SHALLOW-WATER DIVING ACCIDENTS

AT SOUTHERN CALIFORNIA OCEAN BEACHES

Demographic, Sedimentologic,

Medical, Legal and Management Perspectives

Robert H. Osborne, Editor

USC SEA GRANT
University of Southern California

SHALLOW-WATER DIVING ACCIDENTS AT SOUTHERN CALIFORNIA OCEAN BEACHES:

Demographic, Sedimentologic, Medical, Legal

and Management Perspectives

Edited by

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INTRODUCTION

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Each year, there are numerous diving accidents of various types at the ocean beaches of southern California. These accidents sometimes leave the diver seriously injured and may have catastrophic consequences for the victim's life. Beach administrative organizations have humanitarian, financial and legal interests in assuring the safety of resident and visiting beach users, and therefore have an interest in supporting efforts to reduce the frequency of such accidents.

Among these diving accidents, there is a general category referred to as "plunging-dive" accidents, which involve swimmers who run or jog into shallow water and dive toward the base of an oncoming wave. At some point along the dive trajectory, the victim's head strikes either the gently-sloping sea floor, the slipface of a longshore ridge, or the bottom of a runnel or hole. Upon impact, the victim's head is temporarily held in place due to a slight compaction of the water-saturated sand. The momentum of the remainder of the body may cause the chin to be thrust against the chest, and the neck may be broken or other serious damage may be done to the spinal cord and/or other parts of the upper body.

While the details of cause and effect vary from case to case, the following factors may contribute to the occurrence of plunging-dive accidents.

1. A diver may erroneously assume that his/her body will stay close to the water's surface when performing an entry dive in "shallow" water; when, in fact, the body will attain depths in excess of approximately one meter (3.28 feet).

2. The turbidity of the nearshore water along the mainland coast of southern California renders it virtually impossible to see the sea-floor topography in water more than about one meter deep.

3. A diver may assume that the sea-floor gradient always slopes offshore. This assumption generally is true, provided an equilibrated swell-produced beach profile has been attained; however, this assumption may not be true when a storm-produced beach profile is present or when there is a transition from a storm- to a swell-produced profile. At these times, ridge and runnel systems or erosional features may occur in the nearshore and beach zones. Such features may have landward-inclined slip faces or slopes, which may result in the presence of one or more topographic elements along the sea floor with "reversed" slopes.

4. When present in the nearshore zone, ridge crests and erosional features may not be easily identifiable due to the occurrence of calm water or the depth of the ridge crest (greater than 1.3x the wave height).

5. A swimmer may have dived safely in a given area, and may incorrectly assume that the nearshore zone maintains a rather constant topography through time, and is therefore always safe.

6. Many swimmers in southern California may be occasional beach users or visitors from inland areas with little knowledge of either ocean processes or physical characteristics associated with beach and nearshore zones.

The present two-year study of shallow-water plunging diving accidents at ocean beaches in southern California has three principal objectives. These are:

1. to document the frequency and demographic characteristics of such accidents;

2. to prepare a multidisciplinary technical report describing the frequency and demographic aspects of such accidents, as well as providing relevant medical, biomechanical, sedimentological, managerial and legal perspectives; and

3. to determine the most cost-effective method(s) to increase public awareness and advise beach users of the danger associated with shallow-water plunging dives, and to distribute these recommendations to the public and concerned agencies.

The present report addresses objectives 1 and 2, and a report to be prepared during the 1987-88 academic year will address objective 3.

It is hoped that this investigation will prompt further studies to address many remaining questions concerning the demographic, behavioral and physical aspects associated with plunging-dive accidents.

FREQUENCY AND DEMOGRAPHIC ASPECTS OF SHALLOW-WATER DIVING ACCIDENTS IN SOUTHERN CALIFORNIA

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INTRODUCTION

The purpose of this report is to present data acquired as part of a study of plunging-dive accidents at southern California ocean beaches. These data will be used in the second year of the study to aid in determining the most cost effective methods of public education concerning the danger of such dives.

METHODS

Data Collection

Sources of Data: Accident data were obtained from Major Incident Reports filed by lifeguards at the time of the accidents. Beach management personnel were questioned about beach physiography and signage. Huntington Beach, Los Angeles County and the State of California provided general statistics for beach usage. Times and heights of tides were obtained from National Oceanographic and Atmospheric Administration (NOAA) tide tables for the West Coast of North America and Hawaii.

Criteria for Inclusion: The following criteria were used in selecting accidents for inclusion in this study:

(1) The time period of interest is 1976 through 1986. Newport Beach, Huntington Beach and the State of California provided records for the entire study period. The remaining beach management offices either do not retain records for that length of time, or were missing data from some years.

(2) The severity of the injuries usually was not given on the accident forms, so any accident considered serious enough to have a Major Incident Report filed for it was included. This was a source of variability among beaches -- some beach management offices included everything from death to skinned noses, whereas others only included injuries that required a doctor's attention. When available, the severity of the injury was recorded. The condition reported for victims in this study is generally the condition at the time of removal from the beach, since ultimate condition is not often reported.

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Participating Agency	Years of Data Available	Signage	Data Quality
Los Angeles	1978-1986	Posted in 1981	Generally good; better in recent years
Huntington Beach	1987-1986 (Records have been kept for the last 24 years)	Posted in the last few years	Good to very good
Newport Beach	1976-1986	Posted in the last few years	Good to very good; better in recent years
State of California	1976-1986	Variable, based on specific hazards	Generally good
San Clemente	1976-1986	----	Good in recent years, fair in earlier years.
Laguna Beach	1976,1978-1986	----	Good in recent years, fair in earlier years.
City of San Diego	1983-1986	Variable, based on specific hazards	Good
County of San Diego	1980-1986 1978, 1979	----	Good Incomplete
City of Coronado	1986	----	----
County of Santa Barbara	1982-1986	----	Fair

Table 1. Participating agencies and data quality.

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(3) Only those accident reports that specified a seaward dive from shallow water were included. It was frequently not possible to tell how a given accident occurred. Therefore, it is likely that some applicable accidents were not included.

(4) Accidents involving dives from seawalls, piers, groins, docks, boats, rocks or other objects were not included in this study. Accidents involving rocks were included only when the victim's head struck a submerged rock as a result of a plunging dive.

Recording of Data

Information taken from the accident report forms was copied onto standard data forms. The following items were included when available: date, time, location, age of victim, address of victim, surf height, disposition of victim, a description of the accident, and the condition of the victim. Estimates for the times and heights of tides on the days of the accidents were then obtained from appropriate NOAA tide tables.

PARTICIPATING AGENCIES

Table 1 is a list of the participating agencies, the amount of data available, and the quality of those data. Data quality was considered to be good if the causes of accidents were included in the reports. Causes were hard to determine from poor data, resulting in few usable accident reports from those data sets. Table 1 shows the years of data available and the number of accidents per year for each non-zero-accident beach. Figure 1 shows the location of each beach for which data were gathered. Table 2 shows a breakdown of the accidents by year at each beach included in this study.

The following beach management agencies agreed to participate, but data quality was insufficient for inclusion in the study: City of Santa Barbara, City of Oceanside, and Camp Pendleton. Ventura County agreed to participate, but the data were never made available.

Non-Participating Agencies

The following beach management agencies chose not to participate in the study: the City of Long Beach, the City of Seal Beach, and the City of Del Mar.

TABLE 2. Years of data available for each beach and the number of applicable accidents during each year.

Beach	76	77	78	79	80	81	82	83	84	85	86
Zuma			0	0	0	1	0	0	0	0	1
Corral			1	0	0	0	0	0	0	1	0
Topanga			0	0	0	0	0	0	1	0	0
Will Rogers			0	0	0	1	0	0	0	0	0
Santa Monica			0	0	1	0	0	1	0	0	0
Venice			0	0	0	0	1	1	5	2	1
Dockweiler			0	0	0	0	0	0	1	0	0
Manhattan			0	0	0	0	1	1	1	1	0
Hermosa			0	0	1	1	0	0	0	0	2
Redondo			0	0	0	0	0	1	0	0	1
Huntington	0	0	1	0	3	0	0	2	1	1	1
Newport	2	4	5	5	5	6	3	1	5	3	1
Bolsa Chica S.B.	1	0	1	1	2	1	0	1	0	3	0
Huntington S.B.	1	1	1	1	0	1	2	1	0	0	0
Manhattan S.B.	0	0	0	1	0	0	0	0	0	0	0
Moonlight S.B.	0	0	0	0	0	0	0	0	1	0	0
San Buenaven. S.B.	0	0	0	0	1	1	0	0	0	0	0
San Clemente	0	3	1	0	0	1	0	0	2	0	0
Laguna	0		2	0	1	0	2	0	2	4	0
City of San Diego								4	2	2	0

STUDY AREA

CALIFORNIA

San Buenaventura St. B

Zuma Beach

Topanga Beach

Will Rogers St. B

Manhattan Beach

LOS ANGELES

Santa Monica Beach

Venice Beach

Dockweiler St. B.

Hermosa Beach

Redondo Beach

Huntington Beach

Bolsa Chica St. B.

Newport Beach

Laguna Beach

San Clemente Beach

Moonlight St. B.

SAN DIEGO

U.S.A

MEXICO

PACIFIC OCEAN

N

10   20 Mi.
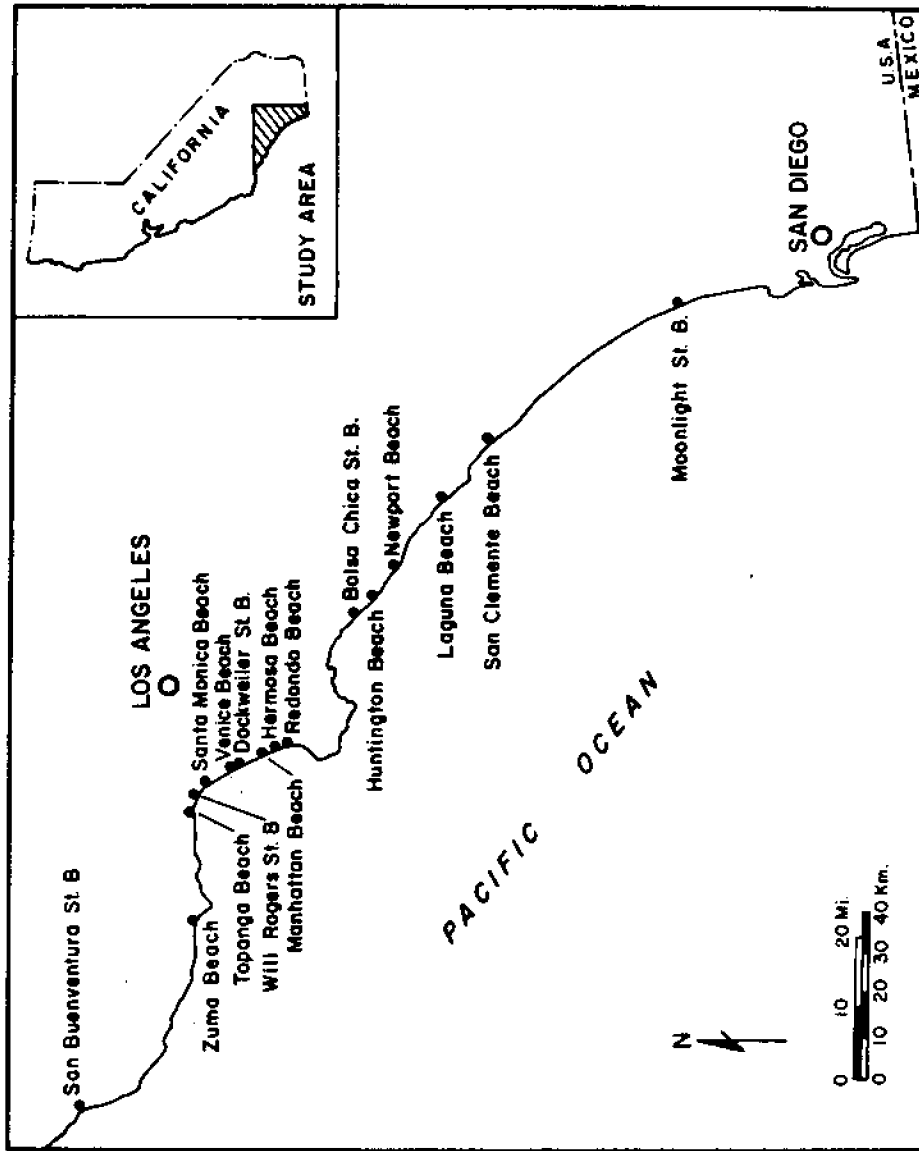
0   10   20   30   40 Km.

Figure 1. Location map showing beaches for which plunging dive accident data were obtained.

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RESULTS

The data sets from the individual beaches were generally too small for separate analysis. Data quality and number of years of data available also varied considerably; therefore, direct comparisons between and among beaches cannot be made. The entire data set was used to obtain most of the demographic information.

Accident Statistics

One hundred twenty-five accidents were identified as resulting from plunging dives. Eighty-six percent of these (107 accidents) occurred to males, and 14% (18 accidents) to females. The range of victims' ages was 6 to 59 years old, with a mean of 20.7 years and a standard deviation of 8.5 years (Fig. 2).

Condition of Victims

Condition, as used in this report, is generally the condition reported at the time of removal from the beach. Ultimate condition is rarely included on the accident forms. The Very Serious category includes spinal injuries, surgery and extended hospital stays. The Serious category includes broken bones (other than spine) and hospital visits involving treatment. The observed distribution is as follows:

Death:	3
Quadriplegia:	9
Paraplegia:	14
Very Serious:	12
Serious:	6
Not Serious:	45
Unknown:	36

Rate of Accident Occurrence

Because of the variability in beachfront length and number of years of available data, the number of accidents recorded for the individual beaches cannot be directly compared. A mean accident rate for each beach was calculated by dividing the number of accidents by the number of miles of beachfront and by the number of years of data available for that beach. The resulting accident rates can be compared with caution, but the small number of accidents recorded for most beaches must be kept in mind. As an example, Moonlight Beach has had only one plunging dive accident in 11 years but, as a result of the short length of this beach, its accident rate appears relatively high. This high rate is clearly an artifact resulting from the small sample size. Therefore, a distinction is made in the plot of accident rate against beach orientation (Fig. 3) between beaches having only one accident, beaches having two accidents, and beaches having more than two accidents. Table 3 lists the beaches in order of decreasing accident rate.
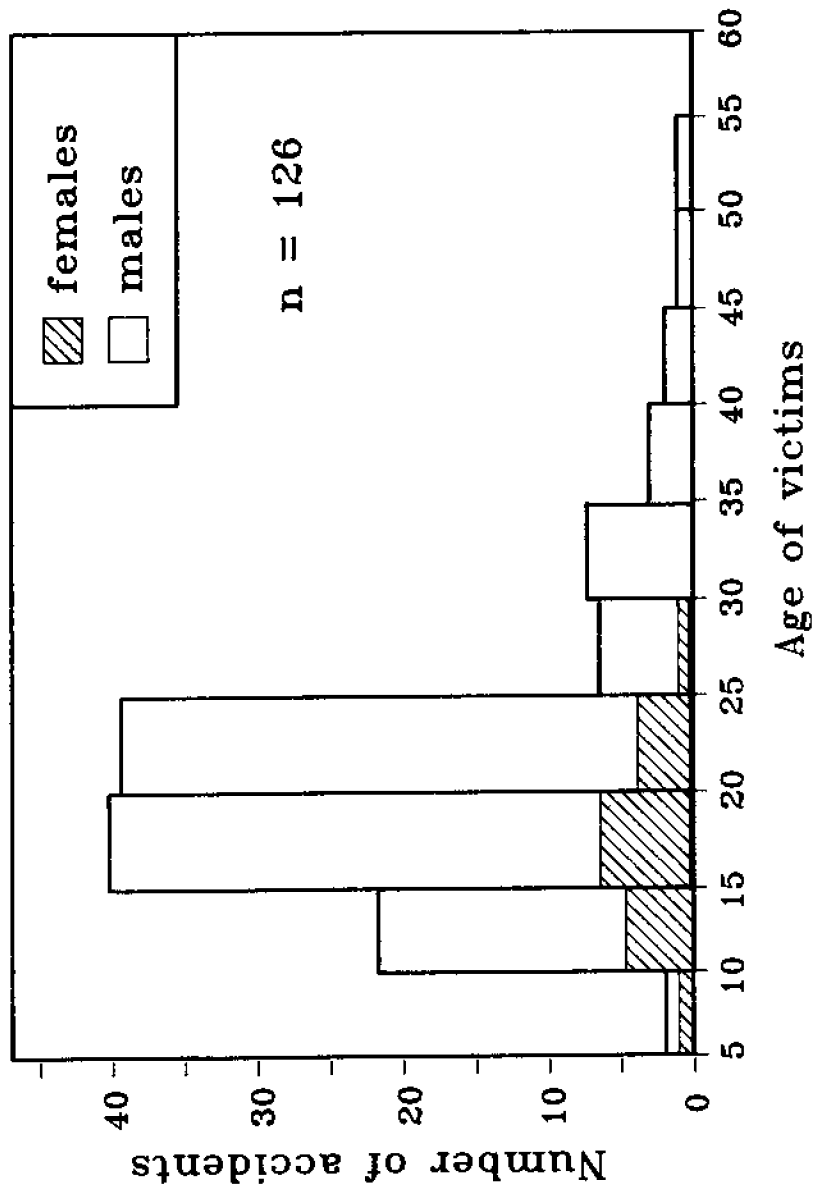
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Figure 2. Histogram showing the distribution of accidents by ages of the victims.
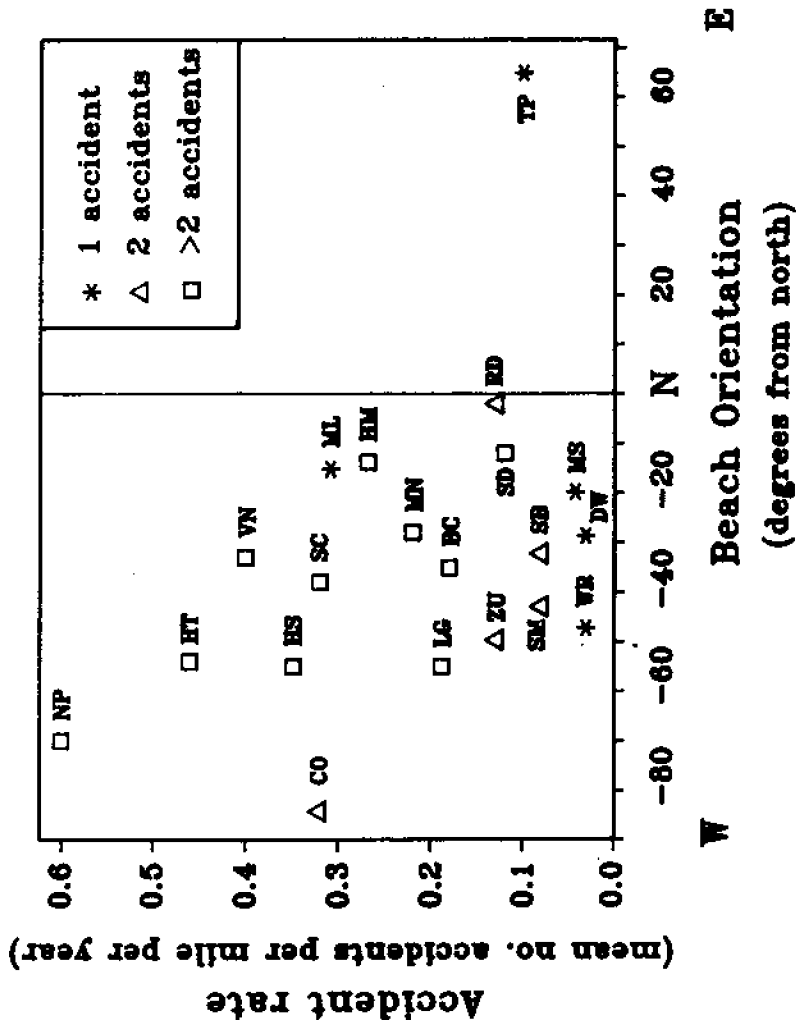
Figure 3. Plot of average beach orientation (degrees east or west of north) against accident rate (mean number of accidents per mile per year). NP = Newport Beach; CO = Corral Beach; HS = Huntington State Beach; HT = Huntington Beach; VN = Venice Beach; MN = Manhattan Beach; ML = Moonlight State Beach; HM = Hermosa Beach; SC = San Clemente; LG = Laguna Beach; BC = Bolsa Chica State Beach; ZU = Zuma Beach; SD = City of San Diego; RD = Redondo Beach; SM = Santa Monica; SB = San Buenaventura State Beach; WR = Will Rogers State Beach; DW = Dockweiler State Beach; MS = Manhattan State Beach; TP = Topanga Beach.

TABLE 3. Beach orientation and accident rate information, in order of decreasing accident rate.

Beach	Number of Accidents	Beach Length (miles)	Years of Data	Accident Rate (ac/mi/yr)
Newport Beach	40	6.1	1976-1986	0.60
Huntington Beach	9	1.8	1976-1986	0.46
Venice Beach	10	2.8	1978-1986	0.40
Huntington State Beach	8	2.1	1976-1986	0.35
San Clemente	7	2.0	1976-1986	0.32
Moonlight	1	0.3	1978-1986	0.31
Corral Beach	2	0.7	1978-1986	0.32
Hermosa Beach	4	1.7	1978-1986	0.27
Manhattan Beach	4	2.1	1978-1986	0.22
Laguna Beach	11	6.0	1976,1978-1986	0.19
Bolsa Chica State Beach	10	5.2	1976-1986	0.18
Redondo Beach	2	1.7	1978-1986	0.13
City of San Diego	3	17.0	1983-1986	0.12
Zuma Beach	2	1.8	1978-1986	0.13
Topanga Beach	1	1.1	1978-1986	0.10
San Buenaventura St. B.	2	2.2	1976-1986	0.08
Santa Monica Beach	2	2.9	1978-1986	0.08
Manhattan State Beach	1	2.1	1978-1986	0.04
Will Rogers State Beach	1	3.2	1978-1986	0.03
Dockweiler Beach	1	3.7	1978-1986	0.03

Beach Use

The average number of beach patrons during the years 1981-1984 was calculated based on estimates provided by the State of California, Los Angeles County, Newport Beach and Huntington Beach. These numbers are the yearly totals of daily visual estimates made by lifeguards. Unfortunately these estimates do not provide information about how many people actually entered the water or how many performed plunging dives. The assumption is made that approximately the same proportion of people at each beach engaged in these activities. Survey data from five of these beaches suggests that this assumption is valid.

Beaches for which data were provided are: Huntington City Beach, Newport Beach, Bolsa Chica State Beach, Moonlight State Beach, San Buenaventura State Beach, Dockweiler Beach, Hermosa Beach, Manhattan Beach, Redondo Beach, Santa Monica Beach, Topanga Beach, Venice Beach, Will Rogers State Beach, and Zuma Beach. These beach use data are presented in Table 4.

Accident Index

The accident rate calculations allow some comparison between and among beaches, but beach usage is a major factor which must be considered in assessing relative degrees of hazard. To that end, an accident index was created by dividing the accident rate (AR) by beach usage (BU), in millions of patrons, then multiplying the result by 100 to simplify the interpretaton of the resultant number (Table 4) ($AI = AR/BU \times 100$).

A primary factor leading to Newport Beach's high accident rate is seen to be the number of patrons that use that beach. Seven of the beaches with two or more accidents have closely grouped indexes, with Huntington Beach having the highest.

Beach Orientation

The average orientation of each beach was measured as an angle from north. A plot of beach orientation against the rate of accident occurrence (Fig. 3) suggests that, for beaches having more than two accidents during the study period, there is a general tendency for the accident rate to increase with increasing angle west of north. In other words, south- to southwest-facing beaches tend to have higher accident rates.

Linear regression analysis was performed to test this result. Beach orientation was tested against the accident rate, accident index, and beach usage. The accident rate correlates more strongly with beach orientation than accident index. Beach use correlates more strongly than the accident index, but less strongly than the accident rate. These results suggest that beach orientation is a contributing factor to the number of accidents that occur, and this contribution is not solely related to beach use. This suggests that physical processes, such as the orientation of the beach relative to incoming swells, play a role in accident occurrence.

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TABLE 4. Accident rate, beach usage (millions of patrons) and accident index information.

Beach	Accident Rate	Beach Usage (millions)	Accident Index (Accident rate per 10,000 Beach Users)
A. Beaches with two or more accidents.			
Huntington Beach	0.35	5.79	6.0
Newport Beach	0.60	10.72	5.6
Manhattan Beach	0.22	4.08	5.4
San Buenaventura S.B.	0.08	1.54	5.2
Bolsa Chica S.G.	0.18	3.55	5.1
Venice Beach	0.40	8.26	4.8
Hermosa Beach	0.27	6.06	4.5
Redondo Beach	0.13	4.42	2.9
Zuma Beach	0.13	7.79	1.7
Santa Monica Beach	0.08	20.76	0.4
B. Beaches with only one accident.			
Moonlight S.B.	0.31	1.03	30.1
Dockweiler S.B.	0.03	3.14	0.1
Topanga Beach	0.10	6.93	1.4
Will Rogers S.B.	0.03	5.27	0.6

Alcohol Involvement

Only four reports mentioned the presence of alcohol. One of those also mentioned marijuana. Many beach management agencies, such as the County of Los Angeles, do not include mention of alcohol unless a witness specifically states that the victim had been drinking. This statistic is, therefore, not a reliable indicator of the possible prevalence of drugs and alcohol.

Year

A plot of the number of accidents against year of occurrence (Fig. 4) shows a peak in 1984, with 1985 also containing a relatively large number of accidents. Only the years 1976 and 1977 are appreciably affected by the variability of coverage between beach management offices. The peak, therefore, may be considered to be real. One possible contributing factor to this peak is an increase in accident documentation in response to legal action. The decrease in the number of accidents in 1986 suggests that increased documentation probably does not account for the entire 1984 peak. The severe winter storm season in 1983 may have been a major contributing factor to this accident peak.

Time of Year

Figure 5 shows that the number of accidents are most frequent during the month of July, with a large number also occurring in August. This distribution corresponds with the times of peak beach usage, and also may correspond with the occurrence of ridges (sand bars) in the inner nearshore zone.

Time of Day

The distribution of times of accident occurrences, converted to Pacific Standard Time (PST) (Fig. 6), shows a bimodal distribution. Modes occur before 11:00 a.m. and after 12:00 noon. This pattern corresponds with the times of peak beach usage, perhaps coupled with a lag during the lunch hour.

Tidal Cycle

Accidents tend not to occur around lower low tide (Fig. 7), since lower low tide generally occurred at night on the days that accidents occurred (Fig. 8).

The position in the tidal cycle was obtained in the following manner: (1) daylight savings time was subtracted from the time of accident occurrence, if necessary; (2) times of the high or low tides preceding and following the accident times were obtained from the National Oceanographic and Atmospheric Administration (NOAA) Tide Tables for Western North America and Hawaii; (3) the time differences between
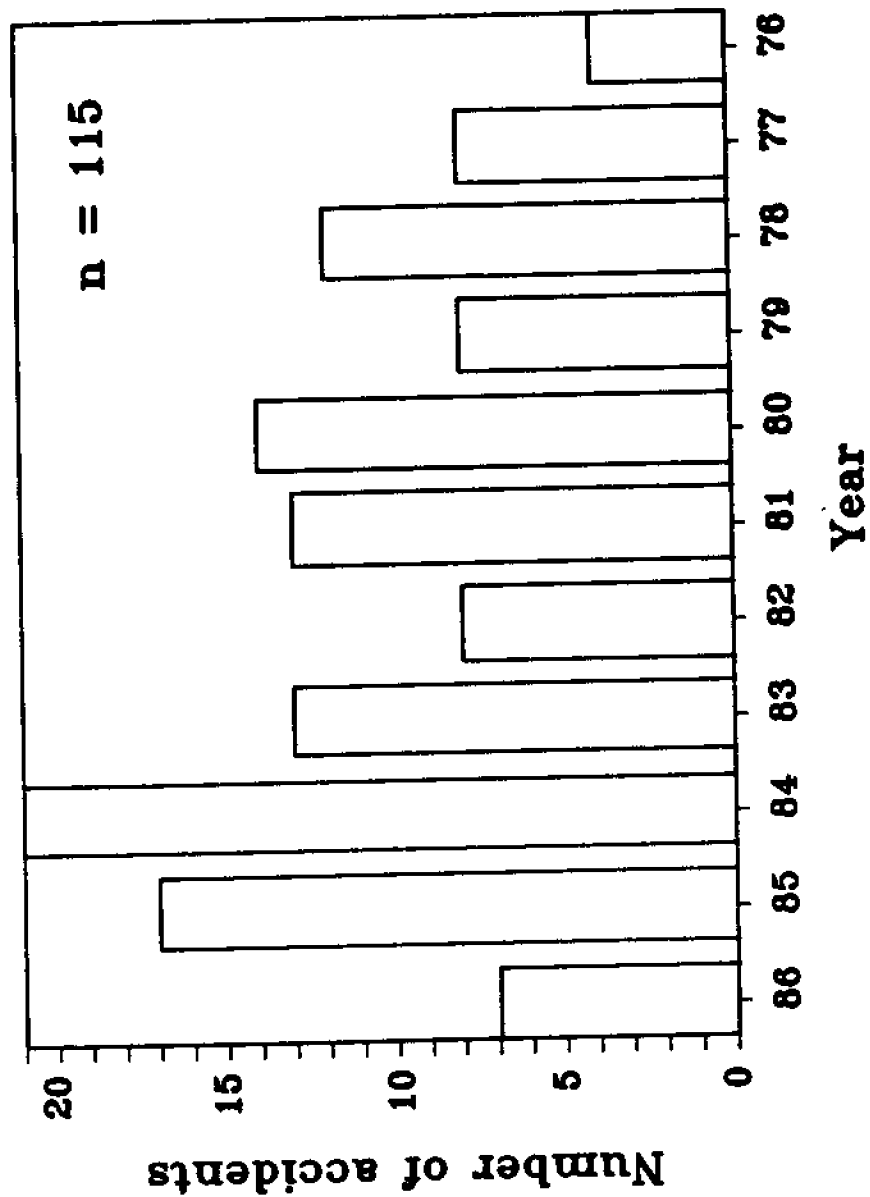
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Figure 4. Histogram showing the distribution of accidents by year of occurrence.
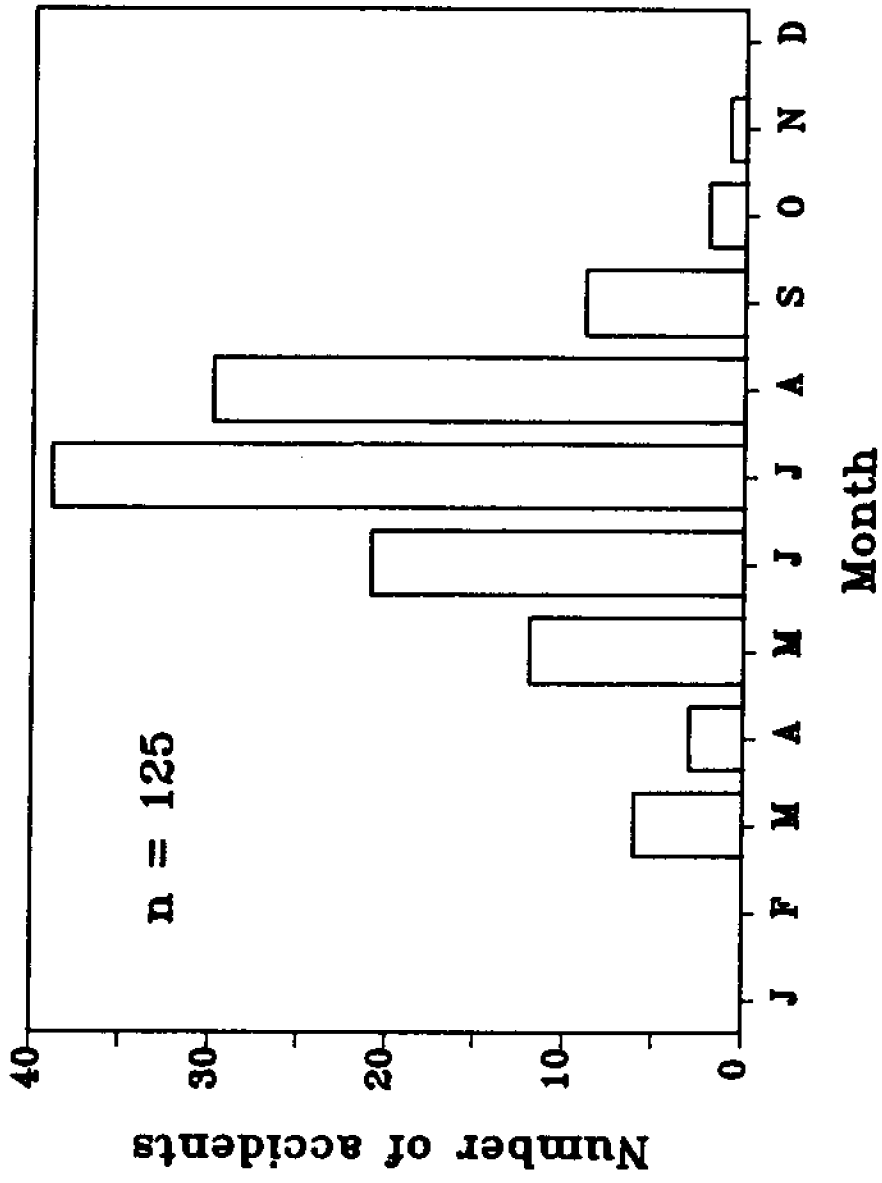
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Figure 5. Histogram showing the distribution of accidents by month of occurrence.
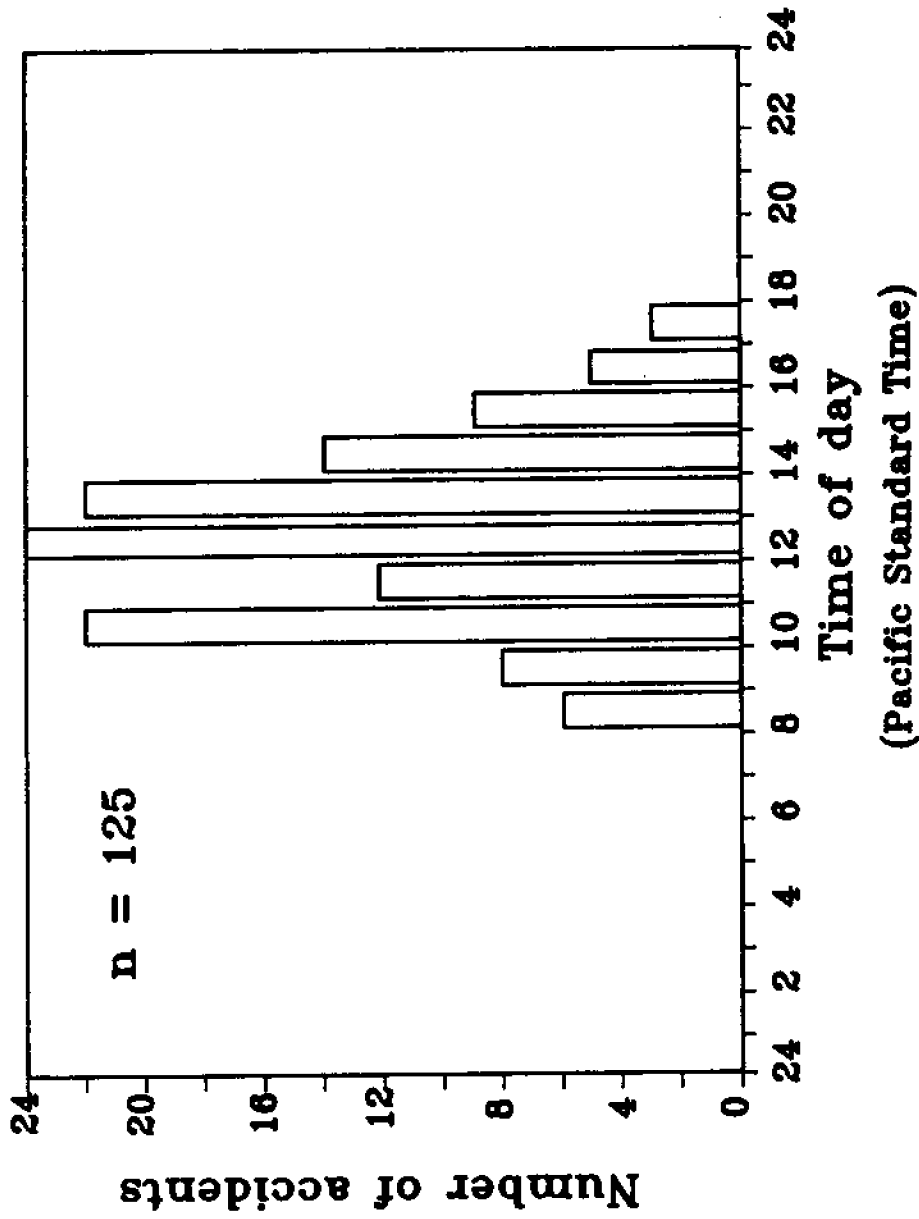
Figure 6. Histogram showing the distribution of accidents by time of day of occurrence.
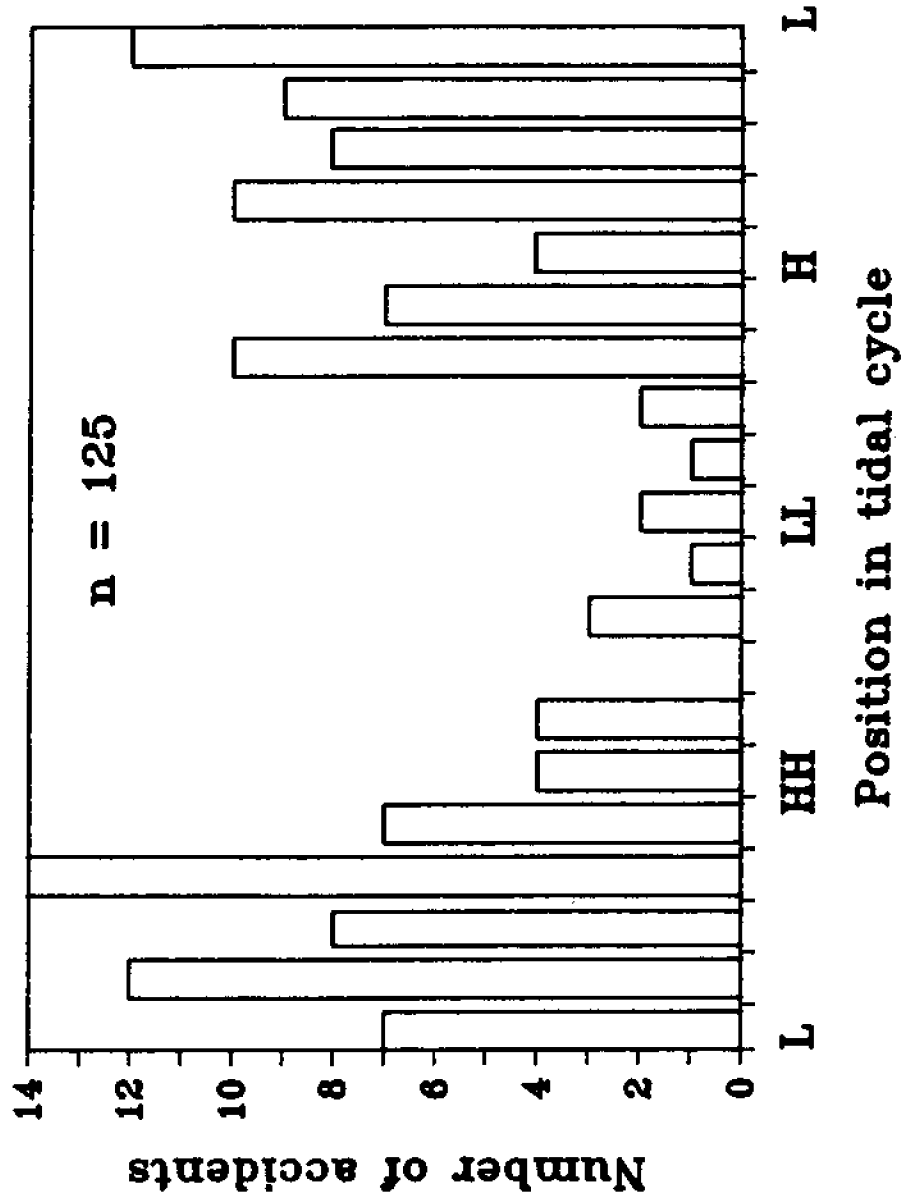
Figure 7. Histogram showing the distribution of accidents by position in the tidal cycle.
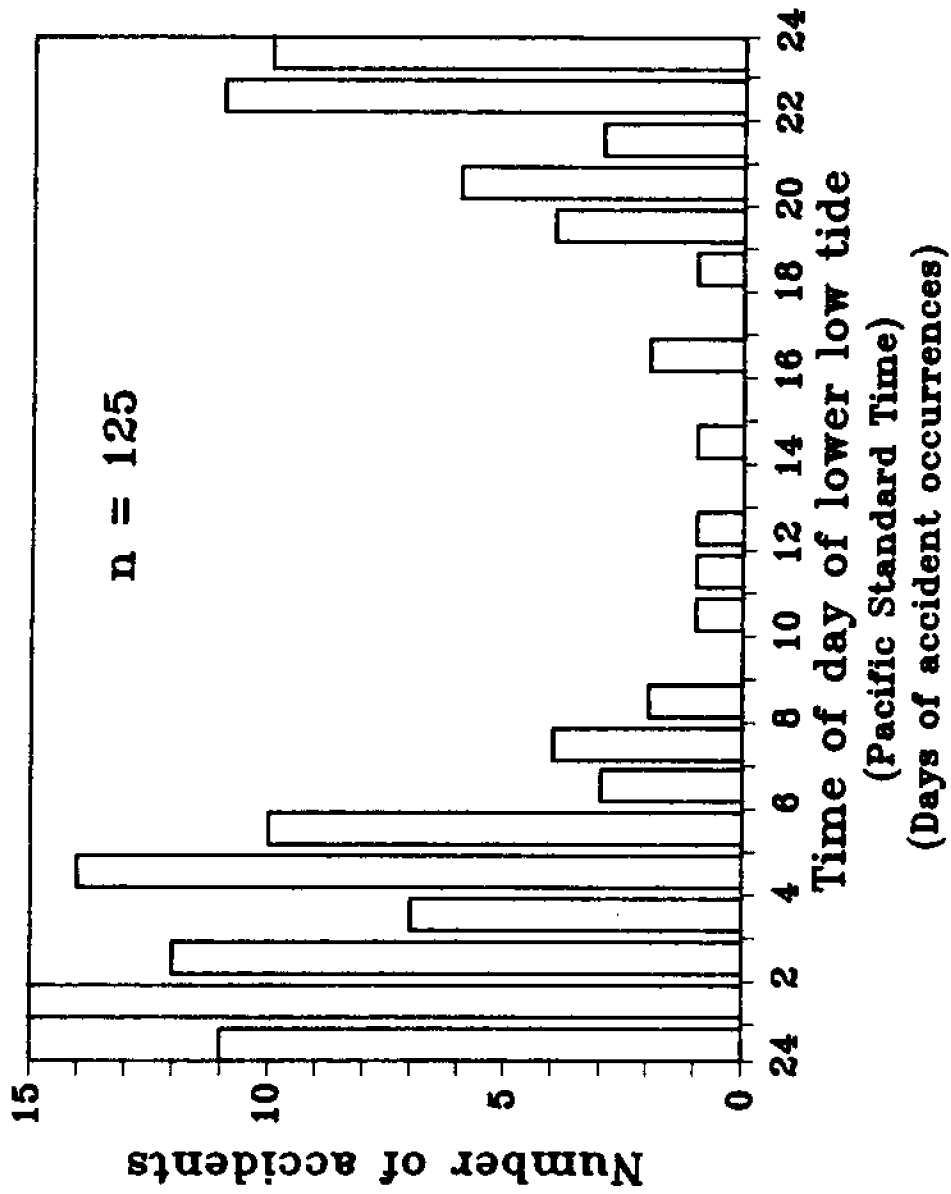
Figure 8. Histogram showing the distribution of time of lower low tides on days that accidents occurred by time of day.

the two tides and the accident were calculated, and the accident time calculated as a percentage of time between the two tides; (4) accident times occurring between higher low tide (L) and higher high tide (HH) were left alone; 100% was added to those occurring between higher high tide and lower low tide (LL), 200% to those occurring between lower low tide and lower high tide (H), and 300% to those occurring between lower high tide and higher low tide. These adjusted percentages form the x-axes of Figures 7 and 8.

Tidal Height

A plot of accident frequency against calculated tidal height (Fig. 9) shows a peak between three and four feet above mean lower low water. Possible contributing factors for this distribution are: average tidal height for southern California beaches; position and depth of sand bar crests; time of day of peak accident occurrence; and months of peak accident occurrence.

Surf Height

Surf height information was available for 73 of the accidents. Because the heights were given as ranges, it is not possible to calculate a mean value. Visual interpretation of a plot of the surf ranges (Fig. 10) shows that the average surf range was about one to three feet. Very few accidents occurred in surf higher than five feet. This distribution reflects normal coastal conditions, and is probably not significant for this study. Surf heights of one to three feet are normal on southern California beaches, with higher surfs rare.

Water Temperature

Water temperature was included in 35 of the accident reports. The range of temperatures was 56 to 72 degrees Fahrenheit, with a mean of 66.5 degrees, and a standard deviation of 4.1 degrees.

Distance Between Victims' Homes and the Ocean

The distance from the victims' homes and the ocean was determined by measuring the straight-line map distance between the victims' home addresses and the nearest point on the coast. This distance is not the distance to the beach where the accident occurred. Addresses within five miles of the coast were measured to the nearest tenth of a mile. All others were measured to the nearest mile. The distances that were less than or equal to 50 miles were averaged together for each beach, and the number of distances greater than 50 miles and all out-of-state addresses were tabulated (Table 5).

n = 125

Tide Height (feet)

(0 datum is mean lower low water)

Number of accidents

40   30   20   10   0

-1   0   1   2   3   4   5   6   7
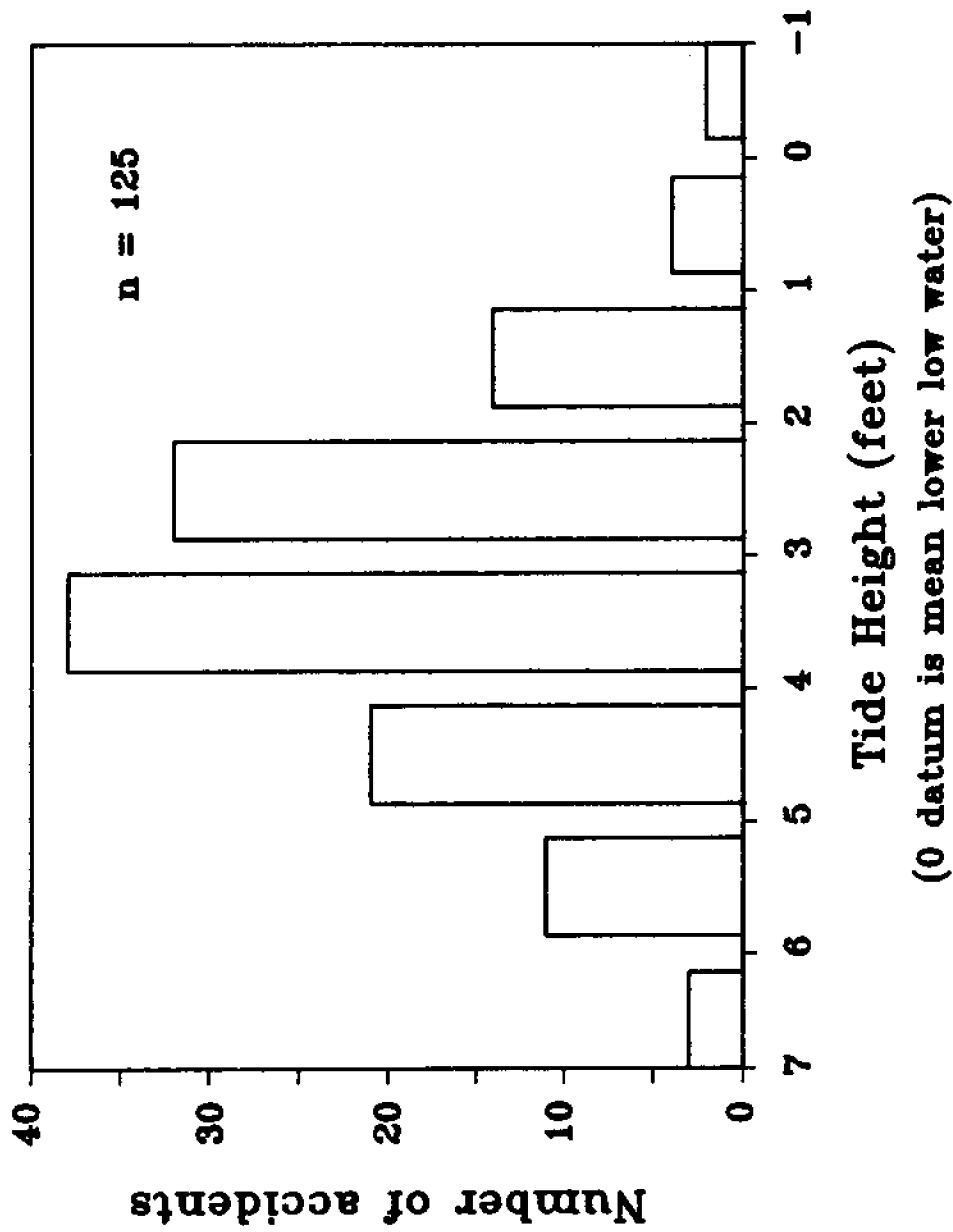
Figure 9. Histogram showing the distribution of accidents by tide height at the time of occurrence.
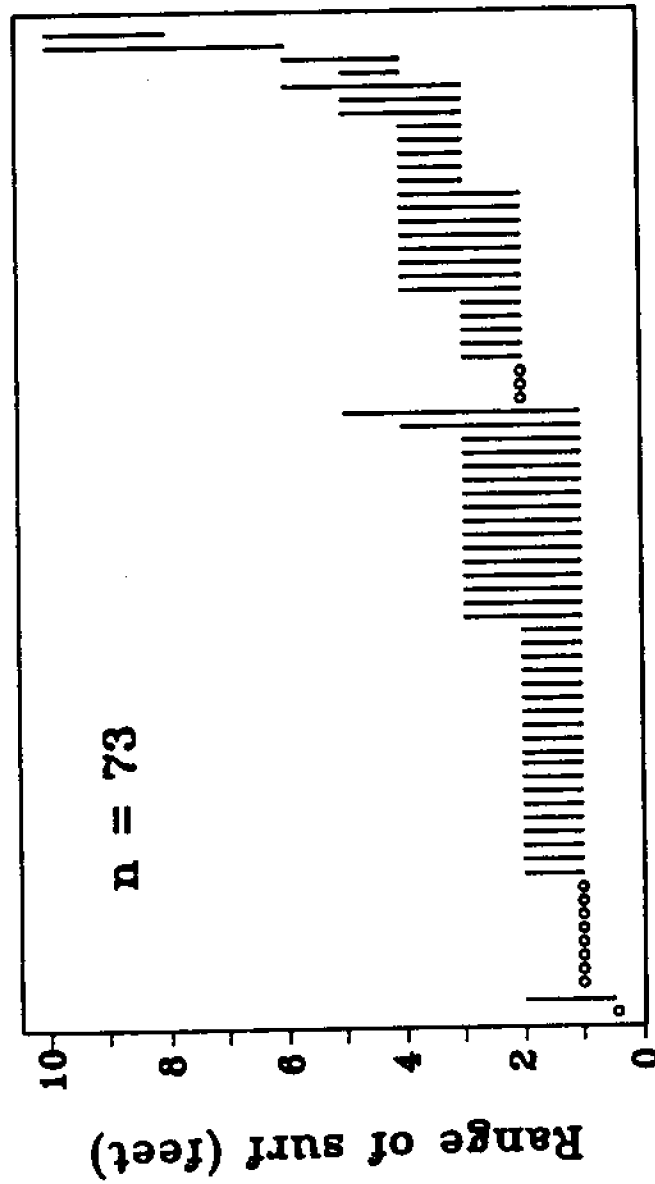
Figure 10. Plot of the ranges of surf height for each accident.

Beach Agency	Total number of Accidents	Number of addresses more than 50 miles distant	Mean distance (miles)	Standard deviation
Zuma	2	---	9.5	0.5
Corral	2	1	11.0	---
Topanza	1	---	12.0	---
Will Rogers St. B.	1	---	0.3	---
Santa Monica	2	---	0.2	0.1
Venice	10	1	8.0	4.9
Dockweiler	1	---	7.0	---
Manhattan	4	---	13.5	3.0
Hermosa	3	---	1.3	1.2
Redondo	2	---	3.0	0.0
Huntington	9	1	16.4	12.9
Newport	39	5	18.9	14.8
Bolsa Chica St. B.	8	---	6.8	5.0
Moonlight St. B.	1	---	20.0	---
Huntington St. B.	7	1	20.7	15.9
Manhattan St. B.	1	---	0.1	---
San Buenaventura St. B.	2	---	30.0	20.0
San Clemente	7	---	4.7	4.1
Laguna Beach	9	2	9.9	12.0
City of San Diego	9	2	6.7	6.6

TABLE 5. Distance between victims' homes and the ocean, by beach.

A plot of these distances (Fig. 11) shows that most victims lived within twenty miles of the ocean, with many living within the beach community. Newport Beach differs from the general pattern in that many of the victims lived more than twenty miles from the beach. Most of these victims lived in inland communities in Orange and Riverside Counties. Huntington Beach, Bolsa Chica State Beach, and Huntington State Beach also had victims from more than twenty miles from the ocean. This distribution could be a contributing factor in the relatively high accident rates shown for these beaches.

A beach safety survey conducted as part of the public education portion of this study indicates that this distribution reflects the pattern of beach usage. Newport Beach was found to have a higher percentage of patrons that lived at a distance from the beach than did the Los Angeles County beaches studied.

CONCLUSIONS

The population most at risk from injuries resulting from plunging dives are males between the ages of 16 and 25.

South- to southwest-facing beaches tend to have higher accident rates. The peak accident time is July and August. At this time of year, the swells generally come from the southwest, and tend to build the beaches by ridge migration and amalgamation onto the beachface. The south- to southwest-facing beaches in Orange County tend to have large quantities of sand, and are very heavily used during the summer months. The beach orientation, sandy nature and heavy use are probably the major factors contributing to the high accident rates in this stretch of coastline.

The beaches included in the study that had the highest accident index were Huntington Beach, Newport Beach, Manhattan Beach, San Buenaventura State Beach, and Bolsa Chica State Beach. The beaches with the highest accident rates are Newport Beach, Huntington Beach, and Venice Beach. Factors that may contribute to these relatively high indexes and rates are: (1) beach orientation; (2) number of people entering the water; (3) presence of sand; and (4) the demographics of beach population. Santa Monica appears to be an exception with its high beach usage and low accident rate.

Newport Beach has had the highest number of accidents. Because of the high beach usage, the accident index is similar to those of other beaches. However, the high accident rate suggests that particular attention should be paid to this beach when developing policies to reduce accident occurrence.
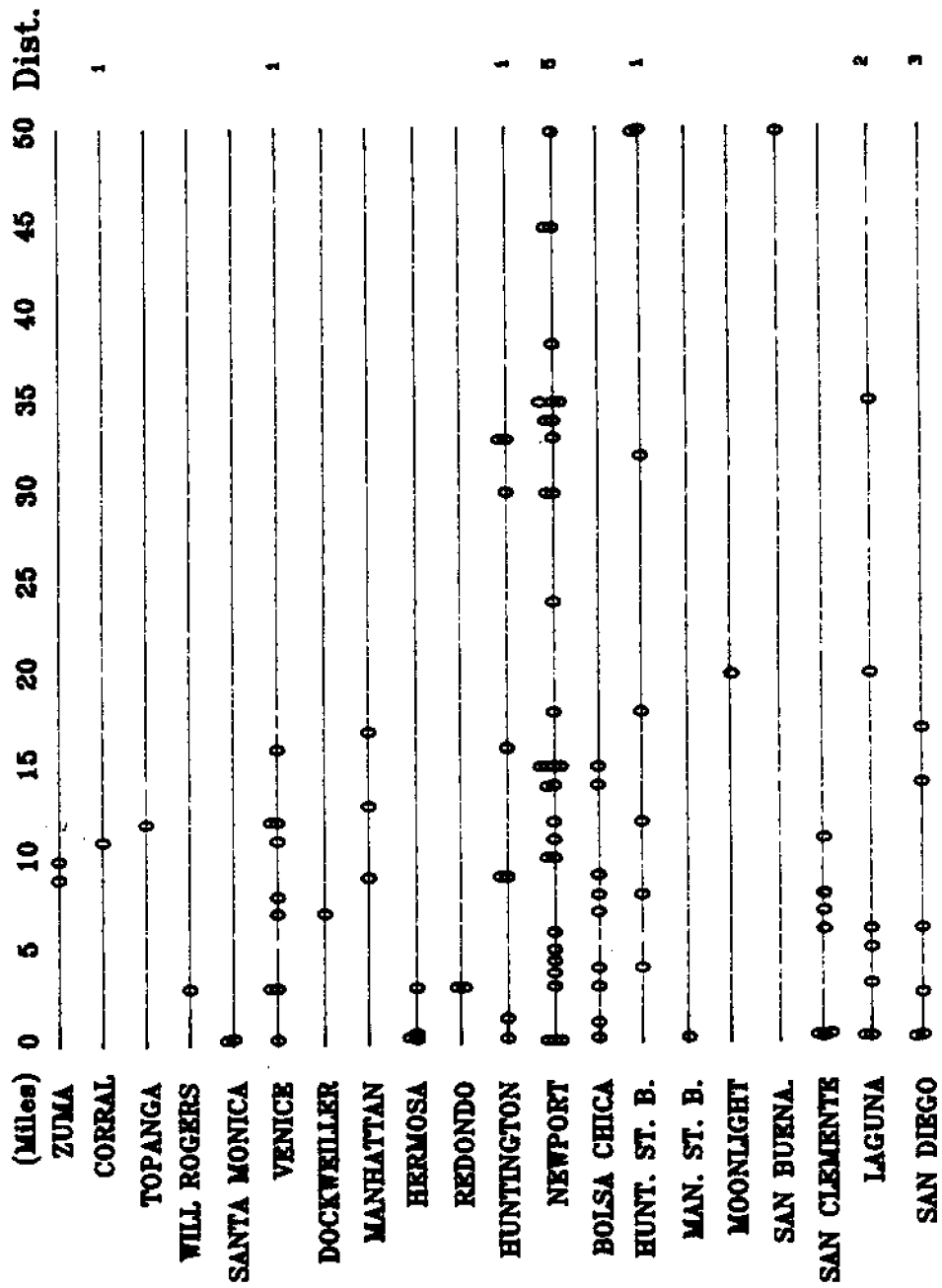
Figure 11. Plot of the distance between the victims' homes and the ocean. Distances greater than 50 miles are tabulated in the column labeled "Dist." (Distant).

BEACH SEDIMENTOLOGY

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INTRODUCTION

This paper presents an overview of oceanic processes and sediment responses typical of southern California beaches. Accordingly, it is based upon well-established principles rather than site-specific data from the many beaches present in the study area.

A beach (Fig. 1) consists of the zone of unconsolidated sediment that extends landward from the low-water line to the place where there is a marked change in material or physiographic form, or to the line of permanent vegetation (usually the position of the effective limit of storm waves). On natural beaches, the ever-changing wave and current conditions imposed upon the sediment give rise to an ever-varying beach profile, which is the intersection of the surface of the beach with a vertical plane. The profile of a natural beach is continuously adjusting to associated wave and current fluctuations; an equilibration profile is rarely if ever attained. However, the only way known to cost-effectively understand changes in beach zone topography is in terms of conceptual equilibrium profiles.

Ocean diving accidents involving impact of the head with the ocean floor will necessarily involve contact between the head and either a uniform offshore slope, one or more aspects of a ridge and runnel system or impact with a scour feature present at the location of impact. Each of these topographical features can be associated with various wave patterns, weather conditions, sediment grain size, as well as a number of additional factors. This study does not attempt to characterize any of the specific factors which account for the location of any particular feature at a given time.

It is important to note that nearshore ocean bottom irregularities can be attributed to both constructional and erosional features. A great deal of site-specific data is required to correlate any ocean diving accident with either the presence or absence of a uniform offshore slope, a ridge and runnel system or scouring of the ocean floor.

For purposes of this paper, the term ridge shall refer to a topographically positive depositional feature of the ocean floor, whereas a runnel will refer to a trough characteristically associated with a ridge. A "hole" is generally a circular or elongate scour feature dominantly attributable to erosional rather than constructional processes.

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STORM- AND SWELL-PRODUCED PROFILES

Although a beach profile continuously adjusts in response to changing hydraulic and sedimentologic conditions, the principal change in the profile occurs as a result of sediment transport during storm and swell conditions, which give rise to a conceptual storm-produced profile and swell-produced profile respectively (Fig. 2). The swell-produced profile is characterized by a wide berm, which is the nearly horizontal part of the beach or backshore, and by a relatively smooth offshore profile with no ridges, except perhaps in deep water. In contrast, the storm-produced profile has almost no berm, because the beach and backshore sediment has been eroded and transported offshore, where it may be temporarily or permanently stored as a ramp or low-relief ridge in the nearshore zone. The volume of sand involved in swell-and storm-produced beach profiles for a given area generally remains much the same. The extent of storm erosion depends on a number of factors including the type and volume of backshore material (e.g. bedrock, cobble, pebble or sand), height of storm surge, storm-generated wave conditions, as well as the direction and duration of wave attack.

Following a severe storm, natural beach rebuilding normally occurs by a process involving the landward migration of a series of ridges (sandbars) under the influence of relatively low-energy, fair-weather swell conditions. These ridges have associated runnels on their landward sides, and such topographic couples are referred to as ridge and runnel systems.

RIDGE AND RUNNEL SYSTEMS

The general sedimentologic processes associated with ridge and runnel systems are similar in both marine and lacustrine (lake) environments, and these processes have been documented by: Evans (1940), King and Williams (1949), King (1966), Hayes (1967), Hayes and Boothroyd (1969), Davis and Fox (1972); Davis and others (1972), Parker (1975), Owens and Frobel (1977), U.S. Army Coastal Engineering Research Center (1984), Oxford and Wright (1978), Aubrey (1979), Dabrio (1982), Davis (1983), Fox and Davis (1983), Weishar and Wood (1983) and Moore and others (1984), among others.

In general, sand that has been transported offshore during a severe storm typically is transported landward as a series of two to four ridges, each with a gently-sloping (0 to 10 degrees) offshore face and a more steeply-sloping (10 to 30 degrees) landward slipface. King (1966, p. 342) reports that an abundance of sand in the foreshore zone is an important factor in explaining the distribution of ridge and runnel systems, because this condition reduces the overall beach gradient. According to Komar (1976, p. 300-301), the nearshore slope angle is significant because the position of each ridge may reflect the average breaking condition of waves of a given size. On low-sloping nearshore zones, breaking waves are able to reform over more shoreward runnels, and thus progressively break a second or third time.
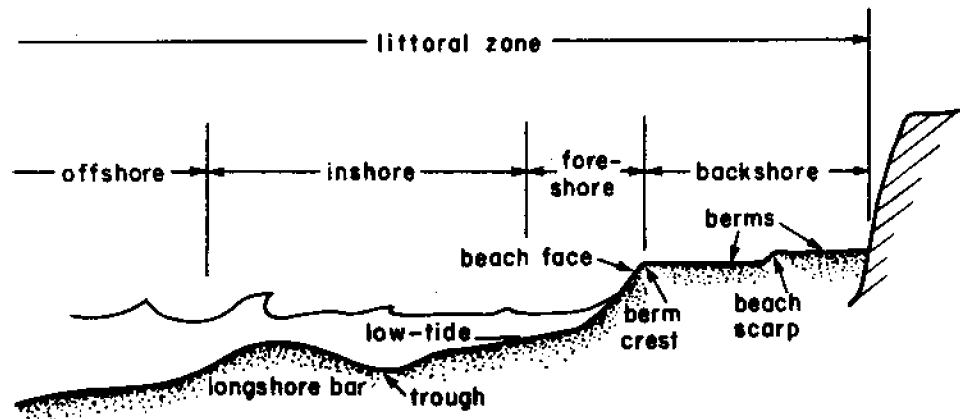
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Figure 1. Terminology used to describe beach topography (after Komar, 1976, Fig. 2-1, p. 12).
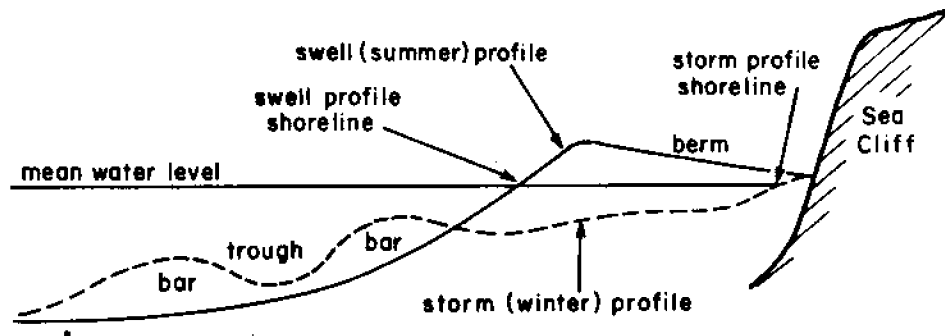

Figure 2. Storm- and swell-produced beach profiles (after Komar, 1976, Fig. 11-1, p. 289).

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Allen (1984, p. 435-446) discusses the morphology, movement and origin of ridges of interest in the present study. Two explanations seem most plausible to explain the genesis of longshore ridges: (1) the surf-beat model and (2) the breakpoint/undertow model. The term "surf beat" refers to the irregular oscillations of the nearshore water level with periods on the order of several minutes. In the surf-beat model, sand is thought to be transported by circulation cells established by the partially long-wave system present in the shorezone. Sand is deposited at the nodes of the surf-beat envelope if bed load (mostly sand and gravel) dominates, and is deposited at the antinodes if suspended load (mostly silt and clay) dominates. In the breakpoint/undertow model, sand is suspended by the turbulence generated by breaking waves, and is transported offshore by the mean cross-shore currents (undertow) to be deposited near the breakpoint of the adjacent wave. Multiple bars can form under the breakpoint/undertow model if the breakers reform, thus establishing subsequent breakpoint and undertow cells. Dally (1987) conducted a laboratory experiment designed to test the hypothesis that long waves, such as surf beat, are responsible for longshore ridge formation. Although experimental conditions were specifically designed to favor this mechanism, little evidence was found to support the surf-beat model. Quite unexpectedly, Dally's experimental results strongly supported the breakpoint/undertow mechanism. In all but one experiment, Dally (1987) reported that ridges did form in the vicinity of the outermost breakpoint. Furthermore, the often assumed requirement of plunging breakers for longshore ridge formation was found to be unnecessary, as predominantly gently-spilling breakers were used in these experiments. Although the surf-beat model cannot be dismissed at this time, Dally's experimental results are quite supportive of the breakpoint/undertow mechanism to explain the origin of ridge and runnel systems.

According to Davis (1978), initially ridges are convex upward with a nearly symmetrical profile. As shoreward transport occurs, the profile of the ridge soon changes to one exhibiting a steep shoreward face and a broad, gently sloping but still convex-upward seaward slope. Fluctuations in water level associated with tide levels influence such morphologic modifications as well as the rate of shoreward migration simply by permitting or preventing wave action acting on the ridge. The absence of appreciable tides, as in lakes, permits more continual modification and migration of such ridges, whereas in tide-dominated areas, the ridge may be subaerially exposed during much of the tidal cycle, and, as a result, its migration rate is correspondingly reduced (Davis and others, 1972c). Furthermore Davis and others (1972c) report that the comparison of ridge and runnel profiles for tidal and nontidal conditions indicates that scale is the only significant difference.

Landward ridge migration occurs by the shoreward transport of sand across the more gently-sloping seaward face of the ridge by waves. At the ridge crest, where breaker and swash action dominate, the sand avalanches down the more steeply-inclined, shoreward-sloping slipface. Although the ridges are the more conspicuous elements in a ridge and runnel system, Parker (1975) indicates that it is more realistic to view the ridges as bedforms (any deviation from a flat bed that is higher

than the largest sediment size present in the parent bed material) through which sand passes from one runnel to another, where continued landward and/or longshore transport may occur. If this process is continued long enough, the leading ridge will eventually migrate to the landward limit of storm-induced erosion, where it will be accreted or "welded" onto the beachface. Ideally, accretion will continue by the progressive addition of ridges to the beachface until a beach profile is established which essentially is in equilibrium with respect to the fair-weather wave (swell) climate, beach slope, sediment grain size, etc. This swell-produced profile will continue to build until the last ridge is accreted to the shoreface, and will remain in a state of approximate equilibrium until the first severe storm.

INNER RIDGE CHARACTERISTICS

Many researchers have documented the landward migration of inner bars or ridges (e.g. Evans, 1939; King and Williams, 1949; Sonu, 1969, 1973; Davis and Fox, 1972a, 1972b, 1975; Davis and others, 1972c; Hayes, 1972; Greenwood and Davidson-Arnott, 1975; Owens and Frobel, 1977; Fox and Davis, 1978; Short, 1978, 1979; Hine, 1979; Sasaki, 1982; and Sunamura and Takeda, 1984). Most of these papers are descriptive in character, but Sunamura and Takeda (1984) have attempted to relate the landward migration of the inner ridge to prevailing nearshore wave parameters and associated sediment characteristics.

The morphology and mobility of the most landward ridge at any given time is of considerable interest to the present study, because this is the ridge most likely to be involved in a shallow-water diving accident, if, in fact, a ridge is involved at all. There is little doubt that the inner ridge migrates shoreward with a marked slip-face slope (10 to 30 degrees), as reported from coastal studies in many parts of the world (e.g. Hoyt, 1962; Davis and others, 1972; Hayes, 1972; Greenwood and Davidson-Arnott, 1975; Owens and Frobel, 1977; Hine, 1979; Hunter and others, 1979; Dabrio and Polo, 1981; and Sunamura and Takeda, 1984).

In a study of the Lake Superior coast, Bajorunas and Duane (1967) made detailed surveys of ridges in water less than 1.5m (4.9 feet) deep. Repetitive surveys from July-October 1964 indicated that the innermost ridge is highly mobile; movement is almost unidirectional advancing from deeper water toward the shore; and that at a water depth of 0.5m (1.6 feet), the ridge loses its topographic identity and merges with the shoreface to complete its accretionary cycle. It is clear that similar processes occur in the marine environment, because few ridges with steep slip-face slopes occur in the very shallow water adjacent to the shore. Bajorunas and Duane (1967, p. 6197-6198, their Figs. 3, 4 and 5) display slip-face slopes ranging from approximately 1 to 6 degrees for the inner ridge. Ingle (1966, p. 30-35, his Figs. 30-32) shows slip-face slopes from 0.2 to 4 degrees from innermost ridges observed at Goleta Point, Trancas, Santa Monica Bay and La Jolla in southern California. On the other hand, the author has measured slip-face slopes from 12 to 25 degrees on innermost ridges along the 48th Street groin field near Newport Beach, California. It is not immediately apparent why the slip-face slopes measured at Newport Beach are so much higher.

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Ridge spacing also is quite variable, but ranges on the order of 10 to 50m (33 to 164 feet) for inner ridges to as much as 75 to 300m (246 to 984 feet) for the outermost ones (Allen, 1984, p. 438). In some belts the ridges are long, straight or gently arcuate and almost perfectly parallel over distances from several to many kilometers. In other cases, longshore ridges may be slightly sinuous in plan view, but have crestal zones that widen and shoal locally. Other more complexly-shaped ridges have been described as arcuate, lunate or cusp-shaped. Some ridge sets are remarkably consistent in pattern, whereas other sets lack an obvious pattern. Shepard (1950), and Hands (1976) have observed that ridge height, water depth at the ridge crest, and water depth in the adjacent runnel all increase with increasing wavelength toward the sea.

SEASONAL VARIATION IN THE BEACH PROFILE

Wave heights in excess of approximately three to four feet combined with four-to five-foot tides are required to cause substantive erosion along most southern California beaches. High-energy, high-frequency storm waves are typical of the winter months (November through May) in southern California, whereas small-amplitude, longer-period swell conditions generally occur during the late spring and fall (June through October) (Shepard, 1950; Bascom, 1964). Assuming the occurrence of several severe winter storms per season, beaches may be expected to display storm profiles from November through May, and may be expected to evolve toward and/or exhibit swell profiles during the remainder of the year. It should be stressed that beaches may have swell profiles during much or all of a mild winter, or may develop a storm profile during the summer or fall should substantive wave attack occur during this period.

The time required to evolve from a storm to a swell profile is important to this study, because it is during this transitional phase that ridge and runnel systems migrate onshore. Although beach rebuilding may start during the waning phase of a severe storm, the rate of recovery depends, in part, on the net rate of landward ridge migration. Recorded rates of ridge migration are highly variable, and range from stationary for a period of years (King, 1966) to as much as 29.3 m/day (96.1 feet/day) (Sonu, 1969). Other observed rates of onshore ridge migration include: 1.2 m/day (3.9 feet/day) at Lake Michigan (Evans, 1939); 2.2 m/day (7.2 feet/day) from Ajigaura, Japan (Hashimoto and Uda (1976); 3.3 m/day (10.8 feet/day) at the same location (Hashimoto and Uda, 1977); from 0.83 to 10 m/day (2.7 to 32.8 feet/day) from the Magdalen Islands, Quebec (Owens and Frobel, 1977); from 1 to 5 m/day (3.3 to 16.4 feet/day) from the Oregon coast (Fox and Davis, 1978) and from 4 to 5 m/day (13.1 to 16.4 feet/day) from Dai-nigori-zawa Beach, Japan (Sasaki, 1982). Although the ridge migration rates are highly variable, it seems that values from approximately 1 to 5 m/day (3.3 to 16.4 feet/day) represent the modal range for most nearshore ridges. Sunamura and Takeda (1984) have developed an equation and associated nomographs for estimating the velocity of landward-migrating ridges. This rate appears to be a function of the wave breaker height, the grain size and fall velocity of

associated beach sediment, and the ridge height. Further work is required to determine whether or not this equation is applicable to southern California beaches.

Although the preceding paragraph summarizes relevant information concerning migration rates for individual ridges, at least two other important factors must be considered as a beach evolves from a storm to a swell profile. The first is that most ridge and runnel systems consist of several ridges and the second is that there may be a considerable phase lag associated with the transition from storm to swell profile. The typical occurrence of from two to four or more ridges in a ridge and runnel system clearly increases the time required for this set of ridges to migrate onshore and accrete to the beachface. A number of the bathymetric profiles taken by the U.S. Army Corps of Engineers (1985) show typical ridge and runnel systems at a number of stations in southern Orange and San Diego Counties, California. Less obvious, but probably more important in the timing of beach recovery rates (acquisition of a swell-produced profiles) is a phase lag, during which sand is temporarily stored offshore. Aubrey (1979) monitored the beach profile changes at Torrey Pines Beach, California over a five-year period from June, 1972 through November, 1977. He documented that most coastal erosion is associated with the first major winter storm, and that the sand transported offshore as a result of such storms may be stored for periods from a few months to half-a-year before significant landward transport is initiated. Aubrey (1987, personal communication) reports monitoring the migration of ridges from 0.6 to 1.0 m (1.97 to 3.28 feet) high from the position of the outermost ridge to the beachface. Thus the sand eroded from a beach in early January might not start its return trip to the beachface as part of a ridge and runnel system until the following July. This phase lag plus the time required for the ridges themselves to migrate landward might not place the innermost ridge in very shallow water until middle or late July, and the succeeding ridges may continue to advance shoreward through August or September. Although there is insufficient information to demonstrate a stochastic causal relationship between the occurrence of plunging-dive accidents and the topographic characteric of the associated seafloor, it is possible that ridge and runnel systems may occur along beaches during the months of peak beach usage (July and August).

PREDICTIVE UNCERTAINTIES CONCERNING THE BEACH PROFILE

Unfortunately, too little is known concerning the quantitative aspects of sand transport in the beach and nearshore zone to permit accurate predictions regarding the nature of a beach profile at any given time. For example, little is known regarding sand transport under combined wave and current flows to accurately predict transport rates and pathways. Mass transport velocities, tidal effects, and wind-induced nearshore currents also are poorly understood at this time. Likewise, the mechanics of nearshore wave shoaling as well as the mechanics of the sediment-water boundary layer and near-bottom turbulent flow regime also are in need of considerable study. Each of these topics, among others, must be better understood and relevant variables

monitored on a site-specific basis before it will be possible to accurately predict the nature of onshore-offshore transport at a particular beach. Although our understanding of the quantitative aspects concerning the origin and evolution of storm and swell profiles and of associated ridge and runnel systems remains rather rudimentary, the preceding remarks and references should provide the interested reader with an appreciation of the major sedimentologic processes relevant to the study of shallow-water diving accidents.

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BIOMECHANICS OF SHALLOW-WATER OCEAN DIVING ACCIDENTS

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INTRODUCTION

Most studies investigating neck injuries have dealt with dives into swimming pools, lakes and rivers. None have dealt exclusively with shallow-water ocean diving. This report will focus on the unique mechanics of beach diving accidents. Information from prior studies which relate to this investigation is included.

MECHANICS OF INJURY

In shallow-water ocean diving the body is propelled forward by either running or pushing off forcefully, or a combination of both actions. To provide the least resistance to the water the diver attempts to align his body along its velocity vector which is a combination of the push off and/or the running velocity (V_R) and the velocity due to gravity (V_G). This gravity component is related to the body's clearance above the surface of the water or free fall height (Fig. 1).

The body is moving along a path in the direction of the velocity vector on its entry into the water. Arms are usually positioned so that they encounter minimum water resistance, that is either at the sides or above the head.

After entry, the water produces a dragging action which slows the body's forward movement. If the body continues on in the water and is allowed to slow gradually the body's velocity will slow to the point that no injury will occur. But, if soon after entering the water the head contacts the bottom or an object under the surface, neck injury can occur. Because the impact is unexpected, even if the arms are positioned above the head they are usually ineffective in preventing contact (Lawnicsak and others, 1986).

Head motion is arrested but the remainder of the body continues to move, loading the neck. Thorax and abdomen are stopped by a force acting through the neck with the result that the neck is squeezed between the head and the upper thorax. The initial contact force acting on the head can be low and well distributed, as in the case of a sandy bottom, and not produce bruising or a loss of consciousness. This is because neck fractures are not caused by the initial head impact, but are directly related to the velocity of the body loading the neck. The momentum of the body (the product of velocity and mass) as it loads the neck is sufficient to fracture it.
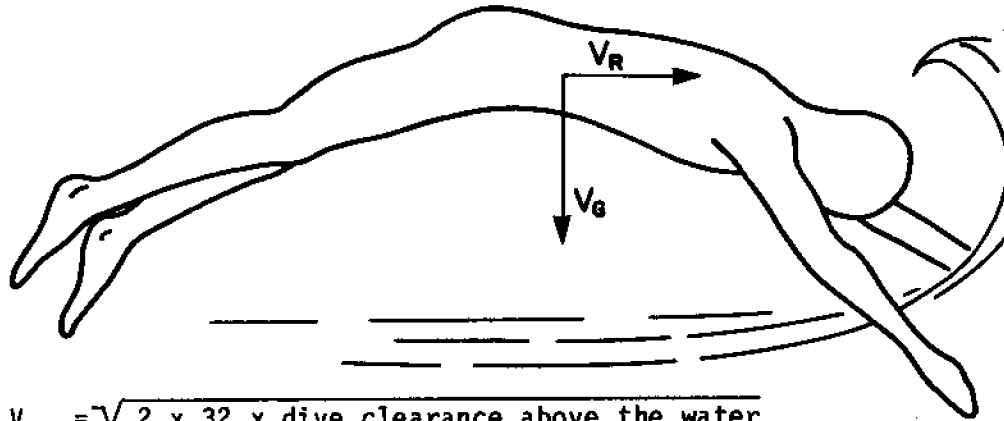
$$V_G = \sqrt{2 \times 32 \times \text{dive clearance above the water}}$$
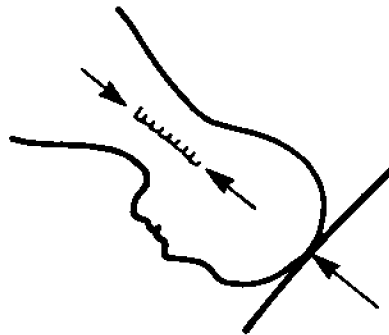
Figure 1. Surf diving velocities.

Figure 2. Critical body and impact surface alignment.

In a dive, the neck is usually straight with the head flexed slightly forward. In this position the neck is especially vulnerable because energy is not easily dissipated and reduction of the force can not be accomplished by any additional flexion or extension of the neck. The cervical vertebrae are loaded by the thoracic spine and the onset of the force is rapid. In shallow-water ocean dives, forces tend to concentrate on the anterior elements of the spine because the contact is on the upper forehead or anterior top of the head (Fig. 2).

TYPES OF NECK INJURY

The body of the vertebra (the anterior structure between the discs) is most frequently involved in diving accidents because this structure receives the greater compressive force. This compression can cause burst, wedge and tear drop fractures (Fig. 3).

Burst Fractures

These fractures involve the whole body of the vertebra. They are comminuted fractures which disintegrate the vertebral body. Alignment of the spine is affected and bone pieces can move posteriorly into the spinal canal.

Wedge Fractures

In a wedge fracture, lateral X-rays show that the vertebral body begins to take on the shape of a wedge. Several vertebra can be involved.

Tear Drop Fractures

In this type of fracture, the front edge of the vertebral body chips off and the fractured pieces appear to be triangular or tear drop in shape in lateral X-rays. The fractured vertebra tends to move posteriorly as well.

The most debilitating injuries occur when the fracture is associated with subluxation or where bone fragments penetrate into the spinal canal. In such cases, the cervical cord is compressed and damaged, and the most severe injuries result in quadraplegia.

Diving-produced quadraplegia is almost always associated with cervical fracture (Scher, 1978). In the few reported cases where the damage is produced by subluxation without fracture (McElhaney and others, 1983), the head pocketed in a soft bottom. In these cases, the load onset was lower.
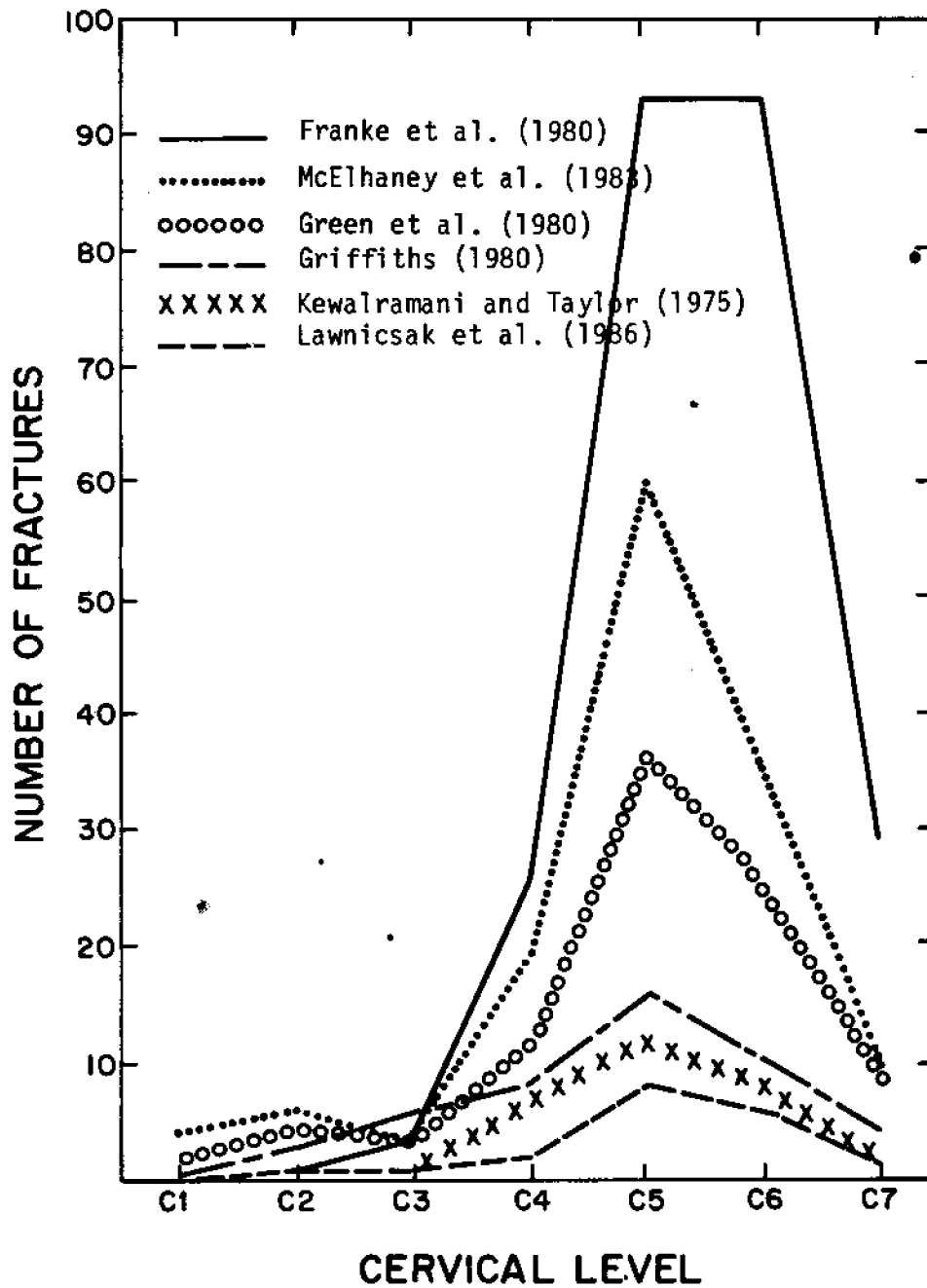
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Figure 4. Distribution of fractures in the cervical spine.

Occasionally at higher velocities, or in the more vertical dives, the vertebral arch is fractured as well. However, these injuries are less likely to occur in a running dive at the beach where the velocities are low and the diver is trying to propel himself forward rather than down.

The vertebra most frequently fractured is C5. This is the region of the neck with the greatest anterior-posterior flexibility. Figure 4 shows the distribution of fractures between cervical levels C1 and C7 reported in the literature (Lawnicsak and others, 1986; McElhaney and others, 1983; Griffiths, 1980; Franke and others, 1980; Kewalramani and Kraus, 1977; Kewalramani and Taylor, 1975; and Green and others, 1980). The percentage of C5 fractures is shown in Table 1.

Injury Factors

The primary factor affecting neck injury is the velocity of the body at the time of head contact. The greater the velocity, the greater the force acting on the neck. This is so because the force is proportional to the rate of change of body momentum.

This general relationship can be expressed by the following equation:

$$F = \frac{d \ (momentum)}{dt}$$

The body velocity just prior to impact is affected by the following factors:

(a) the speed at which the diver is moving as he enters the water,
(b) the forward velocity the diver can obtain from a forceful push off,
(c) the height the diver's body obtains above the water,
(d) the distance traveled in the water before head impact,
(e) the diver's body alignment with respect to the velocity vector,
(f) the water resistance created by diver's body position and orientation.

McElhaney and others (1983) have shown, in reenactment of water injury events, that velocities above 10.2 ft/sec (7 mph) can produce cervical spine injuries.

The athletic individual, who can run fast, push off forcefully and execute what appears to be a "clean dive", i.e., with the body aligned along the velocity vector, is at greatest risk. Table 2 and this study (Beratan and Osborne) indicate that these are generally young men between the ages of 15 and 25 (Lawnicsak and others, 1986; Scher, 1978; Griffiths, 1980; Franke and others, 1980; Kewalramani and Kraus, 1977; Kewalramani and Taylor, 1975; Green and others, 1980; Good and Nickel, 1980).
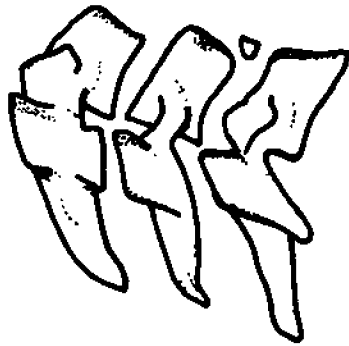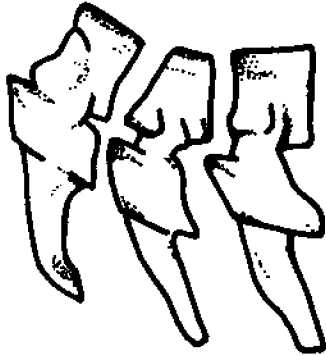
Figure 3. Common types of fractures.

Table. 1. Number of recorded diving accidents and the percentage of
           fractures at the C5 vertebra.

Number of Cases	Reference	% of Fractures at C5
18	Lawnicsak and others, 1986	45
92	McElhaney and others, 1983	65
150	Franke and others, 1980	62
23	Kewalramani and Taylor, 1975	52
72	Green and others, 1980	51

Table 2. Frequency of plunging dive accidents by age groups.

No. of Accidents	Age Group	% of Accidents	Age Group	% of Accidents	Reference
19	15-24	79%	0-24	79%	Lawnicsak and others, 1986
32			0-26	61%	Scher, 1978
67			0-30	77.6%	Griffiths, 1980
150	15-24	62%	0-24	71%	Franke and others, 1980
33	15-24	52%	0-24	63%	Kewalramami and others, 1975
72	13-24	61%	0-24	71%	Green and others, 1980
152	16-25	65%			Good and Nickel, 1980

To get the best push off, the diver starts the dive when the water level is low, so that he is diving into the trough of the wave. In this position the body is higher above the water surface which increases the velocity component due to gravity. A small change in the dive, such as a greater entry angle or a misstep, can propel the diver to the bottom at a speed sufficient to fracture the neck. Thus any lack of coordination due to drugs or alcohol can be devastating (Mennen, 1981; Albrand and Corkill, 1976).

Another important factor affecting the occurrence of injury is the alignment of the body with respect to the head impact force vector. If the force vector does not act in the direction of the body, the body will continue in motion. When this happens the head will slide after the initial contact causing the neck to rotate or bend, but because the momentum of the thorax and abdomen is not abruptly changed the forces in the neck are low and injury is avoided. The nonaligned body also may go into tumbling motion after initial impact, but injury is avoided because the body continues in motion.

However, if the head pockets on the ocean floor at the correct angle and the force acting on the head is directed towards the long axis of the body, neck fracture can occur (Fig. 2).

Thus, the angle of the contact surface is important. Objects under the water that present a surface perpendicular to the dive are most hazardous. These would include underwater structures, rocks, bottoms that rise abruptly, and high sand ridges. The least hazardous would be a gently sloping bottom that is nearly smooth.

INJURY VELOCITY

In cervical injury tests on cadavers the parameter which best correlates with injury is velocity (Nusholtz and others, 1981 and 1983). This is also true in reenacted diving accidents. In tests for the Consumer Product Safety Commission nine swimming pool and water slide accidents were simulated (McElhaney and others, 1983). The objective was to determine the condition under which neck injury would occur.

To insure adequate safety the simulations were done in much deeper water than that in which the accidents took place. High speed movies (200 frames per second) were taken to document the motion and to facilitate velocity computations. The impact velocities ranged from 10.2 ft/sec or 7 mph to 21.5 ft/sec or 14.6 mph. Eight of the nine cases involved fractures of the vertebral body. The results of the simulations show that tolerable velocities for the neck are less than 10.2 ft/sec (McElhaney and others, 1983). Below this level neck fractures do not occur.

The body's momentum is slowed as it enters the water, reducing its velocity. Studies show that in dives from the sides of pools, water four feet deep is required to reduce the body's velocity below the 10.2 ft/sec velocity, and five feet is needed to avoid injury (Lawnicsak and others, 1986; McElhaney and others, 1983; Albrand and Corkill, 1976).

Since the free fall drop height is less in beach dives than in pool dives the amount of water required to slow the body is less. Our preliminary evaluation of reenacted beach dives, which also included pool simulated accidents, indicates that approximately three feet of water is required to reduce body velocity below 10.2 ft/sec. In this investigation the three foot distance is measured along the path of the dive and does not represent a water depth measurement. The diver is running in hip to waist deep water, but the effects of wave action and the additional velocity obtained by diving at the low point of the wave (the trough) are not included. These effects would increase the dive velocity and increase the distance required to slow to 10.2 ft/sec. This wave influence needs to be assessed before safe distances and safe water depths can be defined.

SUMMARY

It is possible to impact structures and subaqueous sand bottom conditions with sufficient velocity to produce neck fracture. The factors affecting injury are velocity magnitude, body alignment and the direction of the impact force vector. Three types of fractures predominate: burst, wedge and tear drop.

In water diving accidents of all types the C5 vertebra is most frequently injured. That is, the fractures tend to occur in the most flexible region of the cervical spine.

Velocities above 10.2 ft/sec have been shown to cause the neck to fracture. This velocity can be obtained in running beach dives.

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MEDICAL ASPECTS OF SHALLOW-WATER DIVING ACCIDENTS
AT SOUTHERN CALIFORNIA BEACHES

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INTRODUCTION

In a typical southern California community, after automobile accidents and gunshot wounds, sports injuries are the third most common cause of spinal cord injury. This is especially common where there is water and shallow water diving.

At southern California beaches, a large number of young men are injured by entering the water and diving head-first with their heads subsequently striking the ocean floor. They may be paralyzed and often remain lying face-down in the water. At first friends may think that they are playing around and do not realize the seriousness of the difficulty. When it becomes apparent that the situation is serious, the friends may drag the victim out of the water. It is best to keep the head and neck as straight as possible, as further movements of the head and neck can aggravate any spinal cord injury that may have occurred.

INITIAL CONDITION

Many of the victims suffer fractures to the neck without severe injury to the spinal cord. These victims notice severe neck pain and often numbness or tingling in the fingers or legs. At this time, their necks should be immobilized, and they should be brought to the hospital where X-rays can be taken to be certain there is no major fracture or instability of the spine, where further neurological damage can occur. It has been estimated that up to 10% of spinal cord injury patients are made worse before they receive definitive treatment. Paramedics have been well schooled in how to immobilize the patient's neck when there is concern that a spinal injury has occurred. Most of the surf injuries involve the cervical area of the spine, although very rarely there can be fractures in the thoracic and lumbar area. If an injury to the head and neck is accompanied by severe neck pain, it must be assumed that a neck fracture has occurred and the neck needs to be immobilized. Other warning symptoms are tingling in the fingers, weakness in the hands and arms, tingling or weakness in the feet, and inability to empty the bladder properly. Obviously severe paralysis reveals injury to the spinal cord.

There is some controversy about the treatment of spinal cord injuries from a medical point of view. Everyone agrees that the head

and neck should be immobilized in a neutral position to prevent further damage. If X-rays of the neck reveal a dislocation of the vertebrae, then most physicians feel that this dislocation should be reduced. In one approach, tongs, which are like a skull caliper, are placed into the scalp after using local anesthesia; weights are then attached, and by this means of traction the dislocation often can be reduced. If the dislocation cannot be reduced by traction, then, at times, surgery must be performed where the fracture is reduced and a spinal fusion is done. Wire and fragments of bone or pieces of plastic may be used to fuse the spine.

TYPES OF INJURIES

Several patterns of injuries can occur with a cervical spine injury. Some patients simply suffer a concussion of the spinal cord resulting in a temporary numbness or paralysis of all extremities that clears very rapidly. There may be further advanced degrees of damage to the spinal cord itself. The anterior two-thirds of the spinal cord is supplied by the anterior spinal artery. If this artery is damaged or compressed by pieces of disc or bone, there will be loss of painful sensation below that point and severe motor weakness below that point. If some part of the spinal cord is intact, there may be some feeling in the lower extremities.

Another injury involves damage to one-half of the spinal cord. This is spoken of as a hemi-cord or a Brown-Sequard syndrome. Symptoms are weakness on one side of the body and loss of painful sensation on the opposite side.

Another pattern of spinal cord injury is termed the central cord syndrome. This problem is associated with severe weakness in the hands and arms and weakness to a lesser degree in the legs, and there may be some difficulty with voiding or passing urine.

Still another type of spinal cord injury is the complete spinal cord injury. This involves complete loss of function of the spinal cord at a point below which all sensation and motor function are lost. The common areas of involvement in the cervical area are the C5-6 and the C6-7 levels. The fifth cervical nerve is associated with movements of the shoulder muscles, the sixth with biceps functioning, and the seventh with triceps functioning. The eighth cervical nerve is involved with hand function. In general, if a patient has evidence of some functioning below the site of the spinal fracture then myelography, in which a contrast agent is placed into the spinal fluid, may be done. If there is evidence of severe pressure on the spinal cord from pieces of bone, pieces of disc or blood clots, then surgery may be performed.

TREATMENT AND LONG-TERM CONDITIONS

At our present level of knowledge, the prognosis is based on the patient's initial physical examination. If the patient has some movement below the site of the fracture, then the prognosis is much better than if there is no feeling and no movement.

In general, if a patient does not show improved motor functioning very rapidly after the spinal cord injury, then the long-term prognosis for walking is poor. Surgical intervention may improve nerve functioning in the arms. If a patient has triceps functioning and can straighten his forearms, then he can get in and out of a wheelchair by himself. Patients with severe weakness in the arms are basically bedridden and will require constant supervision and help for the rest of their lives.

When a spinal cord injury occurs, a multitude of medical problems may occur initially or may represent a permanent condition. With spinal cord injuries at certain levels there may be severe difficulty with breathing. Pulmonary function is brought about by movements of the chest wall supplied by nerves from the thoracic spinal cord and also by movement of the diaphragm, which is supplied by the third, fourth and fifth cervical nerve. When initially injured, a patient may have severe difficulty breathing and require the use of a ventilator for a period of time or require a tracheostomy. In this procedure, an opening is made into the trachea to help with breathing and clearing secretions from the lung. Because patients cannot breathe properly they are predisposed to developing pulmonary infections with pneumonia. Because the nerves to the bladder and bowel are interrupted there is difficulty with bowel, bladder and sexual functioning. A patient that is unable to empty his bladder properly is predisposed to infections in the bladder, infections of the kidney, and the formation of kidney stones and bladder stones. Long-term follow-up by a urologist is necessary because of these difficulties. Bowel movements may be difficult. In some cases this can be controlled by diet and by rectal suppositories. Sexual functioning is impaired because the nerves to the sexual organs are interfered with. This usually means that a man will not be able to have children. Because of the immobility and paralysis of the legs that will occur, the patients are predisposed to phlebitis or an inflammation in the veins of the legs that can cause blood clots to go to the lung. Because of the lack of mobility and lack of normal sensation to the skin, patients also are predisposed to developing pressure sores or so-called decubitus ulcers. These often require major surgical procedures if they become deep enough.

In addition to the medical problems that occur after a spinal cord injury, the patient also undergoes tremendous psychological difficulties. At first patients may deny that they have had a severe injury; for a time they often become severely depressed and finally they normally accept the reality of their circumstances and attempt to live with them in the best way they can.

Depending on the level of the spinal cord injury, some patients require long-term care. A special automobile that can be used with hand controls, especially a van enabling a patient to get in and out of the van in a wheelchair, may be required. The level of the problem will determine how self-sufficient a patient can be. Obviously the long-term medical costs are horrendous in a problem of this nature. With modern

medical care often patients with quadriplegia can live almost a normal life expectancy. Many of the injured are young men who may live for fifty to sixty years, requiring $50,000 to $100,000 of medical care per year. After a spinal cord injury, a patient is usually sent to a rehabilitation hospital for two to four months. They learn to live with the level of disability they have so that they can be as self-sufficient as possible.

At this time, we do not have good treatments for severe spinal cord injuries. Only a small percentage of patients can be helped by surgery. The outcome usually depends on the amount of force actually delivered to the spinal cord at the moment of impact. In experimental animals, the use of cortisone and of other drugs has led to some improvement in conditioning, but as yet none of these treatments has been shown to be effective in man. As in many medical problems, therefore, prevention of injury is most important. Second in importance, in neck injuries accompanied by severe neck pain, is to assume that a neck fracture is present; the neck should be immobilized so no further damage will be done. In the case of a neck injury that becomes progressively worse after the accident, a blood clot or a fragment of bone or disc may be pressing on the spinal cord; the clot can be surgically removed to prevent further nerve damage. Paramedical personnel and lifeguards are now training the recognize the injuries; as a results, victims necks can be immobilized at the scene of the accident.

The cost to society, the medical cost to the individual and his family, and the severe psychological damage resulting from these injuries is beyond a dollar value.

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HEALTH CARE COSTS ASSOCIATED WITH SPINAL CORD INJURY

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INTRODUCTION

No reliable statistics pertaining to the cost of care for the spinal cord injured exist at the present time. Part of the reason for this lies with the fact that systematic data gathering began only 10 years ago and included only those patients served at specific spinal cord injury centers. Although there are over 6,000 reported cases in the National Spinal Cord Injury Data Research Center data bank, little focus has been placed upon actual cost factors (Young and others, 1982). In my private practice as a rehabilitation nurse consultant, I have had an opportunity to manage the care of many such individuals, thus becoming aware of the dollars expended in their care.

The health care costs associated with spinal cord injury are overwhelming to the patient, the family, the third party payer and society at large. It has been estimated that spinal cord injury costs American society $3,000,000,000 annually (Young and others, 1982).

Costs related to spinal cord injury care can be broken down into three phases: acute care costs, intermediate or rehabilitation care costs, and long term care costs. The following paragraphs will describe each of these cost areas in more detail.

ACUTE CARE COSTS

Nationally, the length of initial hospitalization appears to average approximately 5 months according to 1980 statistics (Young and others, 1982). This is consistent with my own experience in managing the medical care of spinal cord injured. During the most acute phase, the spinal cord injured individual is cared for in the Intensive Care setting, usually requiring 24 hour medical monitoring of such vital functions as respiratory, circulatory and renal. The length of stay in the ICU varies greatly (gross average is 7 to 21 days). The average cost of Intensive Care is approximately $3,000 per day.

Once the life-threatening crisis has passed, the patient is transferred to an acute medical/surgical bed for further stabilization. At about the 30th to 40th post-injury day the patient is transferred to the next phase of care -- physical rehabilitation. For many spinal cord injured, return to the Intensive Care Unit may be required if at any time their vital functions become compromised.

INTERMEDIATE REHABILITATION CARE COSTS

Once on the rehabilitation unit, patients are fully assessed by a multidisciplinary team and appropriate therapy (usually 3 to 6 hours per day, 5 to 6 days per week) is commenced. The therapeutic team includes but is not limited to: medical consultants, physical medicine and rehabilitation MD, physical therapists, occupational therapists, psychologists, counselors, recreational therapists, pharmacists, dieticians and nursing personnel. Due to the intensity of therapy, the low patient:caregiver ratio, and the high level of expertise of rehabilitation unit staff, hospital charges during this phase remain high despite the fact that the patient may be medically stable.

The average length of stay in the rehabilitation unit is approximtely 4 months. The approximate cost per day is $2,000 for the respirator assisted quadriplegic, $1,400 per day for the non-respirator assisted quadriplegic and $1,000 per day for paraplegics.

Once the patient leaves the rehabilitation unit and transition to community living, he/she may go directly home or reside for at least a few months in a transitional setting (frequently with relatives). Post-medical monitoring and out-patient therapy can frequently continue for another twelve months at an approximate cost of $1,700 per month.

LONG TERM CARE COSTS

Once the patient has reached maximum benefit from rehabilitation, he/she can then enter the final phase of long term care. The cost associated with day to day care (attendant care), medical monitoring for health maintenance, necessary equipment and supplies averages $100,150 per year. These costs do not remain static, but can rise and fall given such factors as: a change in health status (medical complications), social/environmental changes (emotional/psychological changes) and aging.

The following grid breaks down some of the more predictable costs associated with specific care categories. The figures outlined below represent an average annual estimate of the present day value of equipment, care and services required by 58 spinal cord injured clients from my 1985-1986 case load.

CATEGORY	ANNUAL COST
Medical Care	$15,399
Durable Equipment	$ 3,497
Pharmaceutical & Supplies	$ 6,484
Attendant Care	$71,482
Transportation	$ 3,298

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In addition to the annual costs listed above, there are numerous one-time expenditures for items such as hospital beds, patient lift devices, environmental control systems, wheelchair accessible housing, etc. These items can cost up to $35,000.

Although California is the second highest state for per capita health care expenditure in the United States (Purdy, 1983a), I have not found vast differences in overall health care costs from state to state. Comparison of these annual medical expenditures with those of the non-injured population can be startling. For example, in March of 1986 it was estimated that the per capita expenditure for personal health care in the United States was $1,561 (Parsons and others, 1986). As reported above, the average annual cost of personal health care expenditure for the spinal cord injured is $100,159.

Health care costs are not static. Although there are minor price fluctuations over time in the cost of services, equipment and supplies, the overall trend in valuation of health care is upward. "Various estimates suggest that between one-half and two-thirds of increase in health care expenditures is attributable to inflation" (Purdy, 1986).

Due to the staggering costs of caring for the spinal cord injured, many patients, families and third party payers make the mistake of "cutting corners" in their health care. "Management by crisis" often replaces prudent, ongoing medical monitoring. The injured begin to see their doctors less frequently and only when they perceive themselves as ill. As a consequence, their visits to the emergency room and acute hospital are more frequent. This pattern of behavior is ultimately more costly.

If one looks closely at the relative care costs, one finds that hospital charges have increased at the most dramatic rate. Intensive care unit costs are approximately 3.8 times more expensive than routine hospital care. On the other hand, MD fees have increased at the slowest rate (Purdy, 1983b). Therefore, it behooves the patient to see his/her caregivers regularly as a way of preventing these more costly expenditures.

Another hidden cost of spinal cord injury is the loss of productivity in the competitive labor market. Most of the individuals sustaining spinal cord injury are young males. Few have completed their educations. Most have no competitive work experience. The percentage of those individuals ultimately entering or re-entering the labor force is low. Few patients out of my private practice engage in gainful employment post-injury. Many eventually return to school, however. I suspect the reason for this is that the student status is socially acceptable and many campuses make necessary resources available to increase the injured's access to this environment, e.g., disabled student centers, transportation, note takers, etc.

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Comparison of pre-injury and post-injury employment as reported in Spinal Cord Injury Statistics (1973 to 1981 study) revealed that 17% of the spinal cord injured were working by four years post-injury. Additionally, more paraplegics returned to work than quadriplegics (Young and others, 1982). Despite nationwide efforts to break down barriers to employment for the disabled, the vast majority remain outside of the work place. While some support themselves through structured settlements arising out of litigation, most rely on state and federal entitlement programs as their sole source of income.

CONCLUSION

It is clear that further, more refined data collection is needed to accurately track the massive fiscal impact of spinal cord injury. The foregoing is meant to provide a sketch of the dollars needed to meet the basic health care needs of the spinal cord injured population.

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GOVERNMENT LIABILITY FOR OCEAN ACCIDENTS

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California governmental entities are being deluged with lawsuits arising from personal injuries at public recreation resorts. Most cases arise from patron activities which are dangerous and beyond supervisory control.

California governmental entities can be held legally responsible for a variety of specified acts and conditions as established by the legislature. But today, even people injured by wild animals and bodysurfing are filing lawsuits against their government.

Government Code § 835 sets forth the California rule with regard to public-entity liability for injuries caused by dangerous conditions of public property. That code section states:

> "Except as provided by statute, a public entity is liable for injury caused by a dangerous condition of its property if the plaintiff establishes that the property was in a dangerous condition at the time of the injury, that the injury was proximately caused by the dangerous condition, that the dangerous condition created a reasonably foreseeable risk of the kind of injury which was incurred, and that either:
>
> > "a) A negligent or wrongful act or omission of an employee of the public entity within the scope of his employment created the dangerous condition; or
> >
> > "b) The public entity had actual or constructive notice of the dangerous condition under Section 835.2 a sufficient time prior to the injury to have taken measures to protect against the dangerous condition."

Government Code § 835.2 defines "actual notice" as discussed in Government Code § 835. As defined, it requires "knowledge of the condition and notice of its dangerous character."

That section also defines "constructive notice." Constructive notice exists if the "condition had existed for such a period of time and was of such an obvious nature that the public entity, in the exercise of due care, should have discovered the condition and its dangerous character."

In order to prevent a situation where public entities would be liable for virtually all injuries occurring on public property, the legislature enacted Government Code § 831.2. This section, as drafted, provided immunity to governmental entities for injuries caused by natural conditions of public property. That code section states:

"Neither a public entity nor a public employee is liable
for an injury caused by a natural condition of any unimproved
public property, including but not limited to any natural
condition of any lake, stream, bay, river or beach."

But the protection the legislature granted public entities by
enacting Government Code § 831.2 was effectively emasculated by the
decision of the Fourth District Court of Appeal in Gonzales v. City of
San Diego (1982) 130 Cal. App. 3d 882.

In Gonzales, a woman drowned in a riptide while swimming at a
beach. The beach was served by City of San Diego lifeguards part of the
year. The guards were not present when she entered the ocean and
ultimately drowned. The family filed suit against the City alleging
negligent failure of the City to warn of riptides.

The Court of Appeal held that Government Code § 831.2 was
inapplicable because the situation described was a "hybrid dangerous
condition, partially natural and partially artificial in character."

The Court of Appeal further ruled that the natural-condition
immunity (Government Code § 831.2) was lost because the City had
provided public safety services. Ironically, if San Diego had never
provided lifeguards or other safety services, it would have been found
immune.

There are numerous beaches all along the California coastline which
are obviously dangerous. Our rugged shores are laden with large rocks,
buffeted by the crashing surf. These beautiful, natural wonders are
also favorite resorts for bodysurfers, boardsurfers and energetic
youthful swimmers.

At these beaches there are no lifeguard services, no warning signs,
nor any other protective measures utilized by governments to ensure
public safety.

The irony created by Gonzales was that, if an accident occurs at a
beach of this nature where there is a "known dangerous condition," the
government is immune from liability under Government Code § 831.2.
Because of the absence of protective services, the natural-condition
immunity remained intact.

However, the government was not afforded immunity when injuries
occurred at beaches which were carefully monitored for safety purposes.

When exhaustive safety precautions were present (i.e., lifeguard
services, public safety personnel, warning signs, etc.), and someone was
injured, then immunity could be denied. This was true even when no
dangerous conditions were actually known to exist.

Yet, under the Gonzales decision, when the government left beaches in a known dangerous condition and took no affirmative safety measures, it could be afforded immunity under Government Code § 831.2.

Clearly, governmental entities should be free to provide safety services without fear that by "voluntarily assuming the obligation" to do so, they have somehow inherited responsibility for injuries caused by the natural condition of public property.

In response to the effect of the Gonzales decision, the California Legislature has now enacted additional legislation which will reinstate the natural condition immunity of Government Code § 831.2. The new Government Code § 831.2.5 provides renewed protection to public entities who do attempt to undertake safety precautions. The act of providing services will no longer be a basis for rejecting the natural condition immunity created by the legislature.

If an entity provides services which create hazards, it must be prepared to answer for those hazards. But to the extent the injury was caused by the natural condition of the property, the immunity will again apply, whether safety measures provided were or were not effective.

Litigation arising from ocean diving accidents has become commonplace. Accidents which occur as a result of bodysurfing, board surfing and shockingly imprudent diving practices are quickly transformed into "plunging accidents into concealed sandbars." Detailed investigation nearly always establishes the absence of any bottom irregularity. In virtually each case, the patron either dives or finds himself contacting the flat bottom in extremely shallow water.

Virtually all accidents which occur on public beaches can be avoided. Most injuries involve imprudent activity by patrons. Virtually all such accidents involve some form of dangerous activity. If the activity is performed with skill or care, no injury will result. However, if inartfully or unreasonably executed, injuries can result.

From the perspective of a public entity, such injuries are tragic, but unavoidable. The new legislation provides public entities the freedom to undertake safety measures without the fear that positive effort to alleviate hazards will independently create additional liability.

LIABILITY OF PUBLIC ENTITIES ASSOCIATED WITH DIVING ACCIDENTS RELATED TO RIDGE AND RUNNEL SYSTEMS

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Contrary to the belief perpetrated by some public entities, it is the rare case in which a public entity can be held liable for injuries to persons running and diving into the ocean.

Rightly or wrongly, California law provides immunity to public entities for injuries to persons caused by natural conditions of unimproved property. The immunity applies even though the public entity knows of the dangerous condition, knows that catastrophic injury is likely to be caused by the condition and fails to warn users of the condition.

Thus, even where the condition is concealed, i.e. amounts to a trap to the unknowing, the public entity has specific knowledge of the condition and its dangerous character, knows someone will be injured by it and deliberately fails to warn about it, under California law the public entity cannot be held liable.

The legislative purpose of this immunity is to allow the public to open up unimproved public lands for use by the public in their natural condition without the burden and expense of taking action of protecting the public from injury.

However, liability is not barred where a public entity voluntarily assumes the responsibility of protecting the public with respect to the use of its property and negligently fails to perform that responsibility.

In order to be liable, the public entity must:

1. Voluntarily assume responsibility to protect the public;

2. It must negligently fail to perform that responsibility, i.e. it must fail to act as a reasonable person would act under the same circumstances; and

3. The injury must be caused by the negligent failure to act. Thus, if the public entity is not found negligent, liability cannot occur.

Negligence is defined as the doing of something which a reasonably prudent person would not do, or the failure to do something a reasonably prudent person would do under similar circumstances. It is the failure to use ordinary or reasonable care.

The mere voluntary assumption of lifeguard services does not make a public entity responsible for injuries occurring on its beaches.

The city must be found to have failed to exercise reasonable care in the performance of the lifeguard services. Thus, responsible public entities will not be found liable under California law.

A public entity that voluntarily assumes responsibility to protect the public cannot be found liable unless its failure to exercise reasonable care was a cause of injury. A cause of injury is defined as a substantial factor in bringing about the injury.

Thus, for example, a city which deliberately fails to warn of a known dangerous conditon, knowing people will be injured by its failure to warn, cannot be liable to an individual who would have ignored the warning, if given.

Under this circumstance, the failure to warn would not be a substantial factor in bringing about the injury. The injury would have occurred regardless of the warning. Thus, liability would not attach.

It is a myth that juries find liability when none exists.

Personal experience demonstrates that it is only in the case in which the public entity is irresponsible that the natural biases of people (who believe that if someone is injured by running and diving in the water that it is their own fault), can be overcome.

Those who oppose liability against cities, regardless of the entity's irresponsibility, speak in apocalyptic terms of city bankruptcies. They even argue that to require a city to invoke minimal protection against admitted hazards will result in the necessity to close public beaches.

However, these statements are exaggerations and untrue.

If beaches represent impermissible hazards to people when improperly managed and protected, then they should be closed, but no serious person suggests this is required.

All that the law requires is that where a public entity undertakes the responsibility to protect that it act reasonably under the circumstances, nothing more.

A public entity will not incur liability for dangerous conditions existing on its beaches, even where it assumes the responsibility to protect the public, unless it fails to exercise reasonable care.

It is thus the rare case in which a public entity will be found liable for someone injured as a result of diving and striking a sand bar.

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Responsible cities are protected from liability under California law, as they should be.

On the other hand, California provides a remedy to those injured as a result of the actions of irresponsible cities. The policy of the law is to compensate persons injured by the irresponsible acts of others. Cities are no exceptions.

BEACH MANAGEMENT ASPECTS

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INTRODUCTION

Shallow water diving incidents have been recorded on southern
California beaches since the early days of the first ocean lifeguards
and it is probably safe to assume that this type of injury occurred
infrequently long before this century.

The magnitude of the spinal injury problem in the total aquatic
environment (i.e., pools, lakes, beaches, rivers, parks, etc.) began to
surface in the 1960s and 70s and received national media attention in
the 1980s, primarily due to several civil liability cases and subsequent
judgments. While the number of severe spinal injuries resulting from a
victim running and diving into the surf probably only represents 5 to 10
percent of the known incidents, this study represents a good first step
in dealing with the problem and could have a significant impact in
dealing with the total spectrum of all aquatic spinal injuries. The
members of the Advisory Committee on Beach Management Aspects have been
dealing with aquatic spinal injuries in the ocean environment for over
30 years, and quite understandably already have formed many opinions
relative to the cause, prevention and cure of this type of injury.
However, it is the committee's intent to maintain total objectivity
during the course of the study and refrain from making any definitive
recommendations until all the facts are in. As a means of providing the
reader with an insight into the level of emergency services
being provided by southern California marine safety agencies, including
their training, public education and prevention programs, we offer the
following:

FORMAL TRAINING

Virtually all southern California marine safety and ocean lifeguard
services are members of the United States Lifesaving Association and
adhere to the USLA standard minimum 56 hour training program for entry
level recurrent personnel. The State of California Administrative Code,
Title 17, mandates that ocean and public beach lifeguards be trained and

satisfactorily complete prescribed first aid and cardiopulmonary resuscitation courses. Southern California lifeguard agencies meet and often exceed state requirements. The formal training includes a lengthy session on the management of suspected spinal injury, and in many areas this training is coordinated with local paramedic services. Throughout the year, periodic roll call training sessions are conducted and at these, spinal injuries are quite often the subject. During the past several years, Emergency Medical Technician 1 (EMT-1) certification has become the standard for most permanent lifeguards (i.e., marine safety personnel). It is also an unwritten policy in many areas that recurrent personnel having leadership roles or supervisory responsibilities and who operate backup units or are assigned as a deckhand on rescue boats, be certified EMT-1. In order to motivate lifeguards to enhance their medical aid capabilities, many lifeguard services now reward employees with additional pay upon proof of EMT-1 certification. Handling a suspected spinal injury victim in the ocean environment presents the lifeguard with additional challenges not normally present in other aquatic environments. Due to the additional hazards of surf, rip and lateral currents, inshore holes, sandbars, backwash, and other conditions, lifeguards along the coast of southern California have had to innovative in handling this type of injury. Many new techniques have been developed through experience and many others are certain to follow. In terms of personnel, equipment, emergency backup and medical resources in the impact area, the aquatic safety services in southern California are unequaled anywhere in the world, as attested by activity and attendance statistics.

PUBLIC EDUCATION PROGRAMS

Southern California lifeguard agencies have improved their public education programs tremendously over the past 20 to 30 years, most significantly in the area of Junior Lifeguard programs where boys and girls aged 9 to 17 have the opportunity to receive training in all aspects of marine and ocean safety including developing a keen awareness of the hazards of the ocean environment. Where funds are available, some lifeguard agencies also conduct safety programs for local schools and service clubs, and many issue safety pamphlets and coloring books for small children. Local cable television also has been a great vehicle in recent years for the airing of public safety announcements. It is considerably more difficult to get air time on commercial stations, but some headway has been made in this area in Los Angeles and San Diego Counties. In response to the growing number of aquatic spinal injuries being treated at Hoag Hospital in Newport Beach, California, the hospital developed a film entitled "Wipe Out" which depicts the hazards of striking one's head on the bottom of the ocean and sustaining a debilitating injury. This film emphasizes the great personal tragedy of such an injury, not only to the victim, but also to family members and friends.

LIFEGUARD PREVENTION PROGRAM

In a further attempt to prevent injuries before they occur, lifeguard agencies currently have several methods for making direct contact with the beach public. Signs on public beaches warning bathers of ocean hazards such as rip currents, inshore holes, sandbars, and other conditions, have, over the past few years, become commonplace. Many agencies even have international signs warning against diving into the ocean waters head first. Most services also have the ability to make public address announcements where necessary, and all have the ability to make personal contact with beach users engaged in hazardous activities. Unfortunately, with thousands of people visiting southern California beaches daily and relatively few lifeguards, it is impossible to communicate individually with every beachgoer.

SUMMARY

Spinal injury accidents on southern California beaches, which seem to have peaked in 1983, still remain a considerable concern to all of us in the marine safety profession. Certainly the number of more severe injuries would be even greater if not for the improvements made in recent years in medical aid equipment and medical emergency room facilities. Despite having more highly trained lifeguards working ocean beaches and more diligent prevention programs, there is still a great need to further reduce the number of spinal injuries in the aquatic environment. The impact of beach signs as a means of reducing aquatic injuries on vast open beach areas in southern California or elsewhere is a subject of much controversy. While their existence has already been proven to be of significant value in defending a civil action based on "failure to warn", their actual effectiveness in reducing injuries has never been evaluated. It is hoped that this study will enable us to gain further insight into why these incidents are occurring and how we can best prevent them.

BIOGRAPHIC SKETCHES OF AUTHORS

GERRY ASTER

Gerry Aster has been a registered nurse in California since 1969 and has specialized in rehabilitation from 1973 to the present. Her nursing background combined with a master's degree in rehabilitation counseling enables her to provide a variety of services to the disabled and their families. Since 1983, she has maintained a private practice through which she provides medical management, vocational rehabilitation, and supportive counseling services. A third of her practice is devoted to assessing the long-term care needs of the catastrophically injured and providing expert testimony related to these needs.

WAYNE J. AUSTERO

Wayne J. Austero is a member of the law offices of Herbert Hafif in Newport Beach, California. He is a trial lawyer specializing in damages cases including cases involving public entities. He and Mr. Hafif represented the plaintiff in Taylor v. City of Newport Beach, wherein the city was held liable to the plaintiff (who was rendered a quadriplegic) due to the city's negligent failure to warn of the existence of dangerous hidden sand bars.

KATHI K. BERATAN

Kathi K. Beratan is a doctoral candidate in Geological Sciences at the University of Southern California. She received her master's degree in Geology from the University of North Carolina at Chapel Hill. Her current research interests are terrestrial depositional systems, particularly those of arid regions, and the effects of tectonic activity on such systems.

DAVID B. CASSELMAN

David B. Casselman is a senior partner in the twenty-five-member law firm of Wasserman, Comden & Casselman. He is a graduate of the University of Michigan with distinction and Southwestern University School of Law. Mr. Casselman is trial counsel for the County of Los Angeles, the City of Newport Beach, and various other public entities, corporations, and insurance companies. He has developed a specialty practice in the field of government liability, with broad experience in the trial of ocean-related accident cases.

DOUGLAS D'ARNALL

Douglas D'Arnall is Beach Services Manager for the City of Huntington Beach, California. A certified emergency medical technician and World Lifesaving International training officer, he edited the U.S. Lifesaving Association's publication "Lifesaving and Marine Safety," and served on the editorial committee for the American National Red Cross publication "Basic Lifeguarding."

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Gilbert E. Lee is Marine Education/Recreation Specialist at the University of Southern California Sea Grant Program. He has a B.A. in Geology from Occidental College in Los Angeles and an M.S. in School Administration from the University of Southern California. He was a science specialist with the Los Angeles Unified School District for 36 years, and a beach lifeguard with the Los Angeles County Department of Beaches and Harbors for 33 years.

HOWARD A. LEE

Howard A. Lee is Assistant Chief Lifeguard for the Los Angeles County Department of Beaches and Harbors. He has served as an ocean lifeguard since 1953; the last twelve years in beach safety management. His principal duties include budgetary matters, recruitment and training of lifeguards, developing ocean rescue systems, and coordinating lifeguard response to major emergencies.

ROBERT H. OSBORNE

Robert H. Osborne is a professor of sedimentary petrology at the University of Southern California, where he is serving as Chairman of the Department of Geological Sciences and Director of the Center for Earth Sciences. He received a Ph.D. degree from Ohio State University in 1966, when he joined the USC faculty. His principal research interests at this time include the identification and quantification of ultimate and local sand sources and associated transport paths for use in sediment budget analyses for beach sand. He has served as an expert witness in beach sedimentology for several cases involving shallow-water, plunging-dive accidents.

THOMAS ROGERS

D. Thomas Rogers, Newport Beach neurosurgeon, became very interested in cervical spine problems because of the large number of neck injuries occurring at nearby beaches. Dr. Rogers, a board-certified neurosurgeon, attended medical school at Duke University in Virginia, and completed his neurosurgical residency at Huntington Hospital in Virginia.

GREG SUPER

Greg Super is acutely aware of cervical spine problems due to his treatment of diving injuries related to shifting sand bars in shallow water. As Director of Emergency Services at Hoag Memorial Hospital in Newport Beach, he frequently sees this type of injury. Dr. Super received his M.D. degree from Washington University School of Medicine in St. Louis, Missouri. He completed his medical internship at Washington University Hospital and Clinics, and his emergency medicine residency at the University of Southern California.

BIOGRAPHIC SKETCHES OF AUTHORS, CONT'D.

<u>CARLEY C. WARD</u>

Carley C. Ward is founder and president of Biodynamics/Engineering, Inc. She is also Research Engineer for the University of California, San Diego, Medical School; and Deputy Coroner with the Los Angeles County Medical Examiner's Office. She received her Ph. D. degree in Structural Dynamics and Deformable Solids from the University of California, Los Angeles, and her B.S. in Mechanical Engineering and M.S. in Engineering Mechanics from the University of Michigan.