USE ATTAINABILITY ANALYSIS FOR NEW ALAMO CREEK AND ULATIS CREEK

Technical Memorandum No. 1

Hydrologic and Physical Characteristics of Alamo Creek, Ulatis Creek, and Cache Slough

Prepared for:

CITY OF VACAVILLE

Prepared by:

ROBERTSON - BRYAN, INC.
Specializing in Water and Power Resources

AUGUST 2007

USE ATTAINABILITY ANALYSIS FOR
NEW ALAMO CREEK AND ULATIS CREEK

Technical Memorandum No. 1

Hydrologic and Physical Characteristics of Alamo Creek, Ulatis Creek, and Cache Slough

Prepared for:

CITY OF VACAVILLE
650 Merchant Street
Vacaville, CA 95688

Prepared by:

ROBERTSON - BRYAN, INC.
Specializing in Water and Power Resources
9888 Kent Street
Elk Grove, CA 95624
(916) 714-1801

AUGUST 2007

TABLE OF CONTENTS

Section Page

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

TABLE OF CONTENTS

Section Page

TABLE OF CONTENTS

Section Page

APPENDICES

TABLE OF CONTENTS

ACRONYMS AND ABBREVIATIONS

cfs	cubic feet per second
Delta	Sacramento-San Joaquin Delta
ft	feet, foot
MPWD	Maine Prairie Water District
msl	mean sea level
MUN	municipal and domestic supply
NCDC	National Climatic Data Center
SCWA	Solano County Water Agency
SID	Solano Irrigation District
SWRCB	State Water Resources Control Board
UAA	Use Attainability Analysis
WWTP	wastewater treatment plant

1 INTRODUCTION

1.1 Background

A Use Attainability Analysis (UAA) is being conducted for portions of New Alamo Creek and Ulatis Creek to assess whether the municipal and domestic water supply (MUN) beneficial use is an existing or attainable use within specified segments of these water bodies. The segments being evaluated are:

- New Alamo Creek from Old Alamo Creek to Ulatis Creek, and
- Ulatis Creek from New Alamo Creek to Cache Slough.

Hydrologic and physical data, including precipitation and streamflow data, watershed land uses and channel characteristics, have been compiled for these water bodies, as part of the UAA.

1.2 Purpose of Technical Memorandum

The purpose of this Technical Memorandum is to present the hydrologic and physical characteristics of the water bodies being evaluated in the UAA. Specifically, this Technical Memorandum:

- describes the watershed land uses and physical channel characteristics of the UAA study segments, and
- presents data characterizing the hydrologic regime of the watershed and particularly the segments within the UAA study area.

This Technical Memorandum is the first in a series of Technical Memoranda prepared in support of the UAA.

1.3 Organization of Technical Memorandum

Section 2 presents a summary of the findings. Section 3 provides further information on the physical characteristics of the study area segments, with supporting data characterizing the watershed land uses and channel characteristics. Section 4 presents the hydrologic data, with supporting graphs, illustrating the streamflow characteristics during precipitation and irrigation seasons. Section 4 also quantifies the land use areas that contribute flows to the UAA study area.

2 SUMMARY OF FINDINGS

2.1 Physical Characteristics

The following are the major findings from the review of the physical characteristics of Alamo Creek, New Alamo Creek, Ulatis Creek, and Cache Slough:

1. The upper reaches of Alamo and Ulatis creeks are characterized by steep gradients and primarily natural (forested) land uses.

2. The lower reaches of Alamo/New Alamo and Ulatis creeks are characterized by low gradients in engineered, trapezoidal channels with primarily urban and agricultural uses on surrounding land. New Alamo Creek is an engineered channel designed and constructed to collect and convey stormwater runoff from surrounding agricultural and urban lands, and runoff from the upper watershed, which flows into it from Alamo Creek. Upon its construction, it also conveyed Easterly Wastewater Treatment Plant (WWTP) effluent, which began discharging effluent in 1959. It also is used to convey agricultural conveyance and tail water (i.e., irrigated field drainage water) throughout the irrigation season. During the non-irrigation season, but prior to the start of the winter precipitation season, New Alamo Creek primarily conveys Easterly WWTP effluent and urban runoff. A portion of Ulatis Creek has been diverted into an engineered drainage channel, and lower Ulatis Creek has been extensively realigned and channelized to increase its flow capacity.

3. The transition between Ulatis Creek and Cache Slough is characterized by a widening channel, increasing from approximately 100 feet to more than 1,000 feet in Cache Slough. Numerous tributaries enter the slough from the north and east. Cache Slough is a tributary to the Sacramento-San Joaquin Delta (Delta) and is influenced by tidal action.

2.2 Hydrologic Characteristics

The following are the major findings from the review of the hydrologic characteristics of Alamo Creek, New Alamo Creek, Ulatis Creek, and Cache Slough (for comparison, the Easterly WWTP maximum mean daily discharge was 20.5 cubic feet per second [cfs] for water years 1998–2006):

1. Ulatis Creek flows, upstream of New Alamo Creek, exceeded 20 cfs 9–36% of the time in the months of November through April of water years 1998–2006.

2. New Alamo Creek flows, upstream of Old Alamo Creek, exceeded 20 cfs 10-47% of the time in the months of November through April of water years 1998–2006.

3. The ratio of streamflow rate to Easterly WWTP effluent discharge flow rate to was 5:1 (5 parts streamflow to 1 part effluent) or less 80–96% of the time in New Alamo Creek and 10:1 or less 90–99% of the time in Ulatis Creek in the months of November through April of water years 1998–2006.

4. Flows in the lower reaches of New Alamo Creek and Ulatis Creek, outside the precipitation season (e.g., May–October), are generally less than 5 cfs in each creek, with little to no input from the upper reaches beyond the month of June.

5. Flows in the UAA study segments in New Alamo Creek and Ulatis Creek during the irrigation season (April–October) are dominated by agricultural drainage water, irrigation water, and Easterly WWTP effluent, with no input from the upper reaches.

6. The ratio of New Alamo Creek flow rate to Easterly WWTP effluent discharge flow rate during the irrigation season is typically on the order of 2:1 (2 parts streamflow to 1 part effluent) with available streamflow being comprised almost entirely of agricultural drainage water and a small amount of urban runoff.

3 PHYSICAL CHARACTERISTICS

The Ulatis Creek watershed, which includes the Alamo Creek sub-watershed, covers approximately 150 square miles within the northwestern portion of Solano County. From west to east, the watershed is divided by two topographic highs: the Vaca Mountains and the English Hills. The southern portion of the intervening valley is locally named Lagoon Valley, and the northern portion is named Vaca Valley. Most of the watershed is east of the English Hills within the Sacramento Valley floor. Cache Slough, a northern tributary to the Delta, is the eastern outlet for the watershed (**Figure 3-1**). The following sections describe the watershed and channel characteristics for Alamo Creek, New Alamo Creek, Ulatis Creek, and the upper portion of Cache Slough.

3.1 Historical Overview

In March 1961, under the authority of the Watershed Protection and Flood Preservation Act (Public Law 566, as amended), the Ulatis Soil Conservation District, Solano Irrigation District, and Solano County Flood Control and Water Conservation District jointly developed the "*Watershed Work Plan: Ulatis Creek Watershed*" (Ulatis Creek Watershed Work Plan) to reduce flooding of the agricultural properties within the Ulatis Creek watershed (Ulatis Soil Conservation District et al. 1961). As stated in the Ulatis Creek Watershed Work Plan summary, p. 1-1, *"Frequent and damaging floods inundate vast areas of the lower 65,000 acres of the watershed ... The works of improvement proposed in the work plan would reduce significant flooding to a once in ten-year event."* The improvement works identified in the Ulatis Creek Watershed Work Plan consist of: 1) land treatment measures (e.g., conservation cropping system, proper range use, pasture plantings) and 2) structural measures. The structural measures included, *"...improvement or realignment of 51.9 miles of floodwater channels together with the construction of drop and grade stabilization structures and inlet structures to convey local runoff into the channels."* In addition, the Ulatis Creek Watershed Work Plan directed the raising of existing levees and construction of new levees to protect the lands adjacent to Cache Slough. As stated in the Ulatis Creek Watershed Work Plan (p. 1-10), *"A system of flood gates and pumping facilities will also be installed to remove local runoff from behind the levees."* (Ulatis Soil Conservation District et al. 1961) **Figure 3-2**, taken directly from Ulatis Soil Conservation District et al. (1961), identifies the locations of the channel improvements.

In December 1965, a report titled, *"A Survey of Storm Drainage Southeast of Interstate Highway 80, Vacaville"* was prepared by M.C. Yoder Associates, Consulting Engineers for the City of Vacaville (Yoder Associates 1965). This report was prepared to address stormwater runoff from existing and planned urban areas within the watershed. The summary of this report states:

> *"With the advent of urban development in the area between Interstate Highway 80 and Leisure Town Road, it was necessary to develop a long-range plan for drainage improvements to prevent future drainage problems; thereby, allowing the development of a well integrated system capable of serving the urban tributary areas. Some of the land in the study area has been subject to flooding. However, this will be alleviated as soon as the Alamo and Ulatis Creek improvements proposed in the Ulatis Creek Watershed Work Plan is completed."*

The Basis of Storm Drainage Design section of Yoder Associates (1965) states:

> *"Where storm drains discharge to Alamo, Ulatis, or Horse Creek, the terminal elevations of the proposed storm drains were established to permit gravity discharge to the streams after the channel improvements set forth in the Ulatis Creek Watershed Work Plan are completed."*

The Ulatis Creek Watershed Work Plan (p. 2-14, p. 1-1) states, *"Drastic relocations were required in the case of both Alamo and Ulatis Creeks inasmuch as the location of their present channels is on high ground, precluding their effectiveness as flood channels. ... All structural measures included in the plan will be operated and maintained by the Solano County Flood Control and Water Conservation District."*

With regard to Ulatis Creek, the Ulatis Creek Watershed Work Plan (p. 1-10, 2-15) states:

> *"No improvements will be made on the natural channel between Vacaville and a point approximately one-fourth mile above the Cooper School. From this point to Cache Slough, the lower project limit, the channel improvement will be continuous, consisting of the construction of approximately 4.9 miles of new channel and the straightening and enlargement of 9.7 miles of existing channel. Grade stabilization or drop structures will be provided where necessary. ...A reinforced concrete chute will convey the flows from the Rabbit Creek bypass into Ulatis Creek at the upper end of the improved reach."*

The fact that storm drain inlets and bypasses structures were constructed to convey local runoff into the newly constructed channels presented the need to enlarge their conveyance capacity, as cited above. Additionally, the Ulatis Creek Watershed Work Plan states, "*The use of flood detention reservoirs in the foothill area is not effective because of the large local inflow on the valley floor*."

As shown in **Figure 3-3** (taken directly from of Yoder Associates (1965)), a storm drain was planned to convey the runoff from area "EH," west of Leisure Town Road, and from there the drain would extend northward to the new, constructed Ulatis Creek channel alignment (Yoder Associates 1965).

For Alamo Creek, the Ulatis Creek Watershed Work Plan (p. 1-11) states:

> *"The first unit will include an improved channel to convey the flood flows from the upper project area (Davis Street) to an intersection with Ulatis Creek at a point approximately one-half mile to the east of the intersection of the Elmira Road and the Dixon Highway. The improvements on the upper 2.1 miles of this unit consist of clearing of brush and trees an removal of snags from the existing channel. Below this reach a new trapezoidal earthen channel will be constructed."*

This new trapezoidal channel was constructed to more effectively collect and convey stormwater runoff from agricultural and urban lands because the historic Alamo Creek channel (in the area of modification) meandered through higher ground, thereby precluding it from effective doing so. The newly constructed, trapezoidal channel contains three drop structures and flap gates at the confluence of "Old Alamo Creek," which is referred to in the As Built drawings as "Wycoff drain inlet" (see SCFCWCD (1966), p. 005411).

As shown in **Figure 3-4** (taken directly from of Yoder Associates (1965)), storm drains were planned to convey the runoff from area "ES" to a storm drain on the west side of Leisure Town Road that would, in turn, convey the flow south to the new Alamo Creek channel alignment while runoff from area "ET" would drain directly to the new Alamo Creek alignment (Yoder Associates 1965).

Hence, it is clear from Ulatis Soil Conservation District et al. (1961) and Yoder Associates (1965) that what is called "New Alamo Creek" today is an engineered, realigned, constructed channel that serves as an integral component of an overall storm drainage/flood control plan. Likewise, segments of present-day Ulatis Creek were engineered and realigned for the same purpose. **Figure 3-5** summarizes both historic and current Alamo and Ulatis Creek alignments. The base map in Figure 3-5 is a 1953 U.S. Geological Survey topographic map showing historic conditions. Overlaid on this map is the current New Alamo Creek and Ulatis Creek channel alignments. As discussed above and shown in Figure 3-5, both New Alamo Creek and Ulatis Creek have been extensively modified to convey both agricultural and urban storm runoff. Today, the physical characteristics of these channels reflect their origins.

3.2 Alamo / New Alamo Creek

Alamo Creek originates in the Vaca Mountains and flows east-southeast through the city of Vacaville ultimately joining Ulatis Creek on the Sacramento Valley floor. In the early 1960s, the Solano County Flood Control and Water Conservation District and the U.S. Department of Agriculture, Soil Conservation Service built the Ulatis Creek Watershed Protection and Flood Prevention Project (SCFCWCD 1966). Prior to this project, Alamo Creek's natural channel flowed in a southeasterly direction for over 7 miles and tied into Ulatis Creek approximately 1.5 miles from Cache Slough. As part of this federal project, portions of Alamo Creek within the City were channelized and realigned, cutting off flows from the upper watershed to the lower portion of the original channel. The remnant channel is referred to as "Old Alamo Creek."

New Alamo Creek is an engineered channel designed and constructed to collect and convey stormwater runoff from surrounding agricultural and urban lands, and runoff from the upper watershed, which flows into it from Alamo Creek. Upon its construction, it also conveyed Easterly WWTP effluent, which began discharging effluent in 1959. It also is used to convey agricultural conveyance and drainage water throughout the irrigation season. During the non-irrigation season, but prior to the start of the winter precipitation season, New Alamo Creek primarily conveys Easterly WWTP effluent and urban runoff.

Alamo Creek and New Alamo Creek form a contiguous water body from the headwaters in the Vaca Mountains to its confluence with Ulatis Creek; therefore, the following watershed discussion refers to "Alamo/New Alamo Creek." Reach-specific physical characteristics refer to Alamo Creek (the natural portion) or New Alamo Creek (the channelized portion), depending on the portion being discussed.

3.2.1 Watershed Description

Encinosa Creek and Laguna Creek, two primary tributaries to Alamo/New Alamo Creek, originate in the Vaca Mountains at an elevation of approximately 2,000 feet mean sea level (ft msl) and flow east across Lagoon Valley and through a gap in the English Hills before joining Alamo Creek in the Vaca Valley near the western margin of the City (Figure 3-1). After passing through the City, Alamo/New Alamo Creek drops to the Sacramento Valley floor to the southeast. Old Alamo Creek, another tributary to Alamo/New Alamo creeks, flows east and south on the Sacramento Valley floor before joining New Alamo Creek 3 miles upstream of its confluence with Ulatis Creek. **Table 1** summarizes the channel lengths for these waterbodies. Overall, Alamo/New Alamo Creek travels roughly 20 miles before joining Ulatis Creek.

Alamo/New Alamo Creek watershed land uses are primarily urban and agricultural, with forested areas located in the less intensively developed upper parts of the watershed. **Table 2** presents the land use types and relative percentages within the watershed from the headwaters to Ulatis Creek. **Figure 3-6** shows the distribution of land uses and watershed boundaries.

Table 1. Lengths of various reaches in the Alamo/New Alamo Creek watershed.

Segment Reach / Creek	Segment (miles)	Total Length of Alamo/New Alamo Creek[1] (miles)
Headwaters to Lagoon Valley		
Alamo Creek	3.3	3.3
Encinosa Creek	1.6	--
Laguna Creek	2.7	--
Lagoon Valley to City of Vacaville		
Alamo Creek	2.3	5.6
Encinosa Creek	1.6	--
Laguna Creek	1.8	--
City of Vacaville to Flood control project (New Alamo Creek)		
Alamo Creek	5.5	11.1
Flood Control Project to Ulatis Creek		
New Alamo Creek	8.6	19.7

[1] Total length of Alamo/New Alamo Creek from headwaters to downstream boundary of identified segment.

Table 2. Land uses within the Alamo/New Alamo Creek watershed from the headwaters to Ulatis Creek.

Land Use Type	Area (square miles)	Percent Coverage (%)
Urban	8	18
Agriculture	25	57
Natural / Forest	11	25

Source: Multi-Source Land Cover Data; 100-meter resolution (California Department of Forestry & Fire Protection 2002)

3.2.2 Physical Characteristics of Channel

The physical characteristics of Alamo/New Alamo Creeks channel from its headwaters to its confluence with Ulatis Creek are characterized by three distinct types of reaches: 1) mountainous headwater reaches in the upper part of the watershed; 2) medium gradient reaches traversing the urban foothills region; and 3) engineered flood control channels in low-lying agricultural areas on the Sacramento Valley floor. The following sections describe the general channel configurations of the Alamo/New Alamo Creek reaches.

3.2.2.1 Headwaters of Alamo, Laguna, and Encinosa Creeks to Lagoon Valley

This discussion focuses on the Laguna Creek and Encinosa Creek headwater channels, as well as the upper reaches of Alamo Creek. Defined flow starts at an elevation of approximately 2,000 ft msl. The headwater channels have steep gradients on the order of 350 feet of drop per mile and are comprised primarily of well-vegetated step-pools and riffles. The streams are confined to incised channels that have cut into local sandstone and shale formations (**Figure 3-7**).

Artesian wells, agricultural drainage water, and groundwater springs and seeps contribute to base flow in these reaches. Primary land use types consist of natural or forested areas with agriculture (e.g., orchards) and cattle grazing increasing at the lower elevations of the Vaca Mountains and into the Lagoon Valley. Although predominantly rural, urbanization is increasing in these reaches.

3.2.2.2 Alamo, Laguna, and Encinosa Creeks from Lagoon Valley to the City of Vacaville

These reaches include the portions of Laguna, Encinosa, and Alamo creeks that flow through Lagoon Valley and Vaca Valley just west of the City. The stream channels here are characterized as low gradient (on the order of 16 feet of drop per mile) with riffle-run-pool sequences. These reaches have a subdued topography and consist of relatively confined channels on a wide floodplain between the Vaca Mountains and the English Hills. **Figure 3-8** shows the general form of the stream channels in this portion of the watershed. As Alamo Creek flows through Lagoon Valley and Vaca Valley, it receives flows from Laguna Creek and Encinosa Creek. Primary land uses in Lagoon Valley and Vaca Valley are agriculture and cattle grazing, with increasing urbanization.

3.2.2.3 Alamo Creek from the City of Vacaville to the Flood Control Project

The stream channel in this section meanders through the City, where residential and City properties lie immediately adjacent to the banks throughout most of its course. The channel consists primarily of large deep pools and flat water (i.e., runs), with some short low-gradient riffles interspersed throughout. Stream gradients in this section are on the order of 40 feet of drop per mile, reflecting the increase in slope as the creek passes through the foothill region of the watershed onto the Sacramento Valley floor.

Alamo Creek ends and New Alamo Creek begins at the point where Old Alamo Creek has been disconnected from its original course near the eastern boundary of the City.

3.2.2.4 New Alamo Creek from Flood Control Diversion to Ulatis Creek

New Alamo Creek is an engineered earthen channel that was created as part of the Ulatis Creek Watershed Protection and Flood Prevention Project (**Figure 3-9**) and was designed to convey stormwater runoff from surrounding agricultural and urban lands from just above Leisure Town Road to the confluence with Ulatis Creek. New Alamo Creek conveys all of the flow of the Alamo Creek watershed upstream of this point. Old Alamo Creek enters New Alamo Creek

approximately 3 miles upstream of the Ulatis Creek confluence. The surrounding land use is predominantly agriculture.

Primarily low-gradient flat-water reaches characterize New Alamo Creek, with bank protection (e.g., riprap) near bridges and other erosion-prone areas. In the upper part of this reach, the gradient is approximately 8 feet of drop per mile dropping to 2 feet of drop per mile near its confluence with Ulatis Creek. This reach is leveed and consists of a trapezoidal earthen channel with 2:1 slopes (horizontal to vertical). There are three grade-control structures designed to control flows within the channel, and two seasonal flashboard dams along this reach. The location of flow control features along the realigned channels, including grade control structures, and seasonal dams, is presented in Figure 3-9**. Figure 3-10** shows one of the grade control structures, **Figure 3-11** shows a typical channel section, and **Figure 3-12** shows one of the flashboard dams in this reach.

3.3 Ulatis Creek

Ulatis Creek is similar to Alamo/New Alamo Creek in that it originates in the Vaca Mountains and flows through the City and onto the Sacramento Valley floor. The following sections describe the watershed land uses and physical channel characteristics of Ulatis Creek and its tributaries, from the headwaters to its confluence with Cache Slough.

3.3.1 Watershed Description

The Ulatis Creek headwaters are in the Vaca Mountains at an elevation of approximately 3,000 ft msl. Four tributaries to Ulatis Creek originate in the English Hills north of the City. These tributaries are primarily confined to the Sacramento Valley floor and flow through low-lying agricultural areas before joining Ulatis Creek near the eastern margin of the watershed. From north to south, the tributaries are McCune Creek, Sweany Creek, Gibson Canyon Creek, and Horse Creek (Figure 3-1). Alamo/New Alamo Creek is a major tributary to the lower reach of Ulatis Creek. **Table 3** shows the reach lengths of the major segments of Ulatis Creek. While **Table 4** presents the land use types and relative percentages within the watershed from the headwaters to Cache Slough.

Table 3. Lengths of various reaches in the Ulatis Creek watershed.

Segment Reach	Segment (miles)	Total Length (miles)
Headwaters to the Vaca Valley	5.4	--
Vaca Valley to the City of Vacaville	2.5	7.9
City of Vacaville to McCune Creek	10.7	18.6
McCune Creek to Cache Slough	8.5	27.1

Table 4. Land uses within the Ulatis Creek watershed from the headwaters to Cache Slough.

Land Use Type	Area (square miles)	Percent Coverage (%)
Urban	10	9
Agriculture	86	80
Natural / Headwater	14	11
Source: Multi-Source Land Cover Data; 100-meter resolution (California Department of Forestry & Fire Protection 2002)		

3.3.2 Physical Characteristics of Channel

The physical characteristics of the Ulatis Creek channel from its headwaters to its confluence with Cache Slough are characterized by three distinct types of reaches: 1) mountainous headwater reaches in the upper part of the watershed, 2) medium gradient reaches traversing the urban foothills region, and 3) engineered flood control channels in low-lying agricultural areas of the Sacramento Valley floor. The following sections describe the general channel configurations of the Ulatis Creek reaches.

3.3.2.1 Ulatis Creek Headwaters to the Vaca Valley

The headwater channels begin at an elevation of approximately 3,000 ft msl in the Vaca Mountains. The stream channel in this reach has steep gradients on the order of 500 feet of drop per mile and is comprised primarily of step-pools and riffles confined to moderately to deeply incised channels. The stream channel leaves the steep gradient headwater area and crosses Vaca Valley before flowing through the City. Similar to Alamo Creek, the stream channel in Vaca Valley is characterized as low-moderate gradient with riffle-run-pool sequences. The reach has subdued topography and the channel consists of a relatively narrow channel situated on a wide floodplain between the Vaca Mountains on the west and the English Hills to the east.

3.3.2.2 Ulatis Creek from the Vaca Valley to the City of Vacaville

This section of Ulatis Creek meanders through the City along the base of the English Hills. The channel consists primarily of large deep pools and flat water (e.g., runs), with some short moderate-gradient riffles interspersed throughout. The gradient in this section is on the order of 38 feet of drop per mile.

3.3.2.3 Ulatis Creek from the City of Vacaville to McCune Creek

Near the eastern margin of the City, Ulatis Creek enters the low-gradient Sacramento Valley floor and the Ulatis Creek Watershed Protection and Flood Prevention Project area (**Figure 3-13** provides an aerial photo typical of this reach). The gradient in this section of Ulatis Creek is approximately 7 feet of drop per mile. Hydraulic modifications to Ulatis Creek start just east of Interstate 80 and continue downstream to the confluence with McCune Creek. The modifications consist of 5 miles of channel realignment and new channel construction and 10

miles of straightened and enlarged channel. Levees line the creek on both banks. Flow control features, including levees, channel realignment, grade control structures, and seasonal dams are presented in Figure 3-9

Ulatis Creek's four major tributaries—McCune, Sweany, Gibson Canyon, and Horse creeks—join Ulatis Creek in this reach. These tributaries have their headwaters in the English Hills north of Vacaville and traverse the northern half of the watershed, flowing generally to the southeast before joining Ulatis Creek between Leisure Town Road and Highway 113. Horse and Gibson Canyon creeks are small tributaries just north of Ulatis Creek, whereas Sweany and McCune creeks drain the central and northern part the Ulatis Creek watershed, roughly 50 square miles. Tributary channels are characterized by low- to moderate-gradient flat-water sections, with seasonal impoundments and bank protection material (e.g., riprap) present near bridges and other erosion-prone areas. Gradients in these creeks range from roughly 40 feet of drop per mile in the headwaters area to approximately 6 feet of drop per mile on the Sacramento Valley floor. Horse Creek's channel modifications extend from Interstate 80 to its confluence with Ulatis Creek. Sweany Creek's modifications extend from Highway 505 to its confluence with McCune Creek. These modifications were completed as part of the Ulatis Creek Watershed Protection and Flood Prevention Project.

3.3.2.4 Ulatis Creek from McCune Creek to Cache Slough

Located along the eastern margin of the watershed, the section of Ulatis Creek from McCune Creek to Cache Slough (approximately 8.5 miles) is characterized by a straightened, enlarged, and leveed channel. Alamo/New Alamo Creek is the major tributary in this reach. The typical channel configuration in this section is trapezoidal, as shown in **Figure 3-14. Figure 3-15** shows a flashboard dam installed on Ulatis Creek approximately 0.5 mile downstream of the New Alamo confluence (Figure 3-9). The creek continues downstream an additional 4 miles before receiving flows from lower Old Alamo Creek, which is another abandoned section of Alamo Creek. Stream gradients are on the order of 1 to 3 feet of drop per mile in this section, decreasing toward the confluence with Cache Slough.

Lower Old Alamo Creek historically was the southern section of Alamo Creek and was disconnected from the Alamo Creek watershed by construction of the Ulatis Creek Watershed Protection and Flood Prevention Project. Lower Old Alamo Creek currently discharges into Ulatis Creek through two 60-inch corrugated metal pipe drains with flap gates. During periods of high flows, Cache Slough water backs into Ulatis Creek, restricting outflow from lower Old Alamo Creek and causing ponding behind the flap gates on the lower Old Alamo Creek side of the Ulatis South Levee.

All of the channels in this reach have hydraulic improvements that consist of trapezoidal earthen channels with slopes of 3:1 (horizontal to vertical) and riprap protection placed in areas designated by hydraulic design, and at grade stabilization structures, drainage inlets, flow transitions, and bridges, as well as at inlet areas, to allow local runoff to enter the channels without damaging effects (e.g., erosion).

3.4 Cache Slough

Cache Slough begins at the terminus of Ulatis Creek, approximately 5.5 miles downstream of the confluence of New Alamo and Ulatis creeks. Cache Slough extends approximately 6 miles downstream from Ulatis Creek to the Sacramento River. The Vallejo Pump Station is located at about 400 feet downstream of the Ulatis Creek–Cache Slough confluence.

3.4.1 Watershed Description

Cache Slough is within the Delta. Several local creeks and sloughs enter Cache Slough in this area, including Ulatis Creek, Maine Prairie Slough, Haas Slough, Duck Slough, Hastings Cut, and Lookout Slough. Ulatis Creek and Maine Prairie Slough discharge to Cache Slough at roughly the same general location. **Figure 3-16** provides an aerial photo showing Cache Slough, its tributaries, and the Vallejo Pump Station. The surrounding land use is exclusively agricultural, including grazing (e.g., Vassar Ranch established in 1867).

3.4.2 Physical Characteristics of Channel

The Cache Slough channel changes sharply in character downstream of the confluence with Ulatis Creek—the channel becomes wider, increasing from approximately 300 feet to 1,500 feet because of numerous tributaries entering from the north and east. The change in channel configuration is shown in Figure 3-16; the straightened channel of Ulatis Creek can be clearly distinguished from the more natural channel configuration of Cache Slough.

Cache Slough, being a tributary to the Delta, is tidally influenced. Flows from Ulatis Creek and other creeks entering Cache Slough are affected by the tidal gradient from the Delta. The Cache Slough channel downstream of the confluence with Ulatis Creek, while confined by levees, has not been straightened and retains some natural structures, such as mid-channel islands and point bar features. While Cache Slough is lined with levees, there is considerably more riparian vegetation along its banks than along Ulatis or Alamo Creek channels. Riparian vegetation is present on numerous in-channel features in Cache Slough.

4 HYDROLOGIC CHARACTERISTICS

The hydrologic characteristics of Alamo/New Alamo and Ulatis creeks are described according to precipitation season and irrigation season. These periods were chosen because they represent distinct hydrologic regimes of Alamo/New Alamo and Ulatis creeks, one marked by natural runoff from precipitation, the other marked by agricultural drainage water and little to no natural rainfall-runoff.

4.1 Precipitation Season

The precipitation season, for purposes of this analysis, is defined as November through April, based on local precipitation and streamflow runoff patterns. During the precipitation season, the creek reaches downstream of the Easterly WWTP primarily convey WWTP effluent, rainfall

runoff from the upper Alamo and Ulatis creek watersheds, stormwater runoff from the City, and overland flow from the surrounding agricultural lands. **Figure 4-1** shows the average monthly precipitation and streamflows in Alamo/New Alamo and Ulatis creeks for water years 1998 through 2006. Water years 1998 through 2006 are the focus of the hydrologic characterization of Alamo/New Alamo and Ulatis creeks, because prior to water year 1998, no streamflow data are available for Alamo/New Alamo and Ulatis creeks.

The average monthly precipitation in water years 1998–2006 is compared to the long-term (1949–2006) average monthly precipitation in **Figure 4-2**. As Figure 4-2 shows, the average monthly precipitation for December and February during water years 1998–2004 was about two inches more than the long-term average (1949–2006) for these same months. The same comparison for the month of January shows that the 1998–2006 period is 1.5 inches less in precipitation. The average monthly precipitation in all other months in water years 1998–2006 generally corresponds to the long-term average (1949–2006). The average annual precipitation for the 1998–2006 water year period (28.6 inches) is 3.6 inches more than the long-term average of 25.0 inches. **Figure 4-3** shows the long-term total annual precipitation record for Vacaville for water years 1949–2006 (NCDC 2007).

4.1.1 Streamflow Patterns

This hydrologic evaluation focuses on three reaches of the New Alamo and Ulatis creek system. This first reach is Ulatis Creek from Leisure Town Road downstream to its confluence with New Alamo Creek. This reach provides a characterization of streamflows entering the lower portion of the UAA study area. The second reach is New Alamo Creek from Vanden Road downstream to Ulatis Creek. This reach characterizes streamflows within the reach that accepts Easterly WWTP effluent conveyed down Old Alamo Creek and ultimately discharged to New Alamo Creek. The final reach is Ulatis Creek from its confluence with New Alamo Creek to its terminus at Cache Slough. This reach characterizes the streamflows in lower Ulatis Creek, which conveys Easterly WWTP effluent to Cache Slough.

Two streamflow gauges were used to characterize streamflows in New Alamo and Ulatis creeks: Vacaville-V4, located on New Alamo Creek at Vanden Road, and Vacaville-V3, located on Ulatis Creek at Leisure Town Road. **Figure 4-4** shows the location of streamflow gauging stations in the Alamo and Ulatis Creek watersheds. Both V3 and V4 gauges are upstream of the Easterly WWTP. The maximum mean daily discharge of the WWTP, for water years 1998-2006, was 20.5 cfs. Therefore, to provide a comparison between flows in Alamo and Ulatis Creeks with maximum daily effluent flows, the occurrence of streamflows greater than 20 cfs and greater than 100 cfs are reported. The approximate ratio of streamflow to effluent flow is also provided.

Doppler flow data was collected by the City of Vacaville at Fry Road on Alamo Creek (UAA2) and Brown Road on Ulatis Creek (UAA3) provide supplemental flow data in the UAA study area. Both locations, Fry Road and Brown Road, are downstream of the Easterly WWTP.

4.1.1.1 Ulatis Creek from Leisure Town Road to New Alamo Creek

The Vacaville-V3 gauging station is located at the Leisure Town Road bridge over Ulatis Creek. This gauge records streamflow only during the precipitation season, typically November through May. **Figure 4-5** shows the period for which flow data are available from this gauge for each water year that it has been in service. The City of Vacaville operates all of its gauges to measure storm runoff and the operation of this streamflow gauge is dependent on precipitation forecasts; therefore, the recording period is not consistent from year to year.

Figure 4-6 presents the recorded streamflows in the form of an exceedance plot. As this plot shows, the streamflows during the 1998–2006 water years generally exceeded 20 cfs about 26% of the time, with the exception of February, which exceeded 20 cfs about 35% of the time. Streamflows in excess of 100 cfs were exceeded less than 10% of the time, with the exception of February, which exceeded 100 cfs about 15% of time during water years 1998–2006.

Appendix A provides time-series plots of average daily streamflows in this reach of Ulatis Creek for each precipitation season during water years 1998–2006.

4.1.1.2 New Alamo Creek from Vanden Road to Ulatis Creek

The Vacaville-V4 gauging station is located at the Vanden Road bridge of New Alamo Creek, at the top of this reach (Figure 4-4). As described in the previous section, streamflow gauges operated by the City of Vacaville measure storm runoff; therefore, the recording period of daily streamflows is not consistent from year to year. **Figure 4-7** shows the recording period for this gauge during each year of the 1998–2006 period.

Figure 4-8 presents the recorded streamflows in the form of an exceedance plot. As this plot shows, the streamflows during water years 1998–2006 generally exceeded 20 cfs about 35% of the time, with the exception of February, which exceeded 20 cfs about 45% of the time. Streamflows in excess of 100 cfs were exceeded about 12% of the time, with the exception of February, which exceeded 100 cfs about 20% of time during water years 1998–2006. Supplemental data collected by the City at Fry Road (Figure 4-4, UAA2) during winter, November through April, of water years 2004-2006 is shown in **Table 5.** During the winters of 2004 and 2005, flows at Fry Road were more than 20 cfs about twice as often as measured upstream at Vanden Road bridge (V4). However, during winter 2007, flows were substantially less at Fry Road than the previous two winters. Flows were also less than the 1998-2006 mean flows at Vanden Road bridge. Winter 2007 flows at Fry Road were greater than 20 cfs 29% of the time and never greater than 100 cfs.

Table 5. Percent exceedance of winter flow data on New Alamo Creek at Fry Road. Location is below the Easterly WWTP.

Water Year	November through April	Water Year Type	Flows Exceeding 20 CFS	Flows Exceeding 100 CFS
2005	2004-2005	Below Normal	76 %	26 %
2006	2005-2006	Wet	84 %	32 %
2007	2006-2007	Dry [1]	29 %	0 %

[1] Forecast by DWR on May 1, 2007 with less than 25% probability of being wetter.

The ratio of New Alamo Creek flow rate to Easterly WWTP effluent discharge flow rate to immediately downstream of the confluence with Old Alamo Creek was estimated using the Vacaville-V4 streamflow data. Note that this ratio is not the actual "dilution" ratio, because the ratio does not consider other contributions to Old Alamo Creek, nor does it consider contributions from New Alamo Creek between Vanden Road and the Old Alamo Creek confluence.[1] This area is estimated to contribute less than 10% of the streamflow of Alamo/New Alamo Creek (Camp Dresser & McKee 1990). **Figure 4-9** shows that during the precipitation season of water years 1998–2006, the ratio of New Alamo Creek flow rate to effluent discharge flow rate to just downstream of the confluence with Old Alamo Creek was less than 5:1 (5 parts streamflow to 1 part effluent) approximately 90% of the time, with the exception of the month of February, when the ratio was less than 5:1 approximately 80% of the time. The streamflow-to-effluent discharge ratio at the City's UAA2 gauge (Figure 4-4) during winter 2004-2005 was less than 5:1 about 65% of the time.

Appendix B provides time-series plots of average daily streamflows for each precipitation season during water years 1998–2006 along with corresponding approximate average daily streamflow-to-effluent ratio in New Alamo Creek immediately downstream of the confluence with Old Alamo Creek.

4.1.1.3 Ulatis Creek from Confluence of New Alamo Creek to Cache Slough

Streamflows in the Ulatis Creek reach between New Alamo Creek and Cache Slough during the precipitation season were estimated by extrapolation of flows at the Vacaville-V4 (New Alamo Creek at Vanden Road) and Vacaville-V3 (Ulatis Creek at Leisure Town Road) gauging stations (Figure 4-4). Ulatis Creek at Leisure Town Road receives approximately 28% of the streamflow

[1] *Technical Memorandum No. 3, Easterly Wastewater Treatment Plant Effluent Dilution Analysis*, prepared by Flow Science, June 2005, provides additional information on effluent dilution. Dilution of effluent under three seasonal conditions is presented: (1) November 2004 (dry condition, no irrigation); (2) March 2004 (wet season, no irrigation); and (3) July 2004 (dry season, significant irrigation use).

of Ulatis Creek at Highway 113, which is immediately upstream of New Alamo Creek (Camp Dresser & McKee 1990). Accordingly, the measured streamflow values at Leisure Town Road were adjusted to estimate Ulatis Creek streamflows at Highway 113.

The Ulatis Creek streamflow immediately downstream of its confluence with New Alamo Creek was estimated using the estimated streamflow for Ulatis Creek at Highway 113 and the measured streamflow of New Alamo Creek at Vanden Road. **Figure 4-10** provides a summary of estimated streamflow characteristics in the form of an exceedance plot. This plot shows that streamflows during the 1998–2006 water years generally exceed 40 cfs about 55% of the time, with the exception of February, which exceed 40 cfs about 64% of the time. Streamflows in excess of 100 cfs are exceeded about 10–25% of the time, with the exception of February, which is shown to exceed 100 cfs about 36% of the time during water years 1998–2006.

Supplemental data collected by the City at Brown Road (Figure 4-4, UAA3) during winter, November through April, of water years 2004-2006 is shown in **Table 6**. During the winter of 2004, flows were similar to that estimated above for lower Ulatis Creek with flows more than 40 cfs 60% of the time and more than 100 cfs 25% of the time. Flow data for winter 2005 is incomplete because a high flow storm event in late December 2005 released the Doppler flow monitoring unit from its moorings. A replacement unit was not able to be deployed until June 2006. During winter 2007, however, flows were substantially less at Brown Road than during winter 2004 or the mean 1998–2006 flows calculated for lower Ulatis Creek. Winter 2007 flows at Brown Road were more than 40 cfs 7% of the time and greater than 100 cfs only 2% of the time.

Table 6. Percent exceedance of winter flow data on Lower Ulatis Creek at Brown Road. Location is below the Easterly WWTP.

Water Year	November through April	Water Year Type	Flows Exceeding 40 CFS	Flows Exceeding 100 CFS
2005	2004-2005	Below Normal	60 %	25 %
2006	2005-2006	Wet	NA [1]	NA [1]
2007	2006-2007	Dry [2]	7 %	2 %

[1] Flow monitor lost during high flow storm December 28, 2005.

[2] Forecast by DWR on May 1, 2007 with less than 25% probability of being wetter.

The estimated streamflows for lower Ulatis Creek provide a basis for estimating the ratio of Ulatis Creek flow rate to Easterly WWTP effluent discharge rate. **Figure 4-11** shows that during the precipitation season of water years 1998–2006, the streamflow-to-effluent discharge ratio in lower Ulatis Creek was 10:1 or lower between 80–90% of the time, with the exception of the month of February, which was 10:1 or lower approximately 71% of the time. The estimated streamflow-to-effluent discharge ratio at Brown Road during winter 2004-2005 was less than 10:1 about 78% of the time.

Appendix C provides time-series plots of estimated average daily streamflows for each precipitation season during water years 1998–2006 along with corresponding approximate average daily streamflow-to-effluent discharge ratio in lower Ulatis Creek immediately downstream of the confluence with New Alamo Creek.

4.1.2 Watershed Runoff Contributions

Runoff into Alamo/New Alamo and Ulatis creeks is derived from a mix of natural and forested headwater areas, urban areas, and agricultural areas. The distribution of runoff was estimated by utilizing an existing rainfall-runoff simulation model prepared for the Ulatis Creek Watershed Study (Camp Dresser & McKee 1990). In that study, runoff was estimated using a computerized runoff simulation model, the HEC-1 Flood Hydrograph Package. The software for this rainfall-runoff model was created by the U.S. Army Corps of Engineers to determine flows and runoff hydrographs. The model uses input values for physical parameters such as slope, rainfall, and channel characteristics and uses mathematical equations to predict the runoff that would occur given the selected input parameters. A full description of model development and parameter selection is presented in the Ulatis Creek Watershed Study.

Model parameters were not revised for the current assessment. Only the volume of runoff from the various sub-basins was analyzed. Because total runoff volumes from each sub-basin were of interest, the model used did not consider over-bank flows and all flow remained within the creek channels throughout the watershed. This approach is appropriate in terms of assessing the overall contribution of runoff from a sub-basin and to assess the volume of runoff inputs from different land uses.

Table 7 shows runoff contributions from tributary sub-watersheds as a percentage of total runoff and illustrates the general relationship between sub-basin size, topographic location, and runoff contribution. The distribution of land use is related to the general topography of the watershed. For example, the majority of the McCune Creek watershed is within the Sacramento Valley floor where 98% of land use is agricultural; whereas the Encinosa Creek watershed is mostly forested or natural areas in the Vaca Mountains. The flow of Alamo Creek, which includes flows from Laguna and Encinosa creeks, produces 36% of runoff in the Ulatis Creek Watershed, while Ulatis Creek and its tributaries generates 64% of the volume of runoff within the Ulatis Creek Watershed.

Table 7. Contribution of runoff and percent land use in the Ulatis Creek Watershed.

Sub-Basin	Area (sq miles)	% of Area				% of Runoff Contribution
		Agriculture	Urban	Forest	Total	
Horse	10.1	4%	3%	0%	7%	8%
Sweany	20.5	13%	1%	0%	14%	15%
Gibson Canyon	12.1	7%	1%	0%	8%	7%
McCune	31.0	21%	0%	0%	21%	10%
Ulatis Mainstem	32.1	12%	3%	6%	21%	24%
Subtotal	105.8	57%	8%	6%	71%	64%
Encinosa	3.3	0%	0%	1%	1%	4%
Laguna	5.9	1%	0%	3%	4%	10%
Alamo/New Alamo Mainstem	35.1	14%	4%	6%	24%	22%
Subtotal	44.3	15%	4%	10%	29%	36%
Total	150.1	72%	12%	16%	100%	100%
Source: USACE HEC-1 Flood Hydrograph Package 1998.						

4.2 Irrigation Season

For purposes of this analysis the irrigation season is defined as May through October. During the irrigation season, the creek reaches downstream of the Easterly WWTP primarily convey WWTP effluent and agricultural drainage water, with small amounts of urban runoff from domestic activities (e.g., lawn watering). Rainfall runoff contributes little to no flow during this period; monthly precipitation averages 1 inch or less (Figure 4-2). Water in Old Alamo Creek is comprised of urban runoff from upstream of the WWTP, WWTP effluent, and agricultural drainage water. Water in New Alamo Creek downstream of Old Alamo Creek is made up of WWTP effluent, inflow from New Alamo Creek above Leisure Town Road (primarily urban runoff during most of the irrigation season), and agricultural drainage water. Water in Ulatis Creek, downstream of Leisure Town Road, is made up of inflow from New Alamo Creek, agricultural drainage water, and occasional supplemental inputs from the Solano Project.

Historical streamflow data during the irrigation season is limited. The City does not maintain its gauges (see Figure 4-4, gauges V3 and V4) on New Alamo and Ulatis creeks during the non-precipitation period, so no data are available from these gauges. The City did install gauging stations on New Alamo and Ulatis creeks in the summer of 2004. Additionally, the City and Robertson-Bryan, Inc. (RBI) conducted flow measurements during the summer of 2004. Diversion of water was determined from Maine Prairie Water District (MPWD) and Solano Irrigation District (SID) records. The following sections further describe the hydrologic conditions characterized by each of these elements.

4.2.1 July 2004 Field Measurements and Observations

As an example of irrigation season conditions, field measurements from July 27, 2004, are used to show how New Alamo and Ulatis creeks are typically utilized for irrigation flow management during the irrigation season (May–October). Locations for flow measurements were selected to characterize the summer season movement of water for agricultural operations. A description of field measurements and observations is provided below. **Figure 4-12** provides a simple schematic of the creek system, major operational features, and measured or calculated flow rates at specific locations in the system on July 27, 2004.

4.2.1.1 Old Alamo Creek

The total flow of Old Alamo Creek was measured just upstream of its confluence with New Alamo Creek (Figure 4-12). At this location, the flow includes effluent from the Easterly WWTP, agricultural drainage water, and urban runoff. The measured flow was 29 cfs. The average discharge from the WWTP for the same day was 11 cfs. Therefore, a total of 18 cfs of agricultural drainage water also was being added to Old Alamo Creek. The corresponding approximate dilution of effluent in Old Alamo Creek on this day was less than 2:1 (2 parts streamflow to 1 part effluent) and the available stream flow was almost entirely agricultural drainage water. There was zero input from urban runoff into Old Alamo Creek based on a visual inspection of the creek at Leisure Town Road. Agricultural drainage water enters the creek at a variety of locations, both upstream and downstream of the WWTP's discharge point.

4.2.1.2 New Alamo Creek

New Alamo Creek flows were measured at three locations: (1) immediately downstream of Grade Control Structure #3 (upstream of Leisure Town Road); (2) immediately downstream of the Grade Control Structure #1 (upstream of the Old and New Alamo creeks confluence); and (3) downstream of the MPWD Dam #4, located along Fry Road (Figure 4-4).

The measured flow at Grade Control Structure #3 was 0.5 cfs. This represents urban runoff from the city of Vacaville. There was no flow contribution from the Vaca Mountains area of Alamo Creek or its tributaries the day measurements were taken, based on zero flow observations made at Lagoon Valley Road.

The measured flow at Grade Control Structure #1 was 6 cfs. This flow included the flow measured at Grade Control Structure #3 and 5.5 cfs of agricultural drainage water entering the creek between these two points. No agricultural drainage water was observed along New Alamo Creek from Grade Control Structure #1 to the confluence of Old Alamo Creek.

Flow in New Alamo Creek below the confluence of Old Alamo Creek was calculated to be 35 cfs. Based on this flow, the dilution ratio for Easterly WWTP effluent was approximately 2:1 (2 parts streamflow to 1 part effluent). Stream flow available for dilution at this point in the system is almost entirely agricultural drainage water with a small amount of urban runoff.

Immediately downstream of the confluence is SID's Brown-Alamo Dam. This dam was in place on July 27, but no diversions were being made from the impoundment formed by the dam. No significant agricultural drainage water was observed between the Old and New Alamo creeks confluence and MPWD's Dam #4.

MPWD's Dam #4 was in place on July 27 and 12 cfs was being diverted from its impoundment. Flow measured downstream of the dam was 13 cfs. No agricultural drainage water was observed between Dam #4 and the confluence with Ulatis Creek. There is a 10 cfs difference in flow between the Old Alamo Creek/New Alamo Creek confluence and sum of diversion and flow at Dam #4. This difference is attributed to the fact that measurements were collected over a 2½-hour period, during which time agricultural drainage flows and Easterly WWTP discharges may have fluctuated. Because the diversion and streamflows were measured and gauged, they are believed to be accurate. The 13 cfs measured below the dam also represents New Alamo Creek's flow contribution to Ulatis Creek.

4.2.1.3 Ulatis Creek

The measured flow of Ulatis Creek below MPWD Dam #3 was 14 cfs on July 27. MPWD records indicate the average rate of diversion from the Dam #3 impoundment was 27 cfs for July 27. The inflow to the Dam #3 impoundment was comprised of 13 cfs from New Alamo Creek, an estimated 3–5 cfs from leakage in MPWD Dam #2 (located on Ulatis Creek upstream of Highway 113), and an estimated 23 cfs of agricultural drainage water into Ulatis Creek between Dams #2 and #3.

4.2.2 MPWD Operations

MPWD irrigation demands from New Alamo and Ulatis creeks are supported primarily from agricultural drainage water and Easterly WWTP effluent. Occasionally, MPWD purchases water from the Solano Project to supplement flows in Ulatis Creek to ensure that sufficient water is available at Dam #3. MPWD does not serve any demands below Dam #3 and, therefore, tries to minimize flows passing the dam (Holdener, pers. comm., 2004). Whenever possible, MPWD limits water passing downstream of Dam #3 to leakage through the dam, approximately 5 cfs. Water passing through or over the dam during the irrigation season is dominated by agricultural drainage water and Easterly WWTP effluent.

4.2.3 Overall Irrigation Season Hydrologic Conditions

The general pattern of flows in the New Alamo and Ulatis Creek system during the irrigation season is shown in **Figure 4-13**. The information provided in this figure is based on numerous field measurements and observations by RBI staff during the 2004 irrigation season and with daily records provided by MPWD and the City of Vacaville. Field observations of headwater flow, or lack thereof, were made from May through September 2004. Once headwater flow ceases in the spring, no flow is expected to resume until the rains return in the fall (typically in October or November. Records from MPWD were used to develop average monthly values of

diversions and flows past diversion dams. Easterly WWTP discharge data was summarized for the same period to develop a monthly average value of discharge to Old Alamo Creek. This method provides a general pattern of flows for New and Old Alamo creeks and for Ulatis Creek during the irrigation season. The values in Figure 4-13 are supported by the daily values described above and shown in Figure 4-12.

5 REFERENCES AND PERSONAL COMMUNICATIONS

California Department of Forestry & Fire Protection. 2002. Fire and Resource Assessment Program. Sacramento, CA. Available <http://frap.cdf.ca.gov/data/frapgisdata/select.asp>. Accessed October 2004.

Camp Dresser & McKee. 1990 (February). *Ulatis Creek Watershed Study*. Prepared for the City of Vacaville.

City of Vacaville. 1998. *City of Vacaville Stream Gaging Program*. Prepared by West Yost & Associates.

———. 1999. *City of Vacaville Stream Gaging Program*. Technical Memorandum No. 1–1999. Prepared by West Yost & Associates.

———. 2000. *City of Vacaville Stream Gaging Program*. Technical Memorandum–October 2000. Prepared by West Yost & Associates.

———. 2001. *City of Vacaville Stream Gaging Program*. Technical Memorandum–2001 Water Year. Prepared by West Yost & Associates.

———. 2002. *City of Vacaville Stream Gaging Program*. Technical Memorandum–2002 Water Year. Prepared by West Yost & Associates.

———. 2003. *City of Vacaville Stream Gaging Program*. Technical Memorandum–2003 Water Year. Prepared by West Yost & Associates.

———. 2004. *City of Vacaville Stream Gaging Program*. Technical Memorandum–2004 Water Year. Prepared by West Yost & Associates.

———. 2005. *City of Vacaville Stream Gaging Program*. Technical Memorandum–2005 Water Year. Prepared by West Yost & Associates.

———. 2006. *City of Vacaville Stream Gaging Program*. Technical Memorandum–2006 Water Year. Prepared by West Yost & Associates.

———. 2006a. Daily Cumulative Flow, Easterly Wastewater Treatment Plant.

Holdener, Don. General Manager. Maine Prairie Water District, Dixon, CA. June 10, 2004 – Field visit to MPWD office by Larry Rodriquez of RBI regarding district operations and irrigation delivery records.

Maine Prairie Water District. 2004. Water District Operations Records 2001 to 1004.

NCDC (National Climatic Data Center). 2007. *Annual Climatological Summary:* Station 049200-Vacaville. Available <http://www.ncdc.noaa.gov/oa/ncdc.html> Accessed July 2007.

———. 2004. *Cooperative Summary of the Day TD3200*. Period of record through 2001. Data released November 2002, Version 1.0. Available on CD-ROM. Updated to 2004. U.S. Department of Commerce. National Oceanic and Atmospheric Administration. National Climatic Data Center. Asheville, NC.

SCFCWCD (Solano County Flood Control and Water Conservation District) and U.S. Department of Agriculture, Soil Conservation Service. 1966. Ulatis Creek Watershed Protection and Flood Prevention Project, Solano County, California. As Built drawings for Alamo Creek Channel A-2b.

Ulatis Soil Conservation District, Solano Irrigation District, and Solano County Flood Control and Water Conservation District. 1961. *Watershed Work Plan: Ulatis Creek Watershed*. Prepared under the authority of the Watershed Protection and Flood Preservation Act (P.L. 566, as amended). March 1961.

USACE (U.S. Army Corps of Engineers). 1998. HEC-1 Flood Hydrograph Package. Hydrologic Engineering Center. Davis, CA.

Yoder Associates (M. C. Yoder Associates, Consulting Engineers). 1965. *A Survey of Storm Drainage Southeast of Interstate Highway 80, Vacaville*. Prepared by M.C. Yoder Associates, for the City of Vacaville, December 1965. 34 pp., plus figures.

FIGURES

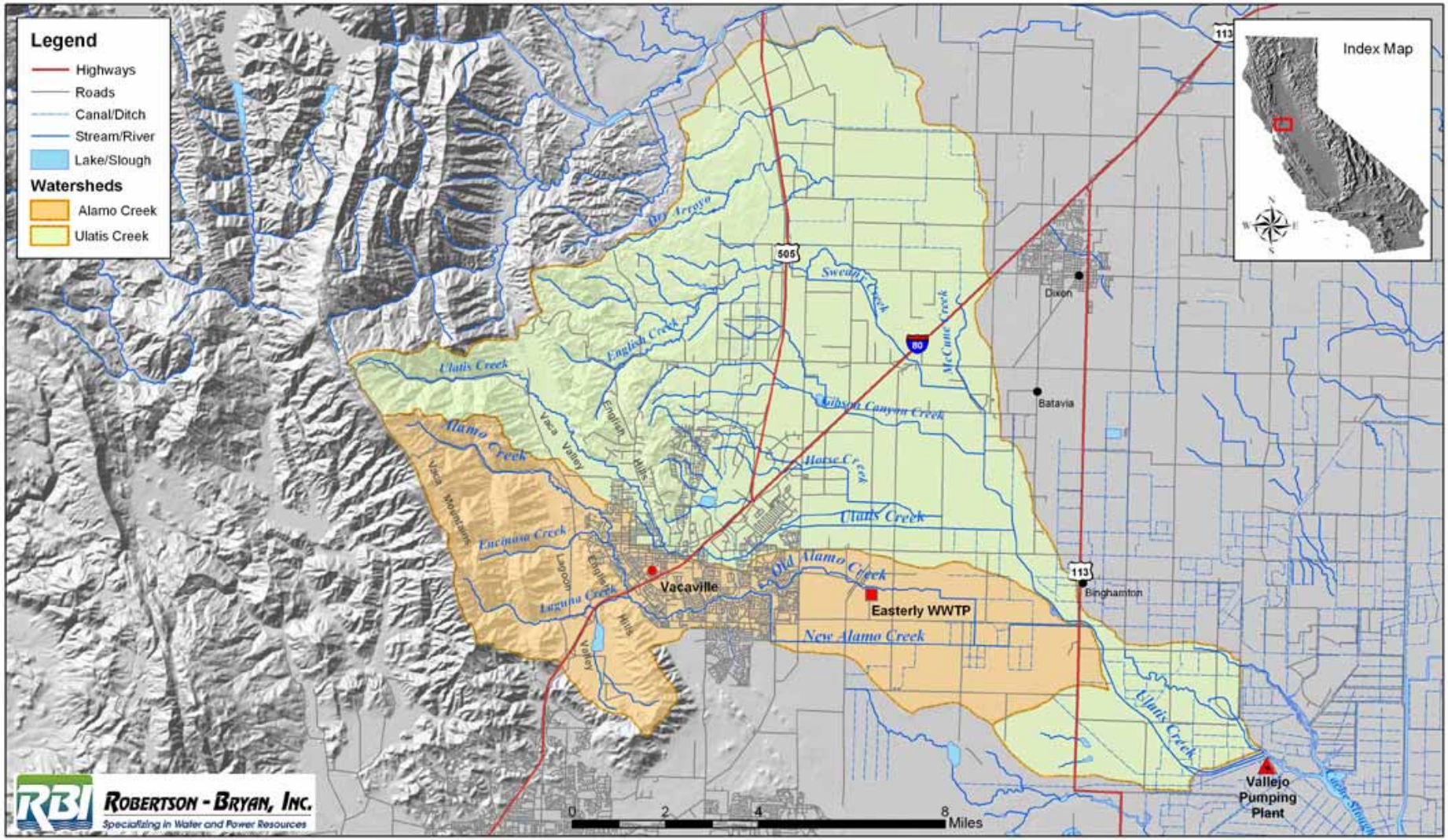


Figure 3-1. Ulatis Creek and Alamo Creek watersheds.

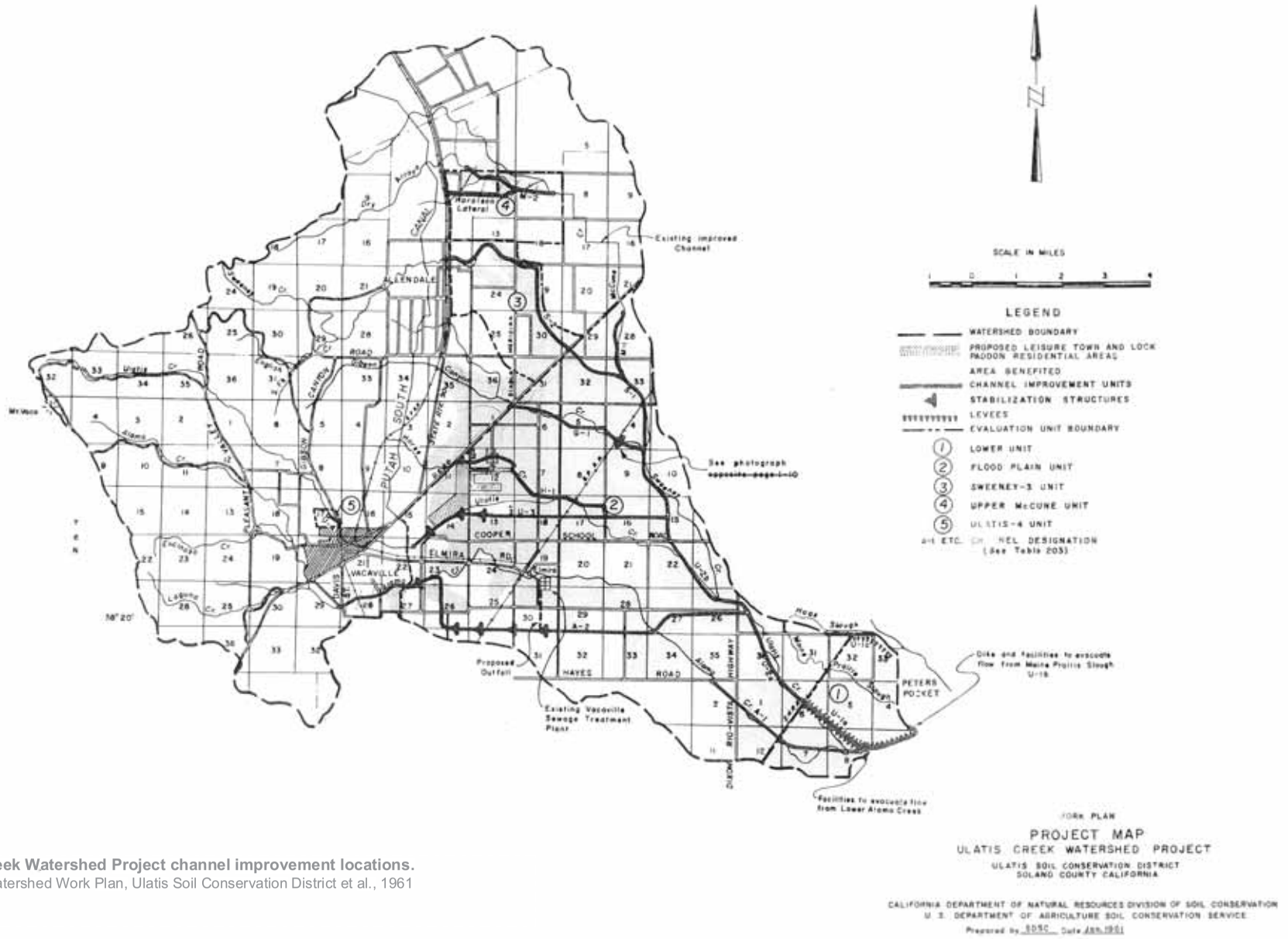


Figure 3-2. Ulatis Creek Watershed Project channel improvement locations.
Source: Ulatis Creek Watershed Work Plan, Ulatis Soil Conservation District et al., 1961
(Blue highlight added.)

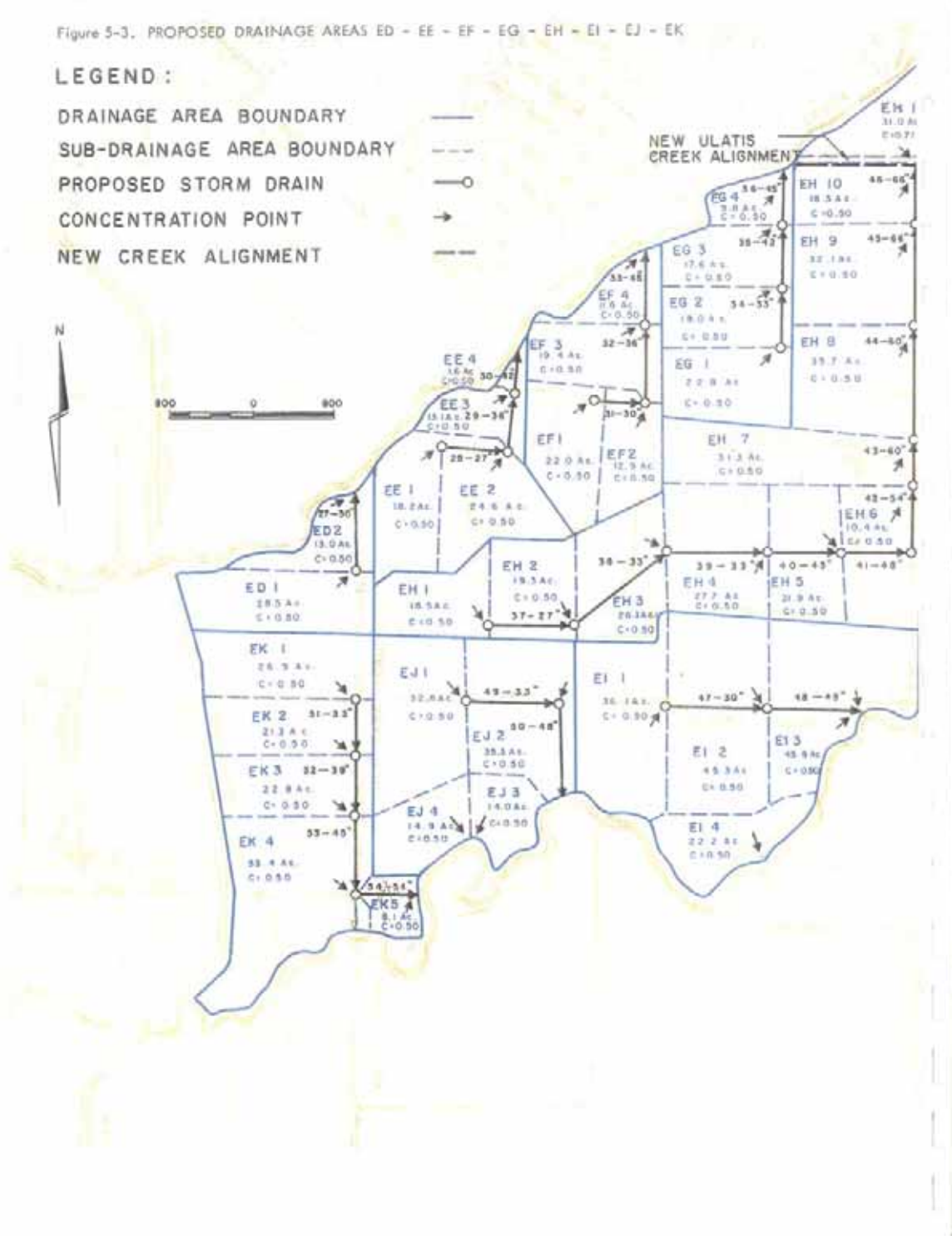


Figure 3-3. Proposed Storm Drain Routes for the drainage areas south of Ulatis Creek and west of Leisure Town Road. Source: Yoder Associates, 1965.

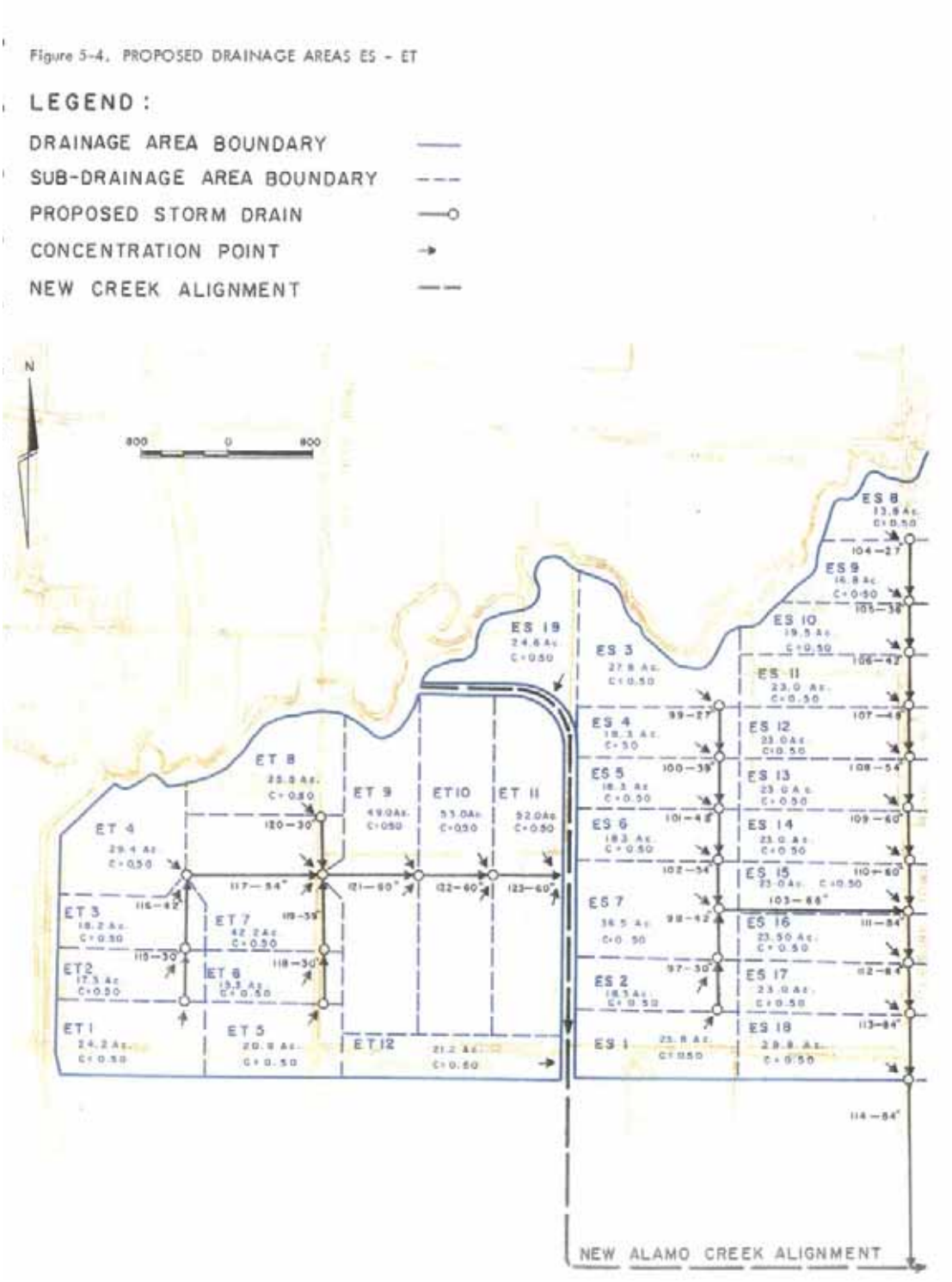


Figure 3-4. Proposed Storm Drain Routes for the drainage areas south of Alamo Creek and west of Leisure Town Road. Yoder Associates, 1965

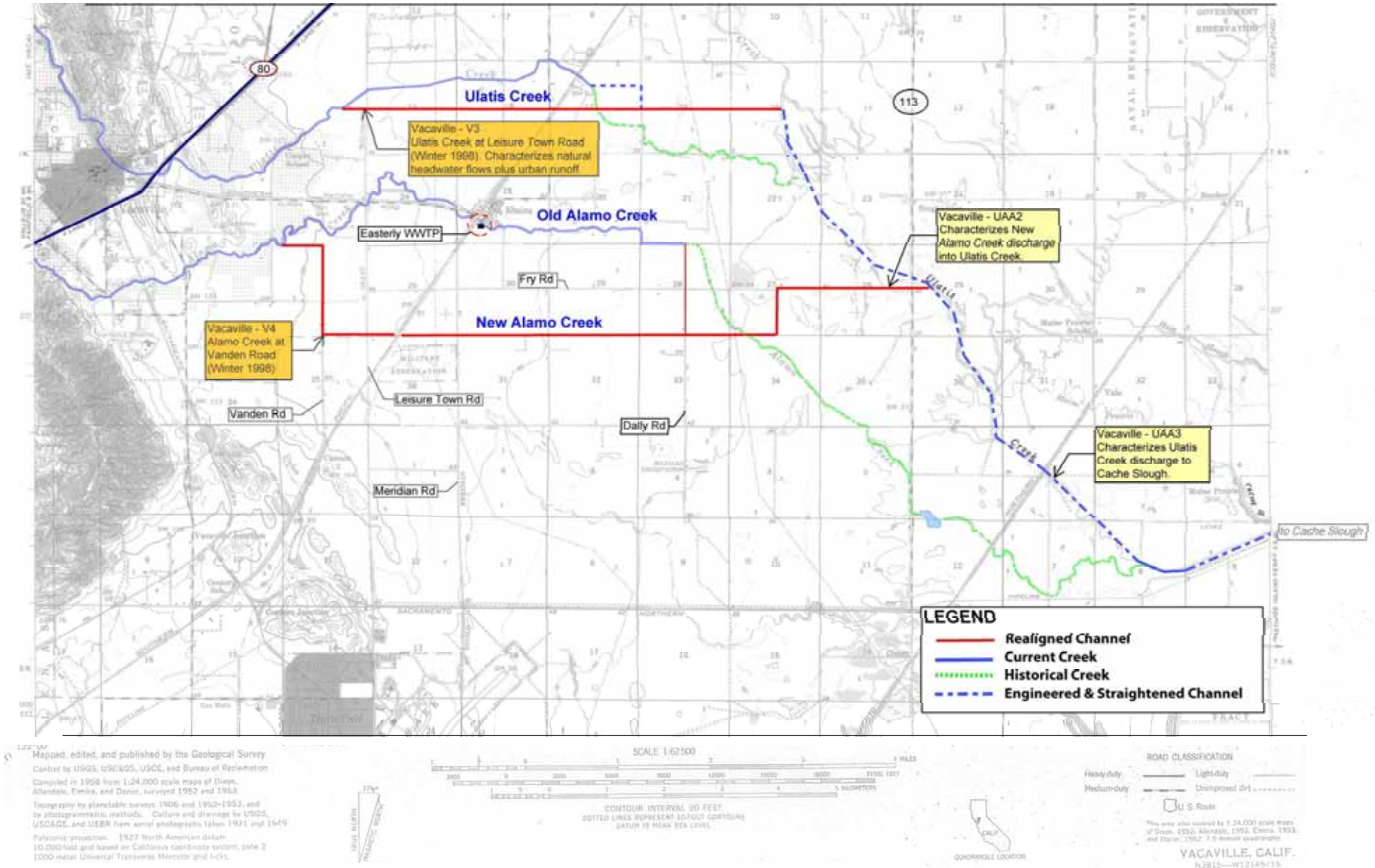


Figure 3-5. Historic and Current Alamo and Ulatis Creek Alignments.

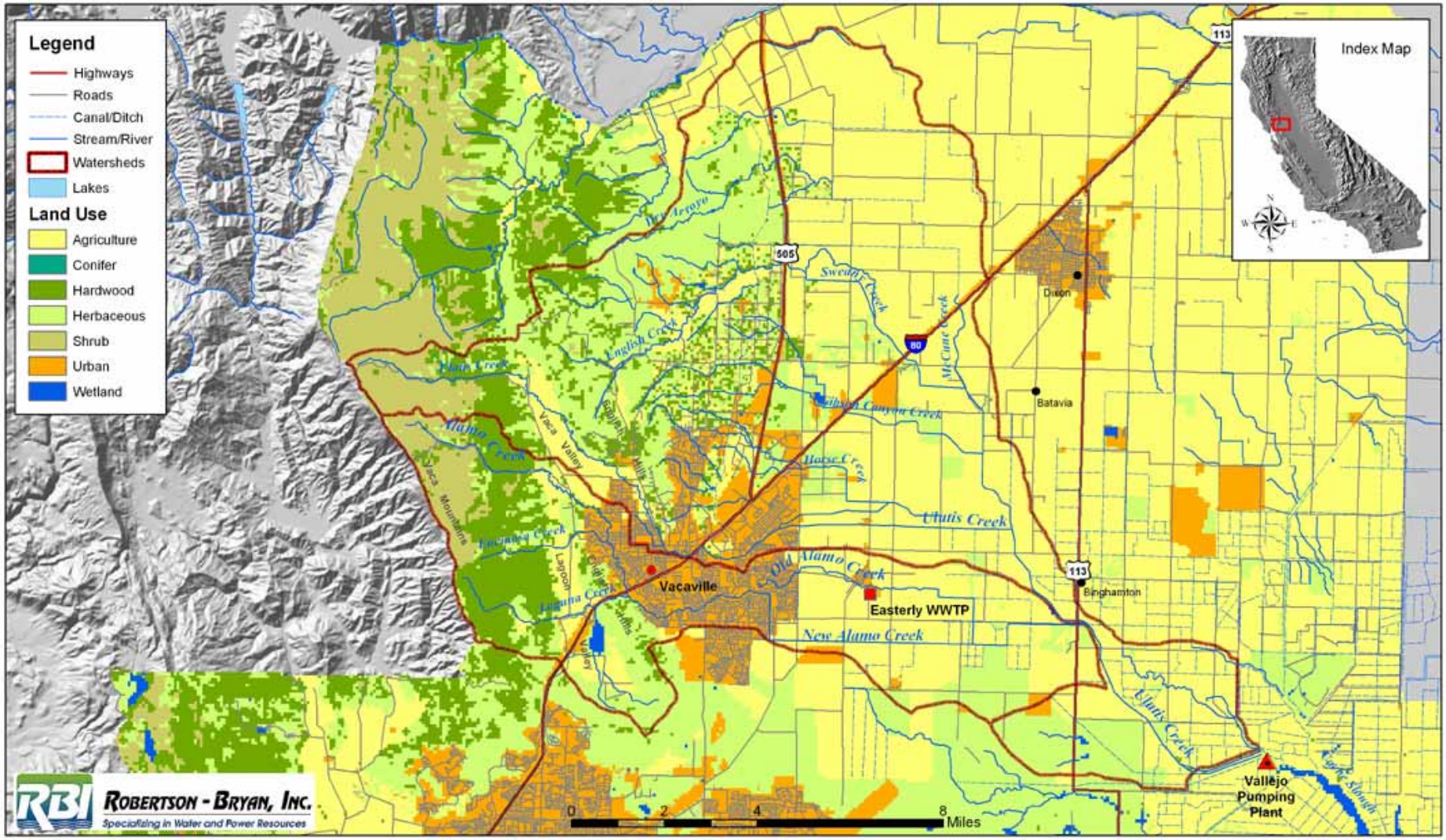


Figure 3-6. Land use categories in the Alamo and Ulatis Creek watersheds.
Source: Multi-Source Land Cover Data (v02_2); 100-meter resolution.

Figure 3-7. Headwater section of Alamo Creek.

Figure 3-8. Low-gradient section between the Alamo Creek headwaters and city of Vacaville.

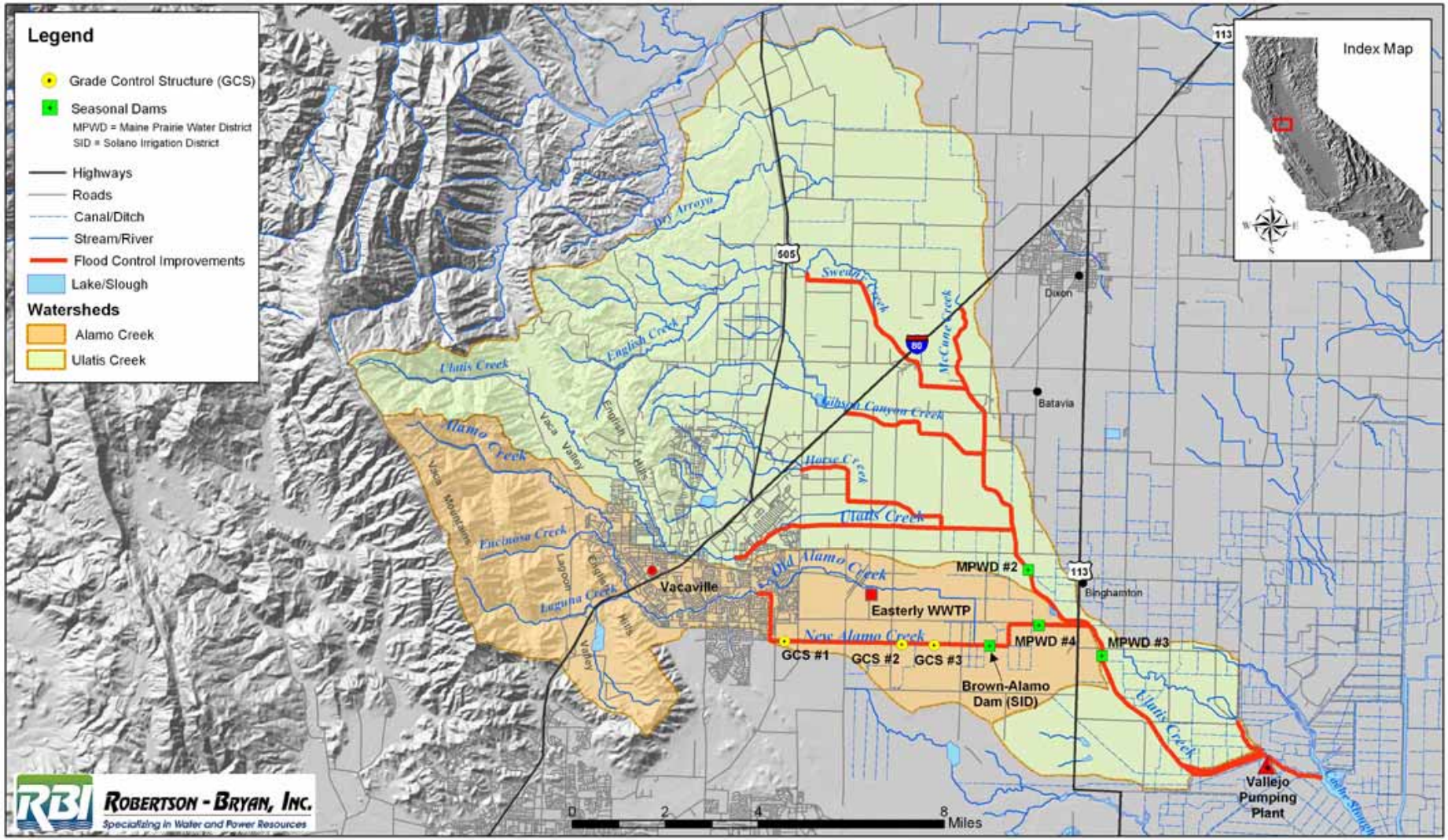


Figure 3.5. Alamo and Ulatis Creek Watershed flood control facilities. Flood control improvements completed as part of the Ulatis Creek Watershed Protection and Flood Prevention Project developed by the Solano County Flood Control and Water Conservation District and the U.S. Department of Agriculture, Soil Conservation Service.

Figure 3-10. Grade control Structure on New Alamo Creek. View looking upstream.

Figure 3-11. Typical channel section of New Alamo Creek. View looking upstream.

Figure 3-12. Maine Prairie Water District Diversion Dam #4. View looking upstream.

Figure 3-13. Ulatis Creek within the Sacramento Valley floor.

Figure 3-14. Typical channel section of Lower Ulatis Creek. View looking downstream.

Figure 3-15. Ulatis Creek at Maine Prairie Water District Dam #3. View looking upstream.

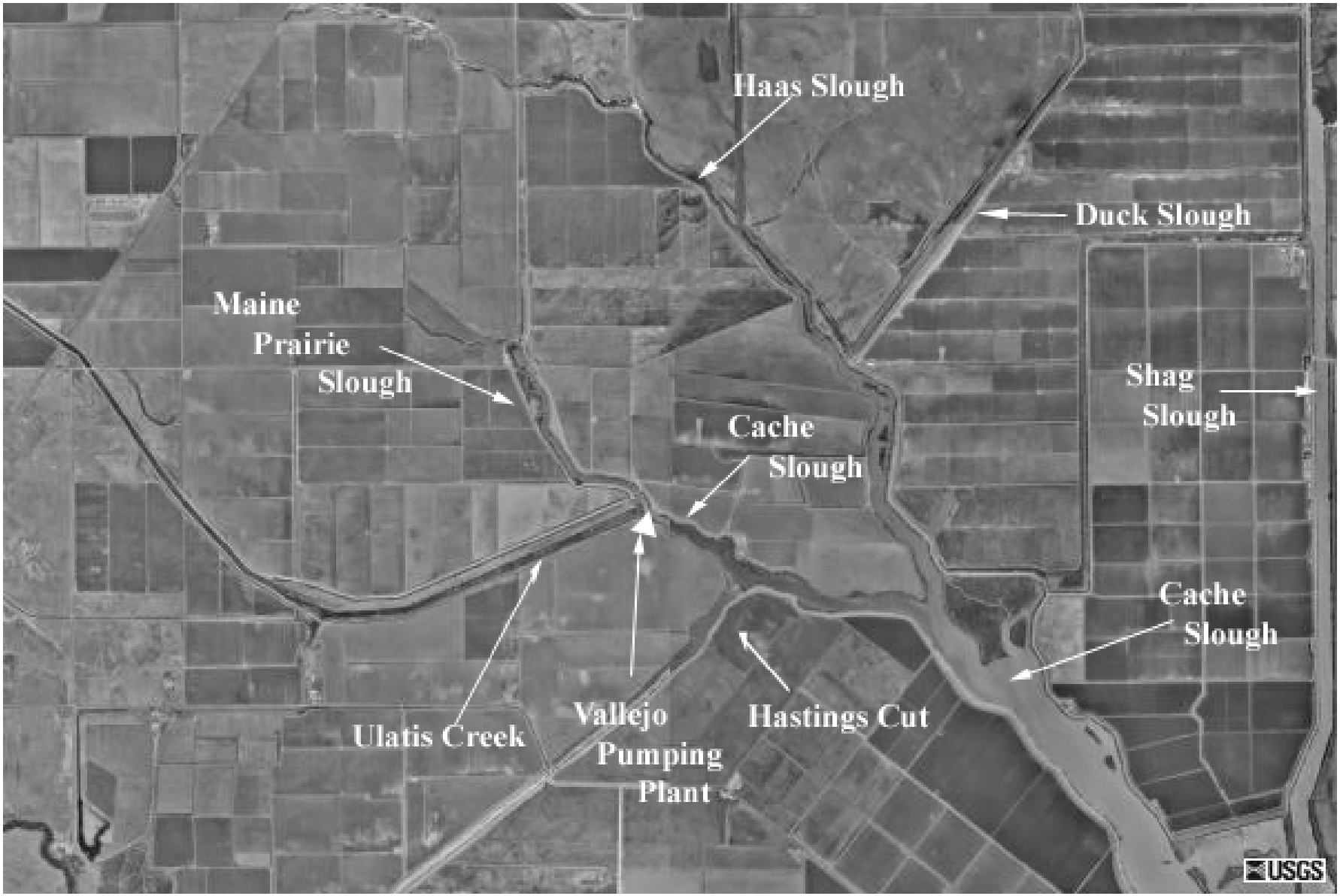


Figure 3-16. Cache Slough and Ulatis Creek within the Sacramento Valley floor.

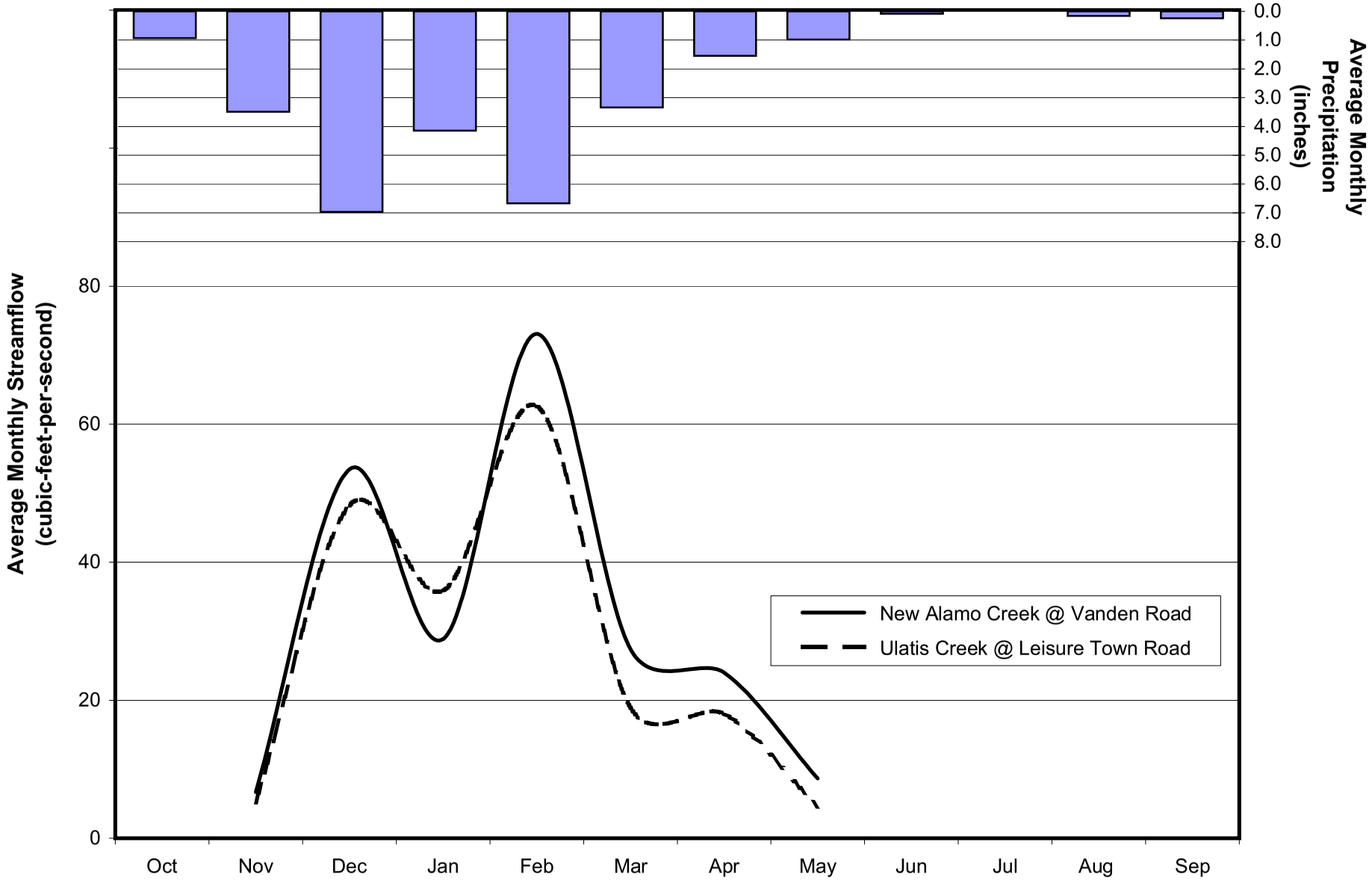


Figure 4-1. Average monthly precipitation for Vacaville (top) and average monthly streamflow for New Alamo and Ulatis Creeks (bottom). Water years 1998–2006. Source: National Climatic Data Center 2007.

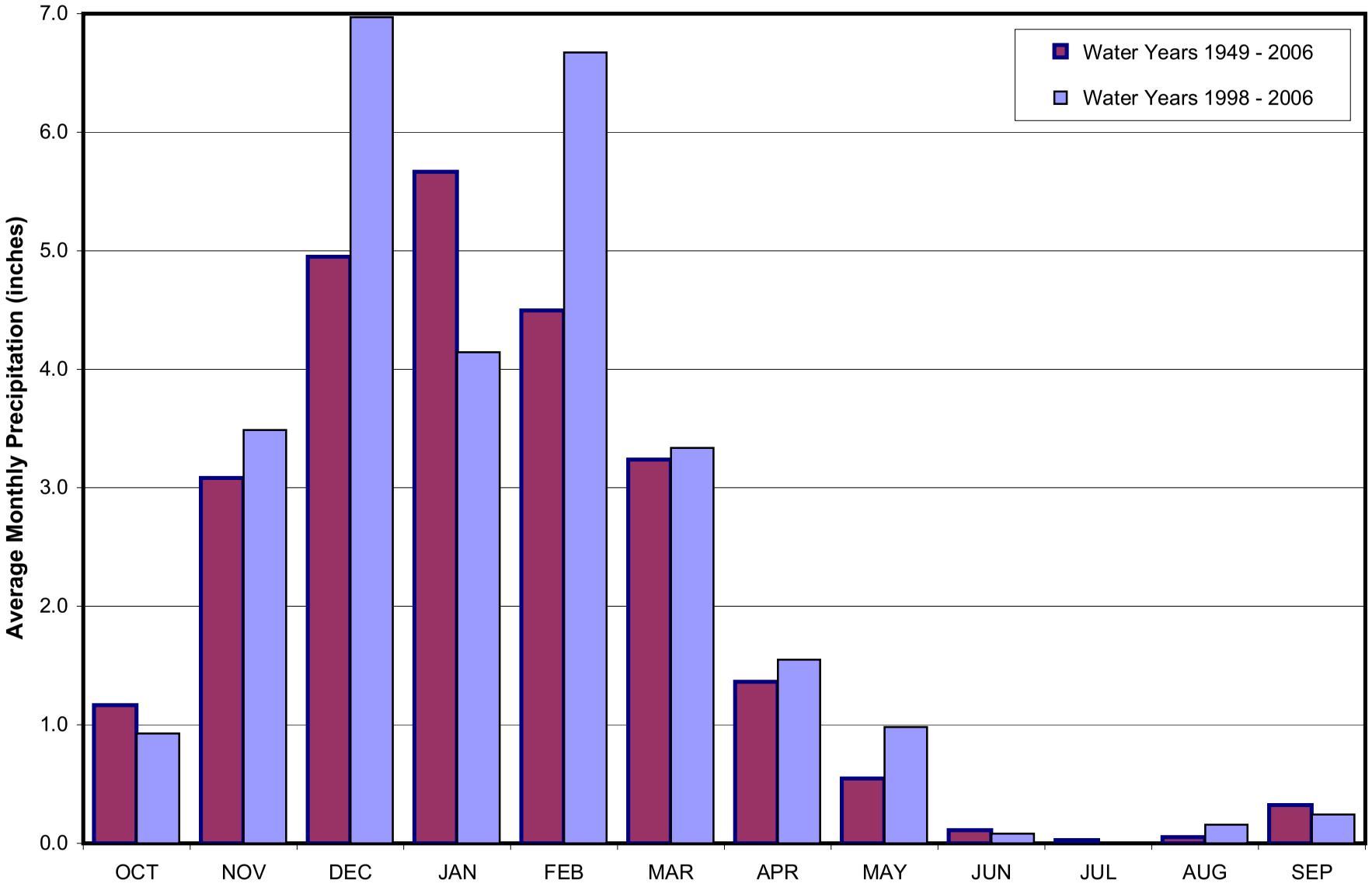


Figure 4-2. Average monthly precipitation for Vacaville. Water years 1949 to 2006. Source: National Climatic Data Center, Cooperative Gauge Num. 49200, 2007.

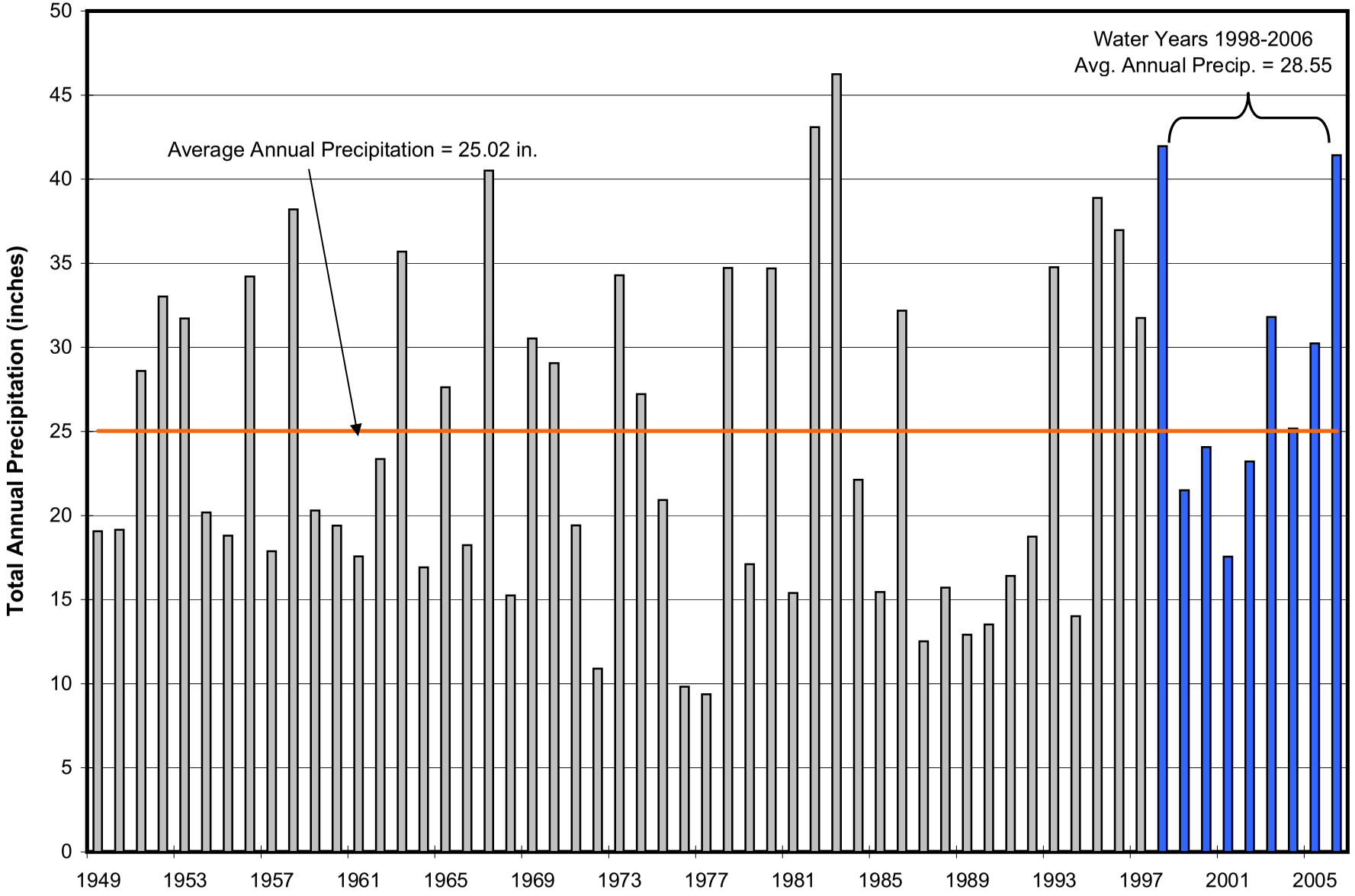


Figure 4-3. Total annual precipitation for Vacaville. Water years 1949 to 2006.
Source: National Climatic Data Center, Cooperative Gauge Num. 49200, 2007.

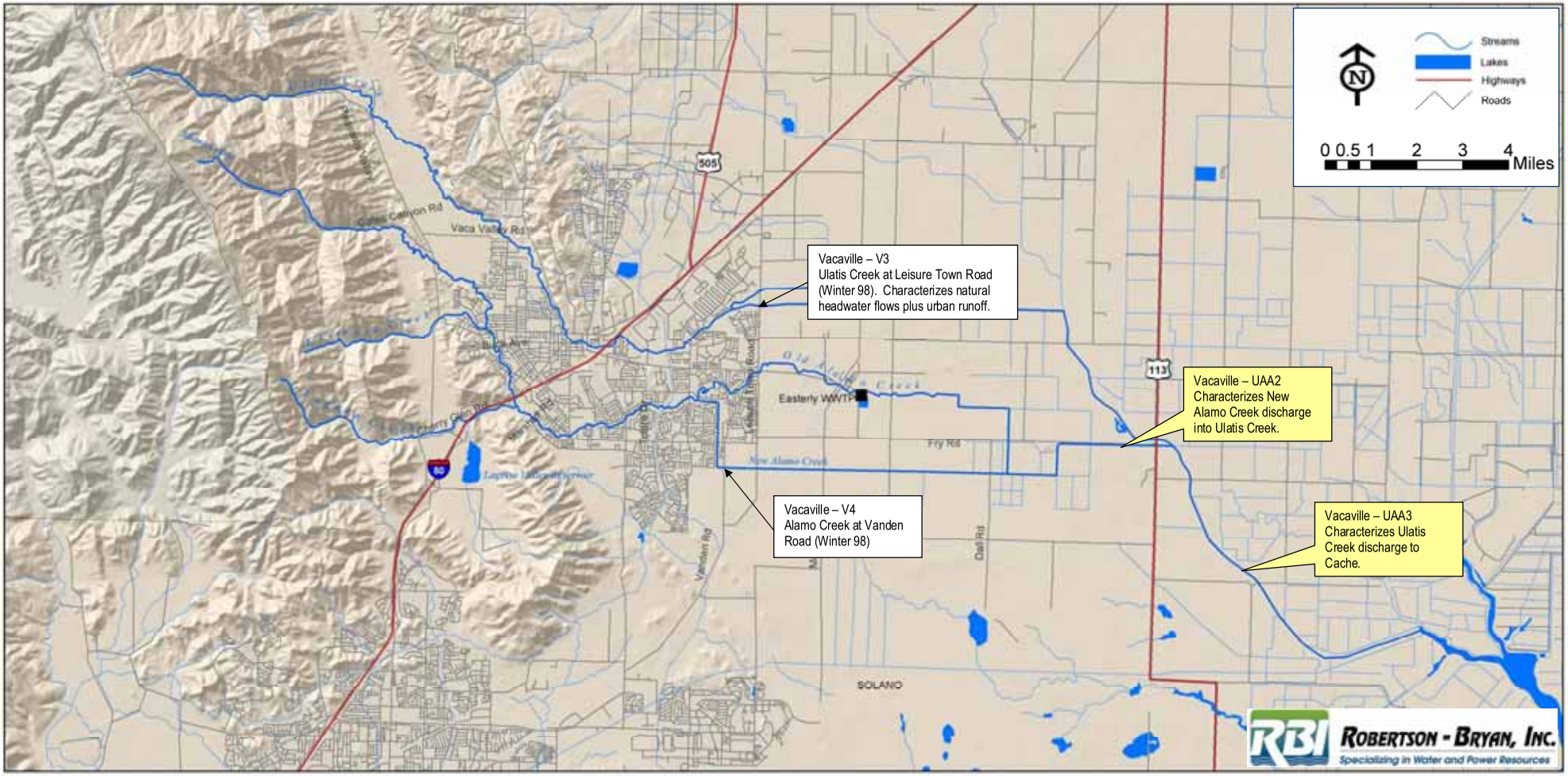


Figure 4-4. Stream gauging sites located on Ulatis and Alamo/New Alamos creeks.

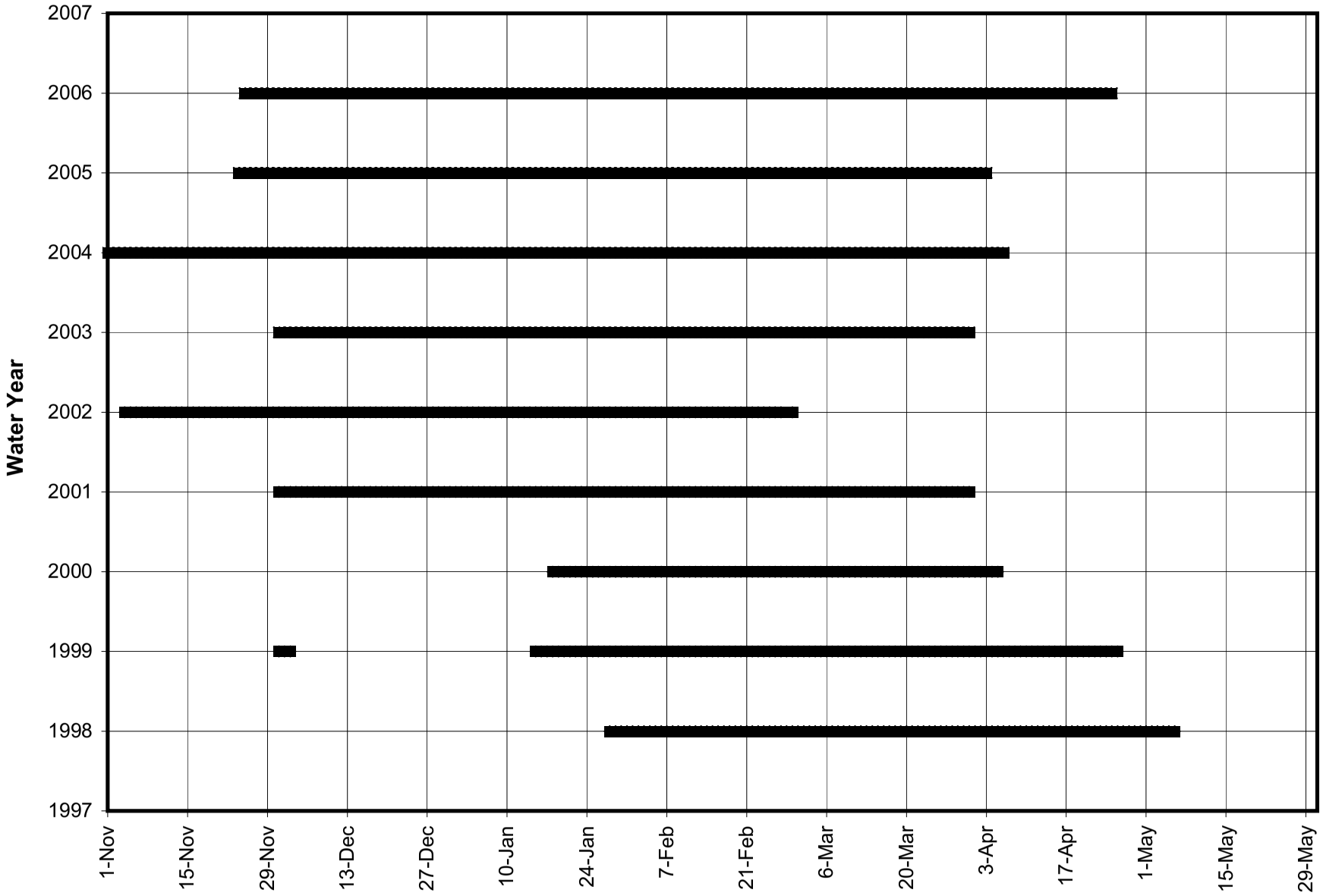


Figure 4-5. Annual recording periods for Ulatis Creek at Leisure Town Road (gage V3). Water years 1998-2006.
Source: City of Vacaville, 1998–2006.

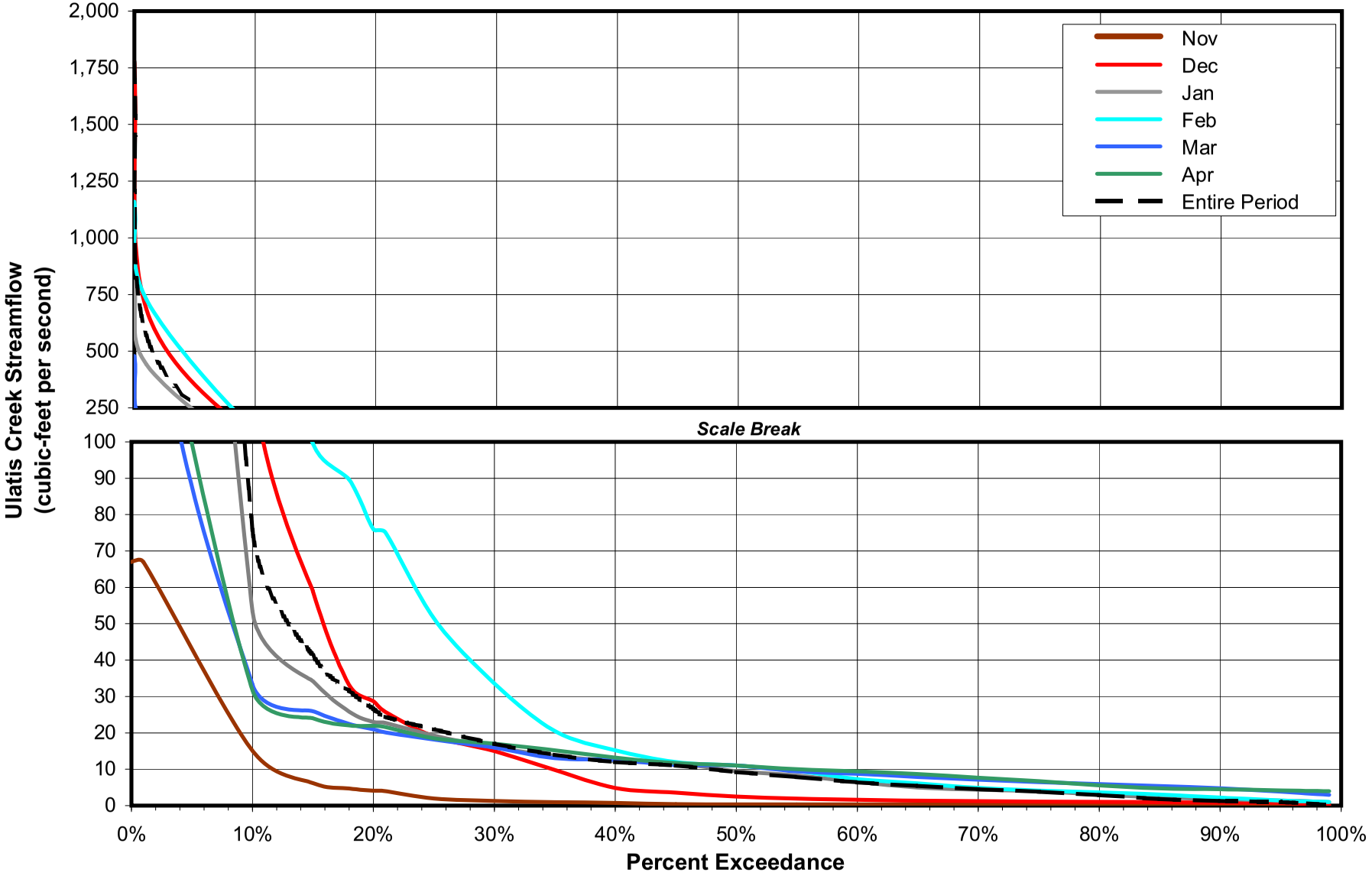


Figure 4-6. Percent exceedance of daily average streamflow during precipitation season. Ulatis Creek at Leisure Town Road. Water years 1998–2006. Note: Nov = 70 values; Dec = 189 values; Jan = 221 values; Feb = 253 values; Mar = 248 values; Apr = 95 values. See Figure 4.5 for specific year and month recording periods. Source: City of Vacaville, 1998–2006.

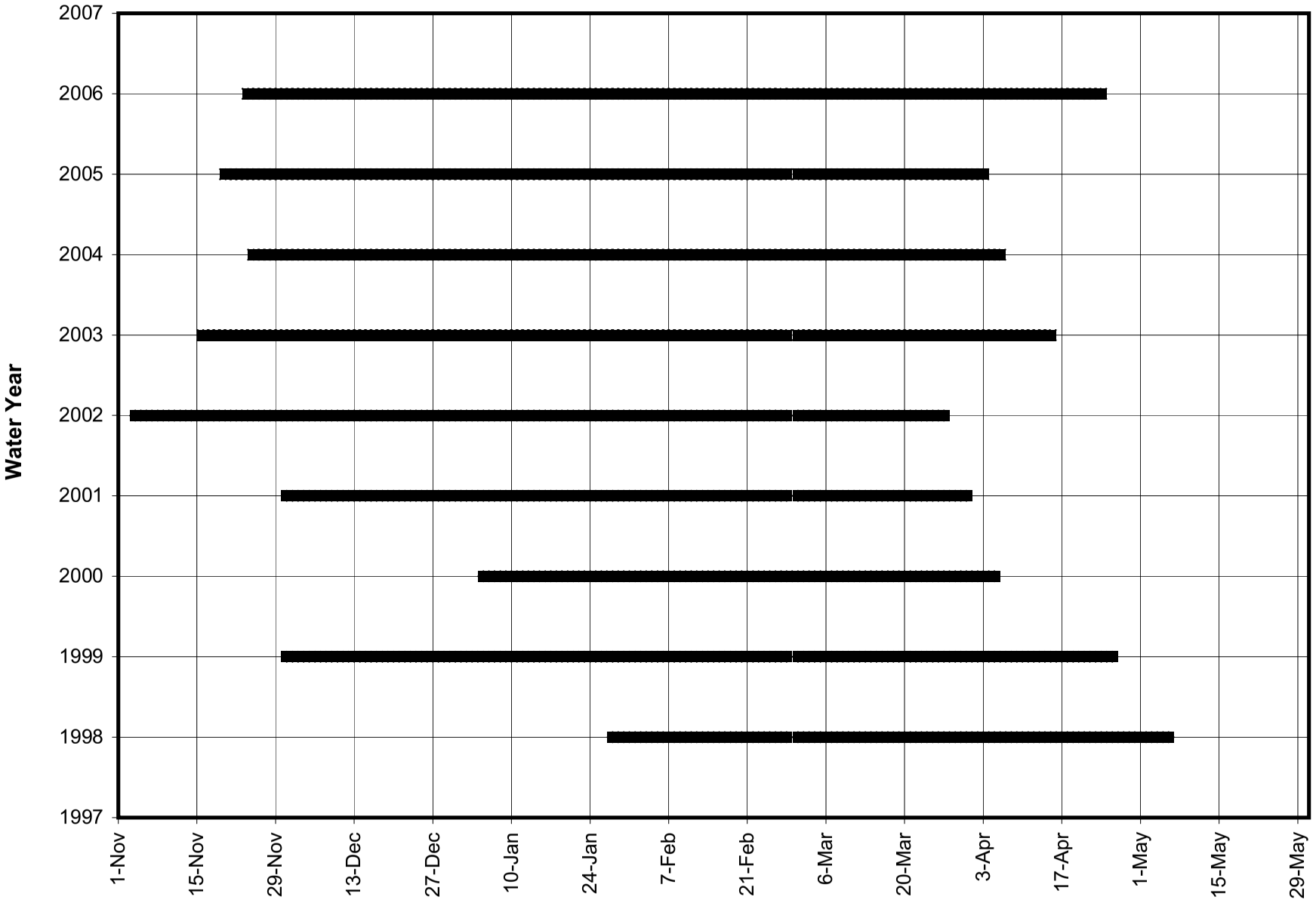


Figure 4-7. Annual recording periods for New Alamo Creek at Vanden Road (gage V4). Water years 1998–2006.
Source: City of Vacaville, 1998–2006.

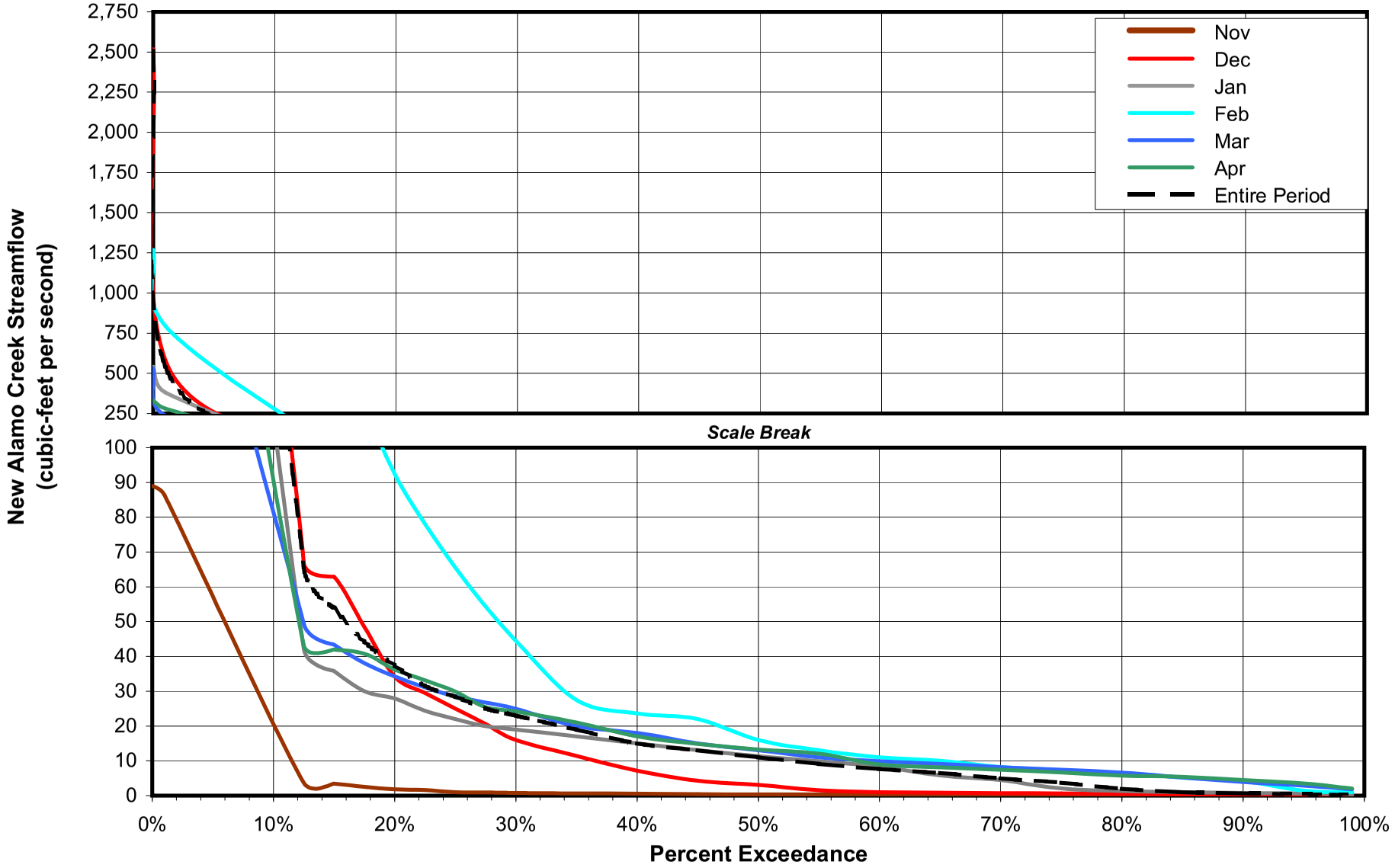


Figure 4-8. Percent exceedance of daily average streamflow during precipation season. New Alamo Creek at Vanden Road. Water years 1998-2006. Note: Nov = 65 values; Dec = 217 values; Jan = 248 values; Feb = 254 values; Mar = 275 values; Apr = 110 values. See Figure 4.7 for specific year and month recording periods. Source: City of Vacaville, 1998–2006.

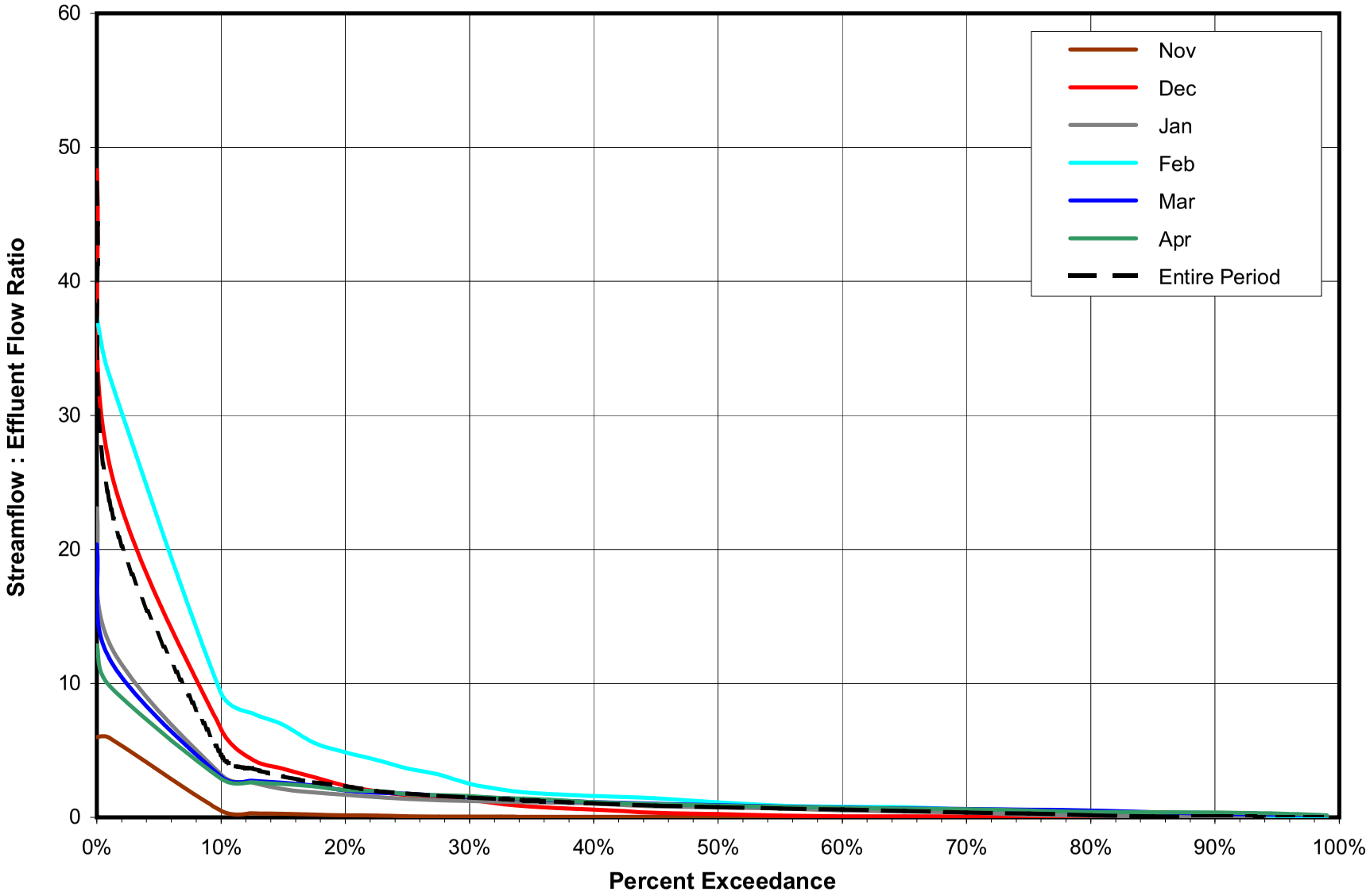


Figure 4-9. Approximate ratio of New Alamo Creek flow rate to Easterly WWTP effluent discharge flow rate immediately below confluence of Old Alamo Creek. Ratio based on Vanden Road gauged data and measured Easterly WWTP discharge for specified period of Water Years 1998–2006. Streamflow contributions from Old Alamo Creek and New Alamo Creek between Vanden Road and Old Alamo Creek are not considered.

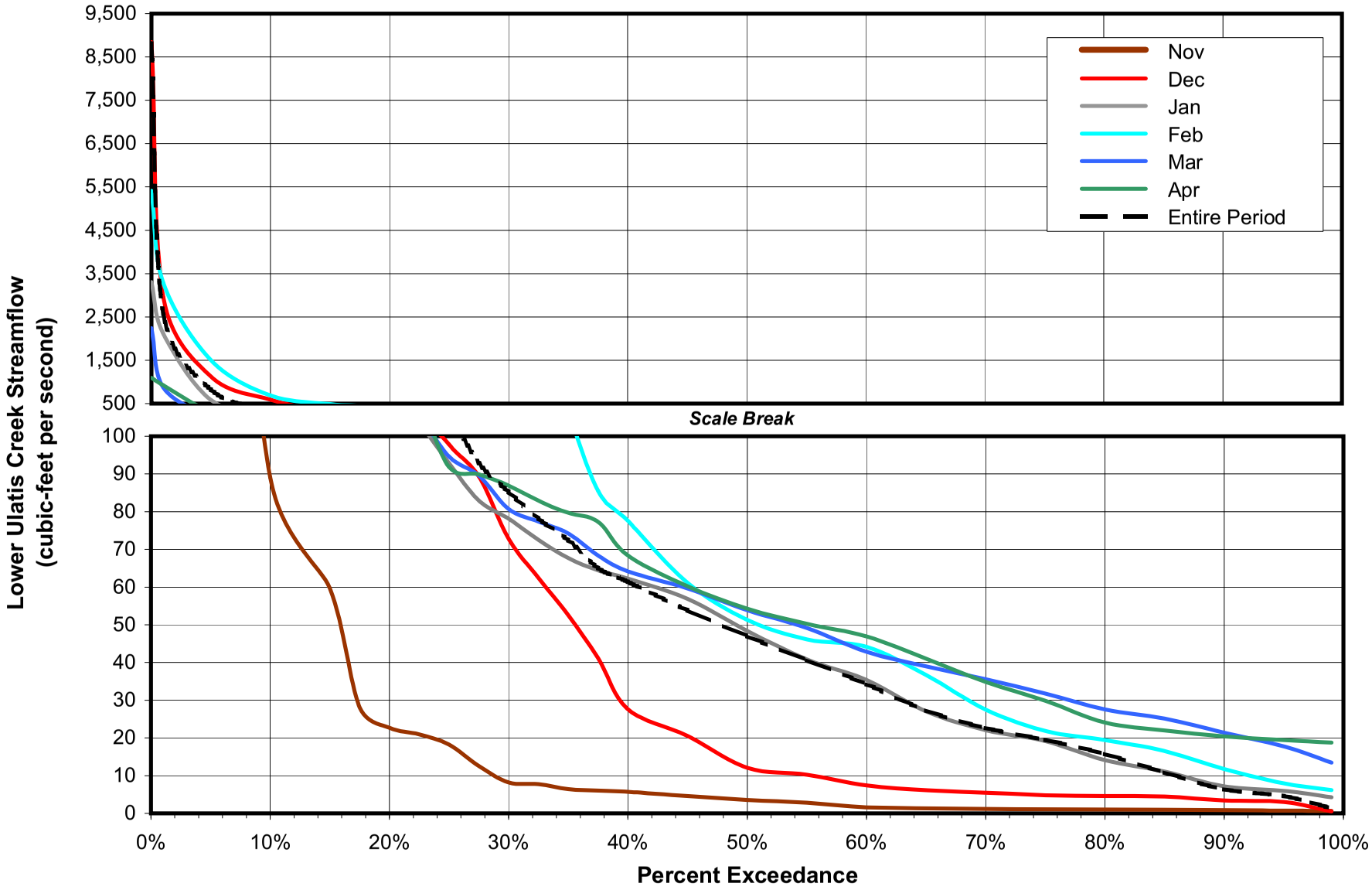


Figure 4-10. Estimated percent exceedance of daily average streamflow during precipitation season. Lower Ulatis Creek immediately downstream of New Alamo Creek. Water years 1998-2006. Note: Nov = 46 values; Dec = 189 values; Jan = 221 values; Feb = 253 values; Mar = 248 values; Apr = 95 values.

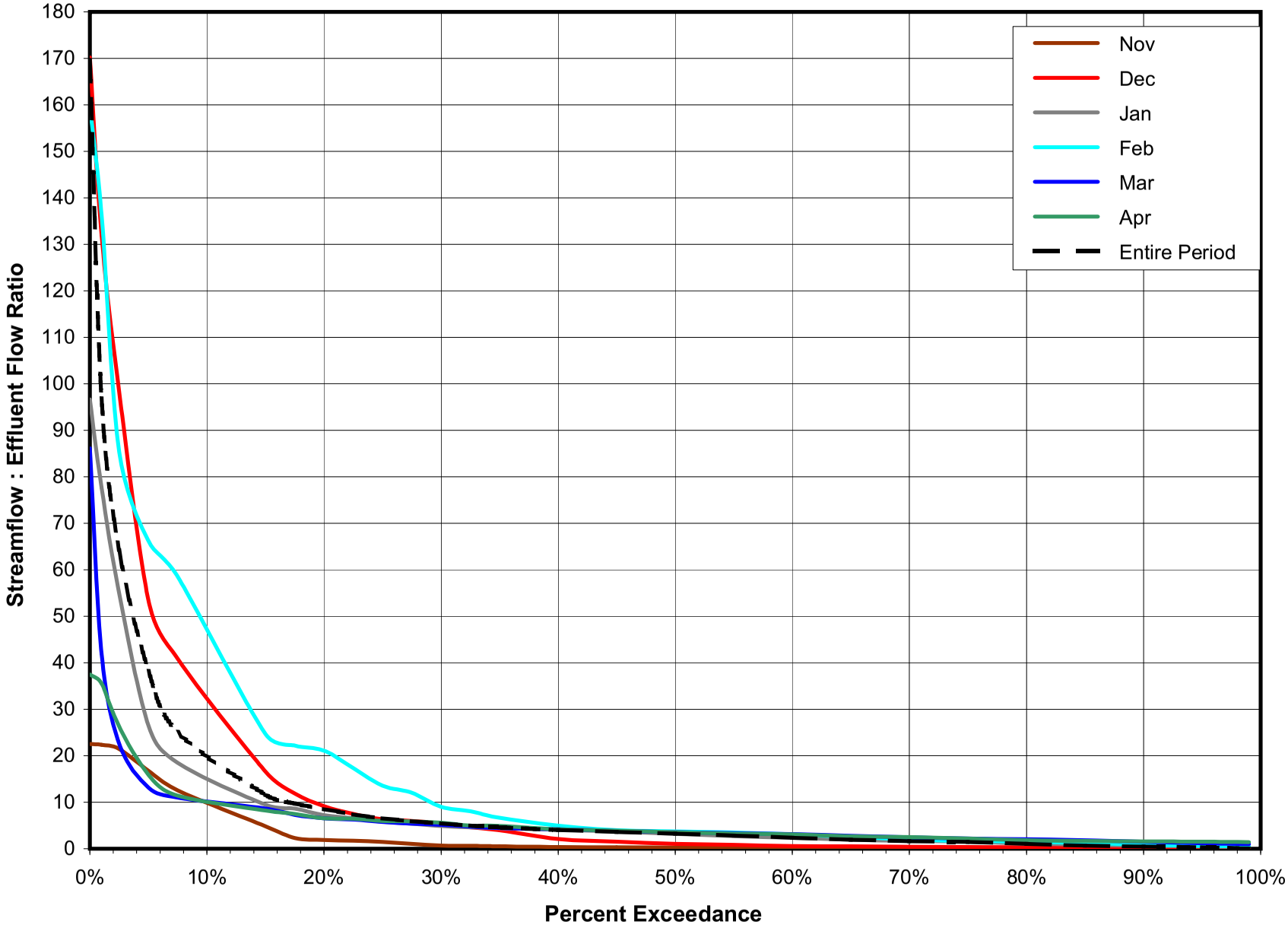


Figure 4-11. Approximate ratio of Lower Ulatis Creek flow rate to Easterly WWTP effluent discharge flow rate immediately below confluence of New Alamo Creek. Water Years 1998–2006.

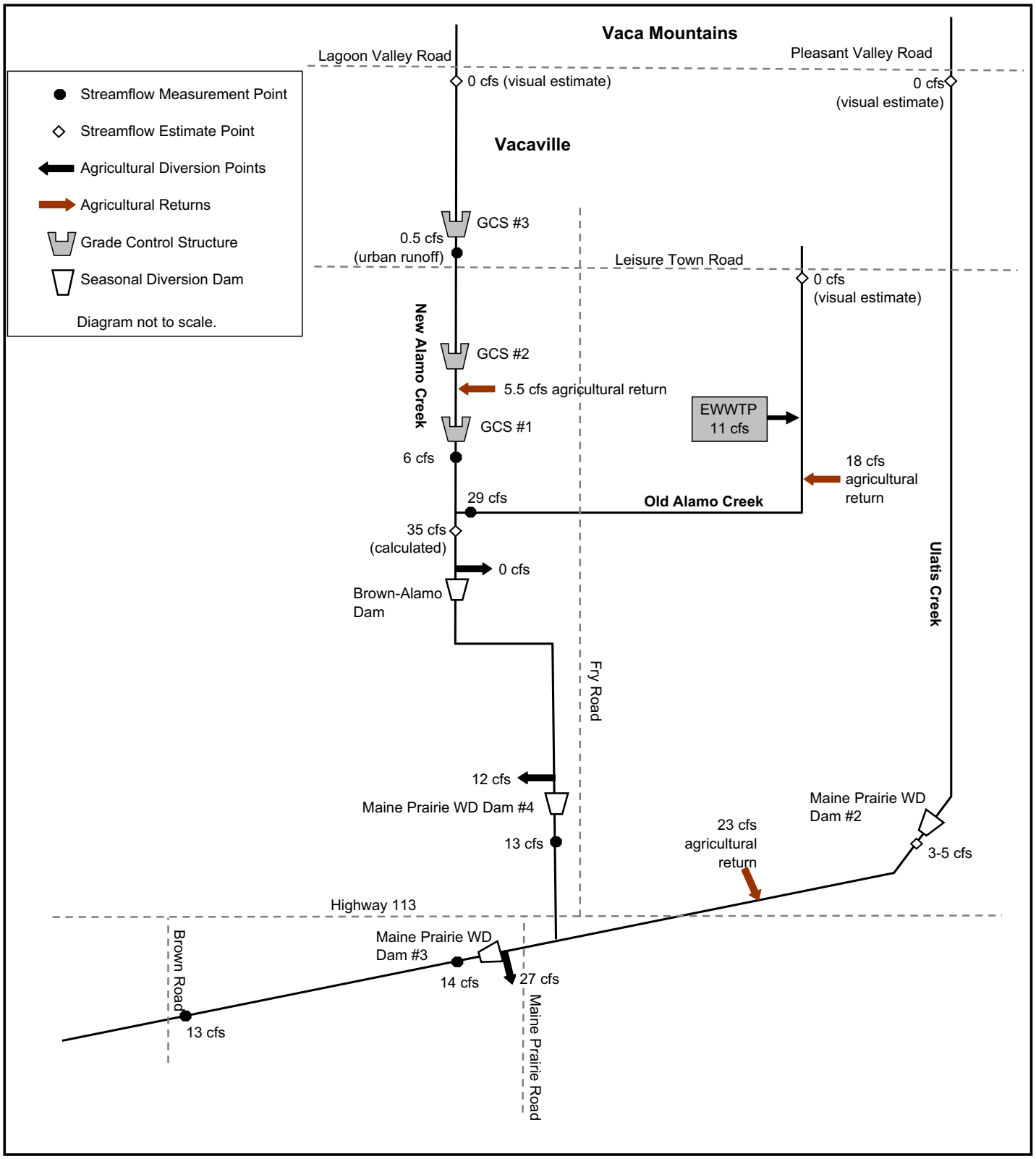


Figure 4-12. Schematic of Alamo/New Alamo and Ulatis creeks flow measurements and diversions for July 27, 2004.

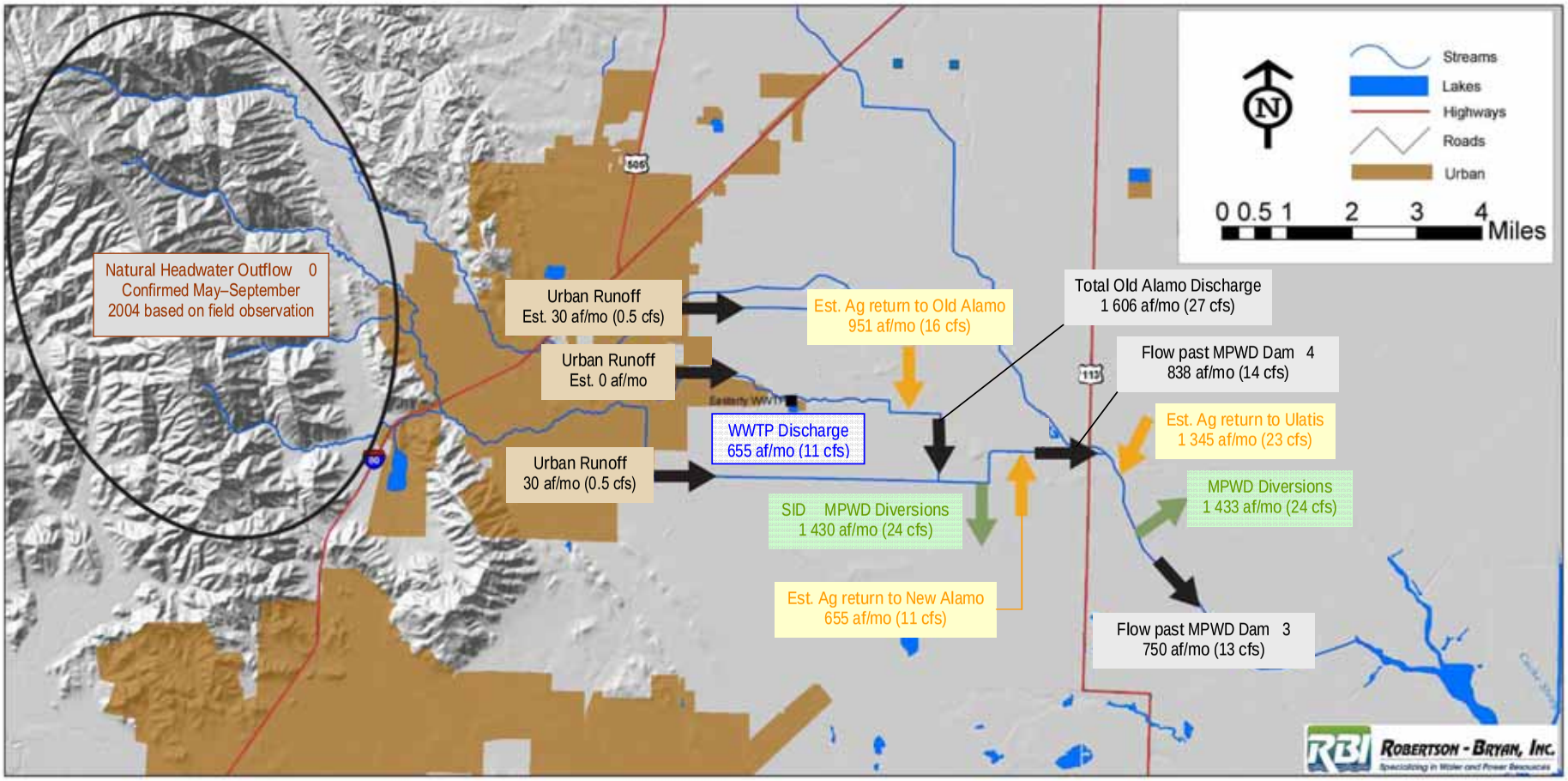


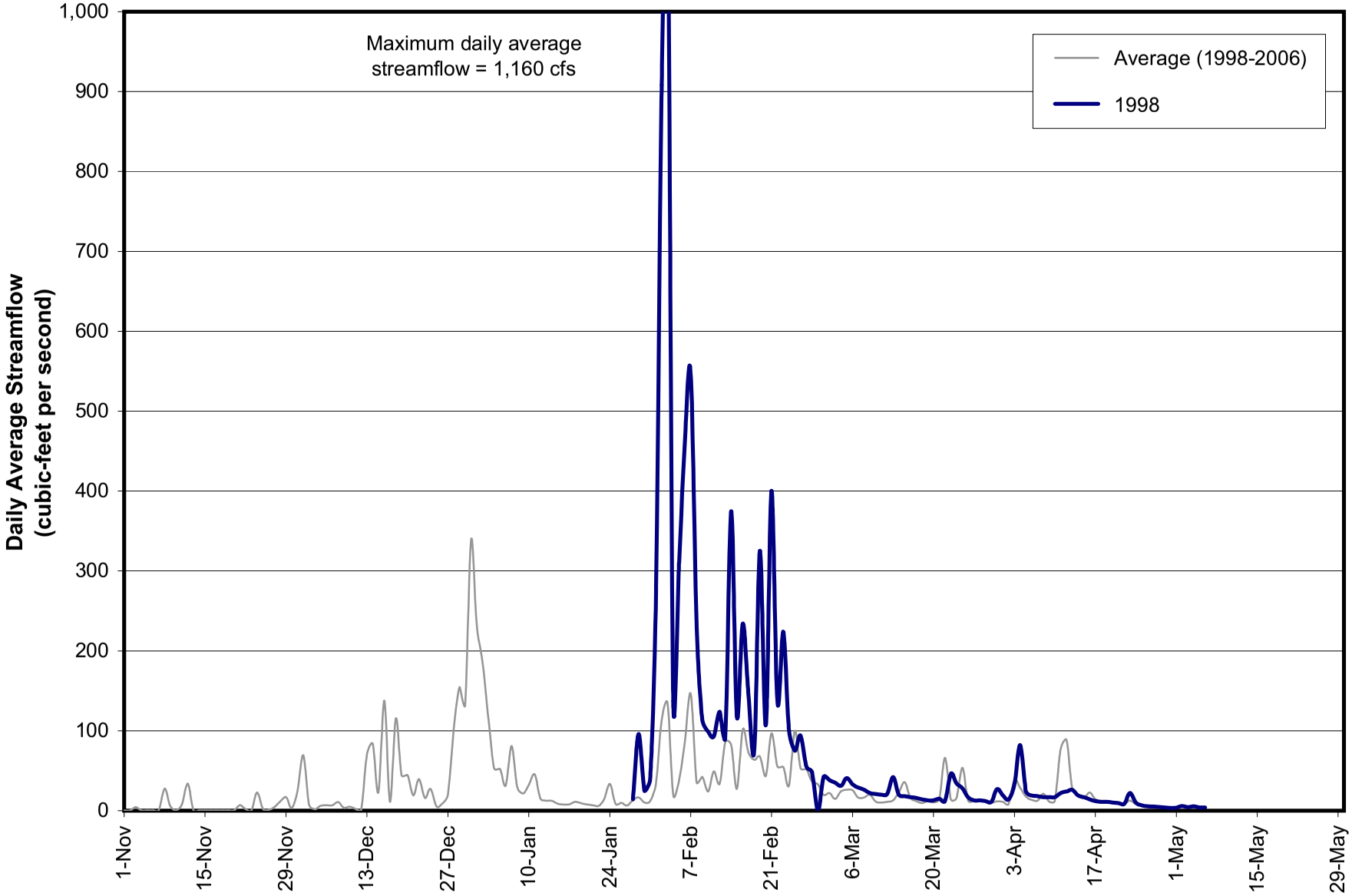
Figure 4-13. Characterization of summer season (May–Oct) hydrology for Ulatis and Alamos/New Alamo creeks.
Source: Maine Prairie Water District 2004, City of Vacaville 2004.

APPENDICES

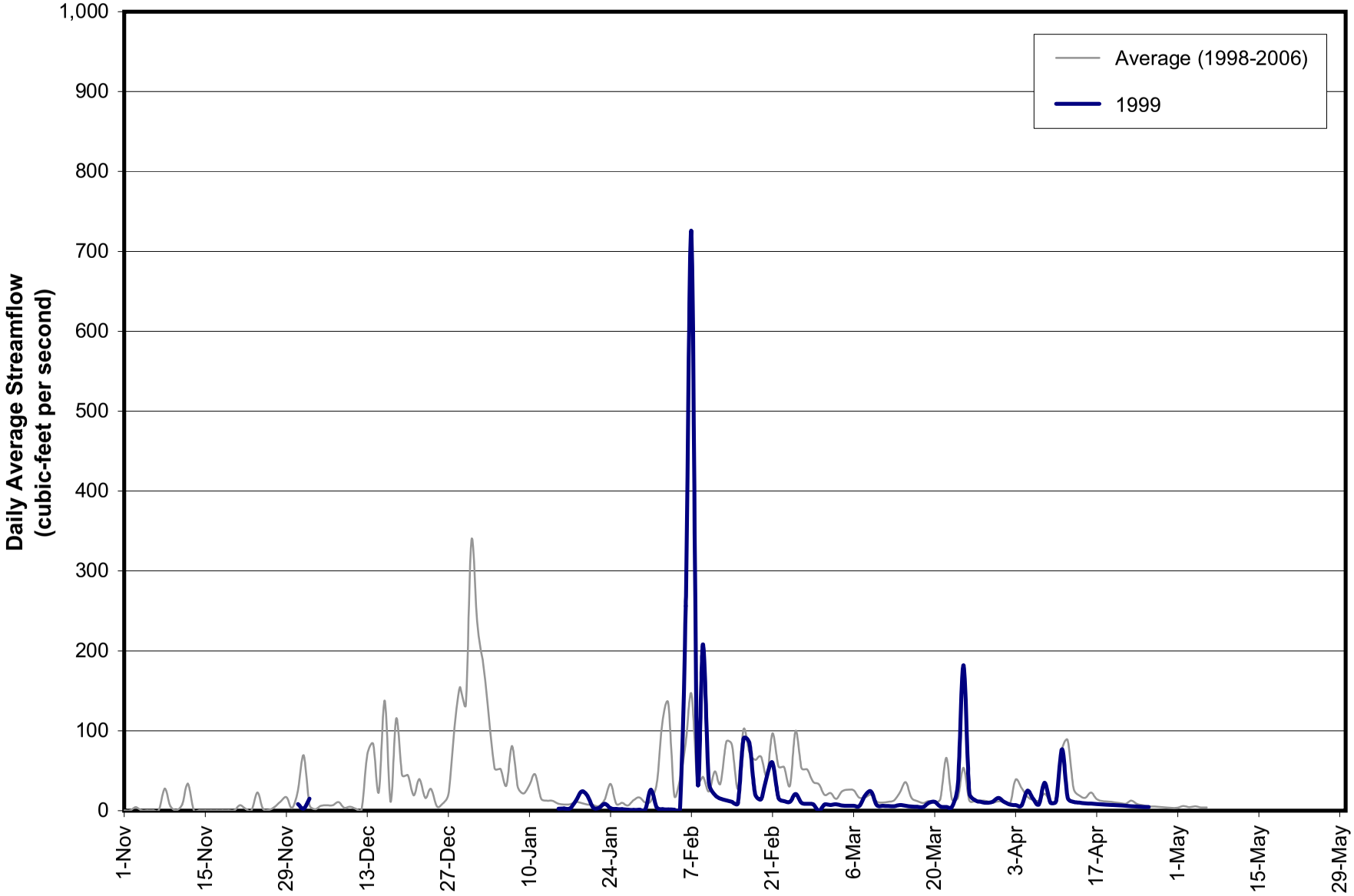
APPENDIX A

ULATIS CREEK DAILY AVERAGE STREAMFLOW FOR PRECIPITATION SEASON LEISURE TOWN ROAD

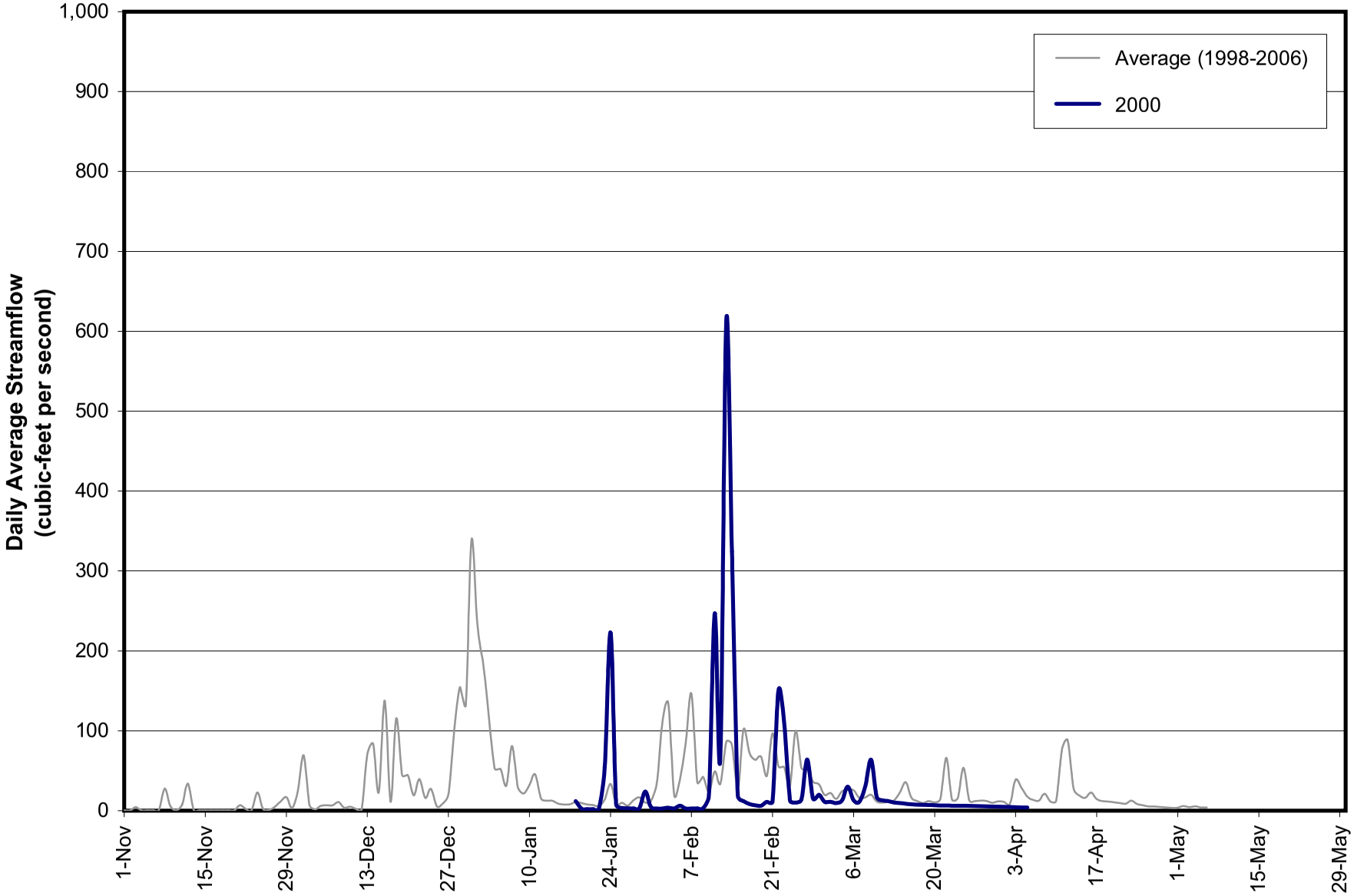
WATER YEARS 1998–2006



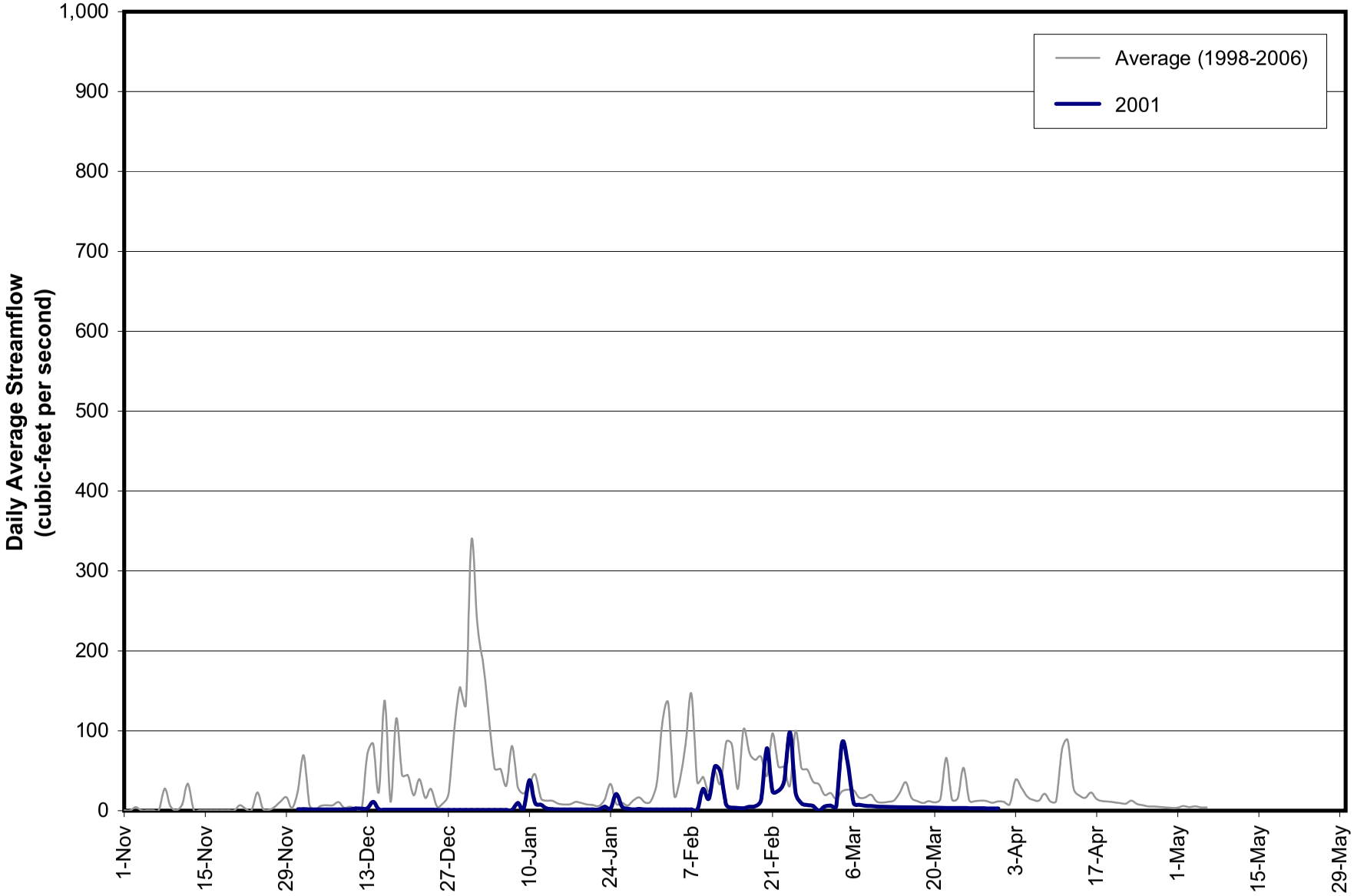
Appendix A (1998). Ulatis Creek daily average streamflow at Leisure Town Road during precipitation season. Water year 1998 (wet year). Water year hydrologic classifications based on Sacramento Valley Water Year Index. Data source: City of Vacaville, 1998.



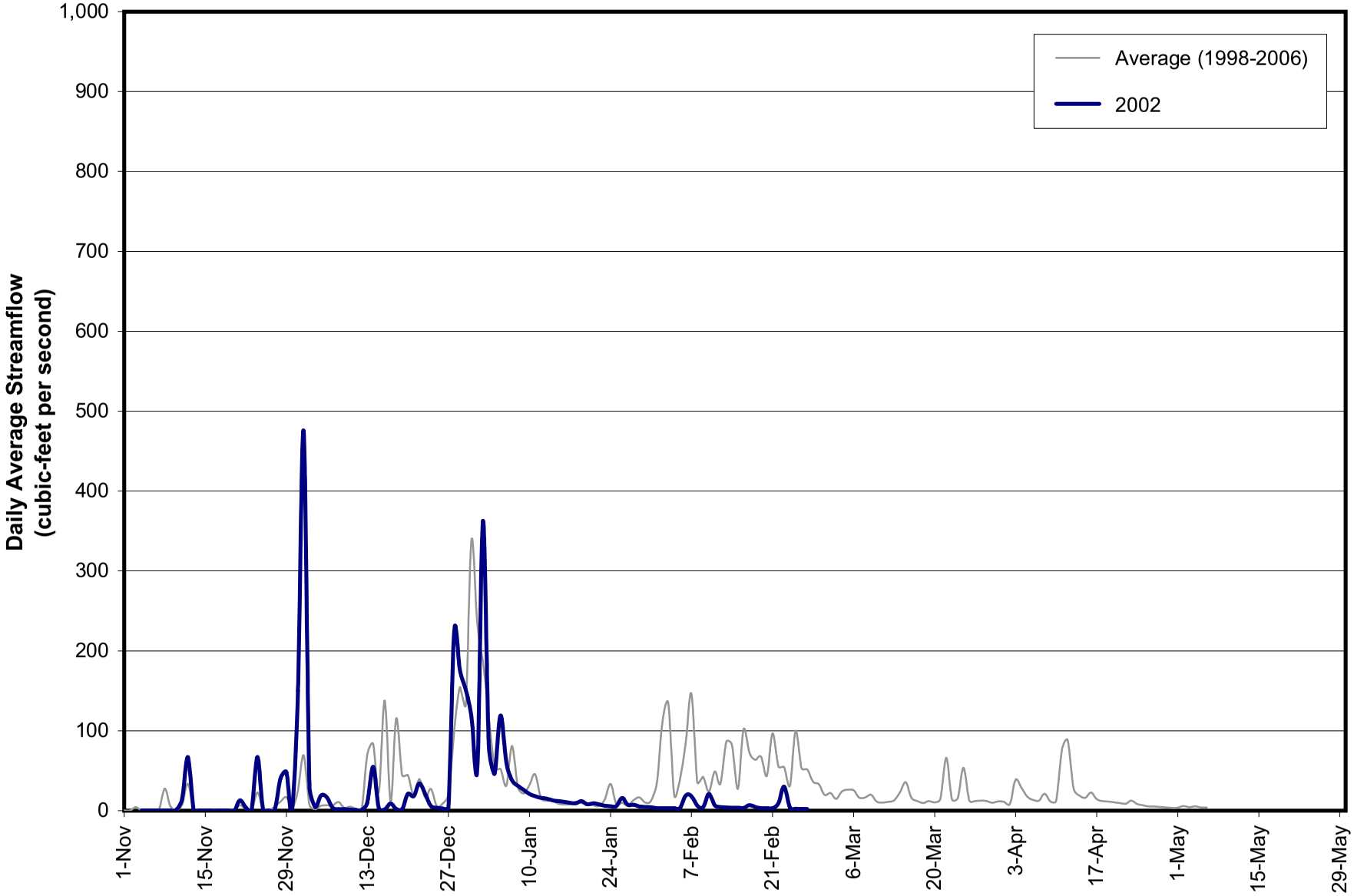
Appendix A (1999). Ulatis Creek daily average streamflow at Leisure Town Road during precipitation season. Water year 1999 (Wet year). Water year hydrologic classifications based on Sacramento Valley Water Year Index. Source: City of Vacaville, 1999.



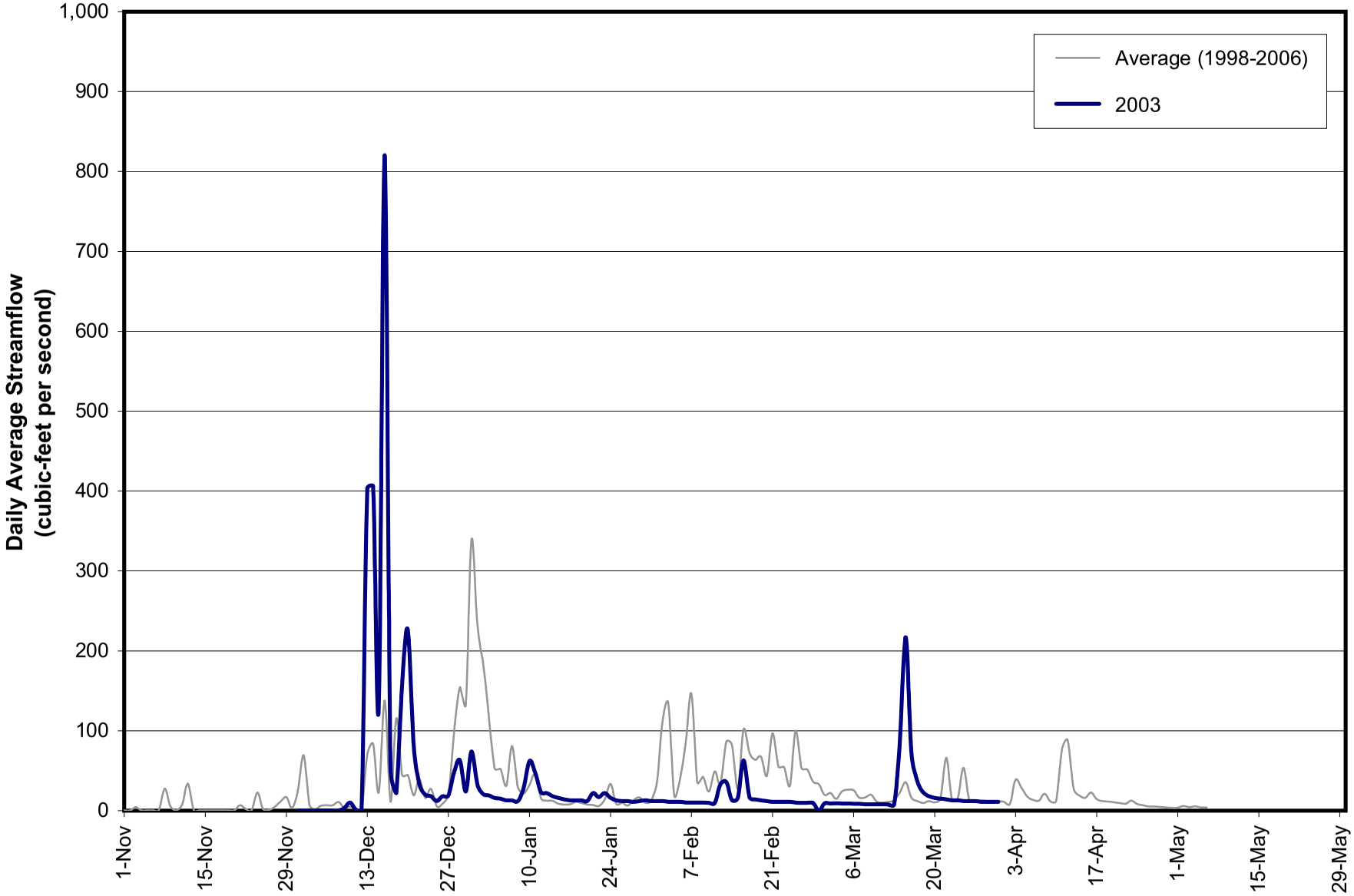
Appendix A (2000). Ulatis Creek daily average streamflow at Leisure Town Road during precipitation season. Water year 2000 (Above normal year). Water year hydrologic classifications based on Sacramento Valley Water Year Index. Source: City of Vacaville, 2000.



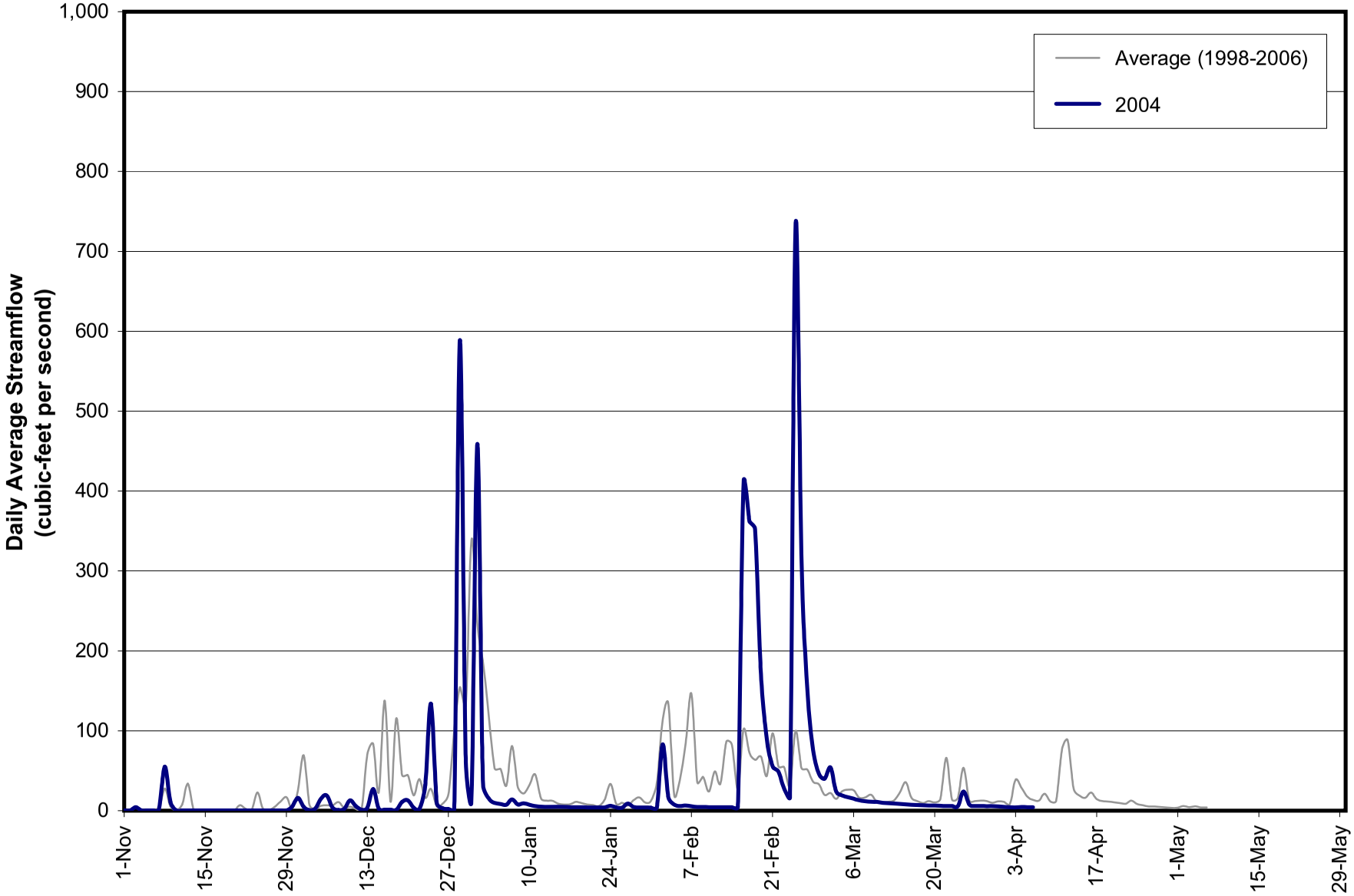
Appendix A (2001). Ulatis Creek daily average streamflow at Leisure Town Road during precipitation season. Water year 2001 (Dry year). Water year hydrologic classifications based on Sacramento Valley Water Year Index. Source: City of Vacaville, 2001.



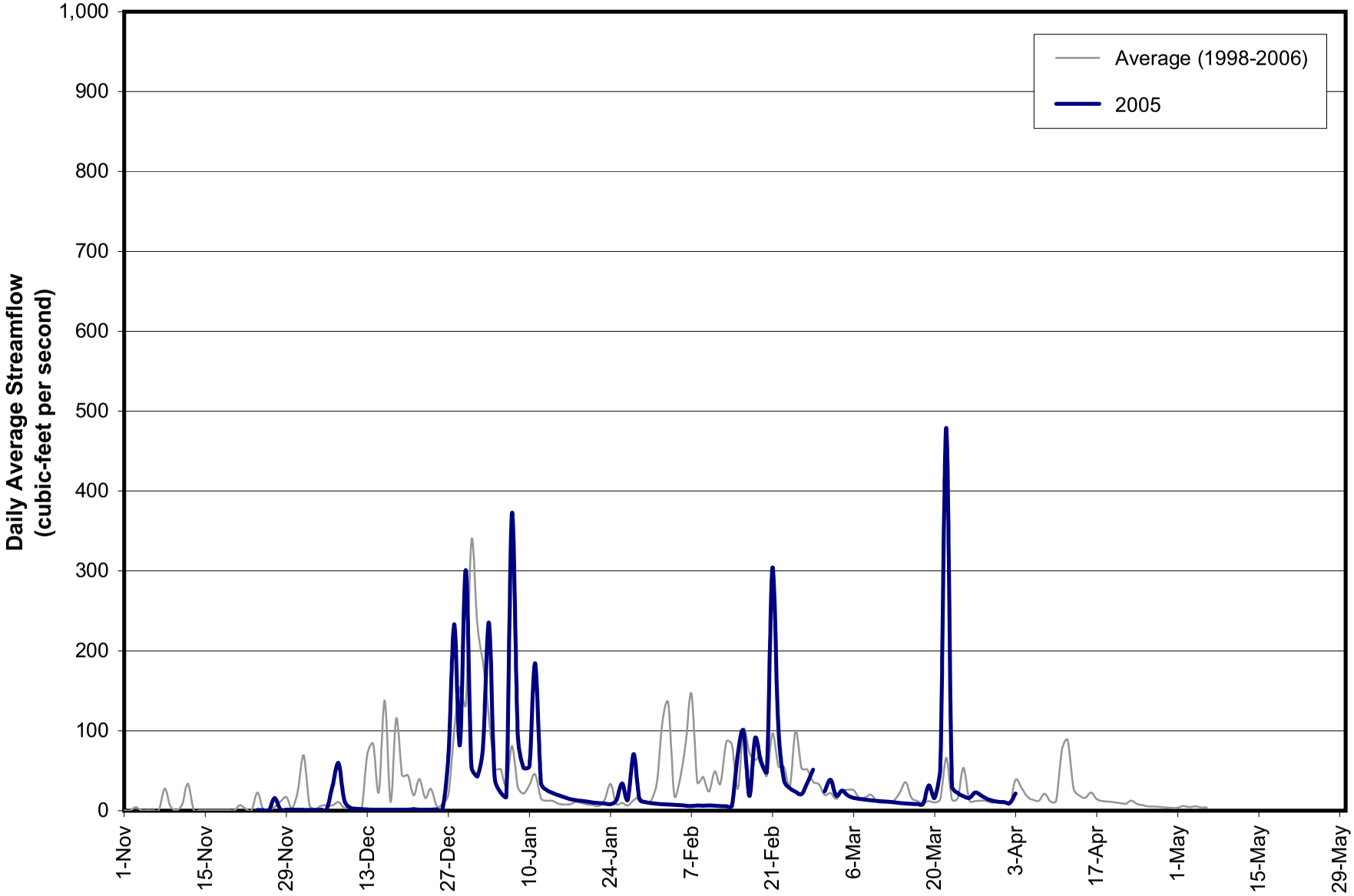
Appendix A (2002). Ulatis Creek daily average streamflow at Leisure Town Road during precipitation season. Water year 2002 (Dry year). Water year hydrologic classifications based on Sacramento Valley Water Year Index. Source: City of Vacaville, 2002.



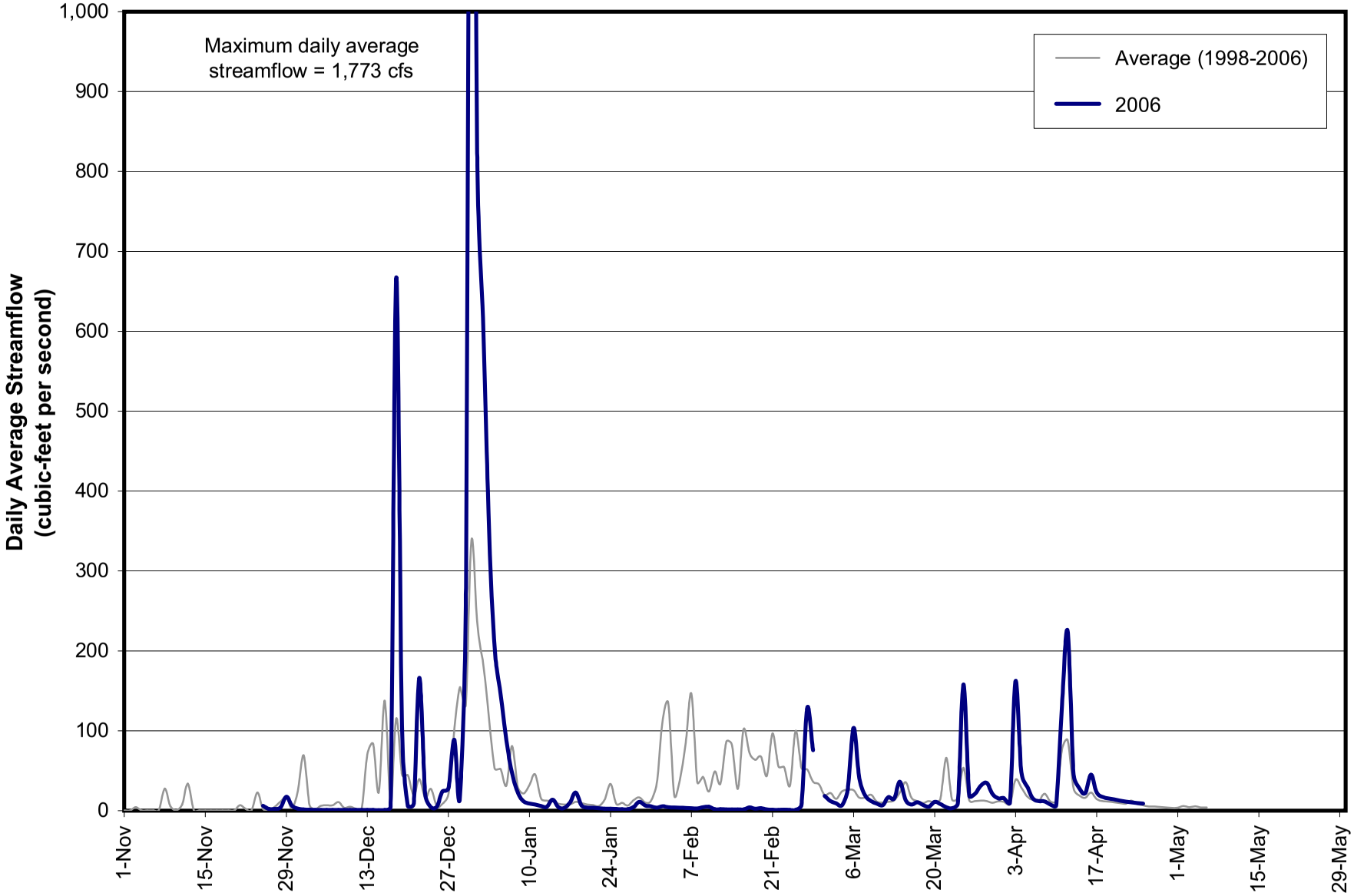
Appendix A (2003). Ulatis Creek daily average streamflow at Leisure Town Road during precipitation season. Water year 2003 (Above normal year). Water year hydrologic classifications based on Sacramento Valley Water Year Index. Source: City of Vacaville, 2003.



Appendix A (2004). Ulatis Creek daily average streamflow at Leisure Town Road during precipitation season. Water year 2004 (Below normal year). Water year hydrologic classifications based on Sacramento Valley Water Year Index. Source: City of Vacaville, 2004.



Appendix A (2005). Ulatis Creek daily average streamflow at Leisure Town Road during precipitation season. Water year 2005 (Above normal year). Water year hydrologic classifications based on Sacramento Valley Water Year Index. Source: City of Vacaville, 2005.

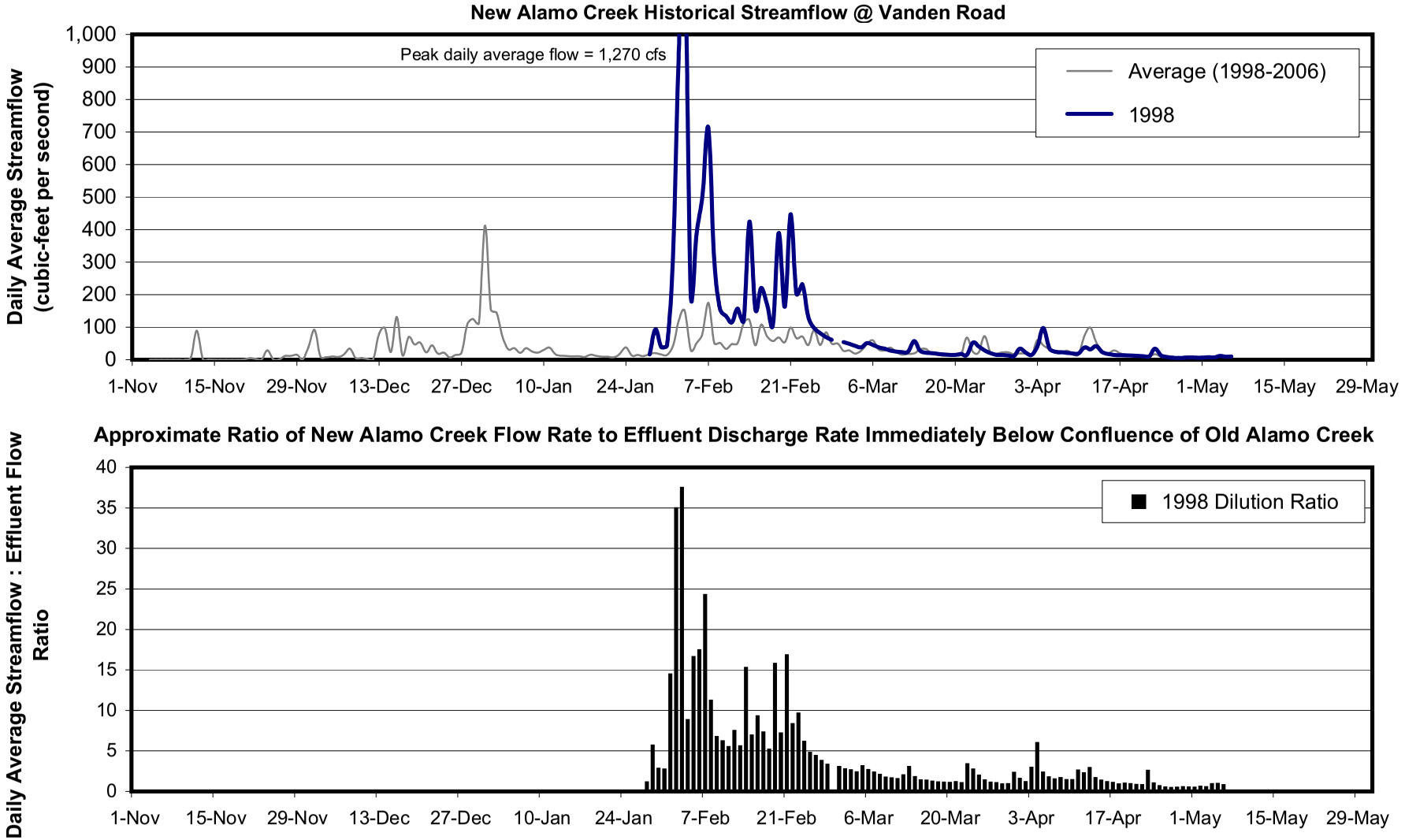


Appendix A (2006). Ulatis Creek daily average streamflow at Leisure Town Road during precipitation season. Water year 2006 (Wet year). Water year hydrologic classifications based on Sacramento Valley Water Year Index. Source: City of Vacaville, 2006.

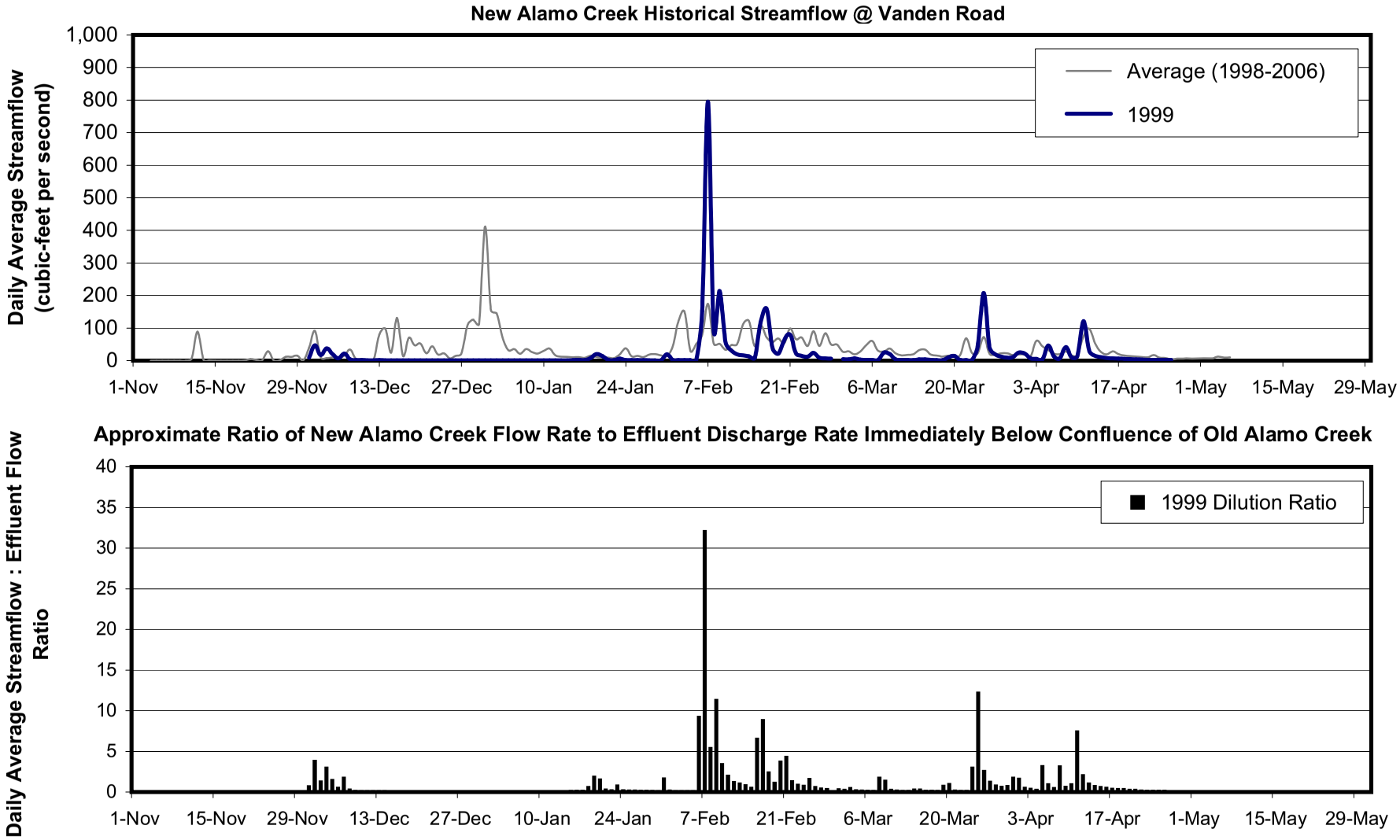
APPENDIX B

NEW ALAMO CREEK AVERAGE STREAMFLOW FOR PRECIPITATION SEASON AT VANDEN ROAD AND RATIO OF STREAMFLOW RATE TO EASTERLY WWTP EFFLUENT DISCHARGE FLOW RATE

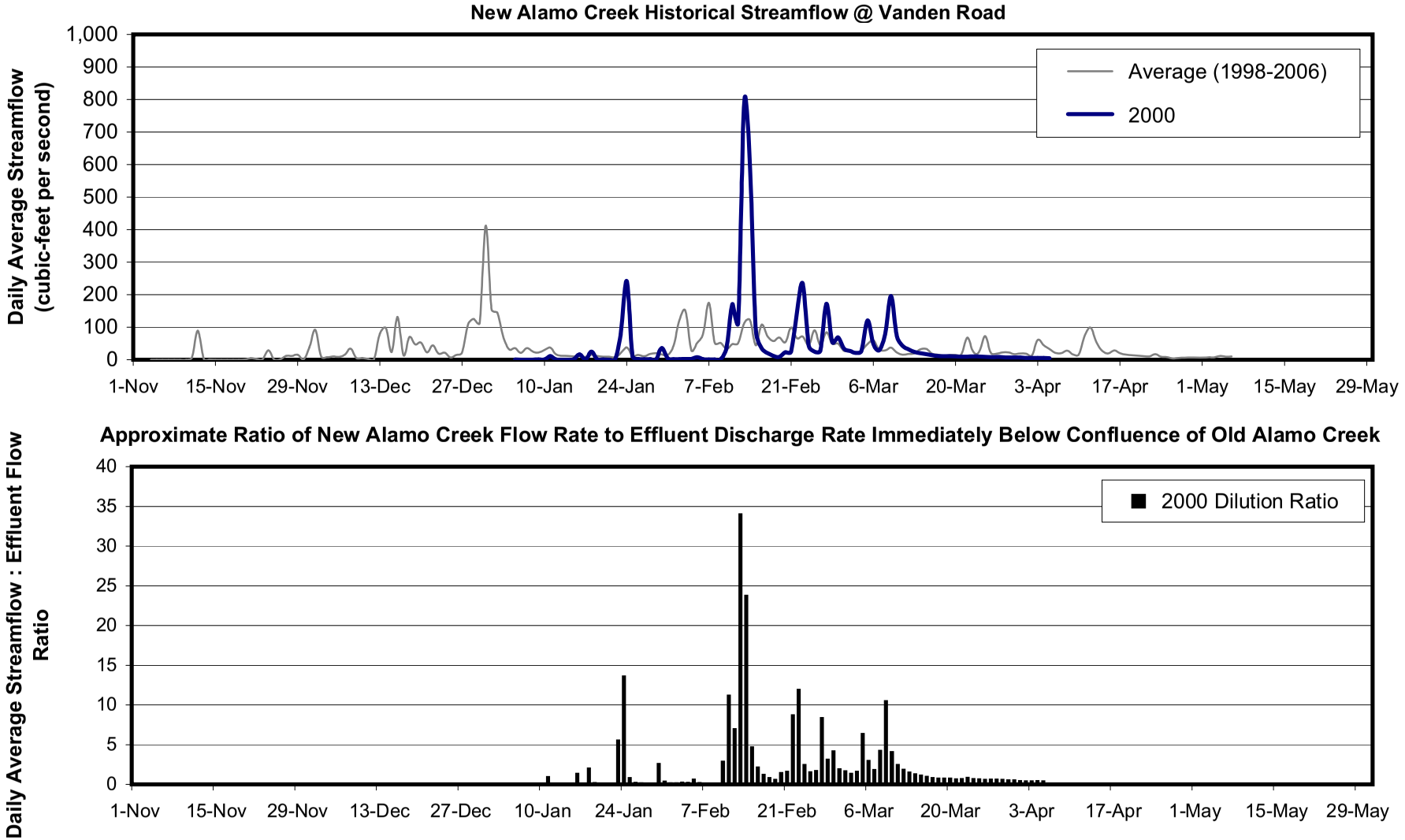
WATER YEARS 1998–2006



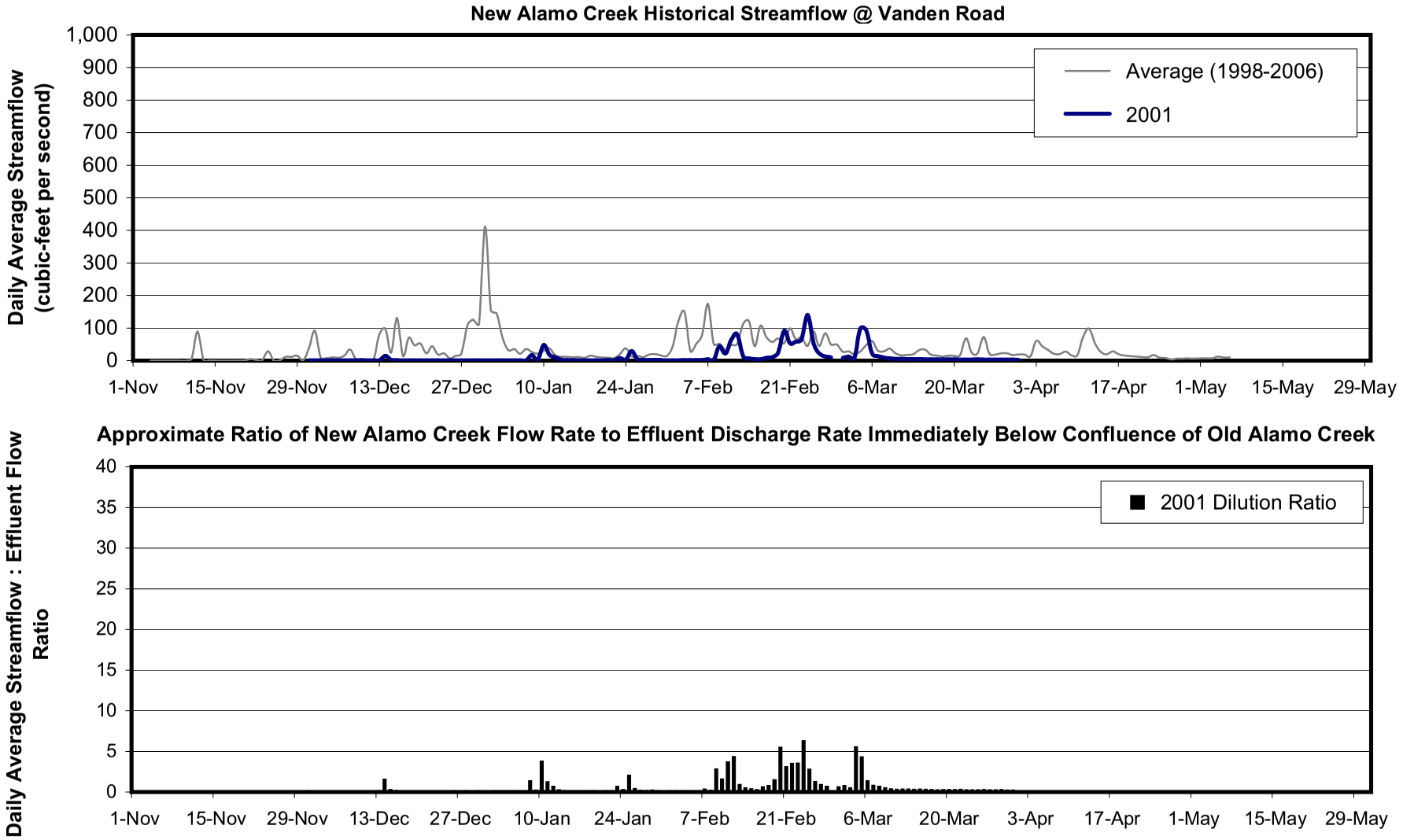
Appendix B (1998). New Alamo Creek precipitation season daily average streamflow (top) and approximate ratio of creek flow rate to Easterly WWTP effluent discharge rate (bottom). Water year 1998 (wet year). Water year hydrologic classifications based on Sacramento Valley Water Year Index. Flow ratio based on Vanden Road gauged data and measured Easterly WWTP discharge for specified period. Runoff contributions into Old Alamo Creek and New Alamo Creek between Vanden Road and the confluence with Old Alamo Creek are not considered. Sources: City of Vacaville, 1998-2006, 2006a.



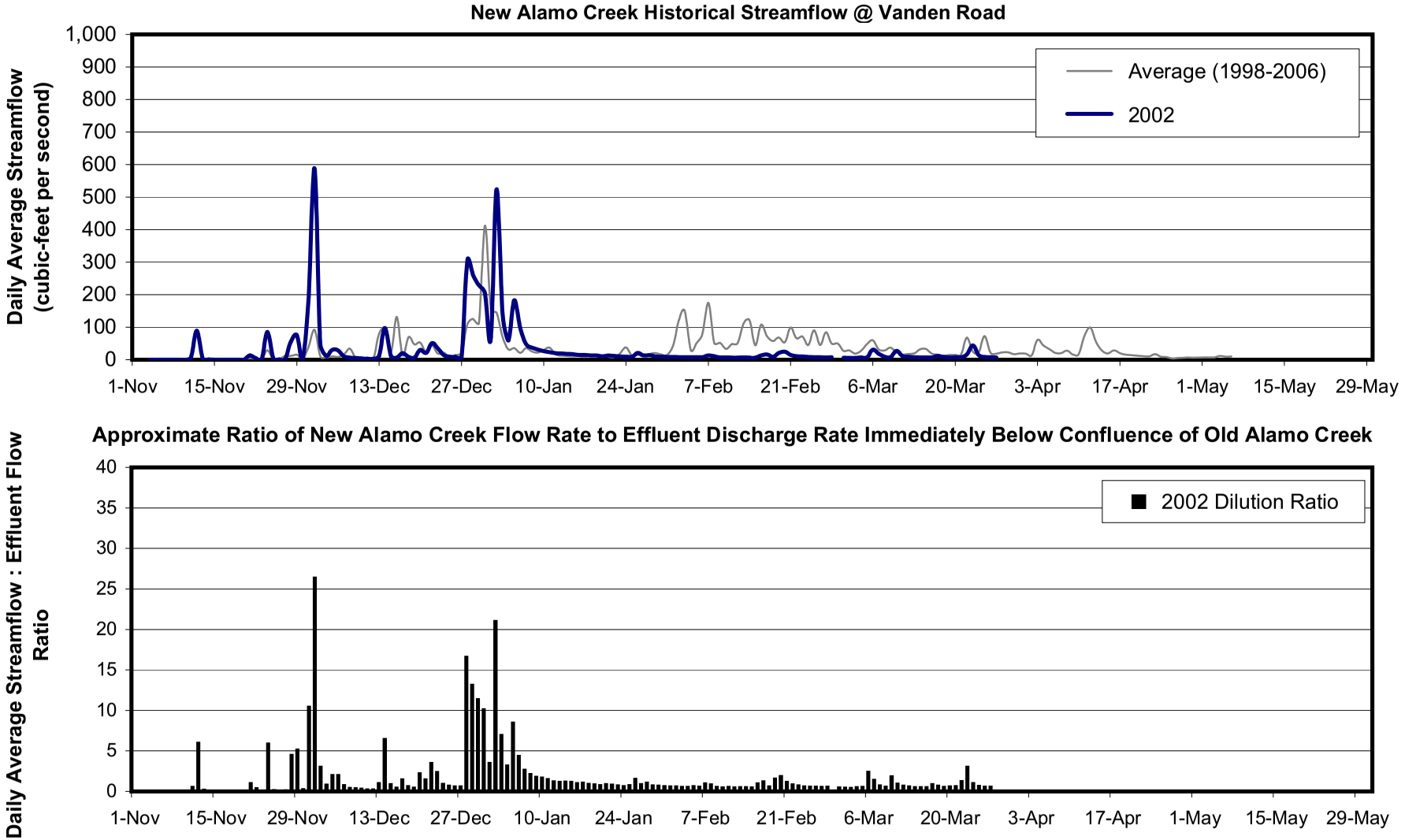
Appendix B (1999). New Alamo Creek precipitation season daily average streamflow (top) and approximate ratio of creek flow rate to Easterly WWTP effluent discharge rate (bottom). Water year 1999 (wet year). Water year hydrologic classifications based on Sacramento Valley Water Year Index. Flow ratio based on Vanden Road gauged data and measured Easterly WWTP discharge for specified period. Runoff contributions into Old Alamo Creek and New Alamo Creek between Vanden Road and the confluence with Old Alamo Creek are not considered. Sources: City of Vacaville, 1998-2006, 2006a.



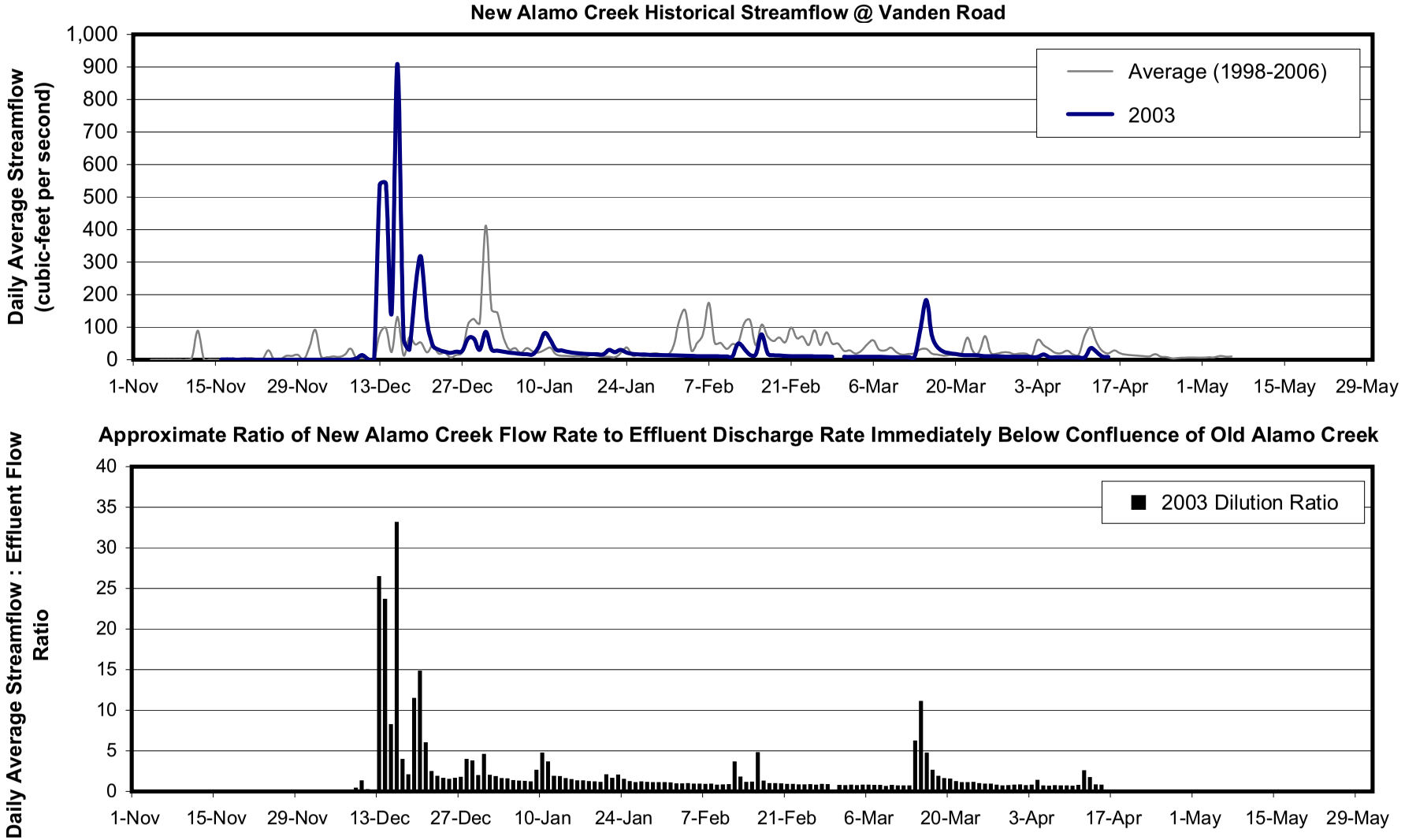
Appendix B (2000). New Alamo Creek precipitation season daily average streamflow (top) and approximate ratio of creek flow rate to Easterly WWTP effluent discharge rate (bottom). Water year 2000 (above normal year). Water year hydrologic classifications based on Sacramento Valley Water Year Index. Flow ratio based on Vanden Road gauged data and measured Easterly WWTP discharge for specified period. Runoff contributions into Old Alamo Creek and New Alamo Creek between Vanden Road and the confluence with Old Alamo Creek are not considered. Sources: City of Vacaville, 1998-2006, 2006a.



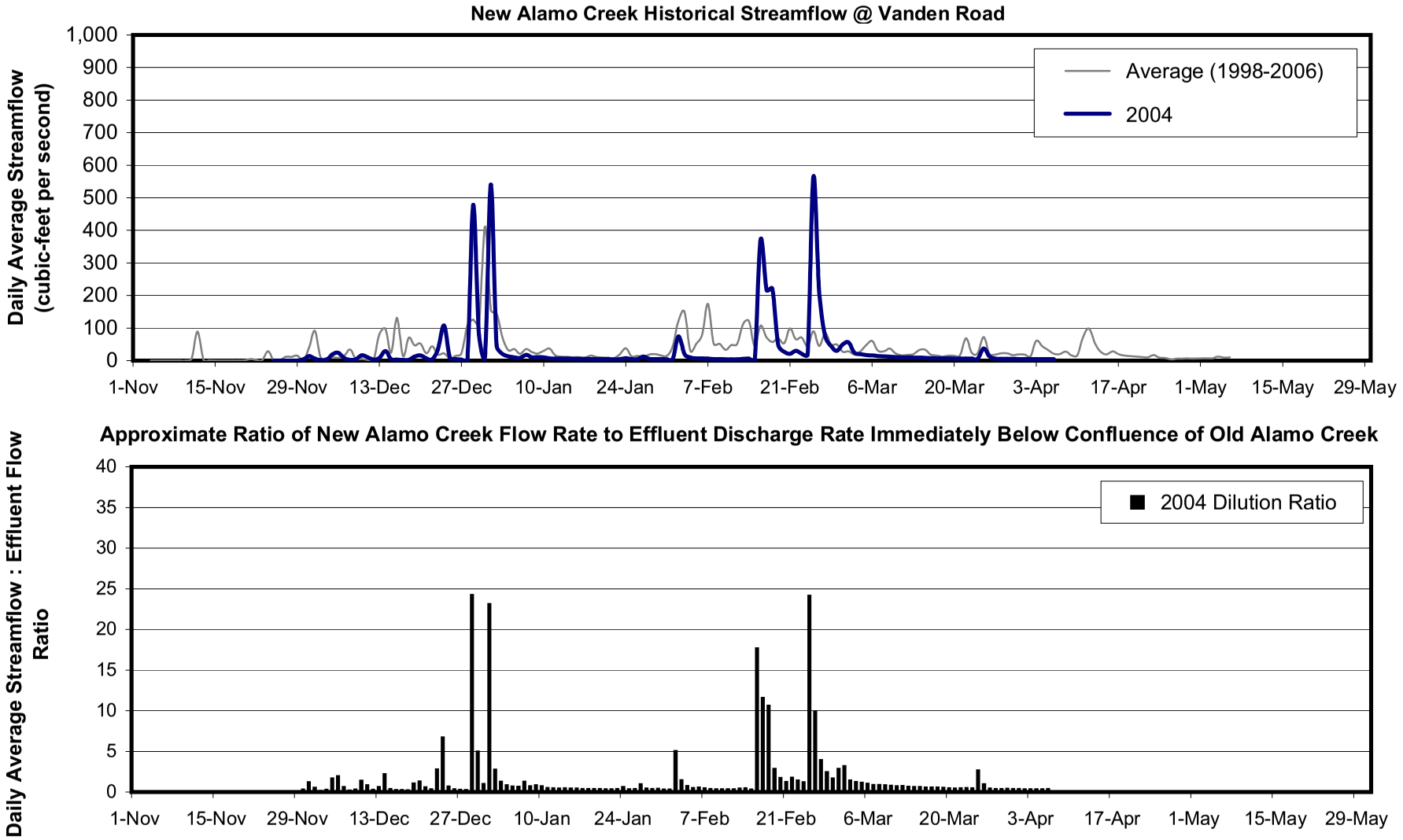
Appendix B (2001). New Alamo Creek precipitation season daily average streamflow (top) and approximate ratio of creek flow rate to Easterly WWTP effluent discharge rate (bottom). Water year 2001 (dry year). Water year hydrologic classifications based on Sacramento Valley Water Year Index. Flow ratio based on Vanden Road gauged data and measured Easterly WWTP discharge for specified period. Runoff contributions into Old Alamo Creek and New Alamo Creek between Vanden Road and the confluence with Old Alamo Creek are not considered. Sources: City of Vacaville, 1998-2006, 2006a.



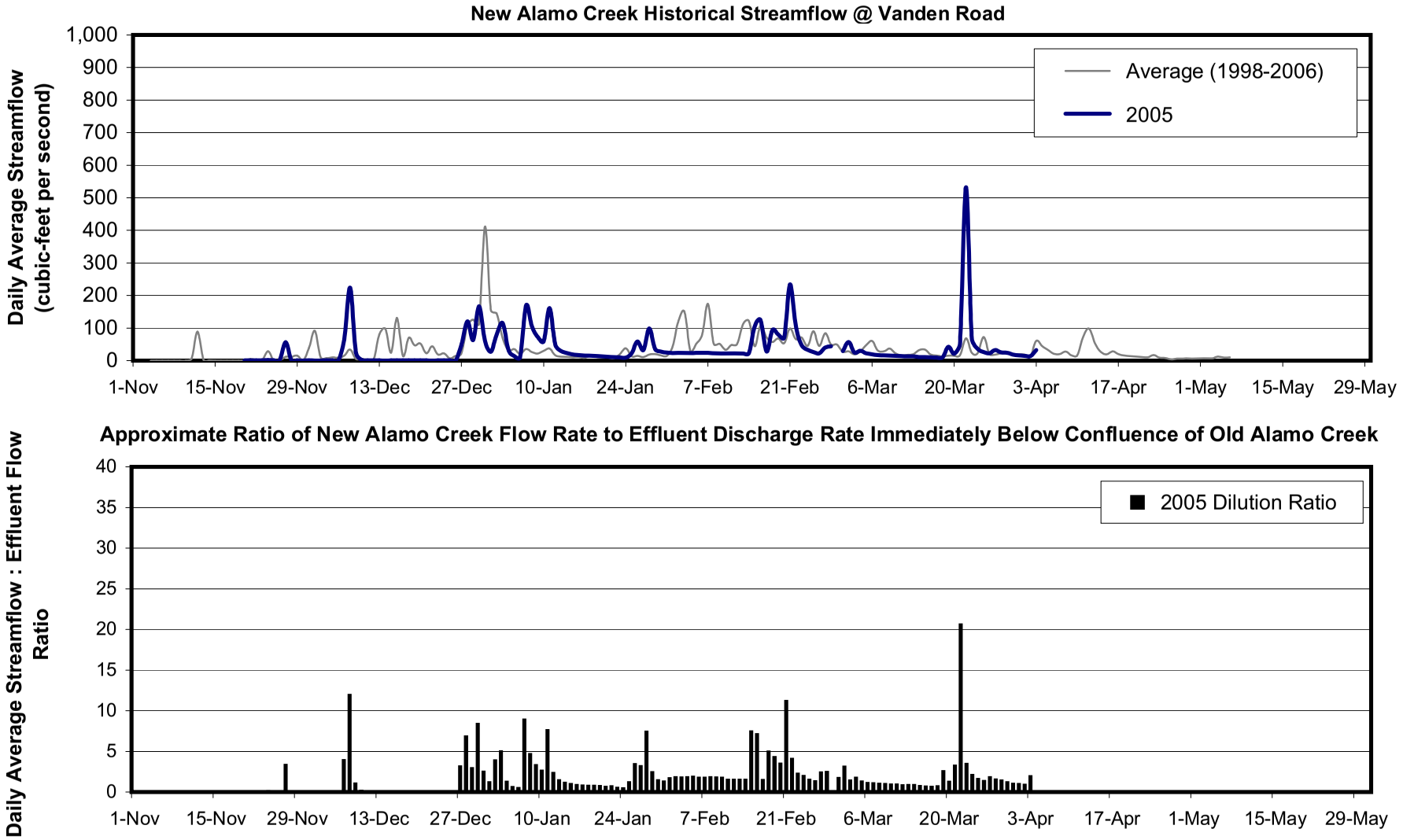
Appendix B (2002). New Alamo Creek precipitation season daily average streamflow (top) and approximate ratio of creek flow rate to Easterly WWTP effluent discharge rate (bottom). Water year 2002 (dry year). Water year hydrologic classifications based on Sacramento Valley Water Year Index. Flow ratio based on Vanden Road gauged data and measured Easterly WWTP discharge for specified period. Runoff contributions into Old Alamo Creek and New Alamo Creek between Vanden Road and the confluence with Old Alamo Creek are not considered. Sources: City of Vacaville, 1998-2006, 2006a.



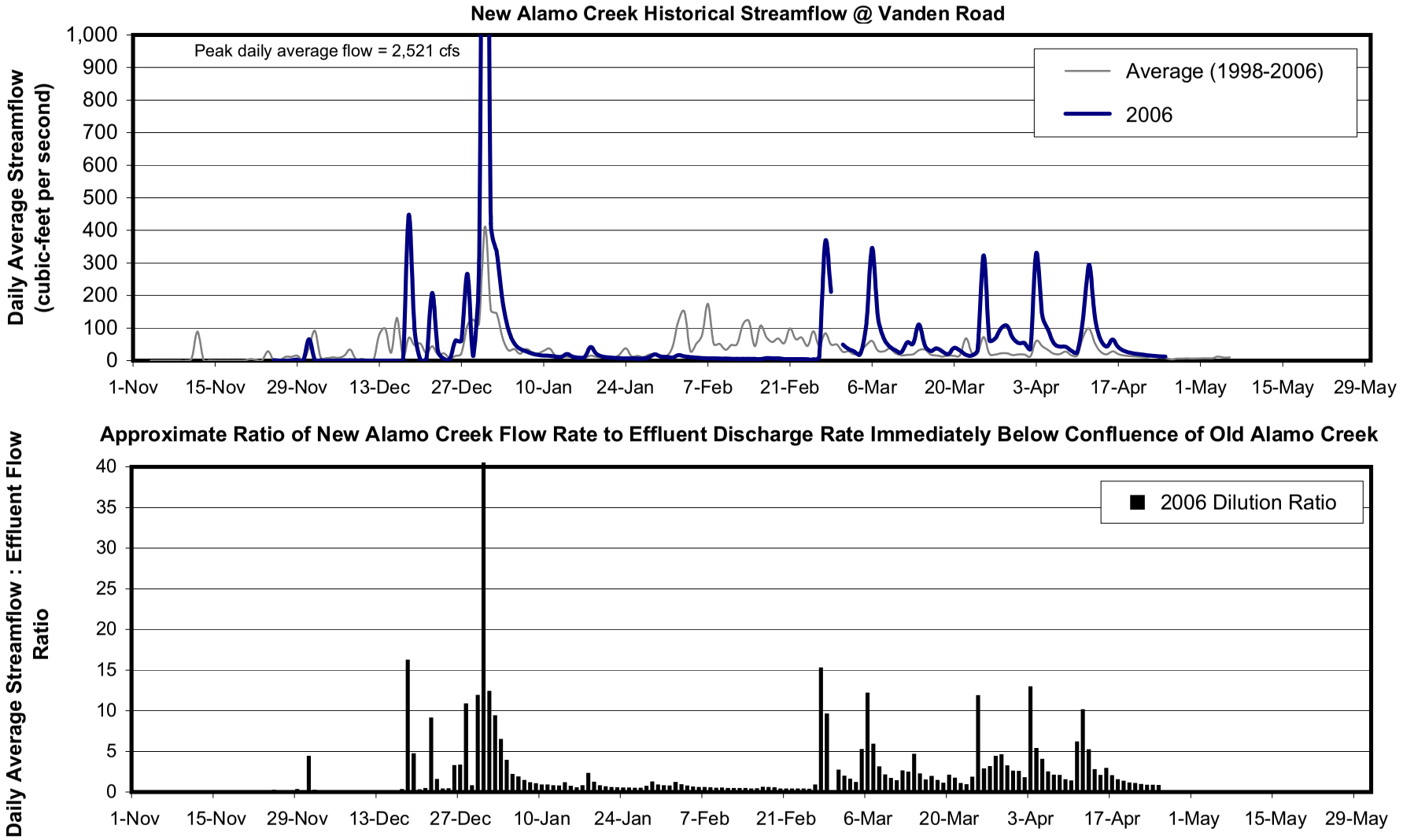
Appendix B (2003). New Alamo Creek precipitation season daily average streamflow (top) and approximate ratio of creek flow rate to Easterly WWTP effluent discharge rate (bottom). Water year 2003 (above normal year). Water year hydrologic classifications based on Sacramento Valley Water Year Index. Flow ratio based on Vanden Road gauged data and measured Easterly WWTP discharge for specified period. Runoff contributions into Old Alamo Creek and New Alamo Creek between Vanden Road and the confluence with Old Alamo Creek are not considered. Sources: City of Vacaville, 1998-2006, 2006a.



Appendix B (2004). New Alamo Creek precipitation season daily average streamflow (top) and approximate ratio of creek flow rate to Easterly WWTP effluent discharge rate (bottom). Water year 2004 (below normal year). Water year hydrologic classifications based on Sacramento Valley Water Year Index. Flow ratio based on Vanden Road gauged data and measured Easterly WWTP discharge for specified period. Runoff contributions into Old Alamo Creek and New Alamo Creek between Vanden Road and the confluence with Old Alamo Creek are not considered. Sources: City of Vacaville, 1998-2006, 2006a.



Appendix B (2005). New Alamo Creek precipitation season daily average streamflow (top) and approximate ratio of creek flow rate to Easterly WWTP effluent discharge rate (bottom). Water year 2005 (above normal year). Water year hydrologic classifications based on Sacramento Valley Water Year Index. Flow ratio based on Vanden Road gauged data and measured Easterly WWTP discharge for specified period. Runoff contributions into Old Alamo Creek and New Alamo Creek between Vanden Road and the confluence with Old Alamo Creek are not considered. Sources: City of Vacaville, 1998-2006, 2006a.

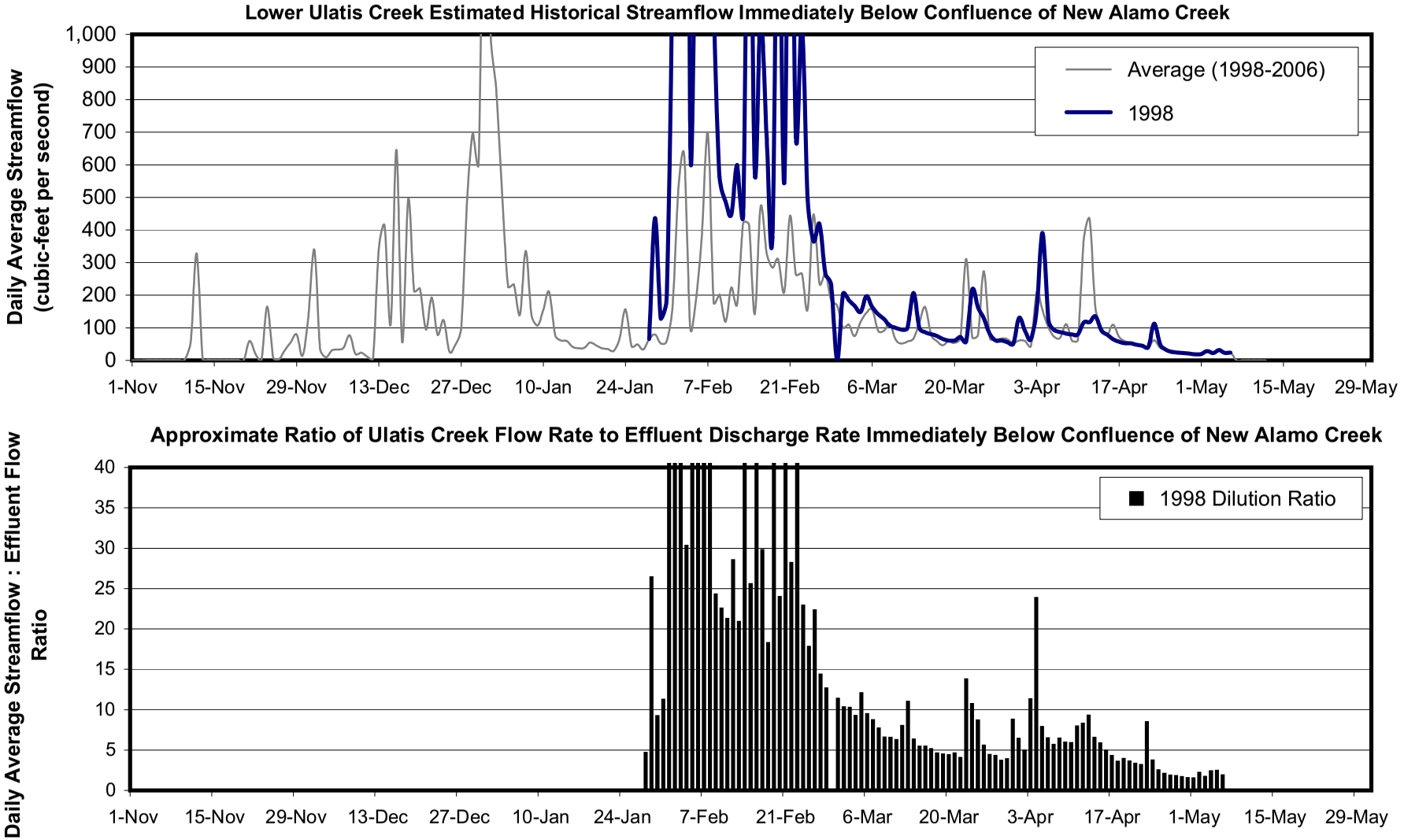


Appendix B (2006). New Alamo Creek precipitation season daily average streamflow (top) and approximate ratio of creek flow rate to Easterly WWTP effluent discharge rate (bottom). Water year 2006 (wet year). Water year hydrologic classifications based on Sacramento Valley Water Year Index. Flow ratio based on Vanden Road gauged data and measured Easterly WWTP discharge for specified period. Runoff contributions into Old Alamo Creek and New Alamo Creek between Vanden Road and the confluence with Old Alamo Creek are not considered. Sources: City of Vacaville, 1998-2006, 2006a.

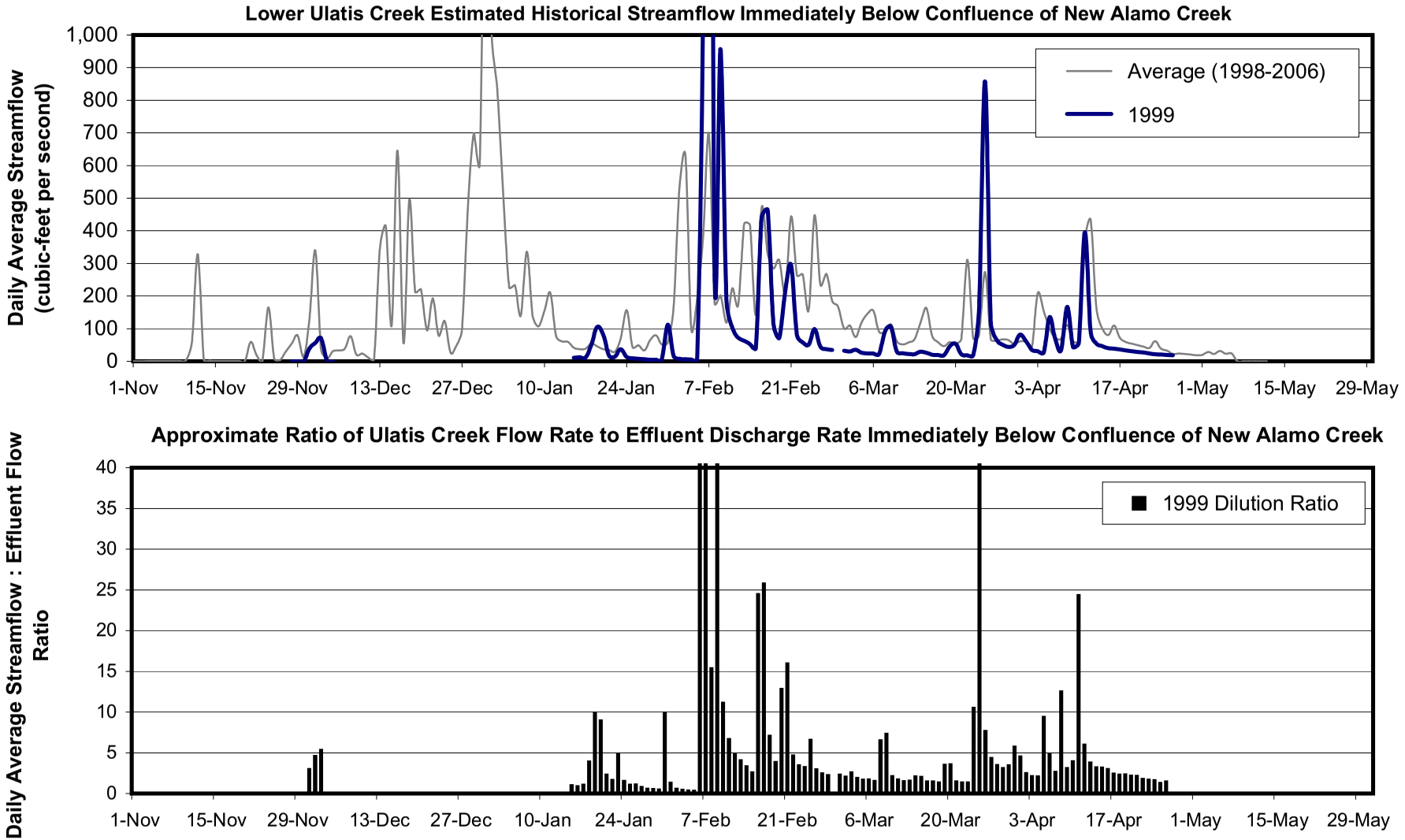
APPENDIX C

ESTIMATED ULATIS CREEK DAILY AVERAGE STREAMFLOW IMMEDIATELY BELOW CONFLUENCE WITH NEW ALAMO CREEK AND RATIO OF STREAMFLOW RATE TO EASTERLY WWTP EFFLUENT DISCHARGE FLOW RATE

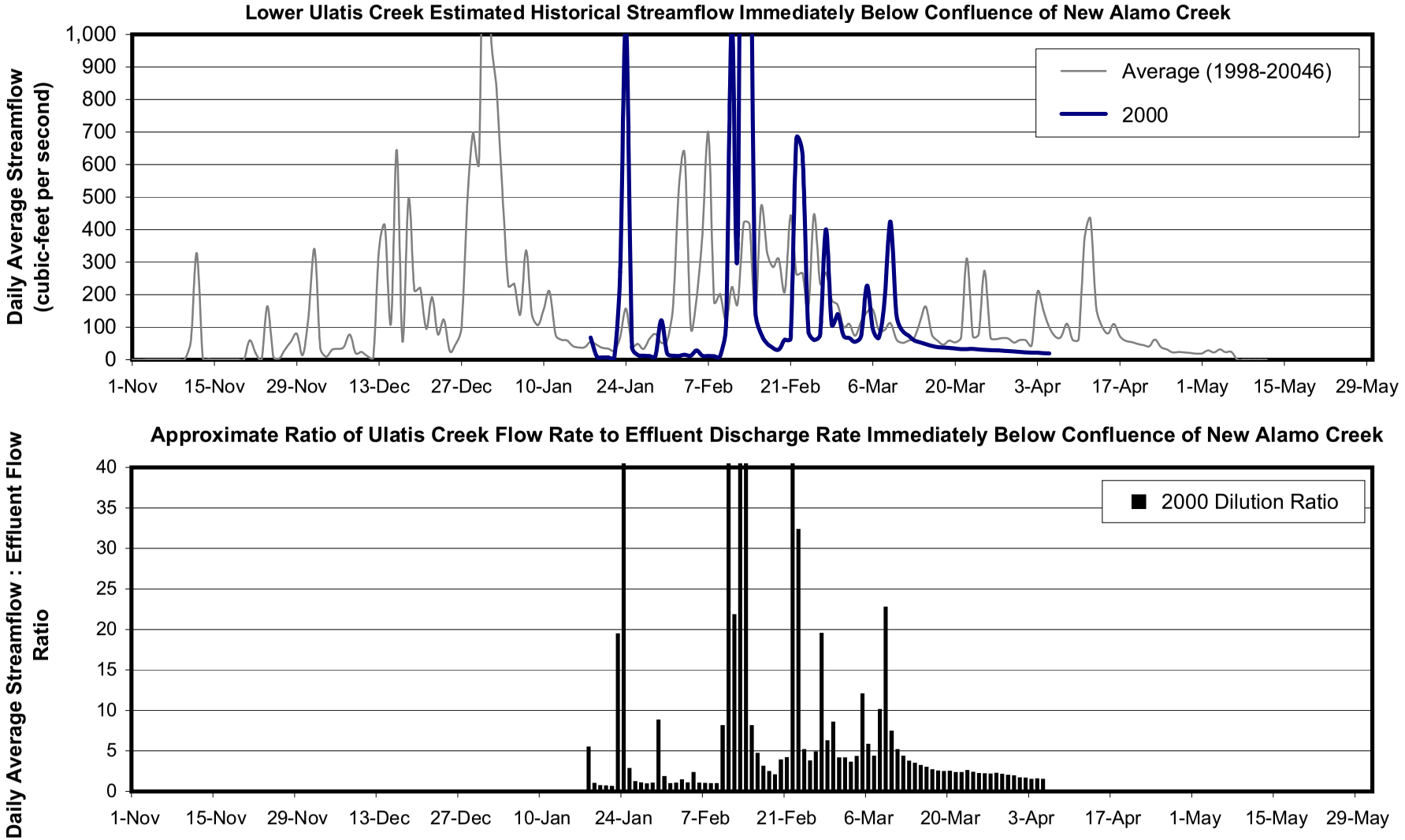
WATER YEARS 1998–2006



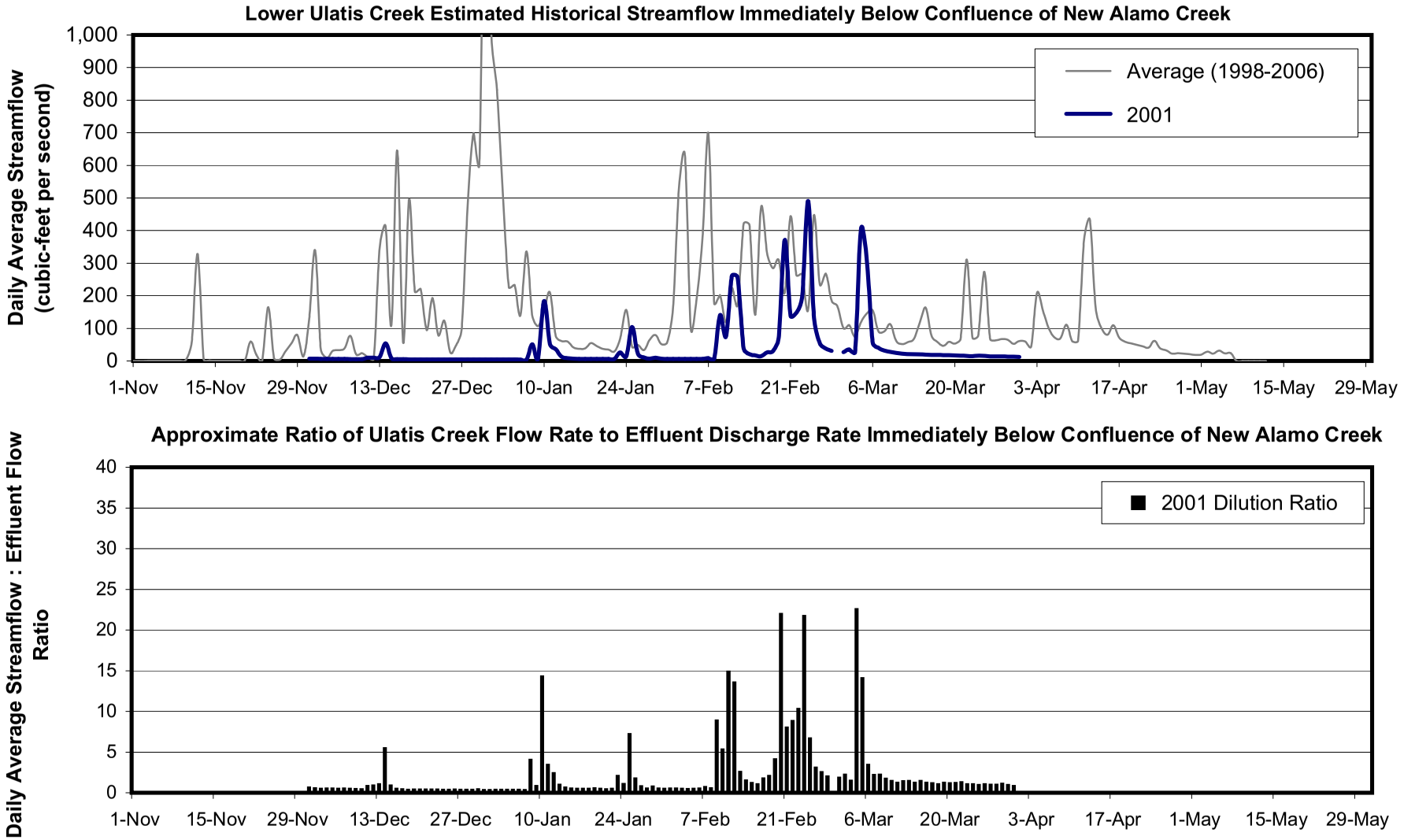
Appendix C (1998). Lower Ulatis Creek precipitation season daily average streamflow (top) and approximate ratio of creek flow rate to Easterly WWTP effluent discharge flow rate (bottom). Water year 1998 (wet year). Lower Ulatis Creek stream estimated from measured streamflows on New Alamo Creek @ Vanden Road and Ulatis Creek @ Leisure Town Road. Water year hydrologic classifications based on Sacramento Valley Water Year Index. Flow ratio based on estimated streamflow and measured Easterly WWTP discharge for specified period. Runoff inputs from agricultural lands between the New Alamo Creek gaging locations and Lower Ulatis Creek are not considered. Sources: City of Vacaville, 1998-2006, 2006a.



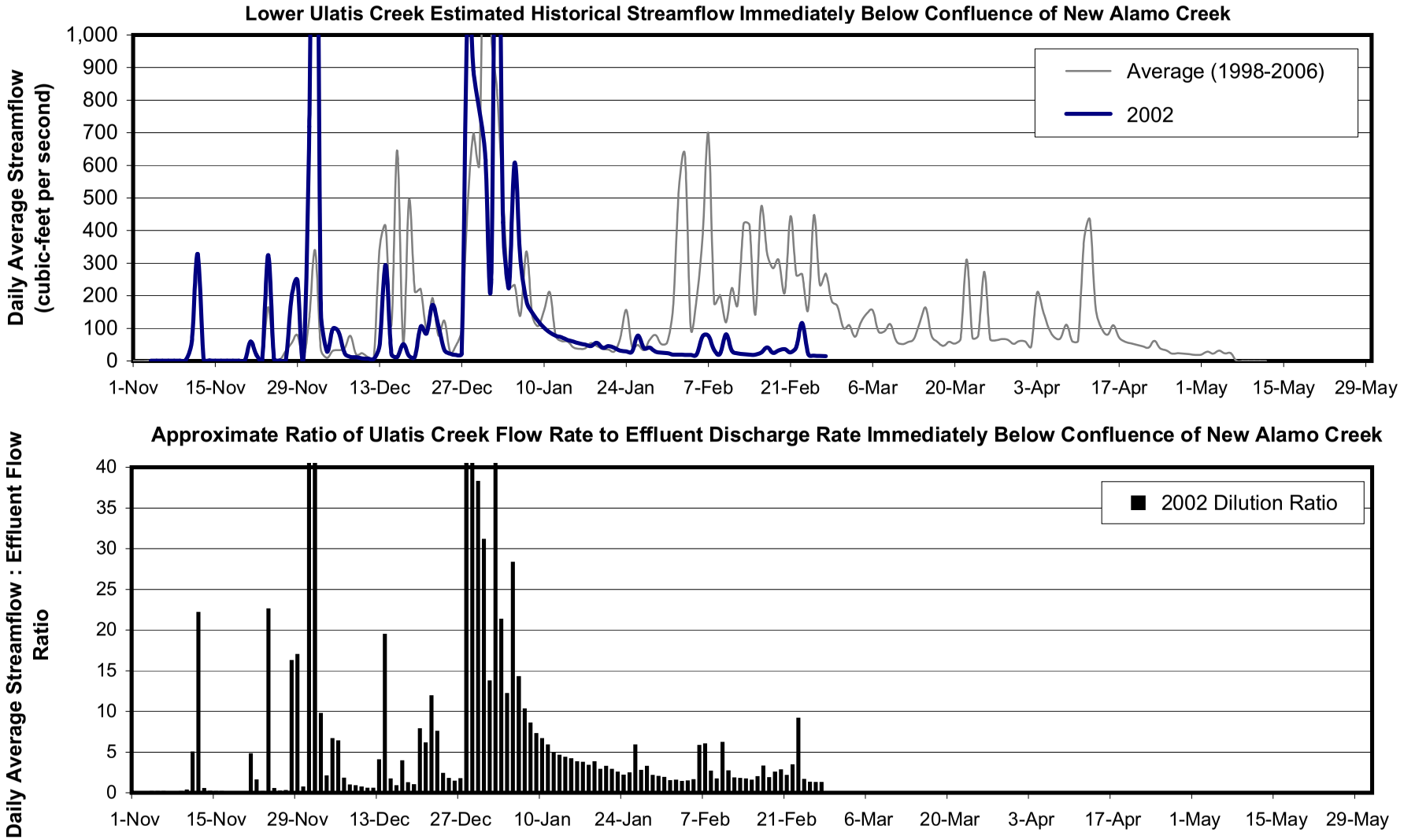
Appendix C (1999). Lower Ulatis Creek precipitation season daily average streamflow (top) and approximate ratio of creek flow rate to Easterly WWTP effluent discharge flow rate (bottom). Water year 1999 (wet year). Lower Ulatis Creek stream estimated from measured streamflows on New Alamo Creek @ Vanden Road and Ulatis Creek @ Leisure Town Road. Water year hydrologic classifications based on Sacramento Valley Water Year Index. Flow ratio based on estimated streamflow and measured Easterly WWTP discharge for specified period. Runoff inputs from agricultural lands between the New Alamo Creek gaging locations and Lower Ulatis Creek are not considered. Sources: City of Vacaville, 1998-2006, 2006a.



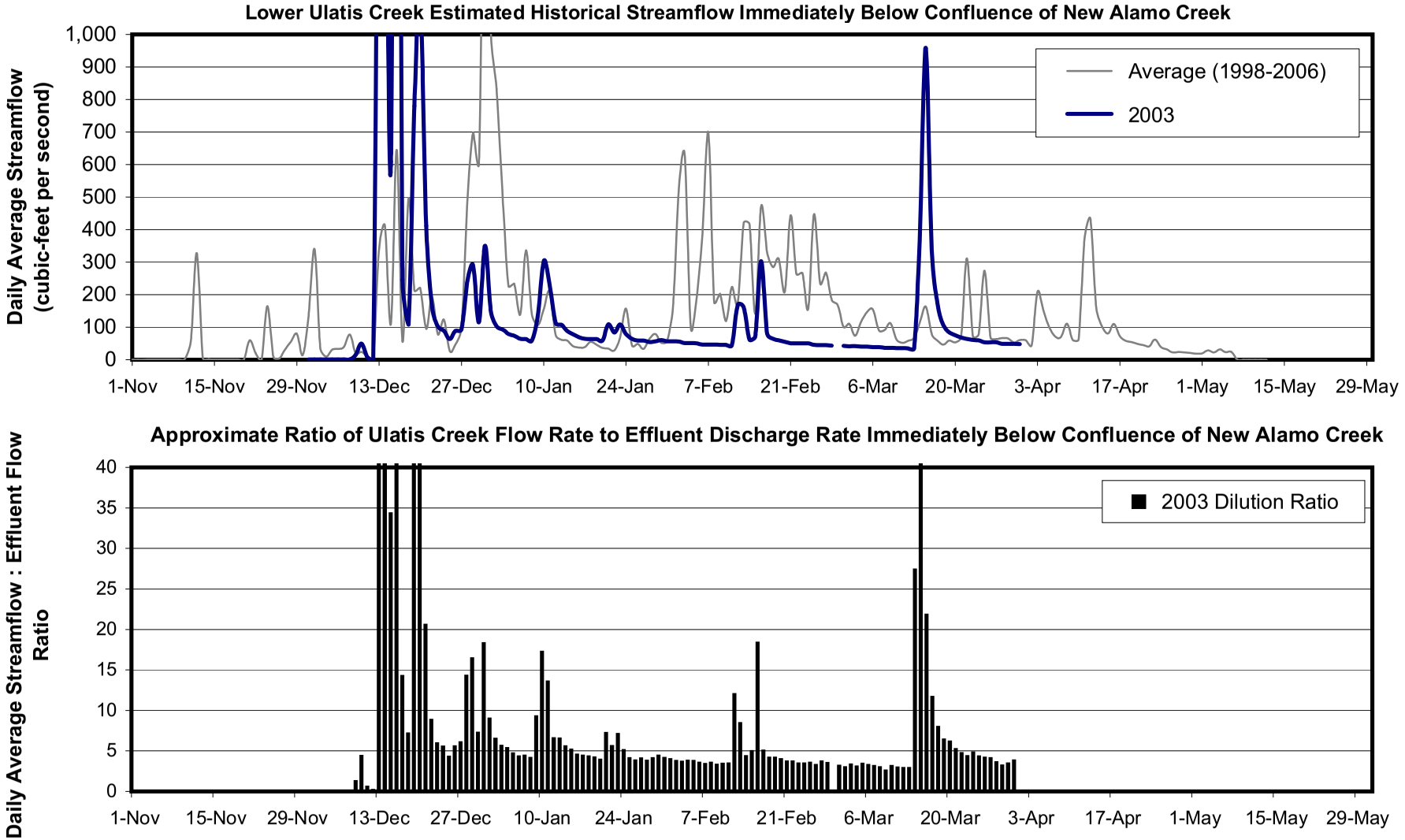
Appendix C (2000). Lower Ulatis Creek precipitation season daily average streamflow (top) and approximate ratio of creek flow rate to Easterly WWTP effluent discharge flow rate (bottom). Water year 2000 (above normal year). Lower Ulatis Creek stream estimated from measured streamflows on New Alamo Creek @ Vanden Road and Ulatis Creek @ Leisure Town Road. Water year hydrologic classifications based on Sacramento Valley Water Year Index. Flow ratio based on estimated streamflow and measured Easterly WWTP discharge for specified period. Runoff inputs from agricultural lands between the New Alamo Creek gaging locations and Lower Ulatis Creek are not considered. Sources: City of Vacaville, 1998-2006, 2006a.



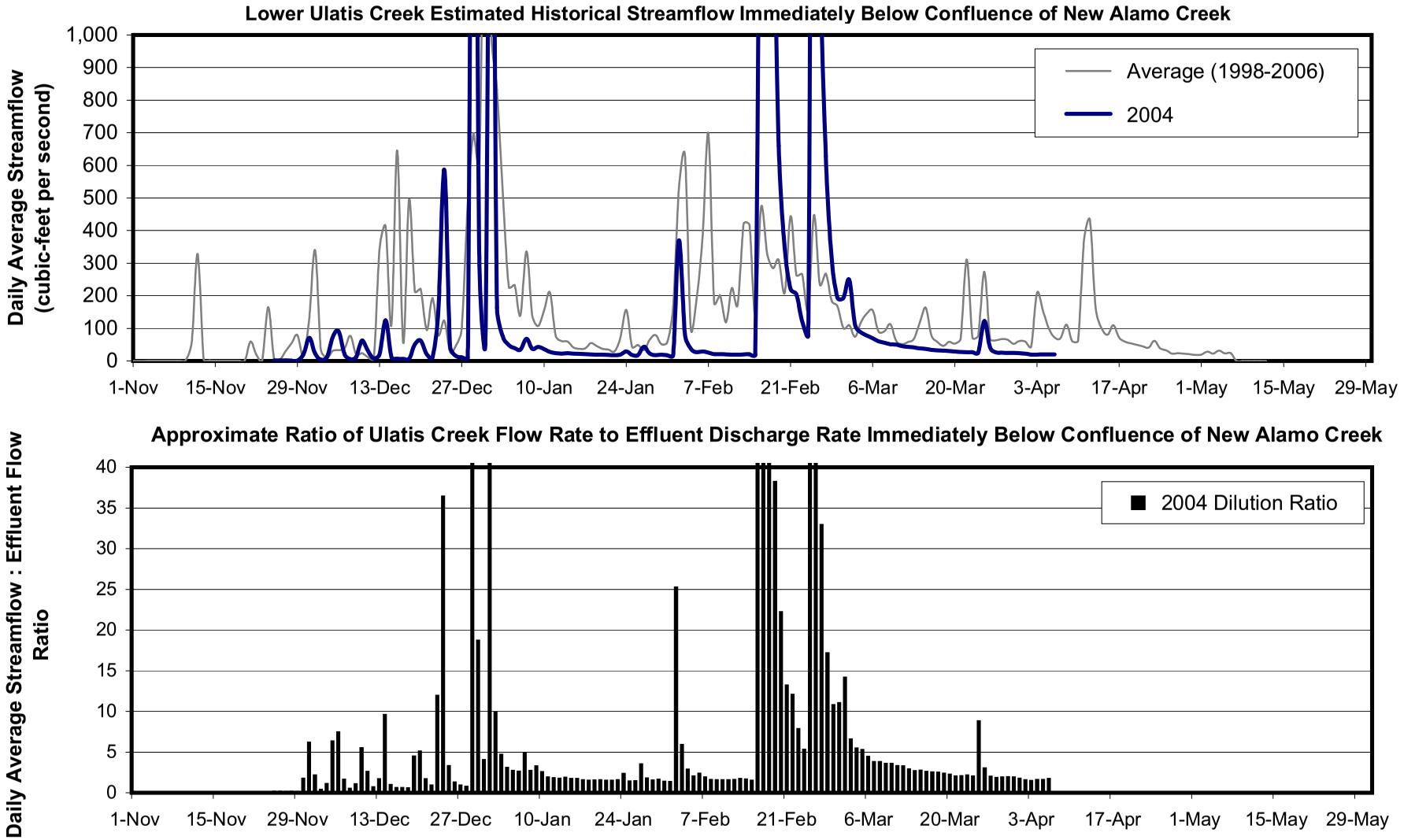
Appendix C (2001). Lower Ulatis Creek precipitation season daily average streamflow (top) and approximate ratio of creek flow rate to Easterly WWTP effluent discharge flow rate (bottom). Water year 2001 (dry year). Lower Ulatis Creek stream estimated from measured streamflows on New Alamo Creek @ Vanden Road and Ulatis Creek @ Leisure Town Road. Water year hydrologic classifications based on Sacramento Valley Water Year Index. Flow ratio based on estimated streamflow and measured Easterly WWTP discharge for specified period. Runoff inputs from agricultural lands between the New Alamo Creek gaging locations and Lower Ulatis Creek are not considered. Sources: City of Vacaville, 1998-2006, 2006a.



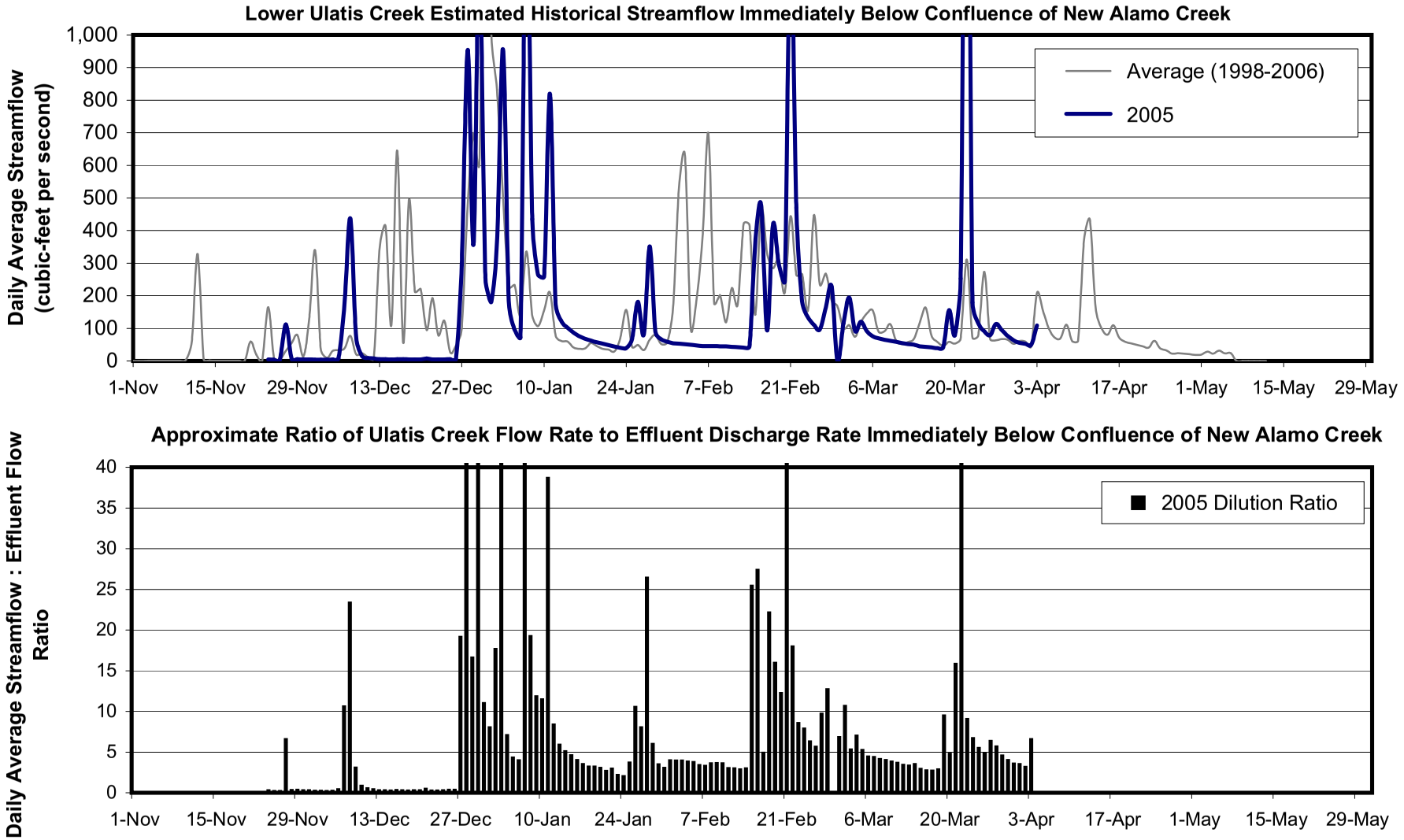
Appendix C (2002). Lower Ulatis Creek precipitation season daily average streamflow (top) and approximate ratio of creek flow rate to Easterly WWTP effluent discharge flow rate (bottom). Water year 2002 (dry year). Lower Ulatis Creek stream estimated from measured streamflows on New Alamo Creek @ Vanden Road and Ulatis Creek @ Leisure Town Road. Water year hydrologic classifications based on Sacramento Valley Water Year Index. Flow ratio based on estimated streamflow and measured Easterly WWTP discharge for specified period. Runoff inputs from agricultural lands between the New Alamo Creek gaging locations and Lower Ulatis Creek are not considered. Sources: City of Vacaville, 1998-2006, 2006a.



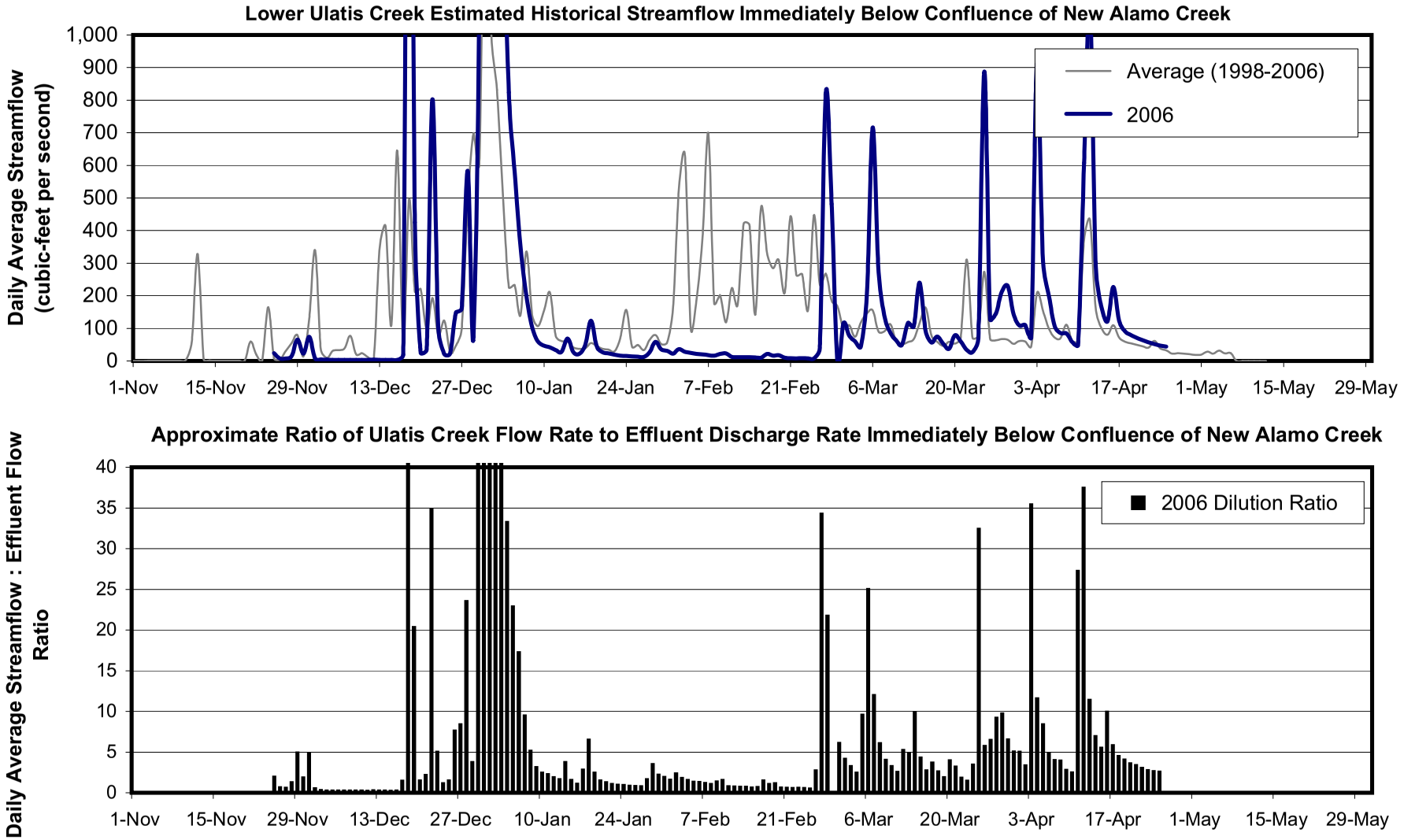
Appendix C (2003). Lower Ulatis Creek precipitation season daily average streamflow (top) and approximate ratio of creek flow rate to Easterly WWTP effluent discharge flow rate (bottom). Water year 2003 (above normal year). Lower Ulatis Creek stream estimated from measured streamflows on New Alamo Creek @ Vanden Road and Ulatis Creek @ Leisure Town Road. Water year hydrologic classifications based on Sacramento Valley Water Year Index. Flow ratio based on estimated streamflow and measured Easterly WWTP discharge for specified period. Runoff inputs from agricultural lands between the New Alamo Creek gaging locations and Lower Ulatis Creek are not considered. Sources: City of Vacaville, 1998-2006, 2006a.



Appendix C (2004). Lower Ulatis Creek precipitation season daily average streamflow (top) and approximate ratio of creek flow rate to Easterly WWTP effluent discharge flow rate (bottom). Water year 2004 (below normal year). Lower Ulatis Creek stream estimated from measured streamflows on New Alamo Creek @ Vanden Road and Ulatis Creek @ Leisure Town Road. Water year hydrologic classifications based on Sacramento Valley Water Year Index. Flow ratio based on estimated streamflow and measured Easterly WWTP discharge for specified period. Runoff inputs from agricultural lands between the New Alamo Creek gaging locations and Lower Ulatis Creek are not considered. Sources: City of Vacaville, 1998-2006, 2006a.



Appendix C (2005). Lower Ulatis Creek precipitation season daily average streamflow (top) and approximate ratio of creek flow rate to Easterly WWTP effluent discharge flow rate (bottom). Water year 2005 (above normal year). Lower Ulatis Creek stream estimated from measured streamflows on New Alamo Creek @ Vanden Road and Ulatis Creek @ Leisure Town Road. Water year hydrologic classifications based on Sacramento Valley Water Year Index. Flow ratio based on estimated streamflow and measured Easterly WWTP discharge for specified period. Runoff inputs from agricultural lands between the New Alamo Creek gaging locations and Lower Ulatis Creek are not considered. Sources: City of Vacaville, 1998-2006, 2006a.



Appendix C (2006). Lower Ulatis Creek precipitation season daily average streamflow (top) and approximate ratio of creek flow rate to Easterly WWTP effluent discharge flow rate (bottom). Water year 2006 (wet year). Lower Ulatis Creek stream estimated from measured streamflows on New Alamo Creek @ Vanden Road and Ulatis Creek @ Leisure Town Road. Water year hydrologic classifications based on Sacramento Valley Water Year Index. Flow ratio based on estimated streamflow and measured Easterly WWTP discharge for specified period. Runoff inputs from agricultural lands between the New Alamo Creek gaging locations and Lower Ulatis Creek are not considered. Sources: City of Vacaville, 1998-2006, 2006a.