Changes in Flood Management along the Pajaro River: A Transition to Watershed Management Approaches and Lessons from the Water Framework Directive and Flood Directive

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Abstract

Flood management planning by the Army Corps of Engineers (Army Corps) on Pajaro River and Correlitos Creek changes from the first levee design in 1945 to the most recent planning actions in 2004 as reflected in flow calculation and project design. The scope of project objectives expanded from the initial flood control project to the more recent whole watershed management study. The Pajaro River experience reflects the trend in flood management from 1945 to current day from single objective engineering methods to regulate flood flows in specific reaches of the river to a more holistic watershed management approach with multiple objectives. The European Union's Water Framework Directive and Flood Directive are models for multi objective planning, which work together to improve rivers and streams to good ecological status. By looking to the previous channel restoration occurring in the European Union, and the influence of the good ecological status requirement of the WFD and FD, Pajaro River can incorporate some of the multiple objective planning measures currently being implemented in the European Union.

Introduction

The Pajaro River drains 1,300 square miles and runs through four counties, Monterey, Santa Cruz, San Benito, and Santa Clara (Curry 2003). Separated by the Diablo Range, the upper and lower watersheds face very different concerns and issues. The upper tributaries drain the mountains east of the Gabilan Range, passing through and converging in the valley of Morgan Hill, Gilroy, and Hollister before slicing through the Santa Cruz Mountains along the San Andreas Fault. Once on the west side of the mountain range, the river winds through the fields of the Pajaro Valley, including the towns of Pajaro and Watsonville, before emptying into Monterey Bay. (Figure 1 and 2)

Flooding on the Pajaro River is particularly and issue where Corralitos Creek converges with the Pajaro River at the town of Watsonville. The Army Corp originally built levees in the lower valley in 1949 to protect agricultural land against the 50 year flood event (CH2MHILL 1997). (Figure 3) Still, the lower portion of the Pajaro watershed continued to be affected by major floods in 1955, 1982, 1986, 1995 and 1998. The existing levees now only protect against the 18 year storm, not near the standard 100 year event (CH2MHILL 1997).

The Army Corps is in a 40 year planning process to increase protection level of the levee system. (Figure 4) The major planning documents include: the original 1945 Definite Project Report for the Pajaro River and Tributaries, 1974 Flood Control alternatives for Pajaro Valley, Pajaro River, Salispuedes, and Corralitos Creek, the 2001-2003 Pajaro River Flood Protection: Community Planning Process Project, and the 2002 Pajaro River Watershed Study. The general trend of these documents is a move from single objective channelized project to multi-objective watershed scale management.

In comparison, the certain countries in the European Union have similarly recognized the importance of ecological benefits into channelized projects. Historically completed on individual projects by only certain countries, the WFD, adopted by member states in 2000, provides the framework of regulation for analysis, protection and enhancement of rivers (European Parliment

2000). The European Union also adopted the Flood Risk Directive, whose purpose was to establish a framework assessment and management of flood risk through management plans. These two directives can give insight to alternative flood management and river function objectives.

The Pajaro River planning process is entering a new era of planning trying to incorporate multiple objectives and basin wide analysis. The WFD and FD, if applied could produce a more coherent plan that would reduce flooding and also increase ecological status.

Methods

Change of Army Corps Planning

To evaluate the change of flow method calculation and project design for the Pajaro River flood management planning I looked at the four major documents the Army Corps has produced or initiated. In each document I evaluated four major components: the drivers and stated goals of the project, hydrologic calculation, and design objectives and features. The goal was to understand the change in the Army Corp planning and what objectives they incorporated into their design.

Drivers and Stated Goals

By identifying the processes used for project analysis, the availability of funding, any change in policies for the Army Corps I identified any drivers for each of the documents. I also identified the stated goals, of the project design.

Hydrologic Calculations

I first reviewed each document to determine how the Army Corps calculated the flood frequency and period of record the calculation was based on. I used a matrix to compare how the Q_{50} changed over time. The current USGS gauges on the Pajaro are located above the confluence of the Pajaro River and Correlitos Creek. I completed one Flood Frequency Graph by combining current data available from the Chittenden Gap gauge and the Freedom gauge to compare with the Q_{50} of previous documents.

Design Objectives and Features

I used a matrix to compare objectives and design features incorporated into the flood control projects.

<u>WFD Comparison for Multi-Objective Planning</u>

I concluded my study with an evaluation of what activities have already been implemented in the European Union and the process from the WFD and the Flood Directive that is used to reach good ecological status. I applied these methods to the Pajaro River as next steps to flood management and restoration.

Results

<u>1945: Definite Project Report on Pajaro River and Tributaries</u>

Drivers and Stated Goals

The Army Corps' cost benefit analysis had a ratio of 1.25 (United States Army Corps of Engineers 1945). Their main goal for this project was flood protection through engineering requirements and structural features. The stated objective of this project was the improvement of the Pajaro River from the mouth to river mile 11.8 and its tributary Corralitos Creek from the confluence with the Pajaro River with high ground by levees, channel clearing, and bank protection works to create flood protection (United States Army Corps of Engineers 1945). This was the only project that was built.

Hydrologic Calculations

The document used Mannings formula for the calculation of the peak flow by measuring high stream flows and their corresponding high water marks for two years previous high stages (United States Army Corps of Engineers 1945).They back calculated to find n, with values of 0.025 at the mouth of Pajaro River to Thurwatcher Bridge and 0.035 from Thurwatcher Bridge to the head of the project (United States Army Corps of Engineers 1945). The Army Corps designed channel capacity at a Q_{50} at 19,000 cfs above Corralitos Creek and 22,000 cfs below Corralitos Creek (United States Army Corps of Engineers 1945).

<u>1974: Flood control alternatives for Pajaro Valley, Pajaro River, Salispuedes & Corralitos Creek</u>

Drivers and States Goals

The Army Corps focused on the National Economic Development analysis to determine the preferred least cost alternative that increased protection along the entire project reach corridor. The US Fish and Wildlife and California Fish and Game Agencies identified preferred alternatives that gave increased protection to the urban areas, but left the rest of the levee system as is for the wildlife benefits it provided (United States Army Corps of Engineers 1974). The stated goal of the 1974 flood control alternatives was to enlarge channel capacity and flood protection levels (United States Army Corps of Engineers 1974). The study did look at entire watershed options for flood storage, but all of the options were determined economically infeasible.

Hydrologic Calculations

The Army Corps used "standard project flood" calculations to determine the design flows. The approved alternative was designed for a $Q_{300\text{-}500}$ of 67,500 cfs flow below the confluence of Correlitos Creek and Pajaro River. (United States Army Corps of Engineers 1974). This report also calculated the Q_{50} as 33,500, the Q_{100} as 45,000 and the Q_{200} as 57,100 (United States Army Corps of Engineers 1974).

<u>2001-2003: Pajaro River Flood Protection: Community Planning Process Project Status Report</u>

Stated Goals and Objectives

This locally preferred plan involved input from stakeholders including agricultural interests, local environmental interests, regulatory agencies, business organizations, residential representatives, and community organizations (MIG Inc and United States Army Corps of Engineers 2001). Because of this, drivers for design included special treatments to specific reaches along the river, increased flood protection and special consideration to vegetation and maintenance. As the only community process, the goal of the process was arriving at a single community flood protection project concept to be included in the Army Corp evaluation and environmental review process. The main objective was protection of the Watsonville area from flooding using a hybrid of approaches (MIG Inc and United States Army Corps of Engineers 2001).

Hydrologic Calculations

The Army Corp and community designed using a Q_{100} of 43,500 cfs upstream and 49,000 cfs down stream of the confluence of Salsipudes and Pajaro (MIG Inc and United States Army Corps of Engineers 2001).

<u>2002: Pajaro River Watershed Study: Pajaro River Watershed Flood Prevention Authority and Army Corps</u>

Drivers and Stated Goals

This study was done though a congressional authorization for an entire study of Pajaro River due to recognition that addressing only part of the watershed resulted in failed projects and continued repairs (United States Army Corps of Engineers 2008). The goal of this study was to identify and evaluate flood prevention and control strategies in the Pajaro River Watershed (RMC Inc 2002). This included a detailed model of hydrologic and sediment patterns, project alternatives involving the entire watershed, including a combination of retention and protection, and focused on the combination of methods for a 100 year flood protection of the Pajaro River.

Hydrologic Calculations

This study prepared a detailed model of the hydrologic, sediment, and flood frequency patterns of the entire watershed using the Pajaro River to the Ocean Flood (PRO-FLO). This model is highly adjustable and based upon rainfall, soil groups, land use and subwatershed routing factors (RMC Inc 2002). This model, using existing conditions, predicted the Q_{100} as 44,600 cfs above and 49,400 cfs below the Salsipuedes and Pajaro confluence (RMC Inc 2002).

Design Features for Pajaro River Plans (Table 1)

	1945-built plan	1974-alternatives	2001-community	2002-watershed
Flood Protection	x	x	x	x
Levee Wall Height	2-8 ft, ave. 6 ft	4-12 ft, ave. 8ft		
Channel Width	50-150 ft	50-300 ft	0-300 ft	
Sediment Transport				x
Berms		x		
Vegetated Corridors		x	x	
Access along levee		x	x	
Recreation		x	x	
Water Quality				x
Wildlife Habitat			x	x
Fish Habitat			x	x
Watershed System				x
Reservoir Storage				x
Design Details		habitat protection alternatives	reach character and treatment of urban reach different than agricultural areas.	storage options in upper watershed

Flood Frequency Comparison

Table 2 compares the planned channel capacity flow and the Q_{50} of each document.

Table 2	1945-built plan	1974-alternatives	2001-community	2002-watershed	USGS Prgm Calc

Designed Protection (Q_x)	50	300-500	100	100	-
Design Protection Flow Amount	22,000	67,500	49,000	49,400	-
Design Calculated Q_{50}	22,000	33,500		42,300	41,181

Figure 7 compares all five calculations graphically.

River Management in the European Union and the WFD and FD

Like rivers of the United States, European rivers have a long history of being channelized for many reasons, including flood control (Brookes 1988). Multiple projects throughout Europe have incorporated mitigation, enhancement, and restoration techniques to their channels (Brookes 1988).

The WFD and FD are the regulatory forces needed encourage good ecological status. The WFD manages rivers through River Basin Districts all heavily modified water bodies in order to reach good ecological status through protection and enhancement (European Parliment 2000). In order to understand the status of the water body and how to proceed with reaching good ecological status, the WFD requires each river basin to analyze the characteristics of the water body, identify the human impacts on the water body, and an economic analysis of the use of the water body (European Parliment 2000). The human impacts include the identification of how the water body is being used and what damage comes from that use. In addition, the economic analysis evaluates whether or not the prices set for the water use is enough for full cost recovery for long term use and damage (European Parliment 2000). With this information, protection and enhancement can move forward with clear information for the most effective actions would be and what costs can be recovered.

Second, the Flood Directive indicates the importance of looking for natural flood plains and existing hydraulic features in order to manage flood risks (European Parliment 2007). This directive is intended to work with the WFD river basins and environmental objectives, but recognizes that there may need to be additional authorities and management.

Discussion

Evaluating the drivers, hydrologic calculation methods, and the design and scope for the Pajaro River through time revealed two key distinctions in the flood planning process. First, the hydrologic calculations focus on understanding the flow amount, prediction of how water will move through the system and how engineering solutions can control this flow. They hydrological studies have looked at the system as a flood control project. Second, multi-objective planning and design has increased from the original flood management measures to the incorporation of more river functions ecological benefits. These two parallel parts of planning along the Pajaro River currently do not have a method for interacting.

In each planning document, more information was known about flood discharge and better calculations could be made. The Q_{50} increased by one hundred fifty percent, from 1945 to 1974. This increase can most be attributed to an increased amount of years on record, including the large flood in 1955. Advancements in the field of hydrology have resulted in complex modeling programs of river systems. In the recent 2002 modeling, a multitude of factors were included in the calculation to give a more detailed understanding of the river system beyond just the flood project reaches.

The largest change has been the shift from engineering and controlling the river through design to understanding the watershed with multiple objectives in project design. The studies and project proposals in 2001 focused on multiple design objectives through stakeholder meetings, such as aquatic and wildlife habitat, access, sedimentation concerns for fish, and wetland function. The studies in 2002 also modeled and researched the entire watershed for design solutions for flooding and recognized the importance of natural methods of flood control such as flood plains, channel design to allow for access, and alternative flood storage.

This shift towards looking at the entire watershed for flood management is an important step for the Army Corps and the flood projects on the Pajaro River. If the Pajaro River were to follow the WFD and FD, it would have to manage the entire watershed as a cohesive river basin authority. The river basin analysis would complete an evaluation of the status of the river, in the modified areas and the non modified areas. Two documents that start to do this on the Pajaro River are the 2001 with the Watershed Flood Management Plan and the water districts' 2004 IRWMP (RMC Inc 2002).

The critical step needed in the Pajaro River is an economic analysis of the river system. This economic analysis would go beyond the current cost/benefit analysis that is currently completed by the Army Corp when looking at flood management projects and include the environmental damage and recovery costs (Riley 1998). This full analysis would benefit the planning process and flood management design by identifying the major human actions causing environmental damage and the full-cost recovery of environmental function along the Pajaro River. This would also incorporate the large watershed health with the flood management actions that are planned for the Pajaro River. This is a key connection of river systems that has not been made on the Pajaro River. The water quality status, supply, flood management, and ecological and biological health of the river are all connected and need to be managed together when planning for flood projects.

Literature Cited

Brookes, A. (1988). Channelized Rivers: Perspectives for Environmental Management, John Wiley & Sons Ltd. .

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MIG Inc and United States Army Corps of Engineers (2001). Pajaro River Flood Protection Community Planning Process: Project Status Report. Pajaro River Flood Protection Community Planning Process. Watsonville, CA.

Riley, A. L. (1998). Restoring Streams in Cities: A Guide for Planners, Policymakers, and Citizens Washington DC, Island Press.

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United States Army Corps of Engineers, E. O. (1945). Definite project report on Pajaro River and tributaries, Calif. [San Francisco, Calif.], U.S. Engineer Office.

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List of Attachments

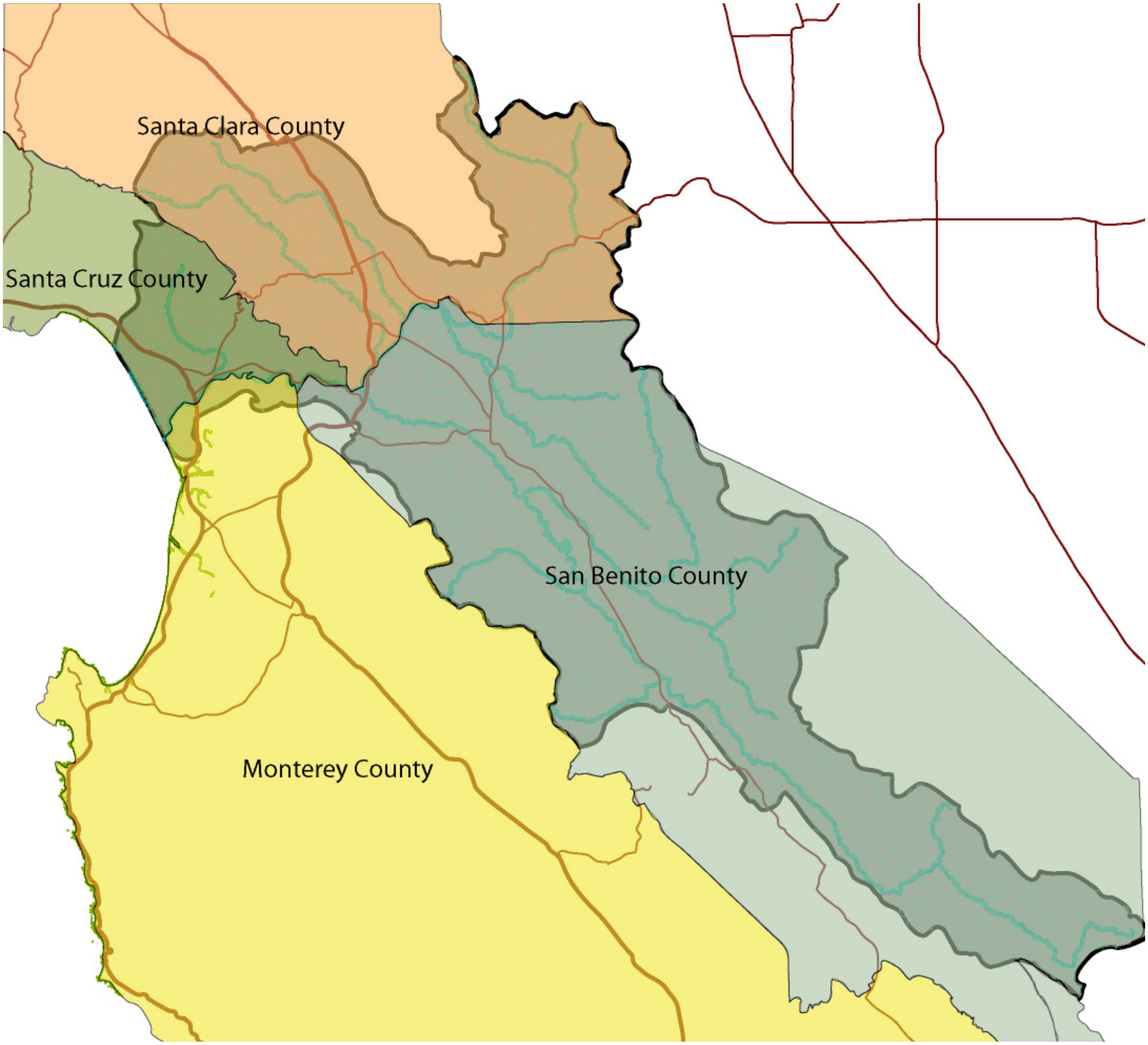


Figure 1: Counties of Pajaro River Watershed

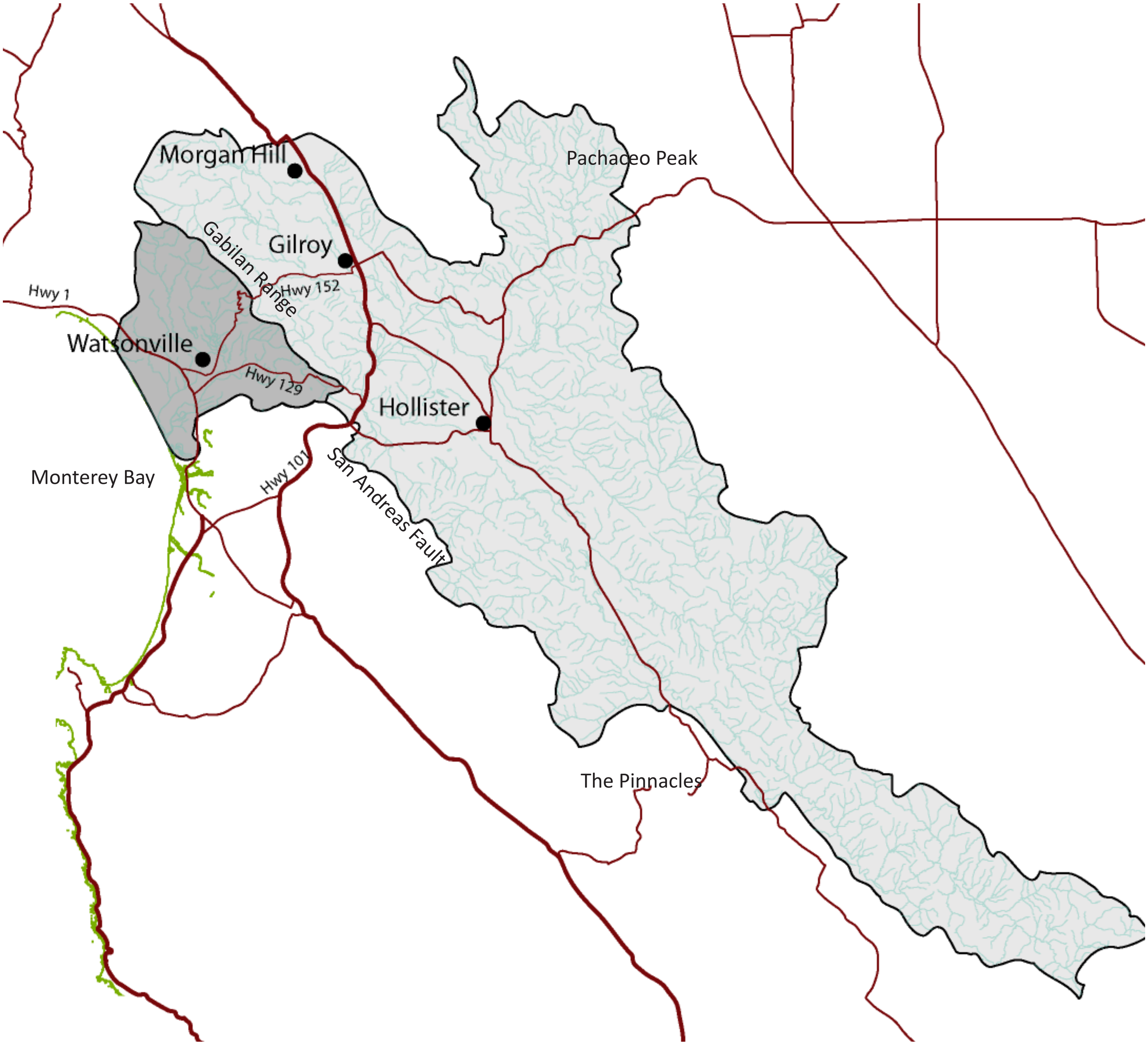


Figure 2: Pajaro River Watershed Context

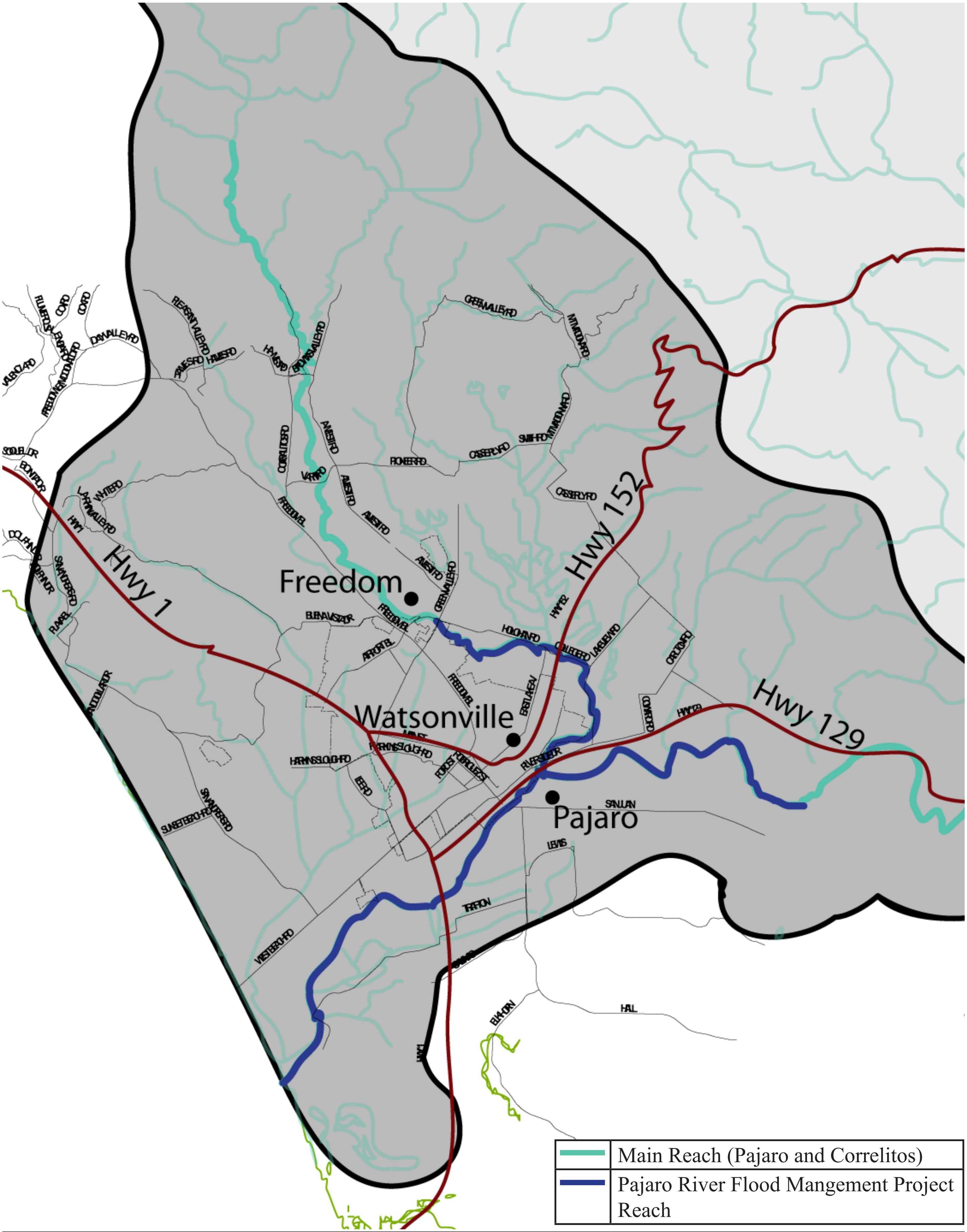
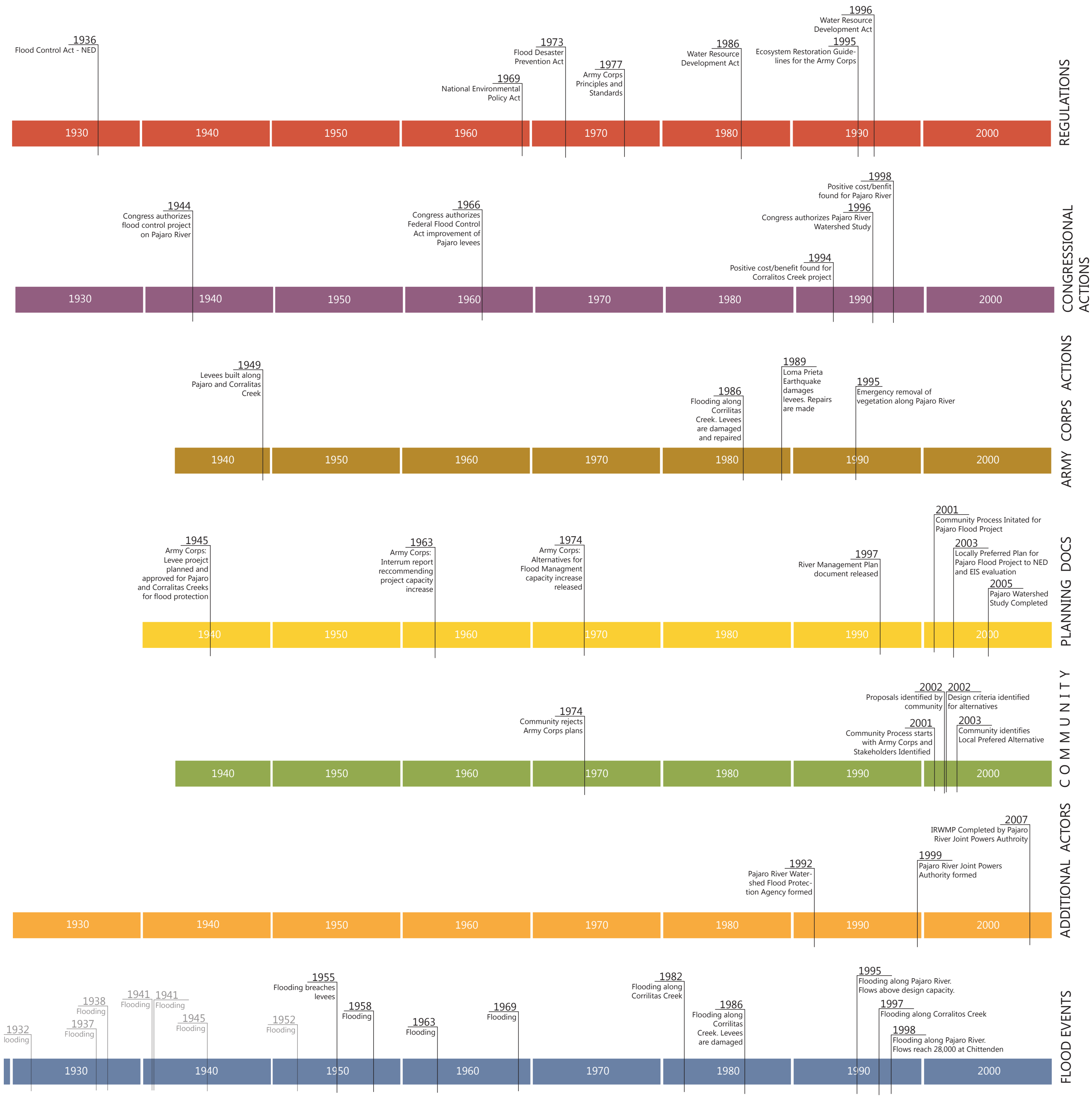


Figure 3: Lower Pajaro River Watershed



Changes in Flood Control Adaptations in Lower Pajaro River

Figure 4: Timeline of Pajaro River

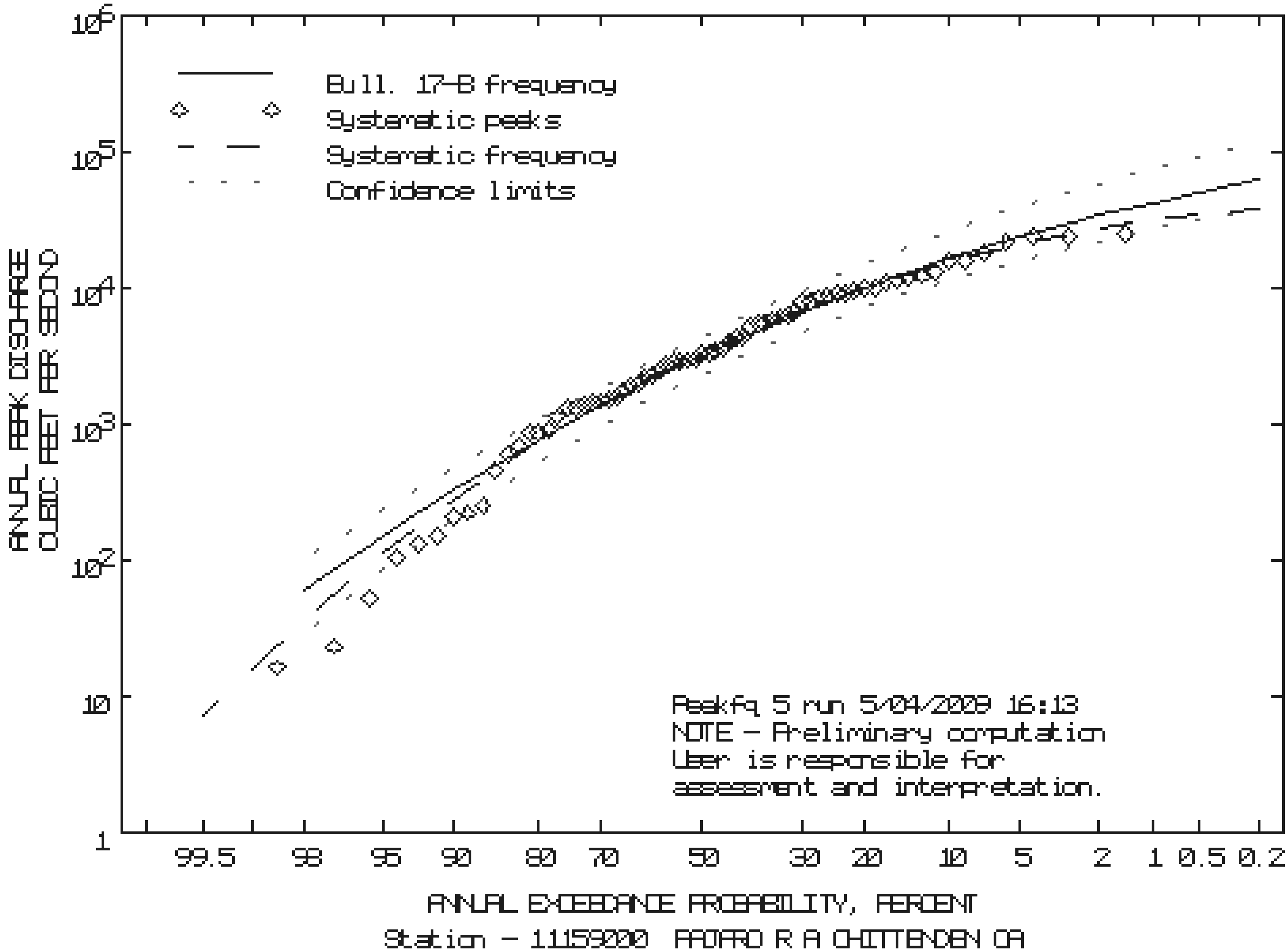


Figure 5: 2009 Pajaro River at Chittenden Flood Frequency Graph

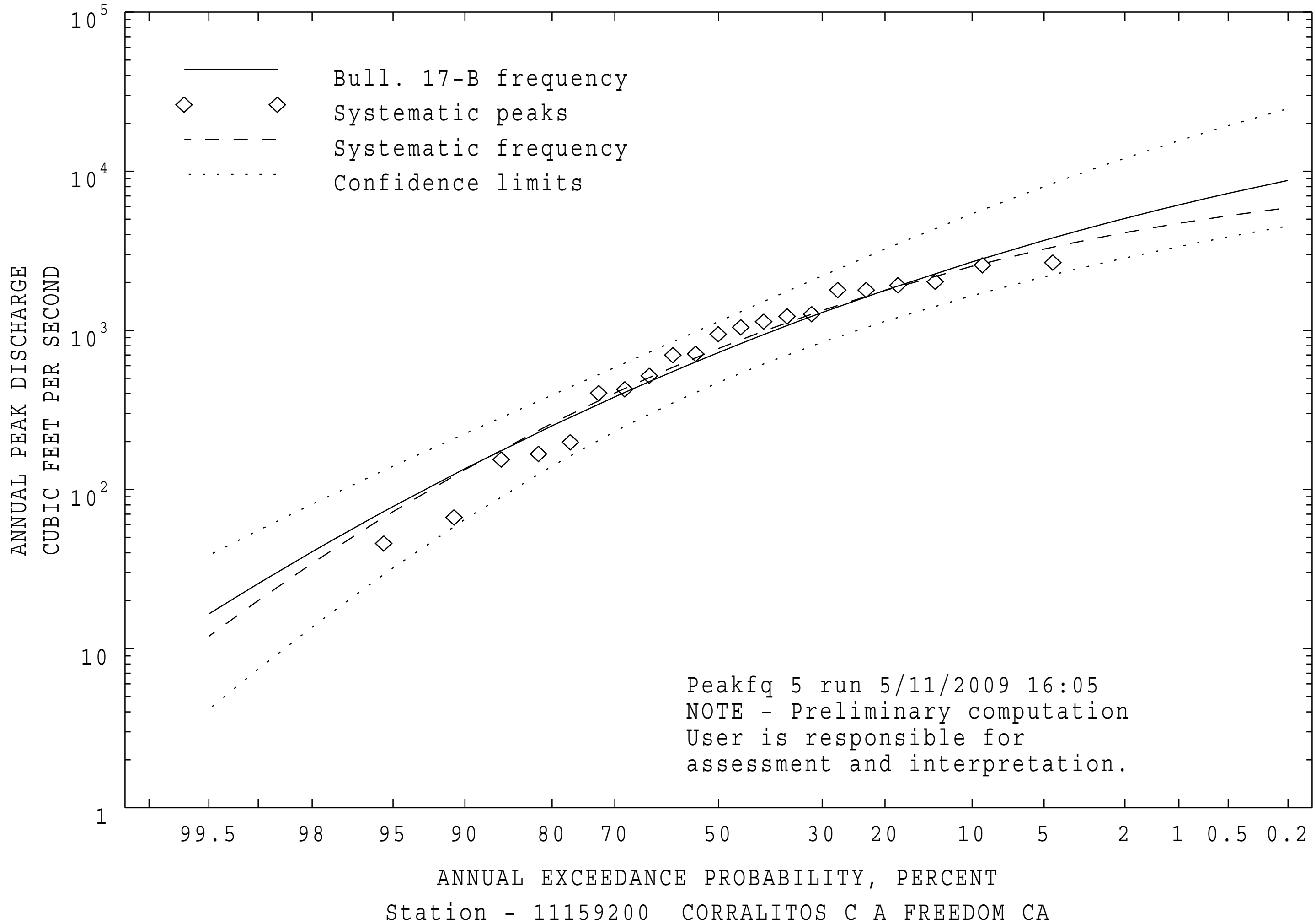


Figure 6: 2009 Correlitos Creek at Freedom Flood Frequency Graph

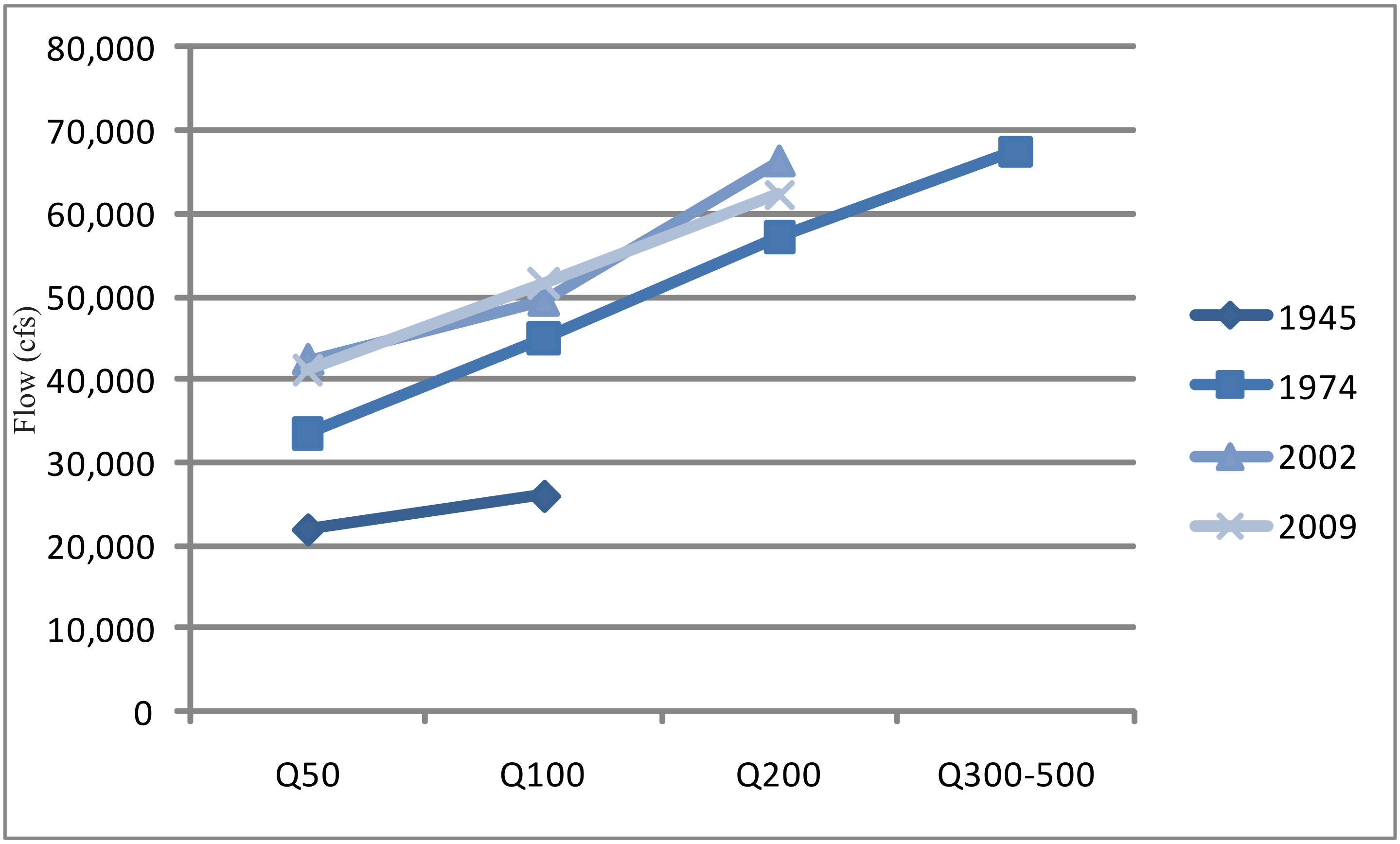


Figure 7: Flood Frequency Comparison

	1945-built plan	1974-alternatives	2001-community	2001-watershed
Flood Protection	x	x	x	x
Levee Wall Height	2-8 ft, ave. 6 ft	4-12 ft, ave. 8ft		
Channel Width	50-150 ft	50-300 ft		
Vegetation Slope Stabilization	Vegetation on some			
Mechanical Slope Stabilization	Jacks, wire			
Sediment Transport				x
Berms		x		
Vegetated Corridors		x	x	
Access along levee		x	x	
Recreation		x		
Water Quality				x
Wildlife Habitat			x	x
Fish Habitat			x	x
Watershed System				x
Reservoir Storage				x
Design Details		habitat protection alternatives	reach charateriza-tion and teatement of urban reach differ-ent than agricultural areas.	storage options in upper watershed

Table 1: Design Features Matrix

	1945-built plan	1974-alternatives	2001-community	2002-watershed	USGS Prgm Calc
Designed Protection (Qx)	50	300-500	100	100	-
Design Protection Flow Amount	22,000	67,500	49,000	49,400	-
Design Calculated Q50	22,000	33,500		42,300	41,181

Table 2: Flood Frequency Calcuation

Appendix A: Pajaro River at Chittenden Gap USGS Flow Calculations

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=1
  Program PeakFq           U. S. GEOLOGICAL SURVEY             Seq.000.000
  Ver. 5.2             Annual peak flow frequency analysis      Run Date / Time
  11/01/2007           following Bulletin 17-B Guidelines       05/04/2009 16:08

                         --- PROCESSING OPTIONS ---

                       Plot option         = None
                       Basin char output   = None
                       Print option        = Yes
                       Debug print         = No
                       Input peaks listing = Long
                       Input peaks format  = WATSTORE peak file

                       Input files used:
                          peaks (ascii)  - F:\HYDRO\PEAK.TXT
                          specifications - PKFQWPSF.TMP
                       Output file(s):
                          main - F:\HYDRO\PEAK.PRT

1
```

Station - 11159000 PAJARO R A CHITTENDEN CA

I N P U T   D A T A   S U M M A R Y

Number of peaks in record	=	70
Peaks not used in analysis	=	1
Systematic peaks in analysis	=	69
Historic peaks in analysis	=	0
Years of historic record	=	0
Generalized skew	=	-0.275
Standard error	=	0.550
Mean Square error	=	0.303
Skew option	=	WEIGHTED
Gage base discharge	=	0.0
User supplied high outlier threshold	=	--
User supplied low outlier criterion	=	--
Plotting position parameter	=	0.00

```
  *********  NOTICE  --  Preliminary machine computations.
*********

  *********  User responsible for assessment and interpretation.
*********


  **WCF109W-PEAKS WITH MINUS-FLAGGED DISCHARGES WERE BYPASSED.       1

  **WCF113W-NUMBER OF SYSTEMATIC PEAKS HAS BEEN REDUCED TO NSYS =   69

    WCF134I-NO SYSTEMATIC PEAKS WERE BELOW GAGE BASE.
0.0

    WCF198I-LOW OUTLIERS BELOW FLOOD BASE WERE DROPPED.       1
21.6

    WCF163I-NO HIGH OUTLIERS OR HISTORIC PEAKS EXCEEDED HHBASE.
223228.0

    WCF002J-CALCS COMPLETED.  RETURN CODE =  2

1


  Program PeakFq           U. S. GEOLOGICAL SURVEY            Seq.001.002

  Ver. 5.2            Annual peak flow frequency analysis      Run Date /
Time

  11/01/2007          following Bulletin 17-B Guidelines       05/04/2009
16:08


                  Station - 11159000  PAJARO R A CHITTENDEN CA



           ANNUAL FREQUENCY CURVE PARAMETERS -- LOG-PEARSON TYPE III


                        FLOOD BASE                  LOGARITHMIC

                  ---------------------  -------------------------------
```

	DISCHARGE	EXCEEDANCE PROBABILITY	MEAN	STANDARD DEVIATION	SKEW
SYSTEMATIC RECORD	0.0	1.0000	3.3954	0.7136	-1.091
BULL.17B ESTIMATE	21.6	0.9855	3.4124	0.6795	-0.736

ANNUAL FREQUENCY CURVE -- DISCHARGES AT SELECTED EXCEEDANCE PROBABILITIES

ANNUAL EXCEEDANCE PROBABILITY	BULL.17B ESTIMATE	SYSTEMATIC RECORD	'EXPECTED PROBABILITY' ESTIMATE	95-PCT CONFIDENCE LIMITS FOR BULL. 17B ESTIMATES LOWER	UPPER
0.9950	--	7.1	--	--	--
0.9900	--	15.7	--	--	--
0.9500	148.5	110.9	137.4	83.6	234.9
0.9000	320.5	274.5	306.3	199.0	474.0
0.8000	755.1	729.0	739.5	514.0	1055.0
0.6667	1565.0	1618.0	1553.0	1123.0	2136.0
0.5000	3126.0	3331.0	3126.0	2292.0	4297.0
0.4292	4078.0	4349.0	4088.0	2989.0	5667.0
0.2000	9877.0	10020.0	10010.0	7027.0	14660.0
0.1000	16310.0	15370.0	16690.0	11230.0	25510.0
0.0400	25950.0	22020.0	26910.0	17230.0	42920.0
0.0200	33790.0	26490.0	35360.0	21930.0	57800.0

0.0100	41870.0	30410.0	44210.0	26640.0	73680.0
0.0050	50040.0	33790.0	53280.0	31310.0	90200.0
0.0020	60750.0	37480.0	65320.0	37300.0	112500.0

1

Program PeakFq U. S. GEOLOGICAL SURVEY Seq.001.003

Ver. 5.2 Annual peak flow frequency analysis Run Date / Time

11/01/2007 following Bulletin 17-B Guidelines 05/04/2009 16:08

Station - 11159000 PAJARO R A CHITTENDEN CA

I N P U T D A T A L I S T I N G

WATER YEAR	DISCHARGE	CODES	WATER YEAR	DISCHARGE	CODES
1938	-8888.0		1974	5400.0	
1940	9880.0		1975	3230.0	
1941	11100.0		1976	104.0	
1942	5390.0		1977	16.0	
1943	9000.0		1978	9420.0	
1944	6080.0		1979	2130.0	
1945	10700.0		1980	8890.0	
1946	1500.0		1981	2680.0	

1947	896.0	1982	12100.0
1948	220.0	1983	15800.0
1949	1980.0	1984	4240.0
1950	1430.0	1985	1360.0
1951	7810.0	1986	13100.0
1952	10000.0	1987	1870.0
1953	2870.0	1988	51.0
1954	682.0	1989	251.0
1955	871.0	1990	148.0
1956	24000.0	1991	2960.0
1957	1110.0	1992	1540.0
1958	23500.0	1993	6630.0
1959	3390.0	1994	600.0
1960	2880.0	1995	21500.0
1961	23.0	1996	8430.0
1962	2910.0	1997	15800.0
1963	11600.0	1998	25100.0
1964	1460.0	1999	4300.0
1965	3300.0	2000	6320.0
1966	1320.0	2001	1280.0
1967	7720.0	2002	2240.0
1968	205.0	2003	2510.0
1969	17800.0	2004	3560.0
1970	5820.0	2005	4010.0
1971	874.0	2006	5110.0
1972	128.0	2007	449.0

```
     1973         8610.0                      2008         1750.0



     Explanation of peak discharge qualification codes

    PeakFQ    NWIS
     CODE     CODE   DEFINITION

       D        3    Dam failure, non-recurrent flow anomaly
       G        8    Discharge greater than stated value
       X       3+8   Both of the above
       L        4    Discharge less than stated value
       K      6 OR C  Known effect of regulation or urbanization
       H        7    Historic peak

       -  Minus-flagged discharge -- Not used in computation
             -8888.0 -- No discharge value given
       -  Minus-flagged water year -- Historic peak used in computation



1

  Program PeakFq           U. S. GEOLOGICAL SURVEY            Seq.001.004
  Ver. 5.2            Annual peak flow frequency analysis      Run Date /
Time
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Station - 11159000 PAJARO R A CHITTENDEN CA

EMPIRICAL FREQUENCY CURVES -- WEIBULL PLOTTING POSITIONS

WATER YEAR	RANKED DISCHARGE	SYSTEMATIC RECORD	BULL.17B ESTIMATE
1998	25100.0	0.0143	0.0143
1956	24000.0	0.0286	0.0286
1958	23500.0	0.0429	0.0429
1995	21500.0	0.0571	0.0571
1969	17800.0	0.0714	0.0714
1983	15800.0	0.0857	0.0857
1997	15800.0	0.1000	0.1000
1986	13100.0	0.1143	0.1143
1982	12100.0	0.1286	0.1286
1963	11600.0	0.1429	0.1429
1941	11100.0	0.1571	0.1571
1945	10700.0	0.1714	0.1714
1952	10000.0	0.1857	0.1857
1940	9880.0	0.2000	0.2000
1978	9420.0	0.2143	0.2143
1943	9000.0	0.2286	0.2286

1980	8890.0	0.2429	0.2429
1973	8610.0	0.2571	0.2571
1996	8430.0	0.2714	0.2714
1951	7810.0	0.2857	0.2857
1967	7720.0	0.3000	0.3000
1993	6630.0	0.3143	0.3143
2000	6320.0	0.3286	0.3286
1944	6080.0	0.3429	0.3429
1970	5820.0	0.3571	0.3571
1974	5400.0	0.3714	0.3714
1942	5390.0	0.3857	0.3857
2006	5110.0	0.4000	0.4000
1999	4300.0	0.4143	0.4143
1984	4240.0	0.4286	0.4286
2005	4010.0	0.4429	0.4429
2004	3560.0	0.4571	0.4571
1959	3390.0	0.4714	0.4714
1965	3300.0	0.4857	0.4857
1975	3230.0	0.5000	0.5000
1991	2960.0	0.5143	0.5143
1962	2910.0	0.5286	0.5286
1960	2880.0	0.5429	0.5429
1953	2870.0	0.5571	0.5571
1981	2680.0	0.5714	0.5714
2003	2510.0	0.5857	0.5857
2002	2240.0	0.6000	0.6000

1979	2130.0	0.6143	0.6143
1949	1980.0	0.6286	0.6286
1987	1870.0	0.6429	0.6429
2008	1750.0	0.6571	0.6571
1992	1540.0	0.6714	0.6714
1946	1500.0	0.6857	0.6857
1964	1460.0	0.7000	0.7000
1950	1430.0	0.7143	0.7143
1985	1360.0	0.7286	0.7286
1966	1320.0	0.7429	0.7429
2001	1280.0	0.7571	0.7571
1957	1110.0	0.7714	0.7714
1947	896.0	0.7857	0.7857
1971	874.0	0.8000	0.8000
1955	871.0	0.8143	0.8143
1954	682.0	0.8286	0.8286
1994	600.0	0.8429	0.8429
2007	449.0	0.8571	0.8571
1989	251.0	0.8714	0.8714
1948	220.0	0.8857	0.8857
1968	205.0	0.9000	0.9000
1990	148.0	0.9143	0.9143
1972	128.0	0.9286	0.9286
1976	104.0	0.9429	0.9429
1988	51.0	0.9571	0.9571
1961	23.0	0.9714	0.9714

```
      1977           16.0          0.9857         0.9857
      1938        -8888.0            --             --
1
```

```
 End PeakFQ analysis.
   Stations processed :       1
   Number of errors   :       0
   Stations skipped   :       0
   Station years      :      70
```

```
Data records may have been ignored for the stations listed below.
(Card type must be Y, Z, N, H, I, 2, 3, 4,  or *.)
(2, 4, and * records are ignored.)
```

```
 For the station below, the following records were ignored:
```

```
 FINISHED PROCESSING STATION:  11159000       USGS PAJARO R A CHITTENDEN
CA
```

```
 For the station below, the following records were ignored:
```

```
 FINISHED PROCESSING STATION:
```

Appendix B: Correlitos Creek at Freedom USGS Flow Calculations

```
1

  Program PeakFq           U. S. GEOLOGICAL SURVEY             Seq.000.000

  Ver. 5.2            Annual peak flow frequency analysis      Run Date /
Time

  11/01/2007          following Bulletin 17-B Guidelines       05/11/2009
16:11


                         --- PROCESSING OPTIONS ---


                      Plot option         = None

                      Basin char output   = None

                      Print option        = Yes

                      Debug print         = No

                      Input peaks listing = Long

                      Input peaks format  = WATSTORE peak file


                      Input files used:

                         peaks (ascii)  - F:\CORR\PEAK

                         specifications - PKFQWPSF.TMP

                      Output file(s):

                         main - F:\CORR\PEAK.PRT


1



  Program PeakFq           U. S. GEOLOGICAL SURVEY             Seq.001.001
```

```
  Ver. 5.2           Annual peak flow frequency analysis      Run Date /
Time

  11/01/2007         following Bulletin 17-B Guidelines       05/11/2009
16:11

                 Station - 11159200  CORRALITOS C A FREEDOM CA



                     I N P U T   D A T A   S U M M A R Y

                Number of peaks in record            =       53

                Peaks not used in analysis           =       32

                Systematic peaks in analysis         =       21

                Historic peaks in analysis           =        0

                Years of historic record             =        0

                Generalized skew                     =   -0.285

                     Standard error                  =    0.550

                     Mean Square error               =    0.303

                Skew option                          =   WEIGHTED

                Gage base discharge                  =      0.0

                User supplied high outlier threshold =   --

                User supplied low outlier criterion  =   --

                Plotting position parameter          =     0.00



  *********  NOTICE  --  Preliminary machine computations.
*********
```

```
  *********  User responsible for assessment and interpretation.
*********

  **WCF109W-PEAKS WITH MINUS-FLAGGED DISCHARGES WERE BYPASSED.      32

  **WCF113W-NUMBER OF SYSTEMATIC PEAKS HAS BEEN REDUCED TO NSYS =   21

    WCF134I-NO SYSTEMATIC PEAKS WERE BELOW GAGE BASE.
0.0

    WCF195I-NO LOW OUTLIERS WERE DETECTED BELOW CRITERION.
37.7

    WCF163I-NO HIGH OUTLIERS OR HISTORIC PEAKS EXCEEDED HHBASE.
11167.7

    WCF002J-CALCS COMPLETED.  RETURN CODE =  2

1



  Program PeakFq            U. S. GEOLOGICAL SURVEY             Seq.001.002

  Ver. 5.2             Annual peak flow frequency analysis      Run Date /
Time

  11/01/2007           following Bulletin 17-B Guidelines       05/11/2009
16:11

                 Station - 11159200  CORRALITOS C A FREEDOM CA



           ANNUAL FREQUENCY CURVE PARAMETERS -- LOG-PEARSON TYPE III


                        FLOOD BASE                 LOGARITHMIC

                  ----------------------  -------------------------------

                             EXCEEDANCE                 STANDARD

                   DISCHARGE PROBABILITY     MEAN      DEVIATION     SKEW
```

SYSTEMATIC RECORD	0.0	1.0000	2.8120	0.5133	-0.876
BULL.17B ESTIMATE	0.0	1.0000	2.8120	0.5133	-0.570

ANNUAL FREQUENCY CURVE -- DISCHARGES AT SELECTED EXCEEDANCE PROBABILITIES

ANNUAL EXCEEDANCE PROBABILITY	BULL.17B ESTIMATE	SYSTEMATIC RECORD	'EXPECTED PROBABILITY' ESTIMATE	95-PCT CONFIDENCE LIMITS FOR BULL. 17B ESTIMATES LOWER	UPPER
0.9950	16.5	11.9	8.9	4.2	38.6
0.9900	25.6	20.1	16.2	7.4	55.2
0.9500	78.2	72.5	64.7	32.1	140.0
0.9000	135.2	133.4	121.0	64.9	224.3
0.8000	251.4	260.6	238.5	140.5	391.9
0.6667	430.4	456.2	421.6	265.3	657.8
0.5000	725.4	769.2	725.4	470.7	1136.0
0.4292	889.5	937.1	895.7	581.4	1425.0
0.2000	1786.0	1781.0	1855.0	1140.0	3242.0
0.1000	2695.0	2530.0	2880.0	1653.0	5405.0
0.0400	4004.0	3463.0	4460.0	2335.0	8943.0
0.0200	5055.0	4112.0	5821.0	2850.0	12080.0
0.0100	6144.0	4710.0	7318.0	3363.0	15560.0
0.0050	7261.0	5255.0	8943.0	3870.0	19340.0

0.0020	8761.0	5897.0	11270.0	4529.0	24730.0

1

Program PeakFq U. S. GEOLOGICAL SURVEY Seq.001.003

Ver. 5.2 Annual peak flow frequency analysis Run Date / Time

11/01/2007 following Bulletin 17-B Guidelines 05/11/2009 16:11

Station - 11159200 CORRALITOS C A FREEDOM CA

I N P U T D A T A L I S T I N G

WATER YEAR	DISCHARGE	CODES	WATER YEAR	DISCHARGE	CODES
1956	-3620.0	H	1983	-2150.0	K
1957	715.0		1984	-488.0	K
1958	2680.0		1985	-1120.0	K
1959	950.0		1986	-5320.0	K
1960	1140.0		1987	-1460.0	K
1961	46.0		1988	-83.0	K
1962	1050.0		1989	-396.0	K
1963	2580.0		1990	-372.0	K
1964	702.0		1991	-780.0	K
1965	1800.0		1992	-1830.0	K

1966	199.0		1993	-1490.0	K
1967	1800.0		1994	-245.0	K
1968	405.0		1995	-2330.0	K
1969	1270.0		1996	-2000.0	K
1970	2030.0		1997	-3540.0	K
1971	428.0		1998	-2190.0	K
1972	155.0		1999	-2250.0	K
1973	1930.0		2000	-4260.0	K
1974	1230.0		2001	-510.0	K
1975	521.0		2002	-867.0	K
1976	168.0		2003	-1390.0	K
1977	67.0		2004	-2050.0	K
1978	-1320.0	K	2005	-1420.0	K
1979	-413.0	K	2006	-2180.0	K
1980	-1560.0	K	2007	-133.0	K
1981	-498.0	K	2008	-965.0	K
1982	-5610.0	K			

Explanation of peak discharge qualification codes

PeakFQ CODE	NWIS CODE	DEFINITION
D	3	Dam failure, non-recurrent flow anomaly
G	8	Discharge greater than stated value

```
X        3+8   Both of the above
L         4    Discharge less than stated value
K      6 OR C  Known effect of regulation or urbanization
H         7    Historic peak

-  Minus-flagged discharge -- Not used in computation
      -8888.0 -- No discharge value given
-  Minus-flagged water year -- Historic peak used in computation
```

1

```
Program PeakFq           U. S. GEOLOGICAL SURVEY            Seq.001.004
Ver. 5.2            Annual peak flow frequency analysis      Run Date / Time
11/01/2007          following Bulletin 17-B Guidelines       05/11/2009 16:11

               Station - 11159200  CORRALITOS C A FREEDOM CA

 EMPIRICAL FREQUENCY CURVES -- WEIBULL PLOTTING POSITIONS

    WATER          RANKED        SYSTEMATIC      BULL.17B
     YEAR        DISCHARGE         RECORD        ESTIMATE
```

1958	2680.0	0.0455	0.0455
1963	2580.0	0.0909	0.0909
1970	2030.0	0.1364	0.1364
1973	1930.0	0.1818	0.1818
1965	1800.0	0.2273	0.2273
1967	1800.0	0.2727	0.2727
1969	1270.0	0.3182	0.3182
1974	1230.0	0.3636	0.3636
1960	1140.0	0.4091	0.4091
1962	1050.0	0.4545	0.4545
1959	950.0	0.5000	0.5000
1957	715.0	0.5455	0.5455
1964	702.0	0.5909	0.5909
1975	521.0	0.6364	0.6364
1971	428.0	0.6818	0.6818
1968	405.0	0.7273	0.7273
1966	199.0	0.7727	0.7727
1976	168.0	0.8182	0.8182
1972	155.0	0.8636	0.8636
1977	67.0	0.9091	0.9091
1961	46.0	0.9545	0.9545
1988	-83.0	--	--
2007	-133.0	--	--
1994	-245.0	--	--
1990	-372.0	--	--
1989	-396.0	--	--

1979	-413.0	--	--
1984	-488.0	--	--
1981	-498.0	--	--
2001	-510.0	--	--
1991	-780.0	--	--
2002	-867.0	--	--
2008	-965.0	--	--
1985	-1120.0	--	--
1978	-1320.0	--	--
2003	-1390.0	--	--
2005	-1420.0	--	--
1987	-1460.0	--	--
1993	-1490.0	--	--
1980	-1560.0	--	--
1992	-1830.0	--	--
1996	-2000.0	--	--
2004	-2050.0	--	--
1983	-2150.0	--	--
2006	-2180.0	--	--
1998	-2190.0	--	--
1999	-2250.0	--	--
1995	-2330.0	--	--
1997	-3540.0	--	--
1956	-3620.0	--	--
2000	-4260.0	--	--
1986	-5320.0	--	--

```
      1982        -5610.0           --              --
1



 End PeakFQ analysis.
   Stations processed :       1
   Number of errors   :       0
   Stations skipped   :       0
   Station years      :      53


Data records may have been ignored for the stations listed below.
(Card type must be Y, Z, N, H, I, 2, 3, 4,  or *.)
(2, 4, and * records are ignored.)

 For the station below, the following records were ignored:

 FINISHED PROCESSING STATION:  11159200       USGS CORRALITOS C A FREEDOM CA


 For the station below, the following records were ignored:

 FINISHED PROCESSING STATION:
```