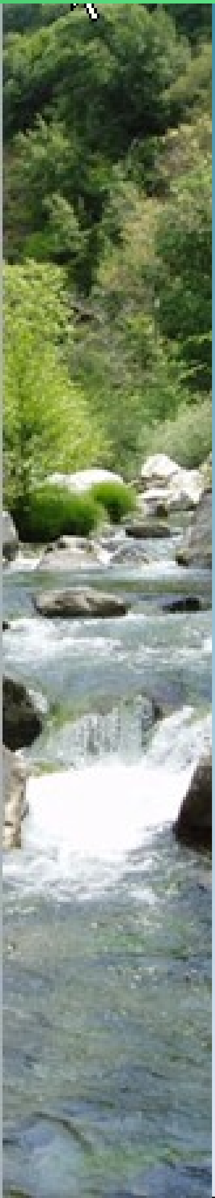


The Carmel River
30 Years of Restoration

A presentation to the

San Jose Branch of the American Society of Civil Engineers

Wednesday, June 20, 2012

Larry Hampson, District Engineer

Topics

Characterization of the Carmel River watershed

- Geology and Basin Characteristics
- Main stem characteristics
- Pre-1960s anthropomorphic effects on stream morphology

Effects of Water Production from Carmel Valley

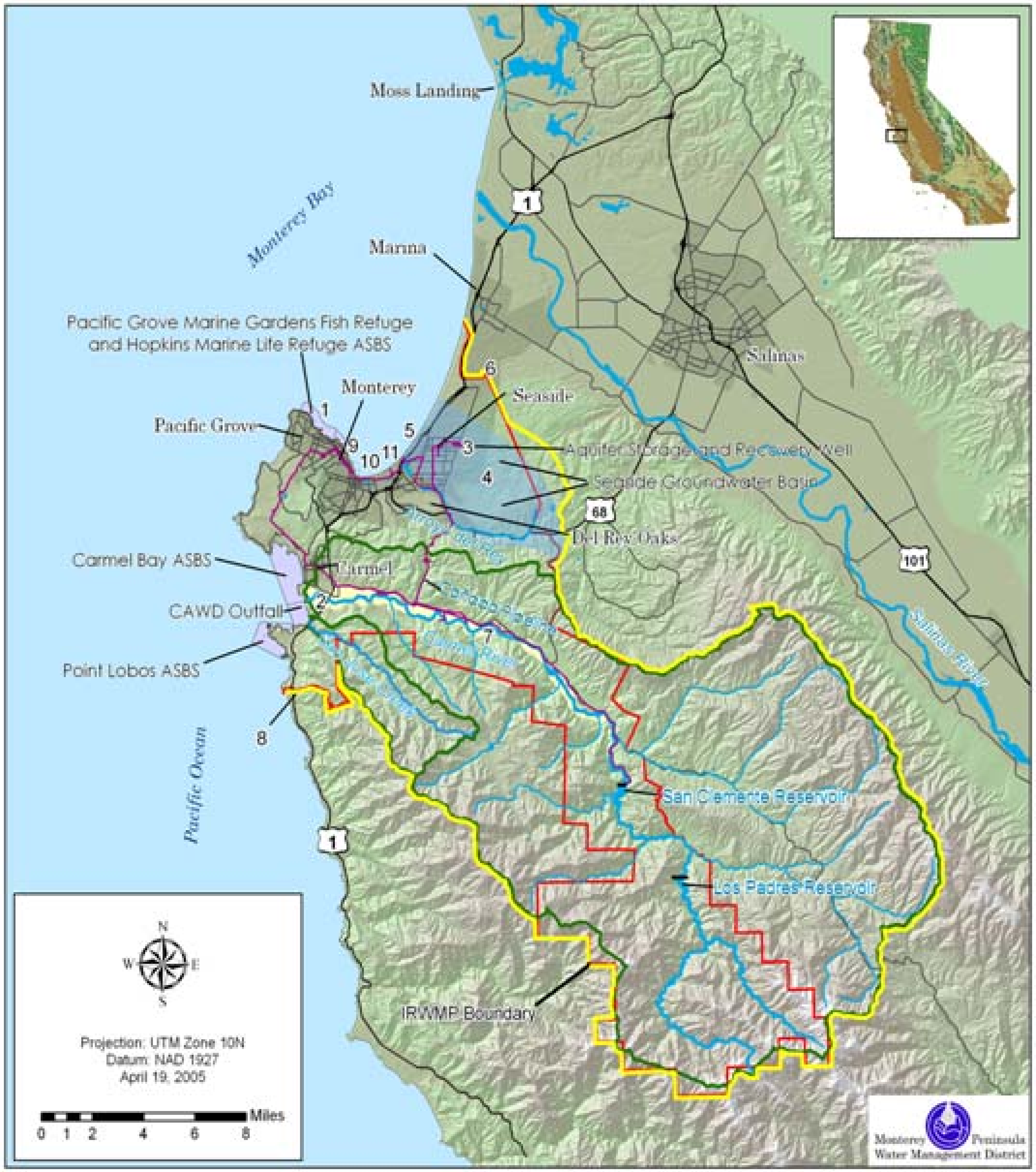
- Carmel River diversions
- Channel instability – 1960's to 1980's

Restoration Program

- Preferred solution
- Implementation

Results

Monterey Peninsula Water Management District



No.	Project	Sponsor
1	Refine ASBS Alternatives	Monterey/PG
2	Lower Carmel River Restoration and Floodplain Enhancement	MCWRA/BSLT/MPWMD
3	Seaside Groundwater Basin Aquifer Storage and Recovery	MPWMD/CAW
4	Seaside Basin Groundwater Replenishment	MRWPCA
5	Seaside 90" Outfall Infiltration Component	City of Seaside
6	CSUMB Stormwater Percolation and Education	CSUMB
7	Carmel River Watershed Volunteer Monitoring Program	CRWC
8	Water Conservation Retrofit Program	MPWMD
9	Sanitary Sewer System Repair and Replacement	Monterey/PG
10	Microbial Source Tracking	Monterey/PG
11	Implementation of Solid Waste Removal Technology	Monterey/PG

IRWMP Area
MPWMD Boundary
Rivers
Cal-Am Pipelines
Roads
Watershed Boundaries
Seaside Groundwater Basin
Carmel Valley Alluvial Aquifer
Areas of Special Biological Significar
City Limits

Population

- Carmel Valley ~ 20,000
- Monterey Peninsula and Carmel Valley total = 115,000

Area

- Carmel R. watershed = 255 sq. mi.
- IRWM Planning area =
- 350 sq. miles

Basic Problem Statement

Problem 1:

The natural range of dynamic forces is greater than development constraints imposed along the river.

Problem 2:

The Carmel River was pushed out of dynamic equilibrium.

Solution

1. Gather and analyze channel data

2. Use a comprehensive approach

3. Be both patient and opportunistic

4. Persevere in the face of opposition and continue project monitoring and maintenance until a project is proven

Carmel River Basin Physical Features

- 255 square-mile watershed, 36 miles of main stem
- 580 acres of main stem riparian area in the lower 18.6 miles

(average of ~ 260 feet wide)

- Large lagoon at the mouth (100 acres)
- Alluvial deposits range from > 150 feet at Hwy 1 to about 60 feet at Rosie's Bridge (RM 14) to < 10 feet in canyon control
- Upper 20 miles are in steep canyons with relatively few structures near the river
- Alluvium is sand-gravel near the ocean and cobble-boulder in canyon-controlled reach
- Gradient varies from 3 to 120 feet per thousand
- Two main stem dams at RM 18.6 and RM 24.8
- Headwaters are in National Forest and Ventana Wilderness
- 60.5 miles of stream are accessible to steelhead

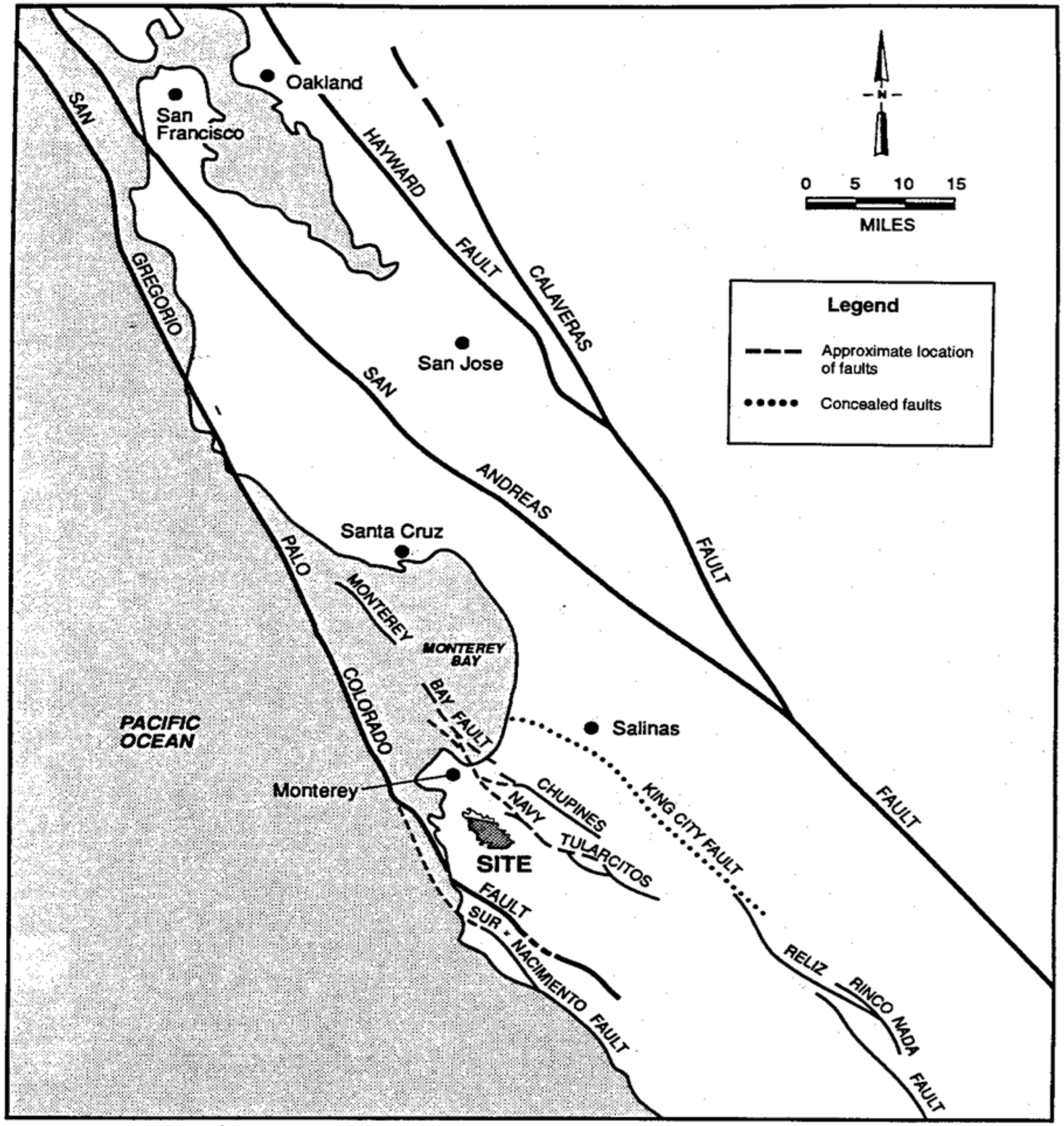
Basin Geology

- Portions of the watershed date from the end of the Cretaceous period (about 65 million years ago)

- A complex quilt of igneous, metamorphic, and sedimentary rocks stitched together by faults of varying ages and other kinds of contacts (i.e., differences in horizontal layers).

Geologic units within the valley include three significant units: Basement rocks of pre-Tertiary age (>65 MYA), consolidated sedimentary rocks of Tertiary age (2.6-65 MYA), and unconsolidated sediments of Quaternary age (<2.6 MYA)

Regional Faults



Source: Cleary Consultants 1994.

Jones & Stokes Associates, Inc.

Figure 6-3
Regional Fault System

Highly Variable Landscape

Above - river flow through the “slot” in bedrock outcrop at the Carmel River mouth, April 25, 2008

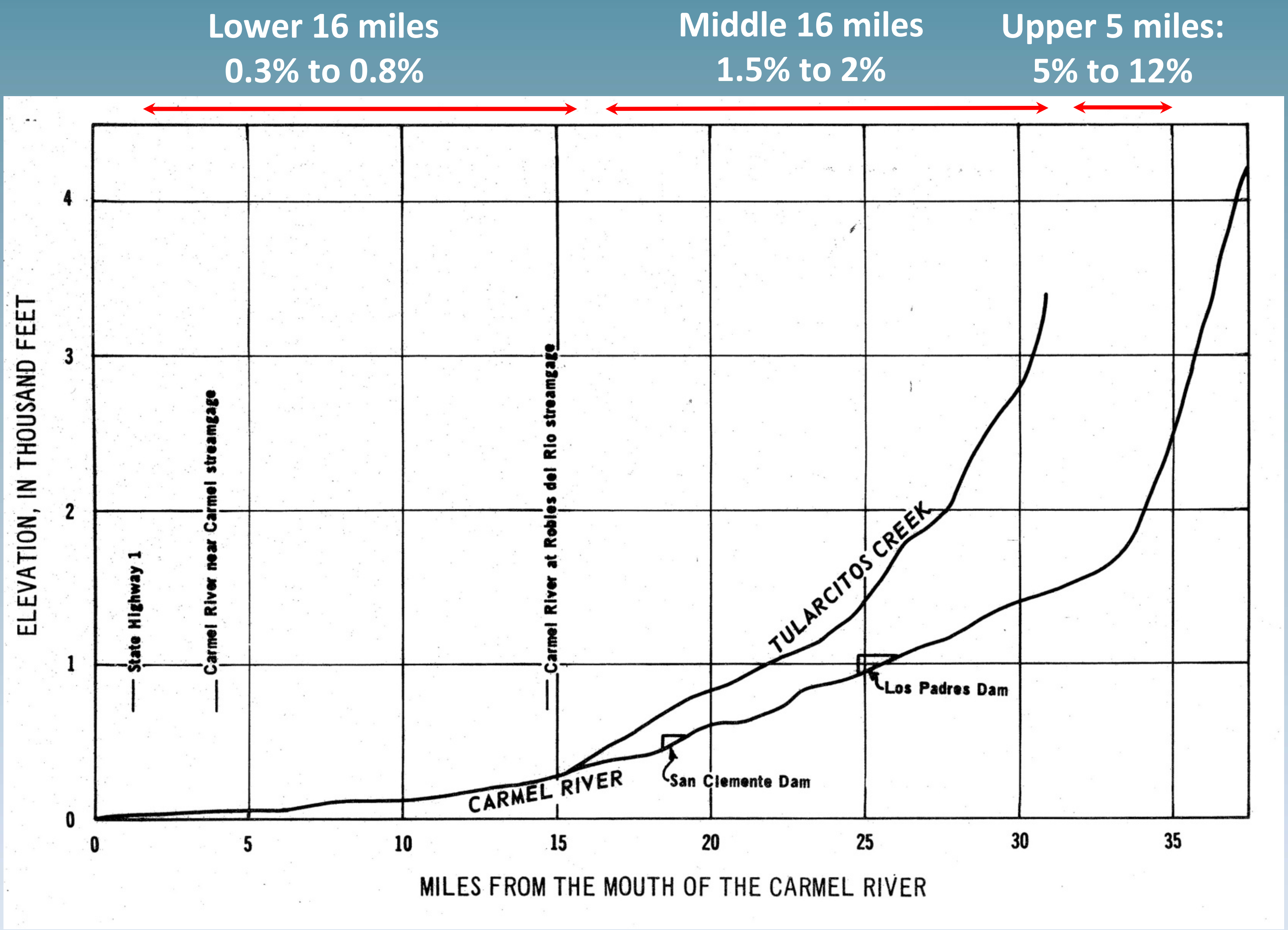
Upper Carmel River - 2007

Rock Basement Layer at Carmel River State Beach (50-60 MYA)

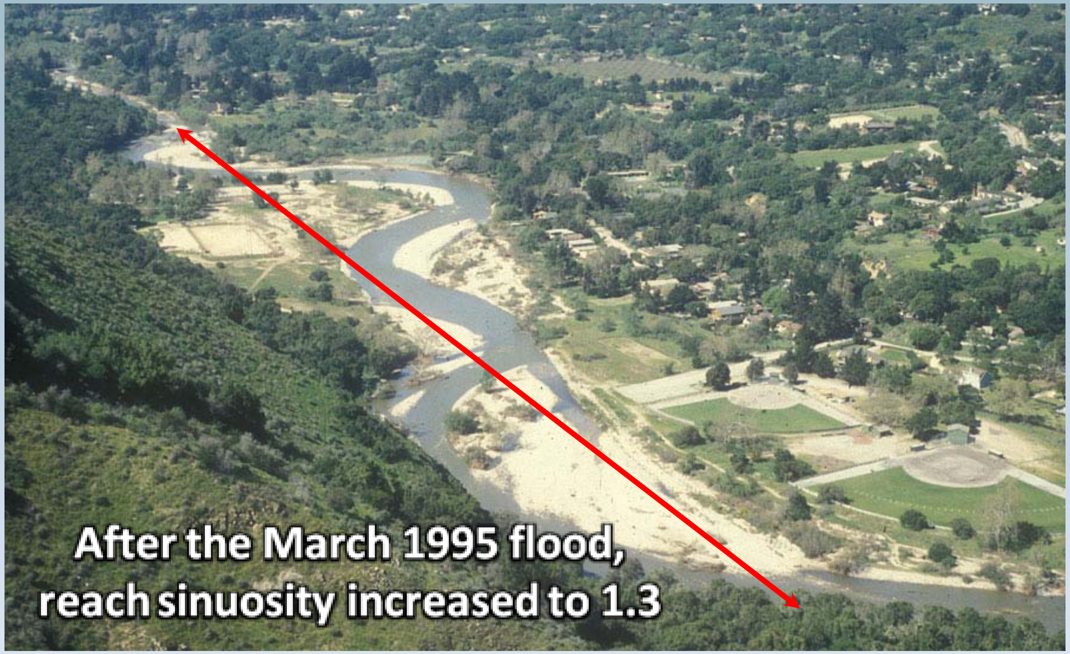
Proto Carmel River

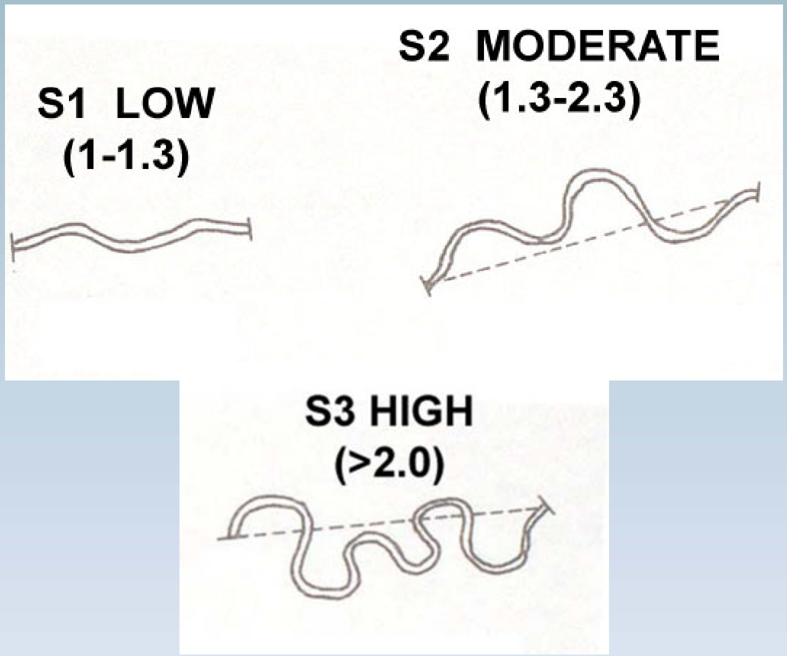
Carmel River at River Mile 8.5

Carmel River Profile



Carmel River Sinuosity





Bed material size

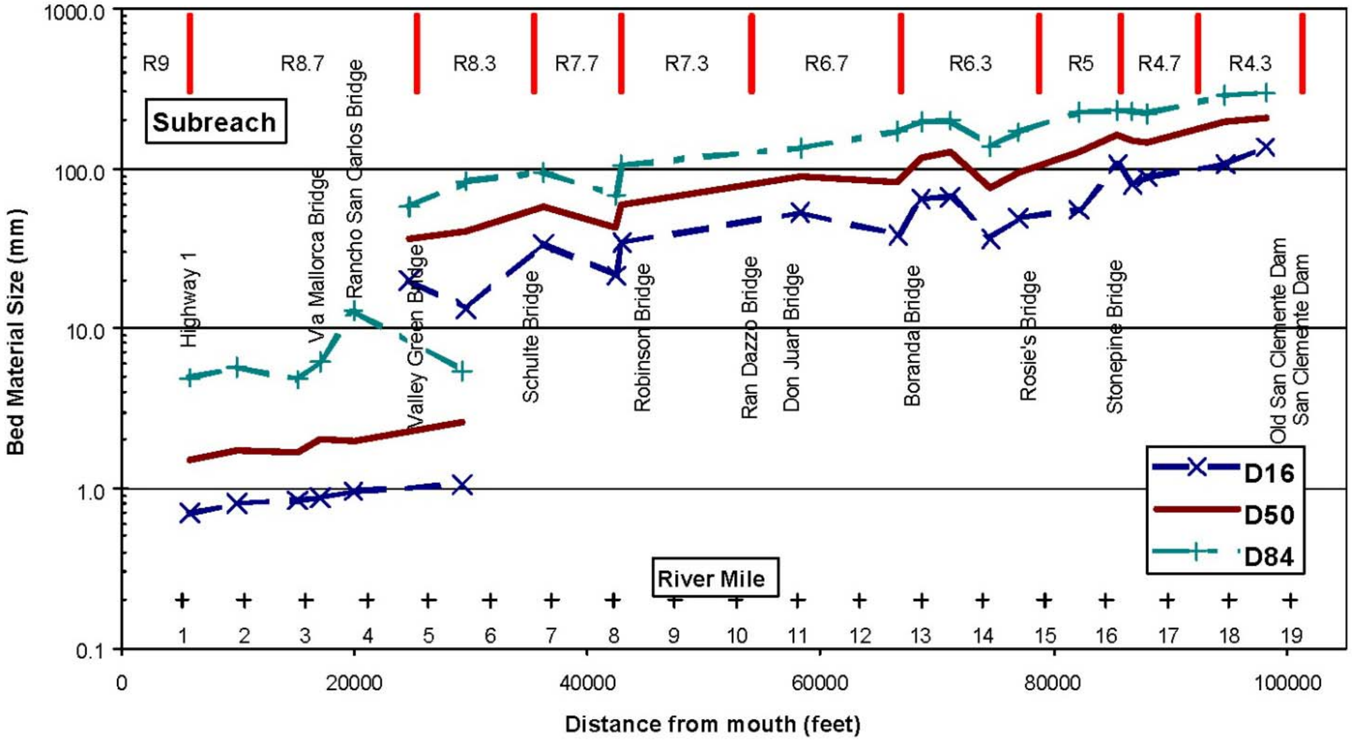


Figure 2.2. Longitudinal variation in bed material size along the Carmel River study reach based on surface sediment samples collected by MEI and MPWMD in April 2001.

Largest particles

Left – RM 12 in alluvium
Below – RM 28 in canyon

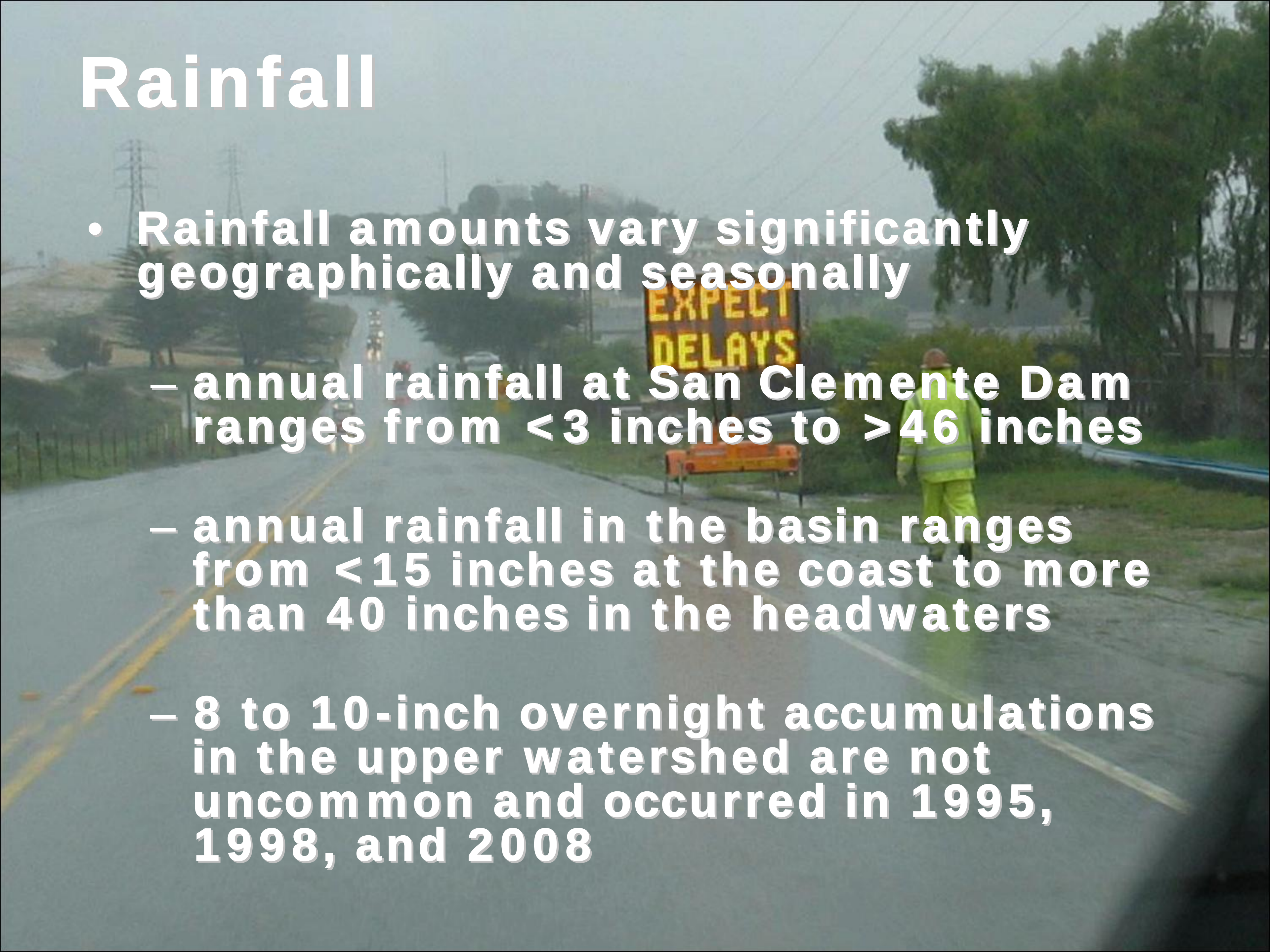
Mediterranean Climate

Left - San Clemente Dam, March 10, 1995 (Photo courtesy of California American Water).

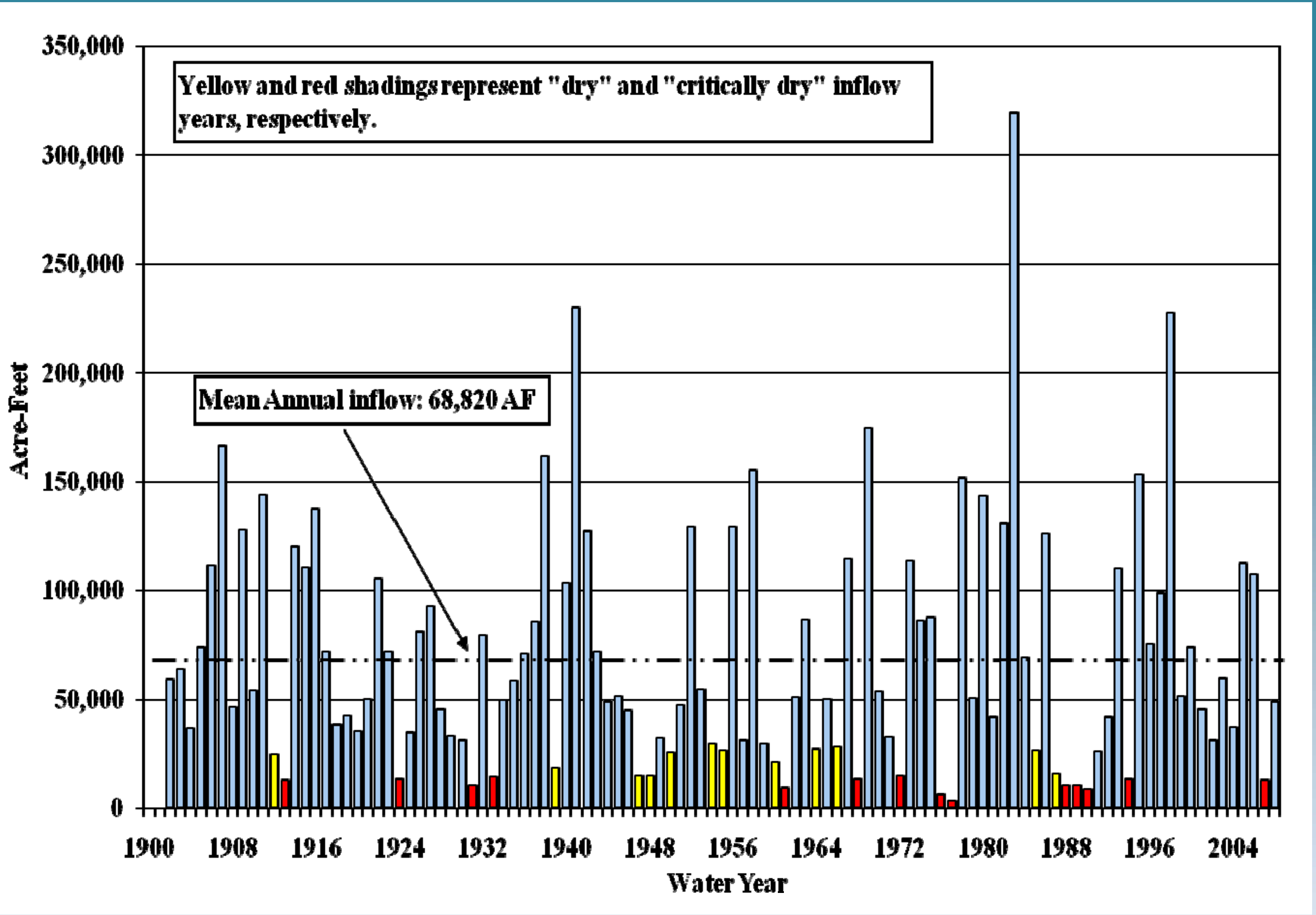
Tree ring study showed an average of one major fire every 20 years

Rainfall

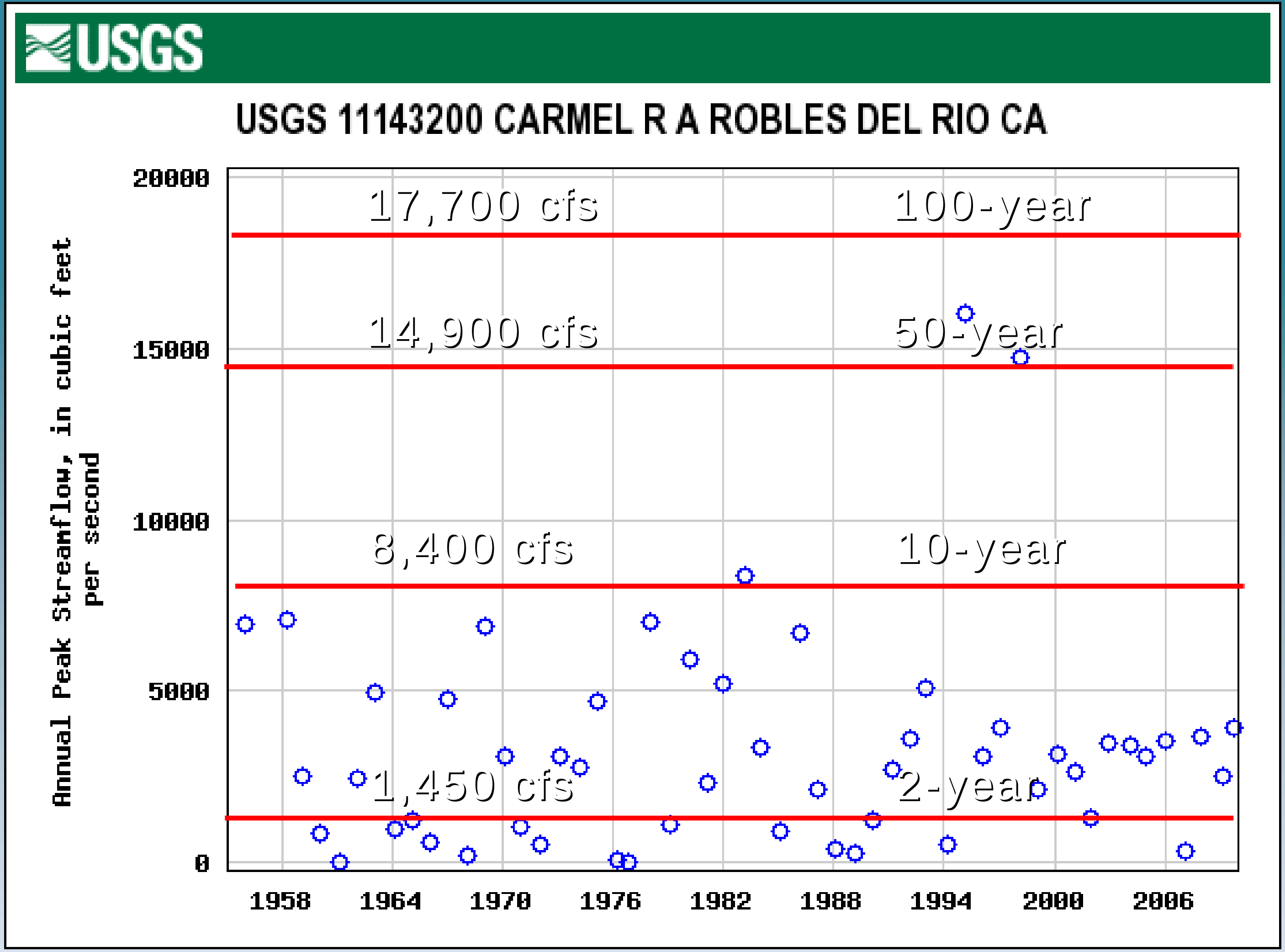
- Rainfall amounts vary significantly geographically and seasonally
  - annual rainfall at San Clemente Dam ranges from <3 inches to >46 inches
  - annual rainfall in the basin ranges from <15 inches at the coast to more than 40 inches in the headwaters
  - 8 to 10-inch overnight accumulations in the upper watershed are not uncommon and occurred in 1995, 1998, and 2008



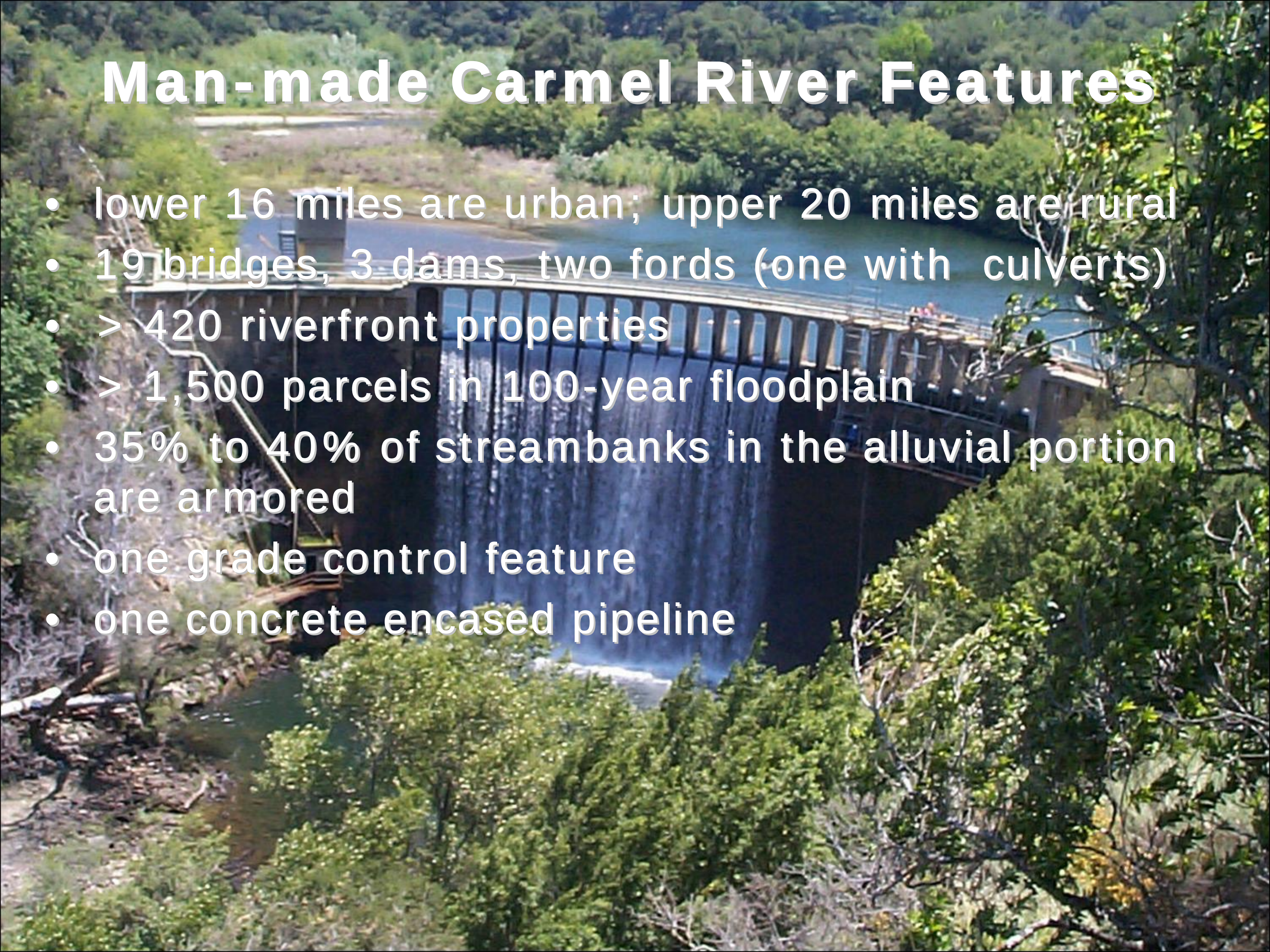
Unimpaired Carmel River Flow at San Clemente Dam Site: Water Years 1902- 2008



Peak Carmel River Streamflow WY 1958 - 2010 Robles Del Rio (RM 14.5)



Measurement Parameter	Orders of Magnitude
• Annual rainfall (inches) (San Clemente Dam)	2 (3 – 46)
• Thalweg slope	3 (0.003 to 0.12)
• Peak recorded annual streamflow (cfs)	5 (0 to 16,000)
• Bed material size (mm)	5 (< 0.1 to > 1,000)
• Annual basin runoff (AFA)	6 (0 to 368,000)
• Measured sediment transport rate (tons/day)	6 (0 to >125,000)



Man-made Carmel River Features

- lower 16 miles are urban; upper 20 miles are rural
- 19 bridges, 3 dams, two fords (one with culverts)
- > 420 riverfront properties
- > 1,500 parcels in 100-year floodplain
- 35% to 40% of streambanks in the alluvial portion are armored
- one grade control feature
- one concrete encased pipeline

Significant Influences on channel form prior to the 1970's

- Beginning in 1921, 100% retention of bedload sediment and partial retention of suspended load in two main stem reservoirs
- Diversions that annually dewater up to 15 miles of the stream
- Gravel mining from 1920 through the 1970s that exceeded replenishment rate
- Floodplain development and river straightening
- Channel clearing activities dating from at least the 1940s through the 1970s

Old Carmel Dam built at RM 18 to serve Hotel Del Monte

- constructed ca 1880
- 700 Chinese laborers
- 25 miles of 12-inch iron pipe
- crossed river in five places
- first Monterey Peninsula water supply
- included five-foot trestle at Robinson Canyon (RM 8.1)

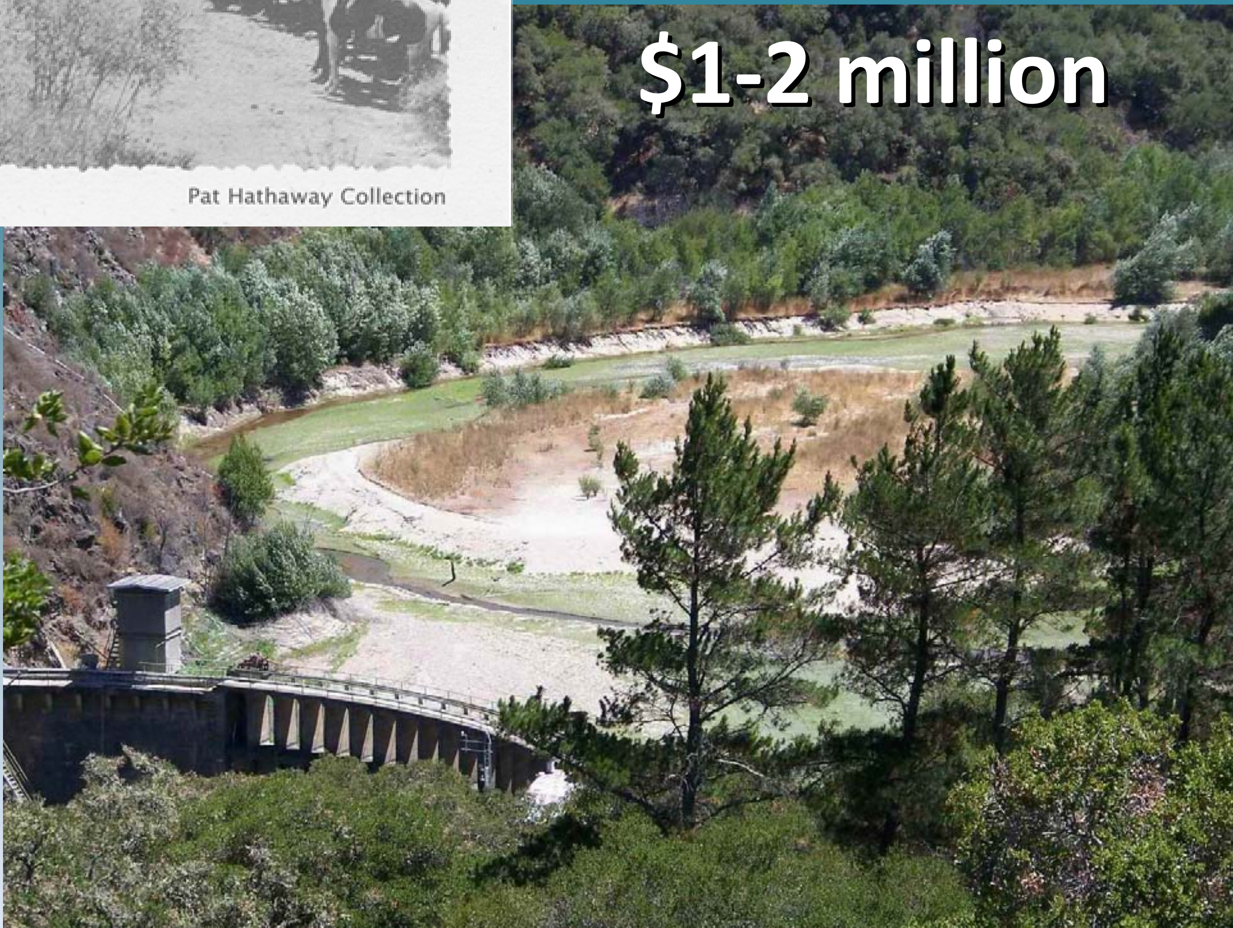
The Carmel River becomes joined to the Monterey Peninsula

Hotel Del Monte opened June 10, 1880 by
Charles Crocker (Pacific Improvement Company)

San Clemente Dam at RM 18.6

1921 cost to build:
$1-2 million

San Clemente Dam • March 29, 1932 Pat Hathaway Collection



2007 estimate to remove:
$83 million

San Clemente Dam Fish Ladder 70 feet – reported to be highest working ladder in California

Usable surface storage in San Clemente Reservoir reduced to ~ 60 AF

Upper watershed is cut off from lower alluvial section

40% of Los Padres Reservoir has silted in over 60 years

Fire hastens mass wasting into Los Padres Reservoir

Channel Mining 1920s-1970s

Photo 41. Valley Rock and Adobe Company's sand and gravel pit. This Carmel River stream channel deposit is narrow, being confined by levees over a distance of 15 miles upstream from the mouth. The stream normally flows most of the year, but after three successive "dry" winters the channel was completely dry in October 1961.

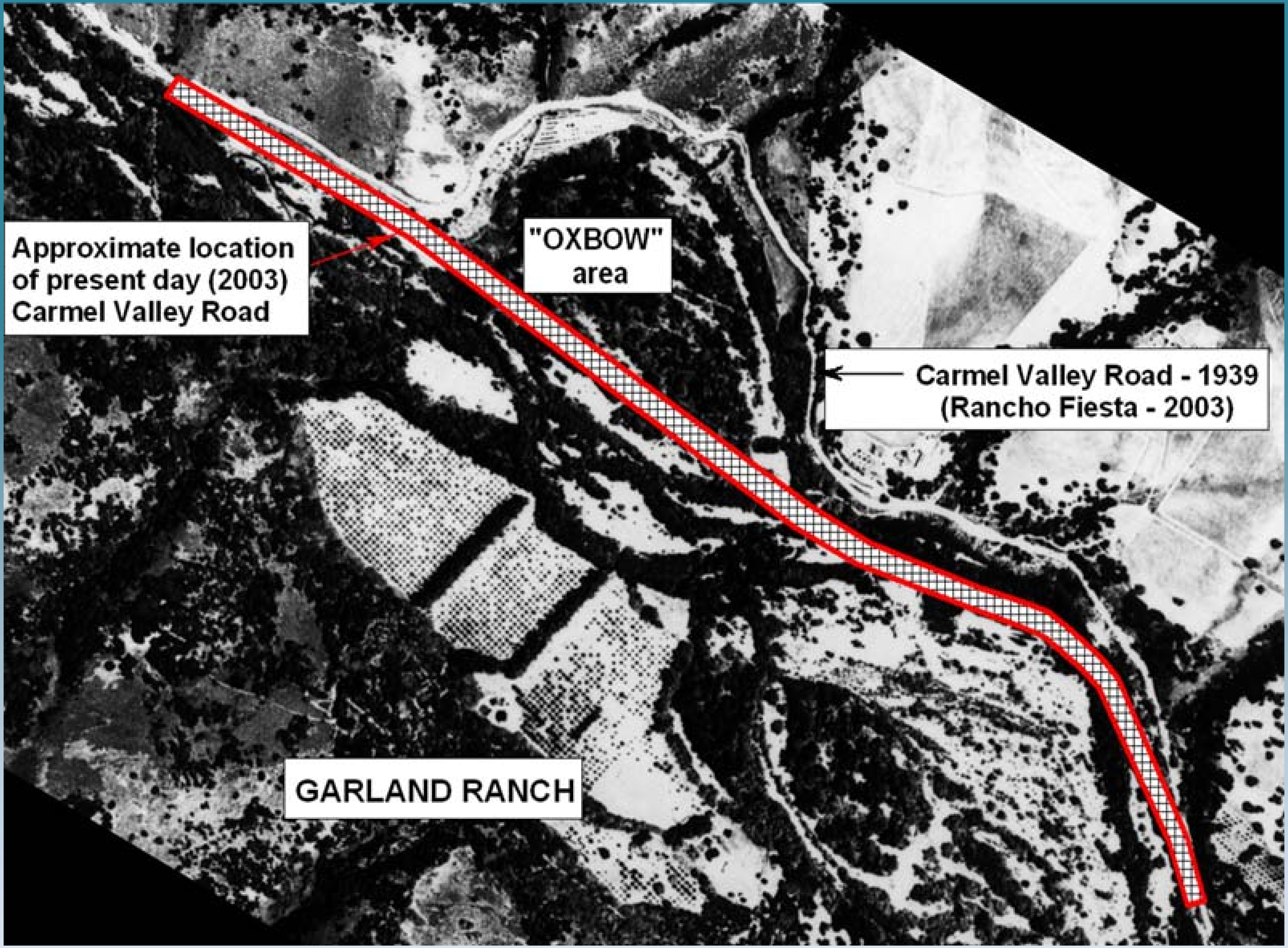
Mid-Carmel Valley – October 1961

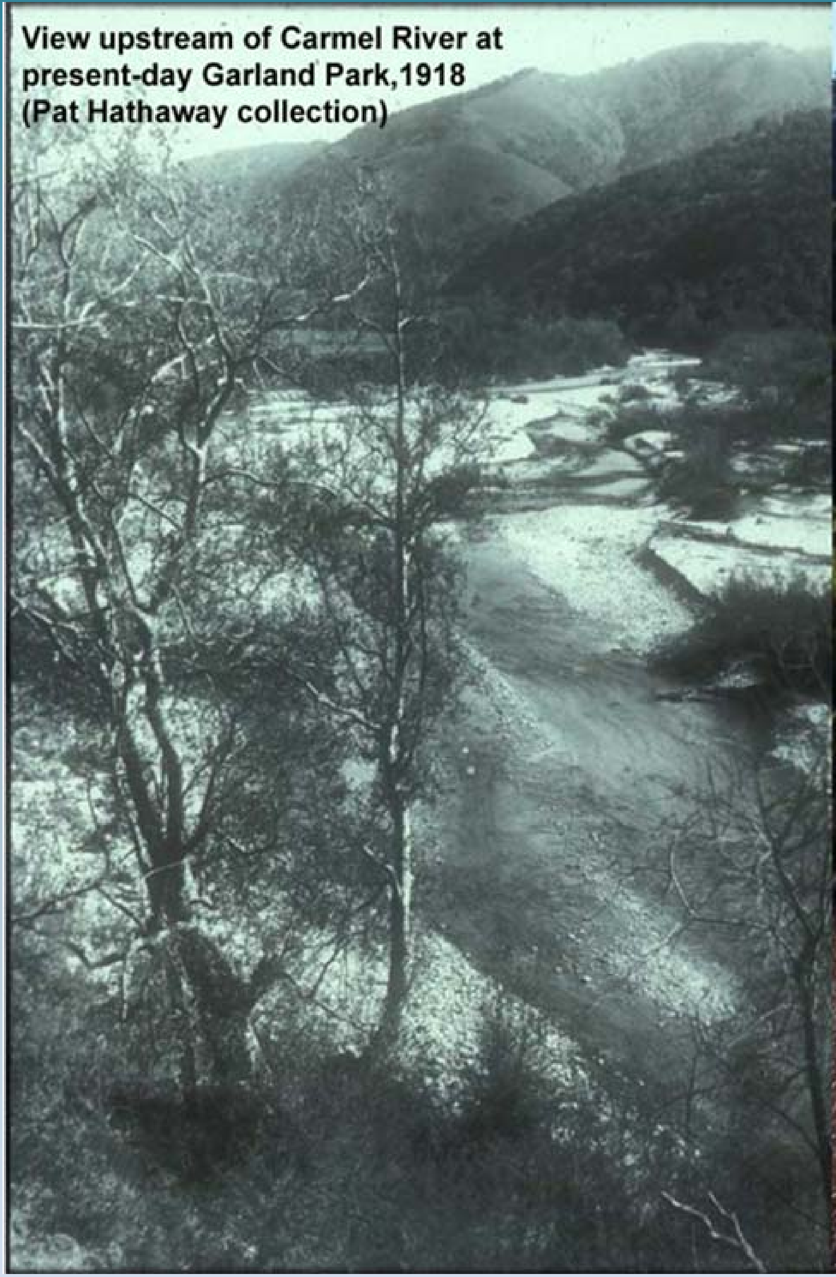
Notes about the Carmel River in 1966:

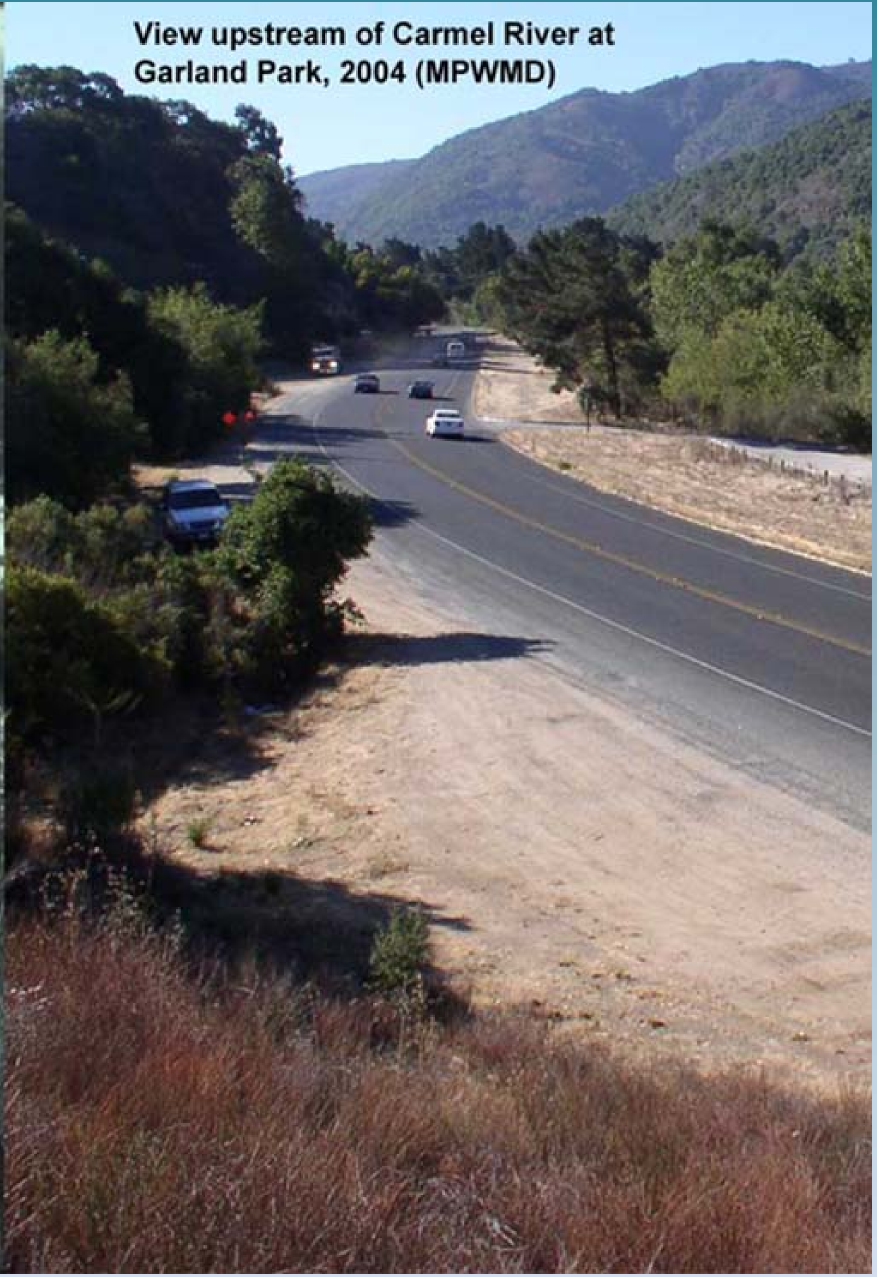
- "Constant exploitation since 1920."
- "…rate of replenishment during flood is small compared to mining."

(Earl W. Hart, Mines and Mineral Resources of Monterey County, County Report 5, California Division of Mines and Geology, 1966, Table 7)

River Straightening







Carmel Valley Road at RM 11

Channel Maintenance – 1940's

Carmel Valley Road at RM 8

Topics

Characterization of the Carmel River watershed

- ✓ Geology and Basin Characteristics
- ✓ Carmel River Characteristics
- ✓ Pre-1960s Anthropomorphic Effects on Stream Morphology

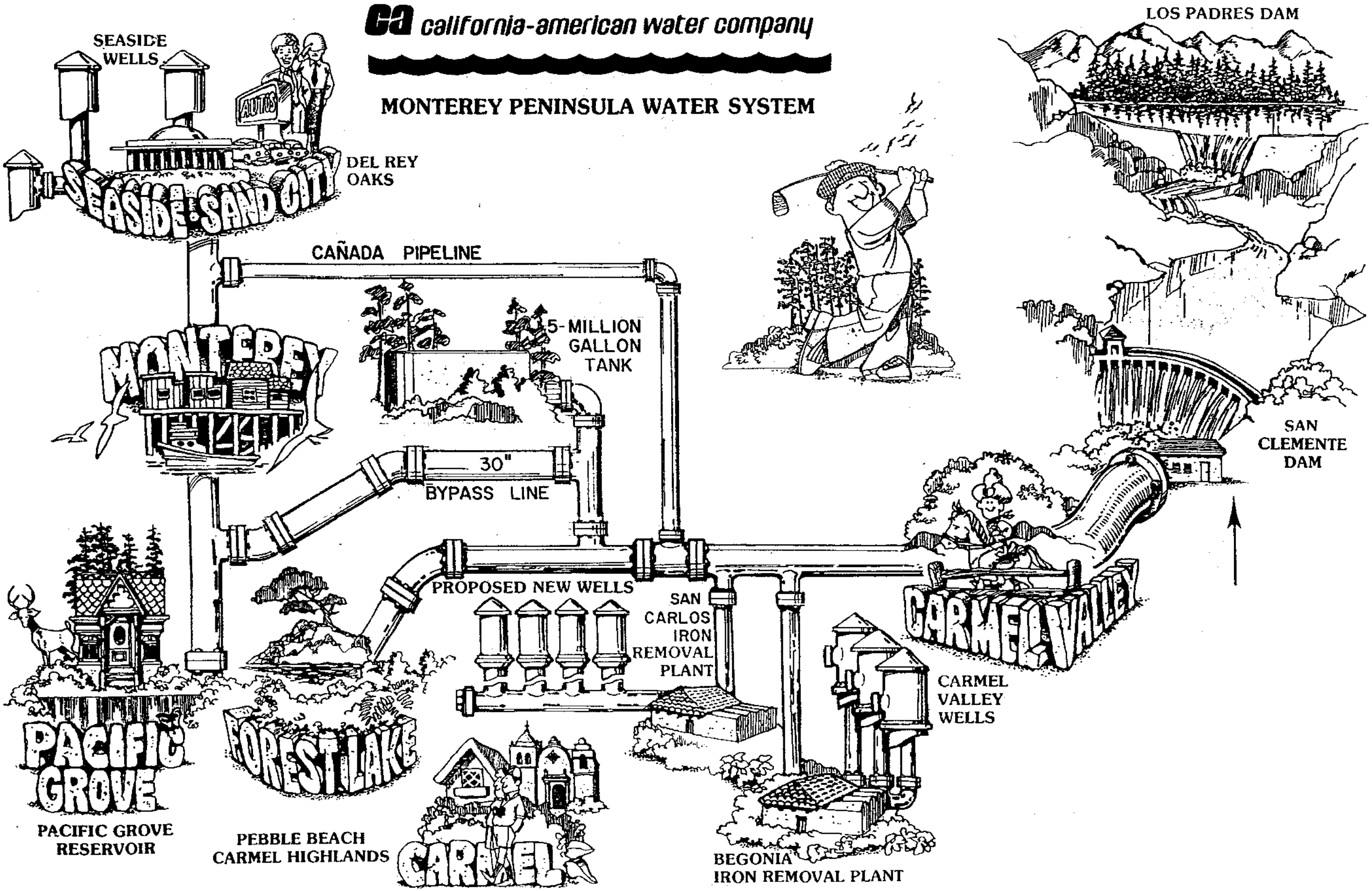
History and Effects of Water Production

- Carmel River Diversions
- Channel Instability – 1960’s to 1980’s

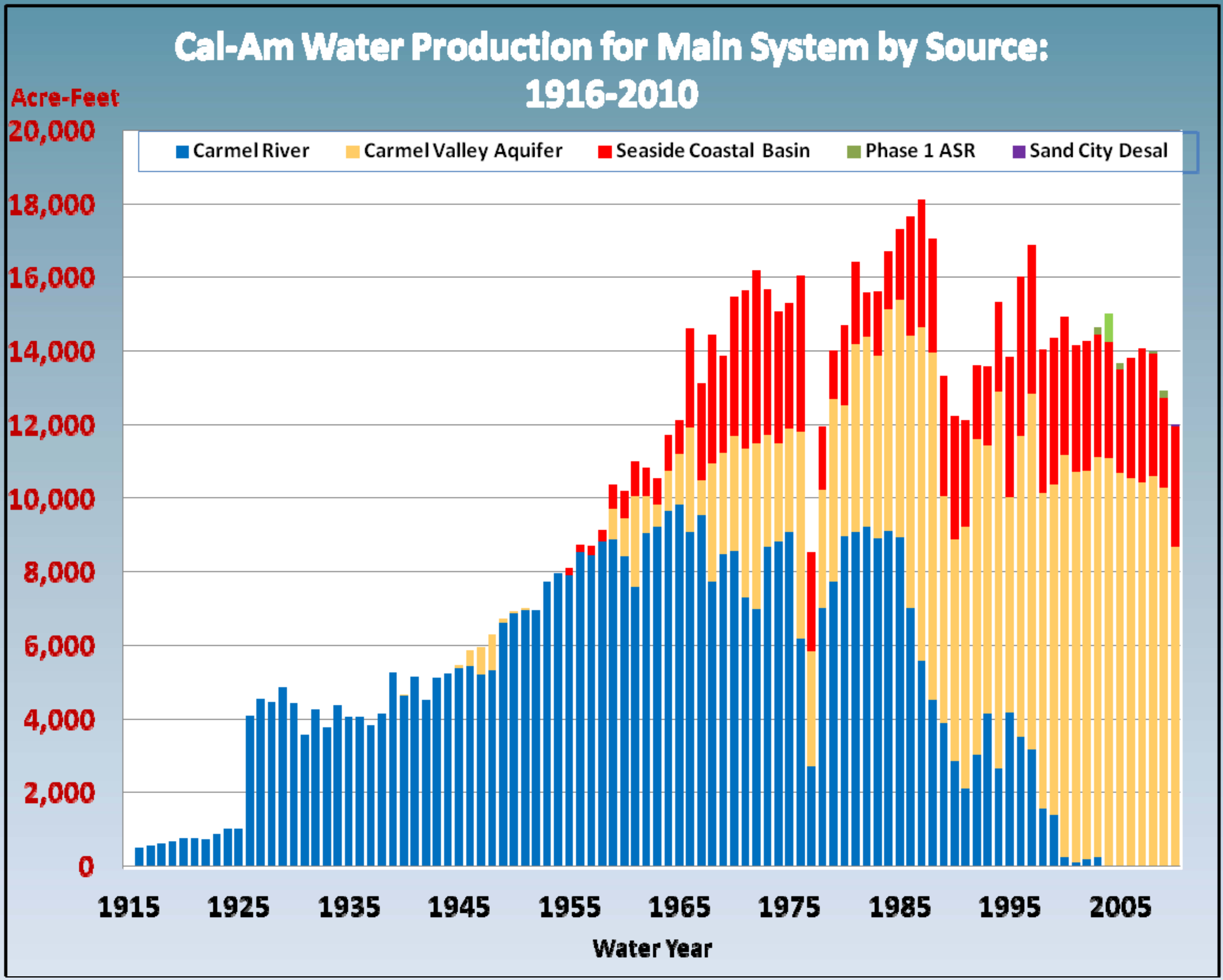
Restoration Program

- Preferred Solution
- Implementation

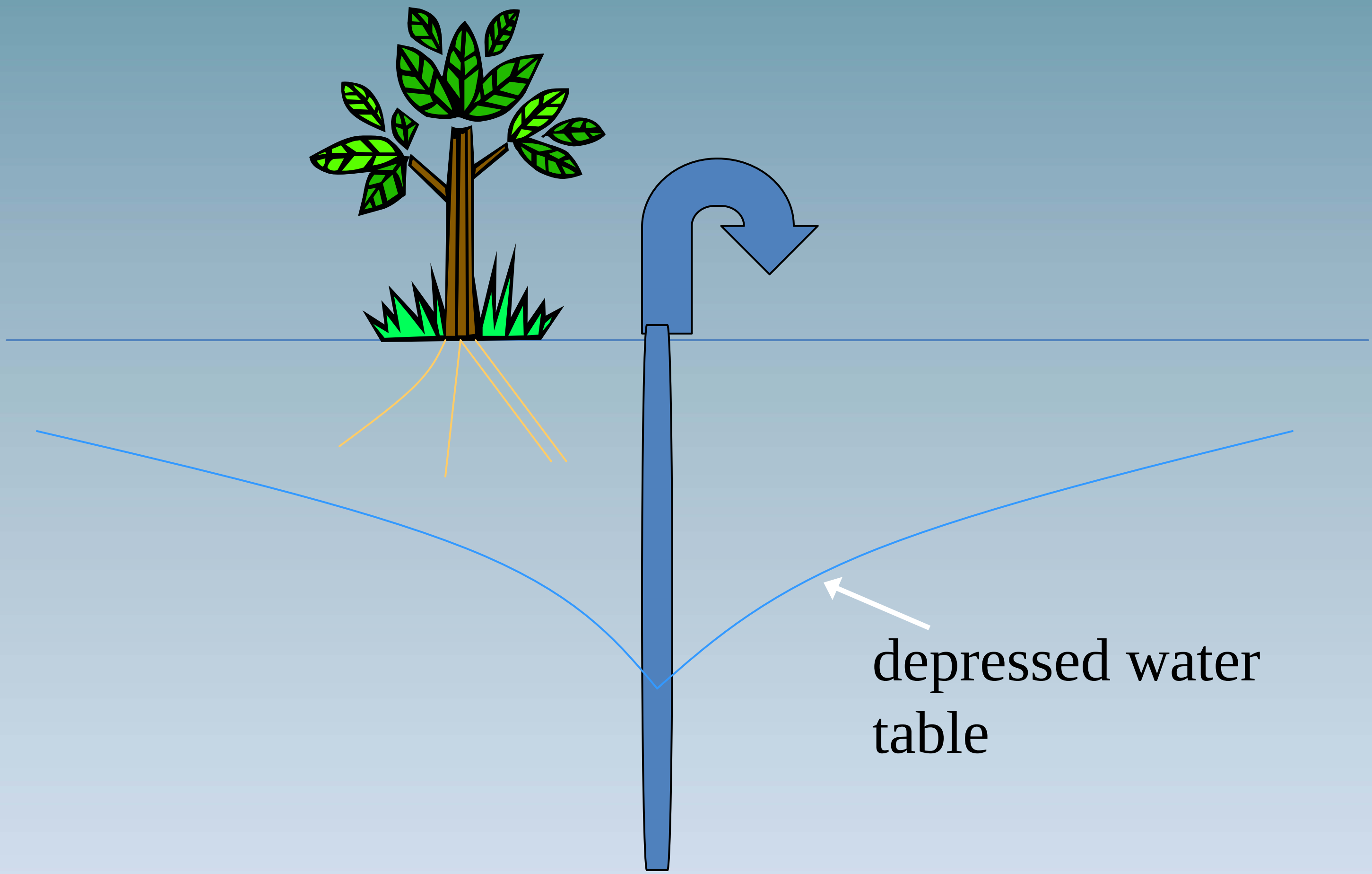
Results


ca california-american water company
MONTEREY PENINSULA WATER SYSTEM
SEASIDE WELLS
AUTOS
SEASIDE-SAND CITY
DEL REY OAKS
LOS PADRES DAM
CAÑADA PIPELINE
MONTEREY
5-MILLION GALLON TANK
30" BYPASS LINE
SAN CLEMENTE DAM
PROPOSED NEW WELLS
SAN CARLOS IRON REMOVAL PLANT
CARMEL VALLEY
CARMEL VALLEY WELLS
PACIFIC GROVE
FOREST LAKE
CARMEL
PACIFIC GROVE RESERVOIR
PEBBLE BEACH CARMEL HIGHLANDS
BEGONIA IRON REMOVAL PLANT

Well Registration and Production Reporting

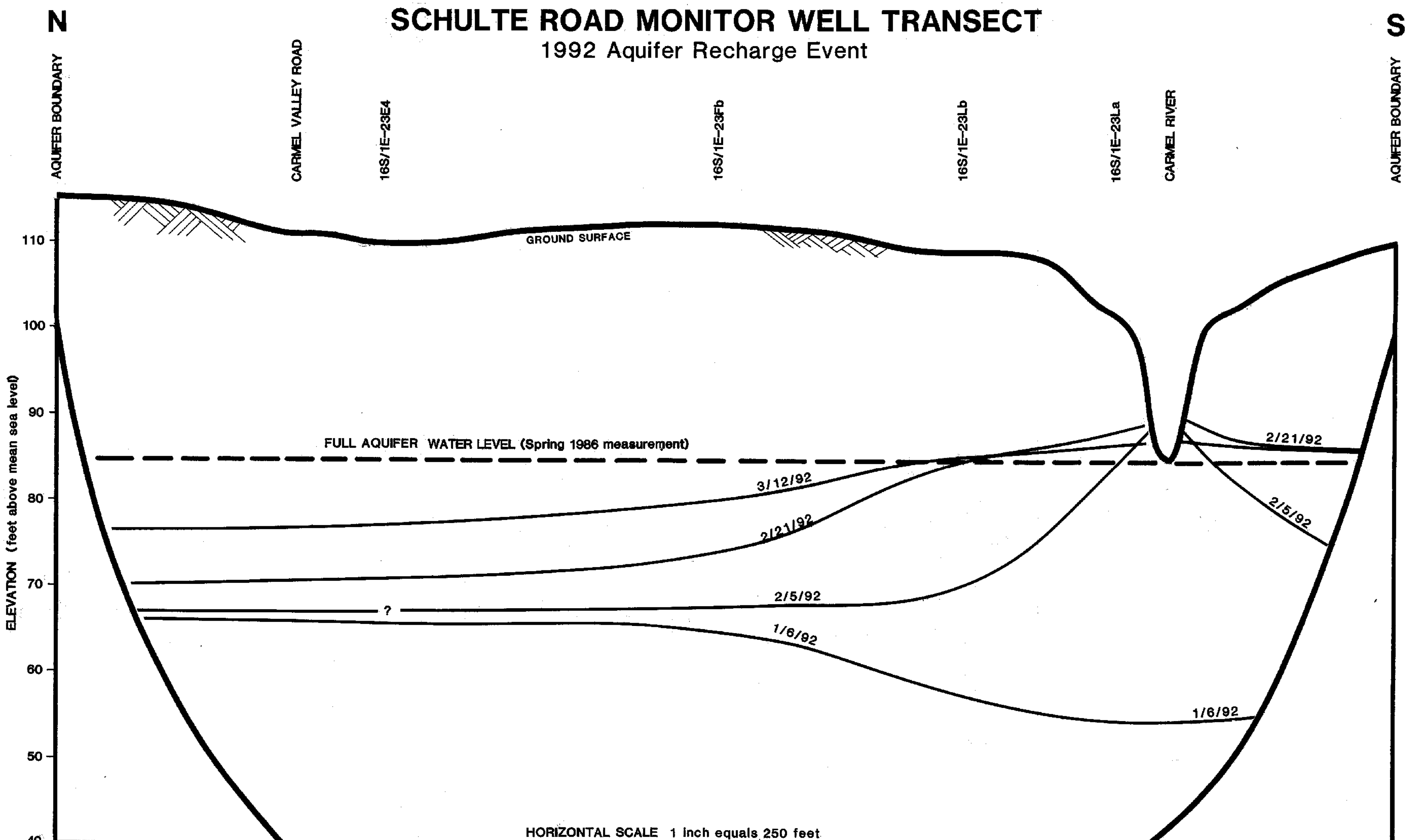


1960's - Groundwater Pumping Increased Significantly



SCHULTE ROAD MONITOR WELL TRANSECT

1992 Aquifer Recharge Event



WELL REFERENCE POINT ELEVATIONS FROM MPWMD

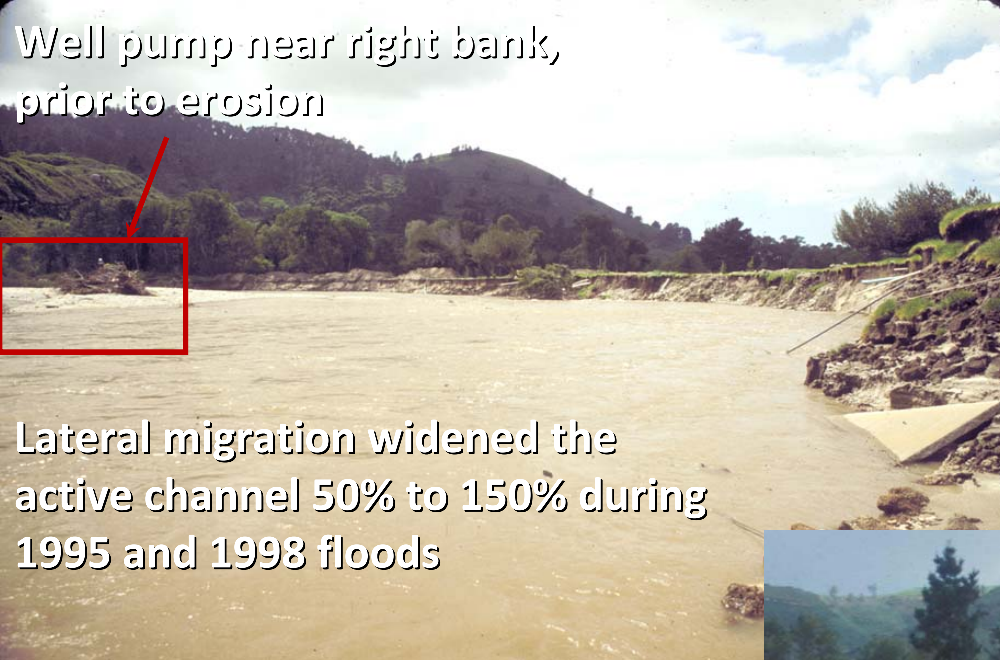
BEDROCK GEOMETRY FROM LOGAN (1983)

JWO 3/92

Diversions dewater the river annually

Carmel River at RM 9 in 1984 (above) and 1980 (right), next to Carmel Valley Ranch

Suburban setting along a meandering river



February 7, 1998

March 11, 1995

Bridges in the Carmel River

January 1994

March 1995

May 1995

Rancho Cañada golf course

(More) Bridges in the Carmel River

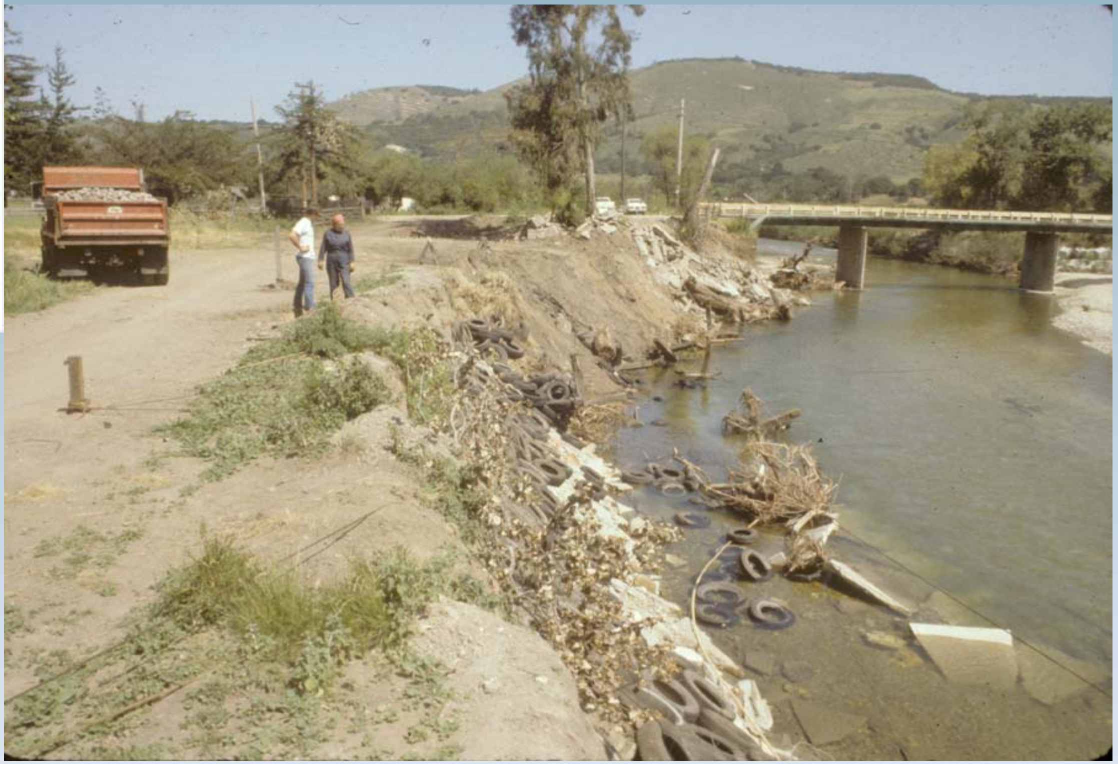
Highway 1 Bridge over the Carmel River
Above - March 10, 1995
Below - March 12, 1995

Temporary Bailey Bridge on Highway 1
Carmel River, Monterey County, CA
April 7, 1995

Stonepine Bridge (RM 16)
April 1995

Lateral migration after 1976-77 drought upstream of Schulte Road Bridge at RM 7

Property owners act unilaterally at Schulte Road Bridge, RM 7



Above – April 1982
Right – May 1982

Locally available, relatively inexpensive erosion protection materials were used (Valley Hills Project, RM 5)

Topics

Characterization of the Carmel River watershed

- ✓ Geology and Basin Characteristics
- ✓ Carmel River Characteristics
- ✓ Pre-1960s Anthropomorphic Effects on Stream Morphology

History and Effects of Water Production

- ✓ Carmel River Diversions
- ✓ Channel Instability – 1960's to 1980's

Restoration Program

- Preferred Solution
- Implementation

Results

Restoration Program

Analysis

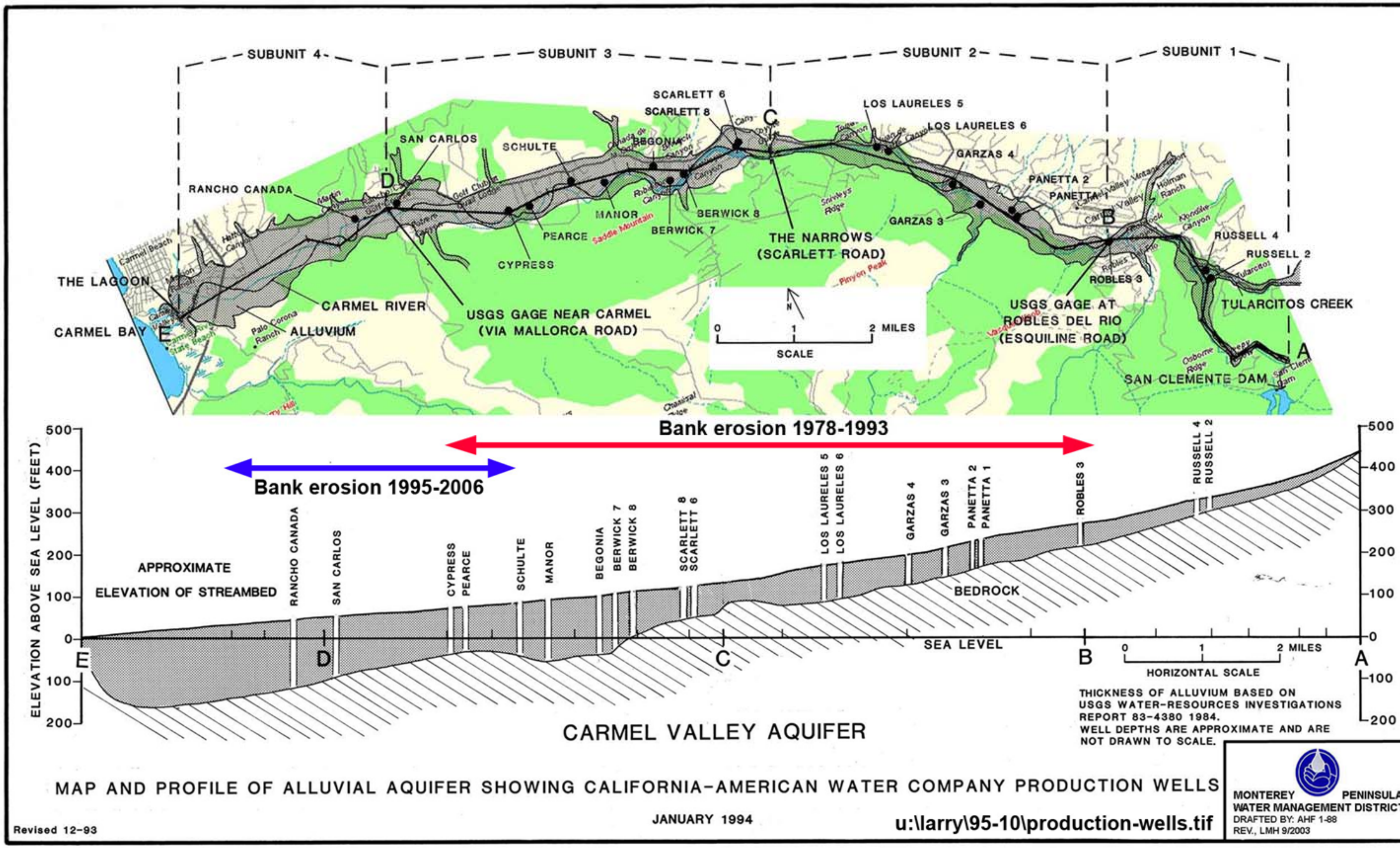
- Aerial photography from late 1920s to present
- Synoptic sediment transport sampling (main stem and tributaries)
- Periodic long profile (thalweg) and cross-section data
- Daily stream gage data (dating to 1958)
- Scientific analysis of historic stream morphology (early 1980s)

Restoration Program

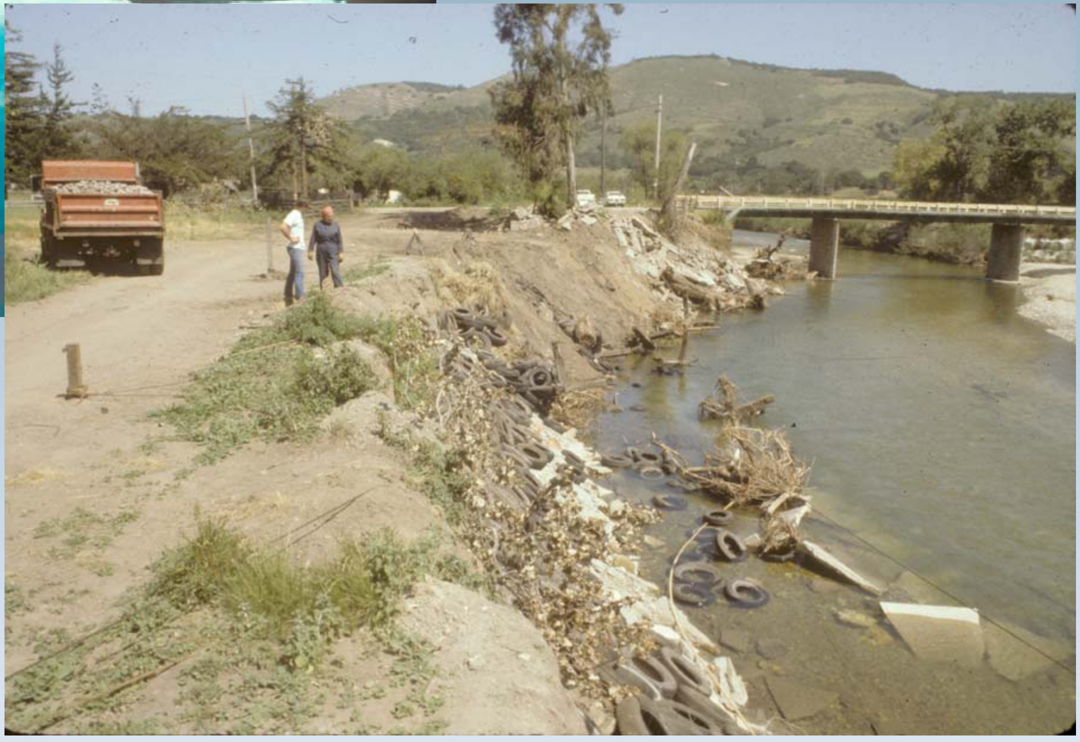
Preferred Solution

- Start at upstream end (RM 15.5) and progress downstream (8 miles of stream work recommended)
- Narrow active channel to carry 2,500 cfs flow (Q_2) and flush excess sediment downstream
- Reconfigure and "train" the channel into the 1966 planform
- Recreate pool-riffle-run profile
- Restore streamside and floodplain vegetation
- Use limited structural protection to resist erosion to a ten-year return frequency
- Avoid emergency work in flowing river (carry out work at low flow)

Integrate management of diversions into restoration program



MPWMD needed a pilot project



Structural protection on outside meander bends integrated with vegetative solution

Note: concrete rubble, filter fabric no longer allowed

Schulte Project – 1982 and 2003

Left - Looking upstream from Schulte Bridge, April 1982. Note tires, wooden jacks, and concrete rubble dumped by the owner on the stream bank to slow erosion.

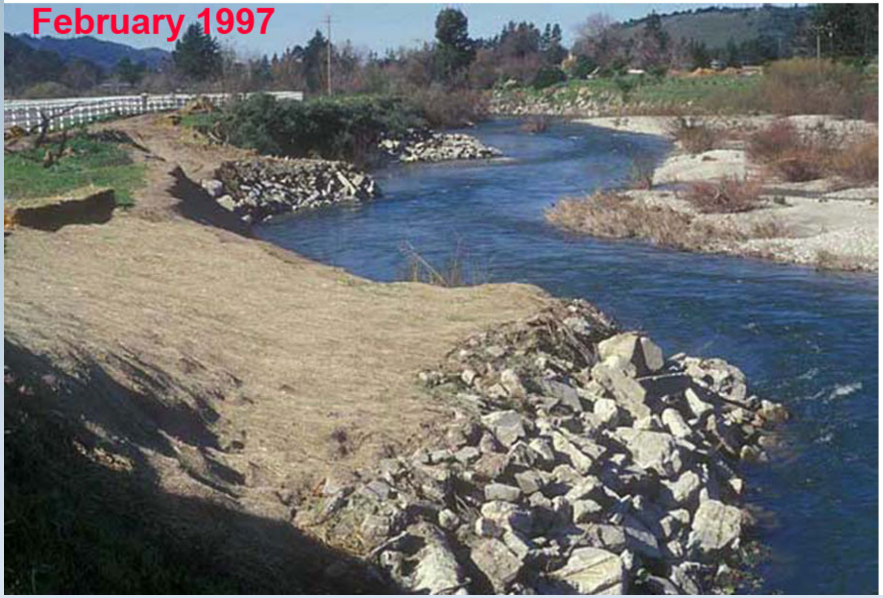
Right - May 2003 - after MPWMD-sponsored restoration work. The arrow shows where the brown well pump building was at the upper left of the 1982 photo. MPWMD continues to maintain and monitor this project area.

Schulte Road Bridge at RM 6.7

Above – after completion in December 1986

Right – May 2002

Chronic dewatering = chronic erosion



Red Rock Area Restoration Project

Left - during drought

Right - during high flow (1993)

Below Left - after property owner performed emergency work

Range of Methods used in 1990s

<u>Hardscape (e.g., RSP, rock groins)</u>

- At bridges
- Within 25 ft. of structures
- Constrained channel (< 200 feet)
- Outside of meander bends

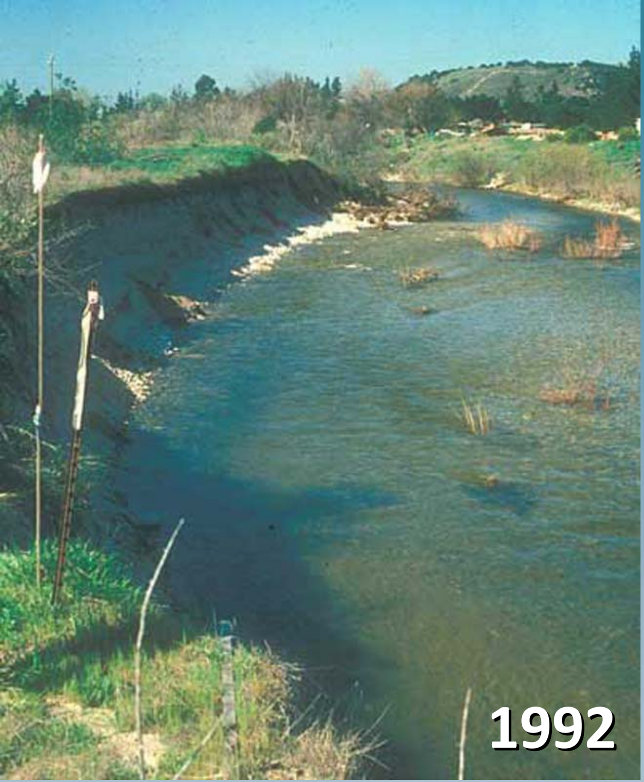
<u>Bioengineering</u>

- Channel width > 400 feet
- Inside of meander bends
- No structures of concern
- Bank deformation not a concern

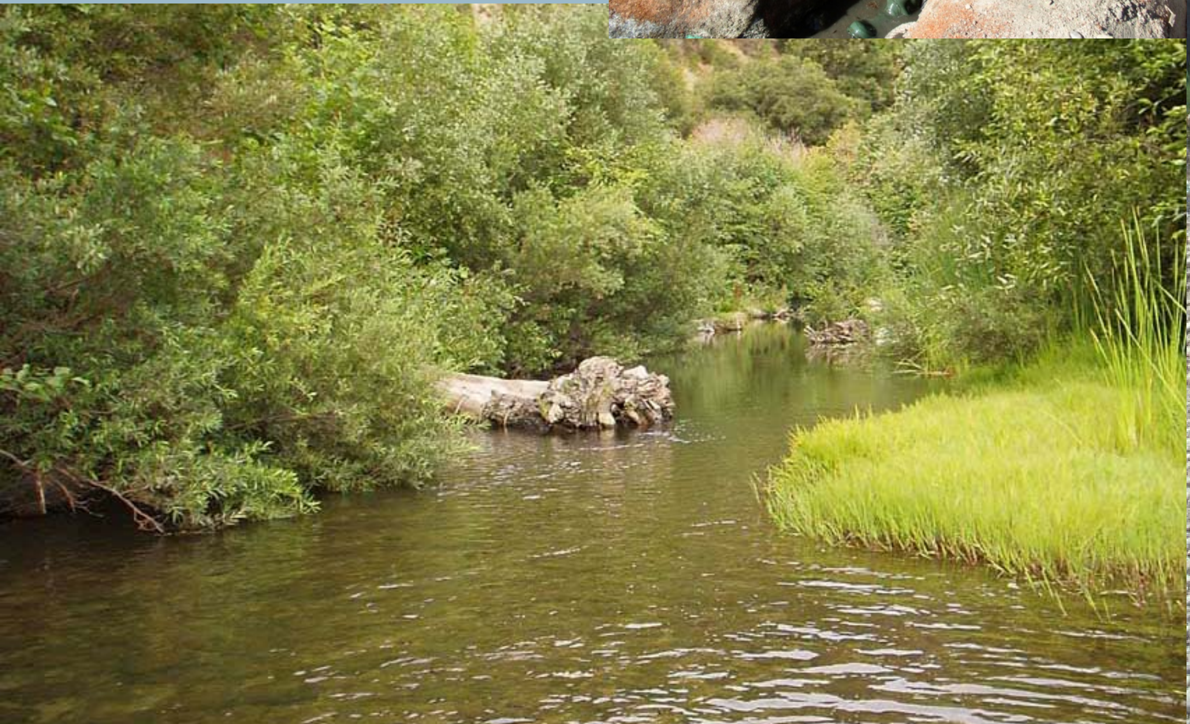
Active Channel Reconstruction

- reconstructed two-year floodplain
- willows stakes in toe trench
- rip-rap in toe and on streambank (no filter cloth)

Typical project evolution



Large wood



Design tools that appear difficult to apply on a site-specific basis

- Sediment transport models – applicable on a reach basis
- Shear stress analysis
  – has not been applied extensively
  – significant variation of grain size distribution both spatially and temporally (active channel changes relatively rapidly from a sand dominated to gravel-cobble-boulder and back)
  – transient forces introduced by gravel bar translation, debris flow, and treefall appear to be more critical as a design constraint
- Two-dimensional hydraulic models – not accepted in flood insurance program, but can provide more information in overbank areas than 1-d model

Applications for two-dimensional analysis of water and sediment flow

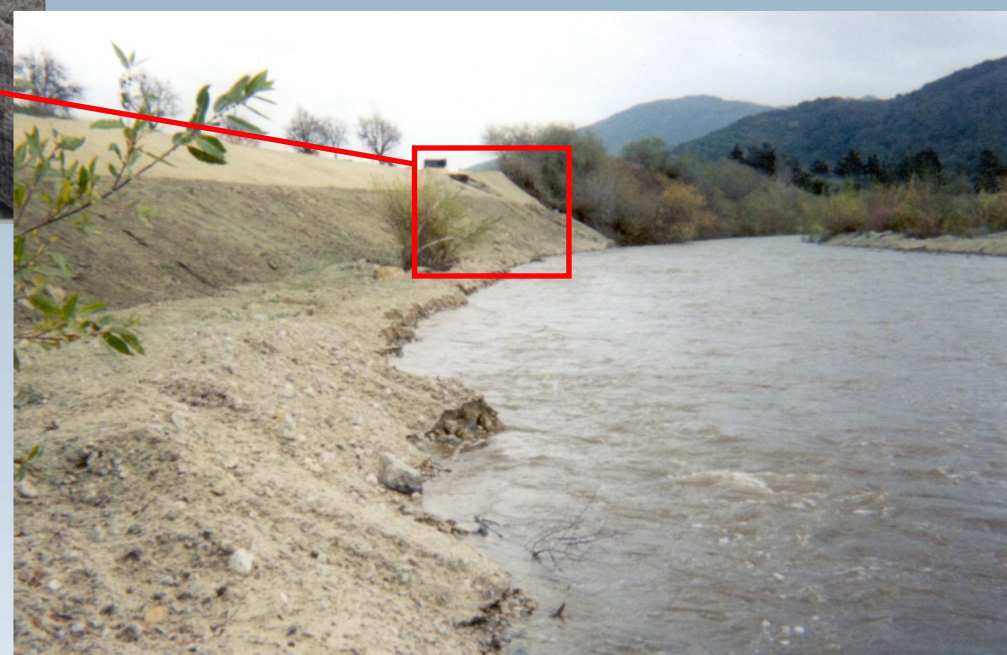
- **Bottom shear stress or bed friction**
- Wind shear stress
- Coriolis force
- **Turbulence-induced shear stresses**
- **Combined current and wave shear stresses**
- Barometric pressure gradients
- Tropical cyclone windfields and barometric pressure fields
- **Coastal storm surge hydrographs**
- **Wetting and drying of elements**
- **Pressure flow under bridge decks**
- **Flow resistance from bridge piers**
- **Flow over roadway embankments**
- Flow through culverts with or without flap-gates
- Flow through gate structures
- Flow through drop-inlet spillways
- **Live-bed and clearwater contraction scour at bridges**
- **Local scour at bridge piers**
- **Transport of eight noncohesive sediment particle size classes**
- **Erosion and deposition of transported sediment**
- **Armoring of channel beds**
- **Wave effects on nearshore sediment transport**
- **Bridge pier riprap sizing**
- **Supercritical flow and hydraulic jumps**
- **Combined one-dimensional/ two-dimensional flow and sediment transport**
- Pressure flow in one-dimensional closed conduits

Examples of where 1-D and 2-D models can and can't help with project design and river management

Left – debris racking during high flows is predictable at some locations

Right – tree fall is random and difficult to manage during high flow events

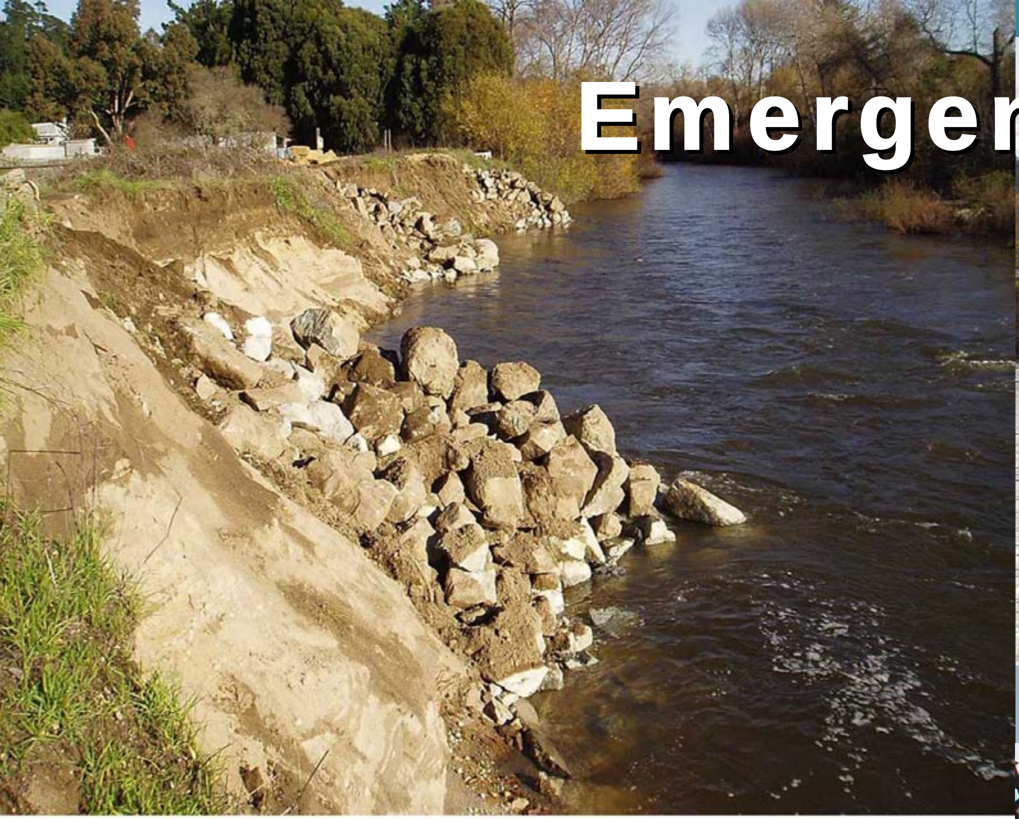
Unintended consequences



A knick in the streambank may be a catalyst for much larger erosional events along the river at high flows

Avoid Emergency Work (if possible)

Emergency Work



Above - after rock placmeent on January 13, 2005. Below - during erosion on January 9, 2005

Topics

Characterization of the Carmel River watershed

- ✓ Geology and Basin Characteristics
- ✓ Carmel River Characteristics
- ✓ Pre-1960s Anthropomorphic Effects on Stream Morphology

History and Effects of Water Production

- ✓ Carmel River Diversions
- ✓ Channel Instability – 1960's to 1980's

Restoration Program

- ✓ Preferred Solution
- ✓ Implementation and How it Works Today

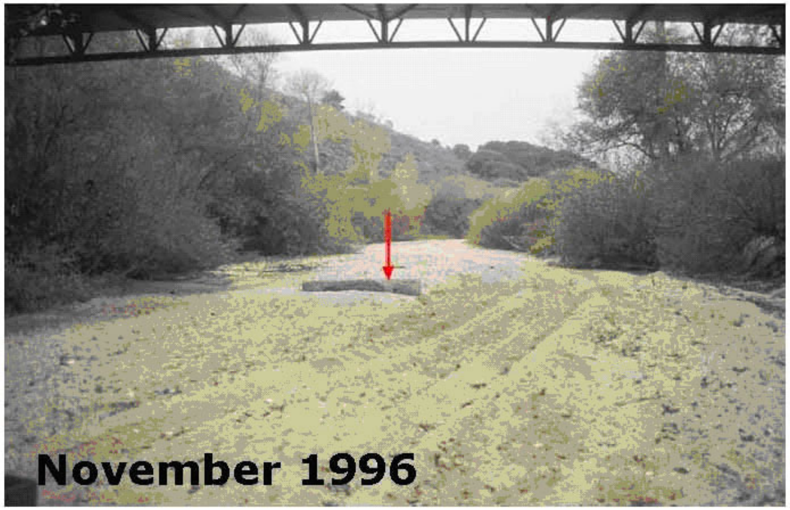
Results

Results (1984-2012)

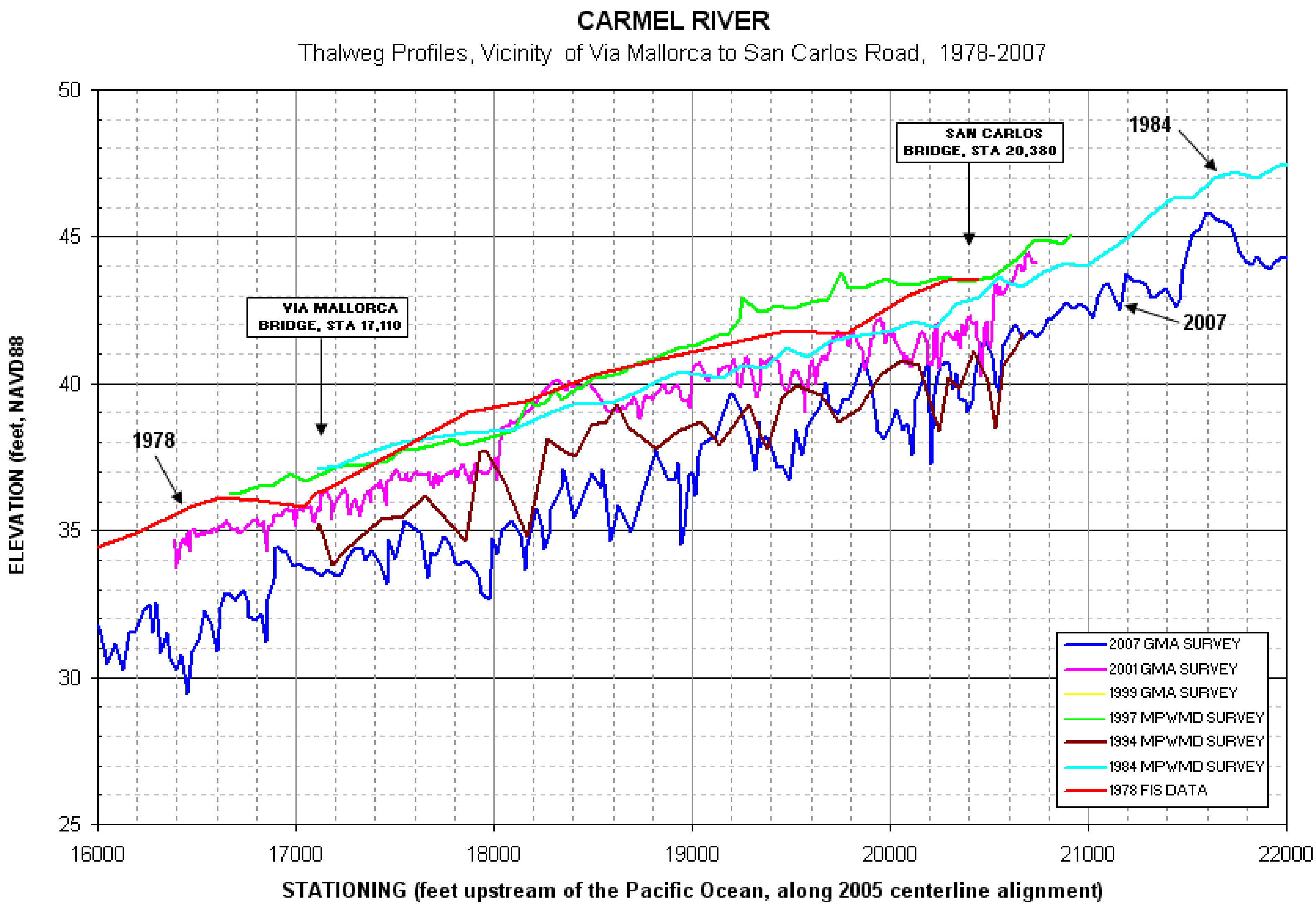
- Area of riparian vegetation increased from about 300 acres in 1986 to 580 acres in 2012
- Natural recovery along six miles of stream encouraged through improved surface and groundwater management practices and by enforcement of regulations
- Spawning habitat for steelhead in the main stem extended by more than four miles
- Area of active instability reduced to just one mile in the lower river
- Streambank hardening and lack of sediment from upper watershed has accelerated channel degradation

Channel Degradation

Rancho Cañada Bridge No. 5

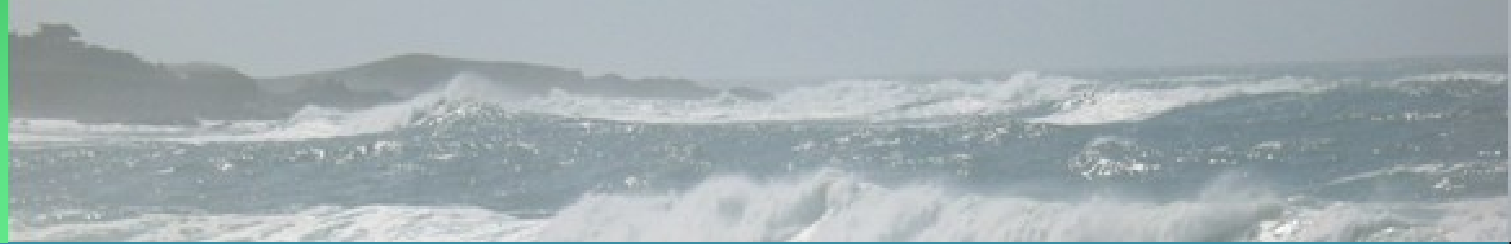


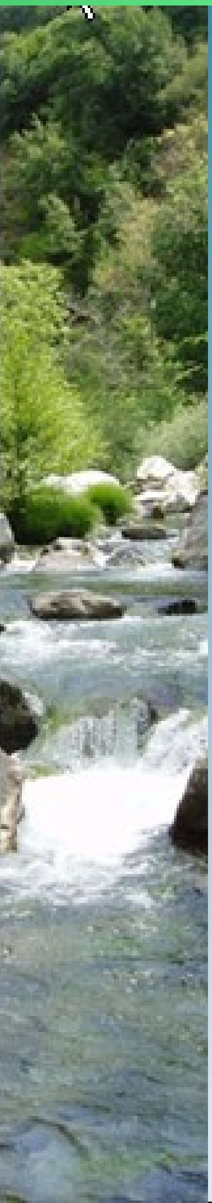
Channel Degradation



Channel Degradation

Carmel Area Wastewater District pipeline located 3,000 feet upstream of Carmel Bay





For More Information

Larry Hampson, District Engineer
Monterey Peninsula Water Management District
P.O. Box 85, Monterey CA 93942
OFFICE: (831) 658-5620
FAX: (831) 644-9560 or MOBILE: (831) 238-2543
larry@mpwmd.net

http://www.mpwmd.dst.ca.us/