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10 AUGUST 1989

HYDROLOGY OF THE MEADOW CREEK DRAINAGE, SAN LUIS OBISPO COUNTY, CALIFORNIA

for

Meadow Creek Wetlands Evaluation
California Dept. of Parks and Recreation

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SAN LUIS OBISPO

EXECUTIVE SUMMARY

The configuration, past history, and rainfall information are presented for the Meadow Creek watershed. The 3,735 acre upper watershed drains into Pismo Lake, which in turn contributes to the lower watershed of 2,688 acres, where much of the runoff is derived from the streets of Grover City. Annual average rainfall is 16 inches, but highly variable. The present Meadow Creek channel below Pismo Lake was formerly the channel of Pismo Creek, which drained into Oceano Lagoon. The present mouth of Pismo Creek developed in 1911.

The peak runoff charactaristics of the creek above Pismo Lake are presented, and the flood volumes entering the lake are calculated using a simple triangular hydrograph model. Flow into the lower watershed is constrained by the capacity of the railroad bridge, and in 100-year storms flooding over the railroad tracks will occur. The recent modifications to Pismo Lake are seen to have much reduced its flood retention capacity. Calculations from theoretical hydrographs are compared with the data from the 1969 storm, supposedly a 100-year storm. FEMA flood maps are seen to show the degree of flooding experienced in 1969.

Hydrologic conditions downstream of the railroad bridge are examined. The channel has a low capacity, due to low levees and low channel slope, and will flood at discharges of 200 cubic feet per second. This may be compared to 100-year storm discharges of 1,000-2,000 cubic feet per second. Flood volumes are calculated, and the flood height is largely determined by the flow from Carpenter Creek, and the ability of the outlet culverts in Oceano Lagoon to flow freely. Flood heights of about 10 feet can be expected over the Oceano Lagoon area after a 100-year storm. Creek restoration between Grand Avenue and Oceano Lagoon will have little effect on flood charactaristics, but creation of islands could much diminish flood storage and increase flood height. Proposed modifications to Oceano Lagoon could similarly have a deleterious effect on flood storage.

It is the opinion of the author that Carpenter Creek should be maintained as a flood relief channel, and that it will be vital ~~is~~ to reducing flood damage in the Oceano Lagoon area. The role of Carpenter Creek in the past is discussed, as is the potential for sea water intrusion, which is not considered a serious hazard. A flooding sequence for the Carpenter Creek area is presented for the present landform configuration.

Sedimentation is not considered a major problem for the watershed below Pismo Lake.

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I - A DESCRIPTION AND BRIEF HISTORY OF THE MEADOW CREEK WATERSHED

DESCRIPTION

The Meadow Creek watershed can be divided into two sections (see figure I-1). The larger section lies on the east and northeast side of Pismo Lake and the Southern Pacific Railroad tracks, and passes under the tracks into the lower section, which drains the bulk of Grover City and the surface of the Grover City- Oceano Mesa. The channel in the lower section drains to the south southeast parallel to, and behind, the line of coastal dunes, and enters the north end of the Oceano Lagoon. Water finally reaches the ocean through culverts under the levees of Arroyo Grande Creek, entering the latter at its mouth.

The upper section of the watershed, including Pismo Lake, has an area of 3,735 acres. Most of the watershed lies in gently sloping hills on the east side of the Highway 101 freeway, and drains into Pismo Lake via Meadow Creek and creeks in Canyon No.1 and Canyon No.2, all of which unite above the freeway culvert. These portions of the watershed either have been, or are likely to be, developed with both housing and commercial structures. The geology is dominated by relatively poorly consolidated Pliocene marine sands, called the Squire Member of the Pismo Formation, or by similar but younger sands of similar composition that were derived from the Pismo Formation and which today lie in a veneer above the Pismo Formation.

The channels, united as Meadow Creek below the freeway, flow almost due west into Pismo Lake. The south side of the channel is the northern flank of the Grover City- Oceano Mesa, dominated by Pleistocene stabilized dune sands. It is likely that the original courses of drainages in the area were diverted to the east and west by the advance of the ancient dune sands.

Below the freeway culverts the channel of Meadow Creek is a densely vegetated riperian corridor that terminates in Pismo Lake. Some water is added to the Lake from the drainage of a narrow zone of streets on the edge of the Mesa, and by water flowing under the freeway from smaller drainages west of Canyon No.1. Some additional water is developed from a narrow but dense commercial strip between the lake and the freeway.

Pismo Lake used to be a swampy area, with relatively little open water surface, but has recently been deep dredged and deepened, and island wildlife refuges have been constructed in the center of the lake.

Runoff from the lake flows under the railroad into a leveed channel that passes on the east side of the California Division of Parks and Recreation North Campground, past the golf course, under Grand

Avenue, and into a densely vegetated riperian zone that terminates in the South Campground and Oceano Lagoon. The North Campground and Golf Course have been constructed in the flood plain of the creek. Drainage from the west-sloping Mesa reaches the riperian corridor and creek through a series of storm drains and as channel flow. The collection area for the lower section of the watershed is about 4.2 square miles, or 2,688 acres, and is dominated by developed, urban land.

As can be seen in the following section, the lower section of the watershed was once the channel of lower Pismo Creek, which now flows to the ocean north of the Meadow Creek channel.

A BRIEF HISTORY OF THE PISMO-MEADOW CREEK WATERSHED

The first maps of the watershed are dated at about 1837. Map Espediente 513 shows Arroyo Grande Creek and the land to the south and east. This is a very crude sketch with notations in Spanish, developed for the purposes of illustrating the bounds of a land grant, and does not reveal any information on the Oceano Lagoon area (see figure I-2).

In 1837 a Diseno, or Picture Map, was filed by Frances Branch as part of a filed request for a land grant from Mexico for the Rancho Santa Manuela. This and the first-mentioned map were prepared by the same person. The map shows Pismo Creek and/or Meadow Creek joining Arroyo Grande Creek at the Oceano Lagoon area, although a lagoon is not specifically shown. The width of the channel behind the dunes is shown to be substantial (see figure I-3).

In 1873 the first of a number of subdivision maps was filed, indicating the economic end, and resultant breakup, of the Ranchos. The map was titled 'Map of Parts of the Ranchos, Corral de Piedra-Pismo- Bolsa de Chamisal, San Luis Obispo County, California, subdivided by Jas. T. Stratton'. The map shows Arroyo Grande Creek entering the eastern end of Oceano Lagoon, at which point it is shown joining a stream from the north, presumably Pismo Creek (see figure I-4).

In September of 1874 an 'official' County Map was produced. The 'Map of San Luis Obispo County. California, surveyed by R.R. Harris' can be seen today in the County Assessors Office and at Cal Poly's Special Collections Library, where the maps clearly show Pismo Creek flowing southward behind the dunes to Oceano Lagoon. There is no indication of a Pismo Creek mouth at the present location (see figure I-5).

A map filed in April 1880, was titled 'Plat of Part of the Ranchos El Pismo and San Miguelito, San Luis Obispo Co. Cal., owned by J.M. Price, subdivided by H.C.Ward'. The map shows Pismo Creek running behind the dunes to Oceano Lagoon, and being clearly labelled as 'Pismo Creek' as it entered the lagoon (see figure I-6). Oceano

Lagoon is shown extending a considerable distance inland through the area presently occupied by the airport and sewer plant. The Oceano Lagoon is shown to be a different shape than that shown in the Stratton 1873 map. It is clear from both maps that Oceano Lagoon's primary drainage is Arroyo Grande Creek, and that the lagoon is elongated along the line of that creek. Pismo Lake is shown to be extensive and reaching well above 4th Street to close to the present freeway bridge. The lower end of Pismo Lake is not receiving inflow from Pismo Creek, but drains westward to connect with Pismo Creek in the area of the North Campground.

In 1886 a map was filed on April 30, titled 'Map of the Subdivisions of a Part of the Ranchos El Pismo and San Miguelito, San Luis Obispo Co., California: R.R.Harris'. Pismo Creek is shown heading to the north end of Pismo Lake, although the junction is covered by notations. Pismo Lake is shown covering about the same area as the present lake, and is elongated to the northwest into what is presumably the inflow channel from Pismo Creek. It would appear to have connected with the lake at present low spot on the railroad, adjacent to the northwest corner of the present lake (see figure I-7).

This map has an inset Plan of the Town of El Pismo, which shows two coastal lagoons (?) flanking the north and south edges of the odd shaped parcel at the western end of Main and Pismo Streets.

In 1887 the developer of Pismo Beach prepared a colored map for promotional purposes. Two coastal lagoons or drainage swales (?) are clearly shown in the vicinity of the western ends of Main and Pismo Streets. The map is on file in Special Collections, Cal. Poly. State Univ. Library, San Luis Obispo, Ca. It is presumed that the map was based on a more official 1887 map, filed on June 11, and titled 'Map of the Town of El Pizmo' (Book A, Page 156, San Luis Obispo County Book of Maps, County Assessor's Office). In this map there is a suggestion that lakes (?) or drainage swales (?) still exist in the vicinity of the western end of Pismo and Main, based on the shape of the subdivided map boundaries. Neither of these maps provides significant information on the Meadow Creek drainage.

Again in 1887, a 'Map of the Town of Grover, San Luis Obispo County' (Book A, Page 6, San Luis Obispo County Book of Maps, County Assessor's Office) was filed (see figure I-8). It shows a channel for Meadow Creek which leaves Pismo Lake at, or close to, the present railroad bridge, running more-or-less along the line of the present channel through the North Campground area, but running well to the west of the present channel through the area of the present golf course, past Grand Avenue, and through the northern portion of the riperian corridor north of the South Campground. There is another channel shown entering Pismo Lake from the northwest side, possibly the Pismo Creek inflow channel shown in 1886 maps. A Southern Pacific Railroad right-of-way is shown on the map, but it is presumed that no track or embankment had been constructed, and that there was no interference with the Pismo Lake inflow and outflow. At this time the railroad's southern termination was Paso Robles (Kreiger, 1988, p.77).

Similar to the above, the 1887 Map of the Grover and Gates Tract, El Pismo Rancho, San Luis Obispo County is filed in Book A, Page 114, San Luis Obispo County Book of Maps, County Assessor's Office.

Of historical interest only, a map was filed on May 19, 1888, titled 'Map of the Pismo Avenue Addition to the Town of El Pismo, surveyed by R.F.Parsons'. It shows a subdivision on the north side of Pismo Avenue, which runs from the western termination of Pismo Street to connect first with the west end of Main Street, and then to the beach. This could indicate that the southern of the two lagoons had been filled to provide land for this subdivision.

At the south end of the drainage, an 1893 map was filed as 'Map of Subdivision No.2, Ocean Beach, San Luis Obispo County' (Book A, Page 150, San Luis Obispo County Book of Maps, County Assessor's Office). It shows Oceano Lake with Gray, Surf, York, and Brook Streets as today, the lake much altered, and Brook St. acting as a creek channel joining the lake to the sea (see figure I-10). Brook is presently parallel to, and just north of, the Arroyo Grande Creek channel outlet. The map would appear to be a plan for future development, as it shows little resemblance to the channel and lagoon configuration shown in the following map. Among other things, Oceano lagoon is shown dredged into a straight edged, rectangular pond.

The 1893 'Map of the Town of Oceano and Adjoining Subdivision' (Book A, Page 147, San Luis Obispo County Book of Maps, County Assessor's Office) shows a complex of creeks and channels at the junction of Arroyo Grande Creek and Oceano Lake (see figure I-9). Arroyo Grande Creek ran through the area of the present airport, joining the Oceano Lagoon at the southeastern end. Outflow from the lagoon was from the southwest corner of the lagoon. The north end of Oceano Lake is not shown, and the lagoon is shown to remain wide through the southern portion of the present South Campground.

In 1894, the Southern Pacific Railroad Company produced a map titled 'Pismo Beach and Vicinity from the Official Map of the Southern Pacific Railroad Company , December 15'. This map clearly shows Arroyo Grande Creek entering the Oceano Lagoon at its southern end, and a narrow lake is drawn all the way up to Grand Ave. and into the North Campground. Pismo Creek is called Villa Creek, and is shown joining the lake at the northern end of what is now the North Campground. No flow of Pismo Creek into Pismo Lake is shown, and the present channel of Meadow Creek is shown, but the creek joins the lake just north of the present Carpenter Creek.

The first train reached San Luis Obispo in 1894, and it is presumed that railroad construction would have started across the Meadow Creek drainage.

On January 30, 1899, Map No.2 of the Town of Oceano, San Luis Obispo County, California was created (see figure I-11). This is an apparently promotional map which shows Arroyo Grande Creek flowing into Oceano Lagoon, but no other creeks entering the "Lake Oceano". The map, which bears realtors notations, is on file with Special Collections, Cal. Poly. State Univ. Library, San Luis Obispo, California.

Modifications around the North Campground area are shown in the 1902 'Map of Grand Beach, California, San Luis Obispo County, California' (Book A, Page 7, San Luis Obispo County Book of Maps, County Assessor's Office). It shows an older channel for Meadow Creek seen on earlier maps, and a new channel cut close to the present channel for Meadow Creek south of Pismo Lake to south of Grand Avenue (see figure I-12). The new channel is shown to leave Pismo Lake somewhat south of the earlier channel, and appears to be artificial.

In 1902-1903 a 'Map of the Town of El Pizmo' (Book A, Page 155, San Luis Obispo County Book of Maps, County Assessor's Office) indicates shows no sign of lakes or gullies west of Pismo St. and Main St. Again, this is of historic information only and has no bearing on the Meadow Creek drainage.

The first detailed geologic map of the area was created in 1904 by H.W Fairbanks. Titled 'Description of the San Luis Quadrangle, California: U.S. Geological Survey Geologic Atlas, San Luis Folio 101', it shows Pismo Creek passing through a series of channels to the west of Pismo Lake, with a minor connection to the lake (see figure I-12). The area of Pismo-Meadow Creek south of Grand Avenue is mapped as open wide channel, rather than the narrow line of a creek, and opens to the south into Oceano Lagoon, which is fed from the south by Arroyo Grande Creek.

It seems that the present mouth of Pismo Creek was still not present in the major storms of 1905. On March 15, the Morning Tribune describes the loss of the old wharf, Post Office, and Cafe Royale at Pismo Beach after exceptionally high tide, and high wave and wind conditions. The damage is again described on March 18 in the Morning Tribune.

In an article titled 'When Mother Nature wept, her tears moved land' in the column called Echoes, by Jean Hubbard, (Five Cities Times-Press Recorder, Arroyo Grande, California, date not found, probably 1960's), she describes a flood in 1905 when: "Pismo Beach took the brunt of the storm that year and the old Cafe Royale, a tavern and dance hall, and 100 feet of the wharf were lost. Pismo Creek previously had meandered to a merger with Arroyo Grande Creek and drained into the ocean near Oceano. Now it cut across the sand dunes and reopened an old channel to the sea." I am not sure that this is wholly correct, and the breakthrough to the sea may have been in 1911. The Telegram-Tribune articles from 1905 make no mention of a break through the dunes.

In 1905 a 'Map of Subdivision No.1, Ocean Beach, San Luis Obispo County' (Book A, Page 149, San Luis Obispo County Book of Maps, County Assessor's Office) shows Oceano Lake, the lake much altered, and Brook Ave. acting as a creek channel joining the lake to the sea. Brook Ave. is presently parallel to, and just north of, the Arroyo Grande Creek channel outlet. The alterations to the lagoon are similar to those shown in the 'Map of Subdivision No.2', filed in 1893 (see figure I-10), and may not represent a real alteration of the lagoon.

A 1906 'Map of the Ocean View Terrace Subdivision #1' (Book 1, Page 1, San Luis Obispo County Book of Maps, County Assessor's Office) shows "Pismo Creek" crossing "Pier Avenue Blvd.", presently Air Park Drive, in the Oceano Lagoon vicinity.

Again in 1906, a 'Map of the Ocean View Terrace Subdivision #2' (Book 1, Page 9, San Luis Obispo County Book of Maps, County Assessor's Office) shows "Pismo Creek" entering "Oceano Lake". Also indicates a complex knot of channels joining Pismo Creek to the northeast of the lagoon, these possibly being part of Arroyo Grande Creek.

At Pismo Beach in 1906, a 'Map of the Kruckman's Addition to the Town of Pismo, San Luis Obispo Cty., Cal.' shows Pismo Creek running parallel to Ocean and Peerless (? now Park Ave.), and bending to the southwest at Cypress St. The creek would appear to be too far west to have drained into Pismo Lake, but would have bent to the south through the campgrounds at, and west of, Highway 1.

A major storm hit the coast in 1909. Reported in the January 21 Morning Tribune is the loss of 300 feet of track at Oceano, washed out along Arroyo Grande Creek (location not identified but likely at the Oceano Packing Sheds). On January 22, the Morning Tribune describes Oceano as being inundated by flood, with 5 feet of water at 'Wheeler's Store' and a 400 feet washout of the S.P. railroad tracks. On January 26 the Morning Tribune describes the fall of 4.35 inches of rain in 15 hours on top of 19.53 inches for the season. It reports that water cuts through Dockery Town and washes away three 'Harvey Houses'. This appears to be destruction of the southern fringe of Pismo Beach by Pismo Creek. Jean Hubbert (ibid) said of this storm: "It was said that Pismo Creek that year 'ran as wide as the Mississippi river and four cottages and two barns were washed out to sea' ".

1911 is a momentous year in Pismo Creek history. Emma Boxfold provided photographs of the 'Villa Creek' flood of 1911 (see figures I-14,-15). An explanation written on photocopies of photographs at County Historical Society Museum states that: "This creek followed the present Highway 1 into Oceano Creek along the side of the sand hills. After days and days of constant rain Pismo Creek backed up little by little into the southern portion of Pismo (Dockery Town). In order to stop this Hans Skov and Temple Boxold opened up an outlet in the sand hills with a spade and the pictures show the result." The pictures show that houses (or more properly, shacks) in Dockery Town were undercut and fell into the channel.

In 1913 B.R. Wood authored the Gazetteer of Surface Waters of California, Part III. Pacific Coast and Great Basin Streams, U.S. Geological Survey Water Supply Paper 297. Page 259 describes Pismo Creek as "flows southwestward to Pismo, then east of south through a tidal marsh to the Pacific". This would seem to be in conflict with the breakthrough to the ocean in 1911, but it is likely that the Gazeteer used out-of-date information, or at least did not recognize the permanence of change. Of interest is the description of the Meadow Creek drainage as 'tidal marsh'.

Some of the sedimentation problems in the area were illustrated by the February 2 edition of The Morning Tribune. The article describes accretion of sediment on the Arroyo Grande flood plain following a major flood. Alluvial flats were raised from an initial elevation of 8-12 feet below the railroad grade to 1-3 feet below the grade on the east side of the S.P. tracks, and were raised from 8 feet below grade to 2-4 feet below grade on the west side of the tracks.

In 1914, on March 6-8, The Morning Tribune describes major flood damage on the Arroyo Grande floodplain.

In 1927, on February 17, The Herald Recorder, (Vol.XXII, No.42, p.1) reports the "Heaviest Storm in Many Years". The article states "The Arroyo Grande Creek at Oceano assumed flood proportions Wednesday morning and about 10 a.m. the banks began to give way before the rush of the water, and by noon it had covered the lowlands south of the Routsahn steel bridge and was rushing down toward Lakeside Park, following the low places. Late in the afternoon the home of W.C. Hart on the Lakeside Park road was threatened, the water flooding the yard." This suggests flooding in the vicinity of the present Oceano Airport and Oceano Lagoon caused by Arroyo Grande Creek levee failure and spillage of the creek northward.

In the 1940's a drain was cut through dunes at the location of Carpenter Creek, which up to this time had not appeared in any maps or historical descriptions.

During the 1950's the golf course area was graded, with dune sands being pushed into the Meadow Creek flood plain. It is thought that all vestigial remnants of the original Meadow Creek- Pismo Creek channel were destroyed at this time, except for a few ponds within the golf course.

The Carpenter Creek drain was destroyed by erosion in 1961 or 1962, and sea water intruded into the Meadow Creek drainage for a short time.

In the 1960's, Lopez Lake was created for water storage and flood control, and much of the flood risk from Arroyo Grande Creek was substantially reduced.

In 1969, the watershed experienced what was probably close to the 100-year storm. Severe flooding took place in the North Campground area, and Carpenter Creek served as a major outlet for flood waters. The channel so-produced was sufficiently deeply excavated to enable sea water to intrude into the North Campground area, although after a few years the channel became blocked by dune sands, as it is today.

In 1984 and 1985 Floodway Maps are produced for various portions of the Meadow Creek drainage . These are included elsewhere in this text. These include the 'Flood boundary and floodway map, City of Pismo Beach, Community Panel Number 060309 0002, August 1, 1984, Federal Emergency Management Agency'. There are also the Community Panel Maps 060304-0727C and 060304-0729C for the Meadow Creek drainage between North Campground and Oceano Lagoon.

This map shows that floodwaters for the 100-year flood will cover all of the North Campground and the area between the dunes on the west side of the campground and the railroad tracks, submerging the travel trailer parks on the east side of Highway One. In addition, flood waters from Meadow and Pismo Creeks intermingle. The Oceano Lagoon- South Campground area is also inundated, and flood waters of Arroyo Grande Creek and Meadow Creek are seen to merge in the 100-year storm.

In 1987 the California Department of Fish and Game, partly in response to environmental degradation in the rapidly developing watershed, dredged the Pismo Marsh into the present Pismo Lake. During the late 1980's development plans in the Pismo Lake drainage provided some hydrologic information which is included below in the report.

RAINFALL CHARACTARISTICS

Long term rainfall information for the area has been stored by the San Luis Obispo County Engineering Department, and by California Polytechnic State Univerity. Figure I-16 is taken from County Engineering Specification Book D, and shows a set of curves used to calculate rainfall intensity for storms of various return periods, or probability of occurence. The average rainfall for the watershed is about 16 inches (1897 to 1947 data), and is contoured for the area in figure I-17. Another set of curves, developed for areas of higher average rainfall in the County, is shown in figure I-18, and may be applicable to some storms in this watershed.

Under figure I-16, the 100-year, one hour storm could deliver 1.5 inches of rain in an hour, and in figure I-18 the storm would deliver 1.9 inches. The 10-minute storms would deliver at rates of 4 inches and 5 inches per hour, but, of course, only for a duration of 10-minutes.

The rain then runs across the land and into drainage channels. The amount of rain that becomes runoff is defined by the Runoff Coefficient, where a coefficient of 1.0 indicates all rain enters the runoff, and 0.5 indicates half the rain enters the runoff. A table of coefficients used in this area are taken from the County Engineering Department's tables, and are shown in figure I-19.

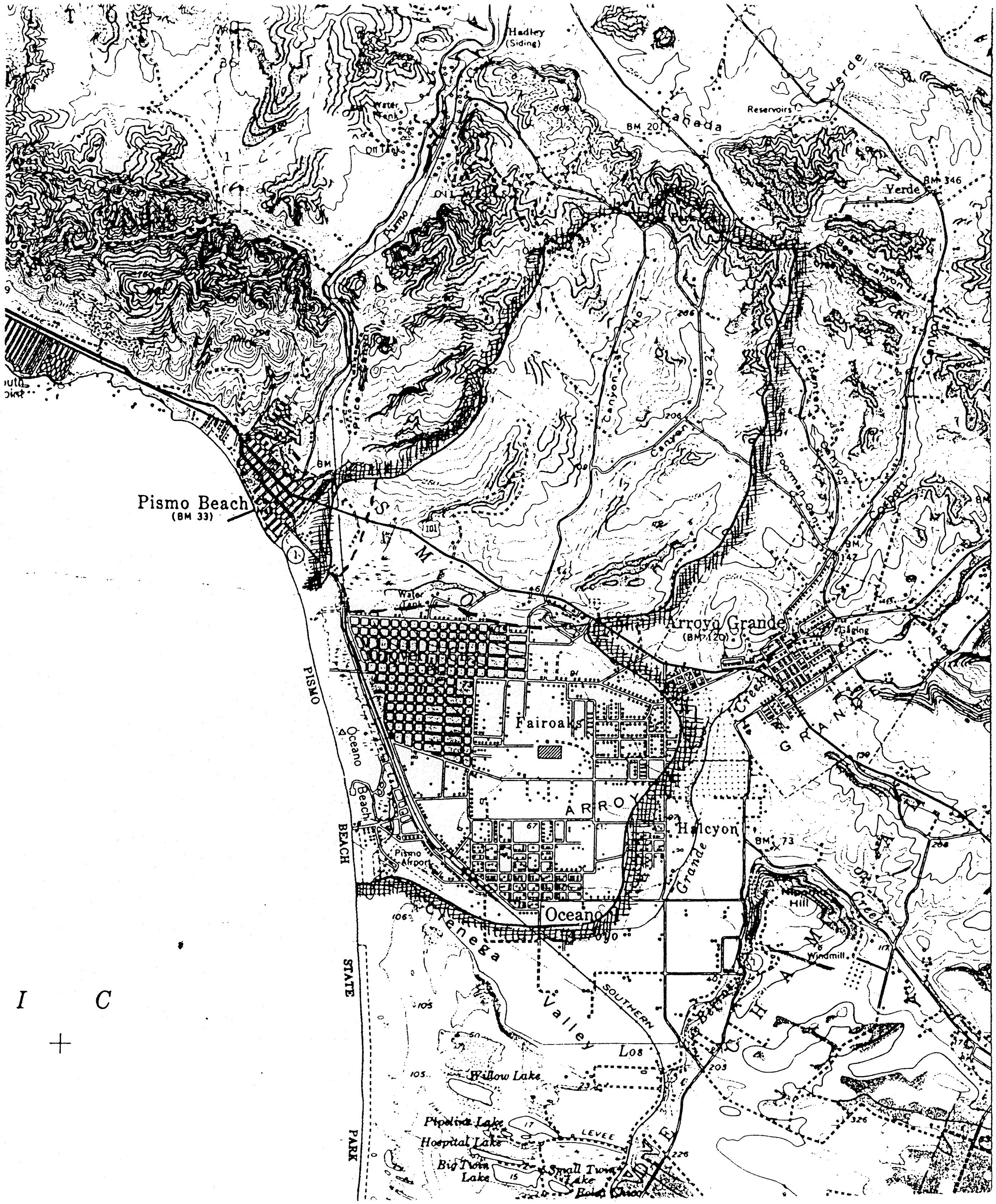
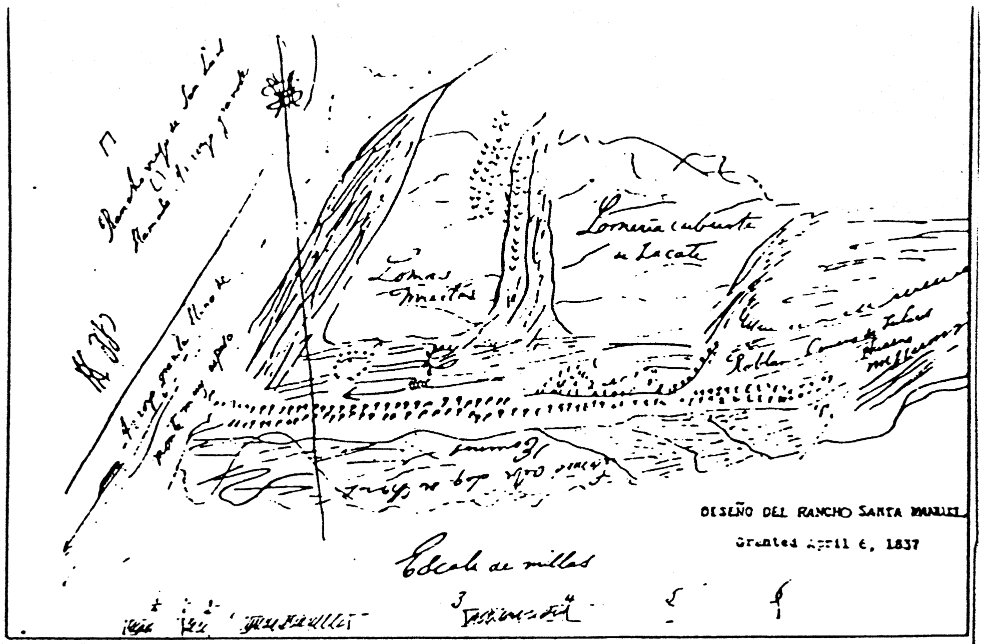


FIGURE I-1: Meadow Creek Watershed. East-West dotted line divides the upper and lower watersheds. Small area adjacent to Pismo Beach may partially drain to Pismo Creek.



DISEÑO — Frances Z. "Francisco" Branch filed this "diseno," a picture map showing the typography of the land he wanted as a grant from Mexico. Rancho Santa Manuela was granted to him on April 6, 1837, and finalized with a survey and a ceremony.

FIGURE I-2: Map Espediente 513, 1837

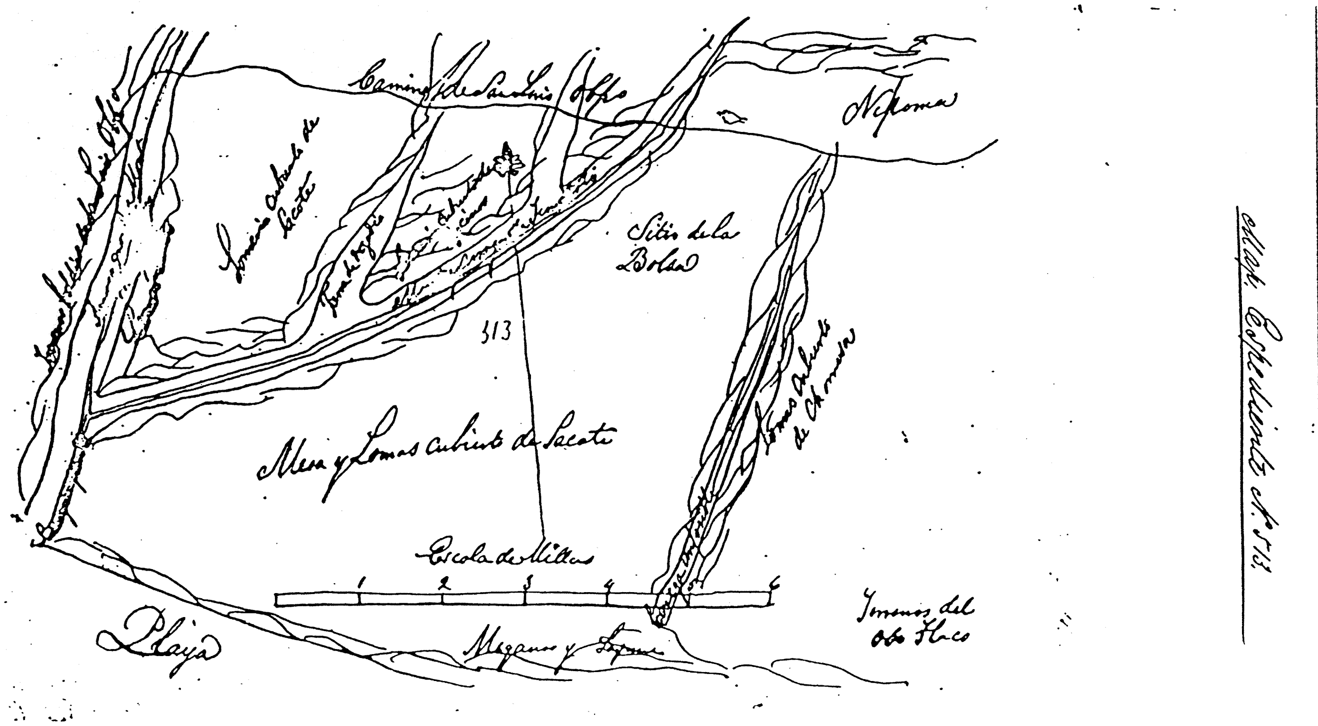


FIGURE I-3: Francis Branch Diseno of 1837

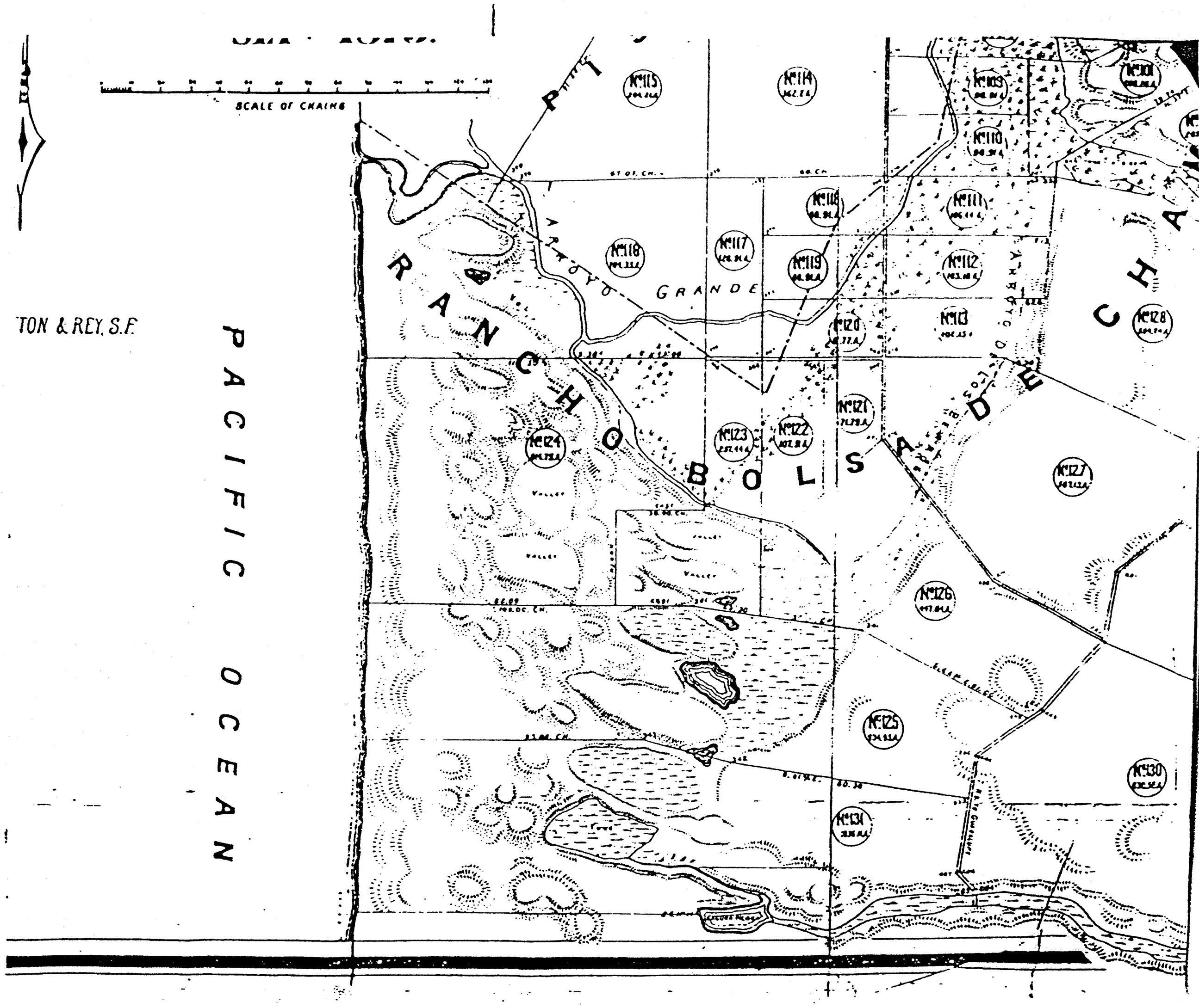


FIGURE I-4: Map of Parts of the Ranchos, Corral de Piedra- Pismo- Bolsa de Chamisal, San Luis Obispo, California, by Jas. Stratton, 1873

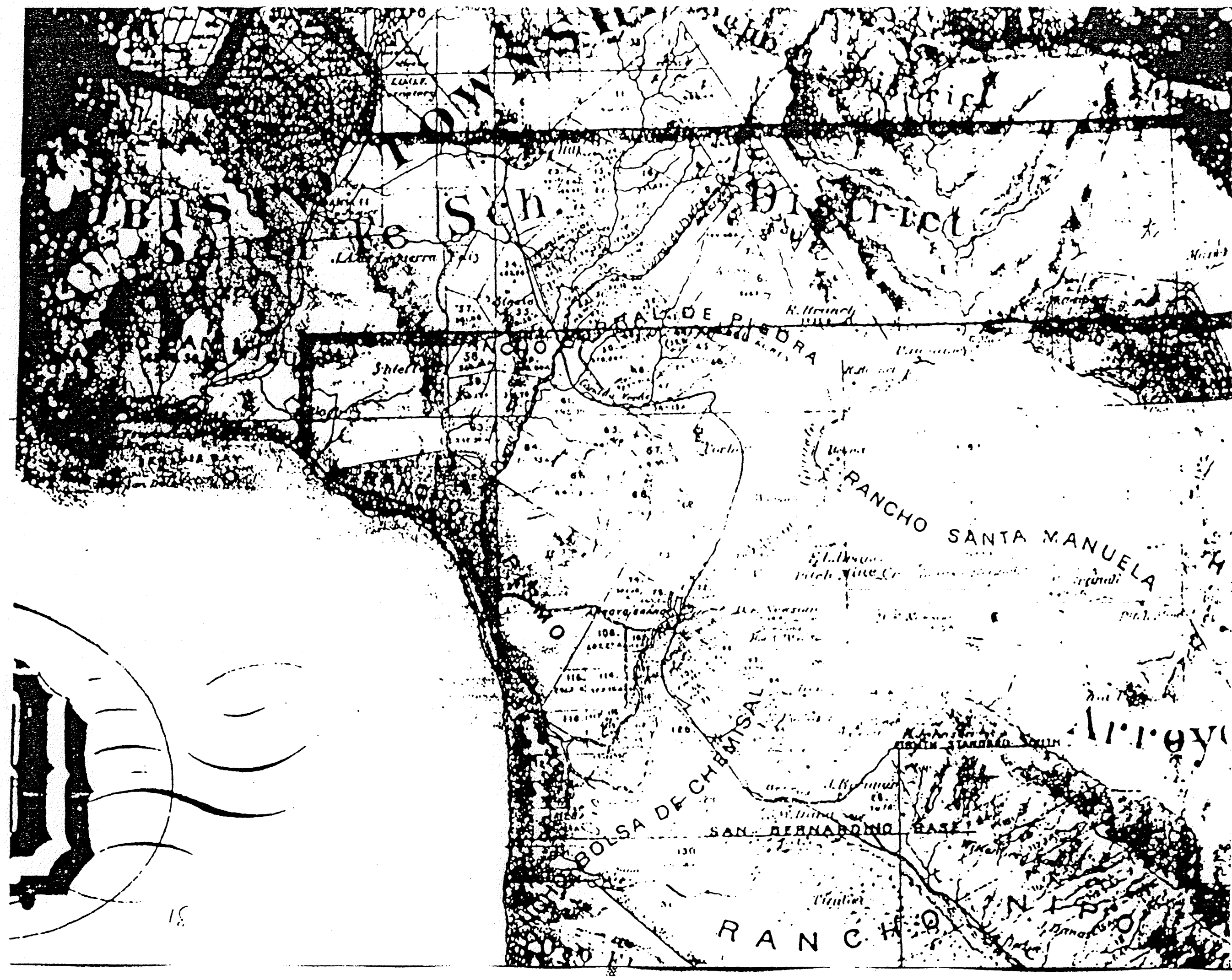


FIGURE I-5: Map of San Luis Obispo County, 1874

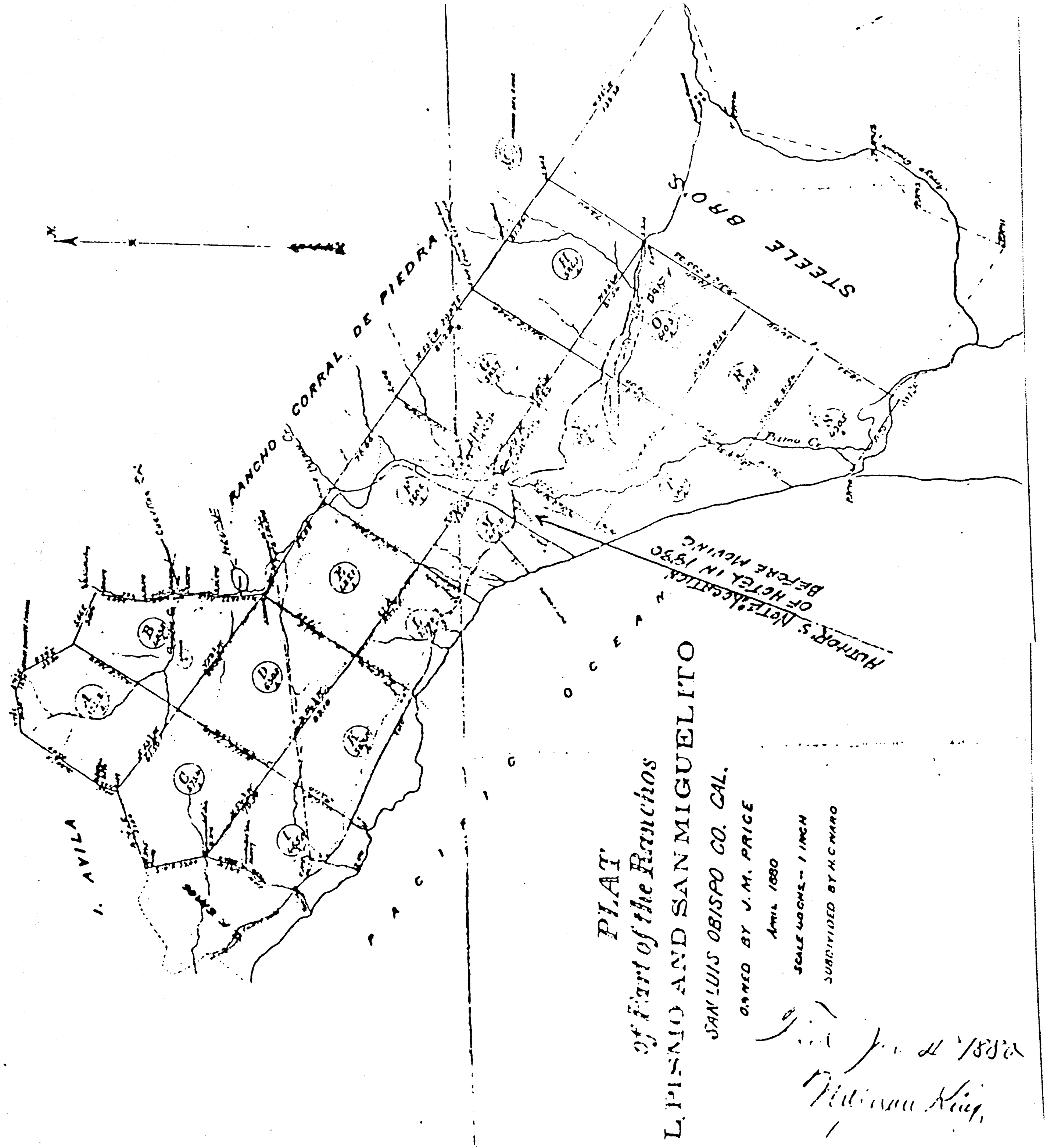


FIGURE I-6: Plat of Part of the Ranchos El Pismo and San Miguelito, San Luis Obispo County, 1880

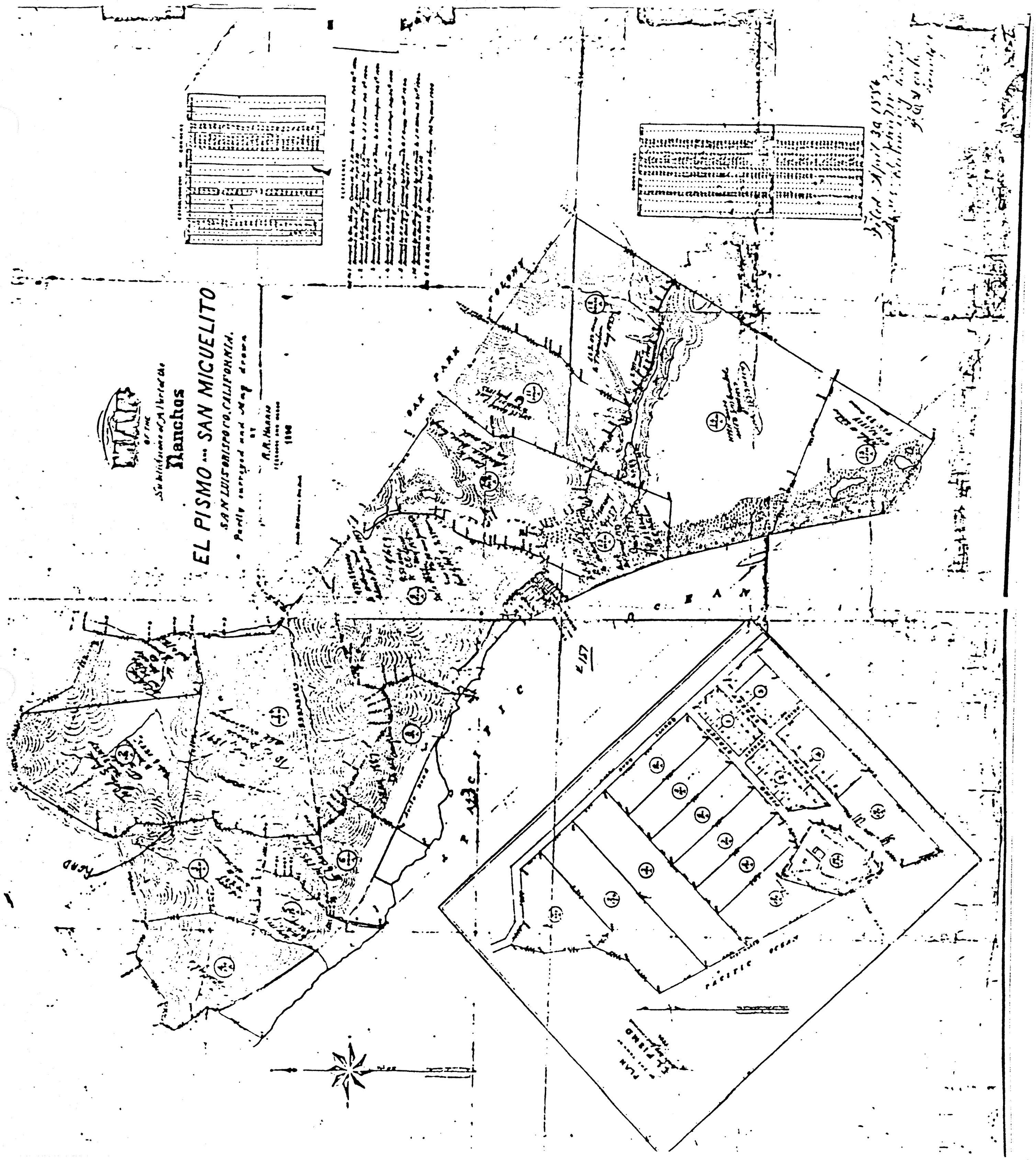


FIGURE I-7: Map of the subdivisions of a part of the Ranchos El Pismo abd San Miguelito, San Luis Obispo, Ca., by R.R. Harris, 1886

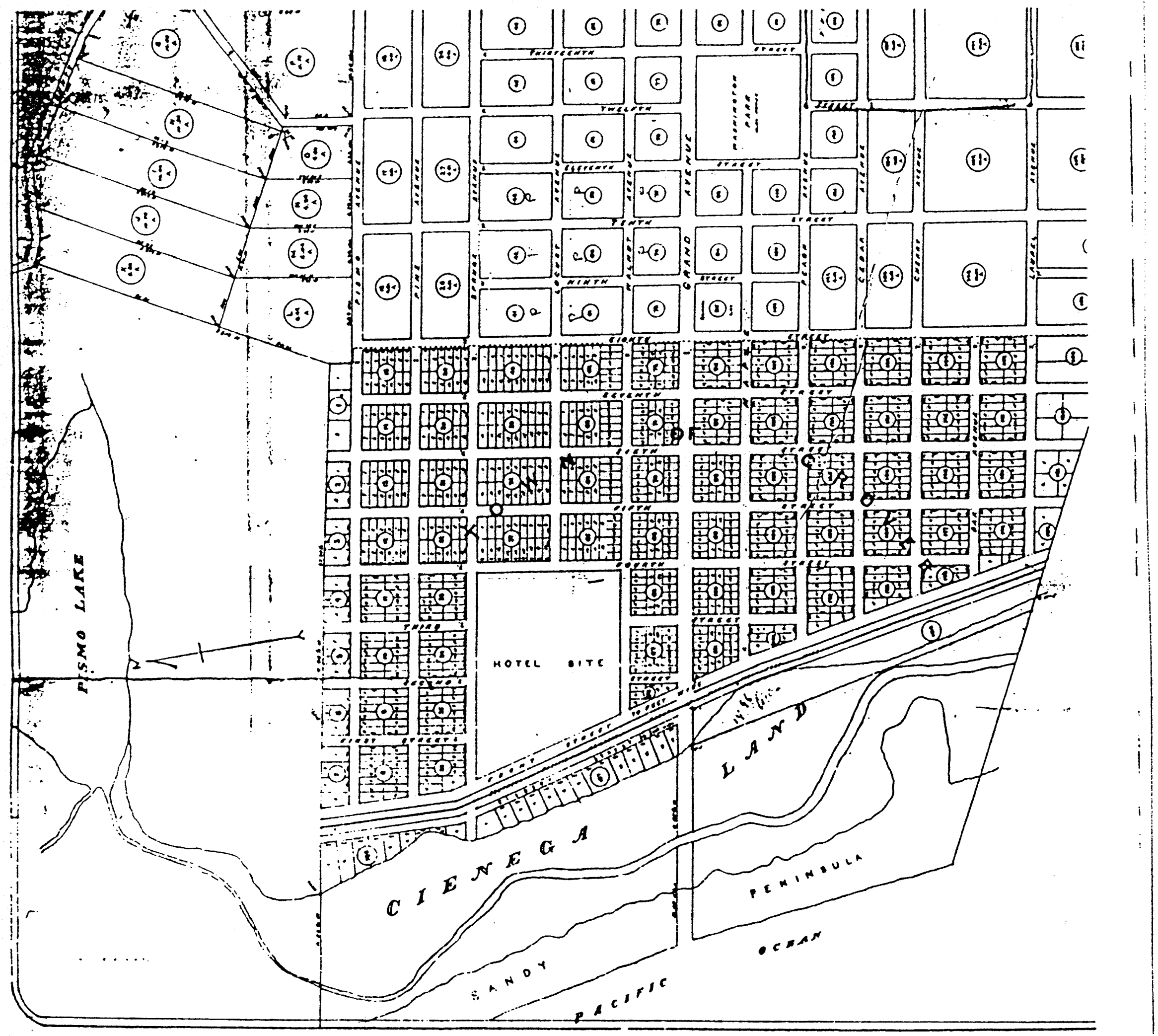


FIGURE I-8: Map of the Town of Grover, San Luis Obispo County, 1887

FIGURE I-9:
1893

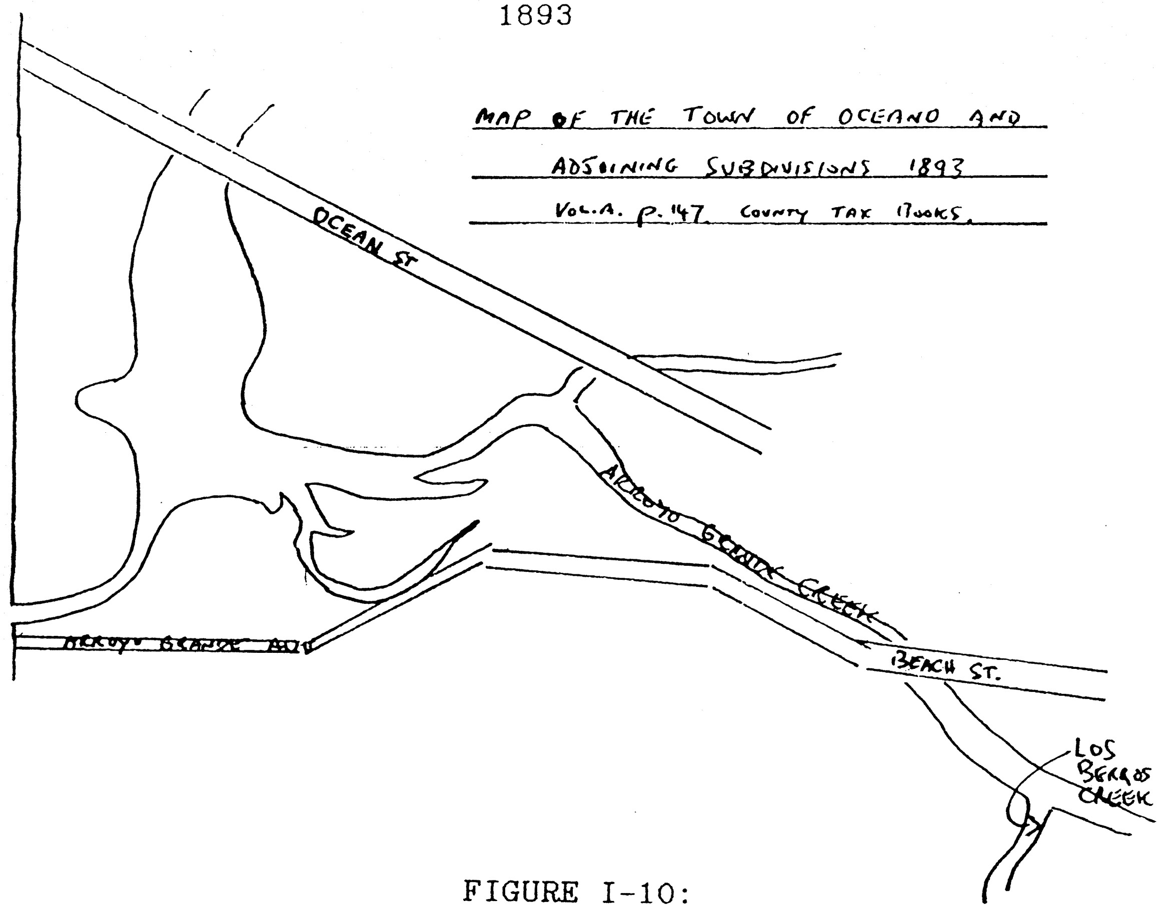
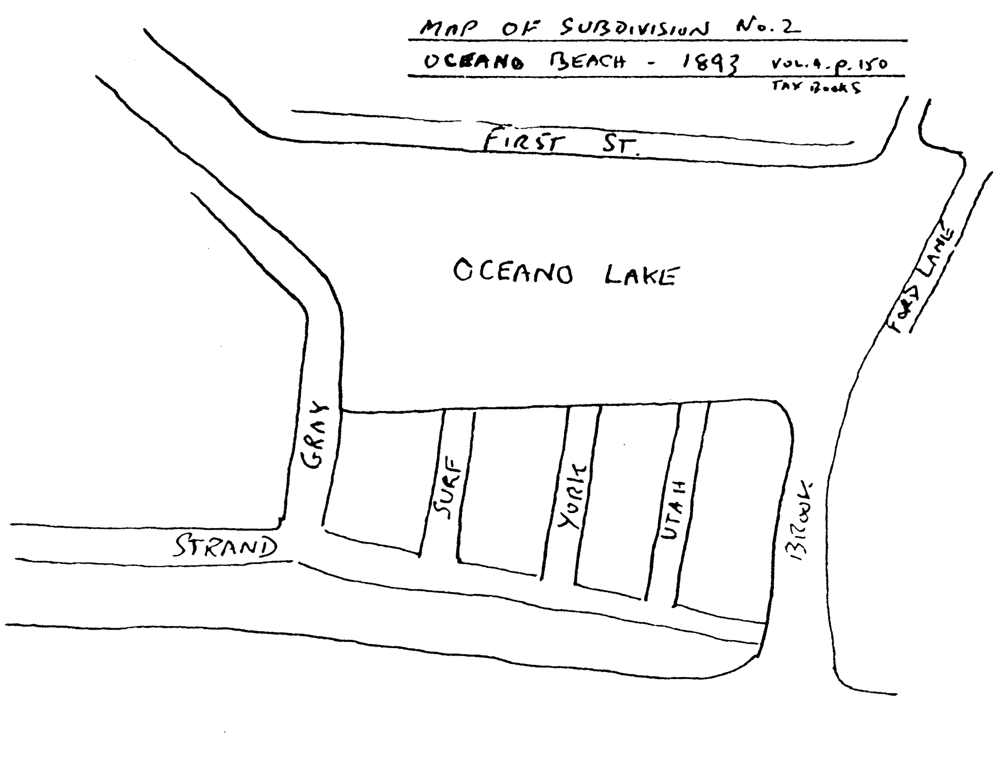


FIGURE I-10:



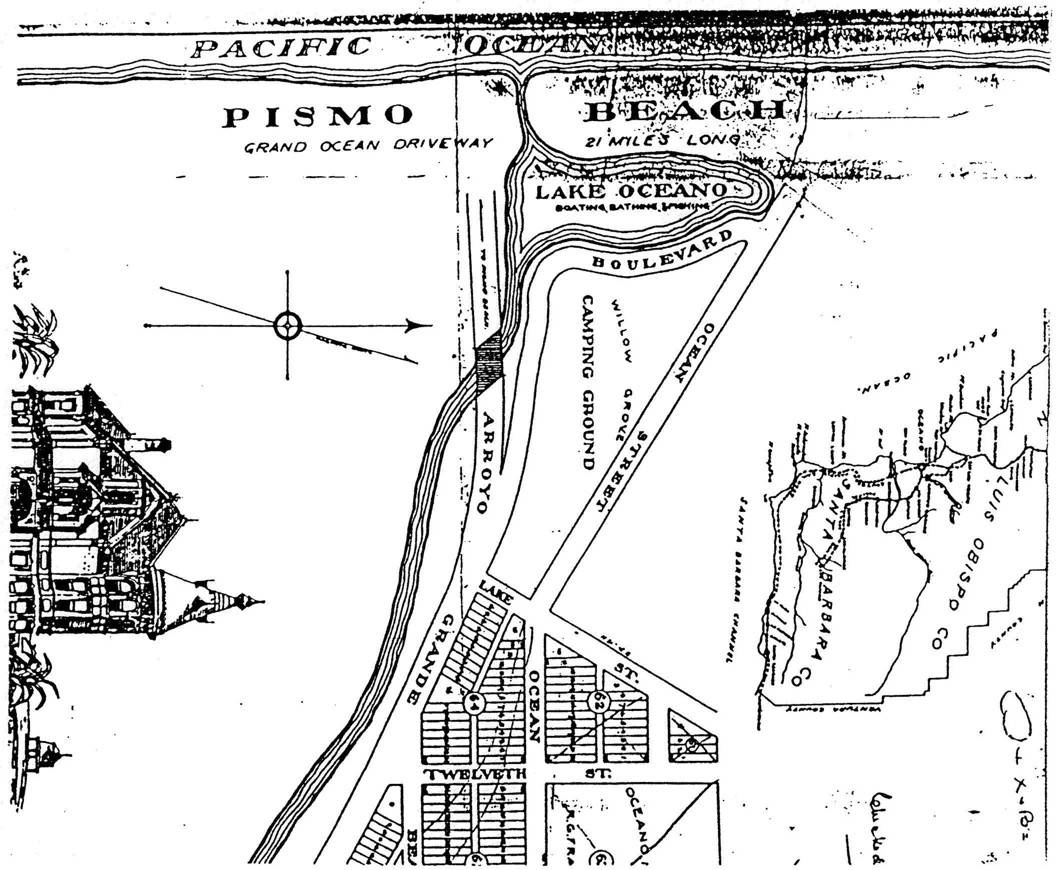


FIGURE I-11: Map No.2 of the Town of Oceano, 1899

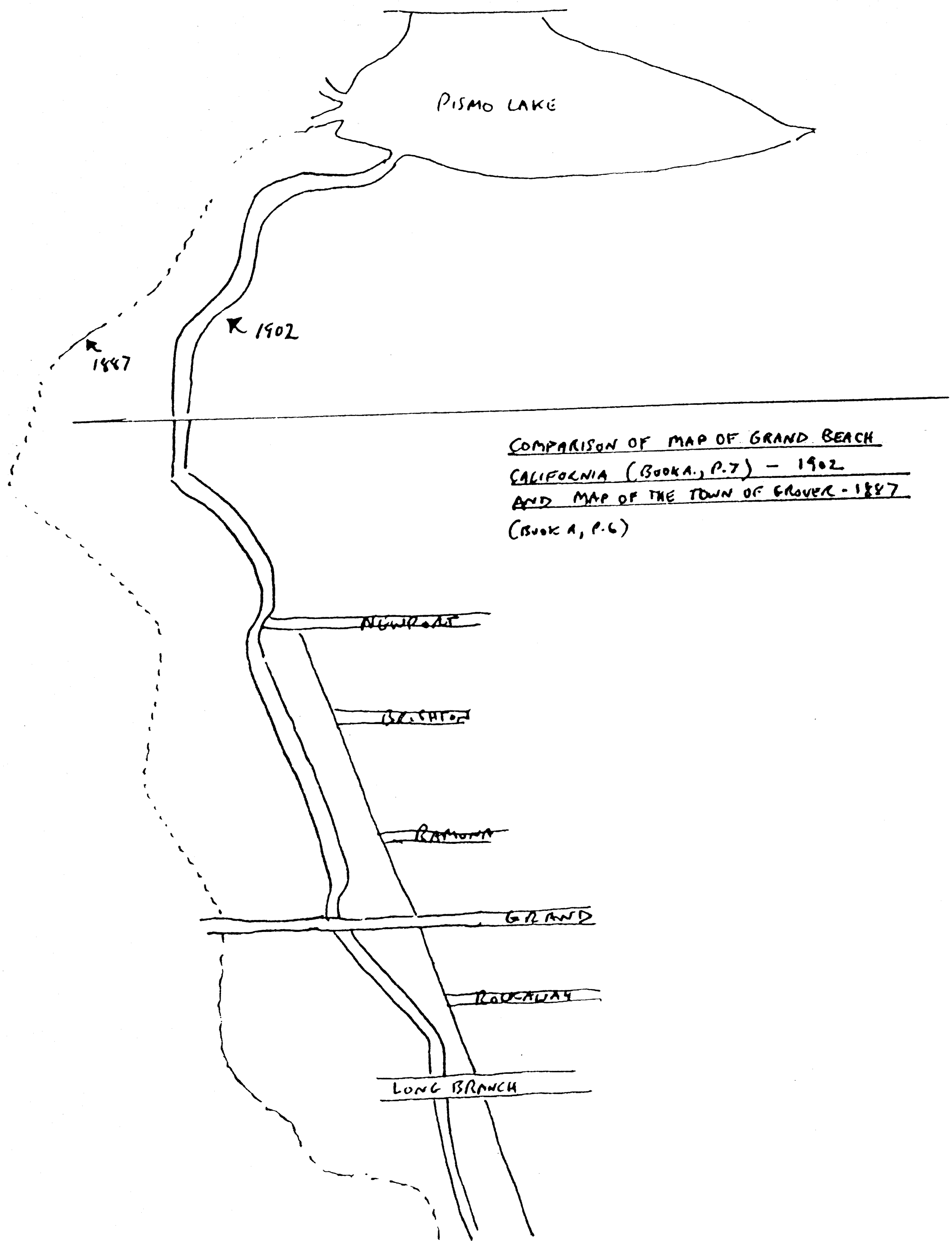


FIGURE I-12: Comparison of maps from 1887 and 1902

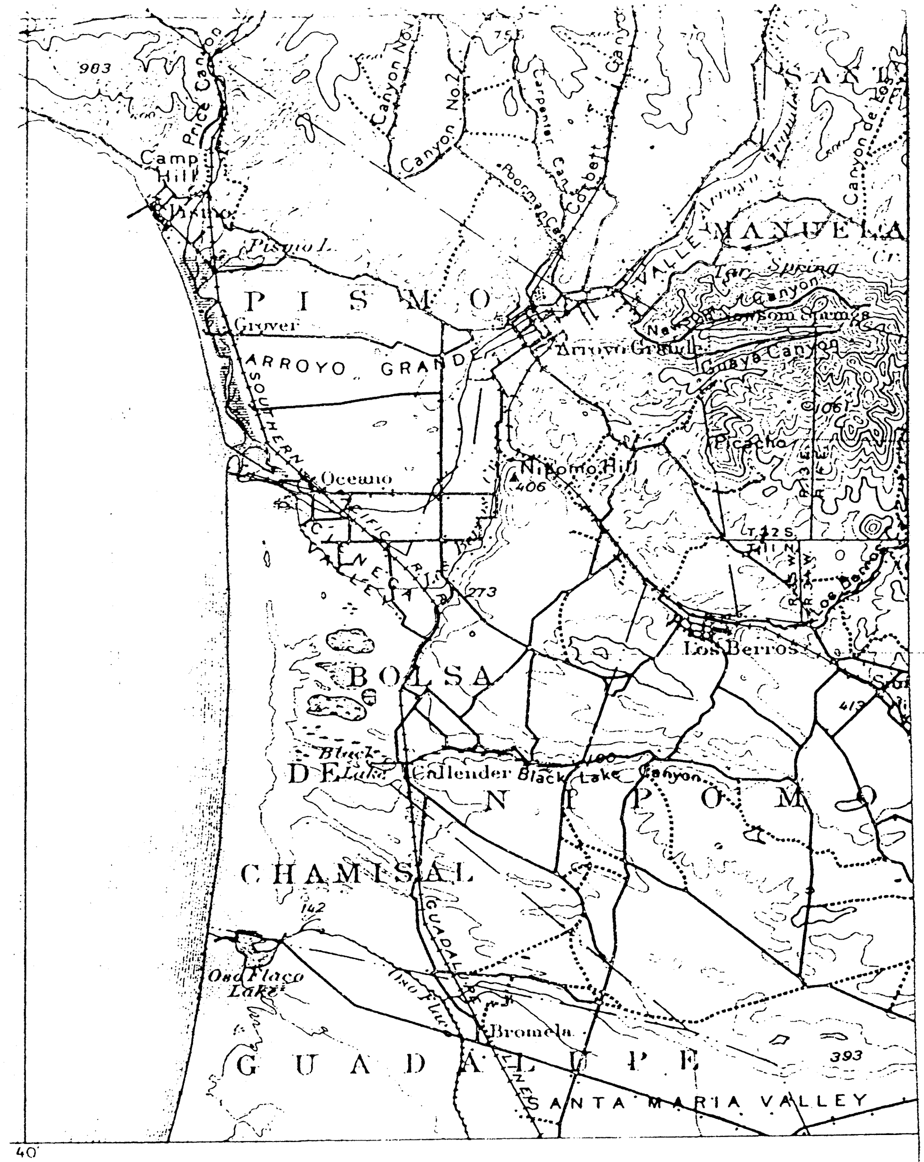
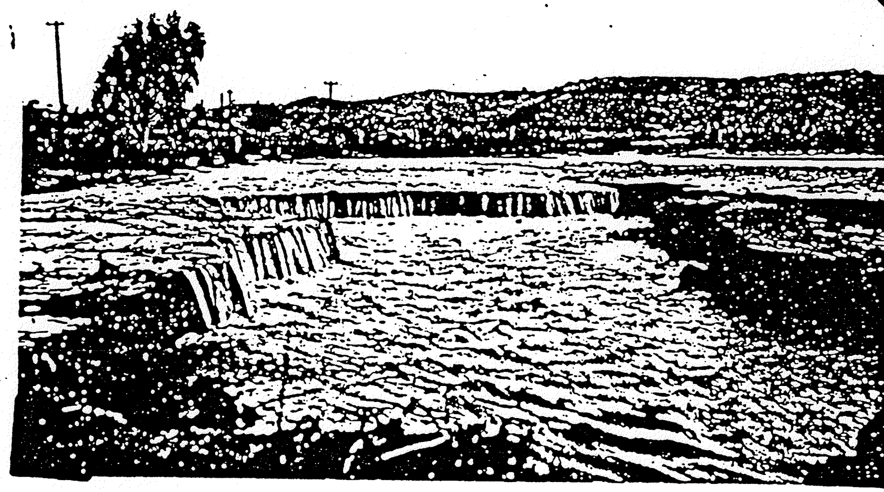


FIGURE I-13: U.S. Geological Survey Geologic Atlas, San Luis Folio 101, by H.W. Fairbanks, 1904

Villa Creek flood in Pismo 1911

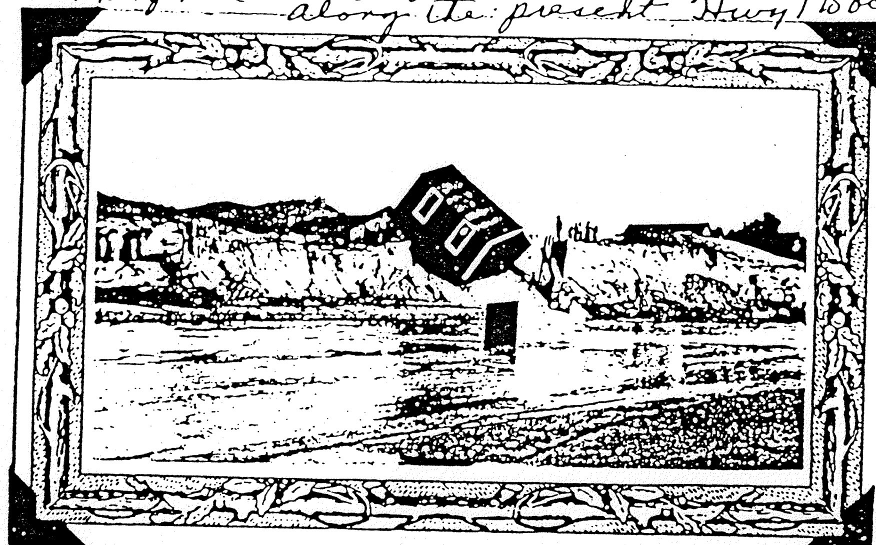
On the right can be seen the remaining homes that were not washed away. there were the name that were Emma Marelli Boardwell and Martha Rotherow Clark on the bank.



This creek followed the present Highway 1 into the Ocean Coast along the side of the sand hills. After days and days of constant rain Villa Creek backed up little by little into the southern part of Pismo (Dockerys) In order to stop this Hans Sker and Temple Bofold (Boz) opened up an outlet in the sand hills with a spade and the pictures show the result.

FIGURE I-15: Flood of 1911, Pismo-Meadow Creek (on back) Boxell's photo

The Villa Creek flood of 1911 - Water backed up in the low sections of Pismo Beach known as Dockery town. An outlet was cut in the sand hills with a spade by Hans Skov and Temple Boxell Making its Course as it is at present. It did flow along the present Hwy 1 to ocean.



In Arroyo Grande the same happen in the center of their city and washed out much top soil and cut that deep path as it is today. And Santa Maria was flooded. The river rise out of control.

1911
Young man on the rock is John Gracia
The horse buggy and men are from Guadalupe

FIGURE I 14 Flood of 1911, Pismo-Meadow Creek

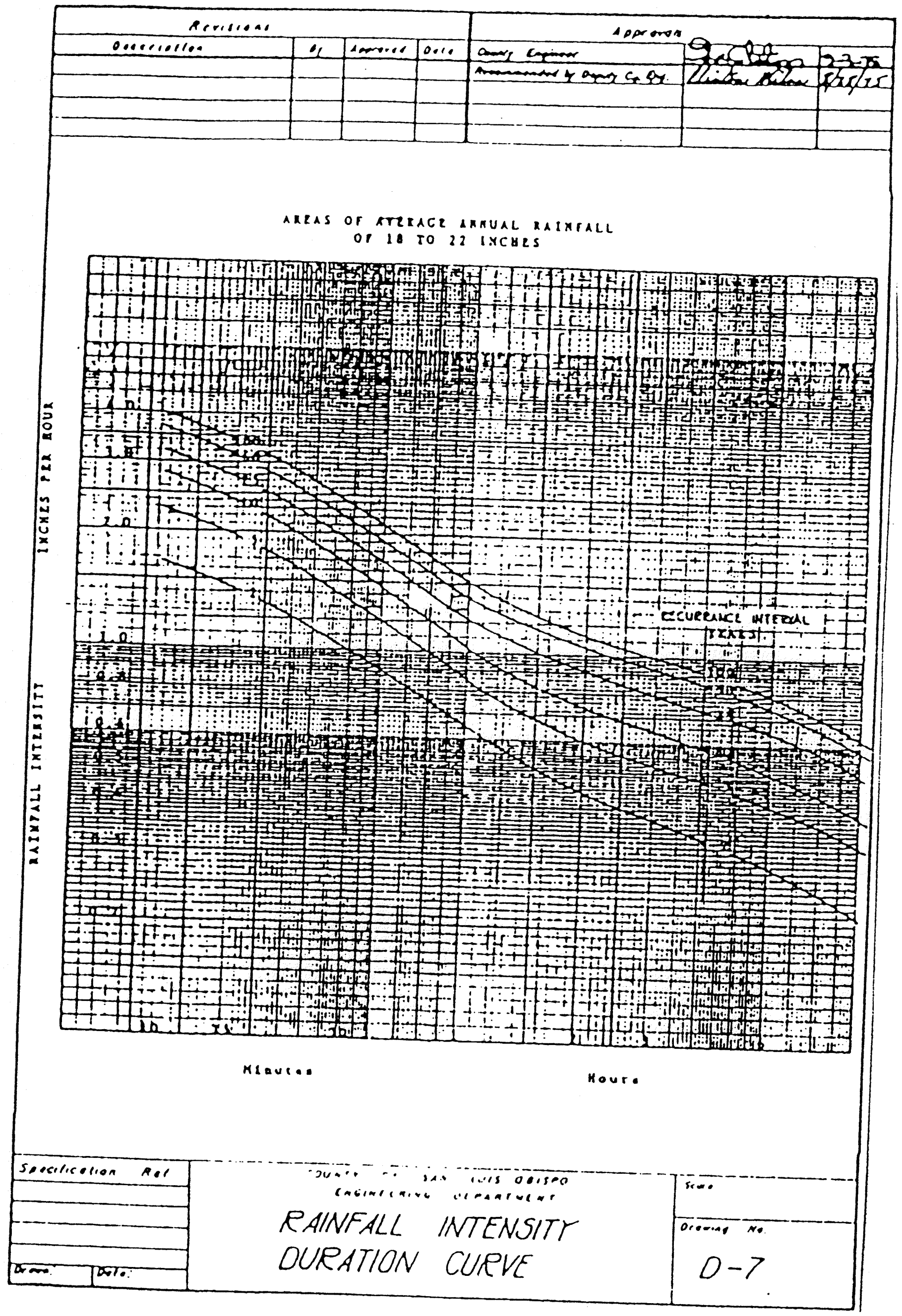


FIGURE I-16: San Luis Obispo County Rainfall Intensity Duration Curve for areas of average rainfall of 18-22 inches

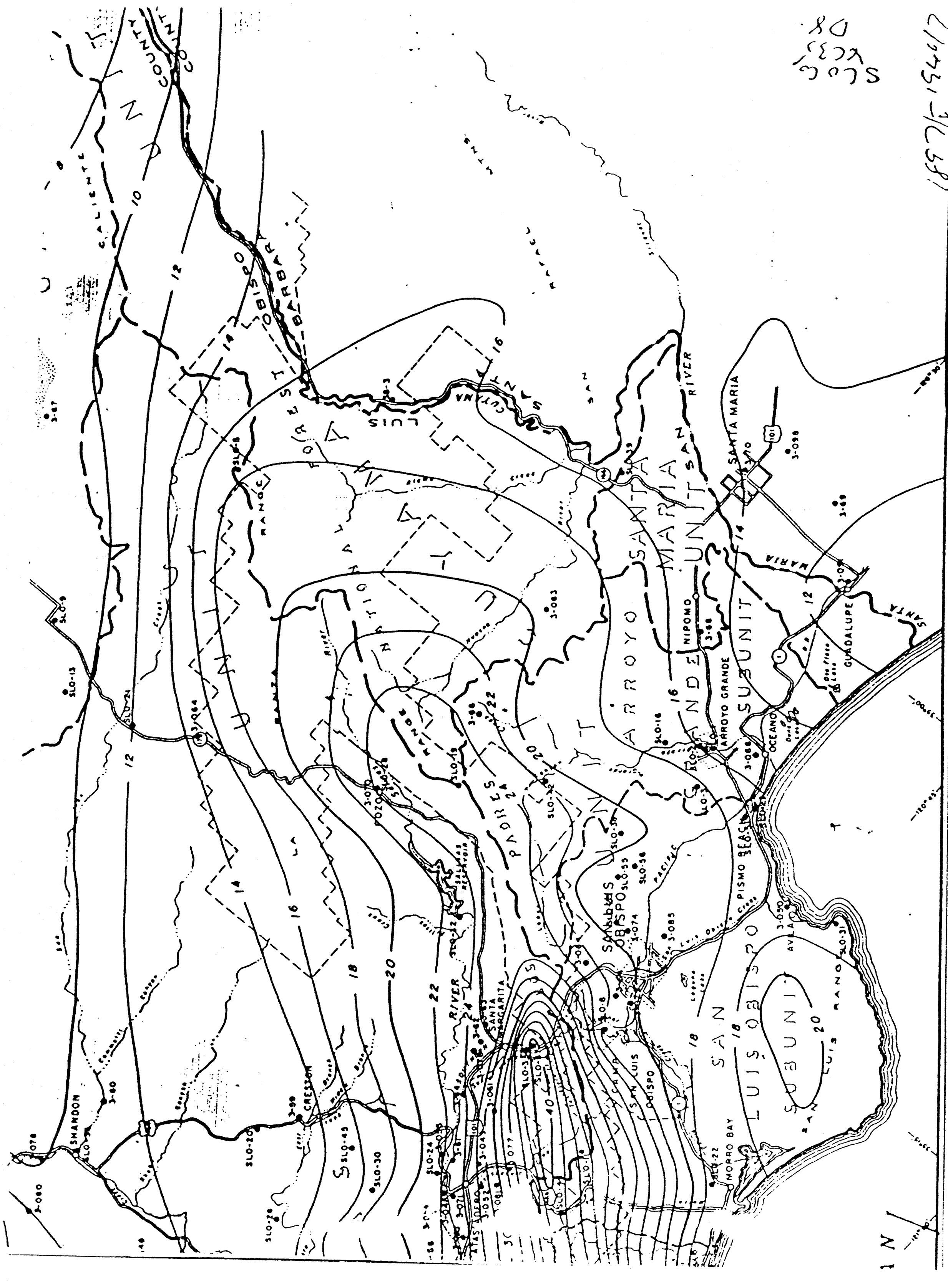


FIGURE I-17: Average rainfall for southern San Luis Obispo County (1897-1947)

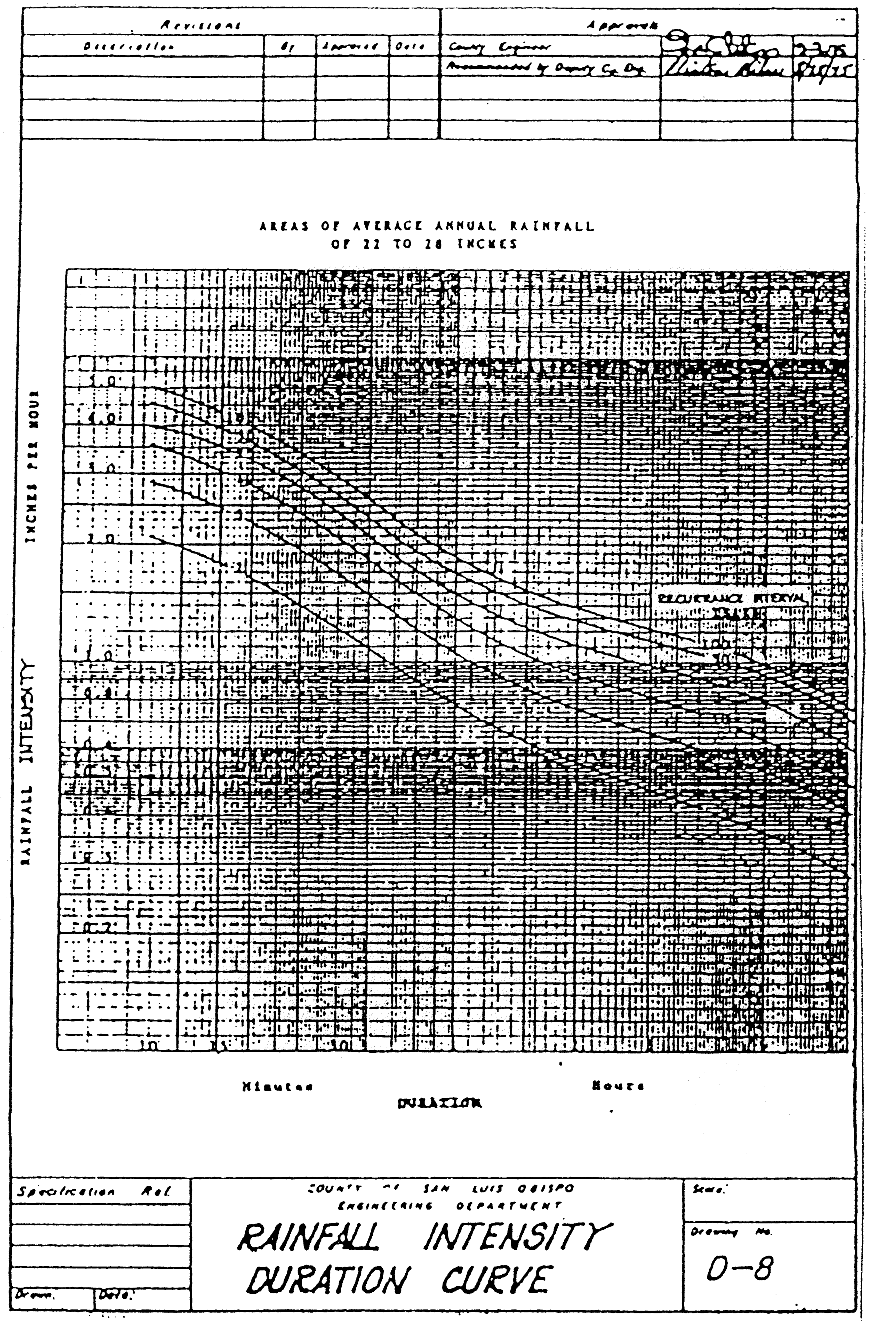


FIGURE I-18: San Luis Obispo County Rainfall Intensity Duration Curve for areas of average rainfall of 22-28 inches

Revisions				Approvals		
Description	By	Approved	Date	County Engineer	[signature]	2-3-75
				Recommended by County Co. Eng.	[signature]	1/25/75

TABLE OF COEFFICIENT RUNOFF CHART

	TYPE OF DEVELOPMENT	TYPE OF SOIL**	COEFFICIENT OF RUNOFF FOR* SLOPE < 2%	2% to 10%	> 10%
URBAN	20,000 sq. ft.	C	.35	.40	.45
	"	S	.25	.35	.40
	10,000 sq. ft.	C	.40	.45	.55
	"	S	.30	.40	.45
	6,000 sq. ft	C	.45	.55	.65
	"	S	.35	.40	.50
	APARTMENTS	C	.50	.60	.70
	"	S	.40	.50	.60
	INDUSTRIAL	C	.55	.65	.75
	"	S	.45	.55	.65
	COMMERCIAL	C	.75	.80	.85
	"	S	.70	.75	.80
RURAL	DENSE VEGETATION	C	.15	.25	.35
	"	S	.10	.15	.20
	MODERATE VEGETATION	C	.20	.30	.40
	"	S	.15	.20	.25
	SPARSE VEGETATION	C	.25	.35	.45
	"	S	.20	.25	.30
	IMPERVIOUS, PAVED, ETC		.85	.90	.95

* Note. These values are in[illegible] to be a minimum, higher values may be required by the [illegible]ty Engineer.

** Note. Soil Type

C = Clay, Adobe, Rock or Impervious Material

S = Sand, Gravel, Loam or Pervious Material

Specification Ref	COUNTY OF SAN LUIS OBISPO ENGINEERING DEPARTMENT	Scale:
Drawn: [illegible] Date: 9-?-72	TABLE OF COEFFICIENT RUNOFF CHART	Drawing No. D-2

FIGURE I-19: Runoff Coefficients used in runoff calculations, San Luis Obispo County

II - HYDROGRAPHY OF MEADOW CREEK ABOVE NORTH CAMPGROUND

The following sections discuss the peak floods and flood volumes that might impact the upper portion of the Meadow Creek watershed. The downstream boundary for this portion of watershed is the railroad bridge and embankment on the west side of Pismo Lake.

The watershed area of Pismo Lake is 3,735 acres, or 5.84 square miles. About 4.4 square miles lie above the freeway bridge at Oak Park, the remainder being east of the lake and in a small strip of Grover City. The watershed is illustrated in figure II-1. The map shows two lobes of the watershed. The northern, or upper, lobe drains into and through Pismo Lake. The southern, or lower lobe, is supplied by urban runoff from portions of Arroyo Grande and Grover City, and by flow from Pismo Lake. A small region of the northern lobe is separated from the remainder of the lobe by a dashed line in the map (figure II-1). This small region may deliver some runoff to Pismo Creek via storm drains.

INFLOW TO PISMO LAKE

MEADOW CREEK INFLOW FROM ABOVE FREEWAY BRIDGE: PEAK DISCHARGE

The inflow to Pismo Lake from Meadow Creek has been calculated at several points. The bulk of the discharge originates above the Oak Park freeway bridge culvert (see figure II-2). Calculations of discharge at this bridge have been made by CalTrans, Garing and Taylor Engineering, Stuhr, Dodson, Ward, and Foster, and the Federal Emergency Management Agency.

The CalTrans study from 1950 shows a watershed calculated area of 2730 acres (4.2 square miles) shows that a peak runoff of 1,250 cubic feet per second might be expected for the 100 year storm, and a peak runoff of 750 cubic feet per second would be expected for the 10 year storm. This was calculated at time when the watershed was undeveloped, and appears to have used a runoff coefficient of 0.35.

Stuhr, Dodson, Ward, and Foster (1977) calculated the watershed to be 2,614 acres, the 100-year storm to be 1.5 inches/hour, and the runoff coefficient to be 0.3, yielding a 100-year discharge at the freeway bridge to be 1,176 cubic feet per second by the Rational Method.

Garing and Taylor (1980) calculated the watershed above the highway bridge to be 4.426 square miles. They used a 100-year storm of 1.3 inches per hour with a time of concentration of 55 minutes and a runoff coefficient of 0.7 to show that a peak discharge of 2,578 cubic feet per second might be expected at the bridge. Garing and Taylor considered this to be a conservative calculation, suggesting that the runoff coefficient was probably lower than 0.7. They also indicated that the double 7x7 feet culvert would carry 2,550 cubic feet per second maximum, and note an earlier CalTrans study that had estimated a 100 year discharge of 2,800 cubic feet per second

F.E.M.A. (1984) calculated the watershed above the freeway bridge to be 4.4 square miles and assigned a runoff factor of 0.7. The following discharges were calculated for the watershed: 10-year storm at 560 cubic feet per second; 50-year storm at 1,800 cubic feet per second; 100-year storm at 2,600 cubic feet per second, and 500-year storm at 5,600 cubic feet per second.

My calculations on watershed area agree with the earlier CalTrans estimate of 4.2 square miles. The key control on discharge across the freeway is the size of the culvert, and any greater discharges from upstream would simply cause ponding above the bridge. Thus a peak discharge of 2,550 cubic feet per second should be considered as a reasonable peak inflow from beyond the freeway, as larger storms would only increase the duration of peak discharge, rather than it's volume.

The problem of added development on the east side of the freeway was recently addressed by Garing and Taylor (1988) in the Los Robles del Mar E.I.R. (see figure II-2) for the City of Pismo Beach. Proposed conversion of grazing lands to residential development was calculated to raise the runoff coefficient from 0.4 to 0.7, but as the development was upstream of the freeway, the added runoff would only increase the backwater flooding east of the bridge rather than raising peak discharge. The mitigation against this flooding was a proposed flood control catchment basin of 8.8 acre feet capacity on the Los Robles del Mar property.

A development plan for Rancho Grande Phase II is being developed at the time of report preparation (see figure II-2). At least 134 lots will be developed within the watershed, and an Environmental Impact Report was prepared by the Morro Group (1989). Both the report and development will be revised, but the report contains significant runoff information. Garing, Taylor and Associates, the project engineer, has estimated that runoff to Meadow Creek could increase 41% due to increases in the runoff coefficients. The coefficients increase from 0.2 and 0.3 to 0.4 in developed areas. All of the water will flow into Meadow Creek above the freeway, contributing to the cumulative flood load that would have to be handled by the freeway culvert. Retention basins with a capacity of 7.5 acre feet are planned for the project. Discussions with Mr. Jim Garing, the project engineer, showed that there has been no study of the effects of retention basins for a built-out watershed, but he indicated that he does not feel that the 100-year storm will bring the freeway culvert to capacity, due to newly installed retention on the Meadow Creek channel to the rear of the K-Mart shopping center (pers. comm. July 12, 1989).

INFLOW BELOW FREEWAY BRIDGE: PEAK DISCHARGE

The capacity of the Fourth Street bridge (see figure II-2) across upper Pismo Lake is larger than that of the freeway bridge, and is composed of two 15 feet x 7 feet oval culverts. One of these culverts is partially blocked with sediment and vegetation, and both contain standing water when the Pismo Lake is at spill level. There is some ponding of Meadow Creek water above the Fourth Street bridge that has developed due to willow growth and channel blockage. The water has accumulated behind a levee on the east side of the creek.

Street drainage from Oceano reaches the Meadow Creek drainage at several points. 100-year flows have been calculated by the Grover City Engineer, (Jim Garing), as about 47 cubic feet per second from the vicinity of 18th St., 42 cubic feet per second from N.12th St., 14 cubic feet per second from the Nacimiento Ave. area, 11 cubic feet per second from the N.6th St. area, and 13 cubic feet per second from area adjacent to the lake. In addition, 30-40 cubic feet per second could be derived from undeveloped areas on the west side of the creek that were not calculated by Grover City. Thus about 167 cubic feet per second of peak flow could enter the drainage from the west side.

Input to the drainage from the east side of the freeway may be derived in part from CalTrans calculations for culvert sizings. In an engineering memoranda, dated August 2, 1950, the following 100-year discharges were calculated between Meadow Creek and Pismo (Villa) Creek. Station 57+84 - 56 cubic feet per second, Station 67+89 - 8 cubic feet per second, Station 70+05 - 25 cubic feet per second, Station 83+42 - 83 cubic feet per second, Station 94+86 - 44 cubic feet per second, Station 102+18 - 27 cubic feet per second, Station 118+15 - 260 cubic feet per second, Station 121+87 - 66 cubic feet per second. All of these stations were calculated for runoff coefficients of 0.4, and total 569 cubic feet per second. If the runoff coefficient is increased to 0.7, the peak flow would be 995 cubic feet per second, and in view that some small drainages were not calculated by CalTrans, a reasonable 100-year flow from across the freeway would be 1,000 cubic feet per second.

Inflow from the developed area between the creek and freeway has been roughly calculated for a developed area of about 40 acres. Using the Rational Method and a runoff coefficient of 0.7, the 100-year discharge will be about 100 cubic feet per second.

Thus an additional 1,267 cubic feet per second could enter the lake from watershed lands below the Oak Park Boulevard culvert at peak discharge, in addition to the 2,550 cubic feet per second entering from above the freeway bridge. There would be some small lag time between the storm event and the arrival at the lake of a flood peak generated in upper Meadow Creek, east of the freeway.

For further discussion, a peak 100-year discharge of 3,800 cubic feet per second has been selected for the flow into the lake. This is a somewhat simplistic assumption, and ignores the effects of riperian vegetation on the creek bed roughness coefficients (U.S. Geological Survey Water Resources Investigation Report 83-4247 indicates that Manning Roughness coefficients could be as high as 2.0 in intensely vegetated areas such as the Meadow Creek corridor). It also ignores the possibility of significant base flow in the creek, prior to the passage of the flood peak, and the retention caused by the 4th street bridge. Some of the effects not considered may cancel each other.

FLOOD VOLUME

The volume of water entering the lake was calculated from a simple triangular hydrograph model with a six hour duration and a 3,800 cubic feet per second peak (see figure II-3). The hydrograph shows delivery of 633 cubic feet per second in the first and sixth hours, 1,900 cubic feet per second in the second and fifth hours, and 3,166 cubic feet per second in the third and fourth hours. The calculated delivery volume contained in the hydrograph is about 940 acre feet.

It is likely that a triangular hydrograph might overestimate the amount of water entering the lake. Taking the watershed at 3,735 acres and a 100-year rain intensity of 0.5 inches per hour for 6 hours, a runoff of 933 cubic feet per second would be developed for a saturated ground runoff coefficient of 1.0. Although the runoff coefficient for the 100-year storm would be very high, due to total ground saturation, the value of 1.0 might be too high. Using a coefficient of 0.8, the storm would produce a runoff of 747 acre feet., and using a coefficient of 0.5, 466 acre feet would be produced. This volume should be considered low, as ground saturation during the last half of the storm would increase the runoff coefficient to 0.8 or greater. This would give a production of 233 acre feet for the first half of the storm, and 373 acre feet for the second half, totalling 606 acre feet. If the entire storm was computed with a runoff coefficient of 0.8, which is how the Corps of Engineers calculates for 100-year events, a runoff of 746 acre feet would be produced.

By these crude calculations, the 100-year storm would deliver about 750 acre feet of water to Pismo Lake. This may be compared to the 940 acre feet developed from the triangular hydrograph. However the higher volume is suitable volume for further discussion as runoff from the 100-year event entering Pismo Lake, as it is unlikely that the storm discharge would not be superimposed on an existing and possibly substantial base flow. It must be assumed that nearly all of this water would eventually pass downstream of the lake toward the North Campground.

LAKE STORAGE AT PISMO LAKE AND RELATION TO OUTFLOW

RAILROAD BRIDGE CAPACITY

The limiting factor in the outflow of Pismo Lake is the capacity of the railroad bridge. Sized like the freeway bridge above the lake, the bridge would be capable of passing a much lower flow rate due to the much lower bed gradient. Using a gradient of 0.0002, a full 5 feet flow under the bridge would discharge at about 275 cubic feet per second, and at a gradient of 0.002 would discharge at about 775 cubic feet per second. Gradient calculations are complicated by the presence of the elevated outlet spillway to the lake on the upstream side, and the essentially flat gradient through the North Campground channel on the downstream side, with flow also being complicated by the slightly smaller capacity of the Highway 1 culvert just downstream. It is thought tha downstream flow would be very slow until a water depth of greater than 4 feet develops west of the railroad, at which overbank flooding would cause an acceleration of channel flow as floodwaters spread across North Campground.

The flow through the railroad bridge would increase if there is a substantial head difference, but this does not appear to be likely, as the head above the bridge is controlled by the elevation of the railroad embankment north of the bridge. With floods under the bridge to depths of 5 feet, the bridge acts as an open channel and not as a culvert under head. However, it is likely that a 3 foot head could develop, and that flow could increase through the culvert to 1,200 cubic feet per second.

With this large number of variables, it is very difficult to compute the real channel discharge at bridge capacity, but it would appear to be under 1,000 cubic feet per second, and probably somewhere around 500 cubic feet per second, until the lake came close to flooding, when the culvert could pass flows as high as 1,200 cubic feet per second under a 3 foot head.

LAKE STORAGE

The lake outflow through the railroad bridge was crudely estimated (above) at 500 cubic feet per second, when the channel was flooded 5 feet deep. In order to get this volume of water flowing over the lake spillway, above the channel leading to the bridge, some head would be needed in the lake. The channel between the spillway and the railroad bridge is 3 feet lower than the spill level of the lake, and therefore 5 feet of water in the channel requires only a 2 foot rise in the level of the lake. Thus about 50 acre feet are stored in the lake at this stage (lake volume after restoration is discussed below).

Beyond this stage, a further 3 feet of water could be stored in the lake before the water begins to flood across the railroad tracks. Thus the lake outflow through the railroad culvert would have a head of 3 feet at the time flooding starts across the tracks, and would flow faster than 500 cubic feet per second, increasing to 1,200 cubic feet per second.

Triangular hydrograph of 3 inch, 100-year storm:

Using the triangular hydrograph discussed above, the 6-hour event would input 633 cubic feet per second in the first and last hour, 1,900 cubic feet per second in the second and fifth hour, and 3,166 cubic feet per second in the third and fourth hour. This would total 936 acre feet.

If the capacity of the bridge would be exceeded for all 6 hours, 246 acre feet would be discharged through the bridge (calculated at a constant 500 cubic feet per second). With the difference between inflow and outflow added to lake storage, the volume increase would be 936-246= 690 acre feet. Using a lake flood storage area of 25 acres, the lake level would rise an impossible 27 feet if flooding over the railroad was prevented, but backwater storage above 4th street would considerably increase the size of the lake, making a real rise of about 18 feet reasonable for a case where there was no flow over the railroad.. The 18-27 feet figures obviously could not be achieved, as flooding over the railroad would hold the flood level to about 5-6 feet. This would result in flooding over the railroad embankment of 690-125 = 565 acre feet, where the 125 acre feet represents temporary lake storage between the spillway and railroad track overtopping elevations. Thus some 565 acre feet of water would come over the railroad. This may be somewhat lower if the head-induced flow through the railroad culvert resulted in a somewhat greater flow as flood head increased.

Reference to the 1969 storm:

The January 1969 rain storm produced 4.93, 5.60, and 5.9 inches as daily rainfall amounts at the California Polytechnic State University rain guage at San Luis Obispo. This storm was rated as a 100-year event, and resulted in the flooding of Pismo Lake over the railroad embankment. Conversations with Mr. Guiton of Oceano indicate that he was present at the Meadow Creek bridge at Highway 1. He remembered water swirling around the Renshaw's Realty Office, and on January 28, 1969, the Telegram Tribune reported that a Mr. Renshaw and a Mr. Le Sage had requested Southern Pacific Railroad Corporation to permanently sand bag the railroad line, and to dragline both Meadow Creek and Pismo Lake. It is therefore evident that the 1969 storm flooded over the railroad right of way, and therefore exceeded the modelled 3 inch- 6 hour storm that was modelled above.

The 1969 storm actually had a Cal Poly guage reading of 10.53 inches in 48 hours, or 0.22 inches / hour. This would appear to be a much lower rainfall intensity than has been used in the calculations above, but meteorologic evidence shows that the 100-year storms are often multiple events generated by the focussing of multiple fronts by the jet stream, and that the rain comes in 3- 6 hour intensive bursts.

Triangular hydrograph of the 4 inch and 5 inch storms:

Scaling upward from the 3 inch storm, peak discharges of 5,066 and 6,333 cubic feet per second would enter the lake from the 4- and 5-inch storms respectively. The 4 inch hydrograph delivers 1,248 acre feet in 6 hours, and the 5 inch delivers 2,080 acre feet in the same time. During the 6-hour period, the railroad bridge would drain off 246 acre feet, assuming an average 500 cubic feet per second outflow, and thus the 4 inch storm would place about 1,000 acre feet, and the 5 inch storm would place 1,834 acre feet, into a combination of lake storage and flooding over the tracks.

Reservations about hydrograph models and the real world:

These calculations, using a simple triangular hydrograph and an outflow capacity of 500 cubic feet per second at the railroad bridge, are obviously simplistic. The hydrograph has been constructed on a base flow of 0 cubic feet per second, which is unlikely to be experienced in the rainy season. The model hydrograph also drops to 0 cubic feet per second at the end of 6 hours, which is certainly incorrect for the real world, due to release of upstream retention storage. Major storms come in groups, and it possible that the 100-year storm could be superimposed on flows of 1,000 cubic feet per second from previous storms. A 5 inch, 6 hour duration storm, superimposed on a 1,000 cubic feet per second baseflow, would result in a flood far more severe than was experienced in 1969.

The level of flooding in the lake will also be affected by the flood level west of the bridge. Increase flood head on the west side will slow the flow rate under both the railroad and the adjacent highway bridge. The entire area of the North Campground and Golf Course, plus the recreational vehicle parks north of the creek, are in the 100-year flood plain, and will suffer flooding from both Pismo and Meadow Creeks.

Thus flood duration in the real world is likely to be considerably longer than that implied from the triangular hydrograph.

HYDROLOGIC EFFECTS OF PISMO LAKE RESTORATION

The net effect of the Pismo Lakes restoration project has been to reduce flood storage retention in the lake, and to worsen the risk of flood downstream. The project produced permanent open water, in the form of dredged channels, at the expense of former wetlands (see figure II-4) that were converted into islands. The result has been a reduction in the flood storage for the basin, as the dredged channels contain a permanent pond that does not represent storage. In a section adjacent to the railroad track, the cross section of the lake available to storage was reduced about 60-65% (see figure II-5). In consideration of the entire lake, and without making a detailed survey, I would estimate that the amount of storage below the lake's flood stage has been reduced about 45-50% by the project. This figure is based on filling the lake to the level of the lowest part of the railroad track, as the islands are graded to this elevation, or about 5 feet higher than the level of the lake.

The result of this reduction of storage will be a faster filling of the lake for those times when the capacity of the railroad bridge culvert is exceeded. The lake level was also raised several feet by the weir at the entrance to the Meadow Creek outlet channel. It appears that the lake has been raised about 3 feet by the weir, which represents 3 feet less storage available in the lake.

The problem will not be aggravated by siltation of the main body of the lake, provided that siltation takes place below the level of the weir. Siltation in the upper sections of the lake, around the 4th Street culverts, will reduce lake flood storage volume.

In the 100-year storm, the flood waters will begin to cover the tops of the dredged islands, and this would result in a decelleration of an increasing flood stage, as the entire area of the lake becomes available for temporary storage. However the amount of flood head over the islands would be slight, due to flood water escape over the top of the railroad tracks.

REDUCED FLOOD STORAGE VOLUME AT PISMO LAKE

The original area of Pismo Lake wetlands was estimated to be 45 acres by the City of Grover City. With the Restoration Project's 45-50% reduction in area for the lake at the no-spill stage, the area for accumulating higher flood stages would be about 25 acres. Thus for every foot of flood rise, there is an additional 25 acre feet entering temporary lake storage. For spillage over the railroad tracks, a flood head of 5 feet is needed, representing 125 acre feet of storage.

The original lake, prior to restoration and the construction of the raised weir, would have needed an extra 3 feet of head before flooding took place over the tracks, and the head would have accumulated over about 45 acres. This would represent at least 360 acre feet of storage before spillage took place over the railroad embankment. The restoration project has therefore reduced retention storage by 360-125=235 acre feet.

POST FLOOD-PEAK DRAINAGE OF PISMO LAKE

After the flood peak has passed, the lake would fall quickly to the level of the railroad tracks, but would need to drop a further five feet through the Meadow Creek channel. The stored lake volume would be about 125 acre feet. Close to 100 acre feet would drain out in the first hour, and about 50 acre feet in the second hour, had no additional water entered the lake. However there is a large amount of retention planned for developments upstream, and there will be a considerable tail to the hydrograph of lake input, and therefore the culvert could be expected to flow at levels sufficient to flood North campground levees for at least 3 hours after water has stopped coming over the railroad tracks.

FEMA FLOOD MAPS

The 100-year flood, according to FEMA models, results in the inundation of the railroad tracks from the railroad bridge over Meadow Creek to the trailer park on the north shore of Pismo Lake. On the west side of the tracks, the entire area of the North Campground and the adjacent recreational vehicle parks are submerged, and the inundation elevation appears to be +20 feet. Bench Marks of 13 feet and 16 feet were shown to be submerged. The FEMA map is illustrated in figure II-6

The flood unites the waters of Pismo and Meadow Creeks, covering the divide at +12 feet along Highway 1. It is likely that much of Meadow Creek's water will flow toward the mouth of Pismo Creek and the ocean during maximum flood stage, but some flooding may be in the opposite direction and would depend on the relative timing of the Pismo Creek and Meadow Creek hydrograph peaks. Flow will be complicated by the floating and damming of waters with mobile homes and recreational vehicles.

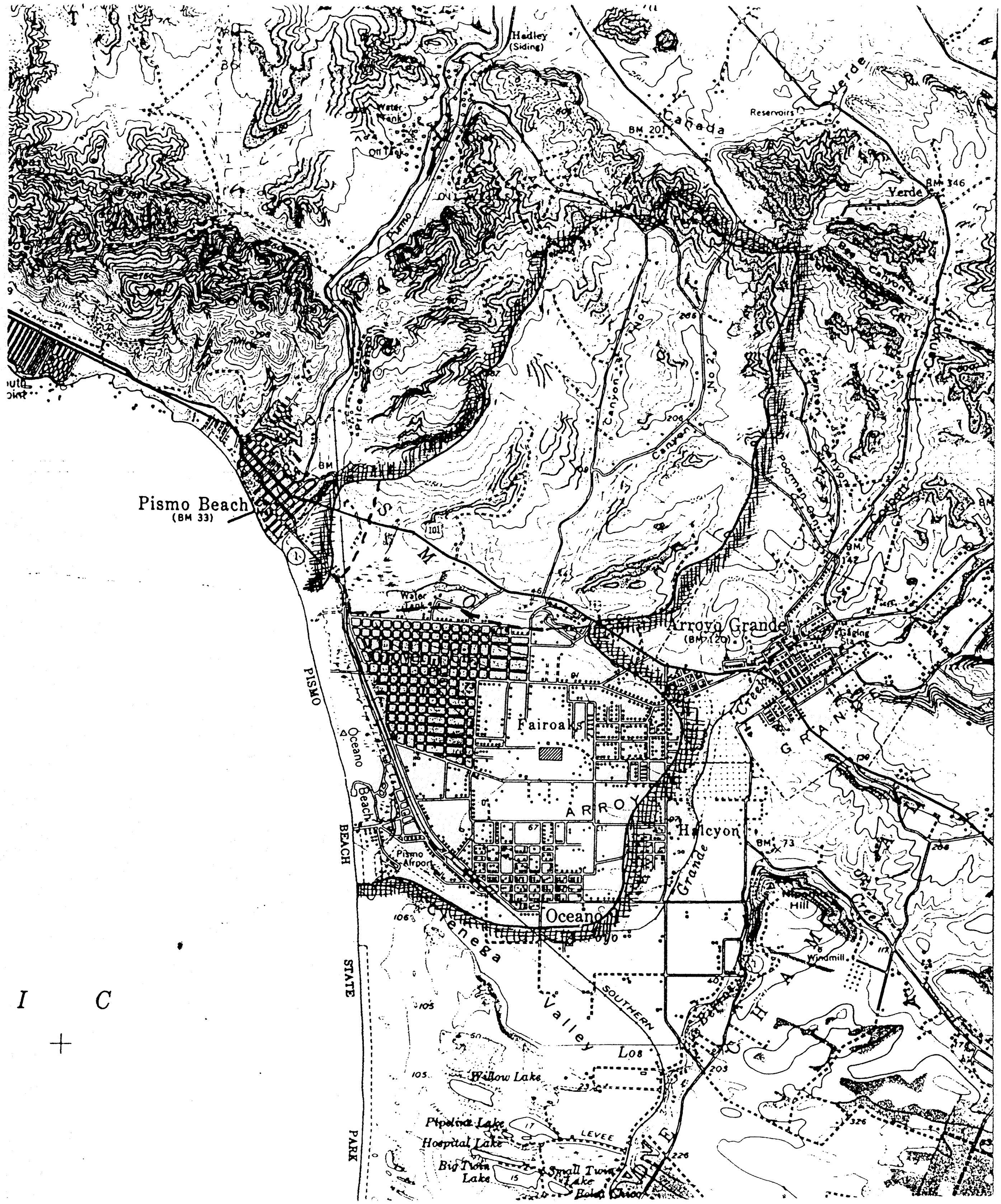


FIGURE II-1 Watershed of Meadow Creek

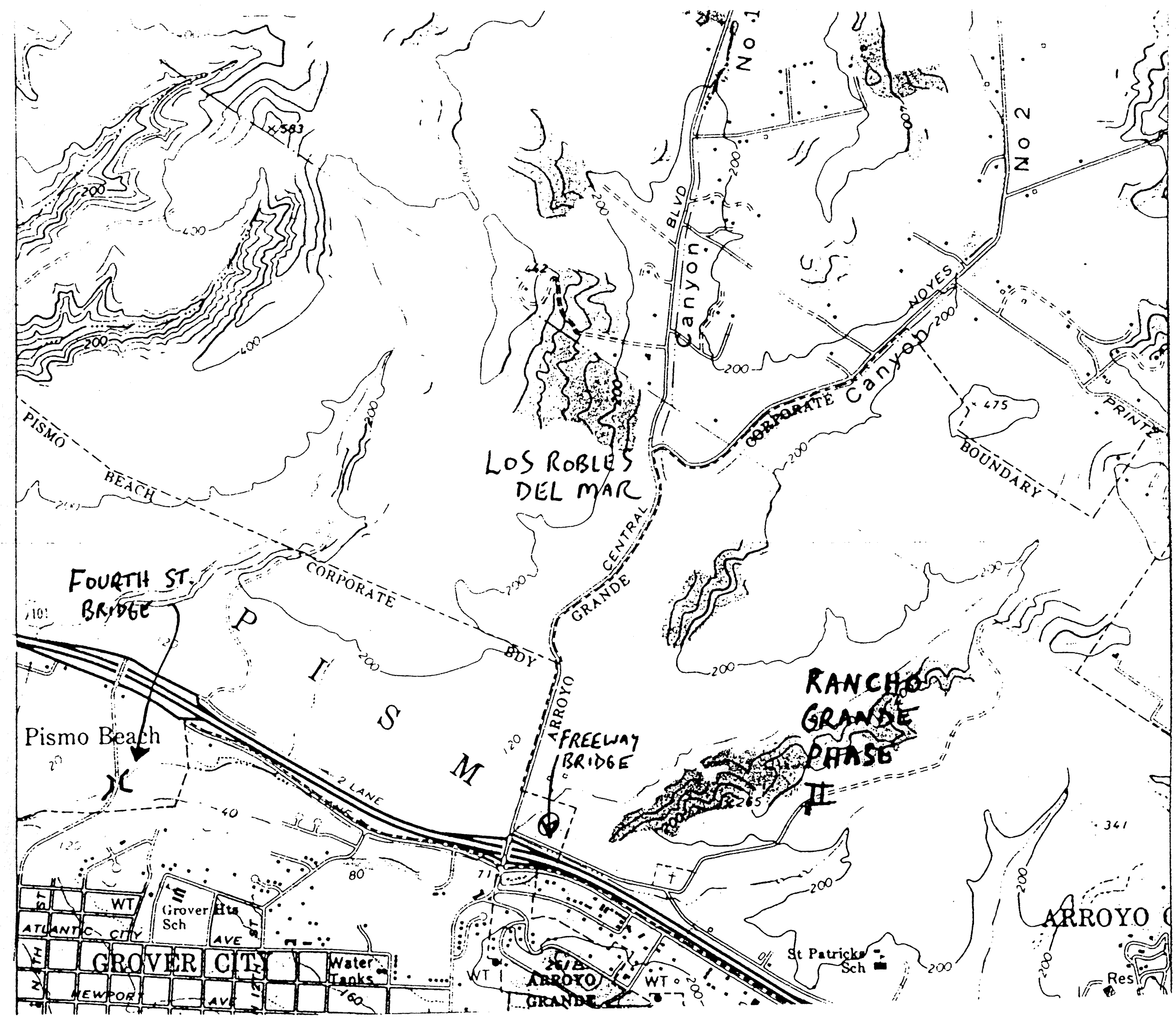


FIGURE II-2 Locations within upper watershed mentioned in text

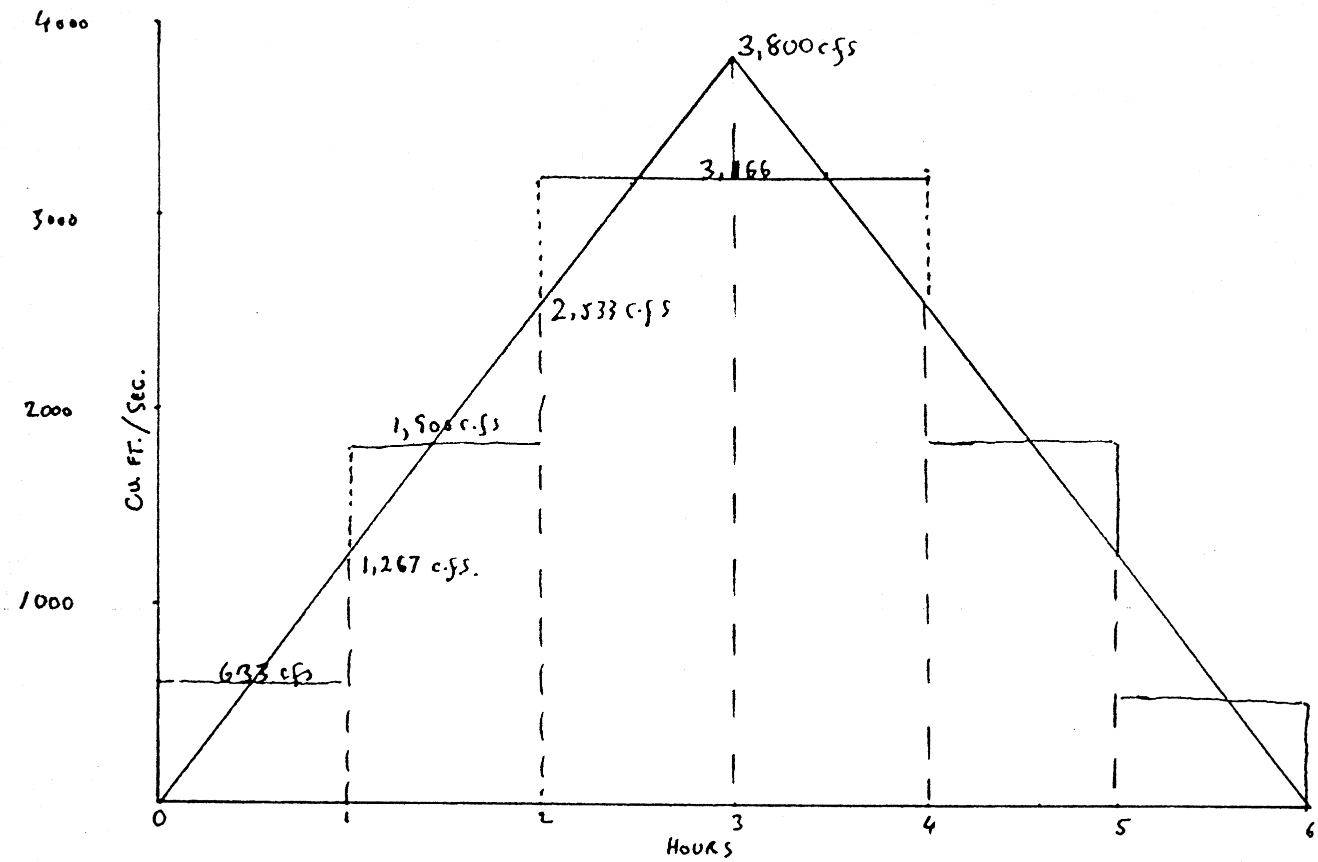


FIGURE II-3 Triangular hydrograph for a flow with 3,800 cubic feet per second peak and an event duration of 6 hours

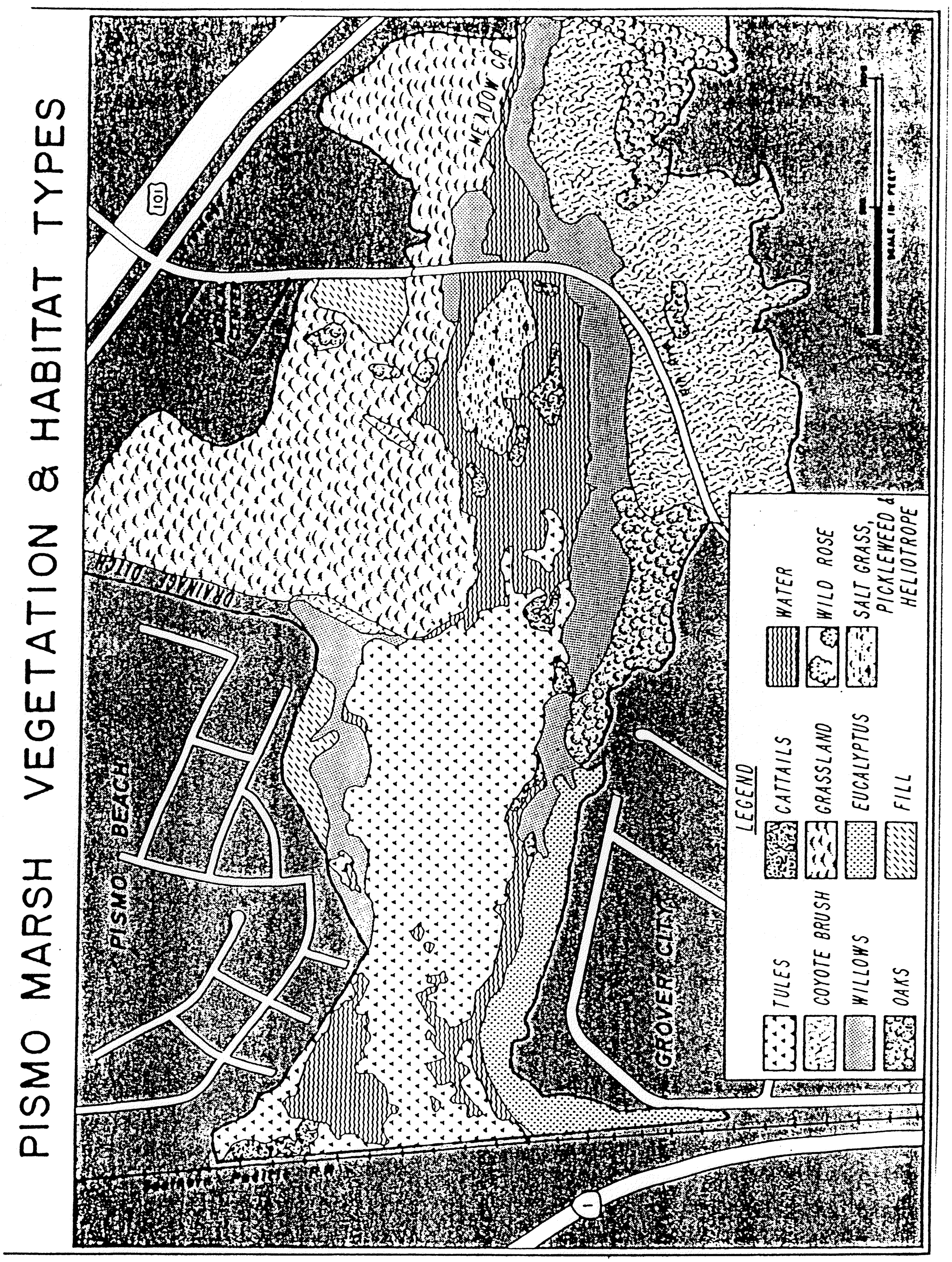
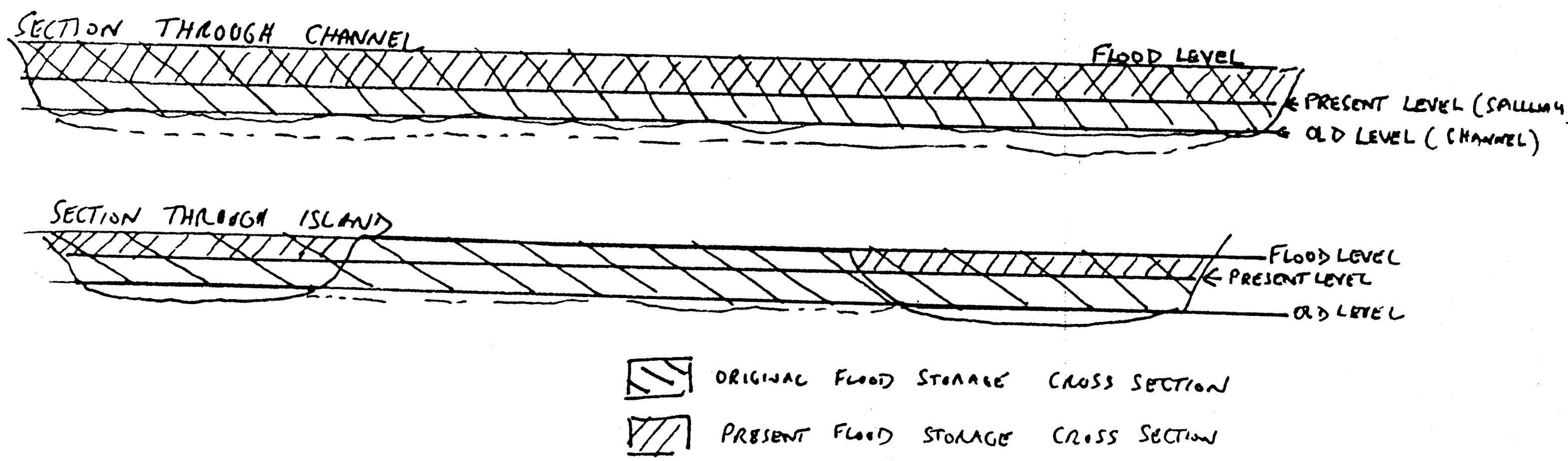


FIGURE II-4 Map of former vegetative distribution for Pismo Lake Cal. Dept. Fish and Game, 1976

FIGURE II-5 Comparison of cross sections through Pismo Lake taken (top) between islands and (bottom) through an island, in which original and present flood storage cross sections are illustrated. Not to scale.



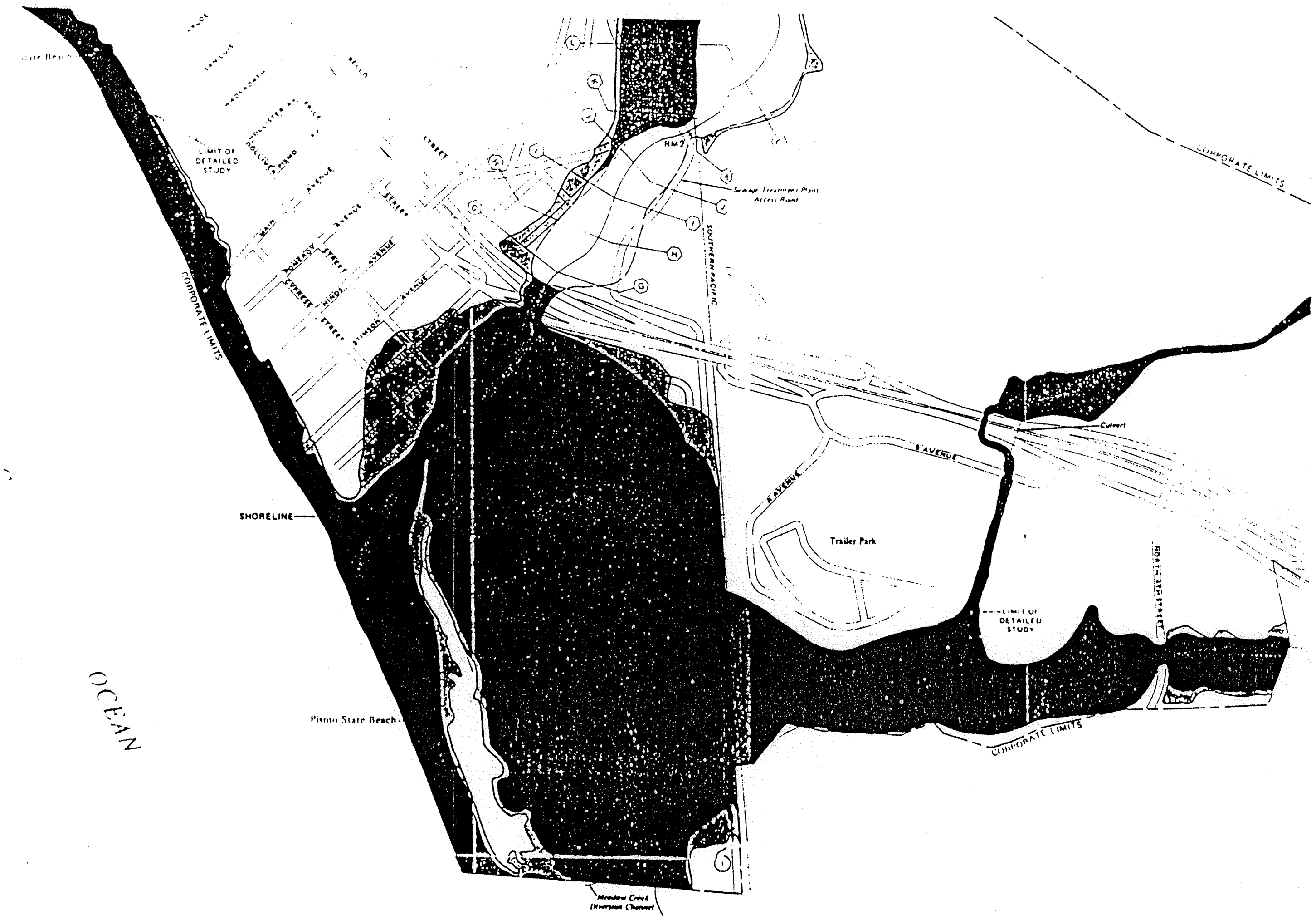


FIGURE II-6 FEMA Flood Map for the 100-year storm, Pismo and Meadow Creeks

III - HYDROLOGIC CONDITIONS DOWNSTREAM OF RAILROAD BRIDGE

GENERAL CHANNEL TOPOGRAPHY

The channel of Meadow Creek below the railroad bridge can be divided into several distinct sections. These are the the North Campground, Golf Course-Grand Avenue, 'tule', and Oceano Lagoon sections.

The North Campground section extends from Highway One to the southern edge of the Northern Campground. It has a 14 feet channel width, and an average depth of about four feet to the top of the levee. Thus any flow depth greater than four feet would result in flooding of the North Campground and Carpenter Creek channel. The impact of Carpenter Creek on flooding is discussed below. Flooding would mainly be on the west side of the creek, except for a narrow zone near the 'Butterfly Trees'. The main features of this channel reach are shown in figure III-1.

The Golf Course- Grand Avenue section of channel is the same width, but flanked by levees 5 feet in height on the west side, and by higher fill on the east side. Flooding would result in inundation of sections of the golf course, but most of the area just north of Grand Avenue exceeds 5 feet in relative height, and the flood would be restricted at this point.

Below Grand Avenue, in the 'tule' section of the channel, the natural form of the original channel is preserved, being several hundred feet wide but clogged with dense riperian vegetation. The more southern sections of the channel are flooded year round, as the upper portions of Oceano Lagoon are reached. At times water stretches from the eastern edge of the coastal dunes to the side of Highway One.

Oceano Lagoon starts within the South Campground, and continues to the edge of Arroyo Grande Creek, where the outlet culverts to Arroyo Grande Creek from Meadow Creek are located.

CAPACITY OF THE CHANNEL

The flood plain of Meadow Creek between the Highway 1 culvert and the Oceano Lagoon is essentially flat, and during the rainy season has standing water in the bed of the creek over the entire distance. Thus, in spite of there being a slight slope, the water surface can be considered more like that of a lake or reservoir than of a stream channel.

The channel has 5 feet or less of available water storage. Using a channel slope of 0.0001 and a Manning Roughness Coefficient of 0.015, it was determined from figure III-2 that less than 200 cubic feet per second of disharge could be accomodated in the channel before flooding took place. During the 100 yr storm over 1,000 cubic feet per second, and possibly over 2,000 cubic feet per second (based on culvert capacity at railroad and Highway 1) would be entering the creek, and for many hours most of this would be stored as flood waters.

FLOOD PLAIN AREA

The area of the flood plain was measured from the Oceano Lagoon to North Campground. The area was measured on magnified 7.5 minute U.S.G.S. quadrangle maps for the elevations below the +10 feet contour, and found to be 153 acres. This would include much of the lowland around Oceano Lagoon, and most of the strip of land between the base of the coastal dunes and the highway. The 10 feet contour crosses the creek in the vicinity of Carpenter Creek channel, and thus the area does not include the majority of the North Campground, the recreational park north of the campground, or the mobile home and trailer parks on the east side of the highway.

FLOOD WATER VOLUMES REACHING WATERSHED BELOW PISMO LAKE

CALCULATIONS USING PEAK DISCHARGE INFORMATION

The dominant inflow is from Pismo Lake, for which flood hydrographs were constructed in the last section. Inflow from the lake could exceeed 2,000 cubic feet per second for a duration of several hours.

There is a substantial flow from the City of Grover City. The Grover City Engineer has calculated 100-year peak discharges into the drainage to be 71 cubic feet per second at the Highway One bridge, 235 cubic feet per second at Grand Ave., 99 cubic feet per second at Manhattan Ave., and 154 cubic feet per second at Mentone Ave.. This totals 559 cubic feet per second. An additional 100 cubic feet per second would be derived from drainage basins at the southern end of the town, totaling 659 cubic feet per second.

This 659 cubic feet per second represents peak flow. If runoff volume is measured as a crude triangular hydrograph of time duration 6 hours and this peak, the volume would be 165 acre feet over the duration of the storm.

There is additional inflow from the area between Grover City and Oceano, which drains into Oceano Lagoon, and from drainage from the City of Oceano, some of which drains into the back-levee area of Arroyo Grande Creek, and thus into Oceano Lagoon. To this must be added the rainfall on the floodplain surface, and on the area of the North Campground that drains southward toward Carpenter Creek rather than Pismo Creek (40 acre feet).

Thus, totalling the above, about 1,145 acre feet could flow into the basin. This figure should be treated with caution. The inflow from very large storms is highly complicated by flooding of both Pismo and Arroyo Grande Creeks, and the exchange of those waters with the floodway of Meadow Creek.

FEMA flood maps of the area are shown in figures II-6, III-3 and III-4. FEMA flood maps suggest flooding at >+16 feet and <+20 feet elevation at Pismo Creek, with a flood of 4-5 feet over the North Campground. FEMA maps of the Oceano Lagoon area show an elevation of +30 feet for flood waters at the railroad bridge over Arroyo Grande Creek, but only +15 feet along the shores of Oceano Lagoon and the South Campground. Flood rise over the entire area of flooding is therefore about 10 feet.

(b) CALCULATIONS USING WATERSHED AREA

The total watershed area is 10 square miles, or 6,400 acres. A 100 year 3 inch storm would produce 1,600 acre feet of precipitation. Runoff would be 1,280 acre feet, given a runoff coefficient of 0.8 that is appropriate for soil saturation.

OUTFLOW TO OCEANO LAGOON CULVERTS

The only route for water leaving the Meadow Creek drainage in normal years is the twin culvert from Oceano Lagoon into Arroyo Grande Creek. These culverts are oval, each having a height of four feet and a width of five feet, and each having a backflow prevention gate on the Arroyo Grande Creek side.

Using Bureau of Public Roads charts, the maximum discharge would be about 140 cubic feet per second per pipe if ungated, and would be much less during a tidal and flood cycle if gated. During inspection of the culvert during this study, it was observed that capacity was reduced from debris jammed up against the gate. In this regard I have estimated a combined flow of 200 cubic feet per second through the gate.

During major floods discharge into Pismo Creek and down Carpenter Creek may also be taking place.

FLOODING DEPTHS FOR 100 YEAR STORM EVENTS

Crude calculations (above) indicate that about 1,200 acre feet of water could enter the Meadow Creek floodplain in the 3 inch, 6 hour, 100 year storm. As the area below 10 feet is about 153 acres, the water depth induced by the flooding would average 7.8 feet. F.E.M.A. flood maps indicate a 100-yr storm inundation of 10 feet, which suggests that the modelling used in this study is compatible with F.E.M.A. models, and that the F.E.M.A. 100 year storm is equivalent to a storm of between 3-4 inches and of 6 hour duration.

During this flood event, the gated pipes at Oceano Lagoon could, at a combined flow of 200 cubic feet per second remove about 100 acre feet in a 6 hrs. This volume has not been subtracted from the totals, as Arroyo Grande Creek is likely to be high, and the flood gates would probably by partially closed. In the event that the gates were open, the 3 inch storm flood heights could be reduced by 7-8 inches, as 100 acre feet represents about 8% of the estimated 1,200 acre feet of inflow.

The accumulated flood storage in and above the Oceano Lagoon could be emptied through the culverts in 72 hours if they were able to flow free, but it is likely that, considering tides and high water in the Arroyo Grande Creek, drainage could take much longer.

Exchange of flow from and to Pismo and Arroyo Grande Creeks is not here considered in the flow calculations, nor is possible outflow through Carpenter Creek.

FLOODING DEPTHS-100 YR STORM SEASON EVENTS WITH DURATION OF A MONTH

Rainfall monthly values of 24 inches occured in 1969, 18 inches in 1916, 17 inches in 1909, 15 inches in 1915, and many months with over 10 inches. Such high rainfall would generate high runoff coefficients, even in undeveloped land. A watershed area of about 10 square miles, or 6,400 acres, by crude calculation, would receive a rainfall of 9,600 acre feet in 1916's peak month, which would yield runoff of 4,800 acre feet if the runoff coefficient was 0.5. In 1969 6,400 acre feet would have been delivered. The runoff from the area in 1916 could be quickly shed into the ocean via both Pismo and Oceano Lagoon -Arroyo Grande Creek, but that today this water would be largely held in flood storage.

There would be a release from Oceano Lagoon via the culverts, but this would be small relative to input, and would be somewhat restricted by high flood stages in Arroyo Grande Creek. If this water volume of 6,400 acre feet was 'placed' over the area of 153 acres, used above, the water 'depth' would be about 31 feet, but this could never be obtained, as the water would drain into Pismo Creek when an elevation of 12-14 feet was reached, would overtop the levees of Arroyo Grande Creek, or would open up Carpenter Creek. There would be major flow of 200 cubic feet per second out of the lagoon through the culverts into Arroyo Grande Creek.

Had the maximum 1969 rain month rainfall been spread out over the month, no flooding would have taken place. The 1969 rain, had the runoff coefficient been as high as 0.8, would have generated 10,240 acre feet of runoff. The culverts to Arroyo Grande Creek would have drained 11,898 acre feet in that time, exceeding monthly inputs to the watershed.

Exchange of flow from and to Pismo and Arroyo Grande Creeks is not here considered in the flow calculations, nor is possible outflow through Carpenter Creek.

EFFECTS OF PROPOSED CREEK RESTORATION BETWEEN SOUTH CAMPGROUND AND GRAND AVENUE

There is almost no bed slope to the creek bed between Grand Avenue and the Park Maintenance Yard, and a permanent pond of standing water can be achieved along the channel with a small amount of dredging. The standing pond at the Maintenance Yard is a year round feature, and does not drop significantly in the summer, which suggests that any further deepening of the channel would not increase flood storage. However any dredging of bank sediments and plant biomass that is presently above the year round standing water level would increase the flood storage in the lagoon, but only by the volume represented between the present ground surface and the standing water level. This volume would not be significant.

The channel is densely vegetated (see figure III-5). Tule and willow removal will increase the efficiency of the channel, lowering its Manning Roughness Coefficient, and speeding the rate at which an infusion of flood water from the north end will be manifested by a water rise at the south end. This effect would be small, and would have very little effect on the performance of the channel and lagoon during time of flood.

EFFECTS OF PROPOSED MODIFICATIONS TO OCEANO LAGOON

The Oceano Community Services District has proposed opening up the floor of Oceano Lagoon in a manner similar to that applied to Pismo Lake. Preliminary plans and costing was prepared by Art Pearson of Cambria. They show existing conditions (figure III-6) and proposed modifications (figure III-7). The project plans include a deepened channel of 2,800 feet in length on either side of an island created in place of the present tule marsh. The channels will be trapezoidal in cross section, with 2:1 side slopes. Widths being considered are between 20-50 feet, resulting in a required excavation of between 8,809 and 28,571 cubic yards.

The effect on storage in the lagoon is dependent upon a number of factors. Additional storage is obtained only when material is removed from an elevation higher than the culverts into Arroyo Grande Creek, as an excavation below that elevation will simply increase the depth of the year-round pond, and not the storage volume above the surface of the pond. One of the channels will pass through a ridge of sand dunes that are presently as high as 19 feet above sea level, and much of the excavated volume will come from this location. Should the sediment from this dune be retained within the lagoon, and piled up between the proposed dredged channels, there may be a considerable reduction in the storage volume currently available over the present tules, although it would be more prudent to move the sediment onto the beach for tidal dispersal. The most inefficient dispersal of sediment in regards to flood storage could take all of the dredged material and apply it to a reduction of storage. This would amount to between 5.46 and 17.7 acre feet of storage loss. However such a disadvantageous sediment redistribution is unlikely to be achieved, as the beach could receive dredge spoils for later wave dispersal. It is possible that flood storage might even increase somewhat, but the record from Pismo Lake shows that storage was reduced by about 50% by the reclamation project. The volumes are small relative to the volume of a large flood, and thus modifications to the lagoon should have little effect on flood storage and levels.

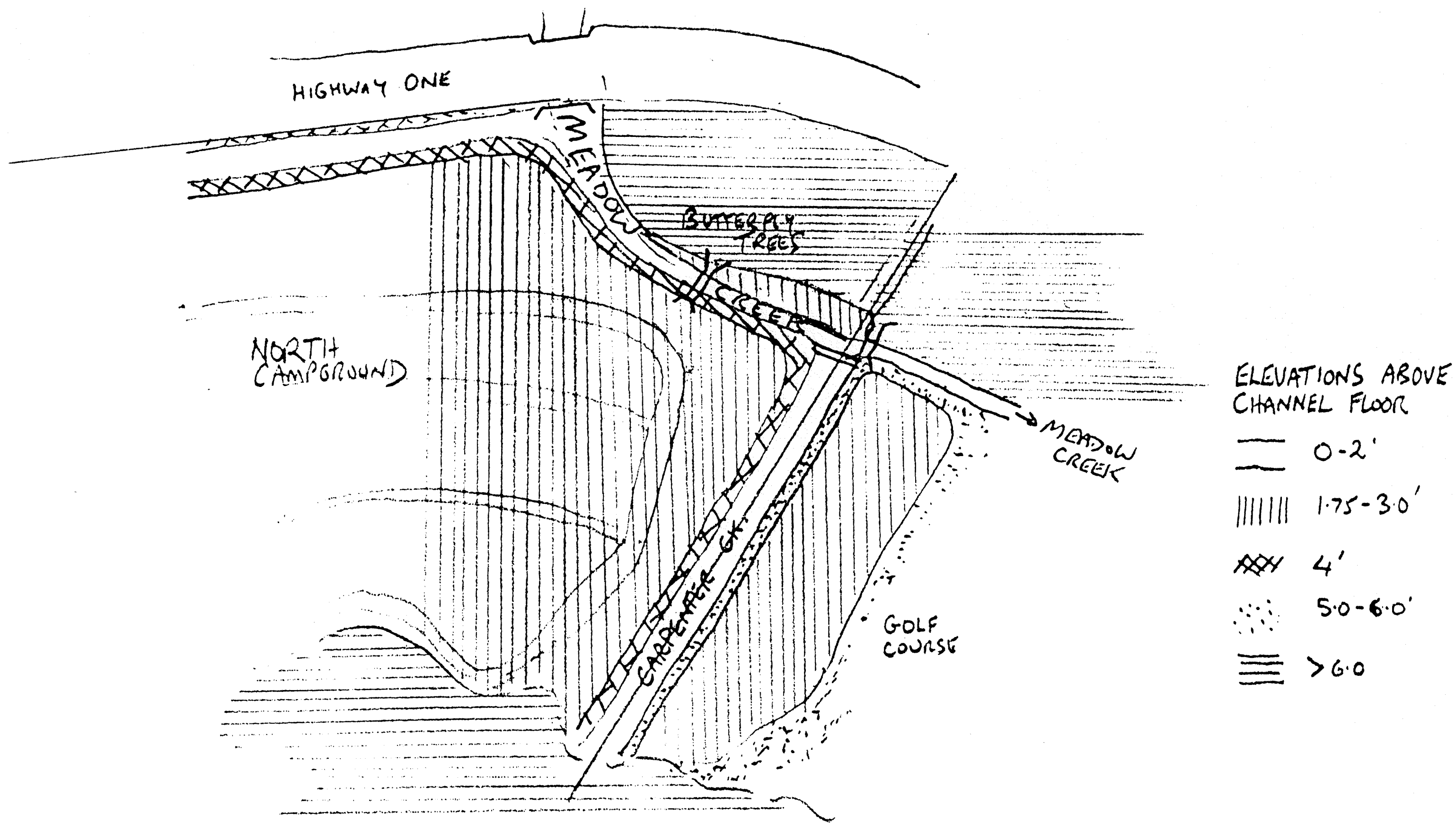


FIGURE III-1 Features of channel near North Campground

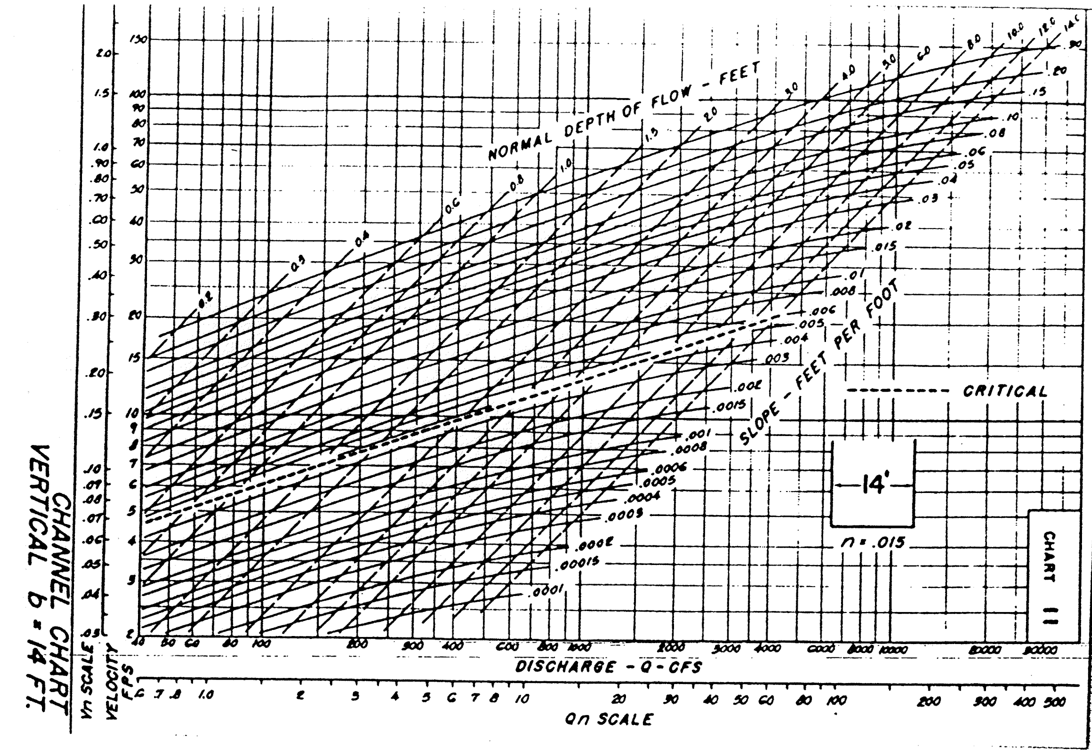
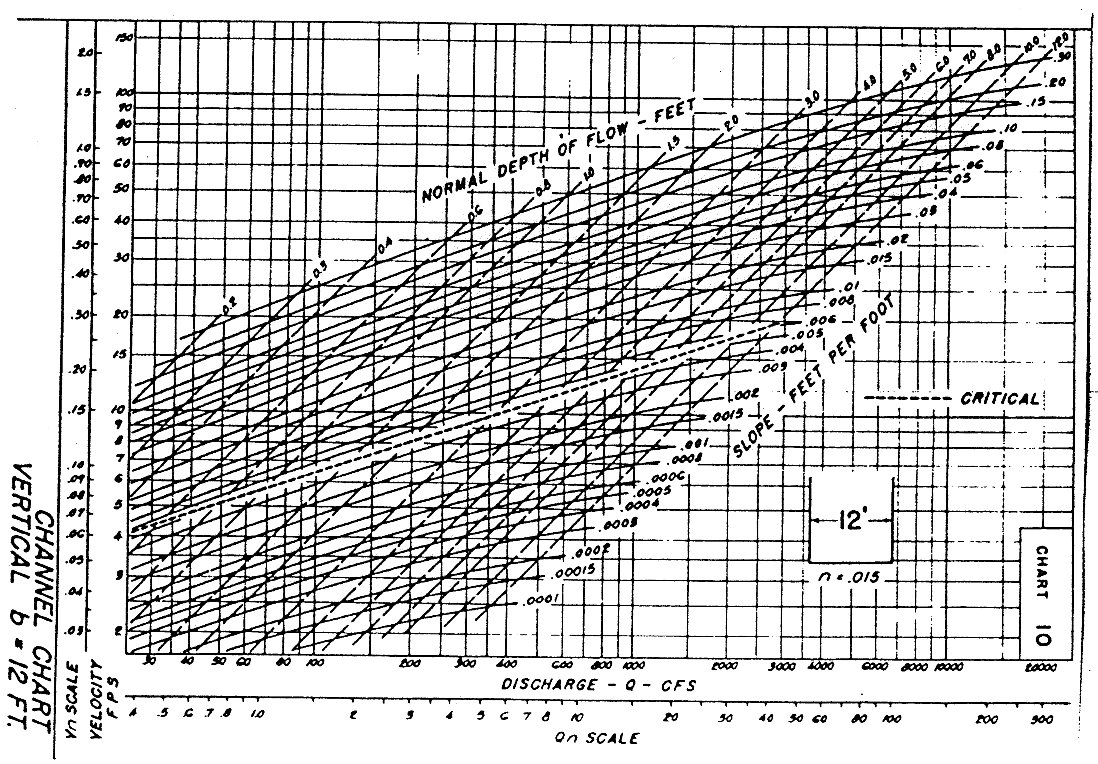


FIGURE III-2 Channel capacity charts, Cole et.al., 1969



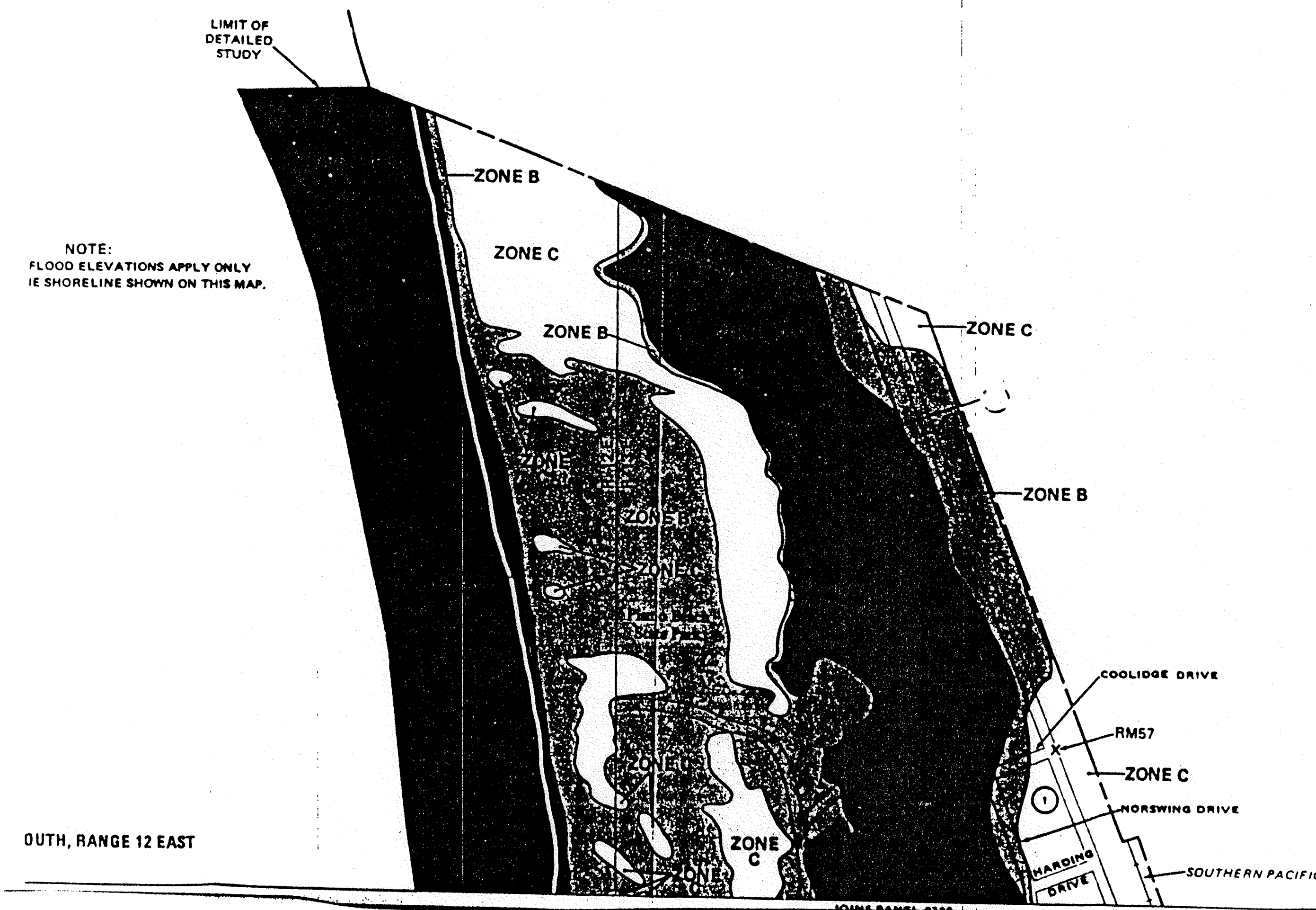


FIGURE III-3 FEMA Flood Map for the central portions of Meadow Creek, just below Grand Avenue

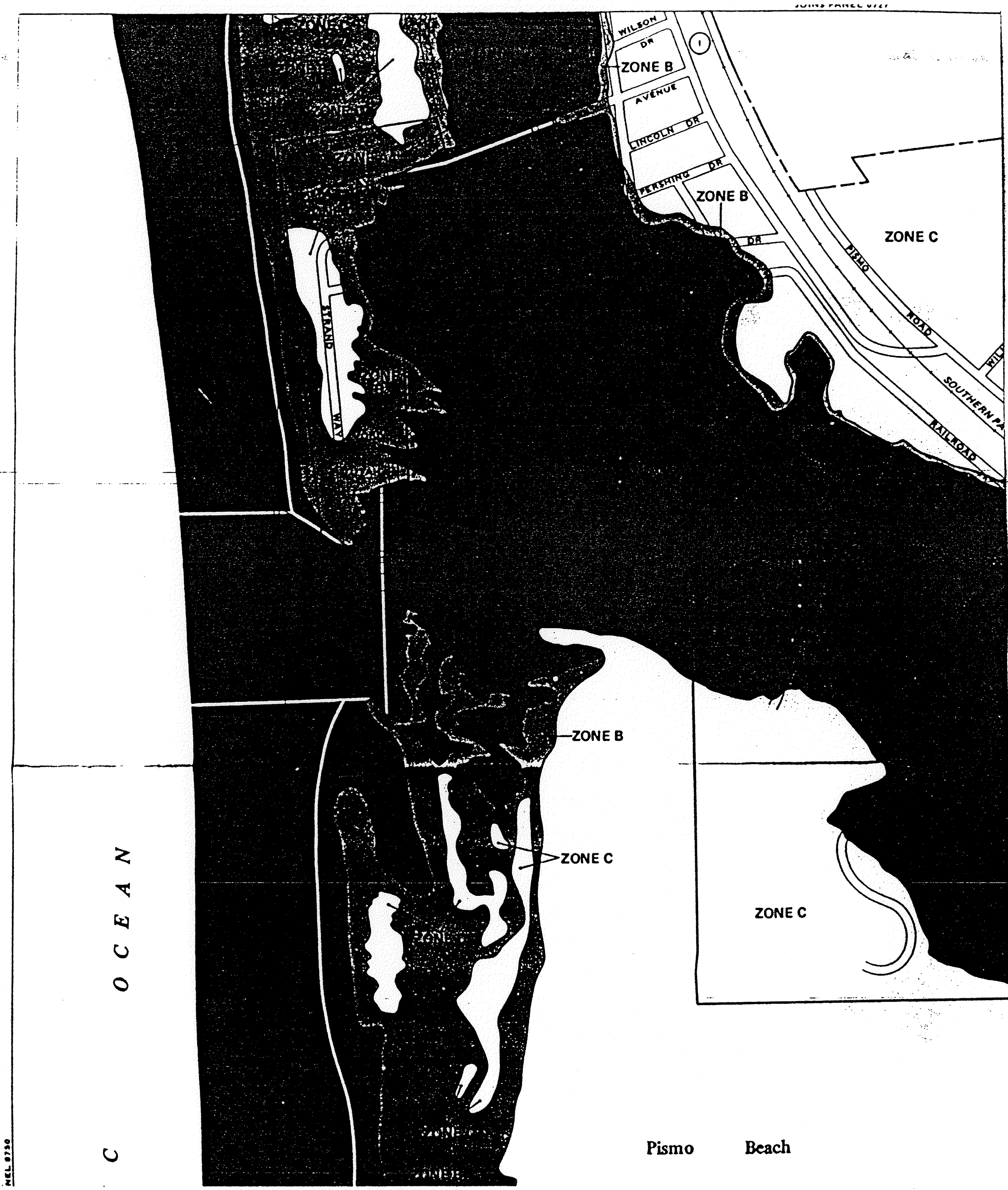


FIGURE III-4 FEMA Flood Map for the lower portions of Meadow Creek, around Oceano Lagoon

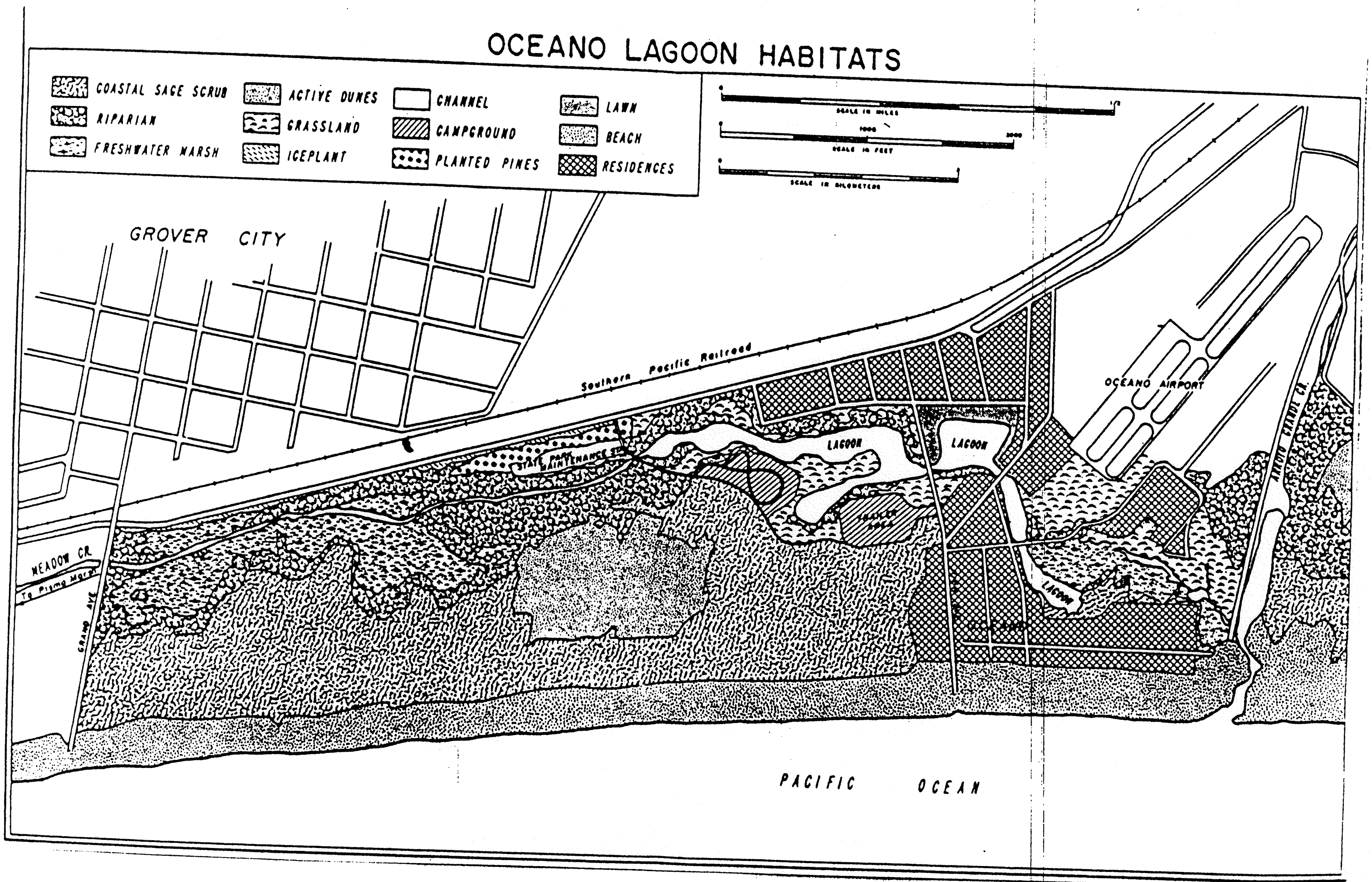


FIGURE III-5 Map of former vegetative distribution for creek below Grand Avenue, Cal. Dept. Fish and Game, 1976

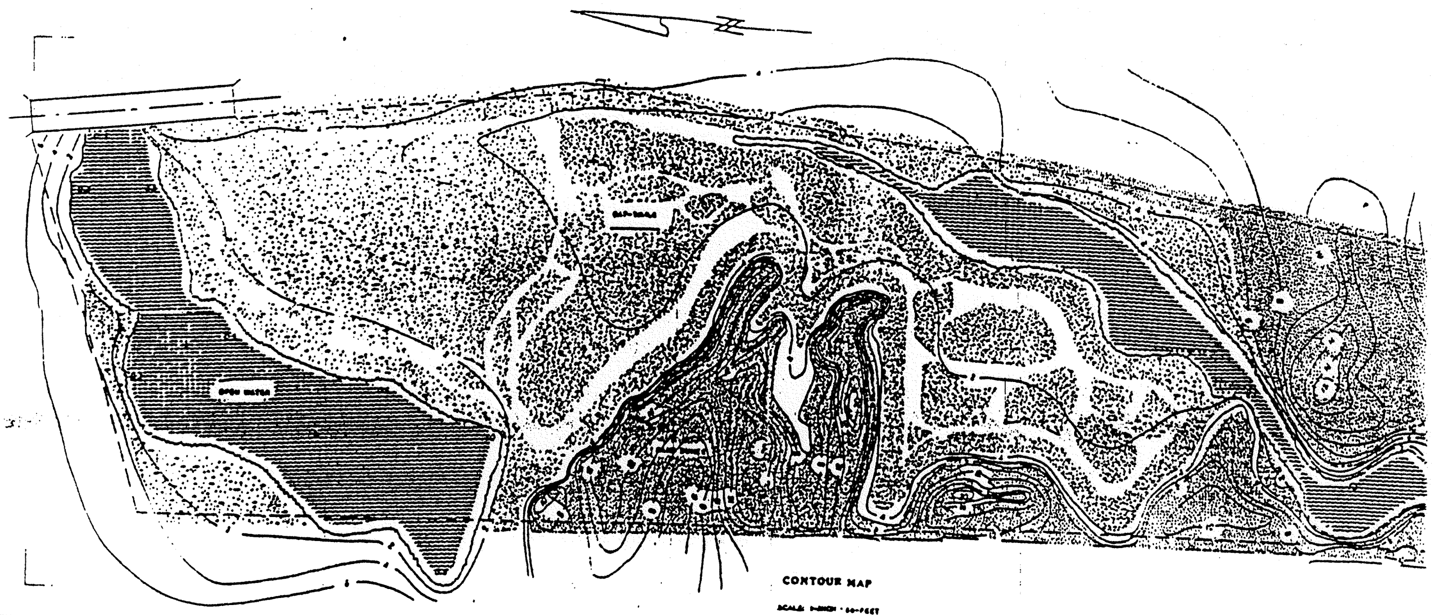


FIGURE III-6 Existing conditions at Oceano Lagoon
Map by Art Pearson for Oceano Community Services District

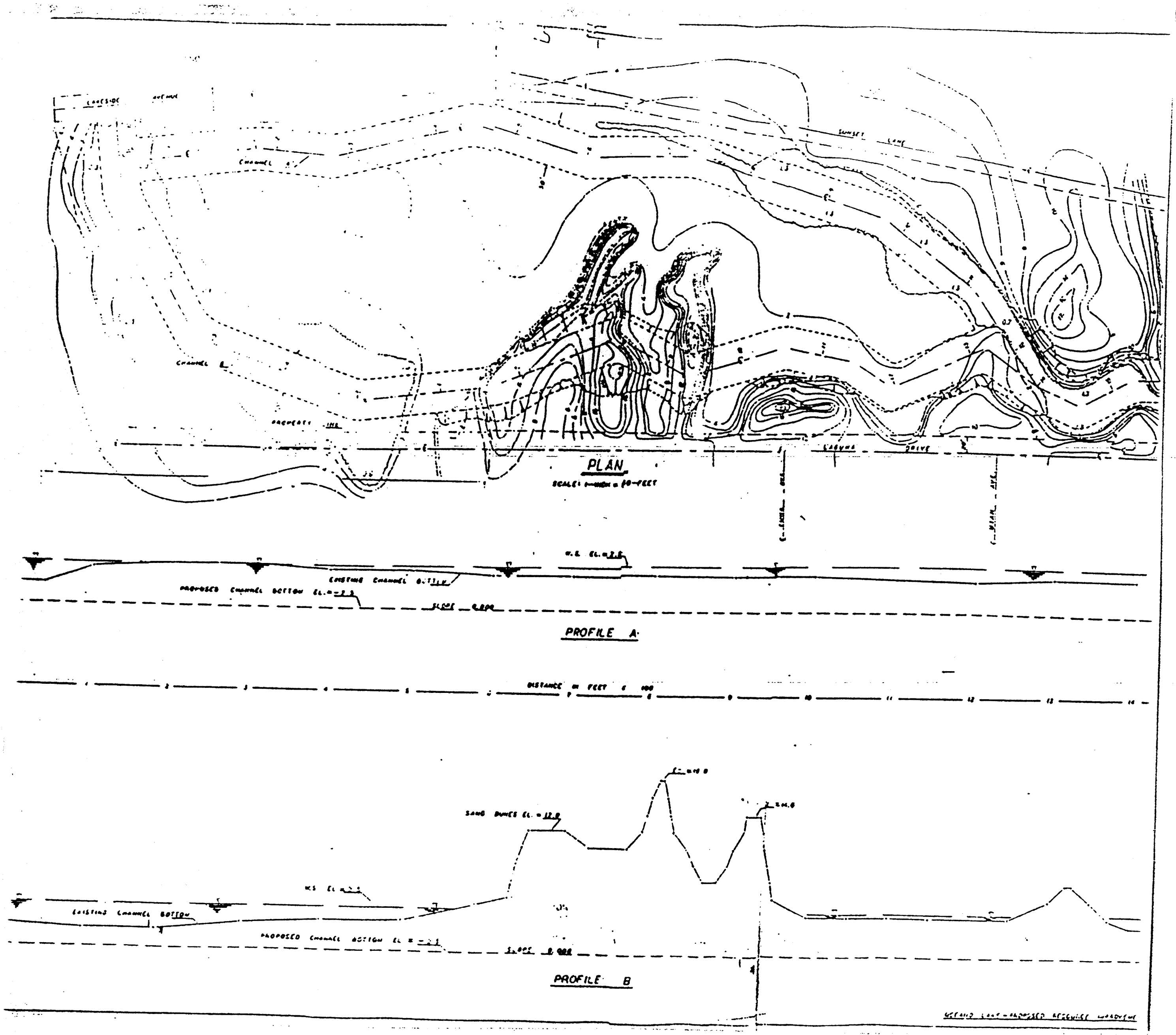


FIGURE III-7 Proposed modifications at Oceano Lagoon
Map by Art Pearson for Oceano Community Services District

IV - THE ROLE OF CARPENTER CREEK IN FLOOD CONTROL

Carpenter Creek lies at the south end of North Campground, along the boundary with the Golf Course. It lies at right angles to the channel of Meadow Creek, both channels being artificial. The Carpenter Creek channel may lie on some ancient channel through the dunes, but there is no evidence of this apart from the height of the dunes themselves. The Creek appears to have been created by man for drainage purposes in the 1940's, and should not be considered a natural system.

HISTORY OF CARPENTER CREEK

Carpenter Creek appears to have been closed off and covered by low dune sands throughout the first half of this century, as all plat maps show Meadow Creek and sometimes Pismo Creek, flowing southward along the rear of the dunes toward Arroyo Grande Creek. They do not show a creek located near the present Carpenter creek channel. It appears that a tile drain of large diameter was placed along the lineament sometime in the mid 1940's, according to the recollections of Mr. Guiton of Oceano. Mr. Guiton remembered a dredge operating in the area, presumably to develop better drainage for agriculture. Sometime during the period 1953-1956, Mr. Guiton was operating a bulldozer in the area of the creek, and uncovered a buried and partially blocked concrete drain. The drain, 6 ft. in diameter, was probably placed during the dredging operation, and when it was uncovered, the drain flowed. However the flow in the uncovered drain resulted in erosion, and the drain was lost, segment by segment from the seaward end, as the drain route became a channel.

In 1961 or 1962 there was a major storm, and sea water cut back along the line of the channel, and flowed for a short time down Meadow Creek toward the lagoon. There are still salt tolerant plants, including Jaumea, Salicornia, and Atriplex, in the channel that borders the south edge of the campground.

The channel remained in place, and during the floods of 1969 the creek carried the majority of flow from Meadow Creek. The head of water required for breakthrough was high, and water surrounded the real estate office by the Highway 1 bridge at Meadow Creek, and covered the North Campground and the areas presently occupied by mobile homes and trailers adjacent to Pismo Lake. At the same time water flowed across the banks of Pismo Creek, connecting with the Meadow Creek 'lake'.

During the 1950's the dunes in this vicinity were highly altered and graded. Large dunes were bulldozed eastward into the channel of the original creek, which lay through the central portion of the golf course. The area formerly resembled the tule marsh on the south side of Grand Avenue, and was filled to provide the present golf course surface. It appears from the difference in elevations on either side of the Grand Ave. bridge that the floodplain was raised about 6 ft. along the former course of the creek. On the basis of old maps, the original course of the creek through the golf course is marked by the present linear small lakes within the golf course. The effect of this grading was to much reduce the channel cross section and storage, and to encourage flooding upstream of the constriction.

THE PRESENT STATE OF CARPENTER CREEK

The present creek is not, in any sense of the word, a creek. The creek consists of a straight drainage ditch bordered by two artificial levees. The southern levee is higher than the northern levee, but neither is higher than 4.5 ft. above the surface of the North Campground. The channel contains some water in the winter, but as the bottom of the channel slopes away from the beach, the bottom of the channel is usually always dry at the seaward end. The main features of the creek are shown in figure IV-1.

The northern levee is continuous with the levee that borders the western edge of Meadow Creek around area of the 'Butterfly Trees'. The southern levee connects with a levee that flanks the eastern edge of the golf course. Due to the difference in height between the two levees, flooding of the campground would begin before flooding of the golf course.

The channel is blocked at its junction with Meadow Creek by a sluice gate, but it appears that the water level on each side is usually the same, due to leakage through the sluice and levees.

At the present time, if the sluice were to be opened, there would not be a significant flow along the creek. The seaward end is blocked by sand dunes that have blown into the old channel. They are still very much lower that the main line of dunes, but at least vertical 6 ft. of sand would have to be moved over many hundreds of feet of potential channel. During a flood, provided there was a head of water in the channel and North Campground, any flow across the dunes would quickly result in erosion and excavation of the dunes to the base level of the creek system. However, in its present state, serious flooding would have to take place before the dunes were eroded. Flooding would be minimized if the dunes had been pre-cut to below the flood stage of the creek.

DRAINAGE CONTROL IN THE CARPENTER CREEK AREA

The western edge of Meadow Creek is constrained by a levee that is 4 ft higher than the base of the channel, extending from the Highway 1 culvert to the junction with Carpenter Creek. Portions of the east side of the creek have a bank height of 2.5 ft. The levee on the west side joins a levee that flanks the north edge of the Carpenter Creek channel, and there is no break in the levee system. The levee is pierced at the Meadow-Carpenter Creek junction by a 16 inch diameter culvert, gated at the Meadow Creek side, and by an 8 inch pipe connected to a pump for draining the surface of the campground.

The Carpenter Creek channel is flanked on the south side by a levee raised to 7 ft above the base of the Meadow Creek channel. The levee joins the Meadow Creek levee, which continues to the south at a slightly lower elevation, dropping to a height of 5 ft. at the golf course fence. The levee on the south side of Carpenter Creek is bounded on its south side by a 200 ft wide swale, with a base at 3.5 ft above the level of the Meadow Creek channel. The swale is bordered on the south side by grading at the edge of the golf course, at an elevation of 7 ft or higher, except adjacent to the creek, where it blends into the Meadow Creek at a height of 5 ft at the Golf Course fence gate.

FLOODING SEQUENCE FOR THE MEADOW CREEK- CARPENTER CREEK JUNCTION

Water level 2 ft:

Flooding starts as the channel reaches a depth of 2.5 ft, flooding the wetland area east of the creek, bordering the 'Butterfly Trees'.

Water level 4 ft:

Inundation of portions of the North Campground develops as the water reaches a depth of 4 ft, spilling into the campground over the entire length of the levee, and also flooding into Carpenter Creek. Flooding of Carpenter Creek would begin at an earlier stage if the gated culvert between the creeks was open.

Water level 5 ft:

Water starts to flow into the swale south of Carpenter Creek, and to flow over the levees into the golf course. The bulk of the central golf course is inundated. Water depths increase in the campground, the flooded area extending to the north and inundating most of the campground

As water continues to rise, flooding increases at the golf course. The channel north of Grand Avenue begins to widen substantially toward the west. However the flow of flood water downstream across the golf course and the undeveloped land north of Grand Avenue would be minimal, and much of the flood peak would be held in storage north of the Golf Course.

As water continues to rise, some would begin to flow into Pismo Creek by breaking across the drainage divide near the entrance to North Campground. If Pismo Creek was also in flood, there might be return flow at, or before, this flood stage for Meadow Creek. However it is most likely that flood peaks would pass down Pismo Creek at a later time than they would pass through the Meadow Creek system.

Water level 7 ft:

The southern levee of Carpenter Creek is inundated, and, as a result, flow velocities across the golf course accelerate. Break out through the dunes to the ocean would still not be taking place, due to the present height of the dunes.

Water level approximately 10 ft:

This high level may not be achieved at Carpenter Creek, due to drainage into Pismo Creek and lower Meadow Creek, but it is clearly considered a possibility by FEMA flood mappers. Breakout through the dunes starts, quickly excavating a channel and dropping the level of flood water to that of the top of the Meadow Creek levees, at + 4 ft.

SUMMARY OF FLOOD SEQUENCE

As flood waters rise, the southern and then the northern portions of the North Campground are inundated, with the flood spreading at the same time throughout the recreational vehicle parks and covering Highway 1. Carpenter Creek receives water primarily from levee overspill, as water is not being specifically routed down the channel. As flood waters drop, water would have to be pumped out of the campground, a long procedure if only the existing 8 inch line is used. The higher levees and graded land between the North Campground and Grand Avenue act a low dam, restricting flow toward Oceano Lagoon until a flood depth of over 5 ft. is developed in the North Campground portion of the channel.

SUGGESTIONS FOR BETTER FLOOD CONTROL AT NORTH CAMPGROUND

OPEN CARPENTER CREEK AND GATE MEADOW CREEK

If Carpenter Creek is maintained as an open channel across the beach, water could be diverted along the channel before the 4 ft flood stage is reached in Meadow Creek. Provided that really large runoff events are preceded by somewhat normal creek flow, the latter could be diverted to the Carpenter channel and used to maintain the channel across the beach. This would require a diversionary gate across Meadow Creek, adjacent to the southern Carpenter Creek levee, possibly a 'leaky' gate to provide some throughflow to Oceano Lagoon. Such a self maintained channel would have to be closely watched, as the amount of channel erosion would depend on the tide stage during the period of peak flow, which in turn controls the local gradient, water velocity, and sediment capacity of the stream. It would be reasonable to presume that the channel would need periodic cleaning, earth moving, and realignment along its seaward end.

It is possible that the Carpenter Creek channel could be replaced by a large diameter culvert, which would eliminate erosion risk but would make sediment more difficult to remove. The seaward end of a culvert would be subjected to undermining, and leakage could produce cavitation under the line. I would suggest that engineering costs would be too high, and that a periodic grading with a heavy tractor would be more economical.

The flood gate could be constructed to a height of 7 ft, equal to that of the southern levee of Carpenter Creek. The gate could be used to 'sweep' high floods toward the sea, along Carpenter Creek, and to prevent flooding to the south. If coupled with an open Carpenter Creek channel, the flood would be diverted to the sea with much greater efficiency than a routing via the Oceano Lagoon and the culverts into Arroyo Grande Creek.

The diversion system would increase flood risk in the North Campground and recreation vehicle areas if the Carpenter channel was not open to the sea. A closed gate on Meadow Creek, and a blocked Carpenter Creek, would pond water to 7 ft, until water could escape to the south and into the southern portion of Meadow Creek, or into Pismo Creek along the edge of Highway 1.

Completely impermeable gating of Meadow Creek is not recommended, as sufficient water should be bypassed to maintain healthy riperian conditions downstream.

Raising the southern levee of Carpenter Creek would also inhibit flood waters from flowing southward across the golf course, and would limit flow to flood waters in the channel, protecting the downstream area to some extent even if Meadow Creek was not gated.

RAISE NORTH CAMPGROUND LEVEES

Raising the levees would allow a greater volume of flood water to be bypassed along the Meadow Creek channel. However the existing 4 ft flood stage results in simultaneous inundation of the surface of Highway 1, and higher flood stages will produce a serious flood damage in the surrounding area. There would also seem to be little advantage in providing for camping under such chaotic conditions. Higher levees also would store a greater pond, should flooding take place, and would require a longer period of pumping to drain the area after the flood had passed.

The raising of just the south levee of Carpenter Creek has been discussed above.

IMPACTS OF FLOOD CONTROL AT CARPENTER CREEK ON LOWER MEADOW CREEK

The present configuration of channels and levees results in flood storage and partial retention in the area of the North Campground, requiring about 5-6 feet of water to develop before significant flooding starts just above Grand Avenue. The area of channel below Grand Avenue is much larger, as the original riperian zone has not been filled, and therefore flood peaks will be less severe. It is significant that, when flooding was closing Highway 1 at the Meadow Creek Bridge in 1969, the highway below Grand Avenue was still open, in spite of the low elevations just south of the Grand Avenue intersection. However, although flood peaks below Grand Avenue might be considerably reduced by the present land configuration, the ultimate standing level of the water in the Oceano Lagoon and South Campground will slowly increase in a balance between outflow an inflow to the lagoon. Weeks of rain might have brought up the pre-flood peak pond in the lagoon, so that even a small rainfall event could precipitate flooding around the South Campground.

If flow into lower Meadow Creek is substantially diverted to Carpenter Creek, the level of water in the Oceano Lagoon could be better controlled, and it would be possible in the extreme case to limit flow to the Lagoon to just the urban runoff from Grover City. This might have the further advantage of protecting the Oceano Sewerage Treatment Plant from flooding, and for protecting homes and businesses currently within the 100-yr. floodplain.

SEAWATER INTRUSION AT CARPENTER CREEK

The opening of Carpenter Creek increases the risk of seawater entering the Meadow Creek channel. Major storm cycles on the Central Coast may be associated with very high tides, due to storm surge. In 1969 the beach between Pismo and Carpenter Creeks was severely eroded, the Telegram Tribune reporting the loss of 300 ft. of beach frontage from the Pismo Coast Village area (San Luis Obispo Telegram Tribune, Jan. 22, 1969). Seawater surged into Meadow Creek through the flood excavated Carpenter Creek.

I have found only one event when this took place, but it has possibly been a common event during the last millenia. Salicornia, a salt loving plant, is common in the lower elevations of the North Campground and in the Carpenter Creek channel, where is it associated with salt-loving Atriplex and Jaumea. These plants grow in saltmarsh, suggesting that the soil salinity is high. The plants south of Grand Avenue appear to be normal, freshwater marsh vegetation, and therefore it must be presumed that the sea water intrusion had little effect south of Carpenter Creek. The presence of Salicornia in this area may not be conclusive proof of sea water intrusion, as there is a patch of Salicornia near 4th Street, above Pismo Lake. It is possible that the Salicornia is a relic of a tidal estuary from before the 1870's, as it is known that during the last half of the last century Pismo Creek passed through the Pismo

Lake area to the Oceano Lagoon, placing the 4th street area at a great distance from the ocean.

Seawater intrusion in large volumes might have a temporary effect on vegetation and wildlife, but would be most likely during a time of high discharge through Carpenter Creek, tending to flush out the salts. If the entrance to southern Meadow Creek is gated, little seawater would reach the riperian corridor south of Grand Avenue.

It is extremely unlikely that a permanent inlet would develop along Carpenter Creek, as the amount of sand available to reform the beach and dunes is very large, and the eroded sand would find its way back during the following summer season.

IMPACTS OF DUNE RESTORATION AT CARPENTER CREEK

FLOOD CONTROL

The flood control afforded by Carpenter Creek is described elsewhere. Dune restoration at Carpenter Creek would have the presumed goal of increasing the size of the dunes to those of the flanking area. Under these conditions the dunes would not be overtopped by flood waters from Meadow Creek, and flooding of the North Campground area would develop to a stage where water could either drain southward toward Ocean Lagoon, or northward to Pismo Creek. This condition essentially exists at this time, as dune height is sufficient to prevent overtopping without help from heavy equipment in opening the Carpenter Creek channel. Thus the dune restoration would not cause the present flood risk to increase substantially. However, the present low dunes can be opened with ease, and a restored dune complex would remain as a permanent fixture.

An open Carpenter channel also provided for flood relief for Oceano Lagoon and the lower Meadow Creek channel, and a restored dune removes that protection.

PRESERVATION OF THE DUNE ENVIRONMENT

A result of closing Carpenter Creek and encouraging dune growth would be the increase in dune habitat and ecosystems. The present 'mouth' of Carpenter Creek is a sandy valley blocked by transverse sand waves that are actively migrating inland between the more stable and higher dunes on the flanks of the valley. There is presently a high wind shear between the flanking high dunes, and therefore the establishment of vegetation by natural process will be difficult, and a parabolic dune will probably develop that will advance toward the campground, and possibly become a nuisance. In addition, if the dunes remain low, they will still be a major foot traffic corridor between the campground - butterfly tree area and the beach.

The dune forms could only be restored in a relatively short time frame by bringing in sand and building the dunes to the point where wind shear is no greater than in the surrounding areas. Revegetation will be difficult and slow, and may require the establishment of brush barriers and other devices to slow saltating and rolling sand grains. The difficulty of letting native vegetation stabilize the dunes is that most of the plants dominant in nearby foredune and active dune stabilization are aliens, such as sea rocket, fig, and dune grass, and that they might colonize at a faster rate than the natives can establish themselves, especially if the public is allowed access to the dunes. Thus it is possible that the dunes could only be established with difficulty as a native - vegetation habitat. The dunes to the south are completely overrun with ice plant, while those to the north are covered by non-native trees. However, as the dune forms exist in these areas, they would be more likely candidates for the restoration dollar.

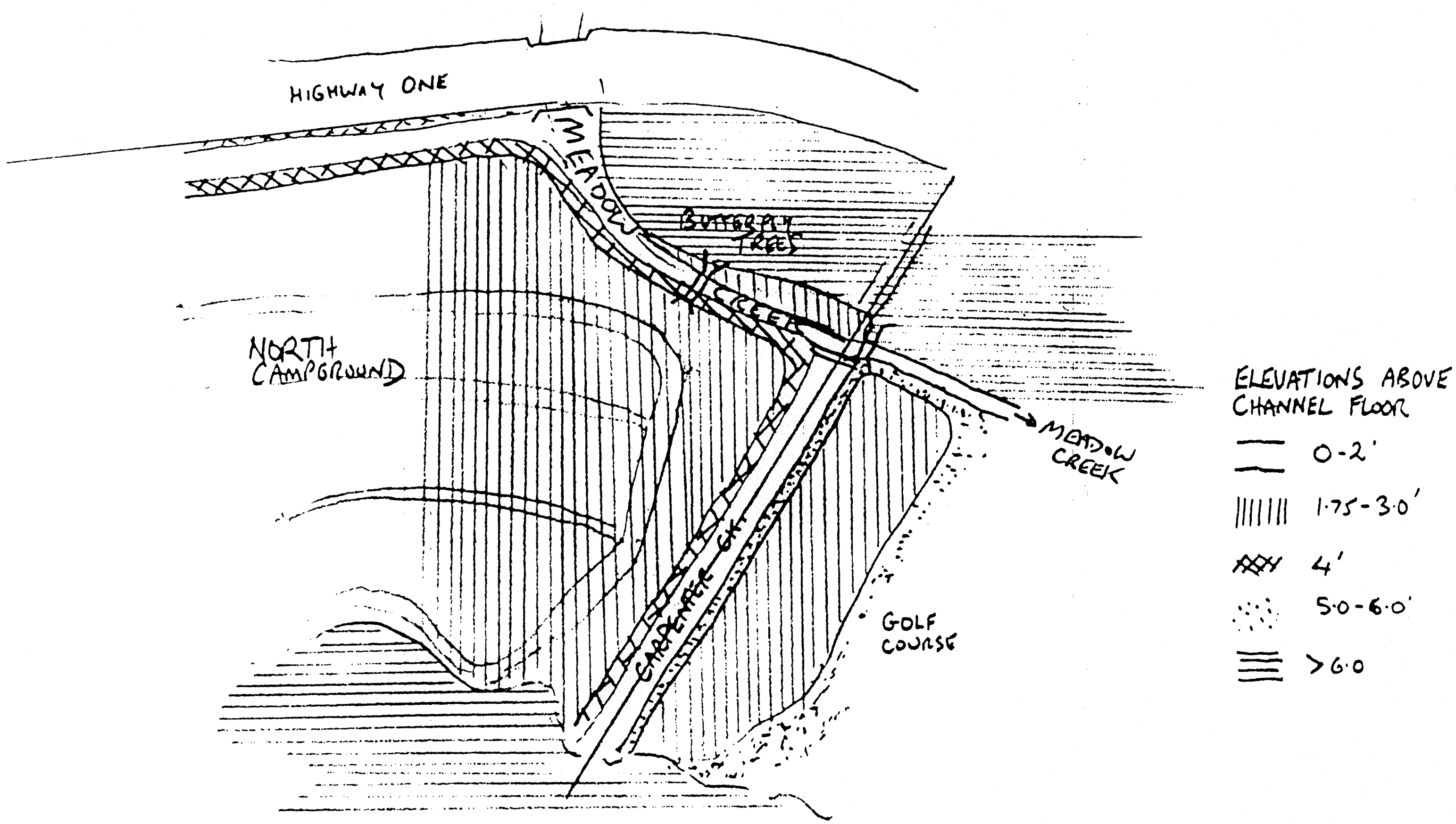


FIGURE IV-1 Features of channel near North Campground

V - SEDIMENTATION AND EROSION

EXISTING AND PAST CONDITIONS

The Meadow Creek watershed has been subjected to increased erosion due to land use changes in the upper parts of the watershed. In 1979 the Regional Water Quality Control Board proposed that erosion control measures be implemented in the watershed, stating hat over 2,000 acres of the 3,735 acres draining into Pismo Lake were 'highly erosive, sandy soil' (Telegram Tribune, Sept. 12, 1979). The problem was later addressed to members of the County Board of Supervisors by soil scientist Clark Moore in 1985 (Telegram Tribune, May 11, 1985, p.1C), and has been considered a significant risk to the Pismo Marsh area by the Department of Fish and Game. However many of these problems have been mitigated through installation of stilling and retention basins. Any sediment reaching the creek below the freeway will probably result in aggradation of the bed and increased flood risk above 4th Street, in Grover City. In a 100-year storm, sediment stored in the channel will be flushed into Pismo Lake, and will significantly lessen the storage capacity, but not much affect the flood retention capacity of the lake. Flood retention capacity is reduced only when portions of the bed aggrade above the level of the spillway elevation for the lake.

It is expected that nearly all of the bed load will be trapped in, or above, Pismo Lake. Sediment escaping the lake will generally be fine, suspended load, materials of fine silt or clay size. It was noted that the fines-content of the water was high, even during the low winter discharges of the 1988/9 season, and this sediment will be carried into the Meadow Creek channel below the railroad and Highway 1.

The floor of the Meadow Creek channel contains only dark, organic rich muds, and these can be expected to slowly increase in thickness as silts settle from the water. Some erosion of these bed deposits may occur at sites of flow concentration during a flood, such as the entrance to Carpenter Creek and the area immediately downstream of a culvert flowing under a pressure head. Flood induced erosion is not likely to be severe in the channel, but during a flood there may be local severe erosion of levees as waters spill out onto the flood plain.

Flood waters ponded behind levees can be expected to drop most of their suspended load, and thus flooding will deposit a thin veneer of mud over all flooded areas.

Significant amount of sand might be dumped into the creek channel below Grand Avenue, as street runoff throughout much of Grover City will reach the channel. Water will be flowing fast on the relatively steep slopes flanking the creek, and will be eroding sand from street margins throughout the ancient sand dunes of Grover City.

Sediment samples from the marsh below Grand Avenue indicate that the floor of the lagoon is building up with dominantly organic debris from the riperian plant community, mixed with silts and clays. Samples taken against the dunes on the west side of the marsh were sandier, due primarily to blown sand. However the sediments indicate that bedload transportation along the main channel is dominated by finer sediments, and that channel flow velocities are generally low.

There is some evidence of coarser sediment in the North Campground-Carpenter Creek area. Gravels were brought up by the dredging that created the Carpenter Creek levees, and there are some scattered pebbles over the entire area. The pebbles are dominated by Monterey Formation diatomaceous shales and cherts, and would appear to be from the Pismo Creek drainage rather than from the Meadow Creek channel. It is presumed that they are flood deposits from Pismo Creek that date from the last century, when Pismo Creek flowed southward to Oceano Lagoon.

EFFECTS OF PROPOSED PROJECTS ON SEDIMENTATION-EROSION

Open Carpenter Creek:

If Carpenter Creek is open during a sustained flood, severe erosion of the beach will result, especially at low tide. The beach sand will be cut to at least the present elevation of the North Campground, and back cutting of the channel could result in a severe erosion risk at the gap in the dunes and in the bed of the present channel. It should be noted that, in 1969, the excavation was deep enough to allow the ocean to flow into the Meadow Creek drainage at highest tide. The problem would be especially severe during a time when the beach sands had been removed by severe longshore drift of the beach sand.

Some of the erosion problems at the campground could be mitigated with suitable channel linings, although the width of the eroding area is likely to be much wider than the dredged channel.

Close Carpenter Creek:

Conditions would remain much as they are today. Sedimentation in the floodplain would increase from the fines in the water moving southward, relative to that which would be experienced if the water flowed sea ward at Carpenter Creek.

Dredge the marsh below Grand Avenue:

Dredging the marsh will have little effect on sedimentation, but may result in sediment being moved somewhat further to the south due to slightly increased velocities in the cleared marsh. This might slightly increase the sediment infill rate of the Oceano Lagoon.

VI. HISTORIC DOCUMENTS PERTINENT TO PISMO-MEADOW CREEK, AND ADDITIONAL REFERENCES

About 1837: Map Espediente 513

Shows Arroyo Grande Creek, and land south and east of the creek. This is a very crude sketch, notations in Spanish, developed for purposes of illustrating bounds of grant. There is no clear indication of conditions at Oceano Lagoon.

1837: Diseno or Picture Map filed by Frances Branch for request of Land grant from Mexico for the Rancho Santa Manuela: Described in Echoes, by Jean Hubbard, Five Cities Times-Press Recorder, Arroyo Grande, Calif., Wed, July 27, 1988, p.8D.

Shows Pismo Creek joining Arroyo Grande creek.

1873 Map of Parts of the Ranchos, Corral de Piedra- Pismo- Bolsa de Chamisal, San Luis Obispo County, California, subdivided by Jas. T. Stratton

Shows Arroyo Grande creek entering the eastern end of Oceano Lagoon, at which point it is shown joining a stream from the north, presumably Pismo Creek.
Copy on file in Special Collections Room, California Polytechnic State Univ. Library, San Luis Obispo

1874 Filed September. Map of San Luis Obispo County. California, surveyed by R.R. Harris

Shows Pismo creek extending behind dunes to Oceano Lagoon. Copies of map on file with County Assessors Office, San Luis Obipso County, and with Special Collections, Cal. Poly. State Univ. Library, San Luis Obispo, California.

1880 filed April 1880, Plat of Part of the Ranchos El Pismo and San Miguelito, San Luis Obispo Co. Cal., owned by J.M. Price, subdivided by H.C.Ward.

Pismo Creek is shown connecting with Oceano Lagoon, which is also connected to Arroyo Grande Creek. Oceano Lagoon and Pismo Lake are shown to be extensive, with Pismo Lake extending to the vicinity of Oak Park Boulevard.

1886 filed April 30, Map of the Subdivisions of a Part of the Ranchos El Pismo and San Miguelito, San Luis Obispo Co., California: R.R.Harris.

Pismo Creek is shown heading to the north end of Pismo Lake, although the junction is covered by notations. Pismo Lake is shown extending well back beyond its present esatern limits, and is shown as a lake.

This map has an inset Plan of the Town of El Pismo, which shows two coastal lagoons flanking the north and south edges of the odd shaped parcel at the western end of Main and Pismo Streets.

1887 Map of the Town of El Pizmo, the New Seaside Resort in San Luis Obispo County, California

This is a colored map prepared for promotional purposes. Two coastal lagoons are clearly shown in the vicinity of the western ends of Main and Pismo Streets. Map is on file in Special Collections, Cal. Poly. State Univ. Library, San Luis Obispo, Ca.

1887 filed June 11, Map of the Town of El Pizmo: Book A, Page 156, San Luis Obispo County Book of Maps, County Assessor's Office.

There is a suggestion that lakes still exist in the vicinity of the western end of Pismo and Main, based on the shape of the subdivided map boundaries.

1887 Map of the Town of Grover, San Luis Obispo County: Book A, Page 6, San Luis Obispo County Book of Maps, County Assessor's Office.

Shows a channel for Meadow Creek well to the west of the present channel and the vicinity of Longbranch Ave., Grover City.

1887 Map of the Grover and Gates Tract, El Pismo Rancho, San Luis Obispo County: Book A, Page 114, San Luis Obispo County Book of Maps, County Assessor's Office.

Shows a channel for Meadow Creek well to the west of the present channel and the vicinity of Longbranch Ave., Grover City.

1888 filed May 19, Map of the Pismo Avenue Addition to the Town of El Pismo, surveyed by R.F.Parsons.

Shows a subdivision on the north side of Pismo Avenue, which runs from the western termination of Pismo Street to connect first with the west end of Main Street, and then to the beach. This could indicate that the southern of the two lagoons had been filled to provide land for this subdivision.

1893 Map of Subdivision No.2, Ocean Beach, San Luis Obispo County: Book A, Page 150, San Luis Obispo County Book of Maps, County Assessor's Office.

Shows Oceano Lake with Gray, Surf, York, and Brook streets as today, the lake much altered, and Brook Ave. acting as a creek channel joining the lake to the sea. Brook is presently parallel to, and just north of, the Arroyo grande creek channel outlet.

1893 Map of the Town of Oceano and Adjoining Subdivision: Book A, Page 147, San Luis Obispo County Book of Maps, County Assessor's Office.

Shows a complex of creeks and channels at the junction of Arroyo Grande Creek and Oceano Lake. North end of Oceano Lake not shown.

1894 Pismo Beach and Vicinity from the Official Map of the Southern Pacific Railroad Company , December 15

This map clearly shows Arroyo Grande Creek enering the Oceano Lagoon at its southern end, and a narrow lake is drawn all the way up to Grand Ave. and into the North Campground. Pismo Creek is called Villa Creek, and is shown joining the lake at the northern end of what is now the North campground. No flow of Pismo Creek into Pismo Lake is shown, and the present channel of Meadow Creek is shown, but the creek joins the lake just north of the present Carpenter Creek.

1899 January 30 Map No.2 of the Town of Oceano, San Luis Obispo County, California.

This is an apparently promotional map which shows Arroyo Grande Creek flowing into Oceano Lagoon, but no other creeks entering the "Lake Oceano". The map, which bears realtors notations, is on file with Special Collections, Cal. Poly. State Univ. Library, San Luis Obispo, California.

1902 Map of Grand Beach, California, San Luis Obispo County, California: Book A, Page 7, San Luis Obispo County Book of Maps, County Assessor's Office.

Shows an older channel seen on earlier maps, and a new channel close to the present channel for Meadow creek south of Pismo Lake to south of Grand Avenue.

1902-1903 Map of the Town of El Pizmo: Book A, Page 155, San Luis Obispo County Book of Maps, County Assessor's Office.

No indication of any lakes west of Pismo and Main.

1904 Fairbanks, H.W., Description of the San Luis Quadrangle, California: U.S. Geological Survey Geologic Atlas, San Luis Folio 101

This is the first detailed geologic map of the area. It shows Pismo Creek passing through a series of channel to the west of Pismo Lake, with a minor connection to the lake. The area of Pismo-Meadow creek south of Grand Avenue is mapped as open wide channel, rather than the line of a creek, and opens to the south into Oceano Lagoon, which is fed from the south by Arroyo Grande creek.

1905 March 15, Morning Tribune: Describes loss of old wharf, Post

Office, Cafe Royale after exceptionally high tide and high wave and wind conditions. No mention of breakout of creek, per se.

1905 March 18, Morning Tribune: Describes damage in the previous week to Dockery Town area of Pismo Beach, and the loss of coastal buildings to high coastal erosion. No mention of breakout of creek, per se.

1905 Map of Subdivision No.1, Ocean Beach, San Luis Obispo County: Book A, Page 149, San Luis Obispo County Book of Maps, County Assessor's Office.

Shows Oceano Lake, the lake much altered, and Brook Ave. acting as a creek channel joining the lake to the sea. Brook is presently parallel to, and just north of, the Arroyo grande creek channel outlet.

1906 Map of the Ocean View Terrace Subdivision #1: Book 1, Page 1, San Luis Obispo County Book of Maps, County Assessor's Office.

Shows "Pismo Creek" crossing "Pier Avenue Blvd.", presently Air Park Drive.

1906 Map of the Ocean View Terrace Subdivision #2: Book 1, Page 9, San Luis Obispo County Book of Maps, County Assessor's Office.

Shows "Pismo Creek" entering "Oceano Lake". Also indicates a complex knot of channels joining Pismo Creek to the north of the lake.

1906 Map of the Kruckman's Addition to the Town of Pismo, San Luis Obispo Cty., Cal.

Shows Pismo Creek running parallel to Ocean and Peerless (?Park Ave.), and bending to the southwest at Cypress St.

1909 January 21, Morning Tribune: 300 ft. of track at Oceano washed out, probably along Arroyo Grande creek (location not identified)

1909 January 22, Morning Tribune: Describes Oceano as being inundated by flood, with 5 ft. of water at Wheeler's Store and a 400 ft. washout of the S.P. tracks.

1909 January 26, Morning Tribune: Describes the fall of 4.35 inches of rain in 15 hrs on top of 19.53 inches for the season. States that water cuts through Dockery Town and wshes away three Harvey Houses. This appears to be destruction of the southern fringe of Pismo Beach by Pismo Creek.

1911 Emma Boxfold photographs of 'Villa Creek' flood of 1911. Explanation on photocopies of photographs at County Historical Society Museum states that:

"This creek followed the present Highway 1 into Oceano Creek along the side of the sand hills. After days and days of constant rain Pismo Creek backed up little by little into the southern portion of Pismo (Dockery Town). In order to stop this Hans Skov and Temple Boxold opened up an outlet in the sand hills with a spade and the pictures show the result."

The pictures show that houses (or more properly, shacks) in Dockery Town were undercut and fell into the channel.

1913 B.R. Wood, Gazatteer of Surface Waters of California, Part III. Pacific Coast and Great Basin Streams, U.S. Geological Survey Water Supply Paper 297.

p.259 describes Pismo Creek as "flows southwestward to Pismo, then east of south through a tidal marsh to the Pacific"

1914 February 2, The Morning Tribune: Describes accretion of sediment on the Arroyo Grande flood plain following a major flood. Alluvial flats were raised from an initial elevation of 8-12 ft. below the railroad grade to 1-3 ft. below the grade on the east side of the S.P. tracks, and were raised from 8 ft. below grade to 2-4 ft. below grade on the west side of the tracks.

1914 February 11, The Morning Tribune: Describes a Mr. Mahu draining a Mudhen Lake swamp in the Arroyo Grande area. Probably not pertinent.

1914 March 6-8, The Morning Tribune: Description of major flood damage on the Arroyo grande floodplain.

1927 February 17, The Herald Recorder, Vol.XXII, No.42, p.1: "Heaviest Storm in Many Years"

"The Arroyo Grande creek at Oceano assumed flood proportions Wednesday morning and about 10 a.m. the banks began to give way before the rush of the water, and by noon it had covered the lowlands south of the Routsahn steel bridge and was rushing down toward Lakeside Park, following the low places. Late in the afternoon the home of W.C. Hart on the Lakeside Park road was threatened, the water flooding the yard."

This suggests flooding in the vicinity of the present Oceano Airport and Oceano Lagoon caused by Arroyo Grande Creek levee failure and spillage northward of the creek.

1970's -1980's When Mother Nature wept, her tears moved land: Described in Echoes, by Jean Hubbard, Five Cities Times-Press Recorder, Arroyo Grande, Calif.

Mentions a flood in 1905 when: "Pismo Beach took the brunt of the storm that year and the old Cafe Royale, a tavern and dancehall, and 100 feet of the wharf were lost. Pismo creek previously had meandered to a merger with Arroyo Grande creek and drained into the ocean near Oceano. Now it cut across the sand dunes and reopened an old channel to the sea."

She describes in 1909: " It was said that Pismo creek that year "ran as wide as the Mississippi river and four cottages and two barns were washed out to sea".

1984 Floodway. Flood boundary and floodway map, City of Pismo Beach, Community Panel Number 060309 0002, August 1, 1984, Federal Emergency Management Agency.

This map shows that floodwaters for the 100-yr flood will cover all of the North Campground and the area between the dunes on the west side of the campground and the railroad tracks, submerging the travel trailer parks on the east side of Highway One. In addition, flood waters from Meadow and Pismo Creeks intermingle.

1985 Floodway. Insurance Rate Map, San Luis Obispo County, California, Panel 727 of 975, Community Panel Number 060304 0727C, Federal Emergency Management Agency.

Map shows 100-year flood inundation for Pismo Beach South Campground area, from southern limit of the City of Grover City to the area of Harding Avenue, Oceano.

1985 Floodway. Insurance Rate Map, San Luis Obispo County, California, Panel 729 of 975, Community Panel Number 060304 0729C, Federal Emergency Management Agency.

Map shows inundation levels for Oceano Lagoon and South Campground area, and includes Oceano Airport. Shows that Arroyo Grande Creek levees could be inundated.

ADDITIONAL REFERENCES USED IN DOCUMENT PREPARATION

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Cal.Poly. State University Rainfall Records, on file Special Collections Room, Kennedy Library, Cal Poly Campus, San Luis Obispo

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Cole, I.R., W.A. Gelonek, Huston, J.W., and Naydo W.R., 1969, Street and Highway Drainage, Volumes 1 and 2, Course Notes: University of California Institute of Transportation and Traffic Engineering

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Grover City, California, 1981, City of Grover City Local Coastal Plan

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Oceano Resource Conservation District, 1989, Proposals to dredge and modify Oceano Lagoon, unpublished

San Luis Obispo County Engineering Department Hydraulic Engineering Guidebook D, 1975