and must be registered with ADWR). There are three types of rights or permits for non-exempt wells in the Phoenix AMA, all having a pump capacity greater than 35 gpm: 1) grandfathered rights, 2) service area rights, and 3) withdrawal permits.

There are three types of grandfathered rights, all derived from past individual water use: irrigation grandfathered rights, Type 1 non-irrigation rights, and Type 2 non-irrigation rights. An irrigation grandfathered right (IGR) is the right to use groundwater to irrigate specific acres of land that were irrigated between 1975 and 1980. Only land with an IGR may be irrigated with groundwater. An IGR specifies how much groundwater can be used, and the IGR may not be sold apart from the associated land. A Type 1 right is associated with land permanently retired from farming and converted to non-irrigation use. The maximum amount of groundwater that may be pumped each year using a Type 1 right is 3 acre-feet per acre, and this right may be conveyed only with the land. Groundwater withdrawn under a Type 2 right can only be used for a non-irrigation purpose. The right is based on historical pumping of groundwater for a non-irrigation use and equals the maximum amount pumped in any one year between 1975 and 1980. Type 2 rights are the most flexible because they can be sold separately from the land or well, and with ADWR approval, the owner may withdraw groundwater from a new location within the same AMA. Most Arizonans receive domestic water through service area rights to cities, towns, private water companies, and irrigation districts that withdraw groundwater to serve their customers.

Withdrawal permits allow new withdrawals of groundwater for non-irrigation uses within AMAs. There are eight types of withdrawal permits covering various groundwater uses that are subject to different requirements. (Arizona Department of Water Resources 2000.)

LOCAL REGULATIONS

Floodplain Use Permits

Floodplain Use Permits are required for conducting almost any type of work in the 100-year floodplain designated by FEMA. These permits are administered by the Pinal County floodplain manager.

General Plan and Zoning

Part or all of Reaches 1-3 lie within the town limits of Superior and are subject to local zoning and other ordinances. This creek restoration and management plan also must be consistent with Superior's general plan, which was last updated in 1987 (Town of Superior 1987). Goals and policies of the general plan relevant to management of Queen Creek are discussed in Chapter 5.

Chapter 4. Sources of Funding

Several federal and state agencies administer grant or loan programs targeted toward implementation of habitat-restoration or recreational-development projects. In this chapter, these programs are described briefly. In Chapter 5, their suitability as sources of funding is evaluated on a case-by-case basis for each of the implementation actions recommended in this plan.

WETLANDS AND WILDLIFE HABITAT

Federal Sources

U.S. Bureau of Reclamation

Under Title 16, the U.S. Bureau of Reclamation (Reclamation) provides grants for the creation of wetlands with special emphasis on effluent reuse. In this context, wetlands also include riparian areas. These grants require 50% matching funds from local sponsors, and the matching funds cannot come from another federal agency. Other than cash, matching-fund credit may be obtained from in-kind labor donations and credit for the value of dedicated land.

U.S. Environmental Protection Agency 104(b)(3)

The EPA provides funding under this program for local wetland-protection efforts, including wetland-protection demonstration projects and wetland-conservation plans. Again, the term "wetlands" is generally interpreted to include riparian areas. These grants require 25% matching funds from a local sponsor. Eligible matching-fund credits are the same as those for the Reclamation grants.

U.S. Environmental Protection Agency – Clean Water State Revolving Fund

The EPA provides low-interest loans to local agencies for a wide range of water-quality programs. The loans are routed through a state-agency clearinghouse that administers the program. Priority for funding is give to programs that implement community-based watershed management. This habitat restoration and management plan is an example of community-based watershed management. A 20% local-sponsor match is required, and matching-fund eligibility credits are the same as for the federal grant programs previously mentioned. Because this is a loan program, the funds borrowed might be eligible as matching funds for Reclamation and EPA 104(b)(3) programs.

U.S. Fish and Wildlife Service – Partners for Fish and Wildlife

The USFWS provides funding to private landowners for habitat restoration, improvement, and creation. Private landowners must provide a 10-year habitat-development agreement. Projects with in-kind services provided by the landowner (e.g., landowner agrees to install structure and maintain it over the term of the agreement) receive higher priority.

U. S. Department of Agriculture, Natural Resources Conservation Service

In 1996, the Natural Resources Conservation Service (NRCS) consolidated a number of its conservation programs for farmers and ranchers into the Environmental Quality Incentives Program (EQIP). EQIP offers 5- to 10-year contracts that provide incentive payments and cost sharing for conservation practices on farmland and rangeland. The practices must be carried out in accordance with a conservation plan developed for the site. Support can include technical assistance and cost sharing up to 75% of certain conservation practices. This program could potentially fund livestock management actions presented in this plan.

State of Arizona Sources

Arizona Water Protection Fund

The Arizona Water Protection Fund Commission provides grants to local agencies to "protect and restore the state's rivers and streams and associated riparian habitats" through the Arizona Water Protection Fund (AWPF). These grants encourage, but do not require, local matching funds. As a result of recent action by the state legislature, funding for AWPF is expected to decrease dramatically in the next several years.

Arizona Game and Fish Department Heritage Fund

The State of Arizona created the Heritage Fund to protect and enhance the states natural and historical resources. The funds are disbursed through several grant programs, some of which are managed by AGFD. The program most closely related to restoration actions proposed in this plan is the Urban Wildlife Habitat Fund, which supports the establishment of wildlife habitat and populations in harmony with urban environments and promotes public awareness of Arizona's native wildlife. Local matching funds are not required.

TRAILS

Federal Sources

Federal Highway Administration – Transportation Equity Act for the 21st Century

Under the Transportation Equity Act for the 21st Century (TEA-21), the Federal Highway Administration (FHA) provides grants to local agencies under a number of programs. In particular, under its Protecting the Environment Program, grant funds are available for "National Scenic Bikeways, bicycle and pedestrian paths, recreational trails, and roadside wildflower plantings". No local sponsor match is required.

State of Arizona Sources

Arizona State Parks Trails Program

The Arizona State Parks provides grants to local agencies through the Trails Program for trail acquisition and improvements throughout the state. A 50% local-sponsor match is required. Federal grant funds are eligible as matching funds. Individual grants are limited to 20% of the total funds available each year.

RECREATIONAL FACILITIES

Federal Sources

U.S. Department of Housing and Urban Development – Community Development Block Grants

The U.S. Department of Housing and Urban Development (HUD) provides a pool of funding through local councils of government for municipal community-development efforts. No local match is required. It should be noted, however, that Superior has identified other priorities for these funds for the next several years.

State of Arizona Sources

Arizona State Parks – Local, Regional and State Parks Program

Arizona State Parks provides grants for local agencies for the development of facilities for outdoor-recreation improvements through its Local, Regional and State Parks (LRSP) program. A 50% local-sponsor match is required, which can be derived from federal funds, and each grant is limited to 20% of the total funds available.

Arizona State Parks – State Lake Improvement Fund

Arizona State Parks also provides grants through its State Lake Improvement Fund to local agencies for the development of urban and rural lakes where boating is permitted. No local sponsor match is required. New lakes constructed must be at least 100 acres in size.

Chapter 5. Elements of the Restoration and Management Plan

KEY CONSIDERATIONS FOR RIPARIAN RESTORATION

The following is a discussion of key considerations that may influence the development of recommended measures for restoring and managing riparian habitat along Queen Creek. These issues emerged through preliminary assessment of site-related opportunities and constraints, and from concerns expressed by agencies and members of the public during the planning process.

Land Use and Property Ownership

Large portions of the plan area are privately owned, including BHP mining claims along Reach 1, commercial and residential properties along Reach 2, undeveloped properties owned primarily by BHP along Reach 3, pasture land along Reach 4, and the Arboretum along Reach 5. Activities proposed in this plan that could affect landowners include actions that take place on their land (such as construction of trails and removal of invasive exotic vegetation) as well as indirect effects of increased flow in their reach of the creek or increased wildlife populations in habitat adjacent to their land. Implementation of riparian habitat-restoration and management activities proposed as part of this plan would require close coordination with these private landowners.

The future ownership and operation of the BHP mine is presently uncertain. BHP has put this mine and several others up for sale, but a purchase has not been finalized. The outcome of this transaction will undoubtedly affect future mine operations and the feasibility of implementing restoration and recreation development actions on parcels owned by the mine. Also uncertain is whether dewatering will be resumed to prevent the underground shafts and tunnels from filling with water while additional mine exploration activities take place. At the present rate of water-level rise in the mine, it would be necessary to resume dewatering sometime in 2000 to prevent one of the more important tunnels from flooding. Future mine ownership and operation will also determine whether a new dewatering water treatment system is constructed, which could tremendously increase the amount of water available for supplemental flow in Queen Creek.

Tonto National Forest owns and manages an approximately 1.5-mile section of the creek in Reach 5 and some lands near the right band of the creek in Reach 4. The National Forest has conducted studies related to riparian habitat along the creek and shares the Town of Superior's objectives for protecting and restoring riparian habitat along the corridor.

Water Supply

Vegetation in the downtown reach of the creek (Reach 2) is sparse and shows signs of drought stress. Further, the limited regeneration of riparian trees suggests that conditions have generally become drier since the mature trees became established. Long-time Superior residents (i.e., 50-70 years) indicated that Queen Creek historically flowed more often and has flowed nearly continuously through the rainy season. Rainfall is not known to have changed, so the most likely cause of decreased moisture availability is decreased streamflow, underflow, or groundwater levels.

As part of the mine closure, BHP stopped dewatering the mine shafts in May 1998. The pumped water is no longer discharged into the settling ponds, from which it formerly overflowed into Queen Creek. When the ponds dry up, the supposed seepage source that supports riparian vegetation along Magma Wash 1 will disappear and probably result in vegetation mortality. The water level in the mine is rising slowly and after 20-30 years will probably reach the level of the creekbed and begin discharging into the creek. This discharge would increase base flow in Reaches 1 and 2, but the quality of the water from the mine could be poor.

New residential development planned in Superior should contribute to additional WWTP discharges. These discharges would increase flows in WWTP wash and make additional reclaimed water available for riparian restoration projects.

Floodway Management

Conditions in Reach 2, the downtown reach of Queen Creek, would tend to increase flood levels. Numerous structures along the left bank (facing downstream) are within FEMA's 100-year floodplain. In some areas, concrete debris and earth fill have been placed in the floodway. Refuse materials also are present in the channel in some areas. Buildings, refuse, vegetation, and woody debris in the channel would increase flood levels by decreasing channel capacity and increasing hydraulic roughness.

In recent years, cottonwood and willow trees were cut along the lower half of Reach 2, apparently to increase floodflow conveyance capacity of the creek. Because these trees stump-sprouted after cutting, however, they have formed shrubby clumps with greater flow resistance than the single-trunk mature trees they replaced. In addition, invasive non-native species, including tamarisk, salt cedar, tree of heaven, and giant reed, are present in some areas. Expansion of these populations could reduce floodway capacity because of their bushy growth, and it could also decrease bank stability because of their rooting characteristics.

Restoration of native riparian vegetation Reach 2 could also increase hydraulic roughness and increase flood levels. Increased flood risk from increased vegetation in the floodway is a concern of local residents and the county floodplain manager. Restoration would probably also require a vegetation-management program in the floodway that maintains adequate flood-conveyance capacity while retaining as much habitat value as possible.

Habitat Quality

Existing riparian vegetation along Queen Creek provides important habitat for a diversity of wildlife species. Cottonwood–willow riparian habitat, characterized by well-developed, structurally diverse vegetation (i.e., herbaceous, subcanopy, and canopy layers) is particularly rare and valuable habitat, especially for breeding and wintering birds.

In areas of the creek corridor that do not receive augmented water supply from discharges, flows are intermittent (Reaches 1, 2, 3, and 4), riparian vegetation is sparse, many mature trees show signs of drought stress, and regeneration of riparian trees appears to be limited. In contrast, areas of the creek corridor that receive perennial or more consistent water flows (e.g., Reach 5) support denser stands of continuous, structurally diverse riparian vegetation, and they have hydrologic conditions suitable for regeneration of riparian trees.

Human activities (e.g., uncontrolled off-road-vehicle use, vegetation clearing for floodway management, pasture-land management, grazing, debris dumping) have disturbed riparian vegetation in some areas. In addition, invasive non-native species (e.g., tamarisk, tree of heaven, giant reed) compete with native plants and diminish the ecological health and wildlife value of the riparian corridor. Further spread of these non-native plants could threaten riparian habitat diversity and quality.

Although the corridor already provides important habitat for a variety of plant and animal species, its habitat diversity and value could be greatly improved. Riparian vegetation restoration could increase the density, width, habitat patch size, and continuity of riparian habitats in the plan area. Riparian vegetation should be enhanced to a level that is naturally sustainable, given water availability and floodway-conveyance requirements.

OVERALL GOAL AND SPECIFIC OBJECTIVES

To guide the development and selection of specific management actions, planning participants (Figure D-4A, "Queen Creek Restoration Advisory Committee") formulated an overall goal for restoring and enhancing riparian habitat along Queen Creek and providing associated recreational opportunities. The following overall goal is a qualitative statement that describes the desired condition of the riparian zone and its relation to the human environment in Superior:

- to protect and enhance native riparian vegetation and wildlife along Queen Creek near Superior in a manner that achieves and balances ecological, aesthetic, recreational, and economic benefits.

In addition to this goal, the planning group also developed several more narrowly defined primary and secondary objectives for riparian restoration, recreational development, as well as resource-management guidelines for the riparian corridor. These objectives are as follows:

Primary Objectives

- Conserve existing riparian habitat along the creek corridor, especially relatively large stands of vegetation.
- Modify land use and water flows along the creek corridor to promote physical processes that lead to natural regeneration, structure, and function of riparian vegetation.
- Expand the area occupied by riparian vegetation by implementing revegetation projects (e.g., grading, seeding, planting) at specific sites where riparian habitat is unlikely to regenerate naturally but will survive and mature once plants become established.
- Enhance the quality of riparian vegetation by actively suppressing or removing invasive non-native plant species.
- Implement management and protection programs that maintain and enhance riparian habitat conditions on an ongoing basis.

Secondary Objectives

- Maintain or decrease the existing level of flood risk for buildings near the creek channel.
- Provide access to the creek channel and riparian corridor along selected reaches for recreational and educational activities that are compatible with protection of habitat values and that respect private land ownership.
- Enhance the aesthetic qualities of the creek corridor so that it is more attractive to the community and visitors.

Some of these objectives may conflict with one another. For example, maintaining flood-conveyance capacity through the downtown reach may require vegetation removal or pruning that limits habitat quality, and recreation activities may also detract from habitat value. These potential conflicts vary from reach to reach and were evaluated in a site-specific context during the formulation of specific management actions.

These goals and objectives are consistent with the Superior general plan (Carter Associates 1987, Town of Superior 1987). The community's interest in preserving and enhancing natural vegetation and habitat along Queen Creek for aesthetic, recreational, and economic reasons is expressed in the following statements from the plan:

Land Use (Discussion). "Open space should be reserved to the areas in Queen Creek's floodplain. This land is developable only under stringent restrictions and it is best suited to remain undeveloped or put to use as parks and recreation land".

Land Use Policy 2.b. "Utilize the approval process of the Planning and Zoning Board to encourage developers and individuals to include amenities and features in their site planning that will enhance the desired character of the Town".

Environmental Protection and Management Goal. "To preserve the existing quality of the natural environment".

Environmental Protection and Management Goal. "To provide the residents of Superior with a healthy natural environment".

Environmental Protection and Management Policy 1. "The Town supports the protection and enhancement of major drainageways and existing floodplains". The policy includes the following objectives:

- "1.a. Incorporate these areas into the overall plan for parks and recreation development", and
- "1.b. Include the flood-prone areas into the zoning-ordinance as areas of open space".

Environmental Protection and Management Policy 2. "The Town encourages the incorporation of open space, parks and recreation facilities, views, hillsides, and natural vegetation in all new residential developments".

Community Revitalization Objective 2. "To create quality physical and economic environments in the downtown area".

Parks and Recreation (Discussion). "The provision of recreation opportunities and park facilities was identified by the citizens of Superior as one of the development requirements with the highest priority".

Parks and Recreation Goal. "To develop passive park facilities and open space and greenbelt areas to increase leisure time opportunities for residents and the attractiveness of the Town".

Parks and Recreation Policy 1. "The Town supports the development of open space plans, natural features, landmarks and passive parks". The policy includes the following objective:

- "1.b. Utilize significant natural features and landmarks, including scenic vistas, in an overall open space system. Queen Creek—particularly within the 100-year floodplain —and other drainageways that limit other developments should be considered as opportunities for such use as well as hiking and riding trails".

RIPARIAN RESTORATION ACTIONS

The planning participants identified and designed specific management actions for possible implementation to achieve the overall goal and specific objectives of this plan. The specific actions are listed in Table 5-1 and include projects, policies, and programs that 1) would contribute to the quantity or quality of riparian habitat along the creek or 2) would create recreational opportunities associated with the creek. The proposed facilities that would result from the actions are shown in Figure 5-1.

The specific management actions described in this section are grouped by their primary emphasis on riparian restoration or development of recreational opportunities associated with restored riparian areas. Because the availability of water to augment streamflow is a fundamental constraint to expanding the area of riparian vegetation, the restoration actions are further grouped by involvement of modified or supplemental streamflows.

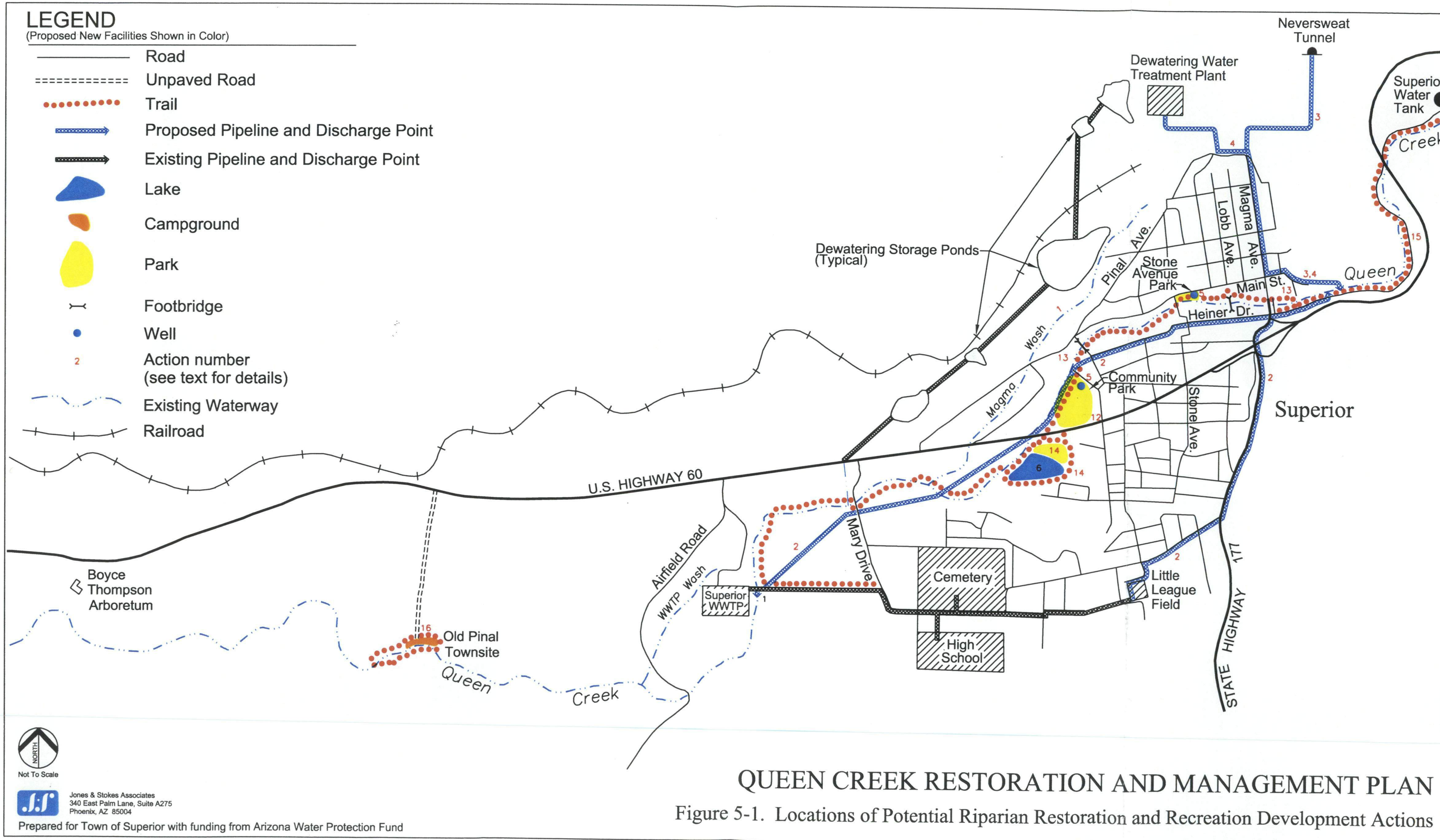
The description of each action includes its objective, location, amount of habitat produced, approximate cost, funding possibilities, secondary impacts and benefits, permitting requirements, and recommended implementing agency. The potential funding sources for each action are summarized in Table 5-2, and applicable permits are summarized in Table 5-3.

All the specific actions in Table 5-1 are individually recommended for implementation, but a few of them compete for the same source of water or achieve similar objectives. Incompatibilities and redundancies among the actions are discussed in the section of this chapter, "Selection of Management Actions for Implementation".

Water Balance Model

The estimates of vegetation acreage that would be restored under each alternative were developed using a water-balance model that calculated the length of reach wetted by each of the flow-dependent alternatives based on existing seepage losses and estimated ET losses under restored conditions. Restored riparian vegetation was assumed to be similar to existing riparian vegetation along Reach 5 in its relative composition of vegetation types and the number of acres of vegetation per mile of creek. The model was developed in a spreadsheet format using Lotus 1-2-3 software. The model calculated gains and losses of water along each of the five reaches of Queen Creek (see Chapter 2) and the washes that convey discharges of BHP dewatering water and treated municipal wastewater. The reach locations are shown in Figure 2-3 in Chapter 2. The following guidelines govern the model results:

- the net outflow from the uppermost reach is the primary inflow to the next downstream reach;
- all flows are monthly, and different sets of monthly values are available to simulate normal, dry, and wet years;



QUEEN CREEK RESTORATION AND MANAGEMENT PLAN

Figure 5-1. Locations of Potential Riparian Restoration and Recreation Development Actions

Table 5-1. Recommended Actions for Habitat Enhancement and Recreation Development

No.	Action
HABITAT RESTORATION ACTIONS	
Flow-Dependent Actions	
1	Discharge Reclaimed Water Where Existing Pipeline Crosses Reach 4
2	Discharge Reclaimed Water in Reach 2
3	Return Freshwater Mine Inflow Directly to Queen Creek
4	Install a New Mine Dewatering Treatment System and Discharge Pipeline to Reach 2
5	Install Wells for Riparian Irrigation and Supplemental Streamflow
6	Construct an Off-Channel Stormwater Lake in Reach 3
Non-Flow-Dependent Actions	
7	Adopt a Creek Protection Ordinance
8	Implement a Creek Cleanup and Anti-Dumping Program
9	Implement a Program to Remove Exotic Vegetation
10	Implement a Program to Minimize Grazing Impacts
11	Manage Floodway Vegetation
RECREATION DEVELOPMENT ACTIONS	
Non-Flow-Dependent Actions	
12	Complete Construction of Stone Avenue Park and Community Park
13	Construct the Old Town Trail along Reach 2
14	Add Access and Park Facilities around the Lake
15	Enhance Trail in Canyon Reach
16	Construct a Campground and Nature/History Trail at Old Pinal Townsite
17	Extend Old Town Trail to High School

Table 5-2. Potential Funding Sources for the Recommended Restoration Actions

Action	USBR Title 16	EPA Clean Water 104 (b) (3)	EPA Revolving Fund	USFWS Partners	AZ Water Protection Fund	AGFD Heritage Fund	TEA 21	AZ State Parks - Trails	AZ State Parks - Local Parks	AZ State Parks - Historical	HUD Community Block Grant
1. Discharge Reclaimed Water Where Existing Pipeline Crosses Reach 4	XX		X		X						
2. Discharge Reclaimed Water in Reach 2	XX		X		X	XX					
3. Return Freshwater Mine Inflow Directly to Queen Creek		XX	XX	X	X	XX					
4. New Mine Dewatering Treatment and Discharge to Reach 2	XX		XX		X	XX					
5. Install Wells for Riparian Irrigation and Supplemental Streamflow	X	XX			X	XX					
6. Construct an Off-Channel Stormwater Lake in Reach 3	X	XX				X					
7. Creek Protection Ordinance						X					
8. Creek Cleanup and Anti-Dumping Program		X	XX	X	X	X					
9. Remove Exotic Vegetation		X	X	X	X	X					
10. Minimize Grazing Impacts		X	X	XX	X						

Table 5-2. Continued

Action	USBR Title 16	EPA Clean Water 104 (b) (3)	EPA Revolving Fund	USFWS Partners	AZ Water Protection Fund	AGFD Heritage Fund	TEA 21	AZ State Parks - Trails	AZ State Parks - Local Parks	AZ State Parks - Historical	HUD Community Block Grant
11. Manage Floodway Vegetation											
12. Complete Creekside Parks									XX		X
13. Build Old Town Trail along Reach 2							X	XX	X		X
14. Add Access/Amenities around Lake							XX	X	XX		X
15. Enhance Trail in Canyon Reach							XX	XX	X	X	X
16. Develop Old Pinal Nature/History Site							XX	X		X	
17. Extend Old Town Trail to High School							XX	X	X		X

Note:

The XX symbol indicates a strong match between the action and the objectives of the funding source.

Table 5-3. Local, State and Federal Regulations and Permits Applicable to the Proposed Restoration Actions

	CHANGE IN FLOW		CHANGE IN VEGETATION				GROUND DISTURBANCE			WATER USE			OTHER		
Action	Wastewater Reclamation Permit	NPDES Point Discharge Permit	ESA Sections 7 and 10	AZ Native Plant Law	Floodplain Use Permit	CWA Section 404 Permit [1]	ASHPA Consultation	NHPA Section 10 Permit	NPDES Stormwater Permit	Surface Water Right	Reservoir Permit	Ground-water Use Permit	Special Tonto NF Use Permit	Safe-Harbor Agreement	ADOT Encroach-ment Permit
1. Discharge Reclaimed Water Where Existing Pipeline Crosses Reach 4	X	X	X												
2. Discharge Reclaimed Water in Reach 2	X	X	X						X						
3. Return Freshwater Mine Inflow Directly to Queen Creek		X													
4. New Mine Dewatering Treatment and Discharge to Reach 2	X	X												X*	
5. Install Wells for Riparian Irrigation and Supplemental Streamflow					X		X	X				X			
6. Construct an Off-Channel Stormwater Lake in Reach 3		X	X	X	X	X	X	X	X	X	X			X*	X
7. Creek Protection Ordinance															
8. Creek Cleanup and Anti-Dumping Program													X		
9. Remove Exotic Vegetation					X								X		

Table 5-3. Continued

Action	CHANGE IN FLOW		CHANGE IN VEGETATION			GROUND DISTURBANCE				WATER USE			OTHER		
	Wastewater Reclamation Permit	NPDES Point Discharge Permit	ESA Sections 7 and 10	AZ Native Plant Law	Floodplain Use Permit	CWA Section 404 Permit [1]	ASHPA Consultation	NHPA Section 10 Permit	NPDES Stormwater Permit	Surface Water Right	Reservoir Permit	Ground-water Use Permit	Special Tonto NF Use Permit	Safe-Harbor Agreement	ADOT Encroach-ment Permit
10. Minimize Grazing Impacts													X		
11. Manage Floodway Vegetation				X	X								X		
12. Complete Creekside Parks															
13. Build Old Town Trail along Reach 2						X	X	X							
14. Add Access/ Amenities around Lake				X	X		X	X							
15. Enhance Trail in Canyon Reach							X	X							
16. Develop Old Pinal Nature/ History Site				X		X	X	X					X		
17. Extend Old Town Trail to High School				X	X		X	X					X		

Note:

* This permit would be applicable if the endangered species, Gila topminnow, was deliberately introduced or if conditions conducive to species migration are expected to result from a restoration action.

[1] Section 404 permits also require a Section 401 water quality certification from ADEQ. Nationwide 404 permits are mostly precertified.

- normal conditions are represented by the median flow value for a given month over a number of years (the period of record is different for each input variable); and

- dry conditions are represented by flows that are exceeded in 8 out of 10 years, and wet conditions are represented by flows that are exceeded in only 2 out of 10 years. These thresholds for wet and dry conditions were subjectively selected to illustrate a reasonable range of conditions for riparian vegetation and aquatic organisms.

In addition, water-budget items included in the model are natural runoff from rainfall, snowmelt, and groundwater discharge in the upper Queen Creek watershed; discharges from BHP and the WWTP; diversion at the Arboretum pump house; seepage losses in the upper watershed area induced by mine dewatering; seepage gains and losses along the lower reaches of the creek where the water table is naturally higher or lower than the creekbed; direct evaporation from the creek surface; and net ET by phreatophytic vegetation along the riparian corridor. Detailed descriptions of assumptions and data used in the model and presentations of model results are provided in Appendix B.

The water demand of riparian vegetation is a particularly useful basic piece of model output for preliminary identification of restoration opportunities. For each of the principal vegetation categories, the model calculates supplemental water demand by multiplying reference ET (see Chapter 2) by the "crop coefficient" (water-use intensity factor) for each vegetation type (see Appendix B) and subtracting the amount of demand supplied by rainfall. Table 5-4 shows the supplemental water demand, calculated monthly, for wet, normal and dry conditions. Supplemental water demand for sycamore-ash-walnut riparian forest is probably between the values for cottonwood-willow and mixed riparian forests.

The water requirements shown are calculated in two ways, for convenience in calculating water supply and demand. Water-supply requirements of a certain restoration design are more usefully calculated as cubic feet per second per acre (cfs/ac), whereas the amount of vegetation that could be supported by a given water supply is more usefully calculated as acres per cubic foot per second (ac/cfs). In the "Net Change in Habitat" section for each flow-dependent action, a table shows the change in acreage of each vegetation type along the affected reach and the estimated canopy density, in percent cover, for each vegetation type after restoration. In Reach 2, for example, additional flow would not only increase the area of cottonwood–willow riparian forest but would increase the canopy density of existing riparian vegetation.

Flow-Dependent Actions

Restoration of riparian vegetation by implementing Actions 1-6, which are described in this section, would depend on available water flow. A sense of the relative magnitude of the major existing discharges and consumptive uses along the creek helps to develop restoration alternatives. These "pieces of the water puzzle" are shown in Table 5-5. Additions to flow include the WWTP discharge and the recent BHP discharge of treated dewatering water. Direct or indirect withdrawals of flow include pumping at the Arboretum Canyon Well; seepage induced by BHP dewatering; and

Table 5-4. Supplemental Water Requirements for Optimal Vegetation Establishment

A. MESQUITE

Year Type	Units	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Dry	cfs/ac	0.00312	0.00163	0.00000	0.00002	0.00053	0.00148	0.00494	0.00727	0.00920	0.00598	0.00444	0.00437
	ac/cfs	321	613	N/A	60,272	1,897	678	202	138	109	167	225	229
Normal	cfs/ac	0.00214	0.00053	0.00000	0.00000	0.00000	0.00059	0.00367	0.00643	0.00832	0.00470	0.00329	0.00347
	ac/cfs	467	1,899	N/A	N/A	N/A	1,701	273	156	120	213	304	288
Wet	cfs/ac	0.00214	0.00000	0.00000	0.00000	0.00000	0.00000	0.00331	0.00570	0.00759	0.00378	0.00073	0.00309
	ac/cfs	467	N/A	N/A	N/A	N/A	N/A	302	175	132	264	1,371	323

B. MIXED RIPARIAN

Year Type	Units	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Dry	cfs/ac	0.00460	0.00138	0.00000	0.00000	0.00000	0.00015	0.00520	0.01210	0.01806	0.01343	0.01127	0.01020
	ac/cfs	217	726	N/A	N/A	N/A	6,608	192	83	55	74	89	98
Normal	cfs/ac	0.00353	0.00029	0.00000	0.00000	0.00000	0.00000	0.00391	0.01094	0.01660	0.01166	0.00969	0.00892
	ac/cfs	283	3,470	N/A	N/A	N/A	N/A	256	91	60	86	103	112
Wet	cfs/ac	0.00343	0.00000	0.00000	0.00000	0.00000	0.00000	0.00354	0.00990	0.01529	0.01026	0.00667	0.00816
	ac/cfs	291	N/A	N/A	N/A	N/A	N/A	282	101	65	97	150	122

C. COTTONWOOD/WILLOW RIPARIAN

Year Type	Units	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Dry	cfs/ac	0.00652	0.00100	0.00000	0.00000	0.00000	0.00000	0.00600	0.01321	0.02226	0.01697	0.01452	0.01296
	ac/cfs	153	1,004	N/A	N/A	N/A	N/A	167	76	45	59	69	77
Normal	cfs/ac	0.00532	0.00000	0.00000	0.00000	0.00000	0.00000	0.00465	0.01198	0.02052	0.01496	0.01271	0.01151
	ac/cfs	188	N/A	N/A	N/A	N/A	N/A	215	83	49	67	79	87
Wet	cfs/ac	0.00510	0.00000	0.00000	0.00000	0.00000	0.00000	0.00423	0.01086	0.01894	0.01333	0.00949	0.01057
	ac/cfs	196	N/A	N/A	N/A	N/A	N/A	236	92	53	75	105	95

N/A -- Not applicable because supplemental water not required.

Table 5-5. Average Annual Magnitudes of Selected Discharges and Consumptive Uses

Discharge or Consumptive Use	Average Annual Flow (ac-ft)
BTA Canyon Well pumping	-40
WWTP discharge	
To park, schools, cemetery for irrigation	+29
To WWTP	+232
Historical BHP dewatering discharge	+434
Maximum possible BHP induced seepage from dewatering	-807
Evaporation and ET	
Queen Creek	
Reach 1	-12
Reach 2	-37
Reach 3	-58
Reach 4	-87
Reach 5	-72
WWTP wash	-18
Magma Wash I	-5
Riparian vegetation near BHP Ponds	-22

Notes:

Historical BHP dewatering discharge rate is the average annual discharge during 1993-1998

The maximum possible BHP induced seepage from dewatering equals the average annual rate of pumping water from the mine in the mid-1990s.

Evaporation and ET losses assume the existing distribution of vegetation and that perennial flow is present (i.e., that ET is not suppressed by lack of water availability).

evaporation and ET associated with riparian vegetation along Queen Creek, the WWTP and BHP washes, and near the BHP storage ponds.

Action 1. Discharge Reclaimed Water Where an Existing Pipeline Crosses Reach 4

Objective

Action 1 would create new mixed-riparian or cottonwood–willow riparian vegetation along the lower half of Reach 4.

Location and Description

A few cottonwood trees are present along the lower part of Reach 4, including seedlings from recent years. These trees are evidence that the water table below the creek is once again close to the land surface at this location after dropping precipitously at the upper end of the alluvial basin traversed by Reaches 3 and 4. Conditions are not quite wet enough, however, to ensure that a cottonwood–willow or mixed riparian forest is firmly established. Rather, tamarisk and mesquite are the dominant vegetation types (Figure 5-2). A small amount of additional flow would create physical conditions more favorable for cottonwood–willow or mixed-riparian vegetation. Active removal of tamarisk (Action 9) would facilitate this conversion.

The new discharge would be implemented by adding a valved turnout where an existing reclaimed-water pipeline crosses Queen Creek a few hundred feet east of the WWTP near the midpoint of Reach 4, or a new pipeline could be installed exclusively for that purpose. The existing 4-inch-diameter PVC pipeline conveys reclaimed water from the WWTP for irrigation use at baseball fields and the high-school football field in the southern part of Superior. After passing under Queen Creek, the pipeline continues east to Mary Drive, along Mary Drive to the playing fields, and then farther east along O'Donnell Drive to the Little League baseball field. Little League officials have never used the reclaimed water for irrigation. Installing a new turnout on the existing pipeline would avoid the need to lay about 500 feet of new pipeline. The new turnout, however, would require installation and remote operation of a valve and installation of a low-rate, low-pressure pump parallel to the existing pump. Operation of the two pumps would need to be coordinated. Discharges to the creek during the irrigation season would have to be interrupted whenever the sprinklers at the playing fields are in operation. The high school has three 10,000-gallon storage tanks for irrigation water, but the baseball and softball fields are irrigated directly from the pipeline. In midsummer, the sprinklers are typically operated 5 days a week for 5 hours a day using the full capacity of the reclaimed-water pipeline (Real pers. comm.). Thus, there would be diurnal fluctuations in the new flow discharged to the creek. Soil-moisture storage, however, would buffer riparian vegetation from adverse impacts associated with the fluctuations.

An alternative design that would have slightly higher initial costs, but which would avoid many of the operational complications just described, would be to lay 500 feet of 2-inch PVC pipe from the existing outfall location, over the top of the hill, and to the new discharge location. The hill and creek elevations are such that the new discharge could be operated as a siphon with no ongoing electricity costs and no need to operate pumps and valves.

Figure 5-2. Cottonwood/Willow Riparian Vegetation Battling Tamarisk along Reach 4.

Figure 5-3. Lush but Somewhat Unnatural Vegetation along the WWTP Wash.

Under Action 1, about 25% of the wastewater generated at the plant (0.09 cfs or 40 gpm) would be discharged at the new location. This rate is recommended to minimize impacts on water supply at the Arboretum and on riparian vegetation in Reach 5. The discharge could be decreased in dry years and in June–August of normal years to ensure that the reclaimed water is optimally allocated for survival of all dependent vegetation areas.

The increased flow duration in lower Reach 4 would create chronically muddy conditions at the unpaved ford where Airfield Road crosses Queen Creek. A small culvert would be installed under the road at the crossing to avoid water-quality impacts and nuisance to drivers.

Planting desirable vegetation is not proposed under Action 1. Improved water availability would encourage existing cottonwood–willow vegetation to become more dominant along Reach 4 without further assistance. Removal of exotic vegetation, however, would accelerate this transition (see Action 9).

Net Change in Habitat

Assuming that the remaining 75% of the reclaimed water continues to be discharged to the WWTP wash, the new discharges to the lower half of Reach 4 are expected to support the following acreages of riparian vegetation:

Vegetation Type	Change in Vegetation Area (acres)	Restored Canopy Density (%)
Mesquite	-4	50
Mixed-riparian forest	0	50
Cottonwood–willow forest	+4	60

The changes in vegetation were calculated using the water-balance model. The new perennial discharge of reclaimed water was assumed to convert existing mesquite vegetation to cottonwood-willow riparian vegetation along the creek banks, and the resulting proportions of vegetation types were assumed to remain as they presently are in Reach 5. The canopy density of existing and new cottonwood-willow vegetation also was assumed to equal the canopy density in Reach 5 (50% coverage of the ground surface in areas mapped as cottonwood-willow vegetation in Figure 2-13. The new discharge was divided by the ET rate per mile of existing vegetation in Reach 5 to estimate the length of channel that would convert to the new vegetation type. Multiplying this length by the number of acres per mile of each vegetation type in Reach 5 yielded the estimated acres of vegetation shown in the table.

The quality of the new habitat would be high. The vegetation would be contiguous with the existing high-quality riparian corridor along Reach 5, thereby providing easy access to wildlife. Cattle and horse grazing, which might affect habitat quality, presently is limited to about two-thirds of the potentially restored segment of Reach 4, and it has not resulted in significant adverse impacts to riparian vegetation. The restored reach is not adjacent to residential areas, and so wildlife disturbance by people and pets would be relatively low.

Cost

The preferred approach to plumbing the new discharge would be to install a new, 2-inch PVC pipe from the existing outfall to the new discharge location on Queen Creek. This small-diameter pipeline would cost about $25 per linear foot to install, plus costs for pipe fittings, check valves, and a siphon air-gap valve, for a total cost of about $20,000.

Funding Sources and Funding Feasibility

Grants provided under Title 16 by Reclamation would be a good source of funding for Action 1 because the program emphasizes wetland restoration through effluent reuse. The EPA's revolving fund could be an additional source of loan funds because the action is part of a community-based plan for riparian restoration at a watershed scale. Finally, AWPF could be attracted by the large amount of high-quality habitat created at low cost by this action.

Impacts and Secondary Benefits

Action 1 would increase the total consumptive use of wastewater upstream of the Canyon Well at the Arboretum and could decrease the annual yield of the well. In recent years, the well has produced about 40 af/yr for irrigation use in the Arboretum, which equals about 15% of the annual wastewater discharge. The consumptive use of water for ET by vegetation along the WWTP wash and Reach 5 is about 35% of the annual discharge in a normal year. In June, which is the month of greatest net ET demand, the ET demand equals about 100% of the WWTP discharge. There are substantial seepage losses in addition to the ET loss, but much of the infiltrated streamflow becomes groundwater that supports riparian vegetation and stream base flow at the bedrock narrows above the Arboretum. Furthermore, recharge from natural streamflow replenishes the groundwater supply, and before the WWTP was constructed, this recharge supported riparian vegetation between the Old Pinal Townsite and the Arboretum. Diverting 25% of the WWTP discharge to Reach 4 is not expected to decrease the well yield substantially because the Arboretum's well pumping is a relatively small percentage of the WWTP discharge and because natural streamflow also partly recharges the groundwater. Furthermore, the Arboretum now has a second well that can provide a backup supply to offset any decrease in yield at the Canyon Well. Finally, discharge from the WWTP is expected to gradually increase as the population and local economy grow in the future. For example, the first business to locate in the new industrial park along Highway 60 generates a wastewater flow of about 17 gpm, which adds to the WWTP discharge.

Impacts on yield at the Arboretum's Canyon Well could be more than offset by gradually phasing out releases to the WWTP wash and instead releasing all the water to Reach 4. The expected ET losses along the restored section of Reach 4 would be about equal to the ET losses along the wash, but seepage losses are lower. The quality of the new riparian vegetation along Reach 4 would be better than that of the existing vegetation along the WWTP wash because occasional high flows in Queen Creek would create a more natural vegetative structure with an open channel. Existing vegetation along the wash is lush and unnaturally dense (Figure 5-3). Vegetation along the wash would revert to desert-plant species that typically inhabit ephemeral washes in the area (e.g., mesquite, palo verde, acacia).

The new vegetation would not be very visible from Highway 60 or most of Superior, and consequently it would not provide significant scenic benefits for residents and visitors. On the other hand, the new vegetation would be far enough downstream from existing creekside homes to avoid any increase in flood risk.

The new vegetation would be located largely on private property. Recreational and educational benefits could be achieved if the landowners granted public access to the creek. The lower part of Reach 4, however, is best suited for habitat emphasis, while Reaches 1, 2, 3, are located closer to town and are the logical locations for recreational development.

Permits and Cooperating Agreements

As a courtesy, landowners along the lower half of Reach 4 should be notified of the proposed additional WWTP discharge point and the resulting extended flow season in Reach 4. Landowners probably would view additional streamflow as a benefit.

Implementation of Action 1 would also require a modification of the NPDES discharge permit issued by ADEQ to the WWTP to reflect the additional discharge location. No objections to this change are anticipated because the WWTP already discharges to the creek without creating adverse water-quality impacts (Tott pers. comm.). The effluent quality already meets the standards for body-contact recreation. The wastewater-reclamation permit issued by ADEQ may also need to be revised, but objections are also unlikely.

Action 1 could slightly decrease the persistence of base flow in the lower part of Reach 5 if the existing WWTP discharge location remains in operation, because the total length of channel receiving flow from the WWTP would increase. This decrease could raise concerns regarding potential impacts on three listed wildlife species that might be present in Reach 5 (i.e., desert pupfish, Gila topminnow, and lowland leopard frog). A small decrease in flow in the lower part of Reach 5 is more likely to decrease the Canyon Well yield slightly than it is to decrease aquatic habitat. In addition, the new aquatic habitat created in the lower half of Reach 4 would replace any decrease in Reach 5. Therefore, the net impact on the sensitive fish and amphibian species would be less than significant.

Implementing Agency

Superior is the logical agency to implement and operate Action 1 because of its existing control and management of the wastewater.

Action 2: Discharge Reclaimed Water in Reach 2

Objective

This action would restore a small amount of the base flow that occurred in Reach 2 under pre-development conditions, and in so doing it would promote increased vigor and expansion of riparian vegetation in that reach.

Location and Description

A new pipeline would be constructed to deliver water from the WWTP to a discharge point somewhere along Reach 2. Two pipeline-route and discharge-point options are available, each with advantages and disadvantages. Option 1 would extend the existing reclaimed-water pipeline from the Little League field east along Sunset Drive to Highway 177 and then north to Queen Creek near the Magma Club. An old water-supply pipeline along Highway 177 that conveyed water from the Belmont Mine to Superior for potable supply was removed in 1998 as part of a package of mine-reclamation activities, and the pipeline is no longer available for conveyance of reclaimed water. The total length of new pipeline needed to reach the Magma Club would be 6,200 feet. With this option, most of the restoration effect would be concentrated toward the upper end of Reach 2.

Option 2 would install an entirely new pipeline from the WWTP along the main sewer easement that generally follows Queen Creek up to the Highway 60 bridge. From there, the pipe could pass under the bridge and past Community Park to a discharge point just upstream of the lower footbridge. This option would require about 7,200 feet of pipeline. One advantage of the second option is that it would focus restoration of live flow and riparian vegetation along the reach near Community Park, where it might be more visible to residents and visitors. Another advantage is that it could deliver reclaimed water for irrigation at Community Park and possibly also recirculate water from the proposed lake below the Highway 60 bridge, discharging it upstream of the park and allowing it to flow back down to the lake (see Action 6).

Initially, reclaimed water would be discharged at a rate of about 40 gpm, or 25% of the total WWTP discharge rate.

Net Change in Habitat

Vegetation Type	Change in Vegetation Area (acres)	Restored Canopy Density (%)
Mesquite	-8	45
Mixed-riparian forest	+3	60
Cottonwood–willow forest	+5	60

Under Option 1, canopy cover would still be incomplete in lower Reach 1 and upper Reach 2 (Magma Avenue bridge to Lobb Avenue footbridge) because exposed or shallow bedrock in the creek channel partially limits where trees can grow (Figure 5-4). Historical decreases in the duration

Figure 5-4. Riparian Vegetation along the Upper Half of Reach 2 is Limited by Shallow Bedrock and Inadequate Duration of Flow.

Figure 5-5. Artificial Fill and Drought Stress have adversely Affected Trees in Reach 2.

of the flow season have also caused drought stress and tree mortality further down Reach 2 (Figure 5-5) The discharge would probably support riparian vegetation all or nearly all the way to Highway 60. Under Option 2, vegetation response would be strong along the lowermost part of Reach 2 and taper off quickly in Reach 3, where relatively large seepage losses would quickly consume any remaining flow.

A vegetation-management program (see Action 11) should accompany Action 2 to avoid creating or exacerbating a flood risk. Generally, removing shrubby vegetation while retaining tall trees in and beside the channel would have less effect on upper-canopy birds (e.g., yellow warblers, orioles, Bell's vireos) than on shrub-dwelling birds (e.g., yellow-breasted chats, Gambel's quail, doves, thrashers). Cover for ground-dwelling mammals and reptiles would also be limited. Domestic cats, however, might limit the abundance of the mammal and reptile species even if shrubby vegetation were allowed to remain. As a result of floodway vegetation maintenance and the presence of predatory pets, the quality of the habitat created by Action 2 would be fair to good, depending on the species.

Cost

A recent pipeline installation in Superior cost $30 per linear foot for an 8-inch diameter PVC pipeline (Zapata pers. comm.). The cost savings for installing a smaller diameter pipe are typically a small percentage of the total construction cost. Using $30 as a conservative estimate of the per-foot cost, the Option 1 (extending the existing line from the little league field to the Magma Club) would cost about $186,000. Option 2 (a new pipeline from the WWTP to the Magma Club) would cost about $216,000. Additional costs would include engineering, environmental, and permitting work and for a pump station.

Action 2 would also incur substantial ongoing operational costs to pump reclaimed water from the WWTP to the lower footbridge or the Magma Club, which are 110 and 225 feet higher than the WWTP, respectively.

Funding Sources and Feasibility

Action 2 has a relatively high cost for the amount of habitat created, but the habitat would be highly visible and would offer substantial aesthetic and recreational benefits in addition to habitat value. Potential funding sources for habitat-restoration projects involving use of reclaimed water include a Title 16 grant from Reclamation and a revolving fund loan from the EPA. The action meets the urban-habitat criteria for partial funding by the AGFD's Heritage Fund. This action would be applicable to the AWPF criteria in restoring riparian habitat to the Queen Creek channel.

Impacts and Secondary Benefits

Restoration of vegetation in the downtown area (Reach 2) would substantially improve the visual aesthetics of the creek channel and would be a basis for developing recreational opportunities. The amount of water released to the creek would create pools and a trickle of flow in the creekbed, and the lush tree canopy would create an inviting, shady environment. Ideally, these physical changes would catalyze a change in public perception of the creek and elevate its status to a prized community resource that would be tended with pride. The increase in water supply for riparian vegetation would greatly facilitate landscaping of the Stone Avenue Park and the larger city park downstream.

Action 2 could impact the yield of the Canyon Well at the Arboretum in the same manner as Action 1. This effect would probably be small and could be mitigated by gradually phasing out releases to the WWTP wash, thereby substituting the relatively natural occurrence of riparian vegetation along Queen Creek for the highly unnatural occurrence along the WWTP wash. The remaining WWTP releases could be discharged at the midpoint of Reach 4 if Action 1 is also implemented, or the releases could be conveyed by a new pipeline from the WWTP directly to the point where the WWTP wash enters Queen Creek.

Action 2 should be implemented in conjunction with a floodway vegetation-management program (Action 11) to avoid increasing flood risk from increased in-channel vegetation.

Permits

Action 2 would require a modification of the WWTP's discharge permit to change the point of discharge. The level of treatment is already adequate for human contact, and relocation of the discharge point to a more upstream location would not raise significant water-quality issues (Tott pers. comm.). A Stormwater Pollution Prevention Plan (SWPPP) permit would also be needed from ADEQ to ensure that appropriate erosion-control measures are implemented during construction of the pipeline. Burying the pipeline where it crosses or follows the channel of Queen Creek would be covered under Nationwide Permit No. 12 for compliance with CWA Section 404. Notification of the USACE would not be necessary. However, ADEQ would probably require CWA Sections 401 water quality certification because the new discharge would create or affect a warmwater fishery. Landowner permission may be needed if segments of the pipeline route do not follow existing rights-of-way. Finally, for reasons similar to those for Action 1, there would be no impact on endangered species that might be present in Reach 5.

Implementing Agency

Superior would be the appropriate agency to implement Action 2 because it already operates the WWTP and owns the utility rights-of-way that the pipeline would follow.

Action 3: Return Freshwater Mine Inflow Directly to Queen Creek

Objective

Action 3 would restore some of the natural flow in Queen Creek by collecting streamflow that has seeped into the mine and discharging it back into the creek.

Location and Description

A substantial amount of stream base flow in Queen Creek is lost to seepage into underground mine tunnels and shafts. Because of the diffuse nature of the fracture system that allows water to seep from the creek into the mine, decreasing seepage losses by plugging the fractures is not feasible (see "Actions Considered but not Recommended"). One location, however, has fairly concentrated seepage and water quality is similar to that of creek water. About 150 gpm of fresh water seeps into the Neversweat Tunnel, which extends from the west-side mine workings near Superior to the Number 9 shaft on Apache Leap. The tunnel crosses below Queen Creek at a relatively shallow depth near the new Highway 60 tunnel in the canyon above Reach 1. Historically, about 50-60 gpm of this inflow has been collected for potable supply in the mine buildings, and the remainder is mixed with the mineralized deep groundwater that is pumped from the mine and treated.

Under Action 3, freshwater seepage into the Neversweat Tunnel that is not diverted for direct use in mine operations would be collected and discharged back into Queen Creek near the Magma Club. The Neversweat Tunnel slopes towards its main entrance on the hillside behind Superior, and collected seepage already flows to the entrance. This water would be conveyed by gravity through a new PVC pipeline to the creek. The amount of flow available for diversion to the creek averages about 90 gpm. The flow responds to rainfall events and is generally higher in winter than in summer. A 2-inch-diameter pipeline would be sufficient to convey the flow. If construction of a new dewatering water-treatment plant is anticipated, however, installing a larger (6-inch or 8-inch) pipe capable of conveying an additional 630 gpm would be prudent.

The fish is occasionally present in Reach 5 when overflow events wash a few individuals down from Ayers Lake at the Arboretum. Because of high losses to predation and frequently discontinuous flow in Reaches 3 and 4, the fish would not likely occupy the habitat in Reach 2 without deliberate reintroduction. Reintroduction of the topminnow is not included in Action 3 but is recommended for consideration after Action 3 has been implemented. USFWS encourages reintroductions into suitable habitat as part of the species recovery plan. However, several practical and legal issues need to be addressed prior to reintroduction. The new habitat must be protected from nonnative predatory fish that are present in many Arizona streams. The small perennial reaches and pools in the canyon above Reach 1 probably do not support such fish, but this should be confirmed by a survey. A fish barrier would need to be installed somewhere between Reach 2 and Reach 5 to prevent predatory fish from swimming upstream during periods of unbroken flow in the creek. A safe harbor agreement with USFWS needs to be reached with the agency implementing the reintroduction, and AGFD requires that reintroductions of listed species be approved by all landowners whose property is affected (Weedman pers. comm.), which in this case would be all of the landowners along the lower part of Reach 1, Reach 2, and possibly Reach 3.

Net Change in Habitat

Assuming that available flow ranges from 65 gpm in June to 115 gpm in January, the following increases in vegetation could be supported (See Action 1 for a description of the calculation methodology):

Vegetation Type	Change in Vegetation Area (acres)	Restored Canopy Density (%)
Mesquite	0	50
Mixed-riparian forest	+3.5	60
Cottonwood–willow forest	+3.5	60

New vegetation growth would be patchy between the Magma Club and the Lobb Avenue footbridge because of constraints imposed by exposed or shallow bedrock. Existing cottonwood and willow trees, however, demonstrate that trees will readily establish themselves wherever boulders or channel features provide some protection from scour and a pocket of alluvium provides some soil-moisture storage. Riparian vegetation would probably increase throughout Reach 2 and possibly uppermost Reach 3. Throughflow to Reach 3 would probably cease for a few months in summer.

As in Action 2, the resulting habitat quality in Reach 2 would be good but somewhat limited by the close proximity of people and domestic cats and by the need to remove shrubs, debris piles, and low branches to maintain flood-conveyance capacity. Canopy-nesting species, however, such as yellow warbler, Bullock's oriole, and summer tanager would benefit from the large increase in available habitat.

Cost

The principle cost of implementing Action 3 would be for construction of the pipeline from the entrance of the Neversweat Tunnel to the Magma Club, a distance of 4,800 feet. At a cost of $30 per linear foot, pipeline construction would cost $144,000. Tees, pressure reducers, energy dissipaters and other plumbing at either end of the pipeline could increase the total by $15,000. Engineering and permitting costs would be in addition to the noted amounts.

Funding Sources and Feasibility

BHP could provide construction equipment, labor, or both that would defray a significant fraction of the total project cost. The company's contribution could serve as matching funds for several grant and loan sources. The EPA's CWA 104(b)(3) grant program targets wetland-restoration projects, and this action would have the additional clean-water benefit of intercepting some of the mine seepage before it becomes mineralized. The EPA's revolving fund could support the project on the basis of its water-quality benefits. Because the mine is privately owned, the USFWS Partners for Fish and Wildlife program is a potential source of funding. The reasonable cost-effectiveness of this action and the fact that it restores natural hydrology as well as habitat could attract funding from AWPF and AGFD's Heritage Fund. Grant funding is generally not available for operation and maintenance costs.

Impacts and Secondary Benefits

The benefits of restoring riparian vegetation in the downtown area were described under Action 2. Briefly, increased flow and vegetation would encourage people to view the creek as an aesthetic community resource and would provide trees for the two city parks.

Action 3 should be implemented in conjunction with a floodway-vegetation management program (Action 11) to avoid any increase in flood risk associated with increased in-channel vegetation.

Permits

BHP's existing NPDES permit for discharge of dewatering water to Queen Creek would need to be modified to include the new discharge location and quality. Because of the good quality of the collected water, no regulatory objections are expected. If construction of the pipeline to convey the collected water to the creek disturbs more than 5 acres, a SWPPP approved by ADEQ would be needed.

Implementing Agency

BHP would be the best organization to implement Action 3 because it would affect, almost exclusively, mine facilities and mine property. Superior would be responsible for floodway-vegetation management and could assist BHP in obtaining permits and funding to implement the project.

Action 4: Install a New Mine Dewatering Treatment System and Discharge Pipeline to Reach 2

Objective

Action 4 would increase base flow in lower Reach 1, Reach 2, and upper Reach 3, which would promote the development of a healthy riparian corridor of cottonwood–willow and mixed-riparian vegetation.

Location and Description

If exploration or active mining is resumed, the mine is expected to convert the treatment method for dewatering water to a new system that does not require storage of the treated water. The treated water would be discharged to Queen Creek immediately after passing through the treatment process, and BHP's preferred discharge point is near the Magma Club (Lira pers. comms.). A new pipeline would be installed to convey the water about 5,200 feet from the existing water-treatment plant near the northern edge of town to the Magma Club.

In addition to discharging at a fairly steady rate, the new treatment system would discharge a substantially larger volume of water on an annual basis than is discharged from the existing ponds because there would be no losses of water to evaporation and seepage in storage ponds. These losses have historically consumed half the water pumped from the mine. The details of the new treatment process have not been disclosed, and so it is not yet clear whether the quality of the treated water will be different from the water presently discharged to the creek. Because the discharge would still be regulated by ADEQ under an NPDES permit, the quality would presumably be high enough to prevent adverse impacts to aquatic and riparian habitats.

The depth of flow created by Action 4 at the paved Stone Avenue and Mary Drive road crossings would be only a few inches, so that it would not create substantial safety or water-quality problems. Depending on the amount and duration of increased flow at the unpaved Airfield Road crossing, a culvert may be desirable there.

Action 4 would create more new streamflow than any other action. The magnitude and persistence of flow below the Magma Club would be sufficient to support Gila topminnow, a federally-listed endangered fish. The fish would not likely occupy the habitat in Reach 2 without deliberate reintroduction. Reintroduction of the topminnow is not included in Action 4 but is recommended for consideration after Action 4 has been implemented. Practical and legal issues that would need to be addressed prior to reintroduction are described under Action 3.

Net Change in Habitat

The discharge rate would equal the dewatering rate at all times. The dewatering rate reportedly averages about 1.1 cfs, increasing moderately during wet periods and decreasing during summer and dry years. Informal conversations with mine staff (Lira pers. comm., Smith pers. comm.) indicate that the range of variation in the dewatering rate is estimated to be ±25%, or between about 0.8 cfs in dry years and 1.4 cfs in wet years. This discharge would create nearly year-round live flow from the Magma Club to the WWTP wash at the bottom of Reach 4, except for a possible gap in the middle of Reach 3 where high seepage rates might shunt the flow entirely underground. These discharge rates are 2-4 times larger than the existing WWTP discharge, and the vegetation response would be dramatic. The following changes in vegetation would be distributed along the lowermost Reach 1 and along Reaches 2, 3, and 4 (see Action 1 for a description of the calculation methodology):

Vegetation Type	Change in Vegetation Area (acres)	Restored Canopy Density (%)
Mesquite	-48	45
Mixed-riparian forest	+24	60
Cottonwood–willow forest	+24	60

The habitat quality created by the vegetation would be high because the ample supply of water would support rapid growth and a full multilevel canopy. The continuity of the riparian vegetation along a long reach of the creek and its connection with the existing high-quality vegetation along Reach 5 would enhance the mobility of wildlife along the creek.

This action is the only one likely to create a relatively lush riparian corridor along Reach 3. Vegetation management to maintain flood conveyance capacity would be needed along Reaches 2 and 3, although removing brush, low tree limbs, and debris piles would somewhat diminish the otherwise excellent habitat value for certain types of animals (see Action 11).

Cost

Assuming a cost of $30 per linear foot, the construction cost of the pipeline would be $156,000. The cost of the new treatment plant is not known. The dewatering water could flow by gravity from the new treatment plant to the discharge point near the Magma Club, and so there would be no ongoing operational costs for pumping. If Action 3 is implemented before Action 4, a pipeline would already be in place between the Neversweat Tunnel and the creek, and only a 600-foot additional segment would be needed between the treatment plant and the Neversweat pipeline. This option would cost only $18,000 to install.

Funding Sources and Feasibility

BHP intends to install the new treatment plant and pipeline independently of this planning effort, assuming that the mine returns to active operation (Lira pers. comm.). Because of the riparian-habitat benefits of this action, however, several grant programs might support the effort. The action could attract funding from Reclamation's Title 16 or the EPA's revolving fund because it improves the use of wastewater to create habitat. AGFD's Heritage Fund might contribute partial funding because the action would meet the fund's urban-habitat objective. This action would meet AWPF criteria in providing supplemental available water for riparian restoration within the Queen Creek channel.

Impacts and Secondary Benefits

The increased growth of riparian vegetation would require a vegetation-management program to maintain flood-conveyance capacity (see Action 11). Unlike Actions 2 and 3, however, Action 4 would require vegetation management in Reach 3 in addition to Reach 2. Although the increase in base flow would be large relative to the water needs of riparian vegetation, it would be negligible compared to the floodflows. For example, the increase of 1.4 cfs in wet years would be <0.02% of the 11,400 cfs flow estimated for a 100-year flood.

The increased flow and vegetation would benefit landowners of riparian areas who use the corridor for grazing. The flow increase could have effects as far downstream as the Arboretum, where the Canyon Well yield would be beneficially increased.

The long corridor of healthy riparian vegetation would be visible from Highway 60 and many other places in and near Superior. This vegetation would create the impression of a substantial "oasis" in the desert surroundings. The lush riparian corridor could also provide developing recreational opportunities at the two city parks and possibly hiking trails along Reaches 3 and 4.

Discontinuing use of the dewatering storage ponds would eliminate the seepage that has historically sustained several acres of habitat along Magma Wash 1 near Pinal Avenue. Mesquite, palo verde, acacia and other upland shrubs commonly found in desert washes would gradually replace the cottonwood–willow vegetation. The mine, however, is not required to continue dewatering and in fact already discontinued it indefinitely as of May 1998. Thus, this secondary impact would not be the result of Action 4 but rather of mine management decisions beyond the control of this planning effort.

Permits

Modification of the dewatering water-treatment process and the point of discharge to Queen Creek would require changes in the NPDES permit and the Wastewater Reuse Permit issued to BHP by ADEQ. Construction of a pipeline from the new treatment plant to the top of Reach 2 could require a SWPPP approved by ADEQ, depending on the amount of ground disturbance. Installation of a culvert under Airfield Road would be covered under Nationwide Permit No. 14 for compliance with Section 404 of the CWA. The floodway vegetation-management program (Action 11) would require the approval of the Pinal County floodplain manager.

AGFD Gila topminnow specialist, Dave Weedman should be consulted further on this to help determine if a safe-harbor agreement will be necessary. A safe-harbor agreement would be necessary if the AGFD determines that Gila topminnow populations at the Arboretum are able to travel to and survive in reaches augmented with supplemental flows from the mine piped into Reach 2 of Queen Creek.

Implementing Agency

BHP is the logical agency to implement Action 4, and the company has expressed an interest in doing so if the mine returns to active operation. Superior could support the mine by co-applying for grant funds to implement this action.

Action 5: Install Wells for Riparian Irrigation and Supplemental Streamflow

Objective

Action 5 would restore small areas of riparian vegetation at strategic locations along the creek to generate public support for further restoration activities.

Location and Description

One obstacle to restoring riparian habitat along Queen Creek is a lack of widespread public awareness of the value and feasibility of restoration. No amount of written promotional material would be as effective in changing public perception of the creek as would a highly visible demonstration project. A small, readily available, and reasonably affordable supply of water is needed to irrigate small areas of riparian vegetation to demonstrate restoration possibilities and create public amenities that would galvanize public support for creek enhancement.

Two logical locations for restoration are the two city parks that adjoin the creek. Stone Avenue Park occupies 0.5 acre of creek terrace at the Stone Avenue creek crossing. It is highly visible from Main Street and has some cottonwood trees in moderately good condition (Figure 5-6). Additional cottonwood or sycamore trees could be planted to create shade. With additional landscaping, they could create a cool, inviting park environment featuring native trees and the creek. Community Park, accessed from Highway 60, includes a 4.5-acre, low stream terrace that has been cleared and is well suited for riparian vegetation (Figure 5-7). Tree seedlings in the adjoining channel appear vigorous, suggesting that shallow groundwater is present. Additional trees could be planted on the terrace if irrigation could be provided during the first few years after planting. A grove of cottonwood and sycamore trees along the creek bank could be integrated into an overall park design that would provide a natural environment immediately adjacent to more developed park areas. Park visitors would experience first-hand the aesthetic beauty, shade, and wildlife abundance provided by restored riparian areas. Construction of park facilities to complement the riparian restoration would be a separate action (Action 12). A revegetation plan outlining the types and locations of plants that would be installed and the design and operation of the irrigation system is presented in Appendix E.

Finding a water supply would be critical to success of demonstration projects, and groundwater would be the best option. The average annual irrigation requirement for the 3.3 acres of cottonwood trees distributed between the two parks would be about 15 af/yr. On the one hand, several other water-supply options would be available for irrigating the new riparian vegetation, but they would be expensive, would require substantial lead time to implement, or would be of uncertain availability. The first option, municipal water, would have a prohibitively high cost for an irrigation supply ($3.37 per 1,000 gallons). The annual cost for irrigating the cottonwoods with municipal water would be about $16,200. The second option, reclaimed water, would be available in limited supply and would require an expensive pipeline to deliver it to the park areas (see Action 2). The third option, mine-dewatering water from a new treatment plant, would not be available for at least several years and could be subsequently discontinued if the mine ceases active operation. Thus, none of these sources are ideal for an initial demonstration project.

Groundwater, on the other hand, would be an ideal water-supply option for demonstration projects at the parks. The small yields typically achieved by domestic wells in Superior would be adequate to meet the irrigation needs of the demonstration projects, and any extra yield could be used to create short reaches of live flow in the creek, which would help to grow additional vegetation. Wells are relatively inexpensive and could be installed quickly. For Action 5, one well would be installed at each of the parks. The wells would be screened at more than 150 feet below the ground surface to avoid directly depleting the shallow groundwater zone that presently supports vegetation along the creek. Wells yield 5 gpm or less in the northern part of Superior near the mine. A single well pumping of a rate of 5 gpm continuously would yield 8 af/yr.

Existing makeshift dirt berms 3-5 feet high along the top of the low-flow channel at both park sites would be removed to restore the connection between the creek channel and the adjoining stream terrace. Removal would improve the long-term viability of restored vegetation and greater integration of riparian habitat into the adjoining park areas.

Figure 5-6. A Well would be used for Rapid Establishment of Cottonwoods at Stone Avenue Park.

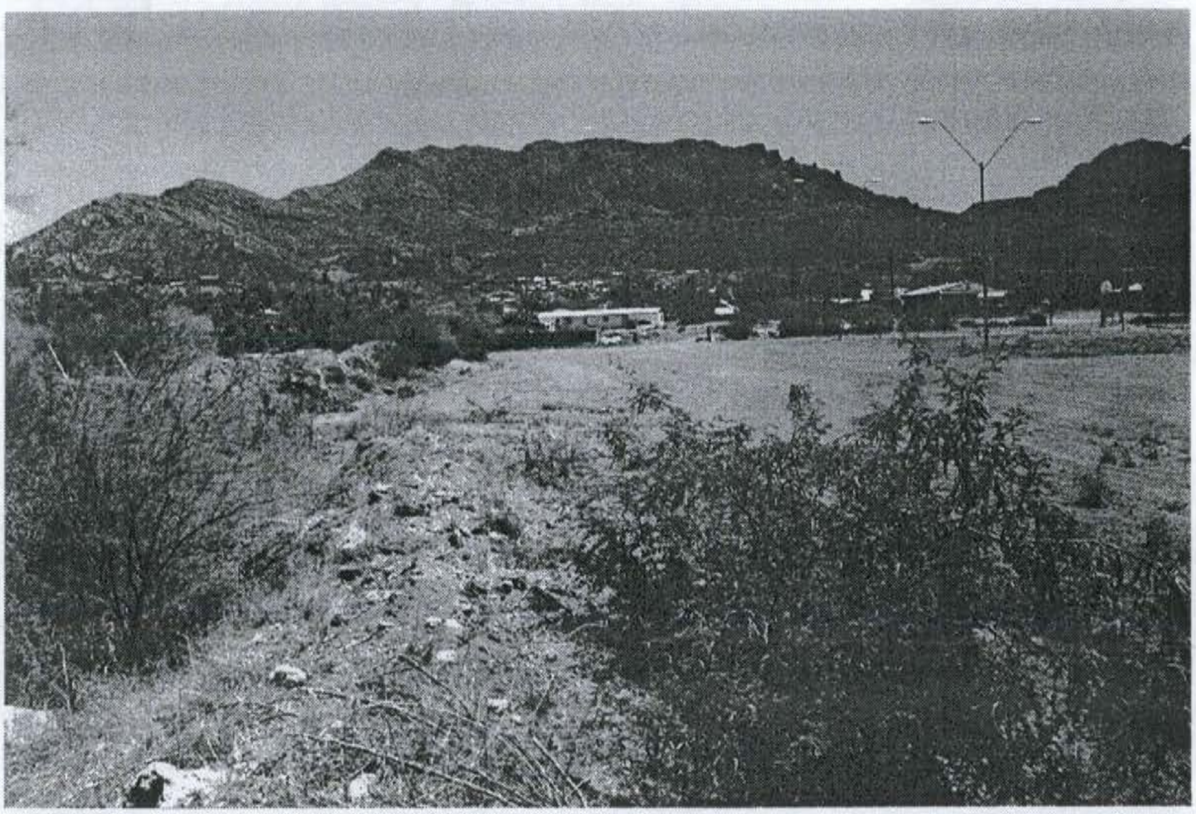


Figure 5-7. At Community Park, a Band of Riparian Trees would Replace the Artificial Berm and the Adjoining Margin of the Graded Area.

Net Change in Habitat

The amount of riparian vegetation that Action 5 would establish depends on the landscape design of the two parks and the yields achieved by the two wells. The minimum area would be about 3.3 acres of cottonwood and sycamore vegetation in areas presently unvegetated or populated by non-native shrubs and trees.

Cost

A 250-foot-deep well capable of producing 1-10 gpm (depending on geologic conditions) would cost about $10,000, including the pump and a small storage tank (Beeman pers. comm., Laveen pers. comm.). Additional costs for engineering, connection to a power supply, and irrigation pipes would probably bring the cost to around $15,000 each. Two wells would cost less than a single well with a pipeline connecting the two parks, and they would yield more water. Site preparation and planting could cost about $10,000, for a total cost of $40,000 for both sites. Costs for a storage tank and pump to allow use of the well for sprinkler irrigation and for facilities such as paths, lighting, interpretive signs, and other park amenities would be covered under Action 12.

Funding Sources and Feasibility

Several sources of funding could be available for Action 5. The EPA's CWA 104(b)(3) grant program targets wetland-restoration demonstration projects like this one. The urban location of the restoration sites could attract the interest of AGFD's Heritage Fund grant program. The action could also qualify for funding under Reclamation's Title 16 grant program, although the action does not involve water reuse. This action may meet AWPF criteria for riparian habitat restoration if it can be demonstrated that the tree planting associated with the parks would contribute wildlife habitat and be self-sustaining on groundwater after a temporary period of well irrigation.

Impacts and Secondary Benefits

The well screens should be installed deeply enough to prevent direct withdrawal of shallow groundwater that presently supports riparian trees along the creek channel. Although the deeper zone that would be tapped by the wells is not entirely isolated from the shallow zone, the low permeability of the intervening geologic materials would buffer the effects of pumping and spread them over a larger area and a longer period of time. The amount of pumping for irrigating the cottonwoods (15 af/yr in an average year) is relatively small compared to pumping at the Arboretum well (40 af/yr) or pumping to dewater the mine (434 af/yr). Therefore, the potential for a small, dispersed adverse impact on existing riparian vegetation would be more than compensated by the two tracts of healthy riparian vegetation that would be achieved through use of the groundwater for irrigation. Ideally, groundwater pumping for irrigation would be only a temporary measure. After a few years, the trees should be able to survive without supplemental irrigation, and eventual augmentation of streamflow in Reach 2 with reclaimed water or mine-dewatering water would also render long-term irrigation unnecessary. Thereafter, the wells could be used to meet other irrigation demands in the parks.

The groundwater that would be withdrawn under Action 5 presently contributes to the overall groundwater supply in the East Salt River Valley subbasin of the Phoenix AMA. That supply would decrease by the amount of water consumed by the irrigated riparian vegetation under Action 5, which would be almost all water pumped from the wells. Presumably, if the Phoenix AMA administrators permit the withdrawal, this impact would be acceptable.

Vegetation in the restoration demonstration areas would be within the 100-year floodplain of Queen Creek and should be managed to prevent an overall increase in flood risk. Management could be achieved through implementation of Action 11.

Permits

ADWR has the authority to regulate groundwater pumping in the Phoenix AMA. The Phoenix AMA may also be involved in the review of requests for pumping permits, depending on the size and intended use of the well. The well at the Stone Avenue Park would fall under the small-well exemption because annual pumping would be only about 2.5 af/yr. The irrigation demand for restoration at the Community Park is about 12.5 af/yr. The restored area could be decreased to a size that could be supported with 10 af/yr of applied irrigation, which would allow the Community Park well to be exempt, as well. Alternatively, part of an existing Type II grandfathered right could be leased from an existing user. The Arboretum was able to purchase Type II water rights from other users in the Phoenix AMA when it installed the new well at the Arboretum in 1997 (Dion pers. comm.). One well owner in Superior who uses less than his allotment has an irrigation Grand-fathered Right. However, it is probably is not worth shopping for Type II water rights until the wells have been drilled and the yields tested. If the yields are <6.2 gpm, the wells cannot produce more than 10 af/yr. If the well yield limits the amount of irrigable acreage at Community Park, restoration could be done in phases. After several years, the trees would become self-sustaining and irrigation could be switched to a new batch of seedlings.

Installation of new wells also would require approval of the Pinal County Department of Environmental Health. This approval would ensure that proper seals are included in the well construction to prevent aquifer contamination and protect public health. Water conservation requirements may also apply, even if the well is small and exempt from water allotment regulations. A Floodplain Use Permit would be needed from the Pinal County floodplain manager. There are no known cultural resources at either site, but the SHPO should be notified in advance of drilling, and surveys could be required.

Removal of the makeshift dirt berms along the top of the creek bank at both sites could be covered under CWA Section 404 Nationwide Permit No. 27 for restoration activities.

Implementing Agency

Action 5 would be implemented by Superior, which owns the restoration sites and would operate the wells.

Action 6: Construct an Off-Channel Stormwater Lake in Reach 3

Objective

Action 6 would create open-water, wetland, and riparian habitats in and along the perimeter of a constructed lake adjacent to Queen Creek. In contrast to all other actions, Action 6 would seek to increase the total amount of water available for restoration by capturing and storing stormwater runoff. It also would be the only action that creates wetland and lake habitats. The project planning team received input from some Superior residents that this action item should be implemented only after the successful implementation of action items that will require less effort.

Location and Description

A lake would be constructed on the left bank of Queen Creek immediately downstream from the Highway 60 bridge by building a berm between the channel and an existing broad, low floodplain terrace (Figure 5-8). A large culvert would fill the lake; the culvert would extend about 400 feet upstream and pass under the Highway 60 bridge to a lateral weir that would be constructed at the edge of the low-flow channel downstream from Community Park (Figure 5-9). During large storms, some local flow would also come from Cross Canyon. A gated, low-level outlet would be installed through the berm at the southwest corner of the lake to allow throughflow of water when sufficient flows are available in the creek and to allow the lake to be drained for maintenance or repairs. A concrete-and-boulder spillway also would be incorporated into the berm near the southwest corner of the lake. Material for the berm would be excavated from the lakebed area, and clay would be added as needed to achieve proper compaction, cohesiveness, and strength.

The maximum lake elevation would be about 1,902 feet above sea level. The lake would occupy the southern two-thirds of the floodplain area and have a surface area of about 4.5 acres. The water depth when the lake is full would increase gradually from northeast to southwest, reaching a maximum depth of about 18 feet when full.

Seepage losses would be high unless clay or plastic liner is installed in the lakebed. The rapid transition from phreatophytic riparian vegetation along the lower end of Reach 2 to the moderately sparse mesquite bosque in Reach 3 indicates that soil permeability is high and that the water table drops steeply as the creek enters the unconsolidated alluvial deposits along Reach 3. .

The feasibility of maintaining the lake in a generally full condition under a variety of climatic conditions using only diverted streamflow as a source of inflow was investigated using a spreadsheet lake-operations model. The model tracked the daily water balance of the lake during a 14-year period and accounted for streamflow at the diversion point near Community Park, well pumping into the lake, seepage losses from the lake, evaporation, rainfall onto the lake surface, and spills (overflows) back into Queen Creek. Details of the model and selected simulation results are presented in Appendix B.

Simulation results indicated that the lake would dry up in autumn of almost every year unless seepage losses were reduced and supplemental streamflow were provided at the diversion point. Graph A in Figure 5-10 shows simulated lake storage during water years 1962–1974, the period for

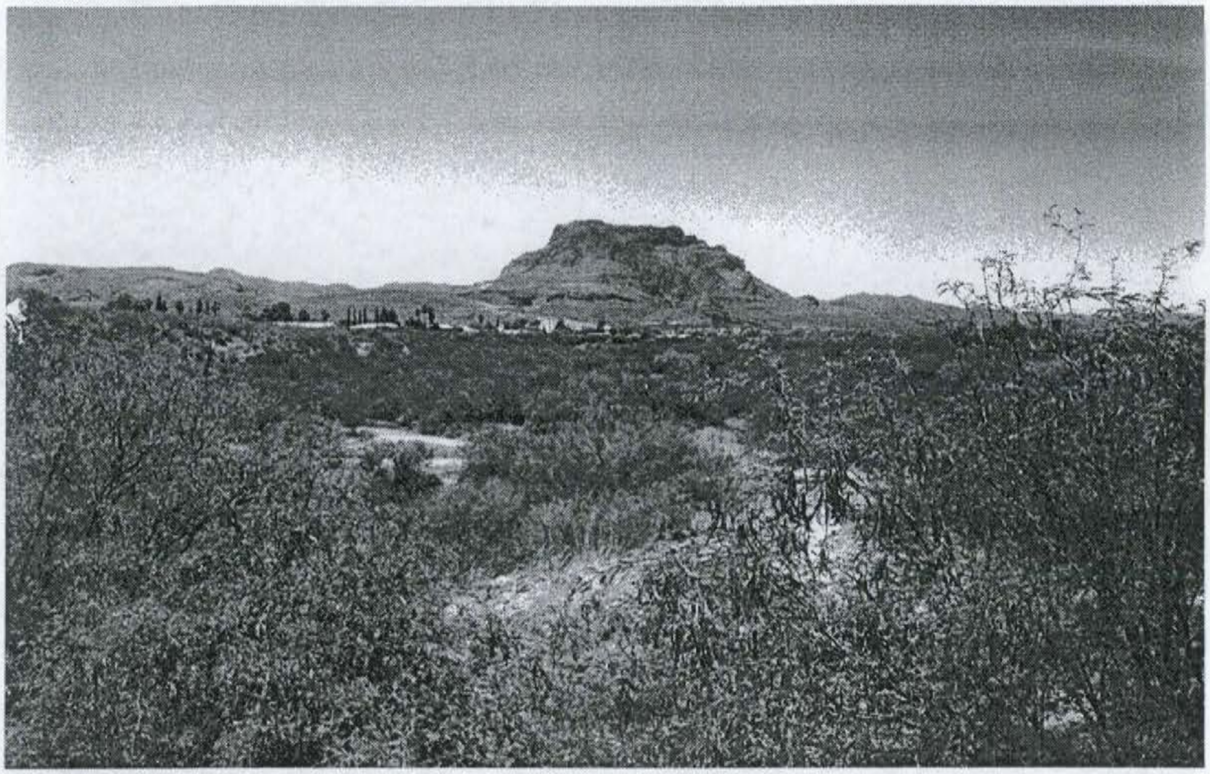
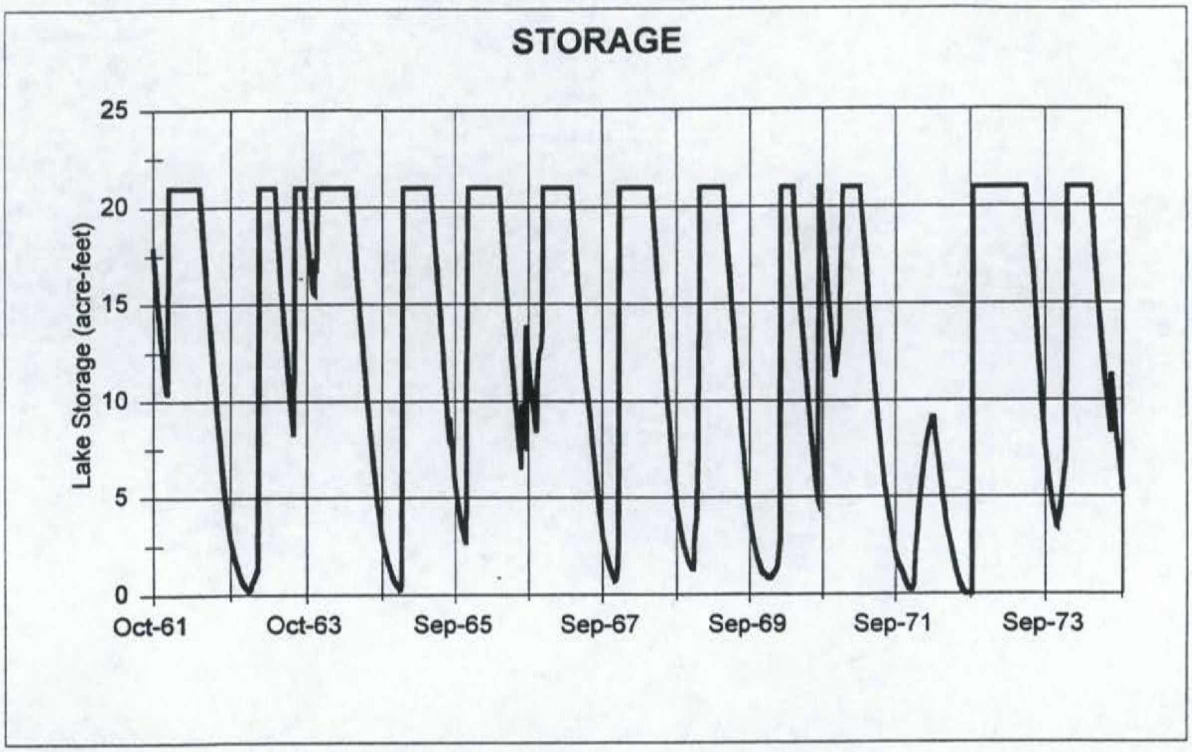
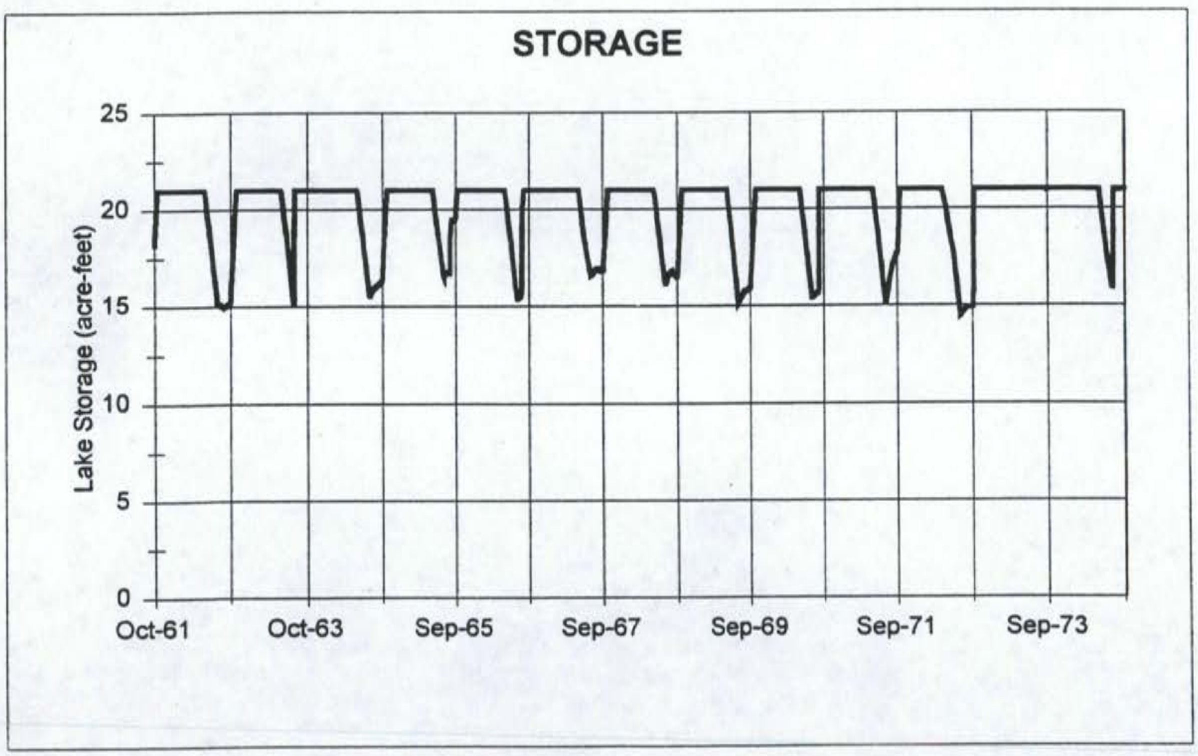


Figure 5-8. The Lake would be Located on this Low Floodplain Terrace Presently Occupied by Mesquite.

Figure 5-9. The Lake Intake Culvert would Pass under the Highway 60 Bridge.



A. Simulated Lake Storage with Default Parameters



B. Reduced Seepage, Neversweat Tunnel Discharge to Queen Creek, and Well Inflow

Figure 5-10. Simulated Lake Storage with Default Parameters and with Measures to Enhance the Water Balance which estimated streamflows in Queen Creek could conveniently be developed. Simulation indicated that the lake would remain full for 4-5 months in winter, when sufficient streamflow would be available to replenish losses to evaporation and seepage. Lake storage would plummet, however, when natural streamflow ceased, and the lake would become dry by autumn.

A number of strategies were simulated for maintaining the lake in a more nearly full condition year-round:

- lining the lakebed to decrease seepage,

- increasing the maximum diversion rate to capture higher flows,

- supplementing Queen Creek flow with water released from the Neversweat Tunnel (see Action 3), and

- pumping 10 af of groundwater into the lake during August through October from a new well next to the lake.

Increasing the maximum diversion rate provided no additional benefit. Individually, the other three strategies provided some benefit, but storage still would decline to only 25% of capacity in most years. Simulation indicated a combined strategy of both reducing seepage and adding Neversweat Tunnel discharge to the creek would maintain the autumn lake level at about 50% of capacity. Further, addition of a well would provide a limited amount of water, but during the most critical season. It would keep autumn lake levels at an acceptable 75% of capacity (see Graph B in Figure 5-10).

The decrease in lake area associated with a 25% decrease in lake storage could be minimized by recontouring the shallow (northern and eastern) edges of the lakebed. Creating a steep lakebed slope around the entire perimeter of the lake would minimize the decrease in lake surface area resulting from each incremental decrease in storage. For the safety of swimmers and waders, the steep lakebed should not include an abrupt drop-off. Maintaining a large lake surface area would be beneficial for supplying soil moisture to shoreline vegetation in summer and fall and would enhance the year-round appearance of the lake as well.

It should be noted that the ADWR Phoenix AMA has reviewed this action item and noted that the evaporation rates used for modeling the lake are less than those used by ADWR. For this reason, more groundwater may need to be pumped to make this action feasible. More groundwater pumping would jeopardize the exempt status of the proposed well and limit the feasibility of this project unless an alternate water source is located.

The lake created under Action 6 could potentially serve as habitat for the Gila topminnow, a federally-listed endangered fish. Although its natural habitat is primarily creeks, it also inhabits lakes and is found in Ayers Lake at the Arboretum (Petrie pers. comm.). The fish would not occupy the new lake without deliberate reintroduction. Reintroduction of the topminnow is not included in Action 6 but is recommended for consideration after Action 6 has been implemented. The principal practical issue to be resolved would be excluding nonnative predator fish from the lake. A fish barrier at the intake might be sufficient to exclude adult predators under normal operations, but eggs and fry might still pass through. Fish could also enter during floods, when Queen Creek inundates the floodplain area where the lake would be located. Finally, anglers might intentionally introduce popular game fish into the lake. Regulatory issues surrounding deliberate reintroductions of listed species are described under Action 3. The AGFD would need to be involved in any proposed introduction programs of Gila topminnow into the lake because they oversee the status of this species throughout the state.

Net Change in Habitat

Cottonwood–willow riparian vegetation would probably grow along the shoreline of the lake. On the relatively steep slopes of the natural bluff at the south edge of the lake and the berm along the west edge, the band of vegetation would probably not exceed the width of a tree canopy (about 30 feet). The shoreline would probably advance and retreat substantially on the shallow slopes along the northern and eastern edges of the lake. A broader zone of riparian vegetation, perhaps 100 feet in width, would probably develop along those shoreline segments. The total area of cottonwood–willow riparian vegetation likely to become established would be 2.8 acres. Cattails may occupy shallow-water areas if lake-level fluctuations do not routinely exceed 5 feet during a typical year. The upper parts of the berm separating the lake from the creek channel would support mesquite. The existing vegetation on the floodplain consists almost entirely of sparse mesquite shrubs. About 8 acres of mesquite would be converted to open water, cottonwood–willow vegetation, and berm slopes.

Lake habitat is rare in Arizona, and so its value would be disproportionate to its small size. The vegetation around the lake would remain in excellent condition because of its proximity to a perennial water source. Recreational use and predation by cats from surrounding residential areas could somewhat diminish the habitat value for wildlife.

Cost

The primary construction cost for Action 6 would be for the berm. Assuming a 20-foot crown width and 3-to-1 slopes to minimize erosion potential and allow for unrestricted vegetation growth on the berm, nearly 15,000 cubic yards of dirt would be moved and compacted during construction. If clay were added to the core of the levee to increase its strength, obtaining and incorporating it would be an additional expense. Clay deposits exist near Superior, but the only surface exposure is dedicated to mine reclamation purposes. Other construction-cost items would include the lateral intake weir, consisting of a low retaining wall along the east bank with a 36-inch inlet port located slightly above the creekbed and a buried well screen for capturing very low flows; 400 feet of 36-inch-diameter culvert; a gated lake-outlet pipe with riser; and the concrete-and-boulder spillway. The intake culvert would be buried and armored with boulders to avoid scour during floods.

The total cost for constructing the berm, intake weir and culvert, outlet pipe, and spillway would be about $250,000. This estimate is based on locally adjusted 1999 unit costs for heavy construction work (R. S. Means Company 1999). Based on costs for a 10-acre artificial lake in the nearby Town of Kearny, a PVC plastic liner (30 mil thickness everywhere except near the shoreline, where 60 mil would be used) laid over a geotextile fabric for puncture protection would cost approximately $130,000 for the 4.5-acre lake proposed in Action 6.

Installing a 3-foot-thick clay liner would increase the cost about sevenfold, even if a local clay deposit is freely available for excavation. Further evaluation of soil permeability at the lake site and the cost of alternative seepage-reduction strategies should be completed before selecting a final lake design.

A well located at the exterior toe of the berm near the southwest corner of the lake and capable of producing 10 af/yr of supplemental water for the lake would cost about $20,000, including extension of power service to the site and installation of well-discharge piping. During the early years of lake operation, the well could supply a temporary irrigation system to establish vegetation on the newly constructed berm.

Operating costs for the lake would be minimal. The flow of water into and out of the lake would be entirely by gravity. The electricity cost for pumping 10 af/yr of water from the well would be about $70. The intake weir and outlet gate would need occasional adjustment to divert flows of the desired magnitude and to provide lake throughflow when flows are sufficiently large. A lateral weir with a crest above the bottom of the creekbed would not accumulate excessive sediment, but the intake pipe might need to be cleaned occasionally.

Funding Sources and Feasibility

Strictly speaking, Action 6 creates rather than restores lake and riparian habitat, but the ecological benefits would be valuable nevertheless and would justify funding under various programs. The EPA's CWA 104(b)(3) grant program could support the action as a demonstration restoration project. It would also meet the criteria for funding under Reclamation's Title 16 grant program, even though it does not involve effluent reuse. The proximity of the lake to Superior and the Highway 60 commercial area would meet the AGFD Heritage Fund's objective of creating habitat in urban areas. It should be noted that funding the implementation of this action may be considered inconsistent with AWPF goals (Swanson pers. comm.).

Donation of the land by BHP could serve as matching funds for any of the aforementioned grants.

The State Lake Improvement Fund administered by Arizona State Parks is limited to lakes with a surface area of at least 100 acres. The proposed lake would have a surface area of about 4.5 acres and therefore would not qualify for funding.

Impacts and Secondary Benefits

The large stream terrace on which the lake would be located does not contribute significantly to conveyance of floodflows in Queen Creek because it extends along only a short reach between the Highway 60 bridge and the natural bluffs 600 feet farther downstream. It forms an embayment during large floods. Its ineffectiveness for conveying floodflows was tested in the HEC-RAS flood hydraulics model by introducing a simulated levee following the alignment of the berm that would be constructed to create the lake (see Appendix B). The simulated levee would have been high enough to prevent overtopping during a 100-year flow event and raised the 100-year flood stage in the creek by <1 foot relative to the unrestricted simulation.

The lake site is presently owned by BHP. Construction of the lake would permanently alter potential future uses of the property. There is little potential for urban development on the parcel, however, because it is located in the active floodplain of Queen Creek. If recreational access to the lake is desired, it would be sensible to transfer the land to public ownership.

Evaporation from the lake would be a new consumptive use of water. It would decrease the amount of water available for instream flows, riparian vegetation, and groundwater recharge downstream from the lake. The surface area of the lake is smaller than the combined surface areas of the dewatering water ponds operated for decades at the mine, however, so that average annual net evaporation from the lake would be only 30 af, or 2% of the average annual discharge of Queen Creek.

Flow in Queen Creek at Highway 60 is too intermittent to support a fishery. Small fish are present farther downstream near Old Pinal Townsite, but the base flow that sustains those fish derives from WWTP discharges and in fluent groundwater seepage rather than from the higher flows that would be partially diverted to supply the lake. Thus, Action 6 would have little if any impact on fish.

A major sewer main crosses the floodplain terrace at the foot of the Highway 60 embankment. By restricting the lake to the lower, southern part of the terrace, access to the sewer would not be restricted by the lake.

The lake would provide tremendous aesthetic benefits to town residents and motorists on Highway 60. The lake and its surrounding riparian vegetation would be easily visible from the highway and from the new rest area presently under construction between the Highway 60 bridge and the commercial buildings to the east. Easy access from the rest area to the terrace north of the lake would offer opportunities for recreation. Shade trees, a picnic area, a trail around the lake, and even fishing-access points could be integrated into the site to provide park-like amenities that complement the habitat restoration.

Permits

Landowner support of the project would be essential and should be obtained before any further engineering or permitting work.

Construction of the berm to impound the lake would require a floodplain-use permit from the Pinal County floodplain manager, who would review and confirm the analysis of impacts on flood stages. A SWPPP approved by the ADEQ would be required for erosion control during construction. Cultural artifacts possibly could be unearthed during excavation of material from the lakebed area to build the berm. Compliance with ASHPA and NHPA Section 106 is routinely required as part of the process for obtaining a CWA Section 404 permit and would ensure that no cultural resources are destroyed.

Diversion of water from the creek to the lake would require an appropriate surface-water right and reservoir permit from the ADWR. This reservoir permit would require that the applicant show recreational and wildlife benefits from the proposed reservoir. Dams are regulated by the Dam Safety Division of the ADWR when they are at least 25 feet tall and contain at least 15 af of water. They also regulate dams 6 feet or more in height when they contain a minimum of 50 af of water (Cox pers. comm.) The proposed lake would have a dam height of 16 feet and a maximum storage capacity of 24 af; therefore, it would not require regulation under the Dam Safety Division of the ADWR. The intake weir and the culvert under the Highway 60 bridge would require a CWA Section 404 permit from the USACE, and the Arizona Department of Transportation (ADOT) would need to approve the use of its right-of-way.

It is generally illegal to artificially refill lakes with groundwater in Arizona, pursuant to the "Lakes bill" passed by the legislature in 1987 (Arizona Revised Statutes §45-125 et seq.). However, the statute creates exemptions for selected circumstances, one of which is for lakes "located in a recreational facility that is open to the public and owned or operated by ... a city, town or county" (ARS §45-125.B.3.). Therefore, title to the property on which the lake would be built would need to be transferred from BHP to the Town of Superior in order to legalize use of a well to provide supplemental lake water.

Removal of mesquite from the floodplain would require a harvest permit under the Arizona Native Plant law. This project would remove one protected plant species (mesquite) to establish other protected species (i.e., cottonwood, ash, willow, walnut). The change in downstream-flow regime caused by the diversions could warrant an analysis of potential impacts on desert pupfish, Gila topminnow, and lowland leopard frog. Habitat for those species, however, would almost certainly be limited by the availability of perennial low flow, and Action 6 would divert water only during periods of relative high flow.

Implementing Agency

This action could not be permitted unless the land ownership was transferred to the Town of Superior. In which case, the town would be the lead agency. The Town of Superior would also be the lead agency to initiate permitting and fund-raising efforts.

Non-Flow-Dependent Actions

Actions 7-11, which are described in this section, would help to restore habitat, but they would not depend for implementation on the availability of increased water flows.

Figure 5-11. Dumping, Fill, and Trash Detract from the Habitat Valve and Aesthetic Quality of the Creek Channel.

Funding Sources and Feasibility

Action 8 would be well suited for funding through the EPA's revolving fund because it targets sanitation (and by implication water quality) as means of enhancing habitat quality. Other programs that fund a variety of habitat-improvement activities might support this action, including the EPA's CWA 104(b)(3) grant program, AWPF, and AGFD's Heritage Fund. Cleanup activities on private land could qualify for funding under the USFWS Partners for Fish and Wildlife program. Youth-employment programs may also qualify for additional sources of funding.

Impacts and Secondary Benefits

To the extent that trash in the creek channel includes broken glass, sharp metal and similarly hazardous materials, the creek-cleanup program could also provide public-health benefits. Water quality could also be improved if liquid wastes are dumped in the creek channel less frequently. Involving the community in cleanup activities would create an awareness that would decrease dumping and littering.

Permits

No permit would be required to implement the measures suggested for Action 8.

Implementing Agency

Action 8 would be implemented by the Superior, with volunteer assistance from riparian landowners, local businesses, and citizen groups.

Action 9: Implement a Program to Remove Exotic Vegetation

Objective

Action 9 would improve the quality of riparian habitat by minimizing the encroachment of invasive non-native (exotic) vegetation that tends to outcompete native plant species and diminish the habitat value for wildlife.

Location and Description

Ailanthus (Chinese tree of heaven), tamarisk, arundo, and oleander are common exotic-plant species found along Queen Creek. Ailanthus is the most abundant and appears to be spreading rapidly, especially in the lower half of Reach 2. It is also common along roadsides and in residential gardens. Tamarisk is particularly abundant along Reach 4. Arundo and oleander are less common but have the potential to become widespread. Tamarisk, Chinese pistachio, African sumac, and Chinese date palm are the most common exotic-plant species along the creek in the Arboretum (Petrie pers. comm.).

Under Action 9, work crews would cut down exotic plants at about ground level, paint the stumps with an herbicide such as Rodeo, and remove the cut vegetation from the creek channel. Hand equipment would be used in Reach 2, where boulders in the creek channel preclude the use of heavy equipment and where the exotics are interspersed with native plants. Tractors could be used along Reach 4, where the channel is smoother and the degree of infestation is higher. The cleared material would be chipped and either left in place, offered to local residents as a garden amendment, or hauled to an offsite disposal area. Cleared tamarisk would be burned to ensure complete destruction of residual seeds. The work would be done in the fall to avoid disturbance of breeding birds and avoid potential contamination of live streamflow with herbicides. Follow-up treatments using hand clearing and herbicide would be done annually. Follow-up treatments typically require only about 10% as great an effort as the first-year treatment.

Control of exotics is considered feasible for the Queen Creek watershed. The upper watershed (Reach 1 and above) contains almost purely native vegetation. The extent of invasion in the other reaches is not great except in a few areas. In addition, restoration of more persistent flows in the creek will tend to favor native species over exotic ones, which typically invade drought-stressed riparian areas. Initial removal of the exotics may be necessary to achieve a vegetation conversion in a reasonable amount of time. Experience at the Arboretum has shown that cottonwood and willow often eagerly reoccupy locations where invasive vegetation has been removed (Petrie pers. comm.).

Net Change in Habitat

Removal of exotic vegetation from the creek channel and riparian corridor will improve the vigor and canopy density of native plant species. The area occupied by native species will increase by the same amount that the area occupied by exotics is decreased. This area cannot be calculated from the vegetation map because the two types of vegetation are intermixed, and they were not mapped as separate polygons. The total increase in coverage of native vegetation along all of the creek reaches would probably be 5-10 acres.

Cost

The cost of exotics removal depends greatly on the local labor cost. In California, a recent bid for the first 3 years of exotics control for tamarisk and arundo at an infestation level of 25% along a 14-mile reach of Cache Creek was about $880 per acre, assuming a combination of hand labor and mechanical clearing (Van Diepen pers. comm.). The cost was about $1,060 per acre for 75% infestation. Assuming similar labor costs in Superior, the total cost for the first 3 years of treatment of 27 moderately infested acres along Reach 2, plus 32 heavily infested acres along Reach 3, and very light infestation along Reach 5 would be about $60,000. Subsequent annual costs would be about $6,000.

Funding Sources and Feasibility

Removal of exotic vegetation requires an ongoing program. Grant programs generally do not fund ongoing activities or operation and maintenance costs. However, the level of effort required in the first year of an exotic-plant control program is often an order of magnitude greater than the effort required for routing follow-up treatments in subsequent years. Therefore, the first-year effort might appropriately be considered a project rather than a maintenance program and thereby qualify for grant funding. Funding sources that could potentially support Action 9 include the EPA's CWA 104(b)(3) grant program and revolving fund, the USFWS Partners for Fish and Wildlife program (for activities on private land), AWPF, and AGFD's Heritage Fund.

Impacts and Secondary Benefits

Hand clearing would have negligible impacts on soils and surrounding vegetation. Use of tractors with cutting heads on extendible arms could disturb the soil slightly and cause a small, temporary increase in suspended sediment during the next flood. Herbicides would be applied only by licensed personnel in accordance with local and state regulations. Spill-prevention equipment and emergency-cleanup equipment would be onsite at all times during the operation to reduce the likelihood and magnitude of accidental herbicide contamination to a negligible level. Herbicide would be applied by hand with spot sprayers directly on stumps and sprouts so that impacts on adjacent vegetation would be negligible. Because residual herbicide on plant leaves and stumps would degrade before the start of the next streamflow season, impacts on water quality would be avoided.

Burning of cut tamarisk would create smoke that would adversely affect air quality for 1-2 days. Burning could be scheduled for agricultural-burn days. If local air-quality managers object to burning, the material could be buried at the landfill, which would also prevent dispersal of tamarisk seeds.

Removal of exotic vegetation will increase the visibility of the creek channel. Most landowners of riparian areas would probably consider this increased visibility a benefit. Some may object, however, especially if exotic vegetation presently provides shade or privacy in their yards. Ideally, public-education efforts would persuade most landowners to recognize the value of removing exotic vegetation and replacing it with native vegetation (see Action 8). To the extent that exotic vegetation impairs flood-conveyance capacity, the Pinal County Department of Public Works has the authority to remove the vegetation to maintain the floodway.

Removal of exotic vegetation from the creek channel in Reach 2 would improve flood-conveyance capacity and should be integrated with Action 11.

Permits

Much of the creekbed is privately owned. Landowner permission to remove exotic vegetation would be requested in all cases. Landowner permission is not required, however, for removal of vegetation that impairs flood-conveyance capacity. Hand-clearing of vegetation does not require a CWA Section 404 permit from the USACE, and the minimal ground disturbance by tractors equipped with saws for mechanized cutting would be covered as a habitat-restoration activity under Nationwide Permit No. 27. Vegetation removal would be minor in Reach 5 and would not significantly impact aquatic habitat conditions for the three listed special-status animal species. A floodplain-use permit from the Pinal County floodplain manager would also be needed for the exotic-plant removal program.

Implementing Agency

Superior would oversee implementation of Action 9 and would probably hire a contractor specializing in removal and control of exotic vegetation to complete the work.

Action 10: Implement a Program to Minimize Grazing Impacts

Objective

Action 10 would minimize the impact of livestock grazing on riparian vegetation and water quality by encouraging and supporting landowners in implementing management practices that protect the riparian zone.

Location and Description

Livestock grazing can degrade riparian areas by browsing the shoots of young cottonwoods and willows, compacting and denuding the soil, and depositing manure in the creek. The shade and relatively lush, tender vegetation found in riparian zones attracts grazing animals, which tend to congregate in those areas. Thus, grazing commonly has much greater impacts on riparian areas than on adjoining upland areas.

By and large, grazing along Queen Creek is well managed and grazing impacts are minimal. Livestock access to the creek channel along Reaches 3 and 4 is restricted to selected areas by fences along the riparian corridor. Although horses have access to the lower part of Reach 4, the vegetation is in good condition and the amount of manure in the creek is tolerable. Grazing intensity is higher on private property along the upper third of Reach 5, and the cattle have unrestricted access to the creek. Mature trees along this segment of the creek appear to be in good condition, but the heavy browsing of the understory may limit the growth of young cottonwood and willow trees. Historically, the riparian area near Old Pinal Townsite was heavily grazed. Tonto National Forest now restricts grazing to only 6 weeks per year in April and May. The vegetation on the National Forest segment is similar in composition and health to riparian vegetation along the Arboretum segment, where there has been no grazing since 1928 (Myers 1993). There have reportedly been some problems with animals escaping into neighboring parcels along Reach 4.

Action 10 would consist of developing written descriptions of low-impact grazing management practices appropriate for Queen Creek and meeting with landowners of riparian areas to review their grazing operations and recommend implementation of low-impact practices. Examples of low-impact practices could include installing fences to restrict cattle access to the creek along the upper part of Reach 5 and changing the grazing season along the National Forest segment from spring to fall to minimize impacts on breeding birds.

Net Change in Habitat

Grazing management would not alter the distribution of vegetation categories shown on the vegetation map, but it could alter the composition and age structure of the vegetation. In particular, the regeneration capability of native riparian trees could be enhanced, leading to a more diverse age structure.

Cost

A small amount of Superior town staff and consultant time (100 - 200 hours) would be needed to develop recommended management practices, meet with landowners of riparian areas who own livestock to review their grazing operations and inspect site conditions, and assist the landowners with implementing improved management practices. The cost of implementing those practices cannot be estimated until they are identified.

Funding Sources and Feasibility

The areas of most intense grazing use are on private property in Reaches 4 and 5. Measures that minimize grazing impacts on the riparian corridor in these properties would qualify for funding under the USFWS Partners for Fish and Wildlife program. Other potential funding sources include the EPA's CWA 104(b)(3) grant program and revolving fund and AWPF. In addition, the Environmental Quality Incentives Program (EQIP) administered by the Natural Resources Conservation Service (NRCS) is a good source of funding for landowners wishing to implement range-improvement measures.

Impacts and Secondary Benefits

Restricting livestock access to the creek channel could decrease the amount of manure in the creek. The decreased input of nitrogen and pathogens would improve downstream water quality.

Permits

No permits would be needed to implement Action 10.

Implementing Agency

Action 10 would be best implemented by an agency involved in rangeland management, such as Tonto National Forest or the NRCS. However, Superior could also provide staff or consultant resources to implement the action.

Action 11: Manage Floodway Vegetation

Objective

The objective of Action 11 is to achieve as much riparian-habitat value as possible along Queen Creek without increasing the flood risk for homes along the creek.

Location and Description

Action 11 strives to balance the goal of habitat restoration with the goal of flood protection. The trunks, branches, and leaves of shrubs and trees in the channel and 100-year floodplain of Queen Creek create a drag force that slows the flow of floodwaters and increases flood stages upstream of the vegetation. Although local residents and the Pinal County floodplain manager think that the 100-year floodplain shown in the FEMA floodplain map (Federal Emergency Management Agency 1981b) is probably overstated, it remains the official indicator of flood risk. Numerous homes are within the FEMA 100-year floodplain, and it is assumed for this restoration plan that any increase in flood stage resulting from increased vegetation is unacceptable.

There are two strategies for managing vegetation in the floodway to improve habitat without increasing flood risk. The first strategy is to remove undesirable non-native plants such as ailanthus, tamarisk, arundo, and oleander. This strategy would be achieved through implementation of Action 9. The second strategy would be to alter the location and shape of native trees and shrubs to minimize their collective resistance to flow. Examples of vegetation-management guidelines that achieve this objective include the following:

- remove all but one stem from multistemmed willow and cottonwood shrubs that have resprouted from stumps (Figure 5-12);
- allow enough trees to reach maturity that they form a closed canopy that suppresses the growth of shrubby vegetation by shading the creek channel (Figure 5-13);
- plant or select for trees whose trunks form a line parallel to the direction of flow, thereby decreasing their individual hydraulic resistence by up to 40% (Li and Shen 1973);
- prune tree branches that are below the 100-year flood level;
- remove shrubby vegetation from areas below the 100-year flood level; and
- remove piles of woody debris that accumulate during floods and obstruct flood flows.

Woody material removed from the creek would be mulched and hauled to an offsite-disposal area or offered to local residents as a garden amendment.

An open understory would not be entirely natural, but it would minimize flood impacts and would create an open, shady, park-like atmosphere conducive to recreational use. Thus, it could achieve an appropriate balance of objectives for restoration along Reach 2. Along Reach 3, the floodplain is very wide and undeveloped. A substantial part of the hydraulic roughness is from mesquite bushes on the floodplain. Any increases in hydraulic roughness caused by increased riparian vegetation along the channel could be offset if necessary by selective removal of mesquite from the adjoining floodplain.

Figure 5-12. Tree Stumps Resprout into Multi-Stemmed Shrubs that Block Flood Flows More than Single-Trunk Trees do.

Figure 5-13. Restored Tree Canopy would Retard the Rampant Growth of In-Channel Shrubs that Block Flood Flows.

Net Change in Habitat

Action 11 would not substantially decrease the area occupied by riparian vegetation, but it would alter its structure by creating a relatively open understory. This somewhat unnatural vegetation structure would not affect all riparian wildlife species equally. Generally, removal of shrubby vegetation while retaining tall trees in and beside the channel would favor upper-canopy birds such as yellow warblers and orioles, and it would discourage shrub-dwelling birds such as Bell's vireos, yellow-breasted chats, Gambel's quail, doves, thrashers, and sparrows. Cover for ground-dwelling mammals and reptiles would also be reduced, and so habitat quality would be only fair for them. Overall, however, the restored vegetation would provide substantially more and better habitat than the existing vegetation.

Cost

The cost of removing and controlling invasive non-native vegetation would be covered under Action 9. Pruning of the remaining native vegetation and removing debris piles would involve similar activities such as sawing, hauling, and mulching. Herbicides would not be used. Actions 9 and 11 could be coordinated and implemented simultaneously by the same work crew. Floodway management would only be needed in Reach 2 and possibly the lower part of Reach 3. Because of the relative abundance, maturity, and density of native vegetation compared to non-native vegetation and the shorter length of creek channel needing treatment, the cost of Action 11 would total about $25,000 for the first 3 years and $2,500 per year thereafter. This cost assumes that Action 11 is implemented in conjunction with Action 9.

Funding Sources and Feasibility

Vegetation management for floodway maintenance is not typically considered a habitat-enhancement activity. Furthermore, it can be classified as a routine maintenance activity that does not qualify for funding under most grant programs. Some financial assistance may be available from the Pinal County floodplain manager, given that County residents pay a flood-control tax that is intended for maintenance of flood-control facilities. Possibly, one or more grant program for habitat restoration could be persuaded to fund the first year of vegetation management, which would entail a much larger level of effort than in subsequent years and thereby qualify as a project rather than a maintenance program. In addition, the funding agencies might also be persuaded that enlightened floodway-vegetation management that retains as much habitat value as possible is vastly preferable to the traditional approach of simply removing all vegetation, which favors stump sprouting and rapid regrowth of shrubby vegetation.

An additional means of developing recreational facilities at Old Pinal could become available if Congress passes the National Forest System Community Purposes Act (S. 1184) introduced in May 1999. This act would allow the Secretary of Agriculture to give selected parcels of National forest land to a state or political subdivision of a state for the purpose of developing recreational opportunities. In this case, for example, land near Old Pinal could be transferred to Superior, the Arboretum, or Pinal County for the purpose of developing a campground, if Tonto National Forest supported the idea but did not have the resources to implement the project itself.

Impacts and Secondary Benefits

Selective removal of shrubby understory vegetation along the flood-prone reaches of the creek would change the visual appearance of the creek. Landowners of riparian areas would benefit from increased visibility of the creek channel as well as from the maintenance of flood-conveyance capacity. Increased visibility of the creek channel would also tend to deter vandalism and dumping.

Tree-canopy area would increase through retention of large trees with branches above the 100-year flood level. The additional canopy would create shade that would retard the growth of shrubs and algae and create cooler water temperatures. Hand-clearing of vegetation would not cause significant soil disturbance or associated impacts on water quality.

Permits

Much of the creekbed in Reaches 2 and 3 is privately owned. Landowner permission would be requested for pruning of trees and selective removal of seedlings and shrubs. However, the Pinal County Public Works Department has the authority, with or without landowner permission, to remove vegetation from the floodway to maintain flood-conveyance capacity. Public education regarding creek management would bolster public support for the overall package of creek-management actions (see Action 8).

The USACE does not require a CWA Section 404 permit for clearing vegetation by hand, and the minimal ground disturbance by tractors equipped with saws for mechanized cutting would be covered as a habitat-restoration activity under Nationwide Permit No. 27. Vegetation removal would be minor in Reach 5 and would not significantly impact aquatic-habitat conditions for the three listed special-status animal species. A floodplain-use permit from the Pinal County floodplain manager would also be needed for the exotic-plant removal program.

Pruning and selective removal of young cottonwood, willow, ash, and black walnut trees would be necessary to maintain adequate flood-conveyance capacity. Presumably, public-safety considerations and the overall increase in riparian habitat that would be achieved by this plan would be adequate grounds for obtaining a permit for selective plant removal.

Implementing Agency

Action 11 would be implemented by Superior in coordination with the Pinal County Public Works Department. Neither Superior nor the County presently have an active floodway-maintenance program, but the County may implement one in the near future (Hoag pers. comm.). County residents presently pay a flood-control tax intended to pay for capital improvements and maintenance of flood-control facilities. Alternatively, Superior has the authority to take over management of the floodway formally from the County. If Superior chooses to assume control, it could design its own floodway-management program and assess landowners to cover the costs of implementation.

RECREATION DEVELOPMENT ACTIONS

Actions 12-17 would incorporate recreation opportunities into the overall enhancement program for Queen Creek. The recreation component would increase use of the creek by local residents and help attract visitors, thereby contributing to the local economy in an ecologically friendly way. It also creates a substantial opportunity to educate the public and to encourage resource stewardship.

Action 12: Complete Construction of Stone Avenue Park and Community Park

Objective

Action 12 would add landscaping and park facilities to Stone Avenue Park and Community Park to allow recreational and aesthetic enjoyment in and adjacent to the riparian habitat restored under Action 5.

Location and Description

Both sites are adjacent to Queen Creek in Reach 2 (see Figure 5-1), and they are owned by Superior and designated as park sites. Various plans for park development have been considered in the past. The conceptual designs presented here emphasize integration of recreational park elements with the natural riparian setting as a means of increasing public awareness and enjoyment of healthy riparian areas.

Stone Avenue Park occupies a 0.5-acre stream terrace sandwiched between Main Street and the low-flow channel of Queen Creek, as shown in Figure 5-14. Community Park includes a 4.5-acre stream terrace that is not landscaped but has some improvements that were constructed during a prior phase of park development, including irrigation mains, overhead flood lights, and a volleyball and basketball court in fair condition (Figure 5-15).

The development objective for Stone Avenue Park is to create a beautiful, shady oasis for relatively quiet, passive enjoyment of the Queen Creek riparian area. This pocket park is in full view of Main Street pedestrians, who view the park from atop a 12-foot-high, river-rock retaining wall built by the Works Progress Administration in the 1930s. Landscaping of the terrace could include additional native shade trees (e.g., sycamores and cottonwoods near the creek and palo verde closer to the wall), demonstration native-plant gardens designed to attract butterflies and hummingbirds, benches, grassy areas, a fountain, and a small toddler play structure. A natural, unbroken transition between the terrace and the attractive, bouldery creekbed would be retained, so that the creek channel and adjacent row of existing and restored cottonwoods would remain the dominant park feature. A conceptual layout is shown in Figure 5-16.

Additional improvements could include shrubs or other screening to conceal the large sewer-vault structure near the park entrance, decomposed granite pathways, lighting, flower beds, and a drinking fountain.

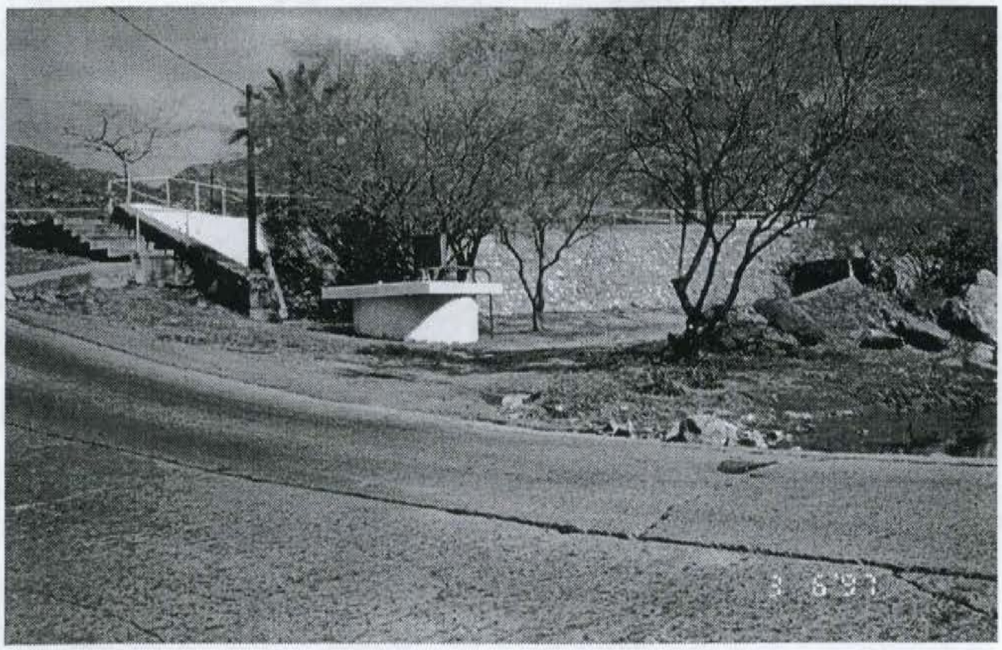


Figure 5-14. Existing Condition of Stone Avenue Park.

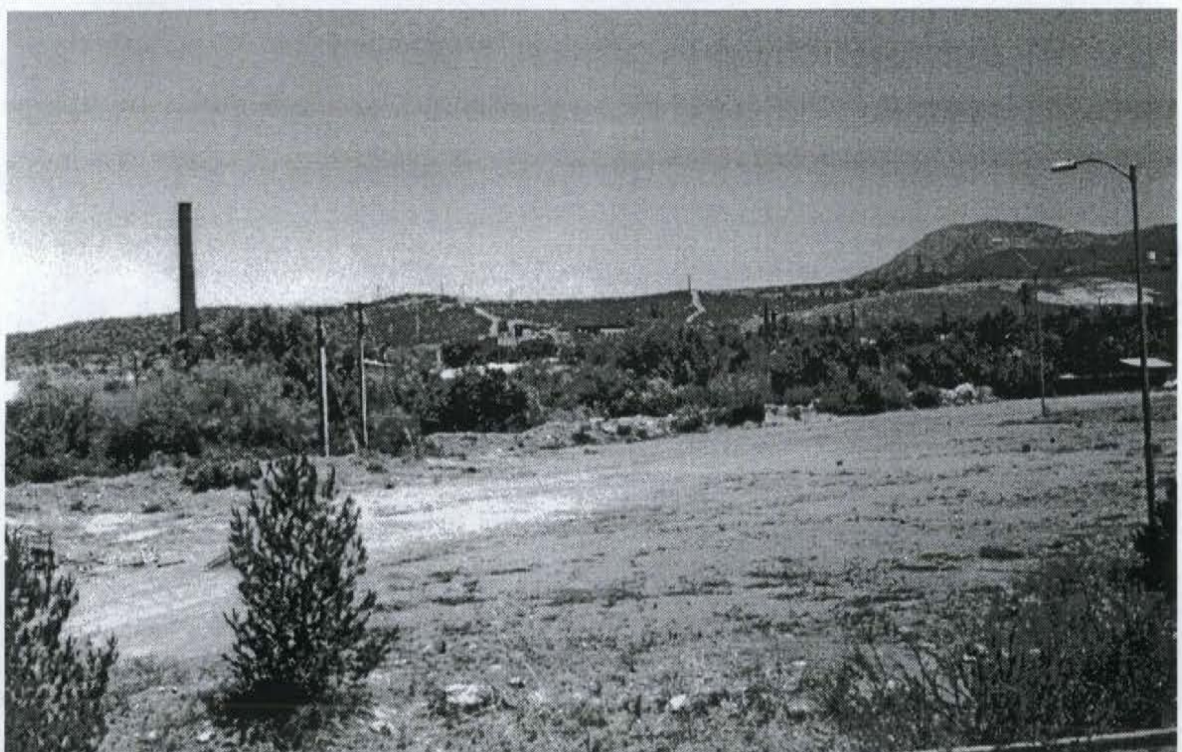


Figure 5-15. View Across Undeveloped Part of Community Park, Toward Queen Creek.

New Elements Proposed in Stone Avenue Park

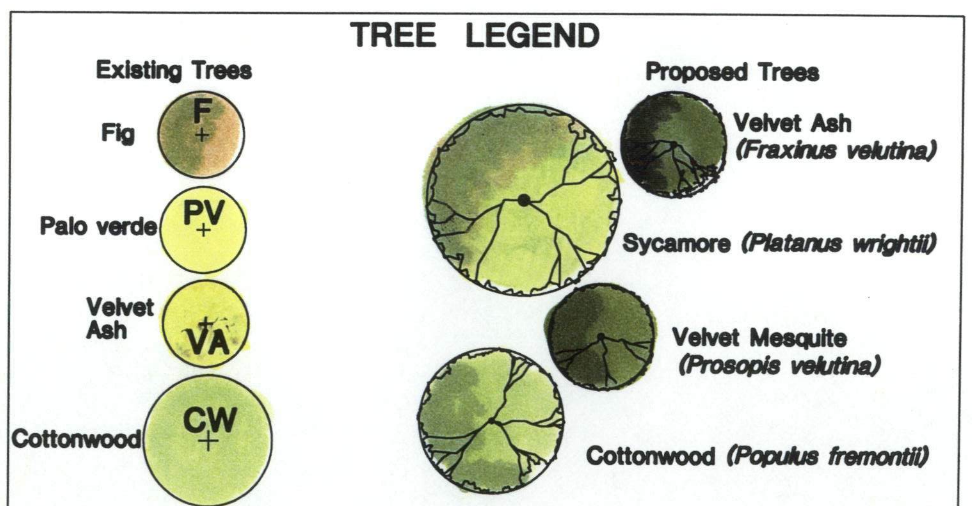
~ Riparian tree plantings of Sycamore, Ash, Cottonwood and Mesquite

~ Trail system around two small habitat gardens:
Butterfly attractor and Hummingbird attractor gardens

~ Habitat gardens with water holders or small bubbler fountains
with interpretive signs identifying local species

~ Four seating areas, each with potential to
accomodate groups of six

~ Botanical identification of native plants
along the path network



J:S
Jones & Stokes Associates
340 East Palm Lane Suite A-275
Phoenix, AZ 85004

Figure 5-16. Schematic Landscape Plan for Stone Avenue Park

The development objective for Community Park would be to invite more active recreation in an aesthetic riparian setting. The park could also serve travelers on Highway 60, from which it is easily accessible. If the Old Town Trail is constructed (Action13), the new park area would only be 200 yards from the new highway rest area along a scenic trail that passes under the highway. The double row of cottonwoods that would be restored along the edge of the creek channel under Action 5 would provide a transition zone between playing fields and the wild area in the creek channel. A conceptual layout is shown in Figure 5-17. The central part of the park would have a large turf area for informal field sports. A decomposed-granite path would wander along the uneven edge of the tall riparian trees between the turf area and the creek channel. The area beneath the trees would have rough grass and scattered native shrubs. Picnic tables with grills would be provided in the shade of the trees. The wooded area would be generally open and invite park users to pass through and explore the undeveloped creek channel where birdwatching opportunities would be good. Riparian trees would also be planted toward the back of the park to screen the utility poles and create a sense of being surrounded by nature. The good health of two young cottonwood trees planted a few years ago near the existing tot playground indicates that shallow groundwater is present throughout the site and that native riparian trees are likely to become self-sustaining once they become established.

Additional desirable facilities would include a small parking lot between the basketball court and Starr Road; a decomposed-granite path from Starr Road to the existing restrooms between the playing fields and the interior grove of riparian trees; additional shrubs to screen the parking area and pump station building; drinking fountains; and low-level lighting along the paths.

To minimize vandalism, it might be desirable to install a surveillance camera at each park and connect them to the police department's existing surveillance system.

Landscaping at the parks could potentially be irrigated by the same wells used to establish riparian trees under the demonstration restoration program (Action 5). Because of its small size, Stone Avenue Park could be entirely irrigated by the well without exceeding the 10 af/yr limit for exempt wells in the Phoenix AMA. At Community Park, the restored trees would have to reach the water table and become self-sustaining before the 10 af/yr of groundwater supply could be freed up for irrigating the turf area. This would occur 3-5 years after planting. The 10 af/yr supply would be sufficient to irrigate about 3 acres of turf.

A revegetation plan for the parks is presented in Appendix E. It describes the types and locations of vegetation to be planted, the design and operation of the irrigation system, and other maintenance measures that would be implemented to ensure successful establishment of the desired vegetation.

Cost

The cost of park facilities depends very much on the number and type of facilities included at each of the sites. Development costs for parks of similar size and with similar facilities in Phoenix indicate that a construction cost of about $140,000 can be expected for the Stone Avenue Park and $400,000 for Community Park.

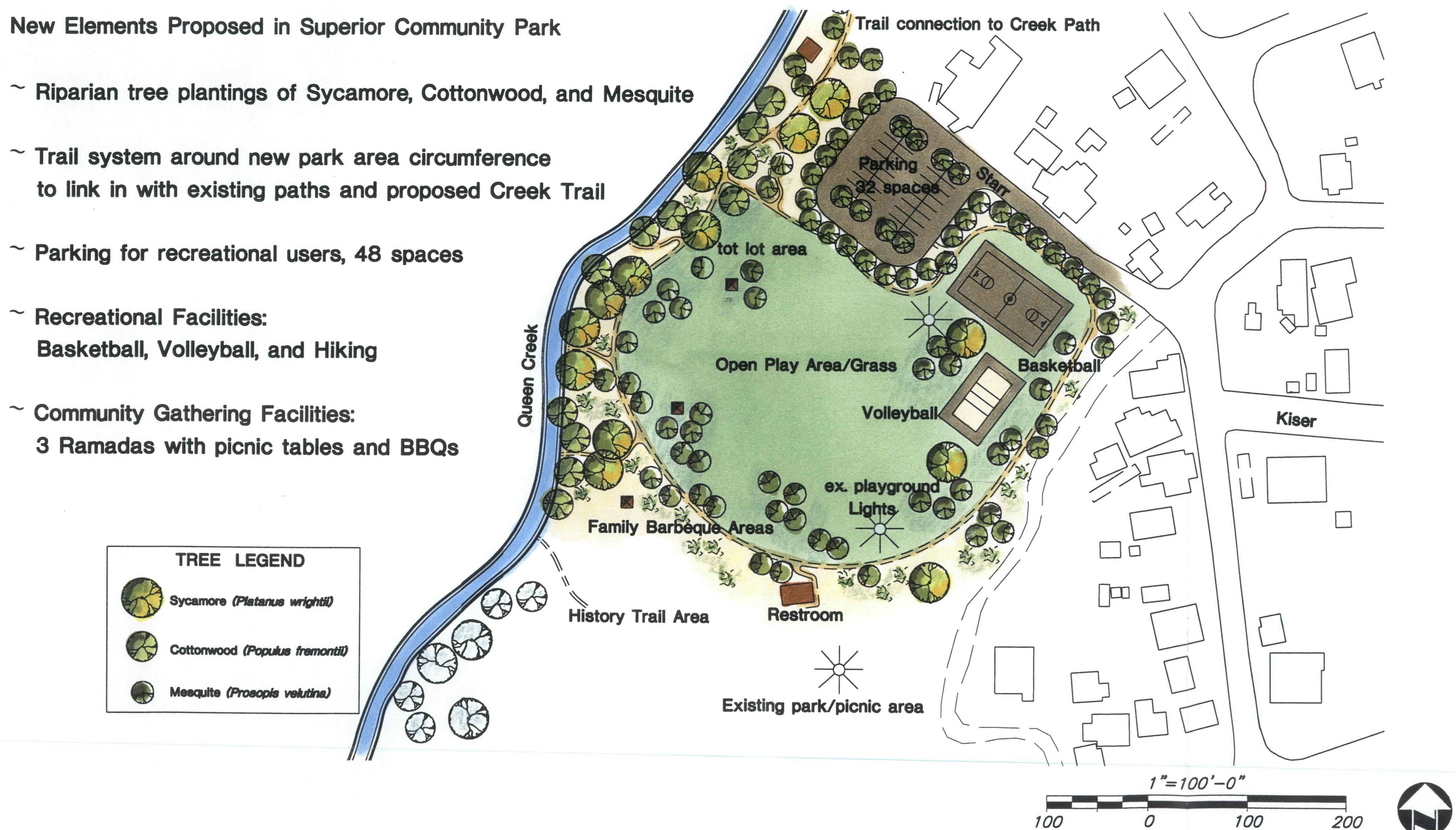


Figure 5-17. Schematic Landscape Plan for Community Park

Jones & Stokes Associates
340 East Palm Lane Suite A-275
Phoenix, AZ 85004

There would be ongoing costs for operating the irrigation and lighting systems, providing garbage collection, maintaining the turf area, weed control, and repairing vandalism damage. These are described in detail in Chapter 6.

Funding Sources and Funding Feasibility

Community Development Block Grants may be used for park development, but Superior has designated this source of funding for other purposes for the next several years. Arizona State Parks' local-parks grant program would be a good source of funds for this action.

The Arboretum might be interested in designing and installing the demonstration native-plant garden at the Stone Avenue Park. The garden would "advertise" the Arboretum and potentially generate additional visitors.

Grant programs generally do not fund operating and maintenance costs. These would have to be borne by Superior.

Impacts and Secondary Benefits

Recreational activities would somewhat diminish the potential habitat value of the restored riparian areas at the two sites. However, most of these impacts would also occur without park development because of the need to prune understory vegetation to maintain flood-conveyance capacity and because the adjacent urban land uses already expose the sites to traffic, pedestrians, and domestic cats and dogs.

Stone Avenue Park would be highly visible to tourists who visit the downtown area, so that the action would noticeably enhance the aesthetic quality of their experience. Thus, the park would contribute toward development of a tourist economy.

The proposed park facilities are appropriate for installation in a floodplain. They would not impact flood-conveyance capacity or be damaged by inundation.

Permits and Cooperating Agreements

A Floodplain Use Permit would be needed from the Pinal County floodplain manager. Both site plans are appropriate for a floodplain location, and so no flood-related objections are expected.

Action 12 would need to conform to the Americans with Disabilities Act, which means that access to handicapped persons should be provided to the extent possible at both parks. The flat terrain at Community Park could easily accommodate wheelchairs and handicapped parking. An existing wheelchair ramp provides access to the existing restrooms on the upper terrace. Wheelchair access at Stone Avenue park would be more difficult to achieve because of the steep drop from Main Street down to the park. It might be possible to construct a doubled-back wheelchair ramp against the retaining wall next to the existing stairs at the northwest corner of the site.

Implementing Agency

Action 12 would be implemented by Superior.

Action 13: Construct the Old Town Trail along Reach 2

Objective

The Old Town Trail would be a developed path for easy walking along Reach 2, following a route that includes segments in the creek channel and along the top of the creek bank, with connections to Main Street in several locations. The trail would link two attractive features of the town by allowing residents and tourists to enjoy an aesthetic stroll that includes the natural beauty of the creek channel and the historical buildings and shopping opportunities on Main Street.

Location and Description

The Old Town Trail could potentially extend from the Magma Club to Community Park and possibly continue under Highway 60 to the new lake in Reach 3 (see Actions 6 and 14), for a total distance of 1.1 miles. A reconnaissance survey of the creek channel suggested that the trail might best include a combination of relatively undeveloped, natural segments and developed segments that could accommodate wheelchairs and bicyclists. The potential alignment shown in Figure 5-1 is based solely on consideration of terrain and the need to provide connections to Main Street and other streets. The support and approval of creekside landowners has not yet been sought.

Existing stairs lead from the Magma Club down to the creekbed, which is rugged and bouldery at that location. Steep banks and bank-top buildings would require that the trail be in the creekbed. A reasonably passable path could be created by moving selected boulders and paving a pathway with mortared cobbles. Closer to the Magma Avenue bridge, consolidated bedrock is exposed in the creekbed and continues intermittently all the way to the Lobb Avenue footbridge. The bedrock is fairly level and even and makes enjoyable walking (Figure 5-18). A stairway could connect the path to Magma Avenue at the northeast corner of the bridge. The trail would continue to be relatively natural and rugged between Magma Avenue and the Lobb Avenue footbridge, weaving back and forth between the channel and low terraces on the north bank. The trail would exit the channel up a stairway or ramp that connects to the northern end of the footbridge.

The trail segment from the Magma Club to the Lobb Avenue footbridge would not be very shady because the shallow bedrock would preclude development of a dense tree canopy even if streamflow is restored. The trail would be too rugged for wheelchairs, and it would be difficult to install light poles that would not be damaged during floods.

Main Street is one-half block from the footbridge along Lobb Avenue. The connection between the street and bridge could be made more clear by creating a paved trail with a distinctive material such as brick. The creekside trail would continue from the footbridge along the top of the creek bank, which presently is a paved driveway for delivery trucks. It would gradually descend by way of ramps and stairs behind the existing buildings to reach the eastern end of Stone Avenue Park.

Figure 5-18. Exposed Bedrock Creates a Natural Trail Surface between Magma Avenue and the Lobb Avenue Footbridge.

Figure 5-19. This Unpaved Creekside Road between Community Park and the Lower Footbridge Could Easily Become a Link in the Old Town Trail.

Most or all of this segment could be wheelchair accessible and well lighted. Stone Avenue would provide another connection to Main Street.

Below Stone Avenue, the trail would continue on a low terrace created in part by removing artificial fill that has been dumped in the channel. Artificial bank protection and fenced back yards would force the trail into the channel itself along much of the distance between Stone Avenue and the lower footbridge. An empty lot on the north bank could allow access to Main Street, and an unpaved road or driveway along the south bank could be the best alignment for part of this segment. The trail would return to the top of the south bank at the lower footbridge and continue from there along an existing primitive path several hundred feet to the eastern edge of Community Park (Figure 5-19). It would be desirable to pave the entire segment of trail between Stone Avenue and Community Park to allow wheelchair access and a shady route for pedestrians and bicyclists traveling between Community Park and the central downtown area. Lighting would be desirable for nighttime use.

To minimize vandalism, Superior may wish to add one or more cameras along the creek to the remote surveillance system operated by the police department. Garbage cans and benches in selected locations might also be desirable.

Cost

The construction cost of the trail depends substantially on site-specific design and engineering considerations related to grading, flood-proofing, stairways, ramps, and lighting. Detailed design work has not been completed. The greatest challenge would be designing a trail that would not suffer substantial damage during floods. In the upper segment (Magma Club to Lobb Avenue), this goal might best be achieved by using a natural path surface as much as possible and planning to remove boulders and replace trail markers after major floods (e.g., once every 10 years on average). The paved segments could be aligned as much as possible along terraces beside the channel, where scour by floodflows is less intense. A concrete path parallel to the direction of flow and anchored into the creekbed with driven steel bars would survive all but the largest floods (perhaps 50- to 100-year events). Path segments that cross the channel over unconsolidated cobbles may need to be constructed to similar engineering standards as the road crossings at Stone Avenue and Mary Drive. Repair may be necessary after major floods, but this cost would be infrequent and would not amount to a large expense on an annualized basis.

Based on per-mile costs of recreational trails in Phoenix, the construction cost for the Old Town trail would be about $175,000. There would also be ongoing maintenance costs associated with lighting, surveillance, garbage collection, and vandalism repairs.

Funding Sources and Funding Feasibility

The Arizona State Parks' trails funding program would be appropriate for the Old Town Trail because it includes a historical element (links to Main Street) and a scenic element. The FHA's TEA-21 program supports scenic bike and pedestrian paths. This agency might find the trail even more appealing if it extends under the Highway 60 bridge to connect with the proposed highway rest area that would overlook the lake. The Arizona State Parks' local parks grant program and HUD's Community Block Grants are other potential sources of funding.

Grant funding is generally not available for ongoing operation and maintenance costs. Superior would have to assume these costs.

Impacts and Secondary Benefits

The average annual flow in Reach 2 is <5 cfs, and the trail would be dry and passable on all but perhaps a few days each year, when intense rainstorms would generate stream flows that would render the trail impassible at some locations.. Use of the trail would probably be minimal during such periods of inclement weather. The risk of being caught in a flash flood is considered negligible and no greater than it is at present, given that the creek is already accessible to pedestrians.

During dry weather, the trail would increase the amount of human activity in the creek channel, which could discourage use of the riparian corridor by some types of wildlife. The presence of humans would probably not have nearly as great an impact as the presence of domestic cats, however, which would be the same as under existing conditions. Birds that primarily dwell in the forest canopy would be the most common type of wildlife and would not be excessively disturbed by people on the ground.

Permits and Cooperating Agreements

The trail would require a CWA Section 404 permit from the USACE because construction would entail regrading parts of the creekbed and pouring concrete or laying asphalt. The trail would not significantly affect the wetland-habitat value of the creek channel and would not impair floodflows, and so approval is likely. The Section 404 permit would entail compliance with the NHPA. Because little excavation would be needed to construct the trail, the potential for impact on archaeological resources is small. Modification of historical buildings along Main Street could probably be avoided entirely.

Implementing Agency

Action 13 would be implemented by Superior.

Action 14: Add Access and Park Facilities around the Lake

Objective

If a lake is constructed on the floodplain downstream from the Highway 60 bridge (see Action 6), Action 14 would provide recreational opportunities that complement the habitat value of the lake and its shoreline vegetation.

Location and Description

Recreational facilities associated with the lake would consist primarily of a lake-perimeter trail with connecting trails to the Highway 60 rest area and to Community Park. The rest-area trail would be an extension of the Old Town Trail (see Action 13) and would pass under the Highway 60 bridge, providing a safe route for pedestrians and bicyclists to cross the busy highway. Spur trails would provide access to the lakeshore at selected locations for fishing and wildlife viewing. Boating would be discouraged to minimize disturbance of wildlife. Water temperatures in summer would be quite warm, and growth of planktonic (microscopic, free-floating) algae would be likely. The algae would render the lake less aesthetic for swimming than pools in the creek near the Neversweat Tunnel discharge, which would be clearer and cooler. Shade structures with interpretive signs, benches, garbage cans, and drinking fountains would be located at two locations along the lake-perimeter trail (Figures 5-20 and 5-21). All segments of the trail would be wheelchair accessible. The segment of trail from Community Park under the bridge and up to the rest area would be lighted for nighttime use. The northern part of the terrace between the lake and Highway 60 would remain vegetated with mesquite. A campground could be developed in this area, but this concept was not enthusiastically supported by participants in the plan-development process because a campground situated close to town could discourage use of lodging and restaurants by visitors.

Cost

Construction costs for similar trails in the Phoenix area indicate that the 3,000 feet of trail would cost about $270,000. Operation and maintenance costs related to trail sweeping, lighting, garbage collection, graffiti removal, and vandalism repair are described in Chapter 6.

Funding Sources and Funding Feasibility

The FHA's TEA-21 would be a good source of funding for the trails, particularly because they would be directly accessible from a highway rest area. Arizona State Parks' trails-grant program might also fund trail construction.

Impacts and Secondary Benefits

Wildlife at the lake and surrounding riparian area could be disturbed slightly by the presence of people and pets along the lake-perimeter trail and more substantially by anglers.

The trails would benefit Superior's economy by providing another recreational opportunity that would attract visitors.

Permits and Cooperating Agreements

The floodplain terrace is presently owned by BHP. Implementation of Action 14 would require that BHP donate or sell the land to Superior, unless BHP chose to undertake the lake restoration and recreational-development projects as a private enterprise.

Figure 5-20. Shade Structures and Interpretive Signs could Enhance the Recreational Appeal of Trails around the Lake or in the Canyon Reach.

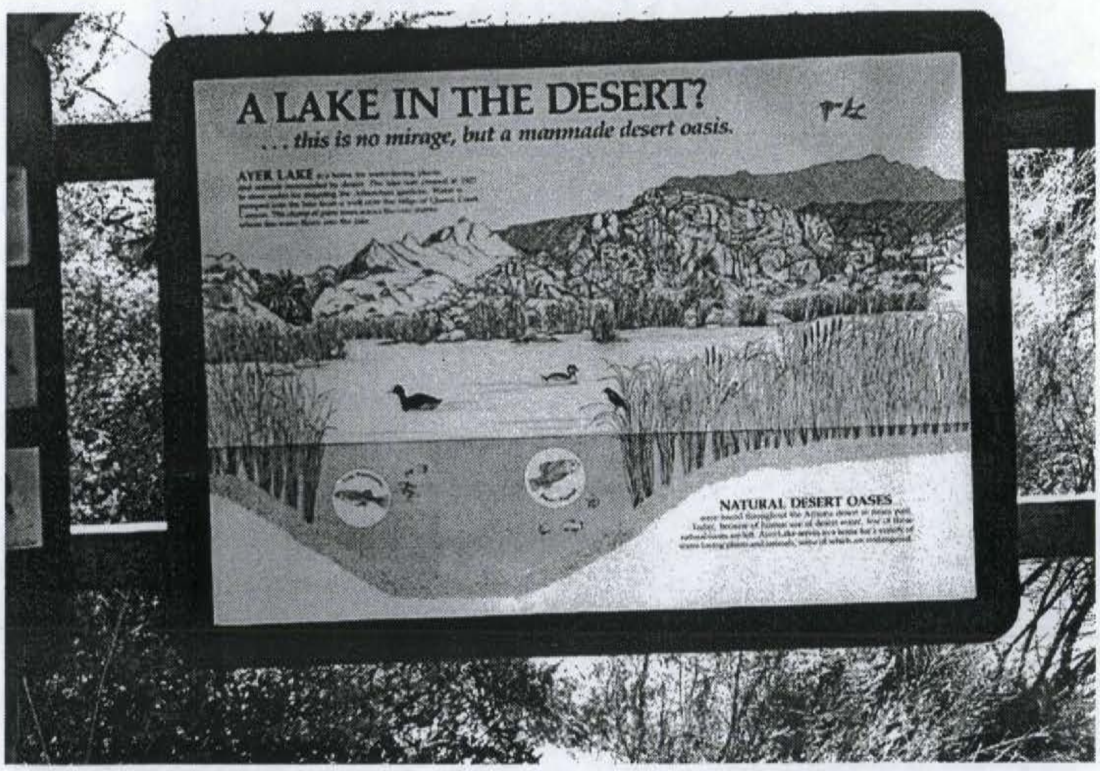


Figure 5-21. Ayer Lake at Boyce Thompson Arboretum Demonstrates the Combined Habitat and Recreational Value of Constructed Lakes.

The density of the existing mesquite shrubs on the floodplain terrace is low enough that few would need to be removed to allow trail construction. A harvest permit under the Arizona Native Plant Law probably would not be required. Any excavation required to install water or electrical utilities should receive prior approval from the SHPO to ensure that cultural resources that might be present in the area would not be impacted.

A Floodplain Use Permit from the Pinal County floodplain administrator would be required for all of the facilities constructed under Action 14. No facilities would significantly decrease conveyance or storage of floodwaters, however. ADOT would need to approve the trail under the bridge and the design and location of the trail segment that descends the Highway 60 embankment from the proposed rest area.

Implementing Agency

This action would require the cooperative involvement of BHP and Superior.

Action 15: Enhance the Trail in the Canyon Reach

Objective

Action 15 would install minor improvements to old Highway 60 in the Canyon Reach to increase its visibility and appeal as a hiking, mountain-biking, and equestrian trail.

Location and Description

Old Highway 60 is the abandoned road that follows Reach 1 of Queen Creek up from the Magma Avenue bridge into the canyon that descends from Apache Leap. The road was built during 1919–1922 using prison labor and was classified in 1993 as eligible for inclusion in the NRHP. The roadbed now consists of deteriorated asphalt but walking on it remains easy. The entire length of the proposed trail is on land presently owned by BHP.

The scenery along the 1.2-mile segment between Magma Avenue and the Superior water tank includes old mine workings; large, stream-polished boulders in the creekbed; occasional groves of sycamore, ash, and walnut trees; dramatic limestone beds on the canyon walls; and the graceful arch of the new, single-span Highway 60 bridge more than 100 feet above the canyon floor (Figure 5-22). Upstream of the new Highway 60 bridge, the trail could continue on the roadbed for the final one-third mile to the water tank, or a parallel footpath could be constructed in the shade of the sycamore trees that line that segment of the creek. A footpath could also extend up the canyon from the water tank about one-half mile to a spectacular narrows with towering, red- rock walls.

Various improvements would be made to the road corridor to enhance the hiking experience. The lower end of the road could be paved or covered with road rock up to the existing gate to provide parallel parking for hikers (Figure 5-23). A trailhead sign at Magma Avenue would inform visitors about the trail. Lack of shade is presently one of the greatest disincentives for hiking along the road. Two shade gazebos with garbage cans would be located at intervals along the segment

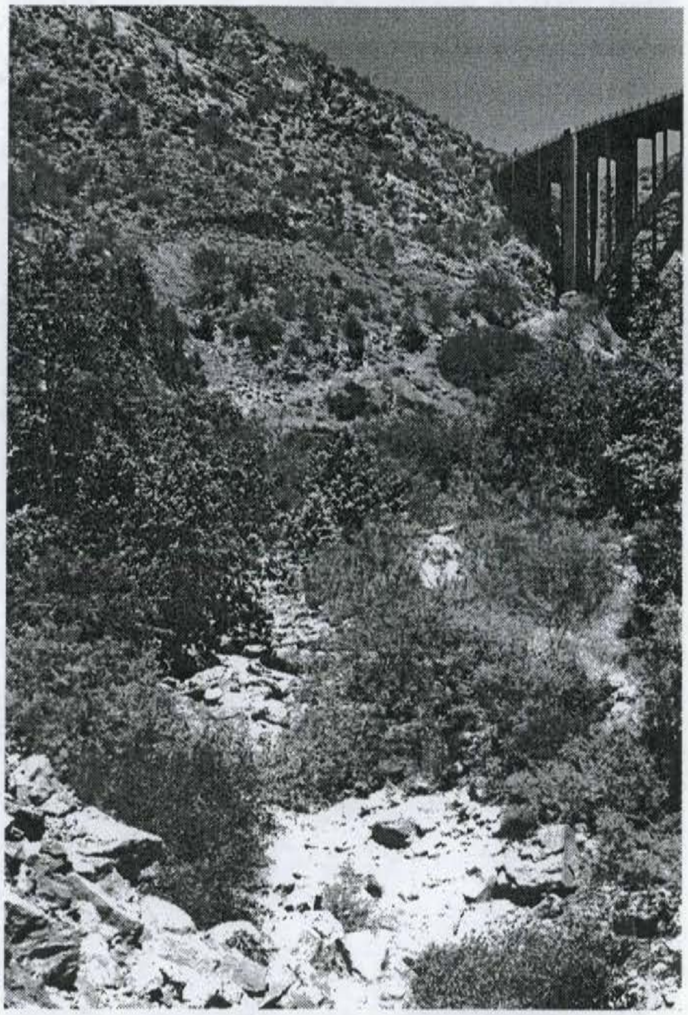


Figure 5-22. Views along Canyon Reach.

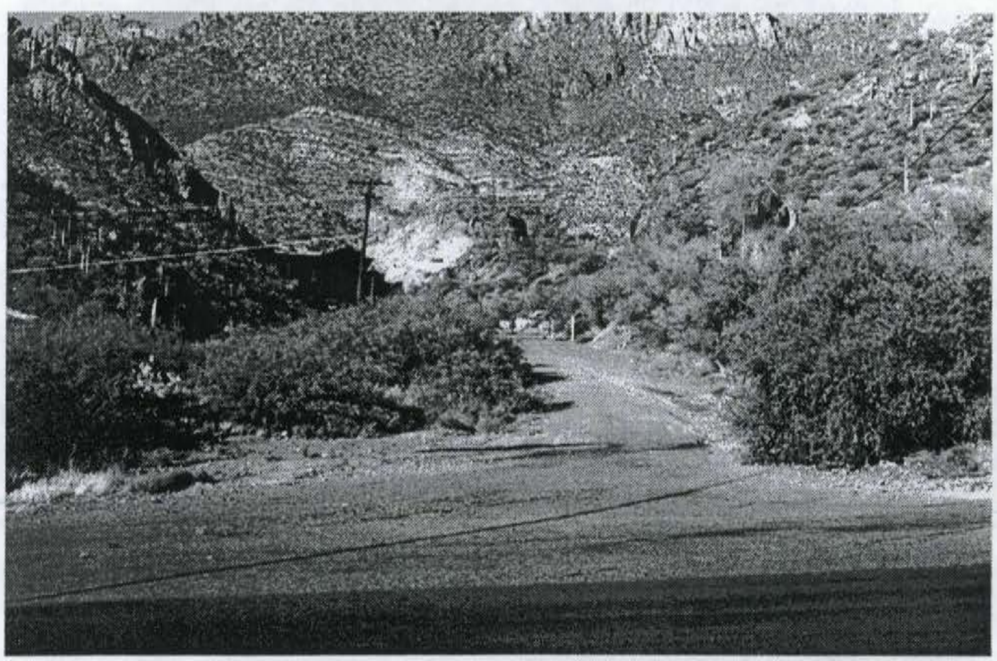


Figure 5-23. Proposed Entrance to the Canyon Reach Trail (Magma Avenue in Foreground)

from Magma Avenue to the new Highway 60 bridge (see Figure 5-20). Drinking fountains would be installed at the trailhead and at the water tank, and a restroom could be provided at the trailhead. The interpretive signs at the shade structures would explain desert plants, geology, and mining history. The surface of old Highway 60 beyond the parking area could also be improved, which would increase its suitability for use by wheelchairs and joggers (at least one local jogger has suffered a knee injury as a result of the rough condition of the existing road surface). Resurfacing the road might not be consistent with preservation of its historical value, however, and would require approval from the SHPO.

Cost

The cost of Action 15 would depend on which amenities are included in the trail design. Installing a restroom would be the most expensive item and could cost more than $50,000. The shade structures, benches, interpretive signs, entrance sign, paving, and drinking fountains would cost about $75,000. Local Boy Scouts or other volunteers might be willing to construct the creekside footpath segments of the trail.

Maintenance costs for the trail would be primarily for garbage collection and restroom servicing. There would occasionally also be costs for repairing vandalized property.

Funding Sources and Funding Feasibility

The FHA's TEA-21 grant program could find the Canyon Trail particularly appealing because it features a historical highway and has easy access for motorists on the new Highway 60. Arizona State Parks' Heritage Fund trails and historical-preservation grant programs also are likely sources of funding. A donation of land or an easement by BHP could serve as matching funds for these grants.

Maintenance costs would need to be paid by Superior, because grant funds are generally unavailable for that purpose.

Impacts and Secondary Benefits

The Canyon Trail would have few, if any, impacts on other resources or people. If a footpath is constructed along the riparian corridor upstream of the new Highway 60 bridge, hikers might disturb wildlife.

The trail could have a beneficial impact on Superior's economy by adding a recreational activity that would help Superior become a destination for tourists. The interpretive signs could add an educational element to the recreational benefits.

Permits and Cooperating Agreements

The support of BHP for this action would be essential, because the trail would be located on BHP's property. The SHPO should be consulted to ensure that trail design and use do not degrade the historical value of the roadway. The grade of the roadway could easily accommodate wheelchair use, but the existing surface is probably too rough. The SHPO should be consulted to determine whether resurfacing a strip along the roadway would be consistent with historical-preservation objectives.

Implementing Agency

This action would be implemented by Superior in cooperation with BHP.

Action 16: Construct a Campground and Nature/History Trail at the Old Pinal Townsite

Objective

Action 16 would create a new recreational destination that offers camping in a beautiful, mature riparian area plus a short system of trails with interpretive exhibits explaining the history of the Old Pinal Townsite and the ecology of desert riparian areas.

Location and Description

The Old Pinal Townsite is located on Tonto National Forest land halfway between the WWTP and the Arboretum, at the midpoint of Reach 5. It is presently accessible by a dirt road that extends 0.5 mile south from Highway 60 and crosses the creek on an unimproved ford. Access is unregulated, and vehicles have created several loops and segments of dirt road along the edge of the riparian area. Although no camping facilities are provided, old fire rings indicate that visitors occasionally camp along these roads. The site is clean and in good condition, except for unnecessarily wide dirt roads and turnarounds.

Old Pinal Townsite was one of the first settlements in the area, predating the discovery of ore deposits and the mining boom in nearby Superior. The townsite occupies about a 1-mile by 0.5-mile area, although its exact extent is unclear because an inventory of cultural resources is still underway. The town was essentially vacated by the end of the nineteenth century, and foundations are all that remain of the buildings. A large flood in the 1890s apparently destroyed many buildings, and fire may have eliminated others. Old artifacts and parts of structures were common until the 1970s but eventually souvenir hunters removed them all.

Development of the historical resources for interpretive purposes would require exhuming and cleaning several of the better foundation specimens. One or more of the buildings could be reconstructed using the original design and materials to illustrate historical conditions better. A paved, handicapped-accessible loop trail 0.5-1.0 mile in length with points of interest and interpretive signs would inform visitors about the history and culture of the town, possibly including examples of technology and materials used in the town's heyday. Less formal trails could also lead visitors to the interesting nearby volcanic-rock formations.

The mature riparian vegetation at the Townsite offers educational opportunities in addition to shade and scenic beauty. The mature, multistoried vegetation assemblage includes numerous native riparian plants, including large cottonwood, willow, and sycamore specimens. The historical loop trail could also include interpretive nature exhibits explaining the hydrology, vegetation, and wildlife of the area.

The campground would benefit the Arboretum by providing nearby camping accommodation and an additional opportunity for visitors to experience and learn about botany and history. A primitive campground is recommended as the most cost-effective type. It would consist of grading the roads and covering them with road rock, installing bollards at selected locations to control off-road vehicle use, and providing fire rings, picnic tables, and portable toilets. Water and electricity would not be provided. This level of development is not uncommon in remote national-forest lands in Arizona.

The development of Old Pinal Townsite as a recreational and interpretive site would proceed in phases. The inventory of cultural resources needs to be completed before development activities can begin. The trail system and interpretive exhibits could be constructed as a day-use facility before the campground is established. The existing road leaves Highway 60 at a very dangerous curve. The turnoff may need to be relocated, and a turning lane and left-turn pocket added to Highway 60, to provide for adequate safety.

Cost

The cost of developing the site depends on the facilities included. The cost of a 1-2 year effort to inventory, stabilize, and selectively restore historical buildings and artifacts could be about \$500,000. Costs for similar facilities at other national forests and parks indicate that a 1-mile paved trail with six interpretive signs might cost \$200,000, including design and construction. Construction costs for the campground can be roughly estimated from costs for existing campgrounds in Tonto National Forest (Carlson pers. comm.). Grading and surfacing the 1-mile entrance road from Highway 60 with road rock would cost on the order of \$75,000. A 20-site campground with picnic tables and fire pits at each site, 0.5 mile of vehicle barrier bollards along a loop road, a composting toilet, and minor grading and revegetation would cost approximately \$137,000. An on-site well and a water distribution system with spigots at several locations would cost about \$24,000 plus an unknown cost for bringing in electrical power to operate the well. Thus, the total campground cost would be approximately \$212,000 without a water supply and \$236,000 with a water supply.

Funding Sources and Funding Feasibility

The Old Pinal Townsite lies entirely within Tonto National Forest, and that agency is the logical source of funding for developing the site. The historical and trail elements could attract funding from other sources, however. The FHA's TEA-21 grant program might contribute funding, especially because the site would offer recreational opportunities for travelers on U. S. Highway 60.

Arizona State Parks' Heritage Fund could provide funding for preservation of the historical buildings and artifacts, development of interpretive signs, and possibly also design and construction of the nature/history interpretive trail.

Impacts and Secondary Benefits

Adverse impacts on historical cultural resources is a great concern, but they would be minimized by a phased implementation approach that would begin with an inventory and assessment of the resources. Increased numbers of visitors could also impact riparian vegetation and wildlife. Vegetation could be protected by developing designated trails and discouraging dispersed foot traffic. Wildlife disturbance is to a certain extent unavoidable, but it could be minimized by requiring that pets be on leashes.

Water-quality impacts to Queen Creek could be minimized by setting back the campsites from the creek channel and by using rail fences and signs to keep visitors on the trails. Provision of a dishwashing sink at the restroom could also minimize dumping of dishwater and food residue into the creek.

Flash floods could pose a safety risk to campers, but posted notices and the occurrence of intense rainfall prior to floods would provide sufficient warning for campers to move back from the creek.

Development of recreational facilities at the Old Pinal Townsite would benefit the Arboretum and the local economy by attracting additional visitors to the area. With the availability of a campground and more things to see and do, increasing numbers of tourists would make the Arboretum and Superior a destination.

Permits and Cooperating Agreements

The interpretive trail would be at least partially in the creek channel and would require a CWA Section 404 permit from the USACE. The inventory of cultural resources and preparation of the site for displaying them to the public would need to comply with ASHPA and NHPA. If native riparian plants or mesquite would be removed during construction of the trail or campground, a permit from the ADA may be needed to comply with the Arizona Native Plant Law.

As the landowner and site manager, Tonto National Forest would obviously need to support implementation of this action.

Implementing Agency

Action 16 would be implemented primarily by Tonto National Forest.

Action 17: Extend the Old Town Trail to the High School

Objective

This trail segment would provide recreational enjoyment of the creek environment in Reach 3 and also provide a direct and safe pedestrian and bicycle path for students commuting between the high school and the downtown area.

Location and Description

This trail would begin at the lake-perimeter trail (see Actions 6 and 14) near the southwest corner of the lake. It would descend the impoundment berm and immediately cross the Queen Creek low-flow channel on a footbridge. The trail would follow the terrace on the north side of the creek to near the mobile-home park, where it would cross back to the south side on a second footbridge. A steep cutbank precludes aligning the trail continuously along the south bank downstream from the lake. Below the second footbridge, the trail would continue another 1,000 feet to Mary Drive. Mary Drive is a broad street with little traffic, so that it provides a safe, direct route for the remaining distance to the high school.

An optional, scenic-loop extension of this trail would continue down Queen Creek below Mary Drive, probably following the north bank to circumvent the concrete plant on the south bank. Another footbridge would bring the trail back to the south bank just before the creek bends sharply to the south. The trail would follow the left (now east) bank another 1,200 feet to a point opposite the WWTP, where it would turn left and follow the utility easement directly east to Mary Drive. This extension loop would be primarily for jogging and enjoyment of the riparian vegetation, which gradually transitions from mesquite to cottonwood–willow riparian forest in that area.

The 5-foot-wide trail would be paved with asphalt, and it would be suitable for use by wheelchairs, bicycles, skateboards and rollerblades. The simplest design would be for daytime use primarily by local residents, with no lighting, shade structures, garbage cans, or interpretive facilities. If the demand for recreational and nature education opportunities eventually exceeds the supply provided by the Old Town, lake, and Canyon trails, additional amenities could be added in the future.

This trail could be built even if the lake is not built (Actions 6 and 14). The Old Town Trail could still be extended under the Highway 60 bridge (as in Action 14), but it would continue to the starting point of the high-school trail on the existing land surface rather than on top of the impoundment berm.

Cost

The main segment of trail with no amenities would cost about $130,000. Most of this cost would be for construction of the two footbridges. Addition of one shade structure with an interpretive sign, garbage cans, benches at several points along the trail, and path lighting for nighttime use would increase the total cost to about $207,000. The scenic-loop extension would cost about $90,000 for the bare-bones option and $167,000 for the full-amenity option, because the additional cost of paving the longer route is more than offset by the need for only one footbridge.

Funding Sources and Funding Feasibility

The FHA's TEA-21 grant program would be ideal for Action 17 because the action offers a combination of recreational and transportation benefits. The trails and local-parks grant program administered by Arizona State Parks would be another appropriate source of funds. If not already committed to other Superior objectives, funding available through the federal HUD community block-grant program could be applied toward trail construction.

Impacts and Secondary Benefits

The footbridges should be designed to withstand a 100-year flood by placing the bridge decks above the 100-year flood elevation and armoring the approach buttresses with boulders to prevent scour when the floodplain is inundated. At present, the entire trail route is fairly isolated and quiet. The trail would increase human disturbance of wildlife to a certain extent.

Permits and Cooperating Agreements

Almost the entire length of the trail route is on land owned by BHP; other private landowners own a short segment on the north bank a short distance downstream from the lake. A trail easement or purchase of these lands would be necessary to implement Action 17.

The trail would avoid construction in the creekbed below the ordinary high-water mark by using footbridges at the creek crossings. As a result, a Section 404 permit would not be needed from the USACE. The trail and bridges would be within the 100-year floodplain, however, and would need to be approved by the Pinal County floodplain manager. The amount of mesquite that would need to be removed during trail construction could necessitate a harvest permit under the Arizona Native Plant Law.

Implementing Agency

Action 17 would be implemented by Superior.

SELECTION OF ACTIONS FOR IMPLEMENTATION

A large number of ideas for restoring habitat and providing recreational opportunities were considered during the planning process. In some cases, proposed actions were dropped from further consideration because of clear technical or economic infeasibility or because some other action could clearly achieve the same result with greater certainty or lower cost. Seventeen proposed actions were retained in the plan, and individually they are each recommended for implementation. However, it probably is not necessary to implement all of the actions to achieve an acceptable level of habitat quality and recreation opportunity. Furthermore, some actions compete for available resources (e.g. reclaimed water) or would not be feasible unless certain other actions have already been implemented. This section begins by describing actions that were dropped from further consideration and continues by clarifying issues regarding redundancy, incompatibility, and sequencing among the recommended actions.

Actions Not Recommended for Implementation at this Time

Some restoration actions were suggested during the brainstorming phase of plan development but were dropped from further consideration when subsequent investigation revealed that they would probably be infeasible or would not likely succeed in achieving the desired effect. These actions and the reasons for dismissing them are described here to document those findings, in case the ideas are suggested again at some future date.

Action: Seal Fractures in Creekbed above Reach 1

There are a few locations in the mine where seepage from the creek is relatively localized, and the seepage rates increase substantially during and following large rainstorm and streamflow events (Lira pers. comm.). One former mine employee described a specific location along the creek between the old and new Highway 60 bridges above Reach 1 where streamflow losses were particularly large. The mine would regulate the rate of seepage by adjusting the location of the low-flow channel with earth-moving equipment (Smith pers. comm.). The original concept for this action was to drill and grout fractures in the creekbed, in the mine near the creekbed, or both to reduce streamflow losses in this leaky zone.

Further development of this action was discontinued after discussing its feasibility with researchers from the University of Arizona Hydrology Department, who studied hydrologic processes and fracture flow in the area during 1988–1996, Illman pers. comm., Thompson pers. comm., Woodhouse pers. comm.). The entire mass of the Apache Leap tuff and the adjoining limestone beds is fractured, and fractures are typically spaced about 2 meters apart. Thus, plugging a few of the fractures would probably only shunt the percolation flow into other nearby fractures. This expectation is consistent with earlier attempts by mine workers to decrease the rate of inflow into the mine. In the early 1900s, a concrete lining was installed along about 300 feet of one tunnel where leakage rates were particularly high. The lining reportedly failed to decrease overall seepage into the mine. A similar effort was implemented aboveground by lining about 200 feet of the creek channel with concrete where the creek crosses above the Neversweat Tunnel in the bedrock gorge near the new Highway 60 tunnel. This measure also failed to eliminate seepage into the mine.

Action: Develop a Hiking Trail Connecting Superior and the Arboretum

In the early phases of plan development, the possibility of constructing a hiking trail (the "Apache Tears Trail") along Queen Creek between Superior and the Arboretum was suggested. This action is not recommended for implementation at this time for the following reasons:

- This relatively remote stretch of the creek offers the best opportunity for high-quality wildlife habitat. Wildlife habitat should be the priority use for this reach to balance recreational use and other human disturbances in restored reaches in the downtown area.

- The final half-mile of Reach 5 is in the Arboretum. The Arboretum's objective for this undeveloped part of its holdings is to minimize human presence in order to maximize wildlife-habitat and natural-resource value.

- A short stretch of public access to this scenic reach is recommended under Action 16, which would create a primitive campground and nature/history trail at the Old Pinal Townsite.

- Complex land-ownership patterns and established grazing uses along the Creek in this reach present potential obstacles to trail development.

The possibility of building the Apache Tears Trail could be reconsidered in the future if monitoring indicates that the restoration actions have been highly successful and the recommended recreational-development actions fall short of meeting recreational needs.

Action: Reoperate Mine-Dewatering Treatment Ponds to Achieve more Continuous Outflow to Queen Creek

If BHP resumes dewatering of the mine, it will initially use the existing treatment and storage pond system (Gray pers. comm.). Dewatering may need to be resumed by the middle of 2000 to prevent key underground mine facilities from being inundated. Conversion to a continuous-process treatment system with direct discharge to the creek would occur only if it proves to be economical in the context of the mine's long-range operating plans, and conversion might not occur for many years. Thus, for at least an interim period, there is a reasonable possibility of continued dewatering discharges to Queen Creek.

Historical discharges of mine-dewatering water from the storage ponds were too sporadic to support riparian vegetation. If dewatering is resumed, the pond releases could be modified to achieve a fairly persistent outflow suitable for the establishment and maintenance of riparian vegetation. This outflow would be achieved by installing valved siphons or other types of outlet structures on the ponds that would allow the pond contents to be released at a regulated rate. Seasonal patterns of dewatering rates, rainfall, evaporation, and seepage would be evaluated to determine a schedule of release rates that would achieve a nearly continuous outflow for 9-12 months per year. The discharge could be at the existing point, which flows into Queen Creek just below Mary Drive, or conveyed by a new pipeline to a point along Reach 2 where the resulting restoration would provide more benefits to Superior residents.

BHP staff and consultants considered this strategy for using mine water to augment flow in Queen Creek to be the least feasible of several that were initially considered (Actions 3 and 4 represent the other strategies and are still recommended for implementation). Several difficulties would need to be overcome to implement this action. The storage ponds cascade from one to another and would need to be individually retrofitted and jointly operated to achieve a smoothing of the discharge rate. The treatment process requires a minimum retention time in the storage ponds, which in turn require a minimum storage volume. Thus, the operable storage available for providing sustained releases would be much less than the total storage capacity of the ponds. Finally, the terms of BHP's NPDES permit generally strive to minimize discharges to the creek and to dispose of as much of the treated water through evaporation and seepage as possible.

Action: Pursue Alternative Sources of Supplemental Flow

Two additional water supplies that could potentially be tapped for supplemental flow in Queen Creek were suggested by members of the advisory committee or the public toward the end of the planning process and were not evaluated in detail for this plan. One suggestion was to convey water from a perennial spring located near the point where U. S. Highway 60 reaches the top of Apache Leap east of Superior. Several significant drawbacks would need to be overcome if this source were to be used. The discharge of the spring is small, and the cost-effectiveness of piping it to Reach 1 or 2 would likely be low. The amount of habitat it would create along those reaches would also be correspondingly low. More importantly, discharge from the spring is already fully utilized to support natural habitat at the spring and along Queen Creek in the canyon above Reach 1. Diverting flow would adversely affect those habitat areas.

The second potential water source is a pair of idle wells drilled by Kennecott Copper Company on the flanks of Picketpost Mountain south of Reach 5. The yield of the wells in not known, although the reportedly flow under artesian pressure (Mears pers. comm.). Technical issued that would need to be addressed to use these wells include their long-term yield and water quality, and the cost-effectiveness of conveying the water to a desirable discharge point along the creek. Legal issues include obtaining permission from the well owner to use the wells and acquiring Type 2 water rights for groundwater extraction in the Phoenix Active Management Area.

Priorities and Potential Conflicts or Redundancy Among Actions

Compatibility among actions was considered to determine whether proposed actions would compete for resources or achieve redundant results. Conversely, some actions would benefit from implementation together. This section documents the compatibility analysis of habitat-restoration actions, recreation-development actions, and recreation-versus-restoration actions.

Habitat Restoration Actions

In general, the recommended actions that focus on habitat restoration (Actions 1-11) are mutually compatible. In some cases, however, the actions are redundant because they would create base flow in the same reach of creek. In other cases, two or more actions compete for the same source of water, and it would not be feasible or necessary to implement them simultaneously. The redundant actions are prioritized in this section and a preferred action is identified. Implementation of the other actions would be contingent on subsequent discovery that the preferred action is infeasible.

Implementation of some actions would be substantially benefitted by implementation of others, or cost savings could be achieved by implementing them simultaneously. Table 5-6 indicates the potential for conflicts, redundancy, or synergistic benefits among the riparian-restoration actions, which can be generally classified as follows:

Insufficient water availability. The amount of reclaimed water presently available for restoration would not be sufficient to support restoration in multiple locations (Actions 1 and 2).

Water supply redundancy. Several actions would provide supplemental streamflow in Reach 2, and only one or two of them are necessary for complete restoration. Either of the dewatering water source options (Actions 3 and 4) could render reclaimed water (Action 2) or wells (Action 5) unnecessary.

Complementary benefits. Removal of exotic vegetation (Action 9) would partially achieve the objectives of managing floodway vegetation (Action 11). The labor, equipment, planning, and logistics for those actions plus creek cleanup (Action 8) are similar, and their may be potential cost savings if they are done at the same time.

Actions 3 and 4 are the preferred strategies for treatment and use of mine-dewatering water. From the standpoint of restoration, it is highly desirable that some level of mine dewatering continue and that the treated water be discharged into Queen Creek at a relatively steady and sustained rate that will support riparian vegetation. If dewatering is permanently discontinued, all the water that now seeps into the mine, which would otherwise contribute to streamflow, would simply be stored in the shafts and tunnels. The mine would not "spill" back into the creek until most of the underground workings have filled with water, a process expected to take 20-30 years. Depending on how the mine is sealed during closure, the water that would eventually seep from the mine into the creek could be highly mineralized and unsuitable for discharge to the creek without treatment, much like the dewatering water presently pumped from the mine.

Action 3 would intercept seepage that enters near the top of the mine and return it to the creek before it becomes mineralized. The water quality would be high, and the seasonal and annual variations in seepage rate would follow natural variations in seepage from bedrock into the creek. This option would also not rely on treatment and is thus more intrinsically reliable in the distant future. Action 4 assumes that normal mine dewatering is resumed indefinitely and that the mine decides to install a new treatment plant and discharge pipeline. This action would eliminate the seepage and evaporation losses associated with the present treatment system and would provide a relatively large flow of water of acceptable quality to Queen Creek at a point near the Magma Club. Increased flow in the downtown area would provide particularly high aesthetic and recreational benefits in addition to the habitat-restoration benefit.

Action 1 with a gradual transition of all wastewater discharges from the WWTP wash to the new discharge point at the middle of Reach 4 is the preferred action for use of reclaimed water. The lower half of Reach 4 is about the same length as the WWTP wash, but the riparian vegetation would

Table 5-6. Potential Conflicts and Redundancy among Recommended Restoration Actions

Action	1	2	3	4	5	6	7	8	9	10	11
1. Discharge reclaimed water where existing pipeline crosses Reach 4		1									
2. Discharge reclaimed water in Reach 2	1			2							
3. Return freshwater mine inflow directly to Queen Creek				3							
4. New mine dewatering treatment and discharge to Reach 2		2	3		4	5					
5. Install wells for riparian irrigation and supplemental streamflow				4							
6. Construct an off-channel stormwater lake in Reach 3				5							
7. Creek-protection ordinance											
8. Creek cleanup and anti-dumping program									6		6
9. Remove exotic vegetation								6			7
10. Minimize grazing impacts											
11. Manage floodway vegetation								6	7		

Note:

See text for explanation of numbered cells.

have a much more natural composition and structure because of the presence of relatively shallow groundwater levels and a full range of natural streamflows in addition to the discharge flows. Phasing out the discharges to the WWTP wash could be postponed until replacement vegetation has become firmly established in Reach 4. By substituting enhanced riparian vegetation along Reach 4 for the existing riparian vegetation along the WWTP wash, the net water supply impact on Reach 5 and the Arboretum's Canyon Well would be nil. Finally, Action 1 is much less expensive than Action 2 and creates as much habitat.

Recreation Development Actions

The recreational-development actions (Actions 12-17) are all mutually compatible provided that recreation demands increase with time so that all the actions are needed. Collectively, they would provide a diverse range of experiences in natural outdoor surroundings and would extend the full length of Superior. Each action would be attractive and usable on its own, if funding or other considerations limit the rate at which they are implemented.

Completion of the two creekside parks is the highest priority for recreational development because of the large number of people served and the lack of major technical, regulatory, and land-ownership issues. Development of the Old Town Trail, the lake, and the trail to the high school would merit high priority for the second phase of plan implementation because of their transportation benefits and their potential for attracting tourists and generating associated economic activity.

Recreation Versus Habitat

Recreational use of riparian areas can negatively impact habitat quality if not managed appropriately. Littering, trampling or damaging vegetation, disturbing wildlife, and increased fire risk are the principal forms of adverse impacts. Wildlife disturbance includes predation or harassment by pet dogs and cats. This plan achieves the restoration and recreational objectives by focusing the development of recreational uses in the downtown area (from the Magma Club at the lower end of Reach 1 to the lake at the upper end of Reach 3), where structures, traffic, pets, and pedestrians are already abundant. Also, the quality of wildlife habitat in this reach will already be slightly suboptimal because of the need to remove selected shrubs, trees, and low tree limbs for floodway maintenance. Fortunately, these vegetation-management practices are compatible with recreational pedestrian use of the creek corridor.

To balance the effects of recreational use of the downtown area, the primary emphases of restoration between Mary Drive and the Arboretum (Reaches 4 and 5) should be increasing the extent and quality of native riparian vegetation and providing the best possible wildlife habitat. The one exception would be development of a primitive campground and nature/history trail at the Old Pinal Townsite.

Chapter 6. Plan Implementation

IMPLEMENTING AGENCIES AND GROUPS

Implementation of restoration and recreational-development actions described in this plan would be spearheaded by a relatively small number of agencies. Superior would take the lead for the majority of the actions. BHP would need to initiate or be closely involved in several of them, and Tonto National Forest would be the lead agency for development of facilities at Old Pinal Townsite (Action 16). Other local agencies and groups that participated in the plan-development process would also continue to have an interest in how and when actions are implemented. Accordingly, a plan-implementation oversight group is needed to maintain communication among these various interests.

The Queen Creek Restoration Advisory Committee (Committee) (Figure D-4A) is recommended as the logical entity to oversee plan implementation. The Committee was established from the BHP Advisory Committee, a group which formed as an ongoing forum for addressing issues of common interest between Superior and BHP, including topics raised in the Queen Creek plan related to land development and dewatering discharges, and this BHP Advisory Committee is expected to continue functioning indefinitely. In addition to the BHP Advisory Committee, the Committee includes essentially all of the parties that were involved in developing this Queen Creek plan and could easily be expanded to include any individuals who want to be involved that are not already involved in either group. Membership and meeting procedures of the Committee are informal and intended to promote public involvement.

IMPLEMENTATION SEQUENCE AND SCHEDULE

Implementation of the plan should follow the sequence of priority described in Chapter 5 in the section, "Selection of Actions for Implementation". Actions that should be implemented first include the demonstration restoration project (Action 5), the shift in discharge location for some of the reclaimed municipal wastewater (Action 1), the creek-protection ordinance (Action 7), and ongoing programs for managing the riparian corridor (Actions 8-11). A cooperative effort with BHP should be initiated as soon as possible to achieve early use of fresh mine water from the Neversweat Tunnel (Action 3). Certain actions, such as constructing recreational facilities at the creekside parks and around the lake, should follow the initial restoration activities at those sites.

The pace for implementing the proposed actions is limited by grant-funding cycles, permitting requirements, and the need for additional design and engineering work. Additional constraints include the level of effort invested by Superior town staff, local residents, and BHP. An ambitious but reasonable sequence and schedule for implementation is shown in Table 6-1.

OPERATIONS AND MAINTENANCE

Operations and maintenance (O&M) costs and issues are mentioned in some of the descriptions of individual implementation actions in Chapter 5. The following discussion provides a more complete description of O&M activities; it provides costs and evaluates the cumulative O&M obligation that would be incurred if all of the recommended actions are implemented. Individual O&M costs described in the following paragraphs are summarized in Table 6-2.

Individual Implementation Actions

Action 1: Discharge Reclaimed Water Where Existing Pipeline Crosses Reach 4

The recommended design for the new wastewater outlet in the middle of Reach 4 is to install a new, 4-inch pipeline from the existing outfall over the hill to Queen Creek, rather than install a tee and spigot on the existing reclaimed-water pipeline that serves the playing fields. This design would allow the field irrigation to be operated entirely independently of the creek discharge and also would avoid the need to operate a pump for the creek discharge. The elevation of the hilltop and the creekbed are such that the creek discharge could be operated as a siphon. This arrangement would eliminate electricity costs and leave only occasional valve settings and discharge-point inspections as the operating cost for Action 1. Maintenance costs for the pipeline are expected to be negligible.

Action 2: Discharge Reclaimed Water in Reach 2

Action 2 requires continuous pumping of water from the WWTP to Reach 2. This action would incur significant operating costs for electricity and maintenance and replacement costs for the pump. The electricity cost for pumping 40 gpm (65 af/yr) would be about $1,250 per year for a discharge point near the lower footbridge and $2,200 per year for a discharge point near the Magma Club. These estimates assume an electricity cost of $0.08 per kilowatt-hour and a wire-to-water efficiency of 0.60. The life expectancy of the pump would be relatively short because it would operate continuously. Assuming a replacement cost of $4,000 every 6 years and an overhaul after 3 years ($2,000), the average annual pump maintenance and replacement cost would be $1,000. About 1 week of staff time would be required for replacement or overhaul. Pipeline maintenance is assumed to be negligible, and inspection and replacement of check valves and float switches at the pump intake would cost <$100 per year and 4 days' labor by a maintenance person on an average-annual basis.

Pumping costs could be decreased by discontinuing the pumping whenever there is natural flow in the creek at the discharge point. Assuming that live flow is present 4 months per year on

Table 6-1. Schedule for Implementation of Restoration and Recreation Development Actions

Action	Implementation Date				
	2000	2001	2002	2003	2004
Preferred Actions					
1. Discharge Reclaimed Water Where Existing Pipeline Crosses Reach 4					
3. Return Freshwater Mine Inflow Directly to Queen Creek					
5. Install Wells for Riparian Irrigation and Supplemental Streamflow					
6. Construct an Off-Channel Stormwater Lake in Reach 3		Design	Construct		
7. Adopt a Creek Protection Ordinance					
8. Implement a Creek Cleanup and Anti-Dumping Program	Major	Minor	Minor	Minor	Minor >
9. Remove Exotic Vegetation	Major	Minor	Minor	Minor	Minor >
10. Minimize Grazing Impacts					
11. Manage Floodway Vegetation	Major	Minor	Minor	Minor	Minor >
12. Complete Construction of Stone Avenue Park and Community Park	Design	Construct			
13. Construct the Old Town Trail along Reach 2			Design	Construct	
14. Add Access and Park Facilities around the Lake				Design	Construct
15. Enhance Trail in Canyon Reach			Design	Construct	
16. Construct a Campground and Nature/History Trail at Old Pinal Townsite	Inventory	Design	Construct	in	Phases
17. Extend Old Town Trail to High School				Design	Construct
Contingent Actions (not scheduled)					
2. Discharge Reclaimed Water in Reach 2					
4. Install a New Mine Dewatering Treatment and Discharge Pipeline to Reach 2					

Note: Actions with significant ongoing activities indicated by right-pointing arrows.

Table 6-2. Estimated Average Annual Operations and Maintenance Costs for the Restoration and Recreation Development Actions

	Labor (person-days)						Direct Expenses					
Action	Police	General Town Staff	Gardener	Maintenance Person	Fire Crew	Total Labor	Electricity	Supplies, Materials, Depreciation	Equipment Rental	Public Education Materials	Contractors	Total Direct Expenses
1. Discharge reclaimed water where existing pipeline crosses Reach 4						0						0
2. Discharge reclaimed water in Reach 2				2		2	820-1,470	730				730
3. Return freshwater mine inflow						0						0
4. New mine dewatering treatment and discharge pipeline to Reach 2						0						0
5. Install wells for riparian irrigation and supplemental streamflow				1		1	300	200			400	900
6. Construct an off-channel stormwater lake in Reach 3			12	2	2	16			400			400
7. Creek-protection ordinance		12				12				400		400
8. Creek cleanup and anti-dumping program		9-12		1		1			200- 400	600		600
9. Remove exotic vegetation		5				5				400	6,000	6,400
10. Minimize grazing impacts		4				4						0
11. Manage floodway vegetation		2				2					2,500	2,500
12. Complete creekside parks	12	6	260	85		363	500	7,500				8,000
13. Build Old Town Trail along Reach 2	12	6		104		122	500	4,000				4,500
14. Add access and amenities around lake	6	4		34		44	200	1,300				1,500

Table 6-2. Continued

Action	Labor (person-days)						Direct Expenses					
	Police	General Town Staff	Gardener	Maintenance Person	Fire Crew	Total Labor	Electricity	Supplies, Materials, Depreciation	Equipment Rental	Public Education Materials	Contractors	Total Direct Expenses
15. Enhance trail in Canyon Reach	8	4		52		64		2,000				2,000
16. Develop Old Pinal Townsite nature/history site				52		52		5,000	4,600			9,600
17. Extend Old Town Trail to the high school	6	4		26		36		4,000				4,000
TOTAL	44	47	272	359	2	724	1,500	24,730	5,000	1,400	8,900	41,530

Notes:

O&M costs for Old Pinal Nature/History site (Action 16) are minimum costs and would be borne by Tonto National Forest. The Town of Superior would be responsible for funding the O&M costs of the other actions.

The O&M costs for floodway vegetation maintenance (Action 11) assume that the work is done by the same contractor and at the same time as removal of exotic vegetation (Action 9).

average, these costs could be decreased by one-third. Thus, total O&M costs would be $1,550-$2,200 per year, depending on the discharge location.

Action 3: Return Freshwater Mine Inflow Directly to Queen Creek

There would be no O&M costs associated with Action 3. Water would flow by gravity from the entrance of the Neversweat Tunnel down a simple pipeline to a discharge point in the creekbed near the Magma Club. There would be no pumping or routine operation of valves.

Action 4: Install a New Mine-Dewatering Treatment System and Discharge Pipeline to Reach 2

Conversion of the existing dewatering treatment system to a new, continuous-process system is contingent on BHP's assessment of its future activities and the economics of conversion. It is assumed that the company would pay all treatment plant O&M costs and the monitoring costs required under the NPDES permit for the discharge. The cost of monitoring is not expected to be any greater than under the existing NPDES permit. There would be no additional O&M costs for discharging the water to the top of Reach 2 because the flow would be by gravity through a simple pipeline with no valves that require frequent operation.

Action 5: Install Wells for Riparian Irrigation and Supplemental Streamflow

The slightly complex wellhead plumbing required to deliver water for sprinkler irrigation (10 gpm at 50 pounds per square inch [psi]) and drip irrigation (1-2 gpm at 15 psi) would require a storage tank, pressure tank, and two pumps (a submersible pump in the well and a booster pump at the storage tank) at each restoration or park site. The energy cost of pumping the maximum proposed amount of 10 af/yr at an average pressure of 32.5 psi would be $143. This cost assumes that any yield not needed for irrigation would be released into the creekbed to create pools and a trickle of flow.

The two pumps have an expected service life of 15 years with little maintenance during the intervening period. With a combined cost of about $1,500 in materials and $1,500 in labor to replace the pumps, the average annual cost would be about $200, which would be paid to a pump-service contractor. The sprinkler timer, pump pressure switches, and other wellhead plumbing have an estimated life of 5 years and would cost $500 and 3 days of labor by a maintenance person to replace, for an annual cost of $100 and 0.6 day of labor. Costs associated with adjusting the timer and maintaining the sprinkler and drip lines are included in the cost of Action 12. The total O&M cost for the Community Park and Lobb Avenue Park restoration sites would be double the amounts just described, about $900 per year.

Action 6: Construct an Off-Channel Stormwater Lake in Reach 3

The diversion weir at the headworks to the lake inlet would operate passively; adjustments of the weir gate would rarely be needed. The weir crest would be high enough off the creekbed and oriented in a direction that minimizes the amount of diverted sediment, and the slope and smooth surface of the culvert between the intake and the lake would prevent significant amounts of sediment from settling under normal operation. It is conservatively assumed here that the culvert (24 or 36 inches in diameter) would need to be vigorously flushed with a fire hose once a year. A small amount of sediment would probably accumulate near the lake inlet from the flushing and from normal diversions. Removing this material and redistributing it on the site would require perhaps 2 days per year of work with a small skip loader.

The berm that impounds the lake would be built with a larger cross section than the minimum required for structural integrity. This additional width would allow large trees and rodent burrows to become established without jeopardizing public safety. A secondary benefit of this strategy is that routine levee inspections and maintenance would not be required.

Vegetation in and around the lake would be entirely natural and would not require significant amounts of active maintenance. It would be reasonable, however, for a gardener to remove litter and dead vegetation 1 day per month.

Emergency access and facilities will be part of the construction plan for Action 6, because this facility is proposed as a public recreation facility owned by the Town of Superior. The Town will need to provide efficient site access for emergency vehicles in order to ensure a high degree of responsiveness to residents or visitors in need and to avoid liability. It is premature to develop a conceptual plan for Action 6, because several agencies will need input on this design process. The conceptual and construction drawings for this action are expected to progress as funding becomes available and property ownership of the land proposed for Action 6 is transferred to the Town of Superior. The following are some general considerations to be included in the design for accommodating emergency vehicle access.

- A path of a minimum width of 20 feet should be maintained clear of trees, and within this area, a minimum width of 16 feet should be maintained clear of shrub planting.
- The path can be planted with low-growing herbaceous material, but will need to be reinforced with structural support to carry the weight of an emergency vehicle.
- The path layout should connect two existing roads.
- The path should provide as direct a route as possible between the furthest point in the facility and an existing road.

Action 7: Adopt a Creek-Protection Ordinance

The ongoing cost of implementing the creek-protection ordinance depends entirely on the level of public education and enforcement desired by Superior. The trail and park facilities would be vulnerable to vandalism, although installation of surveillance cameras would help minimize it. Illegal dumping activities would need to be policed. Costs associated with policing and enforcement activities related to vandalism are included in the O&M costs for each action that would create a new park or trail facility. Enforcement costs for littering and dumping are included in the O&M costs for Action 8.

A public-education program to teach people about the value of the restored creek environment and the acceptable actions and treatment prescribed under the ordinance might require 12 days of staff time plus $400 in publication materials per year.

Action 8: Implement a Creek-Cleanup and Anti-Dumping Program

A creek-cleanup day using volunteer citizens would require about 7 person-days of labor by an event coordinator, work supervisors, and a refuse hauler; and $1,000 in publicity, materials, and refuse disposal. In subsequent years, labor and refuse-disposal costs could be expected to decrease slightly to perhaps 6 person-days and $800. If prison labor is used to clean up the creek, 3 days of coordination and supervision time and 1 day of labor by a refuse hauler would be required.

The anti-dumping element of the program would require some level of enforcement to be effective. A reasonable expectation might be that occasional field inspections and responding to complaints might require 2 person-days per year of general staff time, 4 person-days of followup, and possible legal action.

Action 9: Implement a Program to Remove Exotic Vegetation

The first 3 years of removing exotic vegetation cost much more than subsequent years because of the large amount of prior accumulation and the high rate of resprouting. Subsequent years typically cost about 10% as much as the combined cost of the first 3 years. Based on the estimated cost of $60,000 for the first 3 years, the average annual O&M cost for followup removal in subsequent years would be about $6,000.

These costs assume that work would be done by a private contractor because of the special and hazardous equipment and chemicals used in the process (e.g., power saws, tractor cutters, mulching machines, herbicides). About 2 staff days per year would be needed to arrange, oversee, and inspect the work. Another 2 days per year and $400 in publication materials should be budgeted for public education and responding to citizen questions or complaints. Substantial cost savings could be achieved by having the same contractor provide vegetation management for the floodway at the same time (see Action 11).

Action 10: Implement a Program to Minimize Grazing Impacts

Superior town staff would function mostly as a liaison between landowners, the NRCS, and Tonto National Forest. The need for site investigations and meetings to coordinate modifications of livestock-management practices would probably decline to a small level after the first 1-2 years of the program. It would be reasonable to assume that 4 days of municipal staff time would be needed for ongoing program implementation.

Action 11: Manage Floodway Vegetation

O&M costs for annual tree pruning, debris removal, and selective clearing of shrubs and tree saplings that contribute disproportionately to hydraulic resistance can be minimized by assigning the work to the same contractor who completes the exotic-vegetation removal. The estimated additional cost to add this task would be about $2,500. This cost assumes that up to one-third of the vegetation in the 27 acres of potential riparian habitat along Reach 2 would need some kind of modification, and that selective pruning is slightly more time-consuming than simple plant removal.

Two additional days of general staff time should be allotted to arrange, oversee, and inspect the work; and to inform the public about the program.

Action 12: Complete Construction of Stone Avenue Park and Community Park

O&M costs for maintaining the two parks would include labor, materials, and equipment costs. Maintenance of landscaping and facilities at both parks would require the equivalent of a full-time gardener (260 days per year) and approximately one-third full-time equivalent (85 days per year) of support by a maintenance person/plumber. A rough estimate of materials costs for restroom servicing, electricity (outdoor lighting), fertilizer, seed and nursery stock, and repair or replacement of playground equipment and other fixtures would be about $4,000 per year. The depreciation cost for wear and tear on vehicles, mowers, and tools depends partly on how many other facilities are serviced by the same equipment. A reasonable estimate would be $4,000 per year. The new facilities could attract vandals. Graffiti removal and equipment-repair costs are included in these estimates, but perhaps 12 days per year of additional police effort also should be expected. Park management and a share of administrative costs for the increased groundskeeping personnel might require about 6 days per year of general staff time.

Action 13: Construct the Old Town Trail along Reach 2

The Old Town Trail would feature natural riparian habitat and would not have as manicured an appearance as the two parks. O&M tasks include removing gravel and fallen limbs from the pathway, picking up litter, emptying garbage containers at the trailheads, replacing light bulbs, removing graffiti, and repairing occasional trail damage from floodflows or vandalism. Two days per week of work by a maintenance person should be adequate to maintain the trail in an attractive condition. A rough estimate of materials and electricity costs would be about $2,000 per year and

$5,000 every 5 years for repair of more substantial damage following relatively large flow events. A reasonable allowance for depreciation of equipment and vehicles would be $1,500 per year. Increased police activity to protect the new facilities might add 12 days per year of additional police work, and 6 days per year of general administrative oversight and planning should be budgeted.

Action 14: Add Access and Park Facilities around the Lake

Maintenance activities for the trail around the lake would be similar to those for the Old Town Trail. Assuming maintenance costs are roughly proportional to the length of trail, the average annual O&M cost for the lake-perimeter trail and connecting trails would be about one-third the cost of the Old Town Trail. A rough estimate of this cost would be 34 days per year of labor for a maintenance person and 10 days per year each for a police officer and general staff person. Electricity, supplies, materials, and depreciation of equipment and vehicles would be about $1,500 per year.

Action 15: Enhance the Trail in Canyon Reach

The Canyon Trail would be less developed and have lower maintenance needs than the Old Town and lake-area trails. The trail would not have lighting, and the routine maintenance tasks would consist of picking up litter, emptying garbage cans at the entrance station and shade structures, removing graffiti, and repairing vandalism. Although the length of the trail equals the combined lengths of the Old Town and lake-area trails, the O&M costs per mile are expected to be lower. A maintenance person could adequately cover routine maintenance activities and occasional larger efforts to repair damage by vandals with 1 day per week of labor. Additional police and general staff effort of 12 person-days per year each should also be budgeted. Supplies and depreciation would add an average-annual cost of about $2,000 per year.

Action 16: Construct a Campground and Nature/History Trail at Old Pinal Townsite

O&M costs for new trails and facilities at Old Pinal Townsite would depend heavily on the level of development of the site. Rough paths with small, all-metal interpretive signs and campground services consisting only of portable toilets would entail the least expense. The rental cost for three portable chemical toilets, including servicing, would be $4,600 per year. A weekly visit by a Tonto National Forest maintenance person to collect garbage and make incidental repairs would be the minimum level of service needed to provide reasonably maintained site conditions. More elaborate trails, historical reconstructions, and campground facilities would substantially increase O&M costs. It is assumed, however, that O&M costs at this site would be covered by an entrance or campground fee.

Action 17: Extend the Old Town Trail to the High School

This trail segment would be used primarily by school children commuting by bicycle between the downtown area and the high school. No improvements, such as garbage cans, shade structures, or interpretive signs, would be provided. Maintenance would consist principally of removing gravel and leaves from the path surface, picking up litter, and removing graffiti from bridges and the path surface. Infrequently, repairs would need to be made after large flood events to the asphalt path surface and possibly to bridges. O&M costs would include about 1 day of labor every 2 weeks by a maintenance person and an annual average of $3,000 in asphalt repair or resurfacing. Ten days per year of police and general staff effort should be budgeted, along with $1,000 per year in equipment and vehicle depreciation.

MONITORING PROGRAM

A monitoring program is recommended to assess the effectiveness of the implementation actions and to detect other trends that might be unrelated to the actions, such as drought-induced vegetation changes or invasion of new exotic species. Variables proposed for monitoring are streamflow, water quality, vegetation, and bird populations. Rainfall is already monitored in Superior, and rainfall and evaporation are monitored at the Arboretum. Measurement of these variables need not be duplicated by the proposed monitoring program. Short-term and long-term monitoring programs are described in the following sections for each of the proposed variables, along with recommended procedures for evaluating the data. Short-term efforts would be implemented during the first 3 years of monitoring, and long-term efforts would continue indefinitely thereafter.

Streamflow

Arboretum Gage

The accuracy of streamflow records at the existing stream gage next to the Canyon Well would be improved by developing an empirical rating curve for low flows. The rating curve presently in use was calculated for high flows based on channel geometry, slope, and roughness. It is not accurate for measurement of flows <10 cfs, which is the most common range of flow. An empirical low-flow rating curve would be developed by manually measuring low flows of various magnitudes to establish an accurate relationship between stage (depth) and discharge at low flows. Several visits over one or more years would be needed to obtain a sufficient number of data points. Flow measurements would be made with a wading rod and current meter except at very low flows, for which the salt-dilution method might be used. This rating curve can be merged with the existing curve for long-term monitoring of the full range of flows. The improved accuracy of low-flow gage records would enable flow gains and losses along reach 5 to be calculated more accurately and allow trends in the gains and losses to be detected.

Magma Avenue Gage

A new, two-part gage installed at the Magma Avenue bridge would include a crest-stage gage and a low-flow stream gage to serve two functions. First, the crest-stage gage would record the peak water stage during high-flow events. It would be read and reset after large storms to begin developing a long-term record of peak annual stage. This simple, mechanical device consists of a measuring rod inside a tube that is attached vertically to the side of a bridge pier. The maximum water level in the tube is recorded on the rod by a floating cork, water-sensitive paste, or similar means. The stream-hydraulics model developed for the present planning effort would be used to estimate the flow for each high stage. Over a period of many years, these data points would create an empirical basis for estimating peak floodflows and for potentially improving the estimated 100-year floodflow used in the FEMA floodplain-mapping study.

Second, a low-flow stream gage also would be installed to indicate the flow regime relevant to revegetation and to investigate the accuracy of streamflow estimates that were developed for the present study by correlation with Wetbottom Creek and West Fork Sycamore Creek. The stability of the bedrock channel near Magma Avenue would facilitate accurate measurement of low flows. Two approaches to recording flow are available. The less expensive method would be to install a staff gage in the low-flow channel and have a volunteer (or perhaps an employee at the nearby fire station) read and record the water stage on a daily basis. An alternative method, which would be more expensive but would provide more complete data, would be a data logger and pressure-transducer setup. This equipment would be buried in the creekbed and downloaded at intervals of several months by a technician. Either method would require development of a stage-discharge rating curve for low flows using occasional manual measurements of streamflow. After 2-3 years of monitoring, flow-duration curves can be plotted and compared with the flow-duration curves for Wetbottom and West Fork Sycamore Creeks to confirm their similarity.

Wetted Reach Observations

The distribution and vigor of riparian vegetation is strongly influenced by the duration and season of flow in the adjacent creek channel. The length of channel that would be wetted under each of the riparian-restoration actions proposed in this plan were estimated using limited data and numerous assumptions. Short-term monitoring of wetted reach length is recommended following implementation of one or more of the flow-dependent restoration actions. Visual observation of the presence or absence of flow at convenient creek access points monthly for 1-2 years would be sufficient to confirm or revise the estimated reach lengths calculated for this plan.

Water Quality

As a condition of their NPDES permits, the wastewater-treatment plant and BHP are required to measure and report periodically the quality of their discharges. In addition, Arboretum staff measure the electrical conductivity of Queen Creek water at the Arboretum approximately weekly.

Additional water-quality monitoring is not considered necessary to meet the objectives of this plan. The discharges are regulated to remain within a range of water quality deemed acceptable for aquatic life by the EPA. Small fish are present in Reach 5, and the relatively high salinity (dissolved solids) concentration of the dewatering water discharges has not caused any obvious adverse impacts on riparian vegetation downstream from the discharge point. In fact, Reach 5, which is downstream from both discharges, is the only reach that supports fish, and it is also the reach with the healthiest and most abundant riparian vegetation.

Two sets of water-quality constituents are of potential concern, but investigation and monitoring them are considered beyond the appropriate scope of the present restoration effort. The first set of constituents are metals and acidity, which potentially could seep out of the mine workings if dewatering is permanently discontinued and the groundwater level inside the mine is allowed to rise. Eventually, the water level would rise above the level of nearby points along the bed of Queen Creek, and groundwater would seep into the creek through the same fractures that presently allow streamflow to seep into the mine. The mine seepage could be of unacceptable quality for direct discharge into the creek, much like the dewatering water presently pumped from the mine. The likelihood and magnitude of this impact are speculative because they depend greatly on future mine operations and on mine-reclamation requirements that could be imposed if the mine closes permanently. Furthermore, the soonest the impact could occur would be about 20 years after the dewatering ceases, which would be the time required for the mine to fill with water.

The second set of water-quality constituents of potential concern are pharmaceutically active compounds that are commonly present in treated municipal wastewater. These compounds include drugs such as antibiotics, analgesics and hormone replacements that are excreted in urine, as well as hormone-like compounds used in detergents, none of which are removed by conventional wastewater-treatment methods. Recent studies (Sedlak 1999) have found that the concentrations of these compounds in treated municipal wastewater is commonly in a range that has physiological effects on aquatic organisms. These findings could explain the increasingly widespread reports of endocrine disruption in fish (e.g., partially-developed female reproductive organs in male fish) (Purdom et al. 1994, Harries et al. 1996, 1997). Cause-and-effect relationships between wastewater discharges and these physiological symptoms has not been firmly established, and research into this issue is beyond the scope of a monitoring program for Queen Creek. If cause-and-effect relationships are eventually confirmed, however, new restrictions and requirements for treatment and discharge of municipal wastewater would probably follow.

Vegetation

Short-term vegetation monitoring would consist of annual surveys of vegetation composition, density, and structure at about 12 location along Queen Creek. A single botanist could survey about 12 sites in 1 day. The botanist would select the exact site locations during the first survey, including reference sites relatively unaffected by plan implementation actions and sites influenced by one or more of the actions. An overall distribution should include all reaches of Queen Creek and potentially affected tributaries. Suggested general site locations are listed in Table 6-3.

Table 6-3. Suggested General Locations and Objectives for Vegetation Monitoring and Bird Point-Count Censuses

Site	Location	Actions Monitored/Reference Site
1	In canyon above Reach 1	Reference site: sycamore–ash–walnut woodland
2	Reach 1 below Magma Club	2-4, 7-9
3	Reach 2 below Stone Avenue	2-4, 7-9, 11
4	Stone Avenue and Community Parks	5, 7-9, 11
5	Magma Wash 1	Effects of discontinued dewatering
6	Lake in Reach 3	6, 7-9
7	Middle of Reach 3	Reference site: mesquite
8	Reach 4 above new WWTP turnout	1, 7-10
9	Reach 4 below new WWTP turnout	1, 7-10
10	WWTP wash	1 and 2
11	Reach 5 at Old Pinal Townsite	1-2, 9-10
12	Reach 5 in arboretum	Reference site: cottonwood–willow woodland

Note:

WWTP = Superior Municipal Wastewater Treatment Plant.

Each site would be permanently marked with a rebar stake or fencepost driven into the ground and painted or flagged for easy relocation during subsequent visits. Site locations would also be recorded during the initial visit by measuring the geographic coordinates with a hand-held GPS unit, plotting the location by inspection on a quadrangle map, and measuring the distances and bearings from nearby landmarks.

Vegetation at each site would be documented using the releve method, as described by Ralph et al. (1993). A releve plot would be established at each site. The releve plot consists of a circular survey area centered on a location marker and having a radius of 25 meters if the vegetation is relatively homogeneous or 50 meters if it is heterogeneous. Vegetation characteristics measured at each site would include maximum tree diameter at breast height; canopy cover and height of each vegetation stratum (i.e., tree, shrub, herb, ground); and the species composition and relative cover within each vegetation stratum. Canopy cover would be recorded as a visually estimated percent of total area. Species covering >5% of the releve plot would be identified to the species level; other vegetation would be identified to the genus level. A qualitative indication of vegetation health would also be recorded during each visit. For example, tip withering from drought stress or infestation with mistletoe would be noted.

The specific site locations and sampling methods would be submitted to the Arizona Partners In Flight (APIF) program to ensure that data collected for this project are consistent with data collected elsewhere in the state and thereby usable for regional analysis. All field data would entered into a project database. APIF would be consulted about the parameters and structure of the database, so that the data could be combined easily with monitoring data from other areas.

In addition to the vegetation measurements, photographs facing north, west, south, and east would be taken at each site marker using the same camera height and lens focal length during each site visit.

Vegetation would be surveyed in May of each year along with one of the wildlife surveys. Ideally, surveys would start as soon as the plan is adopted to provide additional baseline information for trend analysis. Surveys should continue annually for at least 3 years and preferably 5 years after implementation of any of the recommended management actions.

In the long term, vegetation monitoring would be achieved by (1) obtaining aerial photographs at a scale of 1 inch = 600 feet every 10 years and (2) planimetering the area and density of cover of each of the four vegetation communities described in this plan. The 12 point-survey locations would also be resurveyed the same year the aerial photographs would be taken to provide ground-truthing of the aerial-photograph interpretation. Long-term vegetation trends would be calculated by simple linear regression of the area and of the product of area and density for each vegetation type. Hydrologic factors that might have contributed to any statistically significant trends revealed by the analysis would be inferred from the type and location of the observed vegetation trend.

Wildlife

One of the objectives of restoring riparian habitat is to provide benefits to wildlife associated with the habitat. Birds are one of the easiest types of wildlife to survey, and it is commonly assumed that habitat conditions beneficial to riparian bird species would also be beneficial to riparian mammals, reptiles, and invertebrates. Bird populations and diversity would be surveyed using point-count censuses at the 12 locations established for vegetation monitoring. This approach would allow any trends in the bird data to be investigated for possible relationships with the vegetation data.

Point-count surveys are relatively simple to implement and widely used. Each monitoring station would be visited during the early morning hours, and all birds detected within a 50-meter radius over a period of 5 minutes would be recorded. Although vegetation surveys are needed only once per year, three separate bird surveys between April 15 and May 31 are recommended. This would allow better monitoring of nesting and transient use by migratory birds. The point-count surveys would be conducted by trained wildlife biologists familiar with the songs and behavior of all bird species commonly found in Arizona riparian habitats. The census data would be entered into the monitoring database in a format approved by APIF so that they may be compared with similar data from other parts of the state.

Cost

Approximate costs for each of the monitoring-program elements were developed to facilitate preparation of a budget and financing strategy for the restoration plan. Most of the monitoring-program elements would have one-time startup costs to establish sampling sites and gaging stations. The costs in subsequent years would be much lower. The estimated cost for each program element in Year 1, Year 2, and Year 3 and subsequent years are shown in Table 6-4.

FUTURE PLAN REVISIONS

Various details of the recommended restoration and recreation-development actions would undoubtedly change as additional feasibility and engineering studies are completed. The sequence and schedule of implementing the actions would also necessarily reflect Superior's level of success in obtaining financial assistance from various sources. None of these minor changes would constitute a substantial modification of the plan that would justify a plan revision. However, changes that involve different sources of water, restoration along other reaches of the creek or its tributaries, or new objectives largely unrelated to the ones articulated in the current plan would justify initiating a new public process to update the plan. Because these changes cannot be foreseen, the implementation oversight group (BHP Advisory Committee) would need to exercise its judgment as conditions evolve and decide whether or when a formal plan revision process is needed.

Table 6-4. Approximate Annual Costs of Monitoring Program Elements

Element	Year 1	Year 2	Years 3+
Arboretum gage-rating curve	$2,200	$2,200	$0
Magma Avenue crest-stage gage	2,000	700	1,700[a]
Magma Avenue low-flow gage			
Option 1: Manual staff plate	5,000	3,000	1,800
Option 2: Data logger	6,000	3,800	4,000
Vegetation surveys	4,300	2,000	2,000[b]
Bird-count surveys	6,400	3,500	3,500
Total	$25,900	$13,600	$12,000

Notes:

[a] Excludes aerial photographs and photo mapping every 10 years at a cost of $4,000.
[b] Excludes flood frequency reanalysis every 10 years at a cost of $1,500.

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Chapter 8. List of Acronyms and Abbreviations

ACHP	Advisory Council on Historic Preservation
ADA	Arizona Department of Agriculture
ADEQ	Arizona Department of Environmental Quality
ADOT	Arizona Department of Transportation
ADWR	Arizona Department of Water Resources
af	acre-feet
af/yr	acre-feet per year
AGFD	Arizona Game and Fish Department
AMA	Active Management Area
APIF	Arizona Partners In Flight
Arboretum	Boyce Thompson Arboretum
ARHP	Arizona Register of Historic Places
ASHPA	Arizona State Historic Preservation Act
AWC	Arizona Water Company
AWPF	Arizona Water Protection Fund
AZMET	Arizona Meteorological Network
BHP	Broken Hills Properties Company
CAP	Central Arizona Project
cfs	cubic feet per second
Committee	Queen Creek Restoration Advisory Committee
CWA	Clean Water Act
EQIP	Environmental Quality Incentives Program
ESA	Endangered Species Act
ET	evapotranspiration
ET_0	Reference evapotranspiration
FEMA	Federal Emergency Management Agency
FHA	Federal Highway Administration
GPCD	gallons per capita per day
gpd	gallons per day
gpm	gallons per minute
HUD	U.S. Department of Housing and Urban Development
IGR	irrigation grandfathered right
LRSP	Local, Regional and State Parks
µmho/cm	micromhos per centimeter
mg/l	milligrams per liter
mgal/yr	million gallons per year
MOA	Memorandum of Agreement
NEPA	National Environmental Policy Act
NHPA	National Historic Preservation Act
NPDES	National Pollution Discharge Elimination System
NRCS	Natural Resources Conservation Service
NRHP	National Register of Historic Places
O&M	operations and maintenance
psi	pounds per square inch
Reclamation	U.S. Bureau of Reclamation
SHPO	State Historic Preservation Officer
Superior	Town of Superior, Arizona
SWPPP	Stormwater Pollution Prevention Plan
TEA-21	Transportation Equity Act for the 21st Century
USACE	U.S. Army Corps of Engineers
USFWS	U.S. Fish and Wildlife Service
WWTP	Superior Municipal Wastewater Treatment Plant

Appendix A. Cultural and Historical Resources

PREHISTORIC CONTEXT

The Archaic period of prehistory in the Desert Southwest is defined by the end of the Pleistocene (circa 8000 B.C.) and the earliest Hohokam evidence (circa 1–500 A.D.). The Southwest was probably occupied by a number of groups with distinctive cultural traditions in the Archaic period, one of which, the Cochise, is recognized to have inhabited southeastern and east-central Arizona (Irwin-Williams 1979). This tradition includes three distinct phases: Sulphur Springs, Chiricahua, and San Pedro.

Material culture of the Sulphur Spring phase (7000–5000 B.C.) indicates the occupation by hunter-gatherers who possessed a well-developed ground-stone technology. It has been suggested that this material might represent the northern extremity of a Mesoamerican hunting-gathering culture. The earliest materials from the Chiricahua phase (5000–2000 B.C.), dating from at least 3000 B.C., reflect a mixed foraging economy and a well-developed ground-stone technology. The chipped-stone tools also present during this period includes a variety of choppers and scrapers, as well as a range of distinctive projectile points. An early variety of maize introduced into the southern Southwest about 2500-2000 B.C. was accompanied in the Cochise area by domestic squash. Additional materials include evidence of woven items, such as basketry, textiles, and sandals (Irwin-Williams 1979).

The San Pedro phase (2000–100 B.C.) includes evidence suggesting the beginning of agriculture. Similarities in artifact assemblages suggest that the San Pedro phase underwent a transition into both the Hohokam and Mogollon cultures. Changes attributed to Mesoamerican stimuli, including increased development of agriculture and the addition of ceramics to the artifact inventory; signal this transition. Worked shell, stone, and maize agriculture, which are indicators of the Hohokam, are found during this last phase of the Archaic period, leading most archaeologists to conclude that the Hohokam pattern developed from the Archaic (Gumerman and Haury 1979, Gumerman 1991).

The Hohokam occupied the middle Gila and Salt Rivers drainage basins in the Sonoran Desert of southern Arizona. Haury (1976) proposes the following chronology for the central Gila-Salt drainage system: the Pioneer Period (1–550 A.D.), the Colonial Period (550–900 A.D.), the Sedentary Period (900–1100 A.D.), and the Classic Period (1100 -1450 A.D.)(Gumerman and Haury 1979). Small villages were first located along riverine environments and consisted of clusters of brush structures constructed in shallow, elongated pits. People of this period domesticated maize, beans, squash, cotton, and later added agave, amaranth, cholla cactus, little barley grass, Mexican crucillo, and tobacco to their crops. In addition, simple canal systems were constructed to irrigate the fields. Animal protein was supplied by rabbits, deer, and big-horn sheep. Artistic and utilitarian items included shell, stone, and figurine complexes, as well as plain, reddish brown, coil-constructed ceramics, which were shaped and finished by the paddle-and-anvil technique (Gumerman and Haury 1979, Gumerman 1991).

By the Colonial period, the Hohokam greatly increased both their cultivated land and occupied territory. Placement of houses became more orderly, and they were often situated around a courtyard. Evidence of the success of Hohokam culture in this period includes expanded, more sophisticated, large-scale irrigation systems and the introduction of platform mounds and ball courts. Crafted items show increased elaboration throughout this period, as well (Gumerman and Haury 1979, Gumerman 1991). Hohokam territory contracted during the Sedentary period, but sites of this period are larger and more differentiated than those of the Colonial period. Agricultural was attempted in previously unused environments, which suggests a change in climate or the quality of agricultural plots. The quality of some arts and crafts declined, but ceramics and shell items took on more diverse and elaborate forms. In addition, copper bells from Mexico were first imported during this period (Gumerman and Haury 1979, Gumerman 1991).

Changing quite significantly during this period, architecture was typified by more surface structures, compounds, multistory houses, houses on platforms, and the construction of fewer new ballcourts. Previous material-culture indicators (e.g., carved stone and shell effigy figures, stone palettes and censers) were no longer made. Red ware and polychrome ceramics replace red on buff. During this last Hohokam period, the customary burial methods were extended inhumation and cremation. Suggested causes for these changes include an intrusion of Salado people from the north, a Salado influence, infusion of ideas or people from Mexico, or simply developments from the previous Sedentary phase (Gumerman and Haury 1979, Gumerman 1991).

Ethnographic Context

Unless otherwise cited, the following discussion regarding the Western Apache is adapted from Basso (1983).

The Town of Superior (Superior) lies within land once occupied by the San Carlos Apache, one of five major groups occupying contiguous territories in east-central Arizona known collectively as the Western Apache. The San Carlos spoke a dialect of the larger Western Apache group, which was in turn part of the Athapaskan language stock.

Prehistory and proto-history of the Western Apache and their forerunning Proto-Apacheans is little known because of the scarcity of recorded information and excavated sites. It is widely accepted, however, that in the sixteenth century, Athapaskan speakers arrived in northern New Mexico and gradually spread to the west and south, and eventually into Arizona. Their descendants are the present-day Apache and Navajo groups (Woodbury 1979). Spanish accounts and corroborating Western Apache clan legends give confident indication that by the 1700s the Western Apaches occupied the area from the Mogollon Rim to the Gila River. The San Carlos Apache consisted of four bands, one of which is the Pinal band. Bands were units in the sense of territorial expanse and linguistic similarities, but they did not participate in any form of political action. A band consisted of smaller local groups, each with exclusive claims to certain farm sites and hunting locations. Each band was headed by a chief, who was selected from the ranks of family-cluster headmen on the basis of skill in hunting or raiding and personal qualities that inspired confidence, allegiance, and respect.

By the 1700s, the Western Apache had acquired the technique of farming, and they used this technology to cultivate maize, beans, and squash. However, because they were dependent upon hunting and gathering for 75% of their food, they did not permanently locate their residences. In April, the people of the Salt and Gila river valleys traveled north to farm on the banks of mountain streams. Here they constructed dome-shaped wickiups, repaired irrigation ditches, and planted their crops. From May to October, groups gathered mescal tubers, saguaro fruit, prickly pear, cholla, mesquite beans, Yucca fruit, acorns, pinon nuts, and juniper berries. Maize was harvested in October, and deer and antelope hunting was conducted in late fall. In November, after jerky was made, the people moved from their farm sites to lower elevation winter camps. By the middle of the 1700s, the Western Apache had established an intricate network of trading and raiding relationships that involved at least a dozen other cultural groups and reached all the way from the Hopi villages in northern Arizona to Spanish settlements in central Sonora. Raiding, as opposed to warfare, was strictly an economic activity aimed at acquiring livestock.

Exploration and Settlement

Although Coronado explored this area in 1542, little other Spanish exploration took place thereafter. Spanish travelers into the region were mainly Jesuit priests whose mission it was to convert the indigenous population to Catholicism. Spanish settlements were established in the larger region in which the Apache raided, adding substantially to the Apaches' economic base. Spanish attempts to combat the Apache's raiding, mainly in the form of presidios, proved to be a weak defense. In the late 1700s, hostilities between the two groups intensified. In 1786, Viceroy Bernardo de Galvez devised a plan to intensify offensive actions and eventually came to a peace agreement with the Apaches. He developed a food-ration system for the Apache, and by 1825, raiding had substantially decreased, and the Apache had become somewhat dependent upon the Spanish. After Mexico won independence from Spain in 1821, the new government was not able to support the presidios or the Apache ration system. By 1831, Apache raiding had recommenced with intensity, and it was met with a Mexican policy of extermination. From 1831 to 1853, the Apache population of Sonora drastically declined. Throughout the period of Spanish and Mexican control of Sonora, however, the Apache remained marginal to the colonial system and managed to maintain their way of life, utilizing those components of the Spanish culture they wished, such as the horse, lance, and firearms, and disregarding those it did not, such as Catholicism.

When the Gadsden Purchase was ratified in 1853, and Arizona came under the control of the United States, Euroamericans began immigrating to the area, many lured by the prospect of making their fortune in mining. It soon became apparent that the newcomers not only wanted to stop the Apaches from raiding, but would stop at nothing to get at the region's rich mineral resources. The hostilities that ensued resulted in harsh, tragic warfare that lasted for almost 40 years. This period of warfare ended with the defeat of the Western Apache and their placement on reservations. In

1870, the Western Apache were removed to the San Carlos Reservation. The United States had three objectives for Apaches on the reservations: their economic development, the establishment of schools to enculturate them, and the establishment of churches for their conversion to Christianity. None of these objectives has been wholly successful. Today, the first and preferred language of many Apache is their native language, and while many have converted quite devoutly to Christianity, native ceremonies are still conducted by shamans, and many of the native spiritual beliefs are still maintained and passed on.

The Arizona region was first explored by non-native peoples during the sixteenth century when Spanish Jesuits began traveling through northern New Spain (California, New Mexico and Arizona) to convert Native Americans to Christianity. The Jesuits succeeded in establishing several missions in Arizona for this purpose. Following Mexican independence from Spain in 1821, Arizona became part of the new Mexican Republic. Twenty-five years later, this land became embroiled in the dispute between the United States and Mexico that culminated in the Mexican-American War (Meyer and Sherman 1991).

The Treaty of Guadalupe Hidalgo, which ended the war in 1848, confirmed the United States' title to Texas and ceded the California and New Mexico territories to the United States for $18 million dollars. By 1853, Mexican President Santa Anna decided to sell additional territory to the United States. During the mid-1860s, a volunteer company composed of local Pima Indians and Euroamerican settlers was organized to quell the aggressive activities of the Apaches. The settlers and the Pima, enemies of the Apaches, organized Company B, Arizona Volunteers, to attack an Apache settlement on Big Picacho mountain. Local tradition says that the Apaches were awakened at daybreak by rifle fire. Seeing no escape, the Apaches retreated to the cliff behind them and jumped to their death from the cliff now known as Apache Leap (Bernard Deutsch Associates 1988).

U.S. officials eventually sent the military into the region to protect U.S. citizens from the Apache raids. Camp Pinal (previously named Mason's Valley and Picket Post) was established in 1870 near the modern town of Superior and served as a military post for this purpose. Colonel George Stoneman, commander of Camp Pinal, was ordered to construct a road from the camp to other military garrisons in Arizona. The trail, known as Stoneman Grade, eventually connected Camp Pinal to Globe, approximately 20 miles northeast. Construction only progressed for the first 5 miles of the route, however, because during construction a soldier named Sullivan discovered what he believed to be silver. This discovery led to the establishment of the Pioneer Mining District and the Silver King Mine (Bernard Deutsch Associates 1988). Camp Pinal was abandoned in 1871, and the site became the location of a ranch owned by Robert Irion.

Mining

The establishment of Silver King and the Pioneer Mining Districts after Sullivan's accidental discovery of silver led to the development of several more mining communities in the area. Three miles southwest of Superior, the mill town of Pinal (originally known as Picket Post) was established in 1878. Within 2 years, six stamp mills were built to process the ore of the Silver King Mine. Pinal quickly became a town with a population of over 2,000 (Bernard Deutsch Associates 1988). The

1881 *Pinal Drill* boasted that the town had two hotels, half-a-dozen restaurants, a dozen saloons, two blacksmith and wagoners' shops, two drugstores, several groceries, a watchmaker, a photograph gallery, a brickyard, a lime kiln, seven stores, a lumberyard, two livery stables, bath rooms, two barber shops, six lawyers, four doctors, and a preacher. The newspaper also announced the existence of a Wells Fargo office, an Oddfellows lodge and several "elegant stone buildings" within the city of Pinal (Murbarger 1964:172).

The Silver Queen Mining Company, which owned mines located 3 miles south of the Silver King Mine, was incorporated during the 1870s. The mining camp that developed around Silver Queen became known as Queen. The economic depression of the 1890s, coupled with the discontinuation of silver coinage in 1893, led to the decline of silver mining. In 1893, Silver Queen stopped production, and Silver King Mine and the Town of Pinal rapidly fell into decline. A group of Michigan businessmen, with the goal of mining for copper ore, organized the Lake Superior and Arizona Mining Company in 1902. The company purchased the Golden Eagle mine a short distance from Silver Queen and laid out the townsite of Hastings at the Queen mining camp. The town was eventually renamed Superior, after the company. Many of the residents of surrounding mining communities, including Pinal, moved to the new Town of Superior (Bernard Deutsch Associates 1988).

In 1910, William Boyce Thompson organized the Magma Copper Company and purchased the Silver Queen Mine. The Magma Company immediately constructed an office building, living quarters, a mess hall, and an assay office. A mill and smelter were soon constructed to process the ore. In 1914, the company constructed the Magma Arizona Railroad to transport the ore. Over the next several years, the Magma Company also constructed a hospital, clubhouse, gymnasium, pool, park, and more than 28 brick houses for administrative employees. Concerned about the destruction of desert plants, Thompson built the Arboretum near his winter home west of Superior along Queen Creek in 1924. The Boyce Thompson Arboretum today encompasses 300 acres of plantings, primarily trees and shrubs collected from arid and semiarid regions around the world. The Arboretum is both a National Historic District and an Arizona State Park.

Superior prospered with the growth of mining companies like Magma. At its peak, the Superior population rose to more than 5,000. The Magma Copper Company was the main employer in Superior for 72 years. In 1971, a decline in copper prices forced the shutdown of the company's smelter. All mining ceased in Superior in 1982, resulting in a major economic loss for the residents, who depended on the industry for employment. Historical research and architectural preservation efforts have helped to preserve the unique history of the town and the area, and many of Superior's residents interpret the history of the area to the tourists who visit the area through the museums, buildings, and stores that reflect Superior's mining history (Bernard Deutsch Associates 1988).

Historical and Cultural-Resource Sites

Recorded Sites

A search of cultural-resources records was conducted at the Arizona State Historic Preservation Office, the Tonto National Forest, and the Arizona State Museum. Recorded cultural-resources sites have been identified within an 800-foot corridor, as well as the customary additional quarter-mile radius from the plan area of Queen Creek. While restoration and management activities under the plan will not take place within the entire quarter-mile-wide corridor, information regarding recorded cultural-resources sites in this area will be useful in assessing the types of sites that might be located within the plan area during future surveys for cultural resources. The following discussion summarizes the results of the three records searches.

Within the 800-foot-wide corridor, nine cultural-resources sites have been previously recorded. Two of the nine sites are prehistoric in nature and seven are historical. Seven of the nine sites have been evaluated for eligibility for listing on the NRHP, of which six were recommended and one was not recommended. According to the records search, none of the nine sites appears to have been evaluated for eligibility for the ARHP.

Within the quarter-mile radius, 19 cultural-resources sites have been recorded, 10 of which are prehistoric in nature and 9 historical. Of the 19 sites, 11 have been evaluated for eligibility for listing on the NRHP, of which 1 is listed, 8 others were recommended for eligible for listing, and 2 were not recommended. According to the records search, none appears to have been evaluated for eligibility for the ARHP.

Potential Sites

The review of the records indicates that certain types of cultural resources seem to be prevalent in the vicinity of the proposed restoration projects. Therefore, it is reasonable to assume that the same types of cultural resources may be found in future surveys for cultural resources. These types of cultural resources might include: prehistoric villages, habitation sites, and sherd areas attributable to either Salado or Hohokam cultures; historical features associated with mining, including adits, prospects, tailings, roads, camps, and towns; and historical roadways, including wagon, dirt, and paved roads.

Appendix B. Hydrologic Data and Analysis

INTRODUCTION

Appendix B documents a variety of hydrologic data, calculations, and models that were used to develop the information presented in the main body of the restoration and management plan. The basic data section (below) simply presents graphs and tables of basic data that may be of interest to some readers. This is followed by sections describing the estimation of flows in Queen Creek by correlation with gaged flows in similar watersheds, reactivation of the Federal Emergency Management Agency's flood hydraulics model, and development of a water balance model to estimate water demand and consumptive use associated with various vegetation restoration actions.

BASIC DATA

This section contains figures and tables that display basic hydrologic data compiled and evaluated during the process of developing the plan. They are presented here without commentary. Figures B-1 through B-12 show rainfall, streamflow at the Arboretum, WWTP discharges, BHP dewatering discharges, groundwater pumping at the Arboretum, electrical conductivity of the creek, and reference evapotranspiration for various time periods and intervals. Table B-1 lists manual streamflow measurements that were made during the plan development process.

ESTIMATION OF QUEEN CREEK STREAMFLOW

Gaged streamflow data are not available for Queen Creek near the point where it enters Reach 1 of the study area. Streamflow data from the gage at the Arboretum already reflect the net influence of inflows and outflows in the study area. Those data might be useful for model calibration but are not suitable for use as estimates of inflow to Reach 1. Historical flow data from the U. S. Geological Survey gage near Whitlow Dam (15 miles downstream from Superior) are even less suitable because of large upstream losses to seepage, evaporation, and ET.

Natural streamflow in Reach 1 was estimated by correlation with gage records for other drainage with similar characteristics. Records for 24 small creek gages operated by the U. S. Geological Survey at various times in the Central Highlands province were screened on the basis of drainage area size, gage elevation, annual rainfall, and the availability of daily rather than peak-flow data. As a result of this initial screening, four gages were selected for further analysis. These gages and their watershed characteristics are shown in Table B-2. For comparison, the watershed

Table B-1 . **Miscellaneous Flow Measurements and Calculated Flow Gains and Losses along Queen Creek, 1997-1998**

Map label	Location	Distance (1) (mi)	July 10, 1997 Flow (cfs)	July 10, 1997 Gain/Loss (cfs)	July 11, 1997 Flow (cfs)	July 11, 1997 Gain/Loss (cfs)	March 4, 1998 Flow (cfs)	March 4, 1998 Gain/Loss (cfs)	March 18, 1998 Flow (cfs)	March 18, 1998 Gain/Loss (cfs)	March 25, 1998 Flow (cfs)	March 25, 1998 Gain/Loss (cfs)	April 27, 1998 Flow (cfs)	April 27, 1998 Gain/Loss (cfs)	May 4, 1998 Flow (cfs)	May 4, 1998 Gain/Loss (cfs)
1	0.5 mi above Magma Club	9.38	--		--		0.52		dry		dry		--		dry	
				--		--		-0.52		0		--		--		--
2	Magma Club	8.97	--		dry		0 (2)		dry		--		--		--	
				--		0		0.20		+tr		--		--		--
3	Magma Avenue bridge	8.74	--		dry		0.20		tr		--		--		--	
				--		0		-0.10		-tr		--		--		--
4	Stone Ave. low water crossing	8.32	--		dry		0.10		pools		--		--		--	
				--		0		0.11		+tr		--		--		--
5	Lower pedestrian bridge	7.84	--		dry		0.21		tr		--		--		--	
				--		0		-0.05		-tr		--		--		--
6	Highway 60 bridge	7.34	--		dry		0.16		pools		--		--		--	
				--		0		--		--		--		--		--
7	Mary Drive	6.38	--		dry		--		--		--		--		Flow	
BHP (3)	BHP dewatering discharge	n.a.	0		0		1.92		1.92		1.92		1.59		1.95	
				--		--		-1.5		-1.39		-1.78		-1.35		-1.88
8	Queen Cr. above WWTP confluence	5.04	--		--		0.42 (4)		0.53 (5)		0.14 (5)		0.24 (5)		0.07 (5)	
WWTP (6)	WWTP discharge to wash	n.a.	0.39		--		0.42		0.41		0.39		0.41		0.39	
				-0.16		--		0.17		-0.28		-0.35		-0.08		--
9	WWTP wash above Queen Cr.	4.77	0.23		0.04		0.59 (4)		0.13 (5)		0.04 (5)		0.33 (5)		--	
				--		--		--		--		--		--		--
10	Old Pinal townsite	3.76	--		--		--		--		flow		--		3.00	
				--		--		--		--		--		--		4.00
11	Boyce Thompson gage	2.28	dry		dry		--		--		--		8.0 (gage)		7.0 (gage)	

NOTES:

All measurements by salt-dilution method except as noted.

(1) Distance is river miles along Queen Creek upstream of the Highway 60 bridge at the west end of Boyce Thompson Arboretum.

(2) Flow went underground for a 100-m reach at the Magma Club on this date.

(3) Monthly discharge of dewatering water from BHP storage ponds, divided by the number of days of discharge to obtain an average monthly discharge rate.

(4) Measured with bucket and stopwatch under difficult conditions. Accuracy probably only +/- 30%.

(5) Measurement is of low accuracy because of insufficient brine strength for salt dilution method. Accuracy estimated to be +0.2/-0.1 cfs.

(6) Daily average flow from the Superior municipal wastewater treatment plant is shown. Hourly flow fluctuations are substantial.

n.a. = not applicable because site is not on Queen Creek

-- = flow not measured or observed

tr = trace of flow (too small to measure)

pools = standing water in channel but no visible flow

flow = flow observed but not measured

gage = flow indicated by permanent streamgage installed at Boyce Thompson Arboretum

Table B-2. Characteristics of Gaged Watersheds Used to Estimate Queen Creek Flow

Watershed	USGS Station Number	Period of Record	Elevation[1] (feet)	Drainage Area (mi^2)	Average Annual Precipitation[2] (in.)
Cave Creek below Cottonwood Creek near Cave Creek	9512280	1980-1997	2,280	82.7	17
Queen Creek at Whitlow Dam Site	9478500	1948-1959	2,046	144	15
Sycamore Creek near Sunflower	9510150	1961-1976	3,308	52.3	22
West Fork Sycamore Creek near Sunflower	9510080	1961-1974	4,000	9.8	24
Wetbottom Creek near Childs	9508300	1967-1997	2,320	36.4	19
Queen Creek above Magma Club	none	n/a	2,900	10.3	22

[1] Elevation is at the gage location, or in the case of Queen Creek, at the point of flow estimation.

[2] Average annual precipitation over the watershed.

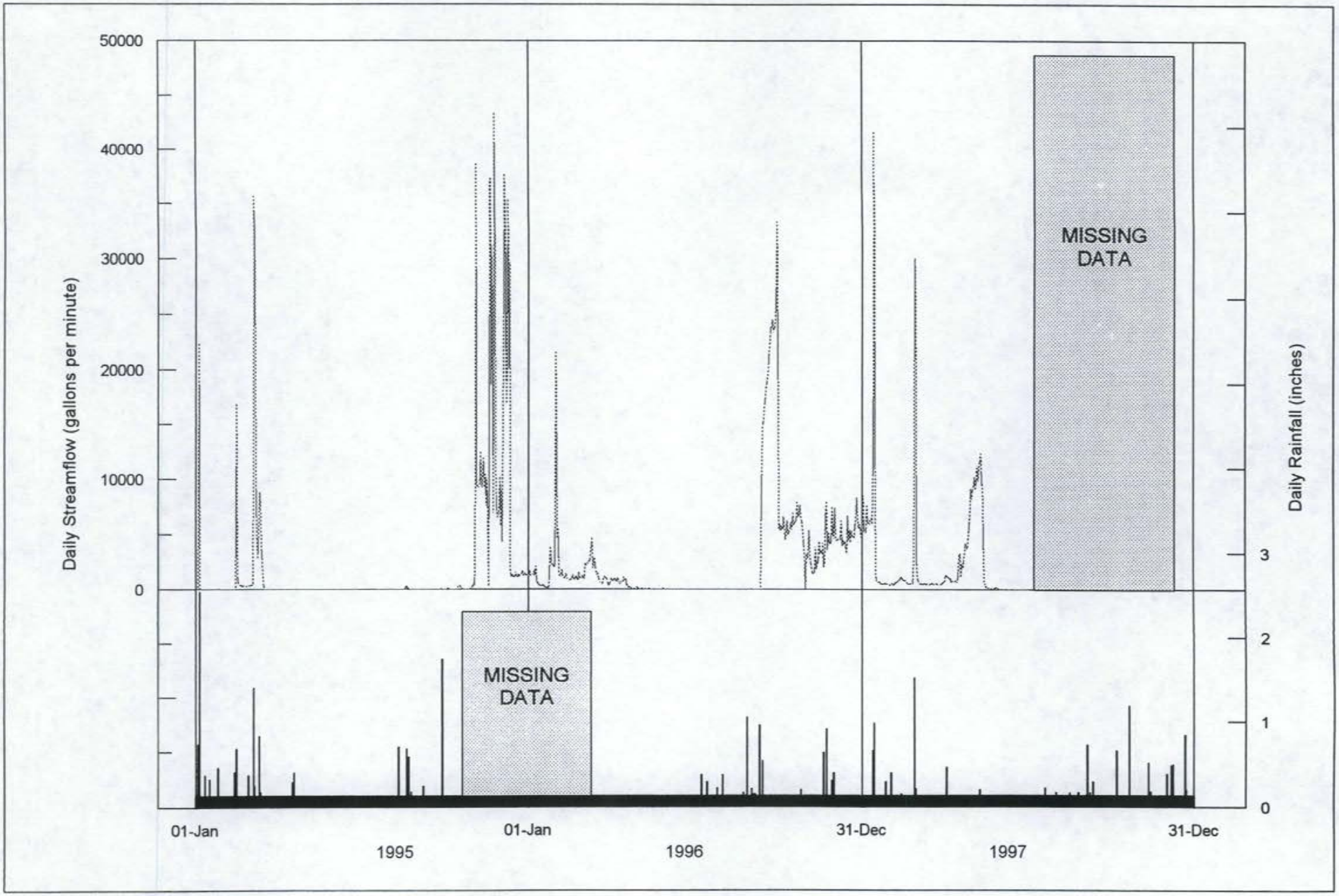


Figure B-1. Daily Rainfall and Queen Creek Streamflow at Boyce Thompson Arboretum during 1995-1997

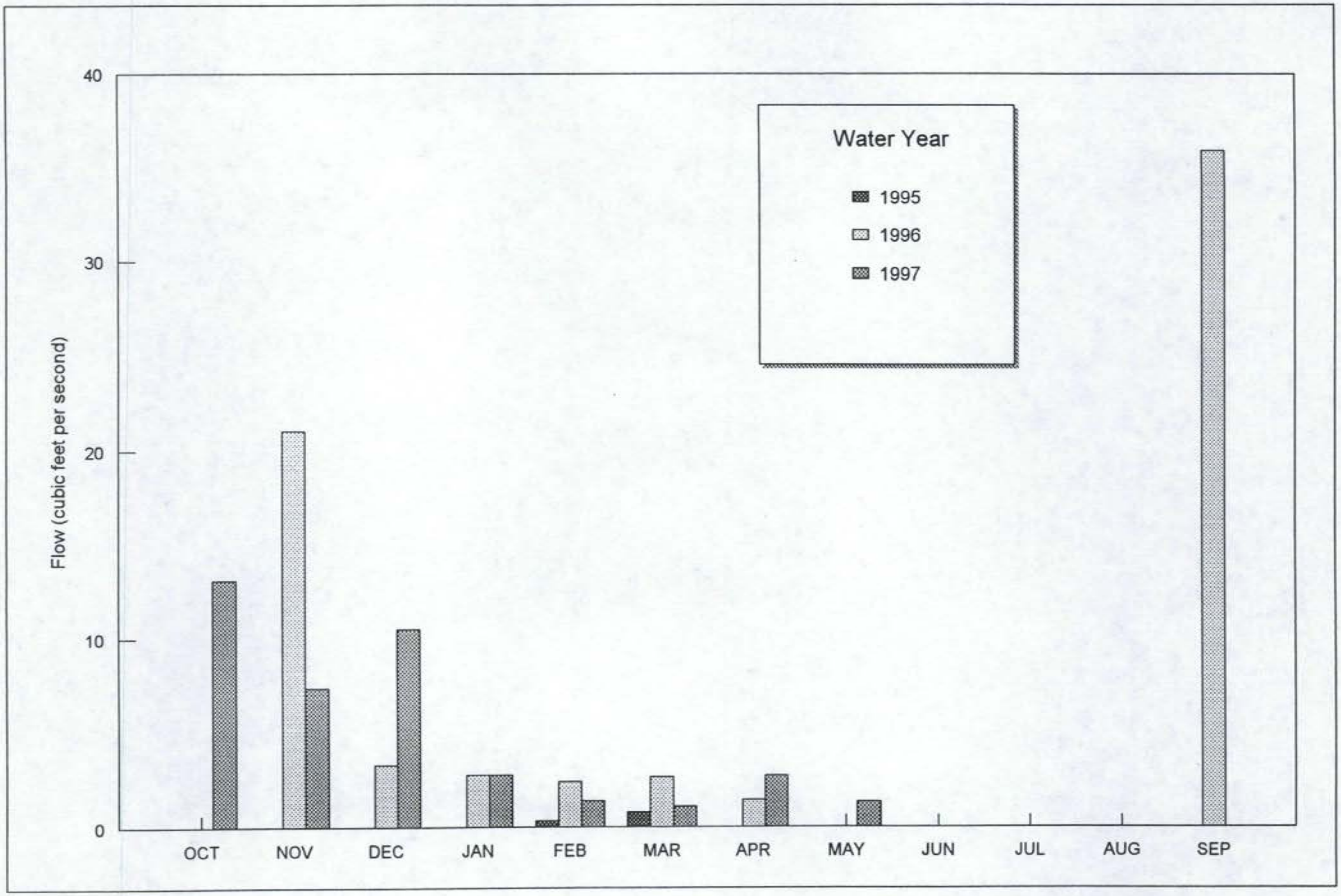


Figure B-2. Monthly Median Flow in Queen Creek at Boyce Thompson Arboretum during Water Years 1995-1997

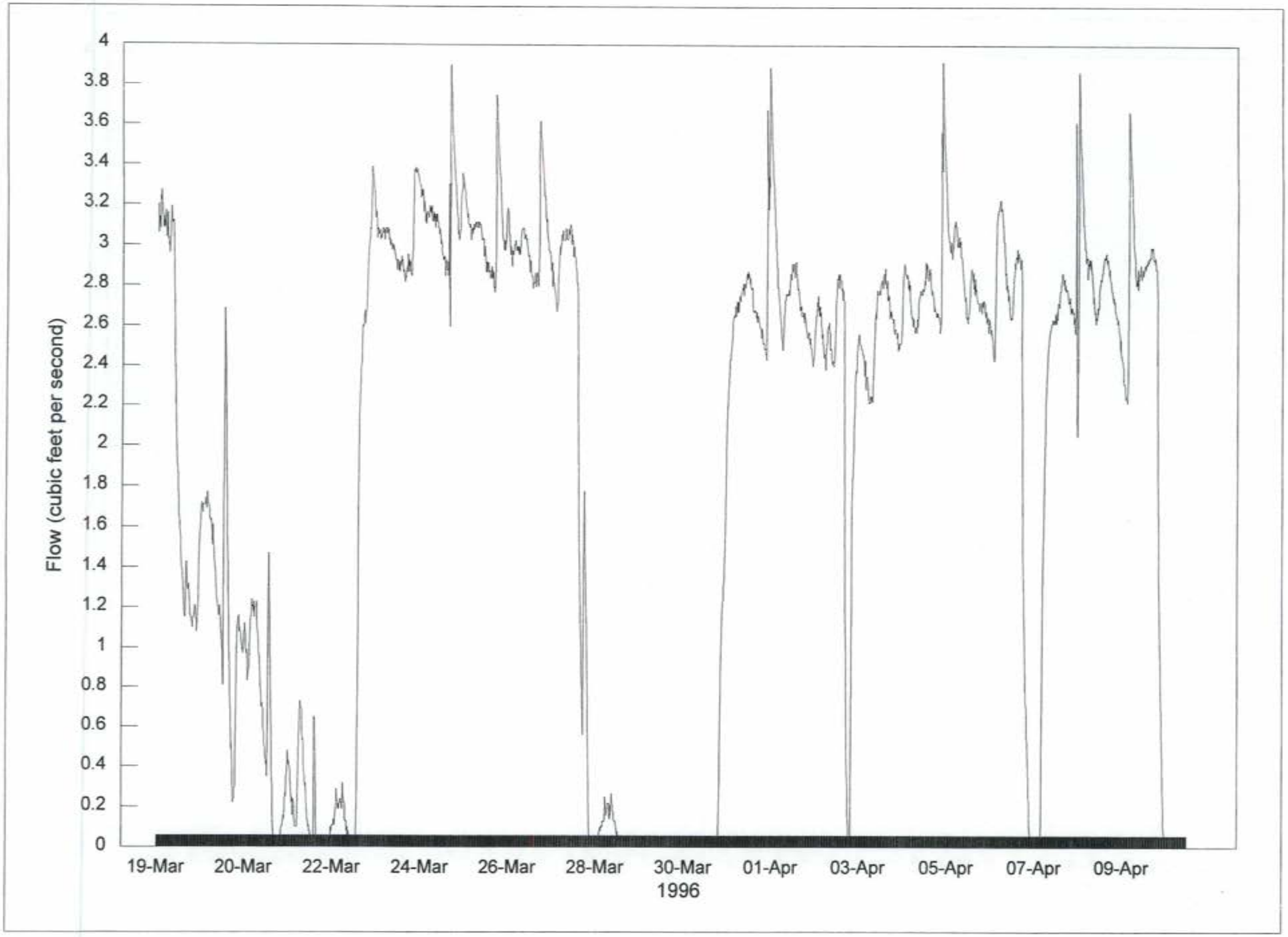


Figure B-3. 15-Minute Streamflow Data for Queen Creek at Boyce Thompson Arboretum, March 19 - April 10, 1996

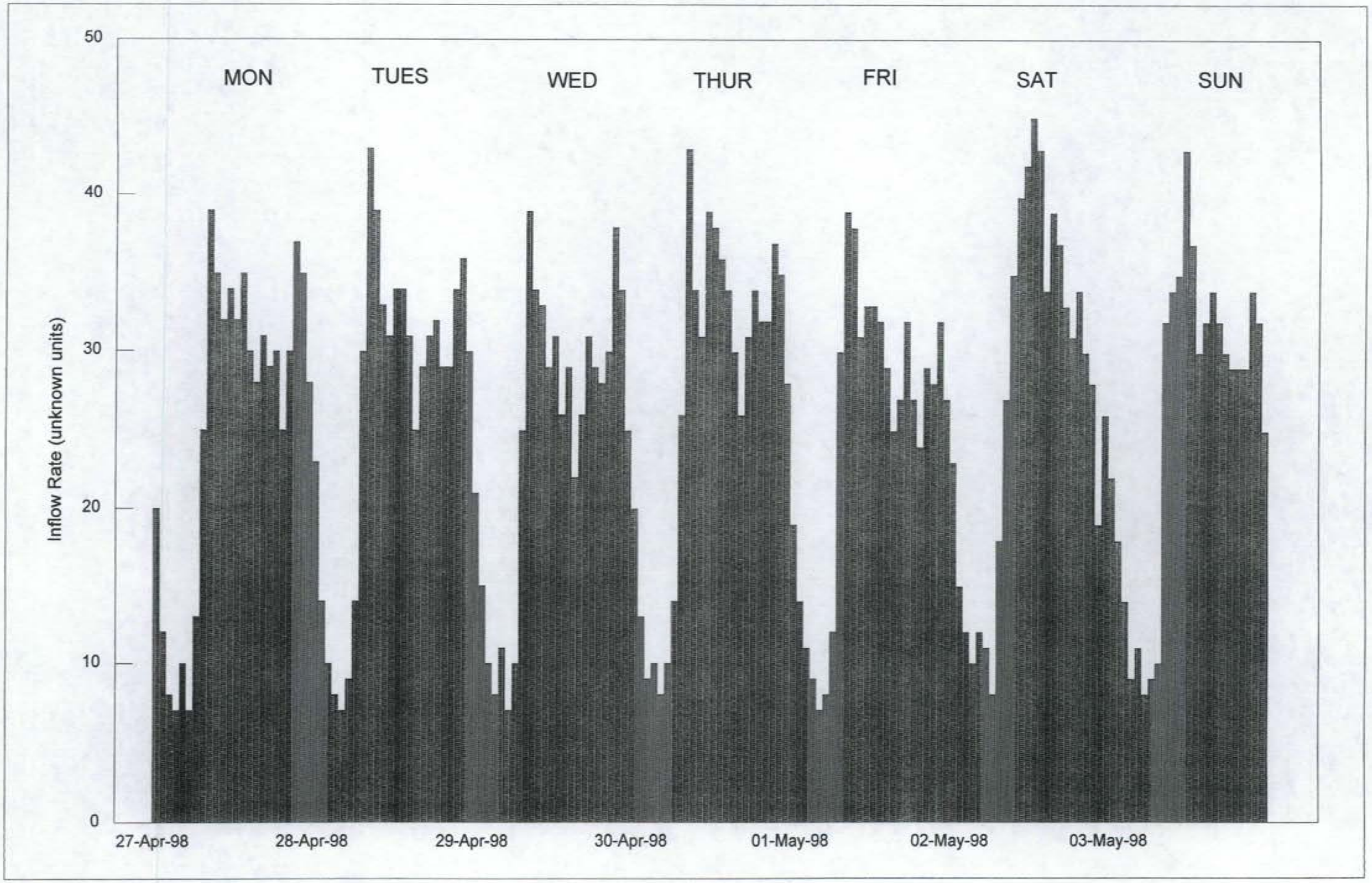


Figure B-5. Quarter-Hourly Inflow Rate to Superior Municipal Wastewater Treatment Plant, April 27 - May 3, 1998

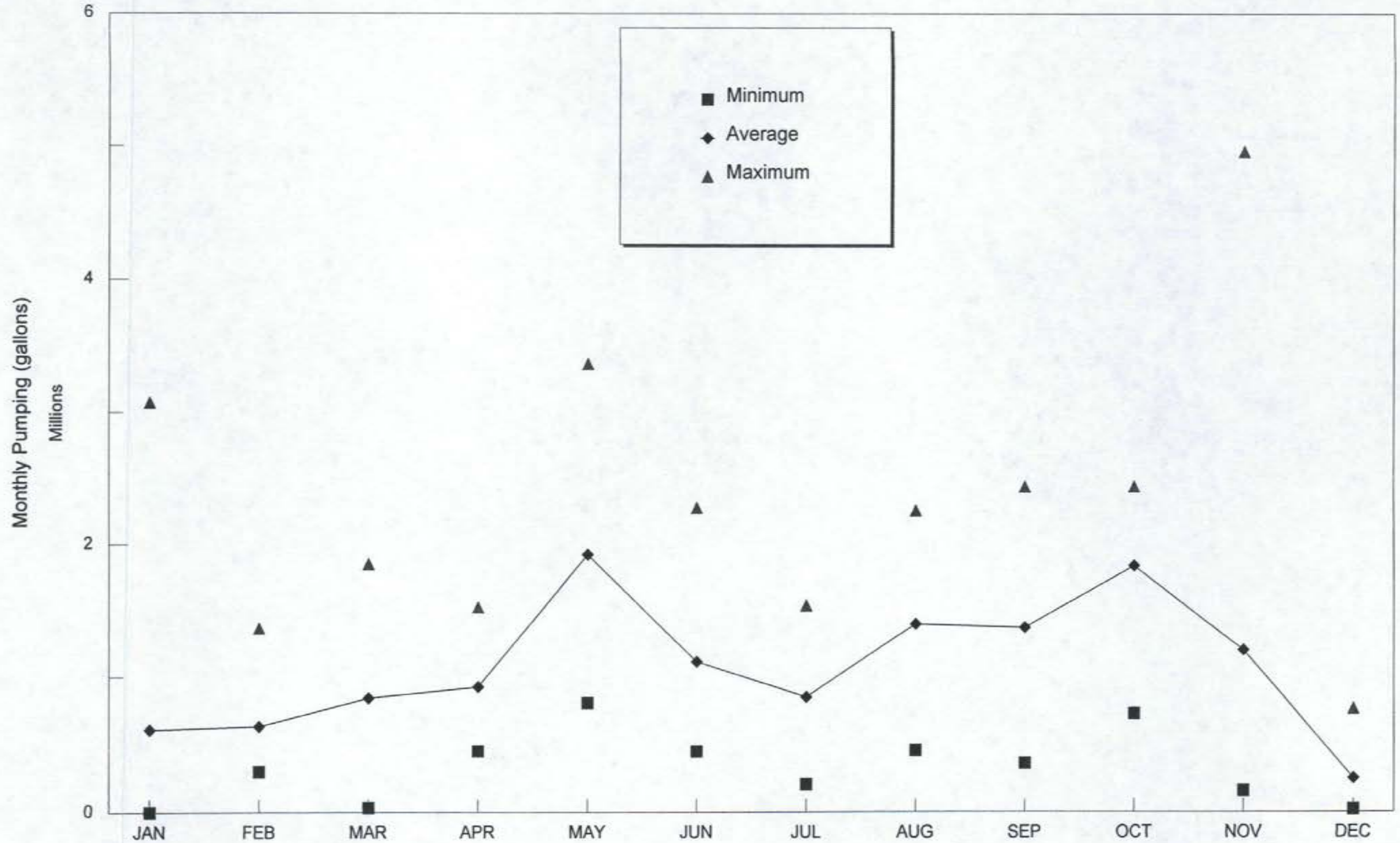


Figure B-6. Monthly Pumping from Canyon Gallery Well at Boyce Thompson Arboretum during 1986-1993

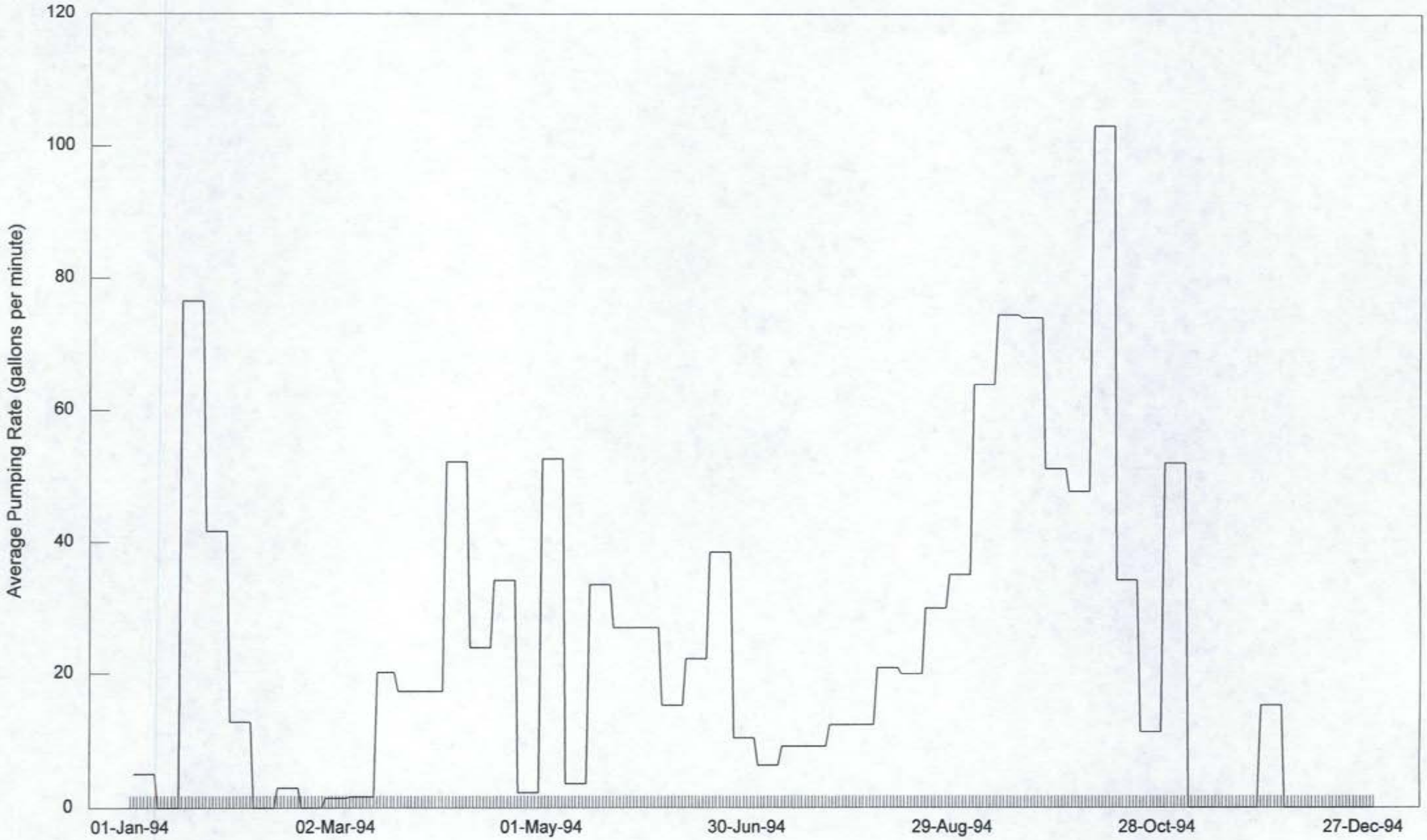


Figure B-7 . Weekly Pumping from Canyon Gallery Well at Boyce Thompson Arboretum during 1994

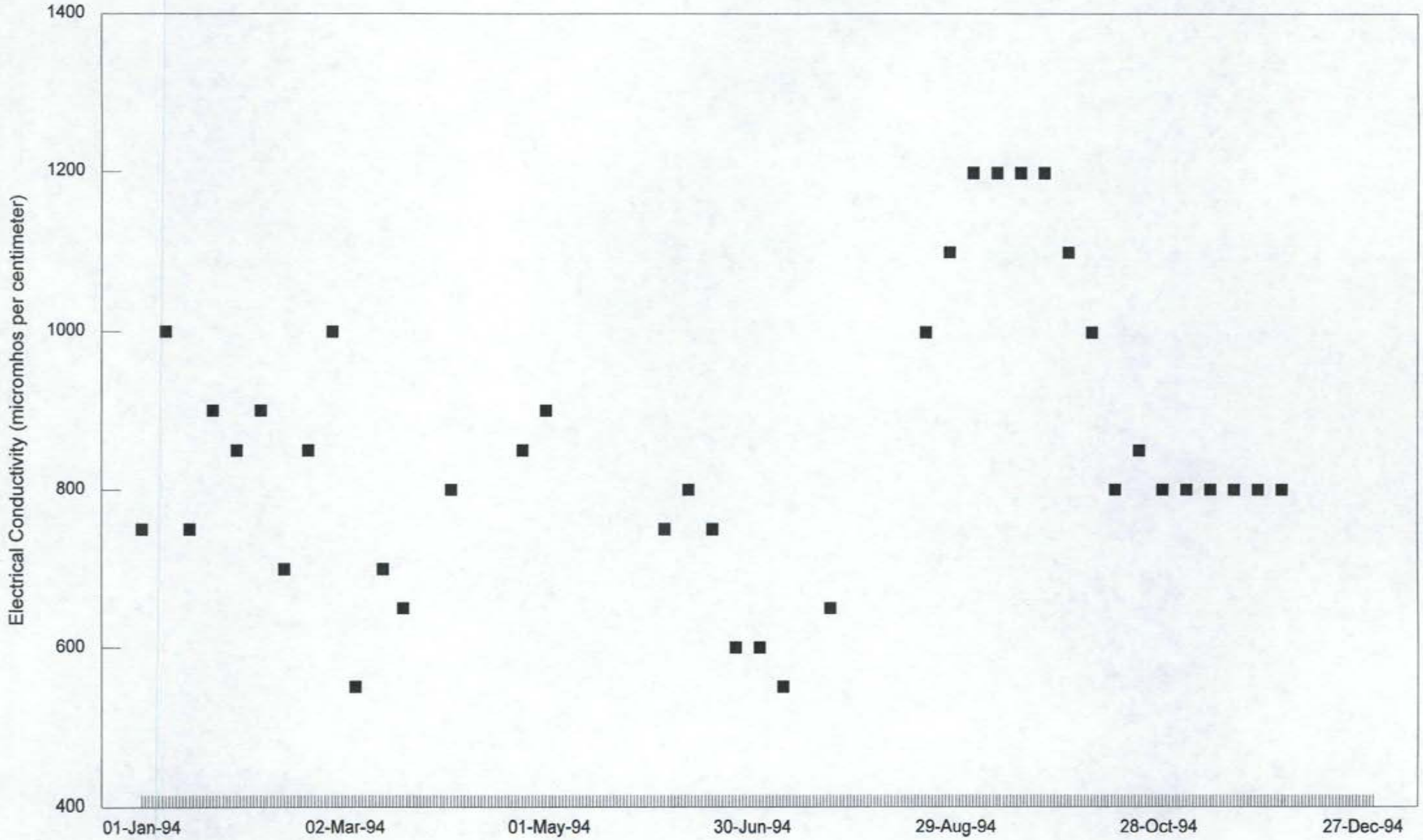


Figure B-8. Electrical Conductivity of Water In Queen Creek at Boyce Thompson Arboretum during 1994

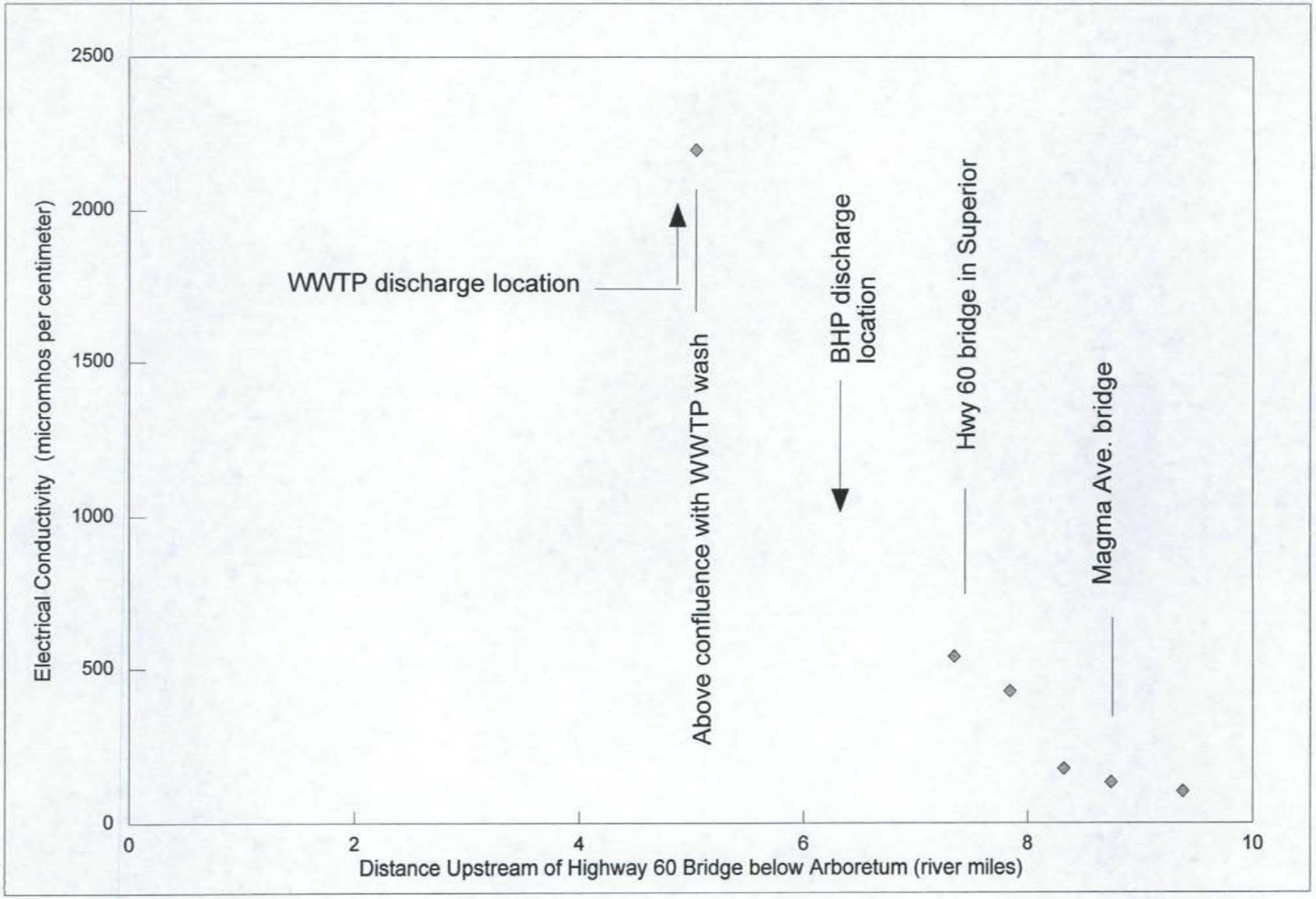


Figure B-9. Electrical Conductivity along Downtown Reach of Queen Creek on March 4, 1998

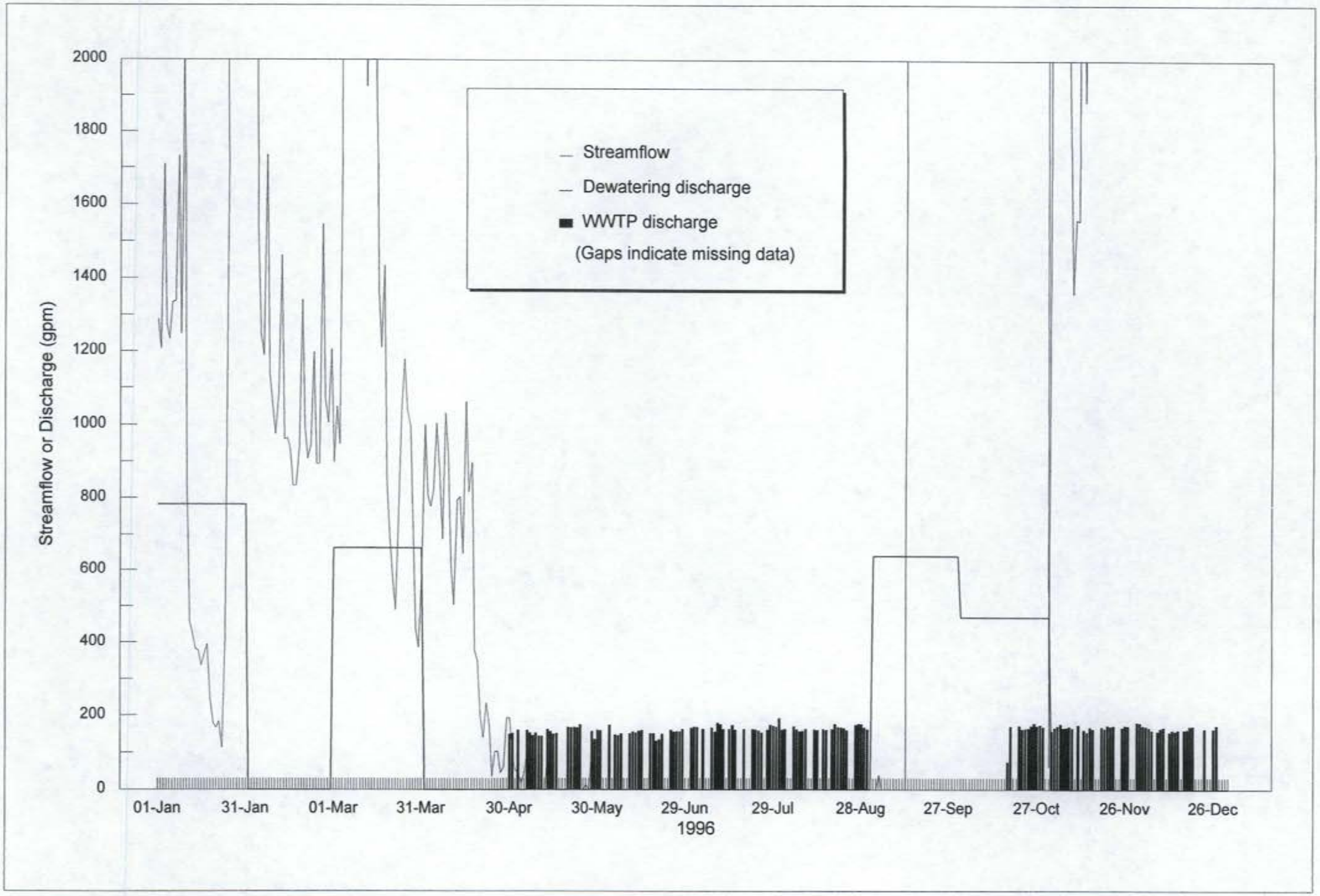


Figure B-10. Discharges to Queen Creek and Streamflow at Boyce Thompson Arboretum during 1996

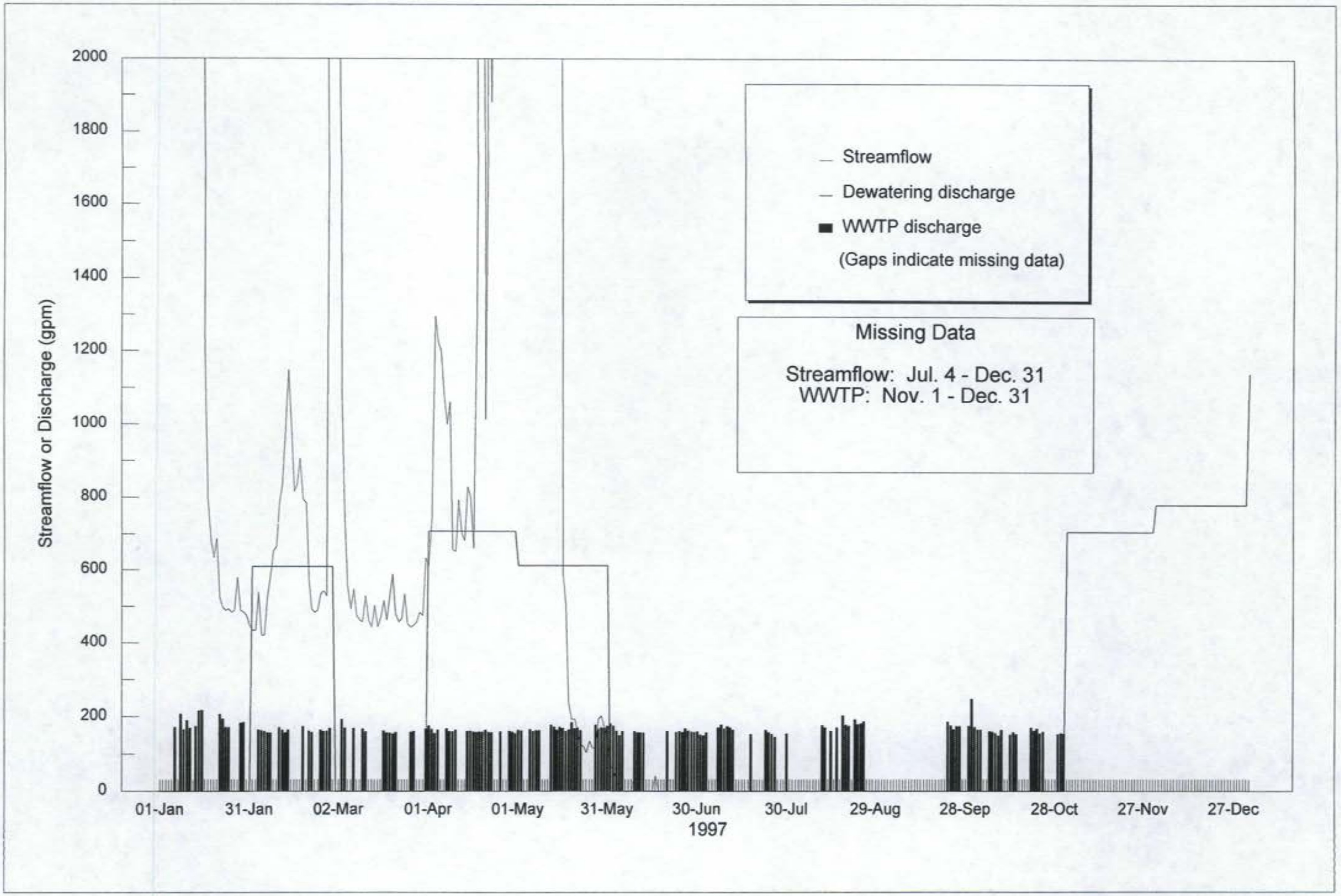


Figure B-11. Discharges to Queen Creek and Streamflow at Boyce Thompson Arboretum during 1997

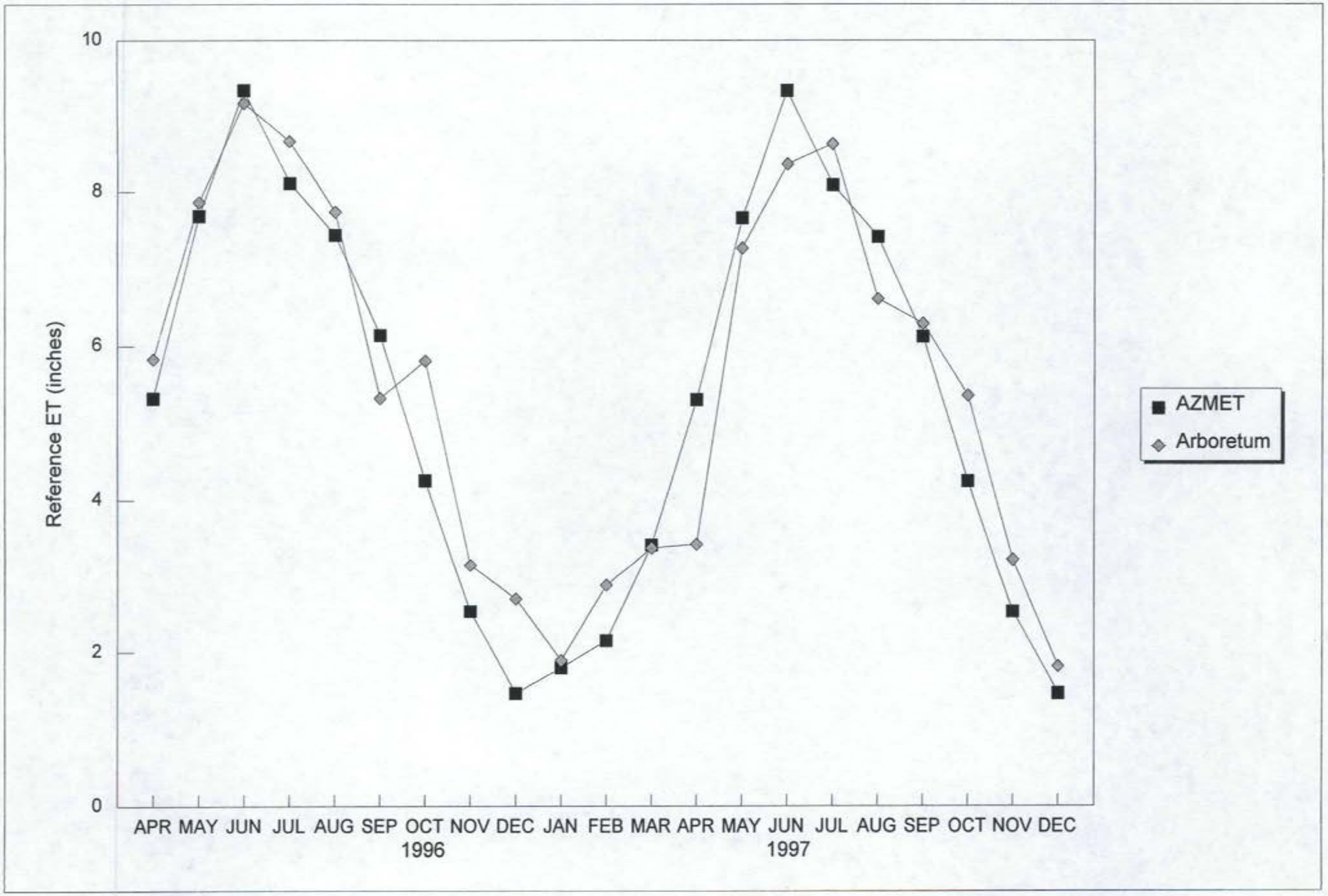


Figure B-12. Monthly Reference ET at Superior during 1996-1997 Estimated from AZMET Data and from Pan Evaporation at Boyce Thompson Arboretum characteristics for Queen Creek above Reach 1 and at the Whitlow Dam site are also shown in the table.

To further investigate the suitability of the gages as candidates for correlation with Queen Creek, flow-exceedance frequency curves were prepared for the entire period of record for each gage. Drainage area and precipitation are known to strongly influence the total volume of runoff from a watershed. To correct for effects related to these factors, the data for each gage was normalized by two different methods so that the frequency curves of all of the gages could be compared directly. The first method of normalizing was to divide the flow values for each gage by the mean annual flow, so that all flows are expressed as a percent of mean annual flow. This method indicates the magnitude of relative fluctuations in flow caused by seasonal and annual variations in climatic conditions.

The resulting curves for the four gages, together with the Queen Creek at Whitlow Dam Site gage for comparison, are shown in Figure B-13A. For clarity, the curves have been cropped to omit infrequent high flows (flows exceeded less than 10% of the time), which are of less importance in meeting the consumptive water-use demand of riparian vegetation than are the more prolonged low and moderate flows. The graph indicates that the distributions of flows in Sycamore Creek, West Fork Sycamore Creek, and Wetbottom Creek are quite similar. Cave Creek has a flatter curve, indicating the common occurrence of a relatively high, persistent base flow. As expected, Queen Creek near Whitlow Dam Site has much less persistent base flow than the other gages because of seepage and evaporation losses along the valley-floor reach upstream of the gage.

The second method of normalizing the flow-duration curves was to divide the daily flows for each gage by the drainage-area size and average-annual precipitation upstream of the gage. The resulting curves are shown in Figure B-13B. This method of normalization indicates the relative yield of the watersheds, or the fraction of precipitation that becomes runoff for various flow magnitudes. Wetbottom Creek has relatively high flows in the 10-50% exceedance range, indicating that losses to deep percolation or ET are relatively small or that rainfall runoff is attenuated by shallow seepage through bedrock fractures or the soil mantle. The curves for West Fork Sycamore Creek, Sycamore Creek, and Cave Creek are nearly identical except for flows that occur <25% (approximate) of the time. For these less frequent, higher flows, the curves diverge in order of drainage-area size, and larger watersheds exhibit lower runoff. This divergence suggests that streamflow losses more strongly affect the larger watersheds.

Data for Wetbottom Creek and West Fork Sycamore Creek were used to estimate flow in Queen Creek. These gages had similar flow-duration curves (i.e., neither appeared anomalous), and their drainage areas were the closest in size to the Queen Creek drainage area.

Monthly flows for the periods of record for each gage (30 years for Wetbottom Creek and 12 years for West Sycamore Creek) were divided by their respective drainage areas and average-annual precipitation amounts to obtain normalized monthly flows. For each month of the year, the annual values were ranked, and the 20th, 50th (median), and 80th percentile exceedance values were selected. Table 2-1 in Chapter 2 shows these values for both creeks and the average for both creeks. The average was multiplied by the drainage area and average-annual precipitation for the Queen

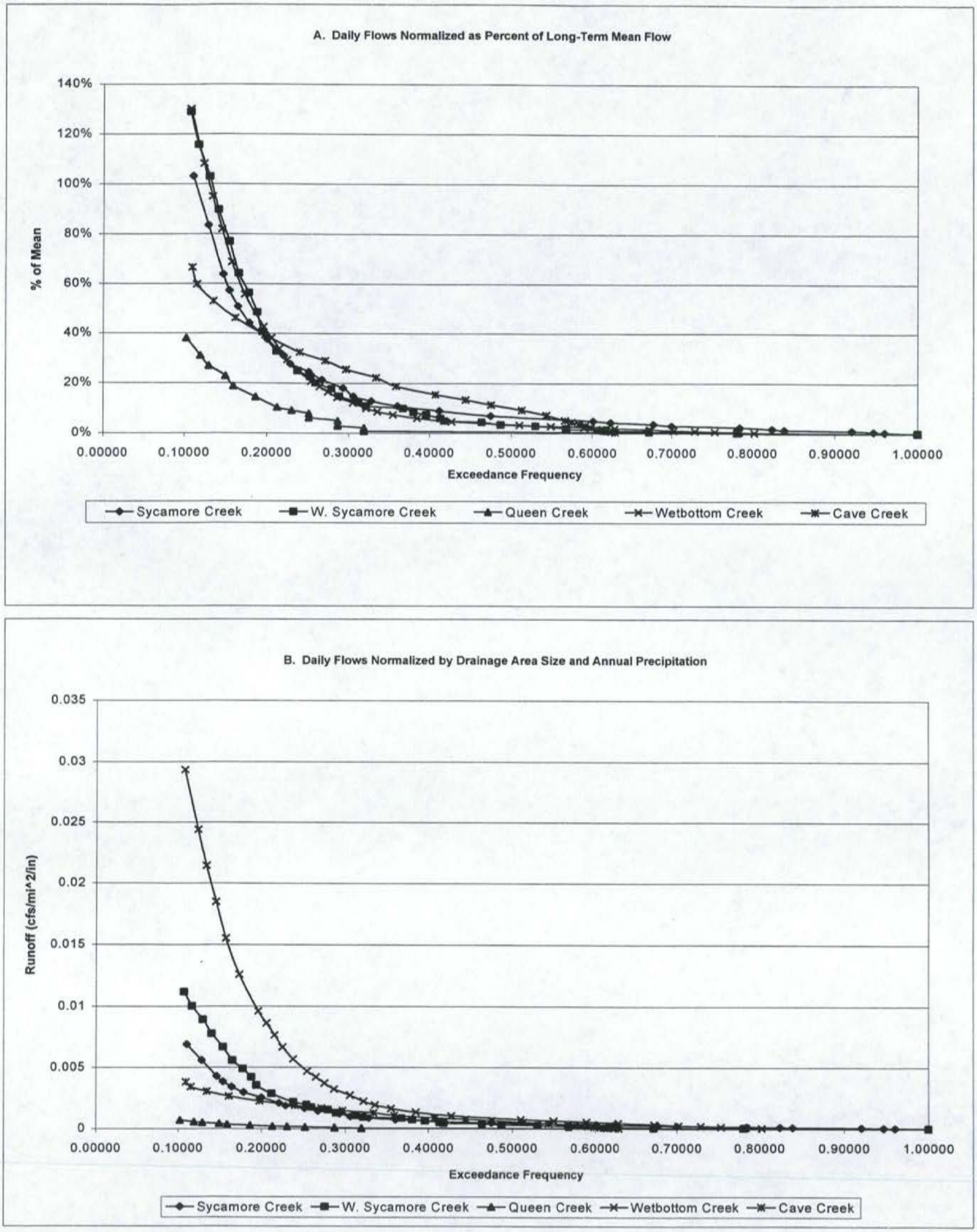


Figure B-13. Flow Duration Curves for Stream Gages Used to Estimate Flows in Queen Creek

Creek watershed upstream of Reach 1 to obtain estimates of monthly flows in Queen Creek (also shown in Table 2-1).

These data are intended to be evaluated on a month-by-month basis because, for any given year, the flows in all months are extremely unlikely to correspond to the same percentile of their respective distribution curves. In other words, it is unlikely that every month of the year would have a flow equal to the 20^{th} percentile or 80^{th} percentile flow. Many months are likely to have flows closer to the median, and some months may have flows even more extreme than the 20^{th} or 80^{th} percentile. Thus, the annual flow for the dry and wet conditions shown in the table would almost never be as dry or as wet as the sum of the monthly flows.

The initial estimates of monthly Queen Creek flows appeared to be generally larger and more persistent than flows measured for this study and reported as typical by local residents. This discrepancy might result from groundwater pumping to dewater the BHP mine, which underlies a substantial part of the Queen Creek headwaters area. Seepage into the mine increases noticeably during rainstorms or high-flow events, indicating that the mine induces seepage from the creek or intercepts groundwater that would otherwise discharge into the creek.

The full extent of hydraulic coupling between the mine and the creek is not known. However, seepage losses induced by dewatering could explain at least some of the discrepancy between the estimated flows and the observed flows. This coupling could also explain the relatively high rate of flow loss measured along the lower part of Reach 1 (see "Seepage Gains and Losses"). The original estimates of inflow to Reach 1 were adjusted by subtracting 50% of the estimated BHP mine dewatering rate, which averages 1.1 cfs. The remainder of the dewatering flow is assumed to derive from seepage along Reach 1, gradual depletions of groundwater storage, and possibly groundwater inflow from areas beyond the Queen Creek watershed.

Surface flow in the tributaries of Queen Creek is rare. The locations of the tributaries and their respective drainage areas are shown in the Queen Creek watershed map (Figure 2-2 in Chapter 2). A gage on Magma Wash 1 near Main Street has not recorded surface flow since a major storm in January 1993. Although infrequent high-flow events (i.e., flash floods) shape channel geomorphology and provide significant groundwater recharge to downstream areas, they are not continuous enough to support riparian vegetation. Thus, for the purpose of developing a water budget to evaluate restoration feasibility along Queen Creek near Superior, inflow from tributaries was assumed to be zero. Arnett Creek, a major tributary to Queen Creek, has a trickle of perennial base flow, but it is in a bedrock reach upstream of the confluence with Queen Creek.

WATER AVAILABILITY FOR RIPARIAN VEGETATION

Riparian vegetation along Queen Creek relies on soil moisture that is replenished in large part by seepage from the creek. Reaches of the creek and tributary washes that have perennial or prolonged flow seasons or abundant shallow groundwater are characterized by relatively lush vegetation. Reaches with highly intermittent flow or little shallow groundwater have sparse, xeric vegetation.

The close association between water availability and the type and vigor of vegetation is amply demonstrated by the existing distribution of vegetation along Queen Creek and its tributaries. For example, the fairly constant, year-round discharge from the WWTP has resulted in dense, vigorous stands of cottonwood–willow riparian woodland and mesquite bosque between the WWTP and the pump house at the Arboretum. Much of this vegetation developed after construction of the WWTP in 1976 (Dion pers. comm.). Similarly, the vigorous stands of cottonwood–willow riparian woodland and mixed-riparian woodland along washes northwest of Main Street and Pinal Street in Superior are clearly associated with availability of shallow groundwater caused by seepage from water-storage ponds at the BHP copper mine. In contrast, washes in undeveloped areas (e.g., Happy Camp Canyon and Silver King Wash) support only desert vegetation similar to the surrounding upland areas plus a few xeroriparian plants such as palo verde. The persistence of flow in Queen Creek in the downtown reach has reportedly decreased in recent years (Zapata pers. comm.), which is consistent with the observed occurrence of drought stress in riparian trees.

Water-Balance Model

A water-balance model of Queen Creek and its associated vegetation was developed to facilitate restoration planning by providing a quantitative analysis tool that relates water availability to vegetation. Specific objectives of the model were to:

- create a conceptual framework for evaluating the hydrologic system,
- provide a means of checking the consistency and accuracy of data from various sources,
- ensure that total inflow and total outflow are balanced for each reach,
- characterize water availability and restoration potential along distinct reaches of the creek,
- identify restoration opportunities and constraints related to wet and dry years, and
- provide a tool for simulating potential restoration alternatives (e.g., types of vegetation, canopy width and density, location along the creek).

The model was developed in a spreadsheet format using Lotus 1-2-3 software. The model calculated gains and losses of water along each of the five reaches of Queen Creek defined in Chapter 2 plus the washes that convey discharges of BHP dewatering water and treated municipal wastewater. The reach locations are shown in Figure 2-3 in Chapter 2. The following guidelines govern the model results:

- the net outflow from the uppermost reach is the primary inflow to the next downstream reach;

- all flows are monthly, and different sets of monthly values are available to simulate normal, dry, and wet years;

- normal conditions are represented by the median flow value for a given month over a number of years (the period of record is different for each input variable); and

- dry conditions are represented by flows that are exceeded in 8 out of 10 years, and wet conditions are represented by flows that are exceeded in only 2 out of 10 years. These thresholds for wet and dry conditions were subjectively selected to illustrate a reasonable range of conditions for riparian vegetation and aquatic organisms.

Water-budget items included in the model are natural runoff from rainfall, snowmelt, and groundwater discharge in the upper Queen Creek watershed; discharges from BHP and the WWTP; diversion at the Arboretum pump house; seepage losses in the upper watershed area induced by mine dewatering; seepage gains and losses along the lower reaches of the creek where the water table is naturally higher or lower than the creekbed; direct evaporation from the creek surface; and net ET by phreatophytic vegetation along the riparian corridor. The procedure used to estimate Queen Creek inflow at the top of Reach 1 was described in the previous section, and the method for developing estimates for each of the remaining input items is described in the following sections. Tables of monthly values for all input variables in the model are presented in Tables B-3, B-4, and B-5 for dry, normal and wet year conditions, respectively.

Streamflow Diversions

Diversions from and discharges to Queen Creek in the study area were described in Chapter 2. That information is summarized here with respect to its inclusion in the water-balance model. There are presently no known direct surface diversions from Queen Creek along the reach included in the water-balance model. An infiltration gallery adjacent to the creek channel in the Arboretum is essentially equivalent to a direct surface diversion. It is located at the downstream end of the modeled reach and thus is not included directly in the model. However, simulated outflow from Reach 5 indicates whether this diversion can be sustained under various alternative restoration scenarios. Seasonal diversion patterns were described in Chapter 2, with additional basic data presented in the first part of this appendix. Annual diversions averaged 40 af until 1998, when a new water-supply well for irrigating the Arboretum was completed near the confluence of Arnett and Queen Creeks. The new well provides supplemental water if the existing well runs short and is intended to meet increases in irrigation demand associated with future expansion of the Arboretum.

Dewatering of the BHP mine induces seepage from Queen Creek and intercepts groundwater that would otherwise discharge to the creek. Thus, dewatering is equivalent to an indirect diversion of streamflow. The rates of diversion assumed in the water-balance model are described in "Seepage Gains and Losses".

Discharges to Queen Creek

BHP Dewatering Discharge. Until May 1998, BHP pumped groundwater out of its mine workings to maintain them in a dry condition. This water was treated and discharged to settling basins near the northwestern edge of Superior. In summer, all inflow was lost to seepage and evaporation. In winter, higher pumping rates, lower evaporation rates, and higher rainfall accretions occasionally caused the pond to exceed its storage capacity. The excess water was discharged to an unnamed wash that crosses beneath Highway 60 just west of Magma Wash 1 and enters Queen Creek near Mary Drive (Figure 2-3). Details regarding historical BHP dewatering discharges are presented in Chapter2 and the "Basic Data" section of this appendix.

Although the average-annual dewatering discharge volume during 1993–1998 was nearly two times larger than the annual discharge from the WWTP, the dewatering discharges were too sporadic to foster the growth of cottonwoods, willows, and other broadleafed riparian vegetation present downstream from the WWTP discharge. Except for small patches of mixed-riparian woodland supported by seepage near the BHP storage ponds, vegetation along the BHP discharge wash and the reach of Queen Creek immediately downstream of that wash (the upper part of Reach 4) consists of mesquite shrubs.

Although BHP dewatering discharges have not by themselves established broadleafed riparian vegetation, they may boost the growth of vegetation in Reach 5 downstream of the WWTP discharge. An analysis of monthly rainfall, BHP discharges, and gaged streamflow at the Arboretum during water years 1995–1997 revealed the following relationships among those variables:

- above-average monthly rainfall in autumn was not always sufficient to initiate streamflow;
- the onset of prolonged flow in autumn or winter of every year coincided with a dewatering discharge;
- intense rainfall could initiate brief flows (flash floods) at any time;
- when winter base flow was already established, it sometimes persisted through a month of below-average rainfall and no dewatering discharge; and
- flow was not always present in spring even if rainfall was above average and dewatering discharges occurred.

The future of dewatering discharges is highly uncertain. They were discontinued in May 1998 when BHP began reevaluating the future of its mining operations in the area. For the purpose of creating a water-balance model to investigate the feasibility of riparian restoration, the baseline condition assumes that no dewatering discharges will be made. Because discharges might be resumed, some preliminary restoration alternatives explored in this analysis include different locations and rates of dewatering discharge. Because the pumping rate required for dewatering increases temporarily following large rainfall events, the average pumping rate for those alternatives is assumed to be 10% above average in wet years and 10% below average in dry years. For alternatives in which the discharge is assumed to be at its historical location, losses from seepage, evaporation, and ET along the BHP discharge wash are subtracted before adding the discharge to the flow in Queen Creek at the upstream end of Reach 4.

WWTP Discharge. Discharges from the WWTP to WWTP wash were described in detail in Chapter 2. The discharge is a continuous flow that averages 0.36 cfs (1 cfs = 448.8 gpm) and has substantial diurnal fluctuations but almost no seasonal fluctuation. In the water-budget model, losses from seepage, evaporation, and ET along the WWTP wash are subtracted before adding the discharge to Queen Creek flow at the upper end of Reach 5. The WWTP discharge is assumed to be the same in all year types, but the losses along WWTP wash vary by year type.

Evaporation

Evaporation from the surface of the stream is commonly ignored in water-budget analyses because it typically is a very small percentage of flow. Evaporation losses from Queen Creek are negligible when flows are high, but they can represent a significant percentage of flow when flows are small. Some of the sources of water potentially available for restoration would provide less than 1 cfs of flow. Consequently, evaporation must be included in the water budget.

Data from an evaporation pan operated at the Arboretum for many years were described in Chapter 2. Average-annual pan evaporation was 60 inches and equaled the estimated reference ET (ET_0) at that location reported by the AZMET (see Figure B-12). ET_0 is usually only 70% of pan evaporation in winter and 60% in summer, because leaves lose water at a lower rate per unit area than an open water surface (Brown 1998). The reason for the equivalence of evaporation and ET_0 in this case is not clear. Losses of water to ET along the creek are much larger than the losses to evaporation because the area of riparian vegetation greatly exceeds the surface area of the Queen Creek. To maintain consistency with the ET calculations, monthly values of evaporation from the surface of Queen Creek were calculated by dividing monthly AZMET ET_0 values by 0.7 in winter (October–March) and 0.6 in summer (April–September). Evaluation of variations in annual AZMET ET_0 indicate that evaporation in dry years (all months) was assumed to be 7% higher than normal and evaporation in wet years was assumed to be 7% lower. The lengths and average water-surface widths at low flow for each reach of Queen Creek are shown in Table B-6.

Evapotranspiration

Monthly ET by riparian vegetation is calculated in the model using the following equation:

$$ET_{i,j} = ETo_j * C_{i,j} * A_i * D_i$$

where:

$ET_{i,j}$ = evapotranspiration by vegetation type i in month j (acre-feet)

ETo_j = reference evapotranspiration (ETo) in month j (feet)

$C_i j$	=	crop coefficient, which equals the ratio of ET by vegetation type i to ETo, in month j
A_i	=	area of vegetation type i (acres)
D_i	=	average percent cover or canopy density of vegetation type i in the area mapped as vegetation type i

The values for the equation parameters for each reach of the creek are shown in Table B-6. Monthly ET_0 for the study area was obtained from statewide AZMET maps of average monthly ET_0. ET_0 in all months is assumed to be 7% above normal in dry years and 7% below normal in wet years, which reflects the measured variation in AZMET annual ET_0. The crop coefficient for a particular type of vegetation is the ratio of actual ET to ET_0. It varies by month, especially for deciduous plants.

Few reliable measurements of crop coefficients are available for individual riparian plant species or for the overall crop coefficient for a mixed-riparian forest. One of the most thorough investigations was a study by the U. S. Geological Survey (Gatewood et al. 1950) that used six different methods to estimate ET by riparian vegetation in the lower Safford Valley, where climatic conditions and vegetation types are similar to those near Superior. The estimated average-annual ET was 72 inches for cottonwoods and 40 inches for mesquite.

Other studies have generally found that ET by willows (various species) is typically somewhat less than cottonwood ET (Young and Blaney 1942, Muckel and Blaney 1945, Robinson 1958). Monthly crop coefficients for cottonwood forest were estimated for this analysis by assuming that ET in winter after the leaves have dropped is 25% of ET_0, which is consistent with comparisons of bare dirt and ET_0 in agricultural settings (U. S. Soil Conservation Service 1970). Gradually increasing the crop coefficient to 1.60 in midsummer achieves an annual ET of 72 inches, which is reasonable for tall trees in an arid environment. Because mesquite is an evergreen, it was assumed to have a crop coefficient of 0.67 in all months, which results in an average annual ET of 40 inches. The crop coefficient for mixed-riparian forest was assumed to have a seasonal pattern similar to but less variable than that of cottonwoods, which is consistent with an assumption that the mixed vegetation will include some evergreen species. Average-annual ET for mixed-riparian forest was assumed to be slightly less than that of cottonwood–willow forest because of the presence of mesquite and other relatively drought-tolerant plants in the vegetation mix. An annual ET of 61 inches is used in the model.

The area of each class of riparian vegetation (i.e., mesquite, mixed-riparian forest, and cottonwood–willow riparian forest) along each of the simulated reaches was planimetered from the vegetation map (Figure 2-13 in Chapter 2). Canopy density was visually estimated from the September 1998 aerial photograph also shown in Figure 2-13. The resulting acreages and densities of vegetation associated with Queen Creek are listed in Table B-6. In addition, there are 20 acres of mesquite (30-50% canopy coverage) and 2.5 acres of mixed-riparian forest (80% canopy coverage) supported by seepage from the BHP dewatering storage ponds northwest of Main Street and Pinal Avenue.

Seepage Gains and Losses

Seepage of water into and out of Queen Creek was estimated by adjusting measured flow gains and losses for depletions from evaporation and ET. These data were then adjusted and applied to reaches of the creek and the tributary washes according to creekbed geology and the estimated elevation of the creekbed with respect to the water table. Streamflow measurements used for the seepage analysis were described in Chapter 2. Manual flow measurements (Table B-1) were used to calculate average seepage losses along each reach (Table B-7). Measured seepage-loss rates varied from 0 to 0.48 cubic feet per second per mile (cfs/mi) of reach length, but the variations were consistent with available hydrogeologic information and concepts. The highest rate was measured along the lower part of Reach 1, where Queen Creek leaves the bedrock canyon and flows out over its alluvial fan, which extends into the valley. Coarse bed materials and high seepage losses are typical at the upper ends of alluvial fans. In addition, seepage into mine workings near the middle of Reach 1 reportedly contribute to high seepage losses in that area. Until dewatering was discontinued in May 1998, the dewatering pumps operated at a fairly constant rate of 1.1 cfs.

High seepage-loss rates (0.38 cfs) were also measured along WWTP wash. The bed of this wash consists of unconsolidated alluvial materials, and along most of its length the wash is substantially higher than the nearby bed of Queen Creek. Thus, the wash is probably perched above the water table. These factors contribute to relatively high seepage loss rates.

In contrast, negligible net seepage losses were measured along the entire length of Reach 2, even when flow was little more than a trickle. Slight gains and losses as the creek passed through coarser and finer bed material resulted from minor shifts between surface flow and shallow underflow through the bed materials, but there was essentially no net flow loss over the 1.1-mile length of the reach. Consolidated bedrock of the Gila Formation is exposed at various places along this reach and is probably covered only thinly with stream deposits along most of the reach. The bedrock permeability is relatively low in areas where the Gila Formation is highly consolidated.

The low seepage loss rates along the downtown reach of Queen Creek are also consistent with measured groundwater levels, which are generally close to the average creekbed elevation. Water levels in two wells at the south edge of town and one well northeast of the Arboretum (Figure 2-2 in Chapter 2) were measured in conjunction with a landfill investigation (Lomas pers. comm.). The wells are 200-300 feet deep, and a single set of measurements is available from November 1992.

Although the water table varied substantially in depth below the ground surface (47-95 feet) and elevation above sea level (2,473-2,625 feet), it was within a few feet of the adjacent creek bed elevation for all three wells, even though the wells are located 1,800-2,700 feet from the creek. These observations suggest that the water table is fairly flat and slopes westward at the same gradient as the creekbed. and that the shallow groundwater system is hydraulically connected with the creek along most of its length. Changes in groundwater levels therefore can increase or decrease seepage losses from the creek. If groundwater levels were substantially lowered, seepage losses would probably increase, although the loss rate might be substantially limited by the variable permeability of the Gila Formation. Conversely, if groundwater levels rose, seepage losses might decline or seepage gains might occur along some reaches.

Seepage losses along the upper two-thirds of Reach 5 were measured once, and the resulting loss rate per mile was higher than the rate for the downtown reach but lower than the rates for the alluvial fan area and the WWTP wash. An average seepage loss rate of 0.13 cfs/mi was calculated for Reach 5.

The model requires an estimate of the seepage loss rate for each reach in every month, and tables of these rates are needed for dry, normal, and wet years. These tables were developed by extrapolating the measured seepage loss and groundwater data in accordance with related data and basic hydrologic principles. Monthly unit seepage-loss rates for each reach in normal years are shown in Figure B-14. In the alluvial-fan area along the lower part of Reach 1, the water table might not be hydraulically connected to the stream because of the relatively steep stream gradient and coarse texture of the alluvial materials. Seepage losses along that reach probably vary in approximate proportion to the amount of streamflow. Thus, seepage loss rates would be highest in the months of greatest streamflow (February–April) and lower in other months. In all months, of course, seepage cannot exceed the amount of flow in the creek, and the model enforces this limitation to avoid incorrectly calculating negative flows. The seepage loss rates measured in March 1998 was used to represent normal conditions, because precipitation amounts during the preceding winter had been close to average.

Farther downstream, seepage is influenced by groundwater levels as well as by the amount of flow in the creek. For the small flows that would potentially be created for restoration purposes, the stage and wetted area of the creek would be relatively constant, and the seepage rate would be primarily influenced by groundwater levels. Except for dewatering pumping that extracts groundwater primarily from deeper strata and the canyon area, groundwater pumping near the creek consists primarily of pumping from a few small wells for domestic purposes. Assuming that this pumping is partly used for irrigation, it probably reaches its maximum rate in summer and minimum rate in winter.

The seasonal distribution of rainfall recharge (highest in winter) and groundwater pumping (highest in summer) would tend to create seasonal fluctuations in groundwater levels, but the fluctuations are probably small. Nevertheless, these variations would tend to result in seepage-loss rates from the creek that are slightly higher in summer and fall than in winter and spring. The estimated monthly distribution of seepage losses along Reach 2 assumes that the absence of net loss in the springs of 1997 and 1998 was correctly measured and that a small loss rate would develop by summer.

Seepage loss rates along Reaches 3 and 4, which were not measured directly, were assumed to be more like the loss rate along Reach 5 than the loss rate along Reach 2. This conservative assumption avoids unrealistically optimistic projections of the amount of riparian vegetation that could be achieved for a given amount of additional flow. The midsummer unit-loss rate was set equal to the loss rate measured in July 1997, and the rate was assumed to decrease moderately in winter and spring.

Seepage loss rates in dry and wet years were assumed to be uniformly 10% greater and 10% lower than the rates in normal years, respectively. This reflects a common pattern of small, gradual groundwater fluctuations in basins that experience only minor amounts of well pumping.

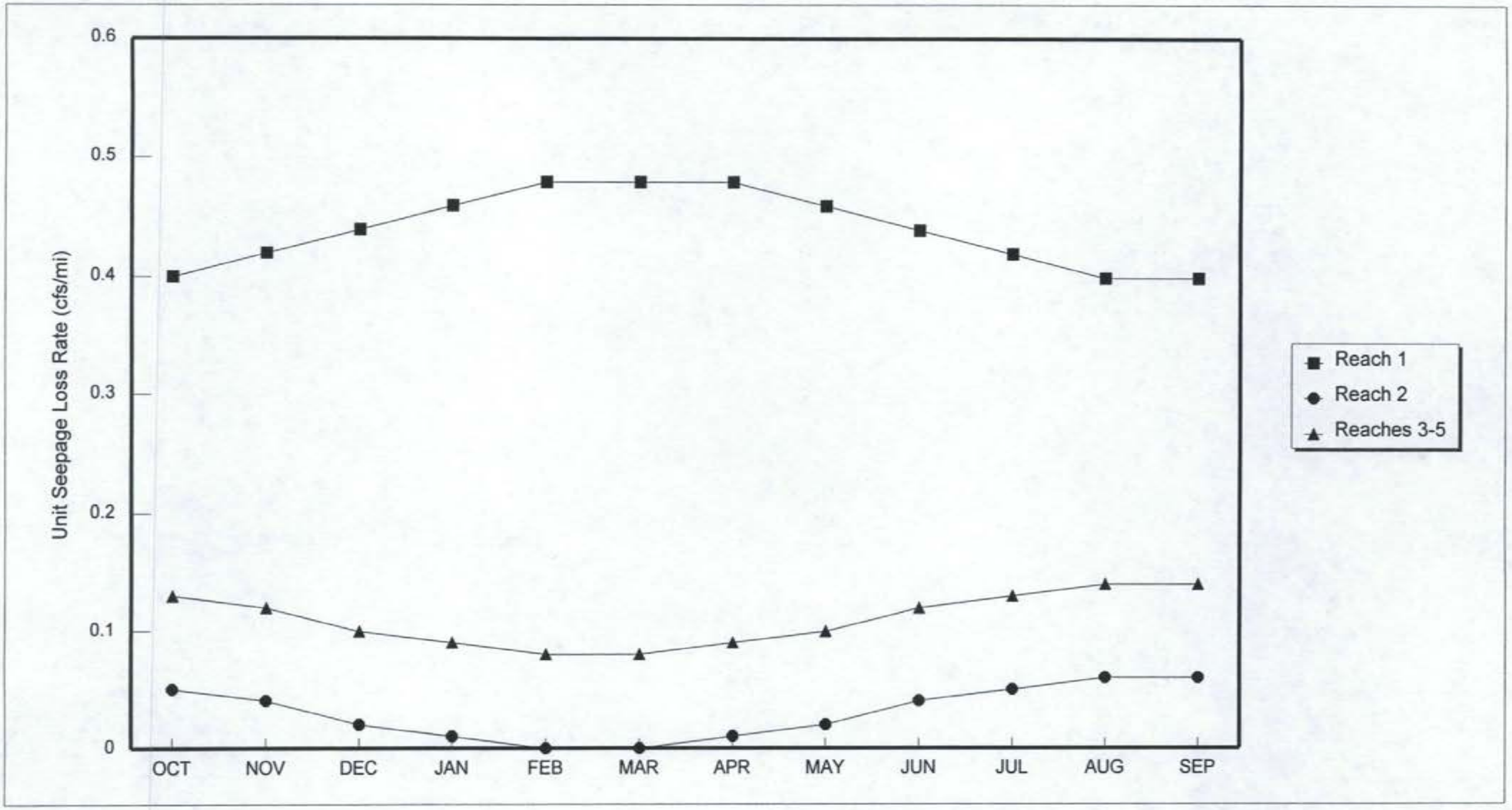


Figure B-14. Estimated Unit Seepage Loss Rates along Queen Creek in Normal Years

Simulation Results for Existing Conditions

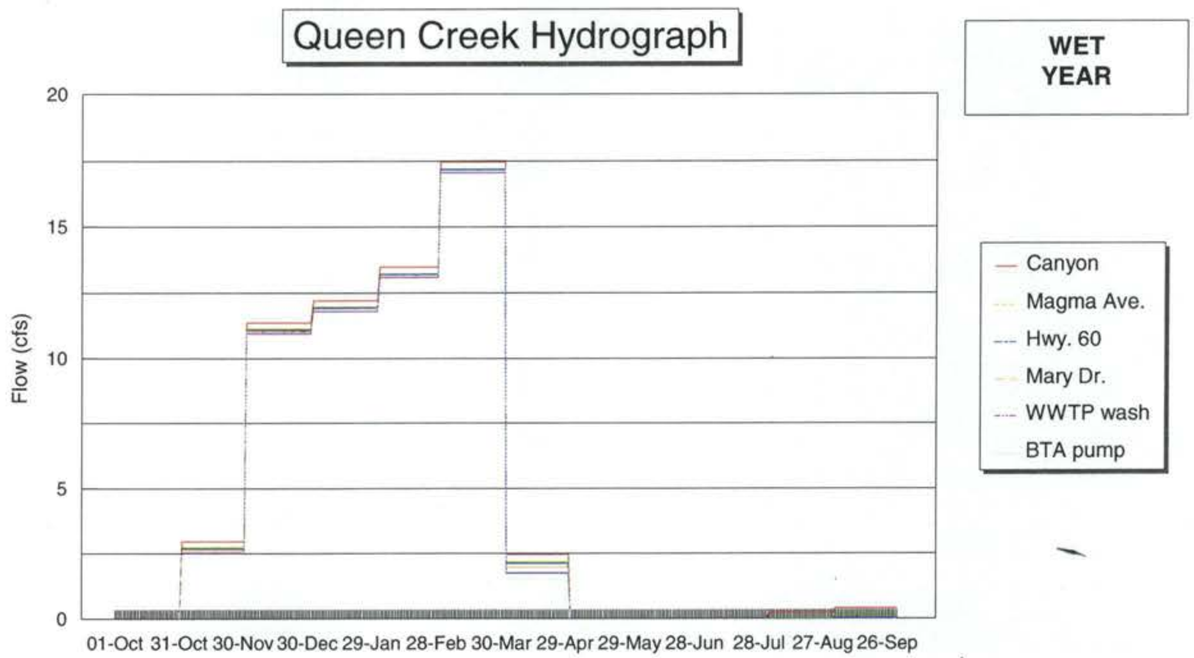
Simulated flows in Queen Creek under existing conditions are shown in Figures B-15A, B-15B, and C-15C (one page each for normal, wet, and dry years). Both the monthly hydrographs and the profiles of flow along the creek reveal that the estimated flow in any month is dominated by natural runoff. Gains and losses associated with the WWTP discharge, evaporation, ET, and seepage are small percentages of natural flow, at least during the 3 months of high flow (January–March). Gains and losses, however, are a substantial percentage of flow in other months, and they strongly influence the distribution and vigor of riparian vegetation. Flow must be present fairly continuously in most months of the year for cottonwood–willow vegetation to become established. This condition is illustrated by the lack of cottonwood–willow vegetation downstream from the large but sporadic BHP discharges and the lush growth downstream from the small but continuous WWTP discharges.

In normal years, simulation results indicate that a small amount of flow (about 0.4 cfs) can be expected at the upstream end of Reach 1 in December and April, resulting in a 5-month flow season at that location. Flow losses along Reach 1 consume most or all of that flow, however, so that Reaches 2-5 have only a 3-month season of natural flow. Reach 5 has a continuous inflow of 0.17-0.22 cfs from the WWTP discharge. This flow is not apparent in the hydrographs because it is typically entirely consumed by seepage and ET within Reach 5.

In exceptionally wet years, simulation results indicate that substantial flows of 2 cfs or more are common in all reaches from November through April. In contrast, any month of the year might be a month of no flow in dry years. Each month is treated independently in the water-budget model, and it is very unlikely that every month of the year would be as dry as indicated on the dry-year graphs in Figure B-15C. The presence of mature mixed-riparian vegetation along the downtown reach indicates that it has historically been able to survive years with negligible streamflow. Possible reasons include (1) some months probably do have flow even in a very dry year; (2) a small amount of persistent base flow or underflow may be present in dry years, such as a trickle of spring discharge not correctly predicted by the gage-correlation method used to estimate natural streamflow; and (3) riparian vegetation is able to survive infrequent dry years on rainfall alone.

In addition to simulating seasonal and annual flow patterns in Queen Creek, the model indicates the amount of supplemental water required per acre to support each of the riparian-vegetation types. Supplemental water is the amount of water needed in addition to rainfall for optimal plant growth and vigor. Table 5-4 in Chapter 5 shows the supplemental water requirements by month and year type for mesquite, mixed-riparian forest, and cottonwood–willow riparian forest. The water requirements shown are calculated in two ways for convenience in calculating supply and demand. Water-supply requirements of a certain restoration design are more usefully calculated as cubic feet per second per acre (cfs/ac), whereas the amount of vegetation that could be supported by a given water supply is more usefully calculated as acres per cubic foot per second (ac/cfs).

In agricultural settings, supplemental water is applied by irrigation. Riparian vegetation can be irrigated, but it is assumed for this analysis that the water would be provided by increasing the frequency and duration of flow in the creek. Supplemental water requirements shown in Table 5-4



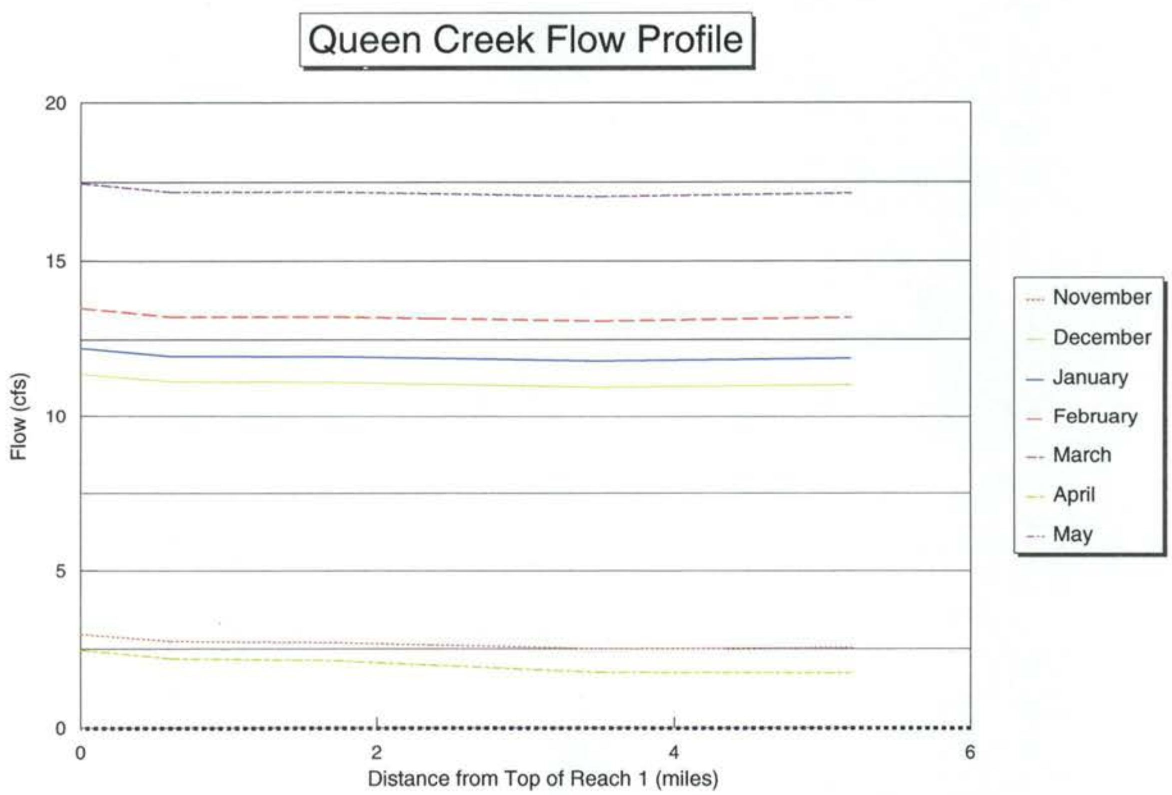
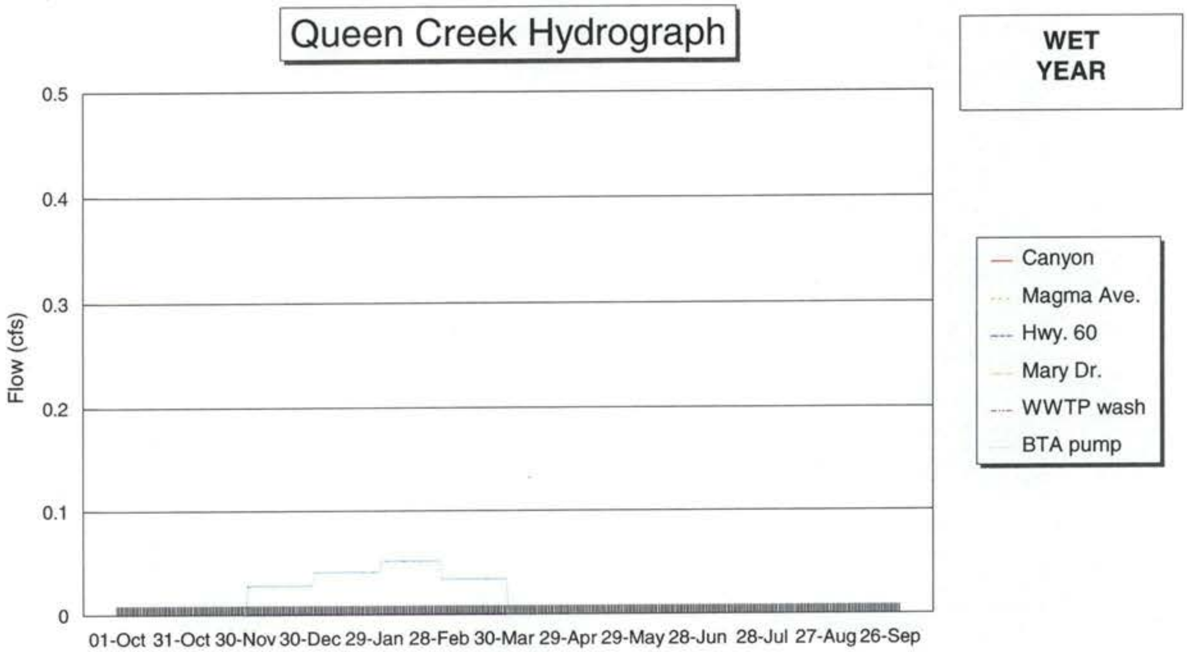


Figure B-15B. Simulated Average Monthly Flows in Queen Creek under Existing Conditions (Wet Year)



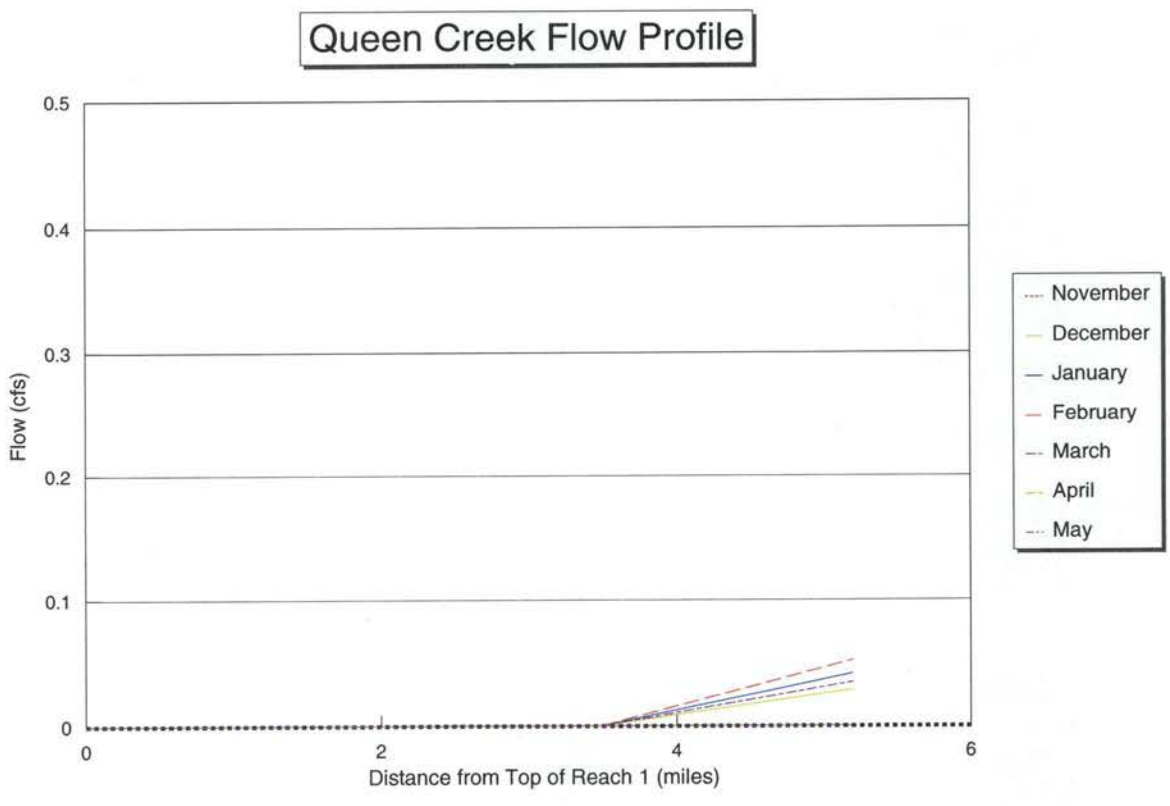


Figure B-15C. Simulated Average Monthly Flows in Queen Creek under Existing Conditions (Dry Year)

do not include losses such as evaporation or percolation below the root zone, which could occur as the water flows down the creek and seeps into the streambank soils.

June is the most critical month for supplemental water requirements, and, of course, dry years require more water than normal or wet years. Assuming vegetation could survive 3 months of suboptimal water supply in late spring or early summer of a dry year, then a steady supply of 1 cfs could restore approximately 200 acres of mesquite, 90 acres of mixed-riparian forest, or 75 acres of cottonwood–willow riparian forest. In normal years, 1 cfs could restore approximately 270 acres of mesquite, 100 acres of mixed-riparian forest, or 85 acres of cottonwood–willow riparian forest.

Model Limitations

The water-balance model provides a convenient means of combining and tracking each gain-and-loss item and ensuring that conservation of mass is correctly maintained as water flows down the creek. However, the accuracy of the model results is no greater than the accuracy of the input variables. The accuracy of metered flows, such as the WWTP discharge and pumping at the Arboretum Canyon Well, is very high. Most of the flow items are estimated by indirect methods, the accuracy of which largely depend on the extent to which conditions in the watershed match assumptions used in the calculations. For example, the model assumes that rainfall-runoff relationships in the Queen Creek watershed are the same as in the Wetbottom Creek and West Sycamore Creek watersheds and that shallow groundwater is in direct hydraulic connection with Queen Creek and undergoes only small seasonal fluctuations.

Major assumptions that limit the ability of the model to answer certain questions or that limit the accuracy of the model include the following:

- The model evaluates only three hypothetical year types rather than a large sample of historical years. This assumption limits information about the duration and intensity of dry or wet periods and precludes an analysis of year-sequence effects.

- The model assumes that years with low rainfall are also years of above-average ET, which may not always be the case.

- Because the model uses a monthly time step, it cannot evaluate the effects of brief flow fluctuations. These fluctuations can affect the restoration effort (e.g., flood peaks may scour or aggrade the channel, brief periods of no flow could cause widespread fish mortality). These effects on vegetation establishment and survival, however, are assumed to be minor.

- The method used to estimate flows in Queen Creek assumes that the rainfall-runoff characteristics of the watershed are similar to those of the predictor watersheds. Factors affecting rainfall-runoff include soil type, ground-slope distribution, and vegetative cover.

Preliminary Evaluation of Selected Restoration Alternatives

The water-balance model was used to simulate several possible restoration alternatives involving various combinations of water supplies and restoration locations. The alternatives were selected purely to illustrate the ability of the model to simulate water requirements and the instream-flow effects of restoration actions and to provide a general sense of the magnitude of restoration that might be achievable with each of several potential water sources. Issues such as cost, water rights, land ownership, and wildlife implications were not considered at this point, but as formal restoration proposals are developed, these issues will be considered in subsequent stages of the restoration-planning process.

For each alternative, an assumed new discharge was added to the reach that would be restored, and the composition and density of vegetation in that reach were adjusted to reflect the expected restored condition. Losses were recalculated and effects on outflow to downstream reaches were noted. For alternatives involving relocation of existing discharges, effects of the decreased release at the existing discharge point were also evaluated.

Available flow in Queen Creek would be the principal limit on restoration of riparian vegetation along Queen Creek. To develop restoration alternatives, it helps to have a sense of the relative magnitude of the major existing discharges and consumptive uses along the creek. These "pieces of the water puzzle" are shown in Table 5-5 in Chapter 5 . Additions to flow include the WWTP discharge and the recent BHP discharge of treated dewatering water. Direct or indirect withdrawals of flow include pumping at the Arboretum Canyon Well; seepage induced by BHP dewatering; and evaporation and ET associated with riparian vegetation along Queen Creek, the WWTP and BHP washes, and near the BHP storage ponds.

Full Restoration of the Downtown Reach

For this alternative, the vegetation outcome was assumed and the amount of water required to achieve that outcome was calculated. The total area of riparian vegetation along the downtown reach (Reach 2) was assumed to remain unchanged, but the composition and canopy density were assumed to be the same as in Reach 5, where relatively lush riparian vegetation has become established in response to the WWTP discharge. The existing vegetation consists of 29 acres of mesquite and 2.5 acres of mixed-riparian forest. Our assumption indicates that after restoration, vegetation would include 18 acres of mesquite and 14 acres of cottonwood–willow forest.

The simulated effects of full restoration on the water balance for Reach 2 are shown in Table B-8. Additional discharges (indicated in Table B-8 as local inflows) were introduced at the upstream end of the reach (Magma Avenue) and adjusted to achieve a reach outflow of 0.1 cfs at Highway 60. The annual amount of supplemental water required was 78 af in a normal year and ranged from 52 af in a wet year to 102 af in a dry year. The maximum monthly discharge rates that would be needed occurred in June and were 0.26, 0.29, and 0.31 cfs for wet, normal, and dry years, respectively. To put the dry-year water demand in context, it equals 39% of the annual WWTP discharge and 24% of the recent average-annual BHP dewatering discharge.

Install a New WWTP Outlet Where the Existing Reclaimed-Water Pipeline Crosses Queen Creek

An existing pipeline delivers reclaimed water for irrigation to Murchison baseball field, Kennedy Elementary School, Superior High School, and the cemetery. The pipeline crosses under Queen Creek due east of the WWTP as it heads to Mary Drive and the irrigation points of use. A new turnout constructed at the stream crossing would be a relatively inexpensive way to increase the length of the Queen Creek reach that benefits from reclaimed-water discharges. Under this alternative, some of the discharges presently made to the WWTP wash would be discharged at the new turnout instead. The initial discharge rate would be selected to meet the minimum seepage, evaporation, and ET demands of riparian vegetation along the 2,980-foot segment of creek between the turnout and the confluence with the WWTP wash (i.e., the lower half of Reach 4).

The water-budget model was used to estimate the releases needed at the new turnout to support completely restored riparian vegetation. The area of riparian vegetation per mile and the vegetation types and canopy densities were assumed to be the same as in Reach 5. This area corresponds to 7 acres of cottonwood–willow riparian forest with 60% canopy density and a decrease of 4 acres in mesquite coverage. Releases at the turnout were adjusted to achieve a minimum outflow of 0.1 cfs at the bottom end of Reach 4 in all months and year types. The simulated water balance for Reach 4 in dry, normal, and wet years is shown in Table B-9. The maximum monthly release requirement would be in June in all year types and would be 0.48 cfs in wet years, 0.52 cfs in normal years, and 0.57 cfs in dry years. The annual discharge volumes would be 123, 168, and 226 af, respectively. These volumes range from about half of the annual WWTP discharge in wet years to nearly the entire discharge in dry years.

The length of the revegetated reach under this alternative is approximately the same as the length of the WWTP wash. If releases at the turnout are made in addition to the existing releases down the WWTP wash, there would be a decrease in the amount of surface flow and underflow arriving at the Canyon Well in the Arboretum. It might be feasible for the Arboretum to make up any decrease in available yield by increased pumping at the new, west well near the confluence of Arnett and Queen Creeks. The pumping cost is greater at the west well, however, and it is not yet clear how much additional pumping can be sustained at this location (Dion pers. comm.).

If releases at the turnout are made instead of releases down the WWTP wash, the existing riparian vegetation along the wash would gradually perish from desiccation. An equivalent amount of riparian vegetation, however, would become established along the newly wetted reach of Queen Creek. The replacement vegetation along Queen Creek would be more vigorous and naturally structured because it would experience flood scour and the irrigation benefits of natural runoff in Queen Creek in addition to the steady trickle of WWTP discharge. Gradually phasing the discharge from one location to the other would allow the Queen Creek reach to become vegetated before the water supply to the WWTP wash vegetation is cut off.

Reoperate BHP Ponds to Provide a More Continuous Discharge Rate

BHP has discontinued dewatering the mine workings indefinitely while the company evaluates its long-term plans for mine operation. The re-operation alternative could be implemented if dewatering is resumed in a manner similar to previous dewatering. Previous discharges failed to promote growth of riparian vegetation because the discharges were too infrequent. Under this alternative, operable outlet gates or siphons would be installed in the BHP storage ponds to enable water to be released at a uniform rate throughout the year, rather than simply spilling when the reservoir overfills during wet periods.

BHP has indicated that this re-operation strategy would be infeasible as a result of existing plumbing connections between the dewatering storage ponds, large residence times required for treatment of the water, and existing discharge permit conditions that seek to minimize the total amount of water discharged. These considerations are explained in the section on "Actions Not Recommended for Implementation at This Time" in Chapter 5. The following evaluation of the re-operation alternative is included in case the concept is reconsidered in the future.

Under the proposed re-operation, seasonal reservoir storage fluctuations would be than during previous dewatering periods. A pond-operations analysis would be needed to determine the "safe yield" of the reservoir as a source of supplemental streamflow. In addition, water-quality considerations might severely constrain dynamic operation of reservoir storage. The treated dewatering water may need a minimum residence time in the reservoir so that pollutants can flocculate and settle to the bottom.

Assuming that storage capacity and water quality are not limiting, the annual volume of water available for steady release would approximately equal the average-annual discharge under recent operation. During 1993–1998, the average-annual discharge was 434 af, which is equivalent to a continuous discharge of 0.6 cfs. The model used a discharge of 0.5 cfs for normal years, taking account of some assumed losses from operational constraints (e.g., spills). The constant discharge rates used were 0.2 cfs in dry years and 0.9 cfs in wet years, reflecting the variations in annual discharge volumes during 1993–1998.

Two discharge-location options were considered (Options A and B). Under Option A, the discharge was assumed to go to the BHP discharge wash, which was the historical discharge point. The simulated water budget for Reach 4 under Option A is shown in Table B-10. The local inflows indicated in Table B-10 for the restored condition in each year type are the continuous discharges at the BHP treatment pond minus seepage and ET losses along the BHP discharge wash between the pond and Queen Creek. In the simulation, the total amount of additional flow entering Reach 4 was 71 af in a dry year, 291 af in a normal year, and 590 af in a wet year. With a uniform seasonal distribution, these flows would create live outflow from the reach all year long during a wet year and for 9 months during a normal year, even after allowing for increased ET losses associated with restored riparian vegetation. In a dry year, the discharge would be completely consumed by seepage and ET losses along Reach 4; the simulation did not show outflow in any month. This result of the simulation indicates that cottonwood–willow and mixed-riparian vegetation might extend most but not all of the way between the treatment pond and the lower end of Reach 4. The simulation assumed the presence of vegetation along the entire length of Reach 4 with a composition similar to that of existing vegetation along Reach 5. If Option A were combined with releases of WWTP discharges at a new turnout about halfway down Reach 4, cottonwood–willow and mixed-riparian forest would certainly cover the entire length of Reach 4 and the BHP wash.

Under Option B, the discharge was assumed to be conveyed by pipeline directly from the treatment pond to a new discharge location near the Highway 60 bridge at the top of Reach 3. The simulated water budget for Reach 3 under Option B is shown in Table B-11. The vegetative response to this new, steady supply of water was assumed to be the growth of 8 acres of cottonwood–willow riparian vegetation and an increase in mesquite density close to the creek channel, similar to the vegetation distribution along Reach 5. The discharge would be more than sufficient to meet the seepage and increased ET demand along Reach 3 in normal and wet years. In dry years, however, the relatively small supply of dewatering water and the increases in seepage and ET losses would together cause all of the released water to be consumed within Reach 3 during April through October. Thus, the riparian vegetation toward the downstream end of the reach might suffer some drought stress in dry years. Vegetation that becomes established in Reach 4 as a result of Reach 3 outflow in normal and wet years might die back somewhat during droughts but would probably regrow when normal conditions returned.

Option B would probably not adversely affect existing mesquite vegetation along the BHP wash because it survives primarily on direct seepage from the ponds.

Collect Freshwater Mine Seepage and Discharge to Queen Creek at the Magma Club

Some of the water that seeps into the BHP mine enters the upper-level tunnels in fairly concentrated flows (Mears pers. comm.). This water has not become mineralized by passage through the ore deposits or mine workings and is probably suitable for direct discharge into Queen Creek. This alternative assumes that a constant flow of 50 gpm could be collected and piped directly to a discharge point near the Magma Avenue bridge at the top of Reach 2.

The simulation results for Reach 2 under existing conditions and under this restoration water-supply alternative are shown in Table B-12. The discharge (equivalent to 0.11 cfs) was assumed to occur in all months of all year types. If no other losses were present, this flow of water could theoretically support approximately 11 acres of vegetation that have a composition similar to that of the existing vegetation along Reach 5. However, some seepage losses also would be expected to occur in summer. Thus, the simulation results indicate that the discharge would be completely consumed by seepage and ET during 3 to 6 months of the year, depending on year type.

In practice, a constant release of 0.11 cfs would probably result in establishment of mixed-riparian or cottonwood–willow riparian vegetation along a short reach immediately downstream from the discharge point. This reach might extend only halfway down the length of Reach 2.

Conclusions

The water- balance model indicates that existing Queen Creek flows during January through March are adequate for supporting a corridor of riparian vegetation but that flows during the remaining months are generally inadequate. This result is consistent with the xeric or drought-stressed condition of riparian vegetation along Reaches 1-4. Restoration of riparian vegetation along those reaches would require increased flow in Queen Creek, particularly during April through December. The need to maintain adequate flow to support existing riparian vegetation along Reach 5 constrains restoration opportunities using the existing WWTP discharge. The need to maintain underflow to the Arboretum's Canyon Well might also be a constraint, depending on how the Arboretum irrigation supply is divided between the Canyon Well and the new well at the west end of the Arboretum.

Dewatering from the BHP mine is by far the largest potential source of water for supplementing Queen Creek flows and supporting riparian restoration. Options for using this water range from simply changing the release rate from the storage ponds to constructing new collection systems and discharge locations. The future of BHP dewatering operations, however, is unclear. Without some assurance that this water would continue to be available in the long term, any vegetation dependent on it could be lost as a result of future changes in mine operations.

LAKE OPERATIONS MODEL

A spreadsheet model was developed to simulate the water balance of the lake proposed for construction under Action 5. The lake would be located on the left bank floodplain of Queen Creek immediately downstream of the U. S. Highway 60 bridge in Superior. The purpose of the model was to determine whether available streamflow would be adequate to maintain a reasonable amount of water in the lake during summer and drought years. The lake would be filled by a streamflow diversion approximately 100 yards upstream of the bridge. The model simulates lake storage and the operation of diversions and releases on a daily basis over a 14-year period. The model accounts for streamflow at the diversion point near Community Park, diversions from the creek, seepage losses from the lake, evaporation, rainfall onto the lake surface, and spills (overflows) back into Queen Creek. The model also calculates the average residence time or age of water in the lake as well as its dissolved solids concentration. The 1961-1974 simulation period is the period of record for the stream gage West Fork Sycamore Creek near Sunflower, which was used as the basis for estimating daily streamflow in Queen Creek. Monthly rainfall at Superior during 1961-1974 was prorated on a daily basis for each month of the simulation period. Evaporation, which is less variable than rainfall, was estimated from average monthly values of pan evaporation at the arboretum multiplied by a pan-to-lake coefficient of 0.7. When full, the lake was assumed to have a volume of 21 af and a surface area of 4.5 acres. At lower storage levels, surface area was assumed to be proportional to the square root of lake volume, which is typical for natural lakes.

For the initial "default" simulation, a maximum diversion rate of 2 cfs was assumed. This is the daily-average diversion rate. Because of the brief, intense runoff peaks characteristic of small desert watersheds, the instantaneous peak flow could easily be 10-100 times greater than the daily average flow on days with storm events. A 36-inch intake culvert could convey 10 cfs (or five times the maximum daily rate assumed in the simulation), which would provide reasonable capture efficiency for most daily-average flows up to 2 cfs. Finally, it was assumed that no minimum bypass flow would need to be left in the creek at the diversion point.

Estimated daily Queen Creek flows are shown in Figure B-16. They commonly exceed 2 cfs for periods of several months in winter but did not reach even 1 cfs for an entire year in water year 1972. Large peak flows, which range up to 250 cfs on a daily-average basis, would be essentially unaffected by the diversions. The hydrograph of simulated lake storage (Figure B-17) shows that the lake was completely full for about half the year (generally December-May) in every year except 1972, when it was never more than half full. Although the lake obviously refills easily, it also loses water rapidly to seepage and evaporation. Thus, in all but two years of the simulation period, the lake was less than 25% full by autumn, and in most years it was essentially empty. This seasonal loss of storage would prevent the establishment or survival of riparian vegetation and the resulting mudflat with dead herbaceous vegetation would be aesthetically unappealing.

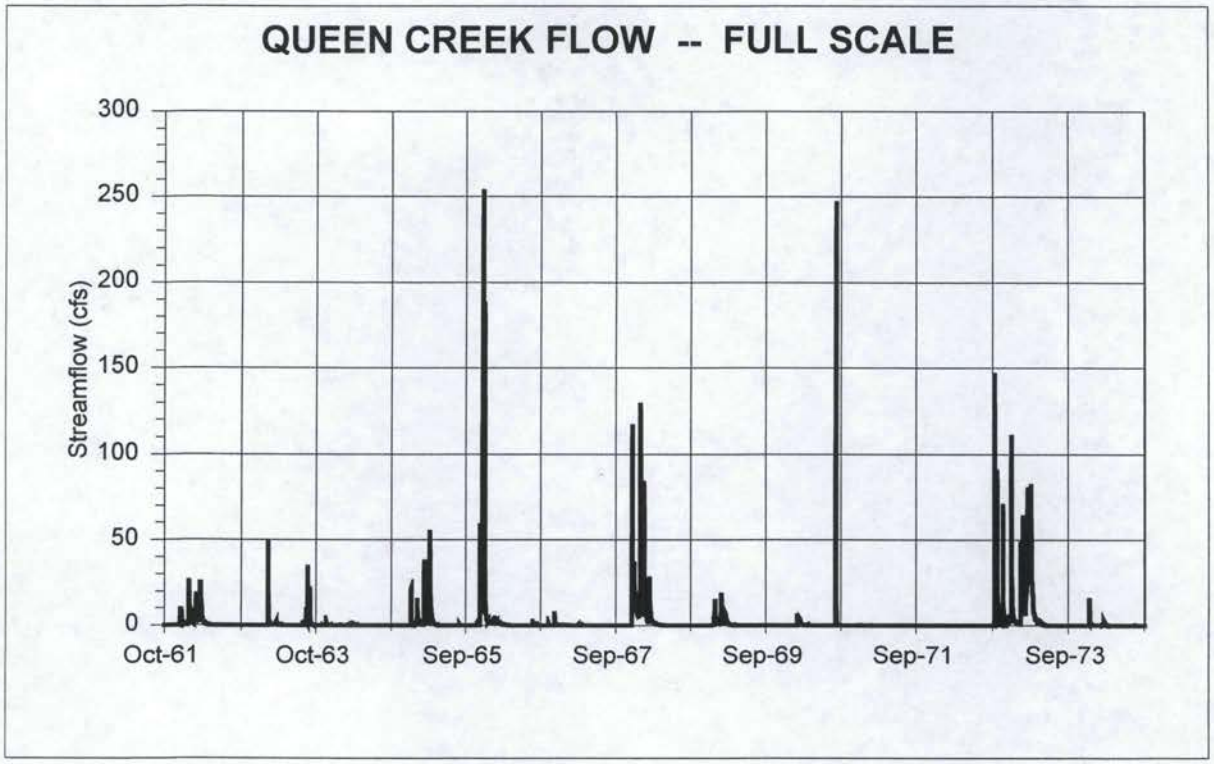
Figure B-18 shows that when the lake is full, additional diversions result in lake overflows. Turnover of the lake water is considered beneficial for maintaining high water quality. The lower graph in the figure shows that evaporation is almost four times greater than rainfall on an average annual basis and even more disparate on a seasonal basis.

Several strategies for preventing seasonal declines in lake storage were investigated with the model, and the results are shown in Figure B-19. If a compacted clay liner were installed in the lakebed during construction, the seepage rate could be decreased to perhaps 0.001 ft/d. This assumes a construction technique similar to that used for landfills, but with less rigorous quality control and performance standards. With seepage decreased to this low level, the lake level would drop to about 25% full by autumn in most years and would never be completely empty (see graph A). This amount of seasonal storage loss would still create problems for vegetation survival around the lakeshore, and the large amount of exposed mudflat would still be unsightly.

A separate simulation was done to see whether increasing the maximum diversion rate would help maintain the lake in a full condition more often. The simulated storage hydrograph with a maximum diversion rate of 5 cfs (graph B) is almost identical to the default simulation. The problem is not inadequate diversion rate capacity but simply the lack of divertable flow during the dry season.

If excess infiltration into the Neversweat Tunnel of the copper mine is collected and discharged to the top of Reach 2 at a constant rate of 90 gpm (0.20 cfs), the resulting flow in Queen Creek would extend downstream as far as the diversion point except during a 2-3-month period in summer. The annual quantity of divertable water at the diversion point would be approximately 66 af, assuming monthly flow losses ranging from 0.01 to 0.29 cfs along Reach 2. With the additional availability of Neversweat water (but no lakebed seepage reduction), simulated lake storage drops to about 50% of capacity by autumn in almost every year (graph C).

An exempt well could be installed next to the lake to capture lake seepage that has percolated to the water table and pump it back into the lake. An exempt well is defined as "...a well having a



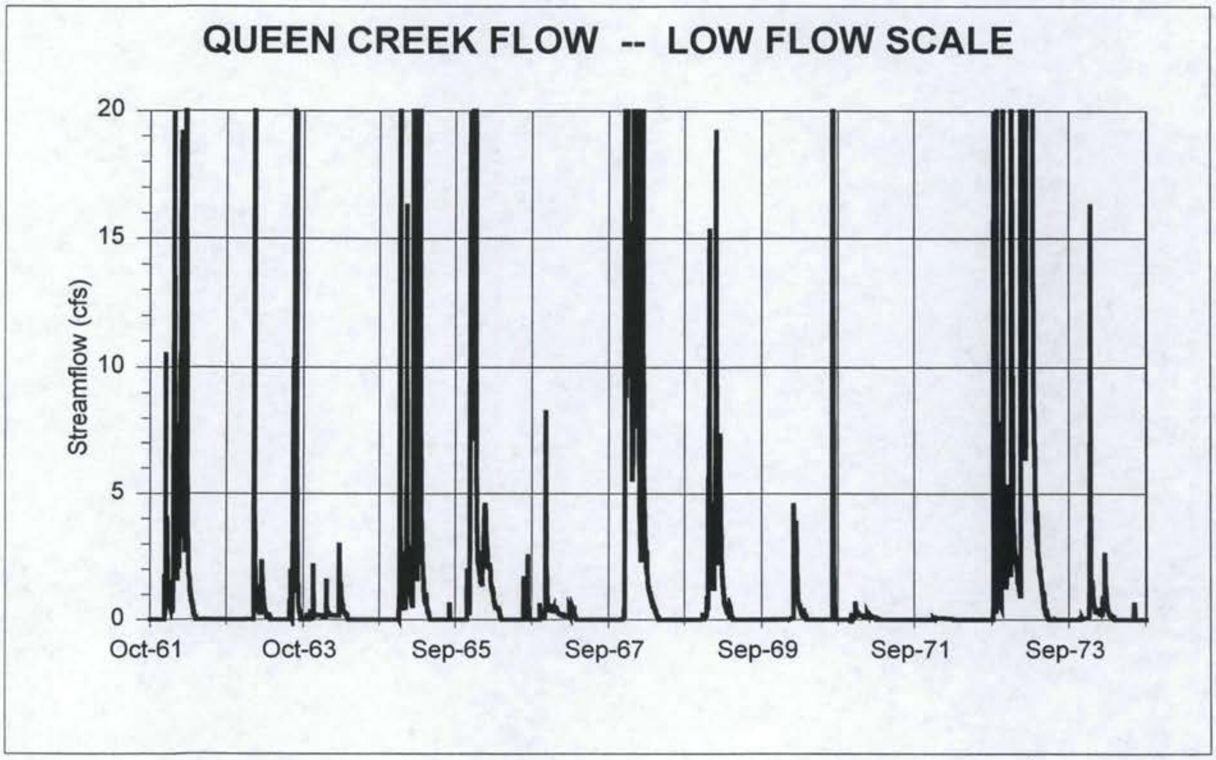
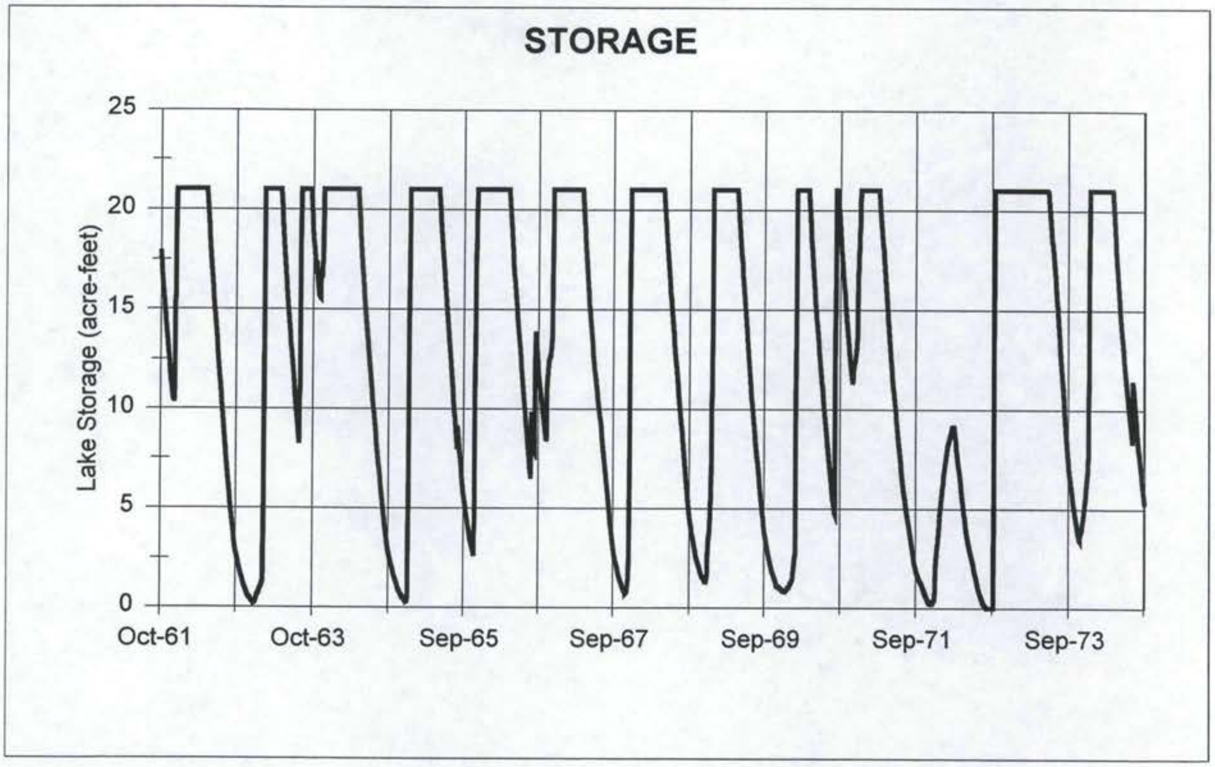


Figure B-16. Simulated Queen Creek Flows at the Diversion Point for the Proposed Lake under Default Conditions



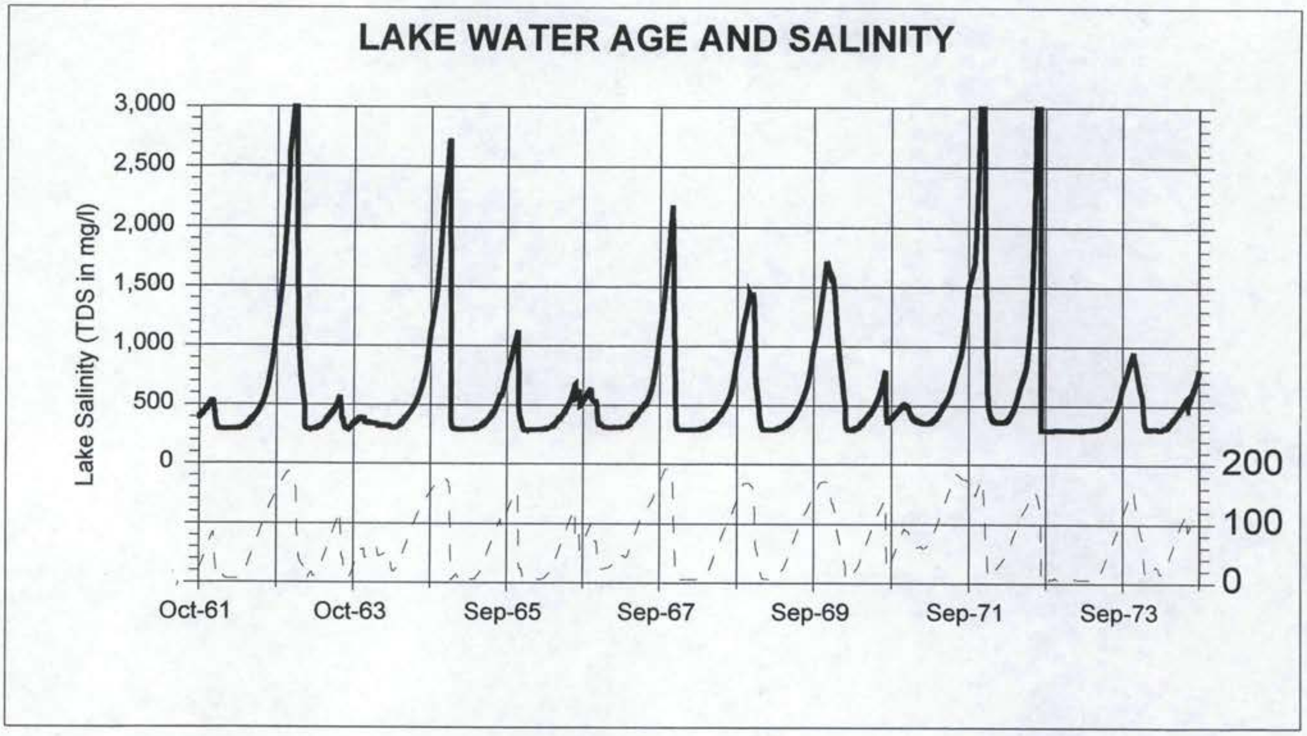
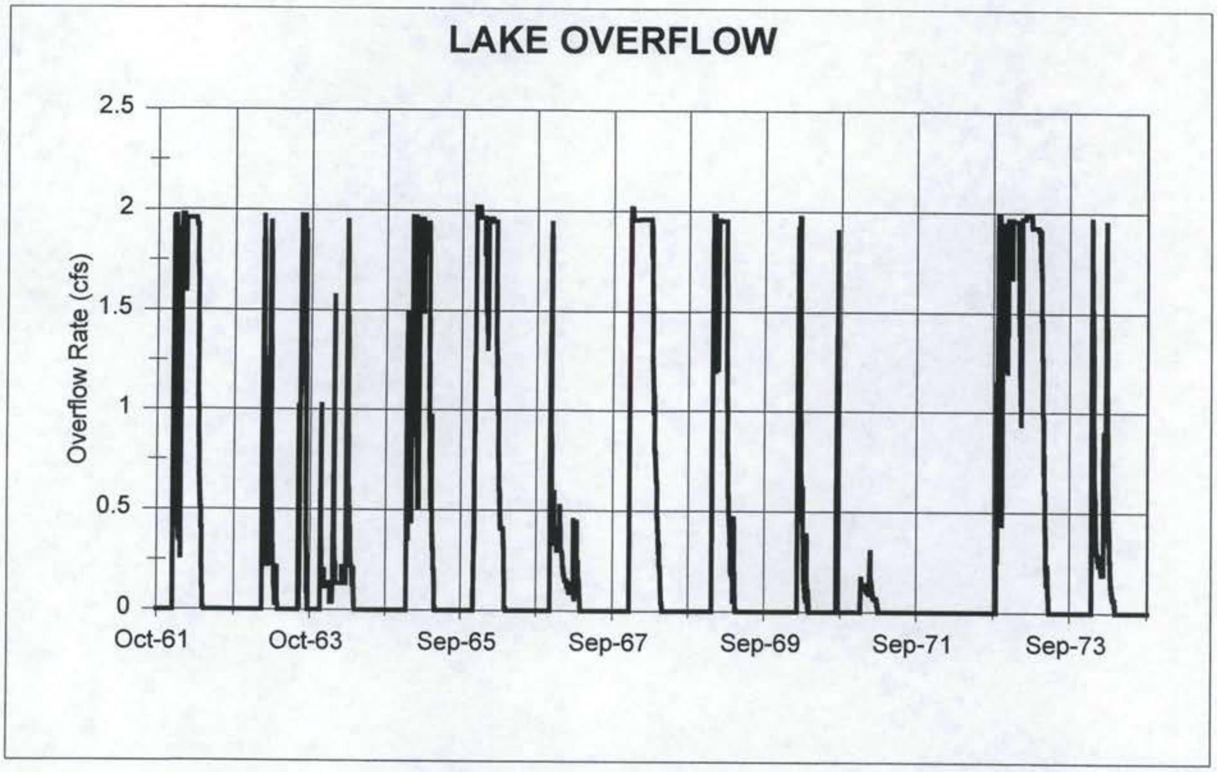


Figure B-17. Simulated Storage, Water Age, and Salinity in the Proposed Stormwater Lake under Default Conditions



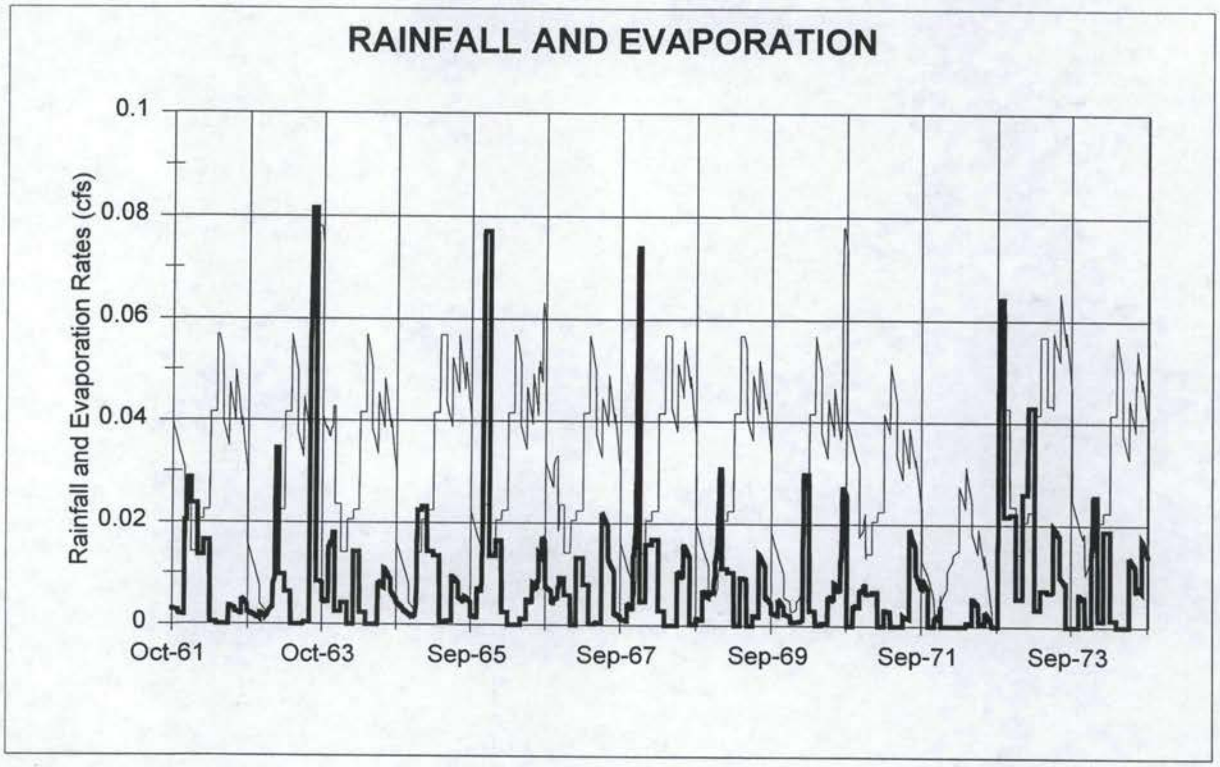
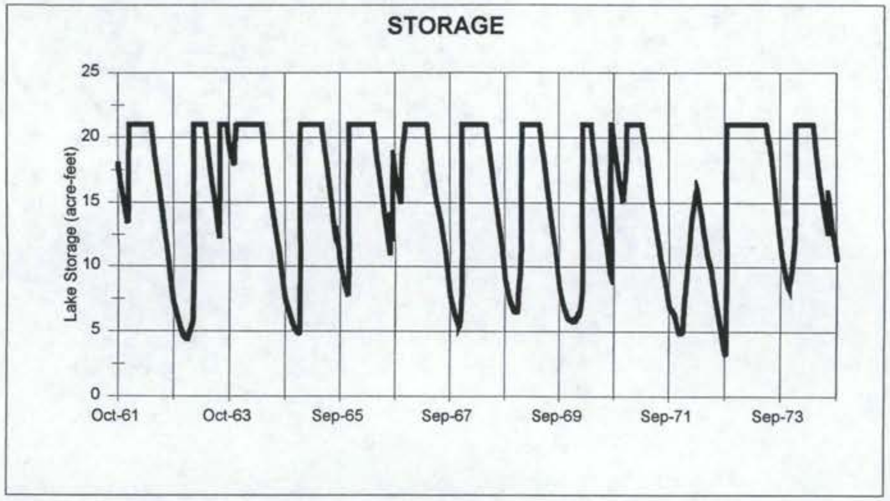
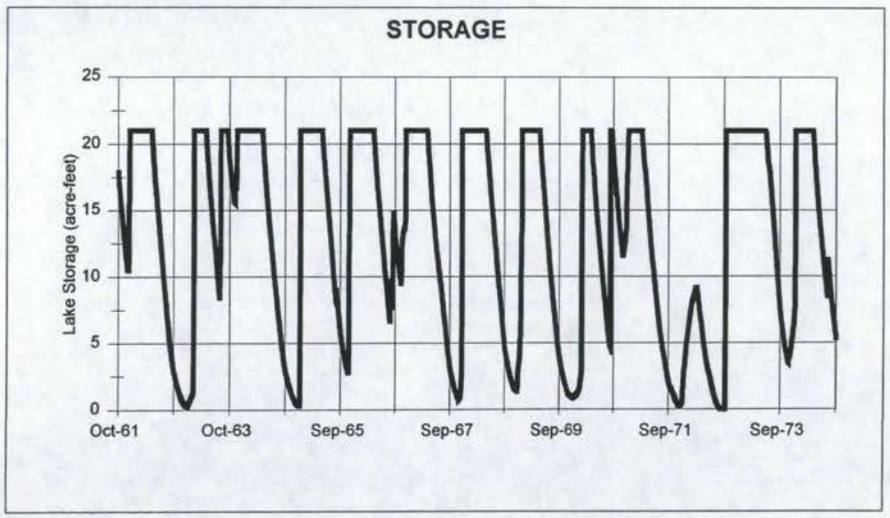


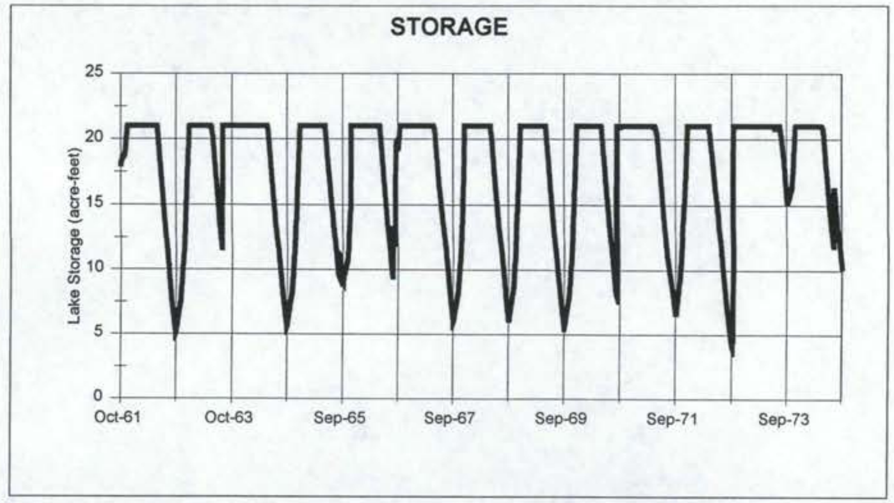
Figure B-18. Outflow to the Spillway and Evaporation and Inflow from Rainfall at the Proposed Lake under Default Conditions



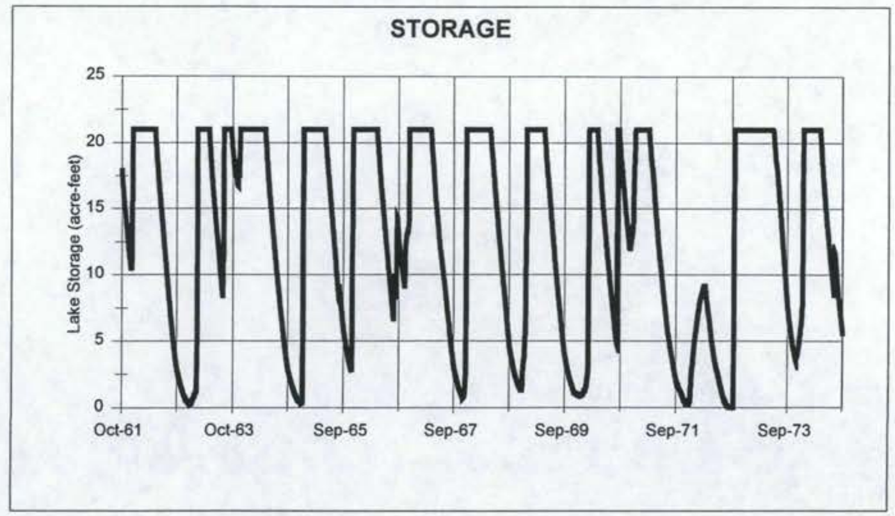
A. Seepage Rate = 0.001 Feet/Day



B. Maximum Diversion Rate = 5 Cubic Feet per Secon



C. Neversweat Tunnel Discharge to Upper End of Reach 2



D. With Well Pumping 10 af/yr into Lake

Figure B-19. Sensitivity of Lake Storage to Seepage Rate, maximum Diversion Rate, and Discharge from the Neversweat Tunnel pump with a maximum capacity of not more than 35 gpm, which is used to withdraw groundwater pursuant to § 45-454" (ARS § 45-402). Withdrawals from exempt wells in the Phoenix AMA are limited to 10 af/yr and only one well may be drilled or used to serve the same non-irrigation use at the same location (ARS § 45-454). State regulations implemented by ADWR do not allow lakes to be filled or refilled with groundwater (Swanson pers. comm.). The maximum benefit of an exempt well would be achieved if pumping were confined to the months of August-October, when the lake water balance is most negative. Unfortunately, the amount of water assumed to be contributed by the well is too small to materially retard the storage declines if seepage losses are still high (graph D, Figure B-19).

Combinations of the above strategies were simulated to determine whether their collective influence would be enough to maintain the lake in an acceptably full condition. Combining seepage reduction with Neversweat Tunnel discharges to Queen Creek brought the seasonal low storage level up to 50% of capacity, which would be marginally acceptable for maintaining riparian vegetation and an aesthetic appearance. Adding the well to those two measures provided noticeable benefits and maintained autumn storage at an acceptable 75% of capacity in essentially all years (Figure B-20).

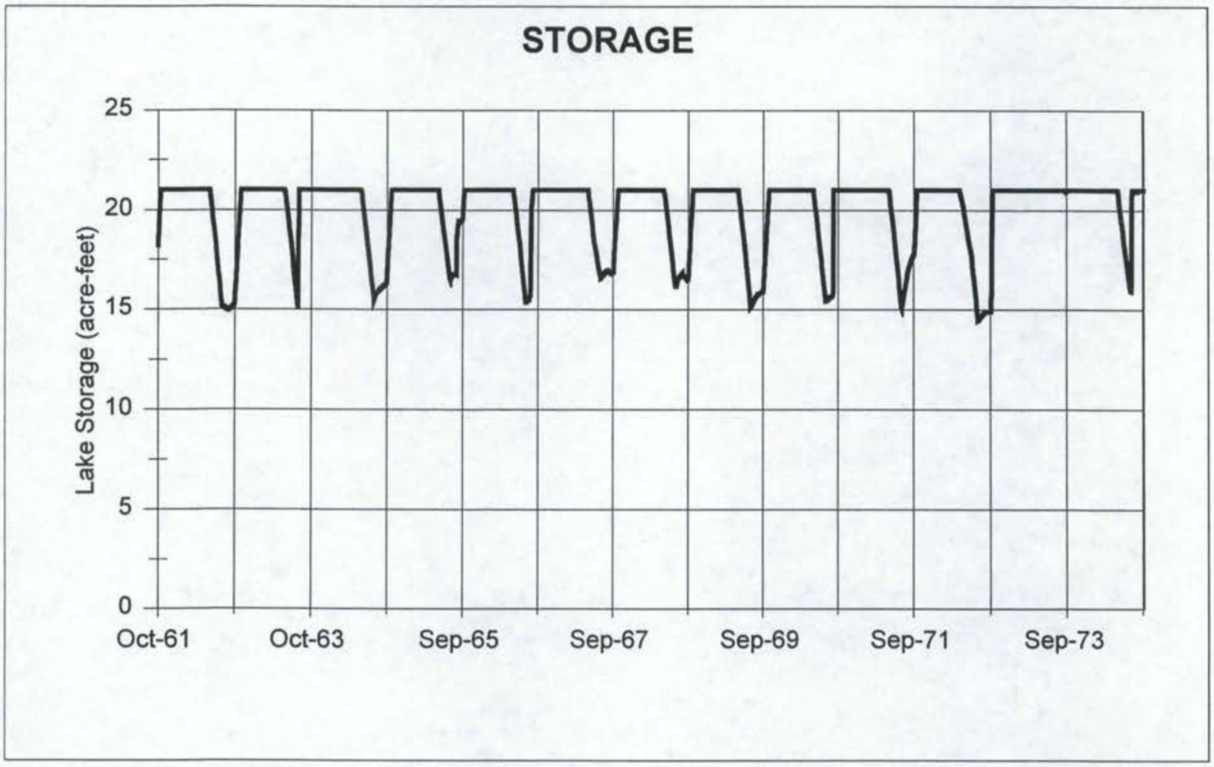
In conclusion, the stormwater lake concept would only be feasible if seepage rates are drastically reduced and supplemental inflow is provided, particularly supplemental inflow during April-October.

FLOOD MANAGEMENT

History of Flooding and Flood Analysis

Changes in vegetation along the Queen Creek channel will affect flood levels during large storms. FEMA completed a flood-insurance study and a flood-boundary and floodway map of Superior in 1981 (Federal Emergency Management Agency 1981a, 1981b). The flood-boundary map shows that a number of residences along Heiner Drive would be inundated in a 100-year storm. (A 100-year flood is the peak flow that has a 1% probability of occurring in any year.) The FEMA 100-year floodplain map is shown in Figure 2-10 in Chapter 2; it was calculated using the HEC-2 flood-hydraulics modeling software developed by the Corps.

Flooding is not perceived as a major problem by local residents because all floods that have occurred in about the last 60-70 years have been contained within the channel and have not inundated buildings along the creek. Harold Smith, who has lived in Superior nearly continuously for 73 years, does not recall a single flood that inundated homes along the creek (Smith pers. comm.). The largest flood he remembers in the last 45 years resulted from a thunderstorm in 1967 that dropped 3.5 inches of rain near King's Crown Peak (Figure 2-2 in Chapter 2). The water reached the third step on one of the footbridges but receded quickly without inundating any buildings. If the storm had been centered more directly in the upper Queen Creek watershed, however, he suspected that the peak floodflow in Superior would have been considerably larger.



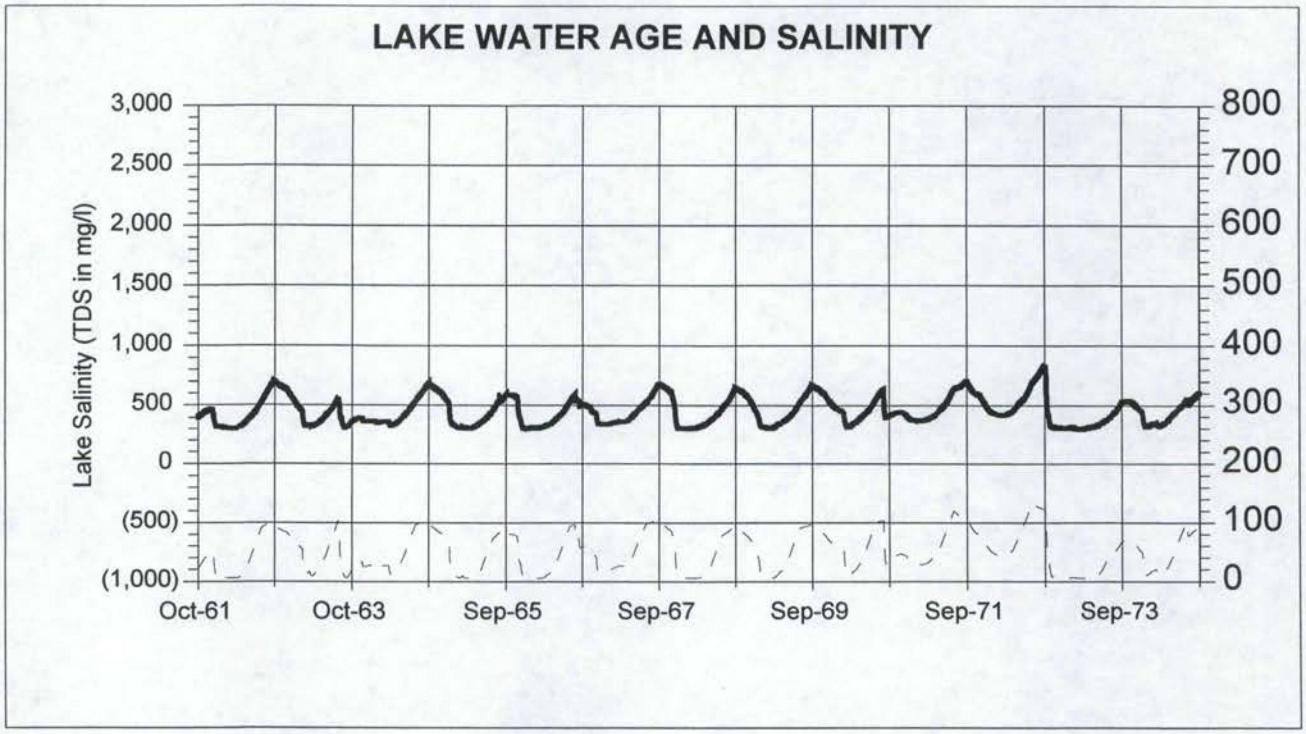


Figure B-20. Simulated Storage, Water Age, and Salinity in the Proposed Stormwater Lake with Reduced Seepage, Neversweat Discharge, and Well Inflow

Mary Palacio, another resident who has lived in Superior since approximately the 1930s, also does not recall any flood that inundated buildings. Her aunt, however, remembers that some residences along Heiner Drive were inundated in a flood in the 1920s (Palacio pers. comm.). According to Mr. Smith and Ms. Palacio, the FEMA floodplain-mapping study in 1981 was not prompted by any real or perceived flood problem, and the study was not followed by any flood-control projects. Mr. Smith understood that the principal purpose of the study was to define a floodplain so that residents could obtain flood insurance. Recurring flood damage in other Arizona towns where floodplains had not been mapped may have motivated FEMA to develop the Superior map in anticipation of potential problems.

It is not clear whether a 100-year flood has simply not occurred in the last 70 years or whether the magnitude of the event was overestimated in the FEMA flood study. Notwithstanding the lack of frequent flood damage, there are a few signs of channel modifications that appear to have been ad-hoc efforts to manage flooding. Numerous willow trees in the channel along the lower end of the downtown reach (Reach 2) were cut down sometime after the January 1993 flood, and a 5-foot-high berm of uncompacted dirt and boulders was also bulldozed into place along the left bank of the channel in the same vicinity. These modifications may simply have been intended to prevent inundation of a large, low terrace on the left bank that at one time was planned to be developed into playing fields. Unfortunately, the tree removal may have increased rather than decreased the flood risk along that reach. The willow stumps have resprouted into dense, multi-stemmed shrubs that have a higher flow resistance than the individual tree trunks they replaced. Sediment deposition and vegetation growth have reportedly decreased the channel capacity in this area, so that this creek segment would be the most likely to experience overbank flooding (Smith pers. comm.).

Update of Flood-Hydraulics Model

The flood-hydraulics model developed by FEMA was updated for this study to provide quantitative estimates of the flood impacts of various vegetation-restoration alternatives. Input data for the original model was obtained from the FEMA Project Library (Lingao pers. comm.) so that hydraulic parameters, such as roughness coefficients and expansion and contraction coefficients, could be correctly duplicated. The updated model was developed using the Corps' HEC-RAS software, which is a relatively new flood-hydraulics simulation program that has largely replaced the original HEC-2 software. Model input and output data were prepared and displayed using the RiverCAD software developed by BOSS International, Inc.

Flood hydrology (the amount of flow during flood events of selected magnitudes) was not reevaluated for the model update. Land use in the Queen Creek watershed upstream of Superior has not changed appreciably in the last 20 years, and the 100-year peak flow estimate of 11,400 cfs developed by FEMA for the original flood study was considered reasonable for use in the update. The update focused on flood hydraulics, which include the size and shape of the floodplain inundated for a given flow magnitude. Changes in channel shape and floodplain vegetation affect flood hydraulics but do not affect the magnitude of floodflow.

Channel Geometry and Roughness

The HEC-2 and HEC-RAS flood-hydraulics models require detailed topographic data for the creek channel. The cross-sectional geometry of the channel is tabulated from the topographic data at numerous locations along the simulated reach and entered into the model. The original model simulated the reach between Stansberry Avenue and Mary Drive. Eleven cross sections were developed from an aerial topographic survey flown in February 1979. A paper-copy map with 2-foot contours is the only information remaining from the original survey.

For the model update, Cooper Aerial Survey Company completed a new aerial topographic survey at a scale of 1:6,000 in September 1998. The resulting digital topographic map covers the reach from about 0.5 mile upstream of Magma Avenue to Mary Drive, and the 2-foot contours have an accuracy of about ±1 foot. The 1998 topography is shown in Figure B-21 along with the locations of the 28 cross sections used in the hydraulics model. Only 10-foot contour intervals are shown in the figure. The shapes of the bridges at Magma Avenue and Highway 60 were surveyed in the field.

Numerous parameters are used in the model to specify how energy losses resulting from channel gradient, channel shape, structures, and vegetation are to be calculated. The principal parameter that would be affected by restoration of riparian vegetation is the roughness coefficient, a dimensionless coefficient that reflects the resistance to flow created by vegetation in the channel and on the floodplains. The original model used a uniform value of 0.045 for the channel and overbank (floodplain) areas along the entire simulated reach.

Model Verification

The accuracy of the updated model was verified by comparing the simulated 100-year floodplain with the floodplain simulated using the original model. To maintain comparability, flow parameters were the same for both models except for minor differences necessitated by differences between the HEC-2 and HEC-RAS program codes. The newly simulated 100-year floodplain is also shown in Figure 2-10, superimposed on the original 100-year floodplain. The two simulated floodplains are generally similar. The floodplain boundary for the updated model shows considerably greater detail because the RiverCAD software is capable of correctly projecting the simulated water surface onto the detailed land surface topography between cross sections, whereas the original model simply connects with a straight line the simulated edge of the water surface from one cross section to the next.

Both models show residences and other buildings within the floodplain, especially on the left (south) bank of the creek between the Lobb Avenue pedestrian bridge and Western Avenue. The additional reach upstream of Lobb Avenue simulated in the updated model did not reveal any additional areas of overbank inundation. The updated model indicates that a few structures northwest of the Highway 60 bridge that were not included in the FEMA floodplain may in fact be within the 100-year floodplain. A plot of each cross section is included at the back of this appendix, and simulated water-surface elevations are indicated in each plot.

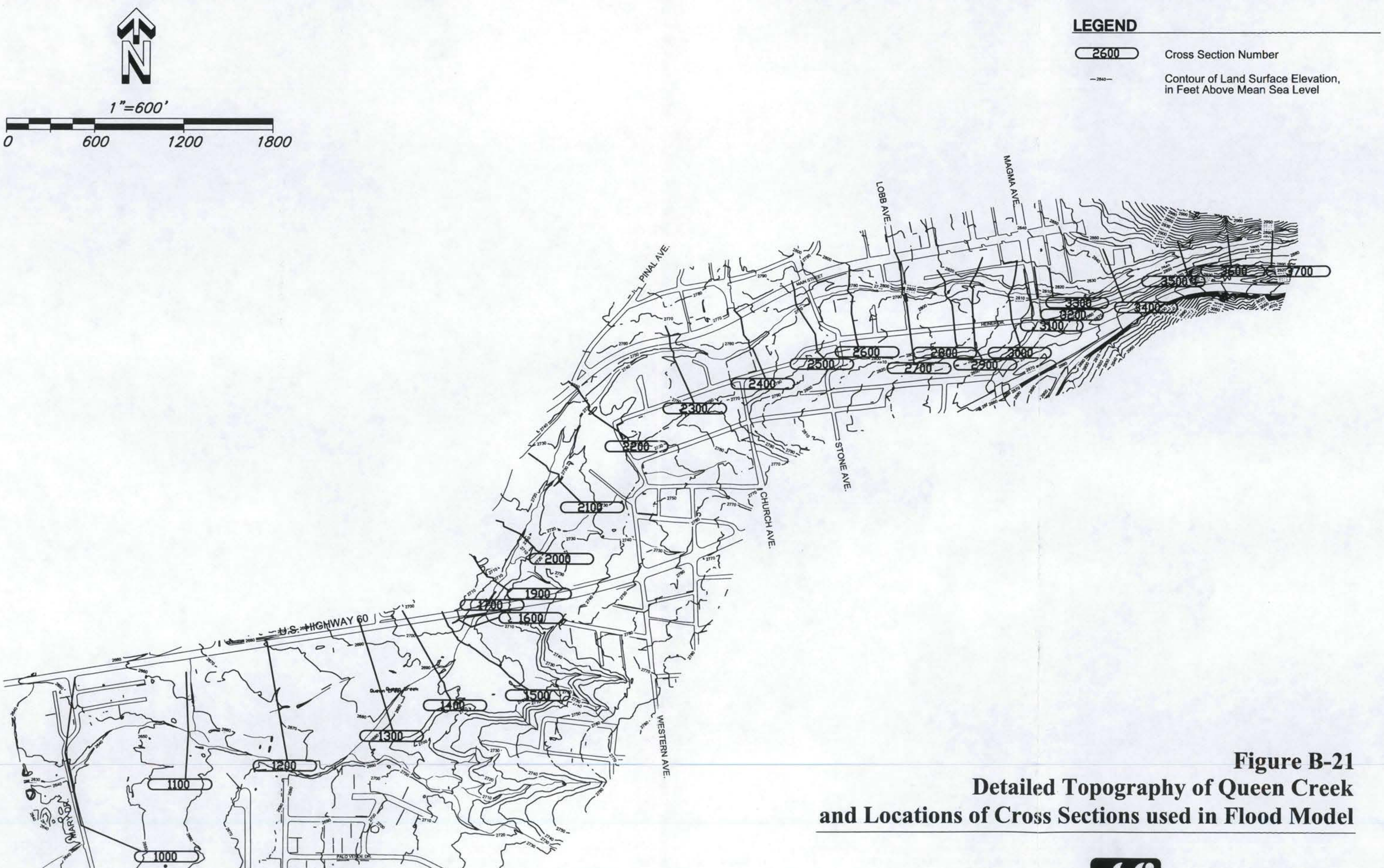


Figure B-21
Detailed Topography of Queen Creek and Locations of Cross Sections used in Flood Model

Jones & Stokes Associates, Inc.

The simulated floodplains are sufficiently similar that the updated model is considered equivalent to the original model for the purpose of simulating the effects of riparian-habitat restoration on flooding along Queen Creek. No calibration or adjustment of model input variables was considered necessary to improve the fit between the original and updated models.

Simulation of Selected Flood-Management Alternatives

The updated flood-hydraulics model was used to simulate several conceptual riparian-restoration and flood-mitigation strategies as a preliminary step toward developing a creek-restoration plan. These simulations are intended to reveal the relative importance of vegetation and other factors on flood stage and floodplain area as well as the relative effectiveness of several restoration-design features that could potentially offset the adverse impacts of vegetation on flooding. This information will help guide restoration planning for Reaches 2 and 3, where flooding is already a problem under existing conditions.

Effects of Vegetation

If streamflow in Reaches 2 and 3 of Queen Creek is augmented to create more perennial flow conditions, and if riparian vegetation were allowed to grow unmanaged into a mature riparian forest with a dense, shrubby understory, the hydraulic roughness would increase. The increased roughness would increase flood stages because additional cross-sectional flow area and a steeper gradient would be needed to convey the same amount of water in the presence of increased resistance to flow. The extreme case of dense riparian vegetation in the channel and overbank areas was simulated to bracket the range of impacts that vegetation restoration could create. A roughness coefficient of 0.075 was selected to represent fully vegetated conditions based on a visual comparison between Queen Creek and other Arizona creeks and rivers where the roughness coefficient has been calculated based on measured historical flood levels (Phillips and Ingersoll 1998).

When the roughness coefficient for channel and overbank areas along the entire simulated reach of Queen Creek was increased to 0.075 from 0.045 (the uniform value used in the original model), the floodplain area increased only slightly. The simulated floodplain is shown in Figure B-22, superimposed on the existing 100-year floodplain. The total inundated area increased only by approximately 15%, but several additional residences along Heiner Drive and near Mary Drive became included within the enlarged floodplain. The relatively small effect of roughness on the shape and overall size of the floodplain suggests that vegetation is not the principal cause of existing flood problems and also that any vegetation restoration along the simulated reaches needs to be implemented in a manner that avoids increased hydraulic roughness or in conjunction with mitigation measures that offset the increase.

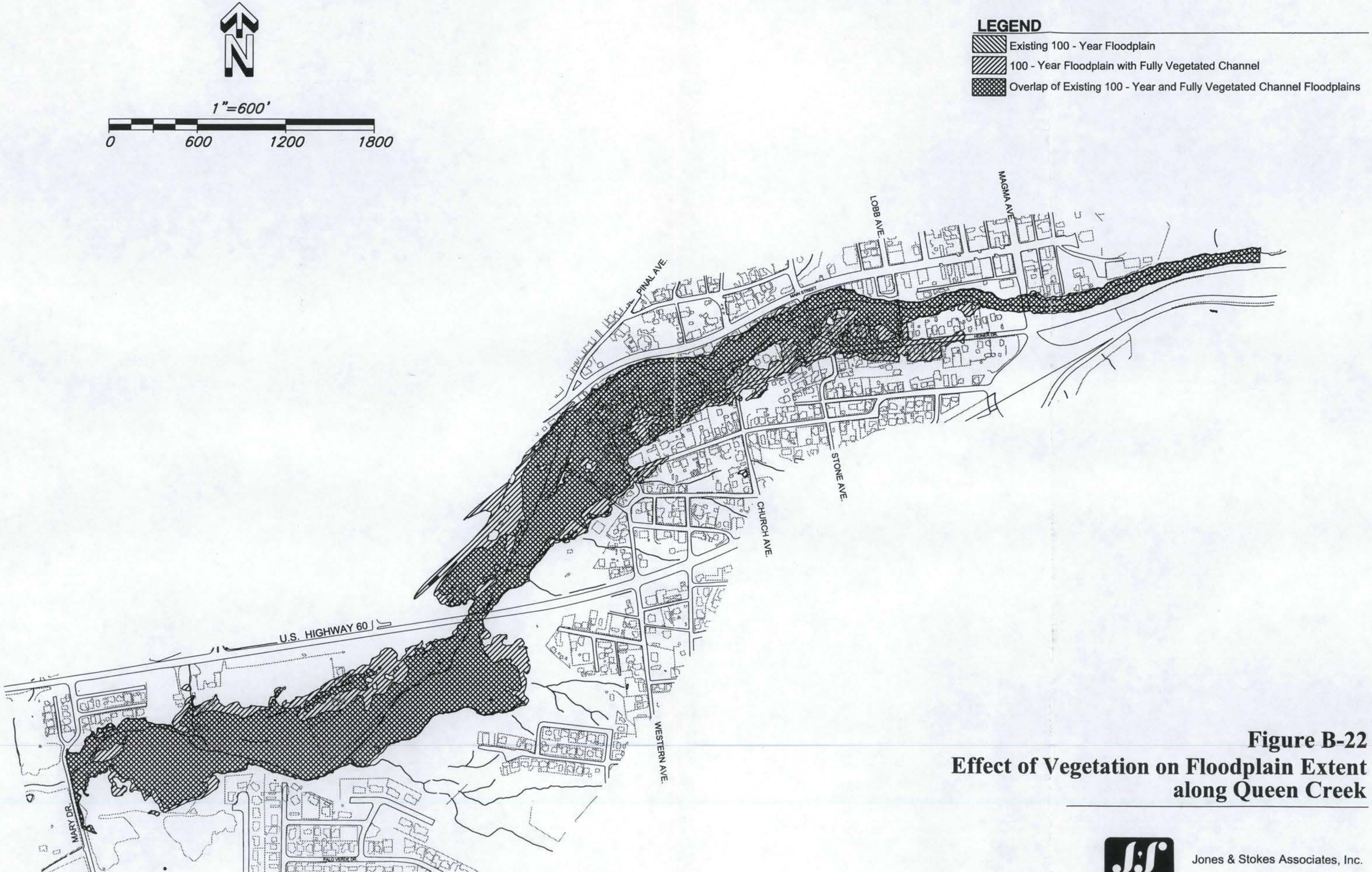


Figure B-22
Effect of Vegetation on Floodplain Extent along Queen Creek

Jones & Stokes Associates, Inc.

Levees

The depth of inundation is only a few feet at almost all overbank locations in the 100-year floodplain. This suggests that levees or floodwalls only a few feet high could eliminate the flood risk for residences along Heiner Drive. A hypothetical levee 4 feet high along the left side of the creek channel from near Lobb Avenue to Highway 60 was simulated and was found to be high enough to contain the floodwater within the channel in all but one location. At cross section 2700 near Lobb Avenue, a levee height of 6 feet was necessary to contain the flow in the channel.

A low levee, less than 1 mile long, would be substantially less expensive to construct than the massive flood-control levees typically constructed along major rivers. Given the lack of recent flood damage, however, it could still cost more than local residents would be willing to pay. Furthermore, a levee would obstruct views of the creek during non-flood periods and contravene efforts to enhance the natural-amenity value of the creek corridor. Levee construction would also probably require removal of some of the vegetation that the restoration project is attempting to protect.

Terraces

Another approach to offsetting the effects of increased vegetative roughness is to enlarge the creek channel by excavating low terraces. Potentially, excavated material could be used to construct levees and to decrease the necessary levee height. The effectiveness of this approach was evaluated by simulating a continuous terrace along the left bank of the creek between Lobb Avenue and the embankment upstream of the Highway 60 bridge. The bottom width of the terrace was assumed to be 40 feet, the terrace elevation was assumed to be midway between the lowest point of the creekbed and the adjoining floodplain (generally 5-6 feet above the creekbed), and a side slope of 2:1 (horizontal to vertical) was assumed to be between the terrace and the floodplain.

The simulation results showed that even a terrace as large as the one included in the simulation would not provide sufficient additional conveyance capacity to contain the 100-year flood flow in the channel.

From a restoration standpoint, the terrace could provide a favorable location for establishment of phreatophytic riparian trees, such as cottonwoods and willows. Construction of the terrace would be expensive, however, because of the large amount of earth moving required. A substantial amount of existing riparian vegetation also would have to be destroyed during construction.

Enlargement of the Highway 60 Bridge

The model was used to investigate whether the Highway 60 bridge might restrict floodflows and contribute to elevated flood stages along the downtown reach upstream of the bridge. If this were the case, then enlarging the bridge span potentially could offset the effects of increased vegetative roughness. This possibility was explored in a test simulation in which the bridge span perpendicular to the channel axis was increased from 95 feet to 135 feet. The resulting simulated floodplain was only negligibly different from the existing floodplain, indicating that the bridge is not presently a flow constriction and that enlarging it would not offset the effects of increased vegetative roughness along the downtown reach.

Vegetation Management

An alternative approach to restoration of riparian vegetation along Reaches 2 and 3 would be to control the type and location of vegetation so that the vegetation provides habitat value without significantly impairing flood-conveyance capacity. Examples of vegetation-management techniques that achieve this balance include the following:

- allowing enough trees to reach maturity to form a closed canopy that suppresses the growth of shrubby vegetation by shading the creek channel;
- planting or selecting for trees whose trunks form a line parallel to the direction of flow, thereby decreasing their individual hydraulic resistances by up to 40% (Li and Shen 1973);
- pruning tree branches that are below the 100-year flood level;
- removing shrubby vegetation from areas below the 100-year flood level; and
- removing piles of woody debris that accumulate during floods and that obstruct flood flows.

An open understory would not be entirely natural, but it would minimize flood impacts and would create an open, shady, park-like atmosphere conducive to recreational use. Thus, an open understory could achieve an appropriate balance of objectives for restoration along Reach 2. Along Reach 3, the floodplain is very wide and undeveloped. A substantial part of the hydraulic roughness is from mesquite bushes on the floodplain. Any increases in hydraulic roughness caused by increased riparian vegetation along the channel could be offset if necessary by selective removal of mesquite from the adjoining floodplain.

This strategy was not simulated because it could be implemented at any level to achieve an overall roughness coefficient between 0.045 (existing) and 0.075 (fully vegetated).

Conclusions

Flood control must be considered a potential constraint on vegetation restoration along Reaches 2 and 3 of Queen Creek, even though there has not been significant flood damage in the last 70 years. To the extent that there is an existing flood risk, simulation results indicate that vegetation is not a large contributing factor. However, additional vegetation could create a significant flood risk. A low levee could eliminate the existing flood risk, but levee construction would probably be expensive and would require substantial impacts on existing vegetation. Vegetation-management practices that provide habitat and amenity value with minimal increases in flood risk may offer a cost-effective and reasonable balance of management objectives along those reaches.

Cross Section Plots

Plots of the 28 cross sections used in the HEC-RAS model are presented on the following pages. Each plot shows the channel geometry, buildings, bridges, and the computed water surface elevation for the 100-year flood event under existing vegetation conditions.

Appendix C. Breeding-Bird Point-Count Survey Results

INTRODUCTION AND METHODS

The value of various riparian-vegetation associations to wildlife was assessed during field reconnaissance of the Queen Creek plan area. Because riparian habitats in the desert southwest are known to provide high-value habitat to a variety of migratory and resident birds, breeding birds were chosen as an indicator of habitat value. Vegetation associations with greater species diversity or populations can be used as an indication that the habitat has potentially higher value.

A point-count survey was conducted on May 27, 1998, beginning at 5:50 a.m. and ending at noon. Eighteen points were surveyed during this period. The areas spanning immediately upstream of Superior to just below the WWTP were surveyed in the early morning. The well-developed cottonwood–willow riparian habitat downstream of the Old Pinal Townsite was surveyed later in the morning. Drainages below the BHP settling ponds and the WWTP, where unnatural water flows have resulted in the establishment of some riparian vegetation, were also included in the survey to determine their habitat value to riparian-associated birds. Survey points in the plan area are shown on Figure 5. A census of each point count was conducted over a 5-minute period and all birds seen and heard from the point were counted. At each point count, vegetation descriptions noting the dominant species were made so that comparison between bird-species richness or abundance and vegetation conditions could be made. These data are summarized in Table C-1 and discussed in the following section.

RESULTS

For the surveyed area, three generalized riparian-vegetation associations were identified by dominant vegetation features: cottonwood–willow riparian, mixed-riparian (i.e., cottonwood, willow, ash, and mesquite), and mesquite bosque. The general vegetation characteristics for each of these associations are described in Chapter 2, "Inventory and Assessment of Historical and Existing Conditions". Census results for each are discussed below. Table C-1 shows all species observed, frequency of occurrence, and abundance within each vegetation association. The following sections focus on the riparian-associated bird species, which are those species that prefer or depend on riparian habitats during the breeding season for food, shelter, and nesting sites. Other species that are not riparian dependent but were common in these habitats are also discussed.

Table C-1: Bird Species Census

Bird Species	Riparian Vegetation Type: Cottonwood-Willow [1] Frequency	(Total Observed)	Mixed [2] Frequency	(Total Observed)	Mesquite [3] Frequency	(Total Observed)	Total [4] Frequency	(Total Observed)
Gambel's quail	0.22	(2)	-	(0)	-	(0)	0.11	(2)
White-winged dove	0.67	(10)	0.50	(5)	0.60	(4)	0.61	(19)
Mourning dove	0.56	(11)	-	(0)	0.40	(2)	0.39	(13)
Inca dove	-	(0)	-	(0)	0.20	(1)	0.06	(1)
Black-chinned hummingbird	-	(0)	-	(0)	-	(0)	0.00	(0)
Costa's hummingbird	-	(0)	0.25	(2)	-	(0)	0.06	(2)
Gila woodpecker	0.11	(1)	-	(0)	-	(0)	0.06	(1)
Ladder-backed woodpecker	-	(0)	-	(0)	0.20	(1)	0.06	(1)
Black phoebe	0.11	(1)	-	(0)	-	(0)	0.06	(1)
Say's phoebe	-	(0)	-	(0)	0.20	(1)	0.06	(1)
Vermillion flycatcher*	0.11	(2)	-	(0)	-	(0)	0.06	(2)
Ash-throated flycatcher*	-	(0)	0.25	(1)	0.20	(1)	0.11	(2)
Western kingbird	-	(0)	0.25	(2)	-	(0)	0.06	(2)
Northern rough-winged swallow	-	(0)	-	(0)	0.40	(2)	0.11	(2)
Verdin	0.44	(4)	-	(0)	-	(0)	0.22	(4)
Cactus wren	0.22	(2)	-	(0)	0.40	(3)	0.22	(5)
Canyon wren	-	(0)	-	(0)	-	(0)	0.00	(0)
Bewick's wren	0.33	(3)	0.25	(1)	-	(0)	0.22	(4)
Black-tailed gnatcatcher	-	(0)	-	(0)	0.20	(1)	0.06	(1)
Northern mockingbird	0.11	(1)	-	(0)	0.40	(3)	0.17	(4)
Curve-billed thrasher	0.22	(2)	0.25	(1)	0.20	(1)	0.22	(4)
Phainopepla	0.22	(3)	0.50	(4)	0.80	(19)	0.44	(26)
European starling	-	(0)	0.25	(2)	-	(0)	0.06	(2)
Bell's vireo*	0.78	(13)	0.50	(2)	0.80	(5)	0.72	(20)
Lucy's warbler*	0.78	(8)	1.00	(5)	0.80	(9)	0.83	(22)
Yellow warbler*	1.00	(19)	1.00	(6)	-	(0)	0.72	(25)
Yellow-breasted chat*	0.78	(12)	0.75	(3)	0.40	(3)	0.67	(18)
Summer tanager*	0.22	(2)	0.25	(1)	-	(0)	0.17	(3)
Northern cardinal	0.22	(3)	0.75	(4)	0.40	(4)	0.39	(11)
Blue grosbeak*	0.11	(1)	-	(0)	-	(0)	0.06	(1)
Abert's towhee*	-	(0)	0.25	(1)	0.20	(1)	0.11	(2)
Song sparrow*	0.56	(7)	0.25	(1)	-	(0)	0.33	(8)
Great-tailed grackle	0.11	(2)	-	(0)	0.40	(3)	0.17	(5)
Bronzed cowbird	-	(0)	-	(0)	0.20	(1)	0.06	(1)
Brown-headed cowbird*	0.11	(2)	0.25	(1)	-	(0)	0.11	(3)
Northern oriole*	0.11	(1)	-	(0)	-	(0)	0.06	(1)
House finch	0.33	(4)	-	(0)	0.40	(4)	0.28	(8)
Lesser goldfinch	0.44	(6)	-	(0)	0.20	(1)	0.33	(7)
House sparrow	0.33	(5)	0.75	(6)	0.40	(7)	0.44	(18)
Total riparian species		(67)		(21)		(19)		(107)
Total all species		(127)		(48)		(77)		(252)

Notes:

(1) Nine points surveyed
(2) Four points surveyed
(3) Five points surveyed
(4) Total of 18 points surveyed
* Riparian-associated species

Cottonwood–Willow Riparian

Of the 18 point counts for which a census was conducted, 9 occurred in this vegetation association, including 3 points in artificially created riparian habitat (see "Artificial Cottonwood–Willow Riparian"). Riparian-associated species most commonly detected in this vegetation association include yellow warbler, Bell's vireo, Lucy's warbler, and yellow-breasted chat. Other riparian-associated species observed included summer tanager, song sparrow, vermilion flycatcher, and northern oriole. Birds with wider habitat affinities that were commonly observed included white-winged dove and mourning dove. Numerically, yellow warbler was the most abundant species, followed by Bell's vireo, yellow-breasted chat, mourning dove, and white-winged dove.

Mixed Riparian

Four census points occurred in this vegetation association. Commonly observed riparian-associated species were yellow warbler, Bell's vireo, and yellow-breasted chat. Other nonriparian species commonly observed included house sparrows and northern cardinals. Numerically, yellow warblers and house sparrows were the most abundant, followed by Lucy's warblers and white-winged doves.

Mesquite Bosque

A census was conducted for five points in this vegetation association. Commonly observed riparian-associated species were Bell's vireo and Lucy's warbler. Yellow-breasted chats were also observed. Notably, no yellow warblers were observed in this vegetation association. Commonly observed nonriparian species included phainopeplas and white-winged doves. Numerically, phainopeplas were the most abundant, followed by Lucy's warblers and house sparrows.

Artificial Cottonwood–Willow Riparian

The overall cottonwood–willow riparian-habitat census included counts for all points located in this type of habitat, regardless of whether the habitat is supported by a natural or artificial water source. Of the nine points included in the census, however, three were located in drainages that support riparian vegetation and provide habitat value to wildlife because of an artificial water source. These three points were segregated from those occurring in naturally occurring cottonwood–willow riparian to determine whether the artificial habitat was used by riparian-associated species that were observed in natural habitats. Riparian-associated species, including Bell's vireo, yellow warbler, and yellow-breasted chat, were observed at all three points; song sparrows, Lucy's warblers, and a summer tanager were also observed. Numerically, yellow-breasted chat was the most common species, followed by Bell's vireos, yellow warblers, song sparrows, and Lucy's warblers.

DISCUSSION

The most frequently observed riparian-associated species was the Lucy's warbler, followed by Bell's vireo and yellow-breasted chats. These observations were made across the three riparian-vegetation associations (Table C-1). Yellow warblers were abundant but restricted to cottonwood–willow riparian and mixed-riparian habitats. Song sparrows were observed primarily in cottonwood–willow riparian habitat. Summer tanagers were observed both in cottonwood–willow riparian habitat and in dense, well-developed, mixed-riparian habitat. Vermilion flycatcher and Bullock's oriole were observed only once in cottonwood–willow habitat.

Although more cottonwood–willow riparian habitat was surveyed than mixed-riparian or mesquite-bosque habitat, survey results indicated that cottonwood–willow riparian habitat supported a slightly greater species diversity than mixed-riparian and velvet-mesquite communities. At the nine cottonwood–willow census points, 10 riparian-associated species were observed; these represented 53% (67/127) of the total birds observed in this habitat. In the combination of the four mixed-riparian and five mesquite-bosque census points, nine riparian-associated species were observed, which represented a combined 32% (40/125) of the total birds detected in these two habitats.

As previously noted, riparian-associated birds were more common, both in species diversity and abundance, in well-developed, structurally diverse cottonwood–willow riparian habitat than in mixed-riparian and mesquite-bosque habitats. The major habitat differences that may account for this appear to be the vertical structure and well-developed herbaceous and subcanopy layers of the cottonwood–willow riparian habitat. Vertical structure is important for canopy-nesting wildlife, such as yellow warbler, summer tanager, and northern oriole. These species are largely restricted to areas with tall cottonwoods and willows. Even in small or structurally uncomplex riparian patches, as long as a tall cottonwood or willow was present, yellow warblers were observed; in mesquite-bosque vegetation lacking tall cottonwoods or willows, however, these three canopy-nesting species were absent. A well-developed herbaceous and lower canopy was needed to support song sparrows.

Artificial riparian habitats below the WWTP and BHP mine-dewatering ponds possess habitat structure similar to native cottonwood–willow riparian habitats. As long as these drainages continue to receive artificial irrigation, they should continue to attract the riparian-associated bird species. Removal of water from these washes would cause an eventual vegetation shift back to mesquite-dominated habitats. If cottonwoods and willows are rooted into groundwater, they could persist and likely provide continued habitat for canopy-nesting species.

These general observations can be used as guides for restoring or creating riparian habitats to support a specific bird community. For example, intermittent drainages occurring on alluvial soils that support mesquite bosque could be converted to mixed riparian or cottonwood–willow riparian by supplying an augmented streamflow. This conversion would facilitate the development of woody riparian and herbaceous vegetation that was observed to support high avian species diversity and abundance.

Appendix D. Announcements for Summaries of Public Workshops for the Town of Superior Queen Creek Riparian Restoration and Management Plan

PUBLIC WORKSHOP #1, OCTOBER 19, 1998

Meeting Announcements and Materials

The announcement for the first public workshop is shown in Figure D-1 and was published in the Superior Sun the week before the meeting. The meeting sign-in list is shown in Figure D-2. Copies of presentation materials are shown in Figures D-3 and D-4.

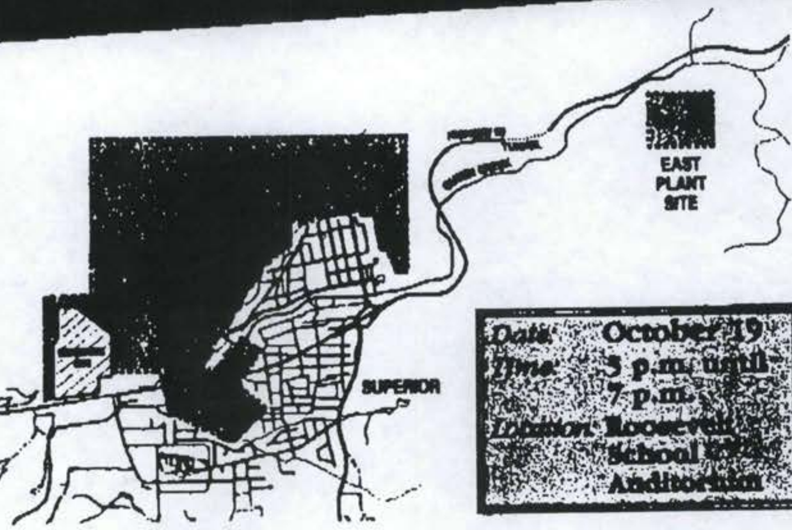
Meeting Summary

The first public workshop for the Queen Creek Riparian Restoration and Management Plan (creek plan) was held from 5:00 to 7:00 on October 19, 1998, at Roosevelt Junior High School in the Town of Superior (Superior). The workshop was conducted as part of a open house held jointly with other organizations and groups active in the community, including BHP, the Superior Historical Society, the Superior Chamber of Commerce, and the Boyce Thompson Arboretum. Each of these groups was provided space in the school auditorium to present materials relevant to their projects and programs. The public was invited to visit each group's space to talk individually with presenters and view exhibits. The open house not only provided an informal forum for the public to learn about and comment on the development of the creek plan, but also an opportunity for presenters to become more informed about other important activities underway in Superior and the vicinity.

Jones & Stokes Associates presented exhibits at the workshop, including a list of the tasks to be performed to develop the creek plan, a preliminary property-ownership map, and a preliminary vegetation map (Figures 2-3 and 2-13 in main text). Approximately 40 people from the community attended the workshop. Jones & Stokes Associates discussed the overall goals and objectives of the plan and the plan-development process with approximately 20 workshop attendees. Common questions that Jones & Stokes Associates addressed during their discussions with attendees were related to the progress of the plan; preliminary findings with respect to the condition of riparian habitat in the creek corridor; potential water sources for increasing riparian vegetation in the creek; and flood management in the downtown reach of the creek.

BHP Superior

Community Open House



BHP will be conducting a Community Open House from 5 to 7 p.m. October 19 at the Roosevelt School Auditorium.

The Open House will include displays and information about current BHP activities in the Superior area, including:

- Potential recreational land uses for the West Plant Site.
- Environmental and remediation efforts.
- Exploration efforts near the East Plant Site.

There will also be displays and information from several Superior organizations and community groups, including:

- Town of Superior.
- Superior Unified School District.
- Superior Chamber of Commerce.
- Superior Historical Society.

The event is a great opportunity to learn about what's new in the community with several different organizations.

The Open House will be an informal event without a set presentation, so feel free to come in anytime between 5 and 7 p.m. on October 19. Refreshments will be served.

See you on the 19th!

BHP
SUPERIOR

Figure D-1

Public Workshop #1 Participants

Name	Address	Phone Number
Oscar R. Montano	335 Marion	689-2122
Ron Baush	307 Palo Verde	689-5559
Jake Reaney	1111 W. Highway 60	689-5800
Ray Dion	38815 U.S. Highway 60	689-2846
Chris Zapata	734 Main Superior, AZ 85273	689-2484
Judy Boshoven	2600 V Street Sacramento, CA	916-737-3000
Michael O. Hing	125 N. Pinal	689-2265
Mary Cagaly	214 Lobb Avenue	689-2248
Polly Drakovich	26 N. Magma Avenue	689-5054
Verna Lira	238 W. Sunset	689-5757
Umberto Haro	301 Palo Verde	689-5394
Billy Precado	314 Bridge Street	689-5740
Bob & Yolanda Dapra Ewing	208 Neary Avenue	689-2652
Dan Arnold	Bus 1134 W. Highway 60	689-5900
Sylvie Perez	437 Silver Street	689-5733
JoAnn Besick	217 Smith Drive	689-2176
Eric Mears	3636 N. Central Avenue, #200 Phoenix, AZ	222-4456

* Please note that this list is not all-inclusive, unfortunately not all participants signed in on the meeting sign-in sheet.

Queen Creek Restoration & Management Plan Status

Task 1 - Community Input & Feedback

- 1st Workshop - Oct. 19th
- 2nd Workshop - Spring of 1999

Task 2 - Access Agreements for Project Studies

- Ownership identified
- Letters sent to property owners

Task 3 - Project Methodology

- Description of Methodology approved by ADWR on Sept. 1, 1998

Task 4 - Inventory & Assessment of Options

- Base map & inventory underway

Task 5 - Riparian Water Supply & Flood Studies

- Water supply and flood conveyance studies underway

Task 6 - Restoration & Management Guidelines

- Scheduled to be complete in April of 1999

Task 7 - Operations & Maintenance Strategies

- Scheduled to be complete in May of 1999

Task 8 - Monitoring Plan

- Scheduled to be complete in July of 1999

Task 9 - Final Plan

- Scheduled to be complete in August of 1999

Figure D-3

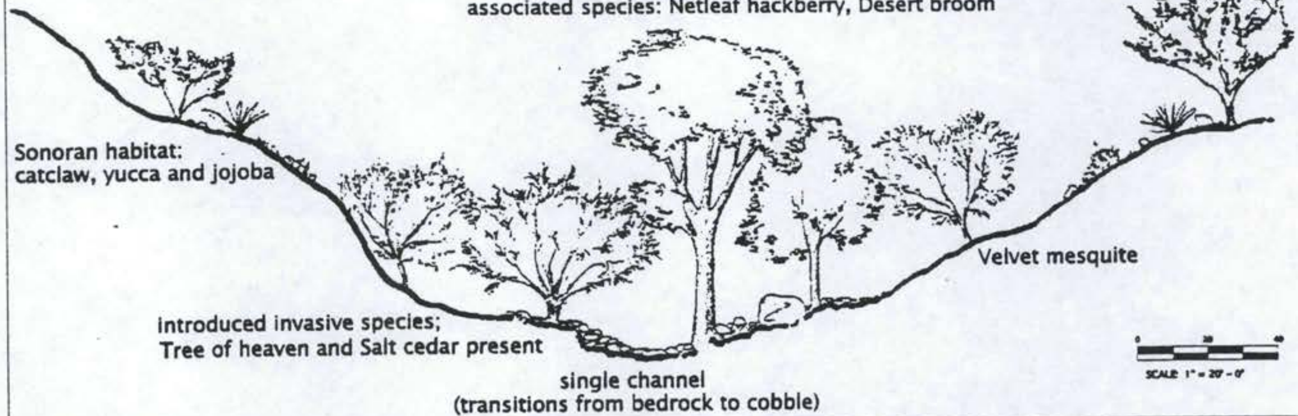
Jones & Stokes Associates
4350 E. Camelback Rd. Suite B-175
Phoenix, AZ 85018

Queen Creek Representative Cross-Sections

Reaches 1-4

intermittent flow

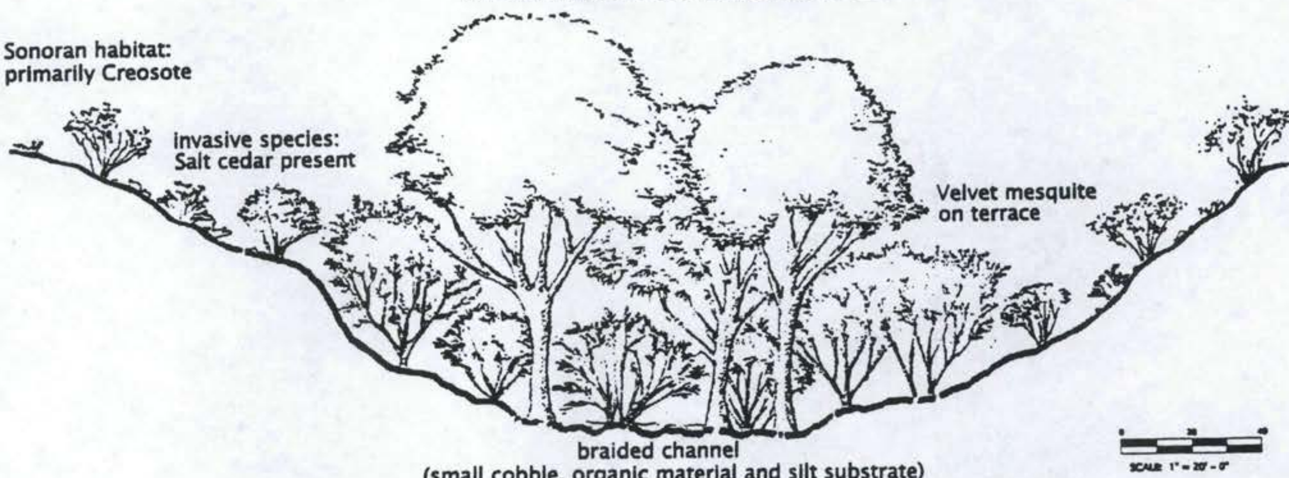
characterized by Velvet mesquite with a few riparian canopy species
such as Fremont cottonwood or Velvet ash
associated species: Netleaf hackberry, Desert broom



Reach 5 WWTP to Old Pinal Townsite

perennial flow

characterized by Fremont cottonwood with Goodding's willow
associated species: Seepwillow, Velvet ash



Reach 5 Old Pinal Townsite to BTA

perennial flow

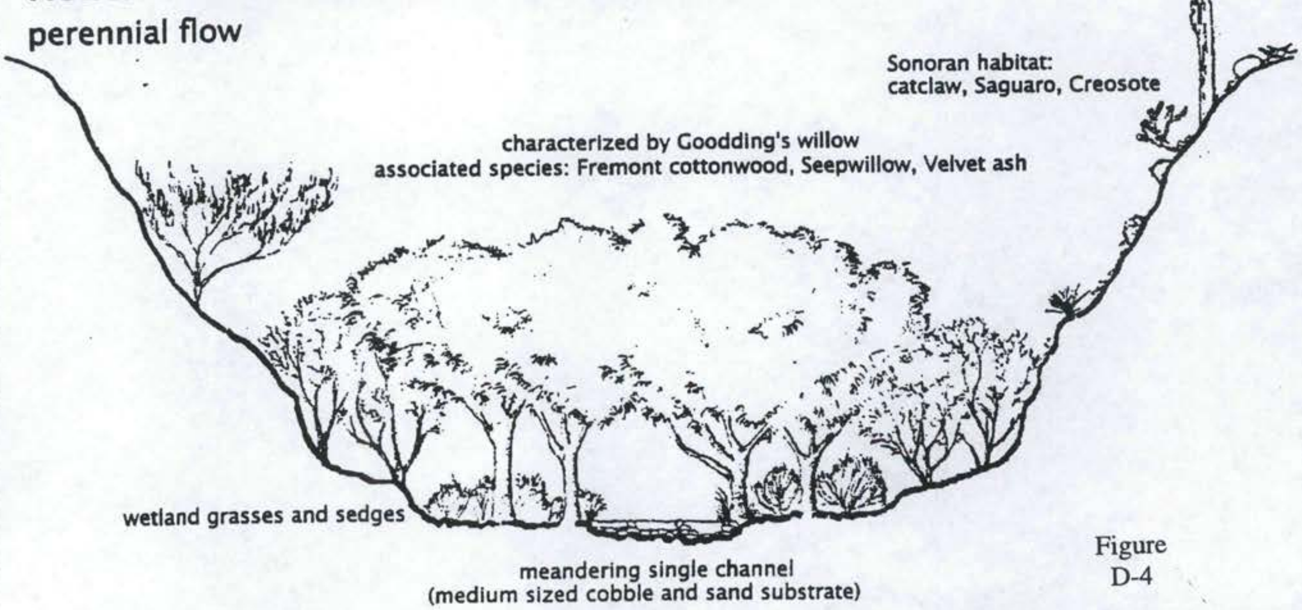


Figure
D-4

The following is a summary of the primary comments received from open-house attendees during the workshop.

- Nearly all participants support the concept of restoring the creek and riparian vegetation to increase habitat value and attractiveness to residents and visitors.

- Accounts from long-time (50-60 years) residents of Superior are that Queen Creek historically flowed more often, nearly continuously through the rainy season. Their perception is that mining development has adversely affected water flows in the creek through the downtown reach, possibly from disrupting the watershed-capturing flows from the creek.

- Preliminary vegetation maps presented at the workshop indicated locations of exotic-plant populations, including tree of heaven, tamarisk, and giant reed. Several landowners at the workshop identified exotic-plant populations located on their properties and inquired about methods to control them.

- The manager from the Boyce Thompson Arboretum mentioned that he has coordinated youth groups (i.e., Boy Scouts) to remove giant reed along the creek within the arboretum. He suggested that these projects be expanded to include sites within the plan area upstream of the arboretum. In addition, Boyce Thompson Arboretum has equipment (e.g., chipper) that could be used for these projects.

- Ideas were discussed to potentially redistribute water in the creek, including piping municipal waste water-treatment plant discharge to an upstream location on the creek, or using dewatering water from the BHP mines. Attendees expressed concerns regarding infrastructure and maintenance costs involved in piping and pumping water to implement these ideas.

- A residential development has been approved in the vicinity of the cemetery in south Superior. This development could result in an increase in the outflow of treated water from the WWTP that may potentially be used for riparian restoration on Queen Creek.

- Water quality of the various water sources feeding the creek may affect existing vegetation and the success of restoration efforts along the creek. Attendees expressed concern that the water quality of outflow into the creek from the BHP mines could be an issue.

- The ADOT has apparently proposed a four-lane highway to Globe, which currently is routed around Superior but is affecting the canyon area at the northeast end of town. Rubble from some engineering exploration work was recently placed in this section of the creek. ADOT is in the very preliminary stages of planning this highway, and it may still be routed through Superior.

- BHP presented conceptual mine-closure alternatives for land reuse and mitigation on their properties. The current area to be reclaimed is 600 acres; 200 acres of this area are currently tailings and 400acres are disturbed land. The total BHP property area is 1,400 acres, including the east mine site. Reuse and mitigation plans involve preparing the properties for public, open-space uses. If further development is proposed, further mitigation would be required by the new property owner. The reclamation activities to prepare the site for open-space uses would start, at the very earliest, 18 months after BHP's expected submission date for the reclamation plan of December 1998.

- Residents expressed dissatisfaction with past riparian-removal practices, which apparently were performed about 10 years ago by the Corps, because they removed overstory cottonwoods and increased growth of shrubs and herbaceous weeds.

- Participants identified groundwater in the purolyte mine, west of town and east of the arboretum, as a potential surface-water source.

PUBLIC WORKSHOP #2, AUGUST 11, 1999

Meeting Announcements and Materials

Announcements for the second public workshop included an advertisement (Figure D-5) and front-page article (Figure D-6) in the Superior Sun the week before the meeting. The meeting agenda is shown in Figure D-7, and the sign-in list is shown in Figure D-8. The principal visual aid used during discussions at the meeting was a poster-sized map of the locations of proposed actions, which is included in the main body of the plan as Figure 5-1.

Queen Creek Restoration Advisory Committee

Chris Zapata; Town of Superior Manager
Cosme Real; Town of Superior WWTP Operator
Roy Chavez; Town of Superior Mayor
Eric Mears; Superior Project Manager, Brown & Caldwell
Dave Lira; Environmental Coordinator, BHP Copper Superior Operations
Bill Gray; Environmental Affairs Manager, BHP Copper
Ray Dion; Park Manager, Boyce Thompson Arboretum
Pete Petrie; Assistant Manager, Boyce Thompson Arboretum
Janet Johnson; Riparian Ecologist, Tonto National Forest
Connie Lane; Globe Ranger District, Tonto National Forest
Larry Widner; Globe Ranger District, Tonto National Forest
Gerri Miceli; Project Manager, Arizona Water Protection Fund, ADWR
Lynn Heglie; Superior Town of Commerce
Rita Wentzel; Superior Historical Society
Joe Clark; Superior resident
Gus Yates; Hydrologist, Jones & Stokes
Ruthanne Henry; Habitat Restoration Specialist, Jones & Stokes
Yolanda Ewing; Town of Superior Council Member

Figure
D-4A

Full circle ...

When President John F. Kennedy was shot Nov. 22, 1963, someone saved three metropolitan newspapers carrying the story. At some point, the papers, *The Phoenix Gazette-Extra*, *The Arizona Daily Star*, and *The Arizona Republic*, found their way beneath the cushions of a sofa. This is where, shortly after the July, 1999, airplane accident that claimed the life of Kennedy's son, John F. Kennedy Jr., Town of Superior Street Department employee Fred Murrieta found them when he picked up the couch for disposal in the town dumpster. Murrieta is also the town's animal control officer.

In another coincidence, Rev. Dennis Van Gorp, pastor of Superior Assembly of God Church, heard about the papers and realized he was in one of them. Van Gorp, who is chaplain for the Superior Police Department and chairman of the Superior Planning and Zoning Commission, appears on page 21 of the *Republic*. The photo by Ralph Campine shows Van Gorp's eighth-grade class praying after the Kennedy assassination.

Photo by Cindy Tracy

Superior Sun, August 4, 1999

PUBLIC MEETING

on Queen Creek Restoration and Management Plan

Superior Town Hall

Wednesday, August 11, at 6 pm

Jones & Stokes Associates will describe habitat restoration and recreation enhancements for possible inclusion in the draft plan.

Town leaders are seeking your input and recommendations.

Funded by Arizona Water Protection Fund

Figure
D-5

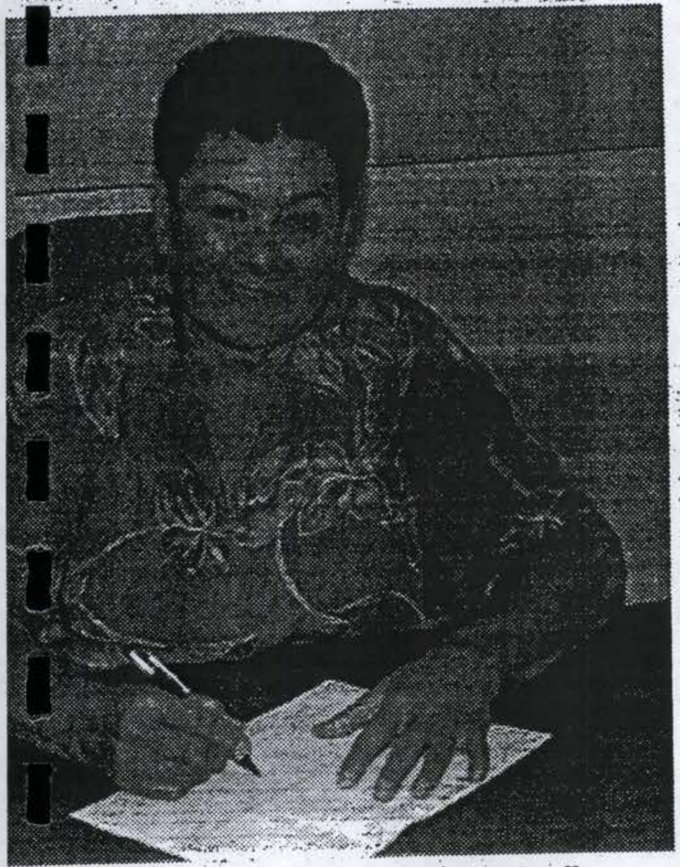
Sun

9

izona 85273

35¢

dership change



: l ks forward to fishing and time with family
m the directorship of the Superior Senior
, she hopes to volunteer in the center's Thrift Shop
n s Site Council.

said.
sted in children in an-
o he'd like to teach
an is considering ways
fterschool program or
class.
1 u 24 years of service

at the Senior Center? "I don't know," she said, "to me, this is the peak of my happiness—working here."

For Ramon, Tellez' retirement means more time with his wife, starting with that relaxing fishing trip. "After 50 years, we get along real good," he said. "We have a good life."

Carolyn Gronland, a program par-

Getting back to nature, getting nature back ...

QC project blends recreation, restoration

Birds and wildlife might not be the only critters that return to Queen Creek if recently prepared restoration concepts are carried out. There could be a habitat for hikers, cyclists and nature lovers, too!

A two-year planning effort to restore natural habitat and provide recreational opportunities along Queen Creek near Superior is nearing completion. The public is encouraged to attend a 6 p.m. meeting on the project August 11 in council chambers at Superior Town Hall. Attendees will hear a description of the draft restoration plan and provide input and feedback for the plan developers.

Superior Town Manager Chris Zapata initiated the creek restoration planning effort with assistance from the environmental planning firm of Jones & Stokes Associates. Together, they successfully obtained a $207,000 grant from the Arizona Water Protection Fund to investigate the feasibility of restoring flow and riparian habitat along the creek. The plan goes beyond the restoration objectives to include recommendations for recreational development compatible with the habitat.

"Recreational facilities such as trails and creekside paths will fulfill a long-standing desire of Superior residents and also make the town more attractive to visitors," Zapata said.

Jones & Stokes has completed in-depth inventories and technical analyses related to present and historical hydrology, vegetation and wildlife. Preliminary results of some of these studies were presented at a public meeting last October. Additional studies and development of specific recommendations for restoration and recreational development have been completed since then.

"The existing vegetation shows signs of drought stress from depleted stream flows," said Ruthanne Henry, from Jones & Stokes' Phoenix office. She said several long-time local residents have stated that the creek used to flow all year long.

Preliminary studies and planning have been carried out under the oversight of a local advisory committee that includes city staff and representatives from BHP Copper, Boyce Thompson Arboretum, Tonto National Forest, the local chamber of commerce and historical society, and others.

The 16 implementation actions recommended in the plan include several options for increasing the amount and duration of flow along selected reaches plus actions for controlling the invasion of non-native vegetation, maintaining floodway capacity, removing litter, landscaping two existing parks to feature natural riparian vegetation and possible even constructing a small lake on the floodplain just below the U.S. 60 bridge. A sequence of trails extending from the canyon above town to the lake and perhaps as far as the high school would link the parks and restored areas.

"The plan is an important step in shaping the future of Superior," Zapata said. He urged local residents to attend the public meeting and help mold the plan to fit their vision of Superior in the next century.

Superior Sun, August 4, 1999

Figure D-6

...s forward to fishing and time with family ...of the directorship of the Superior Senior ...he hopes to volunteer in the center's Thrift Shop ...ts Site Council.

d. ...d in children in an- She'd like to teach ...l is considering ways ...school program or ...ass. ...24 years of service

working at the ...e thrift store.

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For Ramon, Tellez' retirement means more time with his wife, starting with that relaxing fishing trip. "After 50 years, we get along real good," he said. "We have a good life."

Carolyn Gronland, a program participant, volunteer and Site Council treasurer, said Ramon Tellez' contribution at the Senior Center almost equals Becky's. She said Ramon has volunteered his time and labor to the program since his own 1987 retirement. And, of Becky Tellez, Gronland said: "I tell you, she's done a wonderful job."

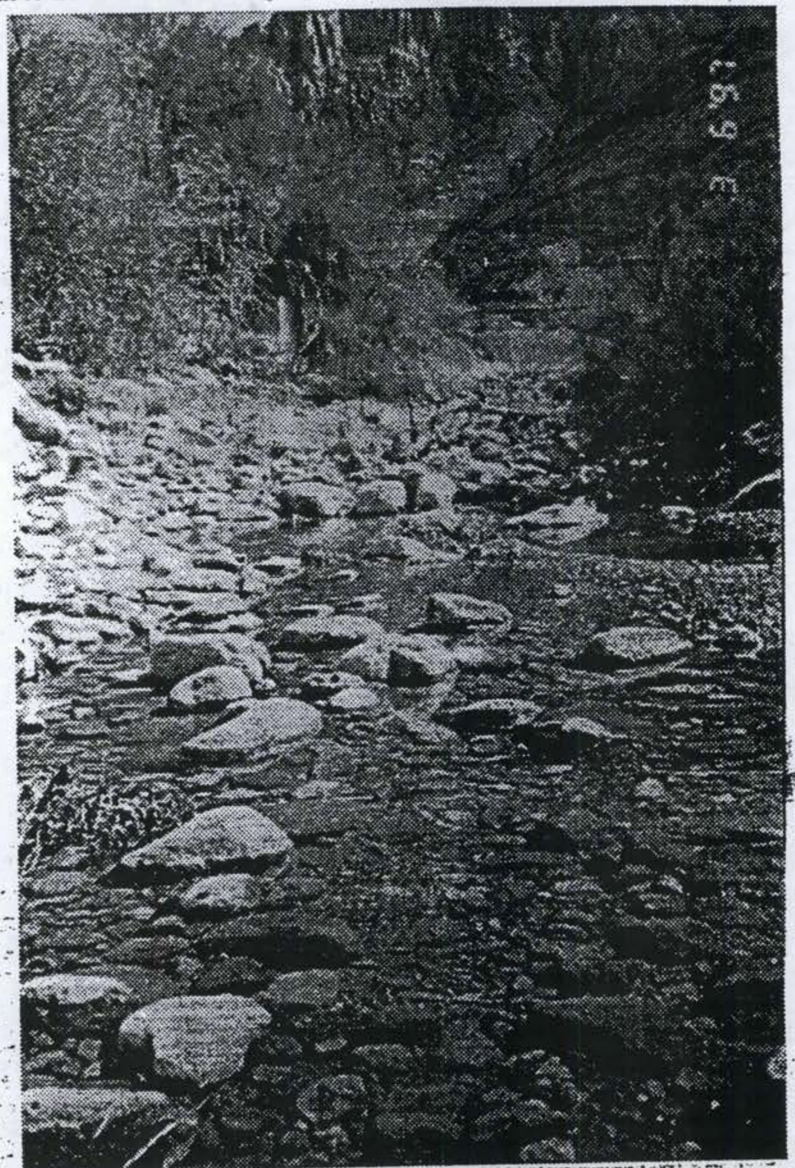
Gronland said she's "hoping and praying" for the continued success of the senior program. She said she started coming to the center with mother, who has since died. After that, she came back for herself.

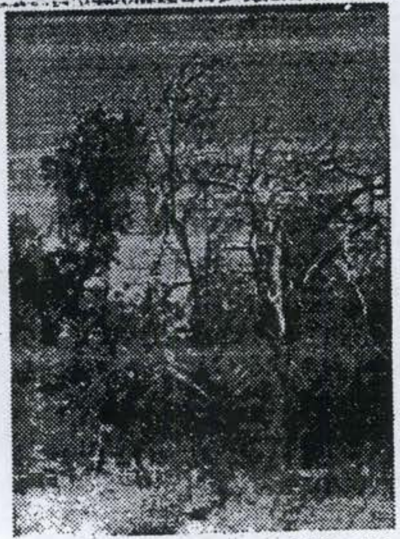
Another center regular, Gordon Tibben, said he was sorry Tellez was leaving. "But I'm also very glad for her and Ramon, that they can enjoy 'life after work' and I wish her and Ramon the very best. She'll be missed by all of us." He said he's appreciated the way Tellez has run the center. "That's been very important to me."

Enjoying a hand of cards by the center's front window, Corina Martinez said she hoped Tellez would enjoy her retirement, while staff member Esther Ulibarri said of Tellez: "I learned a lot from her."

The Superior Senior Center, is open to all people age 60 or older or whose spouse is 60 years or older and invites them to visit. Hot meals are cooked and served once a day and regular activities are scheduled. Coffee is on all day. Meal reservations must be made one day in advance. The number to call is 689-5182.

"The plan is an important step in shaping the future of Superior," Zapata said. He urged local residents to attend the public meeting and help mold the plan to fit their vision of Superior in the next century.





By attending an August 11 meeting at Town Hall, citizens can contribute their input to a plan to restore the natural beauty of the land along Queen Creek near Superior. The project proposal also features trails for recreation and relaxation amid the wonders of this area's native vegetation. The meeting begins at 6 p.m. in council chambers.

Courtesy photos

*spots***

...f U.S. 60. Emission ...on ADEQ's notice in- ...ns of particulate mat- ...ides, carbon monox- ...ioxide." The meeting ...n. at Town Hall. Ob- ...comments may be ...istrict at P.O. Box 987, ... 85232. Questions?

community outreach, acting as a liaison between consumers, mental health providers and the community. He will also attend all board meetings, which are open to the public. For more information on Member Advocate activities, call Huff at (800) 982-1317. For general information on the Pinal Gila Behavioral Health

families to other sources of private insurance coverage or to AHCCCS. Pinal County Division of Public Health was awarded a grant from the Flinn Foundation to help increase insurance coverage for county residents.

To make an appointment for Superior, call Elvia (520) 487-2110. For ...

Weather

DATE	HIGH	LOW	PR.
July 27	101	76	
July 28	97	70	.14
July 29	93	71	

Figure D-6 (Continued)

QUEEN CREEK RESTORATION AND MANAGEMENT PLAN

Public Meeting

Wednesday, August 11, 1999

6:00 p.m.

Superior Town Hall

AGENDA

6:00	Welcome and introductions
6:10	Presentation of restoration and management actions proposed for inclusion in the plan
6:40	Open discussion of proposed actions
8:25	Summary
8:30	Adjourn

Figure D-7

Queen Creek Restoration Plan 08/11/99
Public Mtng.

Name	Address	Phone
Sylvia Perez	437 Silva St	689-5233
Larry O. Diaz	989 "B" CENTER	689-5063
Lynn Hughes	98 Pinal	689-0193
Kristine Gonzales	630 Sonora	N/A
Victor D. Gonzales	630 Sonora	N/A
JOE CLARK	230 TERRACE	689-2220
MARGUERITE CLARK	"	"
April Noriega	275 B. Main St.	
* James Bank	275 B MAIN ST	
J. M. "PETE" PETRIE	BTA, HWY 60	689-2723, 9762
Richard E. Breen	P.O.Bx 623 Superior	689-2820
Chris Zapata	734 Main Street	689-2484
Irene Stevens	586 W Porphyry	689-5612
ROB Ewing	209 Neary	
Yolanda N. Ewing	"	

Post-it® Fax Note 7671	Date / # of pages
To Gus Yates	From Ruthanne Henry
Co./Dept.	Co.
Phone #	Phone #
Fax #	Fax #

MEETING

Facilitators for this meeting included Gus Yates and Ruthanne Henry of Jones & Stokes Associates. Attendees included Sylvia Perez, Mr. Diaz, Lynn Heglie, Kristine Gomales, Victor Gomales, Joe Clark, Marguerite Clark, April Noriega, James Banks, J. M. "Pete" Petrie, Richard Green, Chris Zapata, Irene Stevens, Bob Ewing, and Yolanda Ewing

As an introduction, Yates and Henry presented a brief history of the project, recapping the original objectives envisioned by Chris Zapata of recreational amenities along Queen Creek, aesthetic enhancement of the creek corridor, and increased downtown revitalization. The primary presentation graphic used at the meeting was an enlargement of Figure 5-1 from the draft plan, which shows the locations of proposed actions. Jones & Stokes Associates successfully helped the town to obtain a grant from the AWPF. As a reflection of AWPF's emphasis on restoration of natural habitats, the early phases of the project focused on inventorying plant and animal species present within the Creek corridor and assessing hydrological conditions. Based on the understanding of the natural system gained from these studies, Jones & Stokes Associates and the project's advisory committee developed 17 individual actions that would help meet the riparian-restoration and recreational-development goals of the plan.

Yates and Henry briefly described the 17 proposed action items. Six of them involve flow modifications that utilize reclaimed water, mine-dewatering water, groundwater, or stormwater to supplement base flow in selected reaches of the creek. The 11 remaining actions address vegetation-management issues, park and trail development, and creek protection.

The remainder of the meeting was devoted to questions, comments, and discussion. There were several questions related to water quality and quantity from the mine. Cost was also a concern of several commenters. Yates, a hydrologist, described the quality issues related to the various potential sources of water and also addressed the relative cost effectiveness of the flow modification actions. Most of the funding for implementation of the proposed actions is projected to come from grant sources, with Superior to be responsible for future operations and maintenance costs.

Several residents offered constructive suggestions for improving the plan and increasing its chances of success. Irene Stevens, a school teacher who recently returned to Superior, was very interested in the long-term development of the plan and integrating it into a creek-awareness program for high school students and other activities for younger children. Joe Clark suggested an "Adopt a Reach" approach to keeping the creek clean. Pete Petrie suggested contacting the regional Boy Scout Council to request help with controlling exotic vegetation along the creek corridor. One group of Scouts has helped the arboretum several times in the past. In general, however, success in obtaining the assistance of an individual troop seemed to depend on whether it has had past positive experiences with this type of activity. Yolanda Ewing suggested limiting Action 17 (the trail extension to the high school) to the segment between the lake and Mary Drive. Mary Drive provides a safe bicycle connection for the rest of the way to the high school.

Other comments dealt with the recent flood activity. Kristine and Victor Gomales, who live close to Creek, said that the flow, 1.75 inches in 1 hour, was the biggest in the creek in several years.

Pete Petrie mentioned that a $65,000 bridge at the Arboretum was destroyed by the flows of last week. Richard Greene videotaped the flow shortly after the highest flows. Boulders knocking against each other could be heard on the tape.

There were several comments related to the park concepts. Some residents were concerned that the parks would flood in a rain event, and April Noriega suggested roadside parking would not be adequate during rain events at the Stone Avenue Park. Sylvia Perez cited the example of the Indian Bend Wash park system in Scottsdale, where the parks flood during storm events and are usable at all other times. Chris Zapata mentioned the original concept for the Community Park was to have a large gathering area with an amphitheater at the southwest end of the park. Victor Gomales suggested demolishing the large vacant building at the east edge of the Stone Avenue Park to expand the length of the park, supported the concept for habitat gardens with small water features in the Stone Avenue Park. Mr. Diaz commented that restoration and parks were a low priority, and that Superior had greater need for a doctor available 24 hours a day and a rest home.

Comments on the trails were that those in the Old Town area should be joggable. Bob and Yolanda Ewing noted that the canyon trail road needs surfacing because joggers have injured themselves on the uneven pavement. Bob Ewing also brought up a wildlife concern regarding jogging the Creek trail, namely that 30-40 Javalinas live in the corridor and can frighten joggers. Others confirmed this observation.

The proposed campground and trail for Old Pinal Townsite were discussed. Pete Petrie and Yolanda Ewing noted concern regarding the current access to the area. It was suggested to move the turnoff away from the dangerous curve where it occurs on Highway 60 and connect further down the road. Restoration efforts done by the Boyce Thompson Arboretum have demonstrated that cottonwood–willow communities establish on their own when tamarisk competition is controlled or eliminated. Pete Petrie also mentioned that other exotics are found on their property, including Chinese pistachio, African sumac, and Chinese date palm.

In general, everyone seemed very supportive and enthusiastic about the proposed non-flow dependant action items. There was some discussion about the most efficient way to proceed with the flow-dependent action items. Most in attendance seemed supportive of pursuing the Neversweat Mine source of water and creating a small lake feature. Sylvia Perez mentioned the origin of the name was that a draft entering the mine tunnel reduced sweat on the miners, and the Neversweat tunnel is 500 feet down. Victor and Kristine Gomales mentioned an alternate source of water for the creek by tapping into the springs located in the canyon. This source was considered earlier, and after research and discussion with old timers about the location it was considered not a feasible restoration action.

Appendix E. Revegetation Plan for Stone Avenue and Community Parks

Three of the proposed actions described in Chapter 5 would involve active planting of natural vegetation. Actions 5 and 12 would restore native vegetation along Queen Creek at Stone Avenue Park and Superior Community Park. Action 6 would create an artificial lake with a lakeshore fringe of riparian vegetation on the Queen Creek floodplain below the Highway 60 bridge. The conceptual revegetation plan outlined below will be further refined by Town of Superior staff and consultants prior to applying for implementation funding.

ACTION 6: REVEGETATION AROUND CONSTRUCTED STORMWATER LAKE

Species Selection

Action 6 revegetation would consist primarily of riparian tree species planted along the edge of the proposed high water mark of the lake. Species would be determined by depth to groundwater, samples of soil moisture at different depths, soil texture analysis, salinity levels measured in the soil profile, and anticipated fluctuations in lake level. Based on lake modeling, it is expected that the shoreline will recede vertically approximately 3 feet and horizontally as much as 10 feet. The species expected for planting along the edge are *Populus fremontii, Salix gooddingii, Fraxinus velutina*, and *Platanus wrightii*. Desert upland species such as *Lycium pallidum, Simmondsia chinensis,* and *Atriplex spp.* would be planted on the outer slopes of the berm that would be constructed to impound the northern and western sides of the lake.

Planting and Seeding Methods

For establishment of the riparian trees, applicable steps from Bertin Anderson's Nine Step Plan methods will be used, including (1) preliminary soil analysis to ensure suitable conditions for planting, (2) vertical augering, (and soil sampling as indicated above to determine species selection), (3) installation of a temporary drip irrigation system, (4) planting with fertilizer and mycorrhiza packets, (5) monitoring growth rates, and (6) removing the irrigation system after successful establishment. After the plant pallette had been selected, riparian seedlings will be contract grown by Mountain States Wholesale Nursery from local seed or cuttings. *Fraxinus velutina*, *Prosopis spp*., and *Platanus wrightii* will be grown from seed while *Salix spp.* and *Populus fremontii* will be grown from cuttings. Planting will be done by trained volunteers, contacted from public open house attendance lists or through high school science classes.

For the establishment of the Sonoran shrub species, seeding will take place prior to the winter rain season, with spray hoses laid out at frequent intervals in case of critical drought. Seed will be obtained through Wild Seed of Tempe, Arizona. Wild Seed will be notified that local seed is required. Seed dispersal will be done by Town of Superior maintenance staff. Once the seed has germinated, irrigation will be set up to provide supplementary water until plants are fully established. Engineering of the berm has not been resolved at this stage, but irrigation suitable for dimensions of the berm will be used. This will be a temporary above-ground drip system if possible, or a temporary spray system if uniform distribution of plants covers a significant area. Temporary irrigation will be removed from the site when no longer necessary (estimated tooccur after 2 growing seasons). Lake maintenance staff will be responsible for maintaining irrigation equipment and controlling invasive exotic species until the planted shrubs and riparian trees are firmly established.

Planting schedules and detailed plant and irrigation system layout schematics will be completed and included in applications for grant funding to support the restoration effort. Also, soil analyses following completion of lake construction may require minor adjustments to the revegetation plan.

Long term monitoring could be coordinated with the high school science curriculum. Irene Stevens, a new teacher at Superior High School, has expressed keen interest in potential future connections between with the restoration efforts and the school curriculum. If monitoring was pursued for inclusion in the high school curriculum, students would need training in proper monitoring techniques with a survey protocol developed by trained revegetation monitoring professionals. Professionally supervised monitoring of the site revegetation for at least the first 5 years should be a priority for inclusion in any funding applications for implementation of Action 6. If grant funding is not obtained for revegetation monitoring, this should be made a priority for the Town of Superior in allocating funds for this action.

ACTIONS 5 AND 12: RESTORATION OF RIPARIAN VEGETATION AT STONE AVENUE AND COMMUNITY PARKS

Species Selection

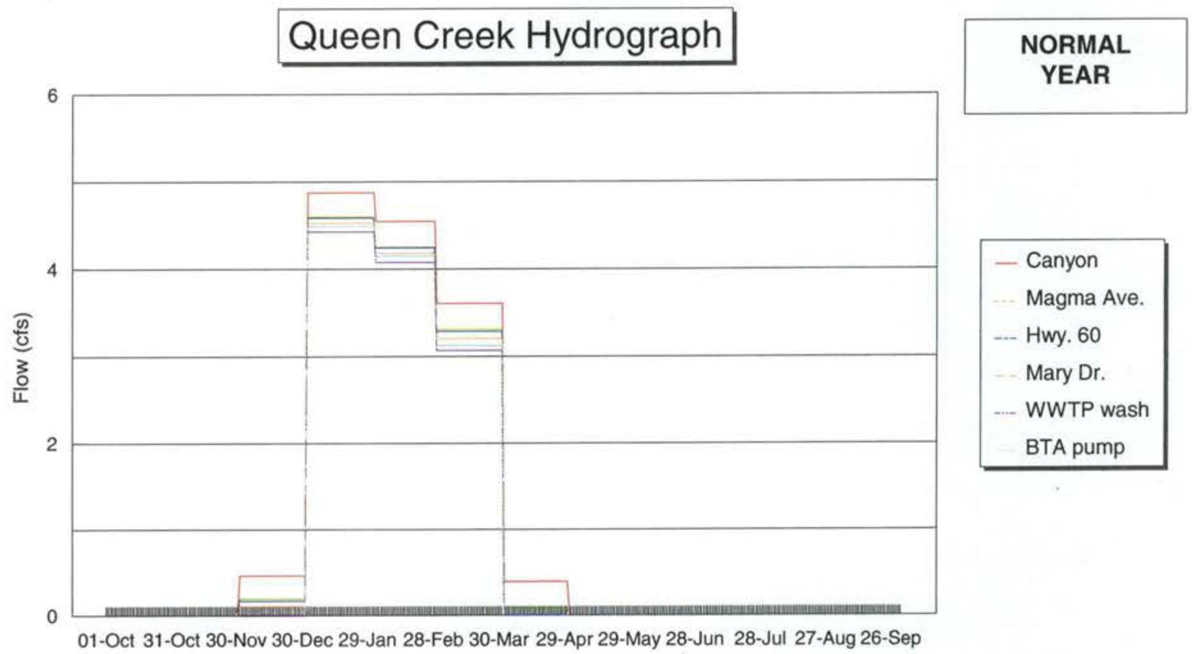
Revegetation for Actions 5 and 12 would consist primarily of planting riparian tree species near the edge of the low-flow channel of Queen Creek. Planting could extend as much as 400 feet from the channel at Community Park, assuming preliminary indications of suitable soil texture and groundwater depth are confirmed upon sampling. The types and locations of existing trees—including two cottonwoods planted 200 feet from the channel at Community Park—suggest that riparian vegetation would be successful at the proposed planting locations. Figures 5-16 and 5-17 (see Chapter 5) present schematic landscape plans for the two parks. Species suggested for planting are *Fraxinus velutina*, *Platanus wrightii*, *Prosopis velutina*, and *Populus fremontii*. However, a more complete analysis of soil and hydrologic conditions will be completed prior to finalizing the particular locations recommended for each of these species. The analyses will include profiles of soil texture, moisture, and salinity; and an estimate of seasonal groundwater levels expected pursuant to separate actions that would augment streamflow in Queen Creek.

Planting and Seeding Methods

For establishment of the riparian trees, applicable steps from Bertin Anderson's Nine Step Plan methods will be used, including (1) preliminary soil analysis to ensure suitable conditions for planting, (2) vertical augering and soil sampling to determine suitable species, (3) installation of a temporary drip irrigation system, (4) planting with fertilizer and mycorrhiza packets, (5) monitoring growth rates, and (6) removing the irrigation system after successful establishment. After the plant pallette had been selected, riparian seedlings will be contract grown by Mountain States Wholesale Nursery from local seed or cuttings. *Prosopis spp.* and *Platanus wrightii* will be grown from seed, while *Salix spp.* and *Populus fremontii* will be grown from cuttings. Planting will be done by trained volunteers, contacted from public open house attendance lists or through high school science classes.

Planting schedules and detailed plant and irrigation system layout schematics will be completed and included in applications for grant funding to support the restoration effort. The details will be affected by the results of the soil and groundwater analysis.

Long term monitoring could be coordinated with the high school science curriculum. Irene Stevens, a new teacher at Superior High School, has expressed keen interest in potential future connections between with the restoration efforts and school curriculum. If monitoring was pursued for inclusion in the high school curriculum, students would need training in proper monitoring techniques with a survey protocol developed by trained revegetation monitoring professionals. Professionally supervised monitoring of the site revegetation for at least the first 5 years should be a priority for inclusion in any funding applications for implementation of Actions 5 and 12. If grant funding is not obtained for revegetation monitoring, this should be made a priority for the Town of Superior in allocating funds for this action.



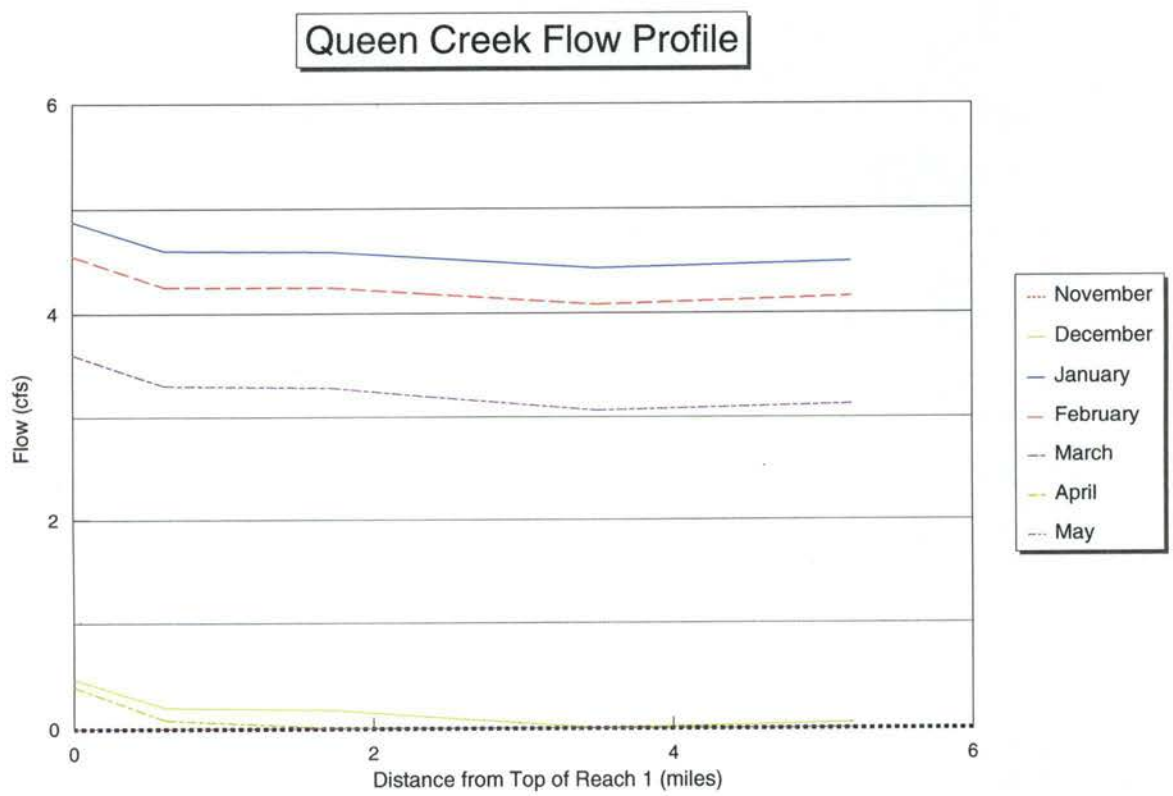


Figure B-15A. Simulated Average Monthly Flows in Queen Creek under Existing Conditions (Normal Year)