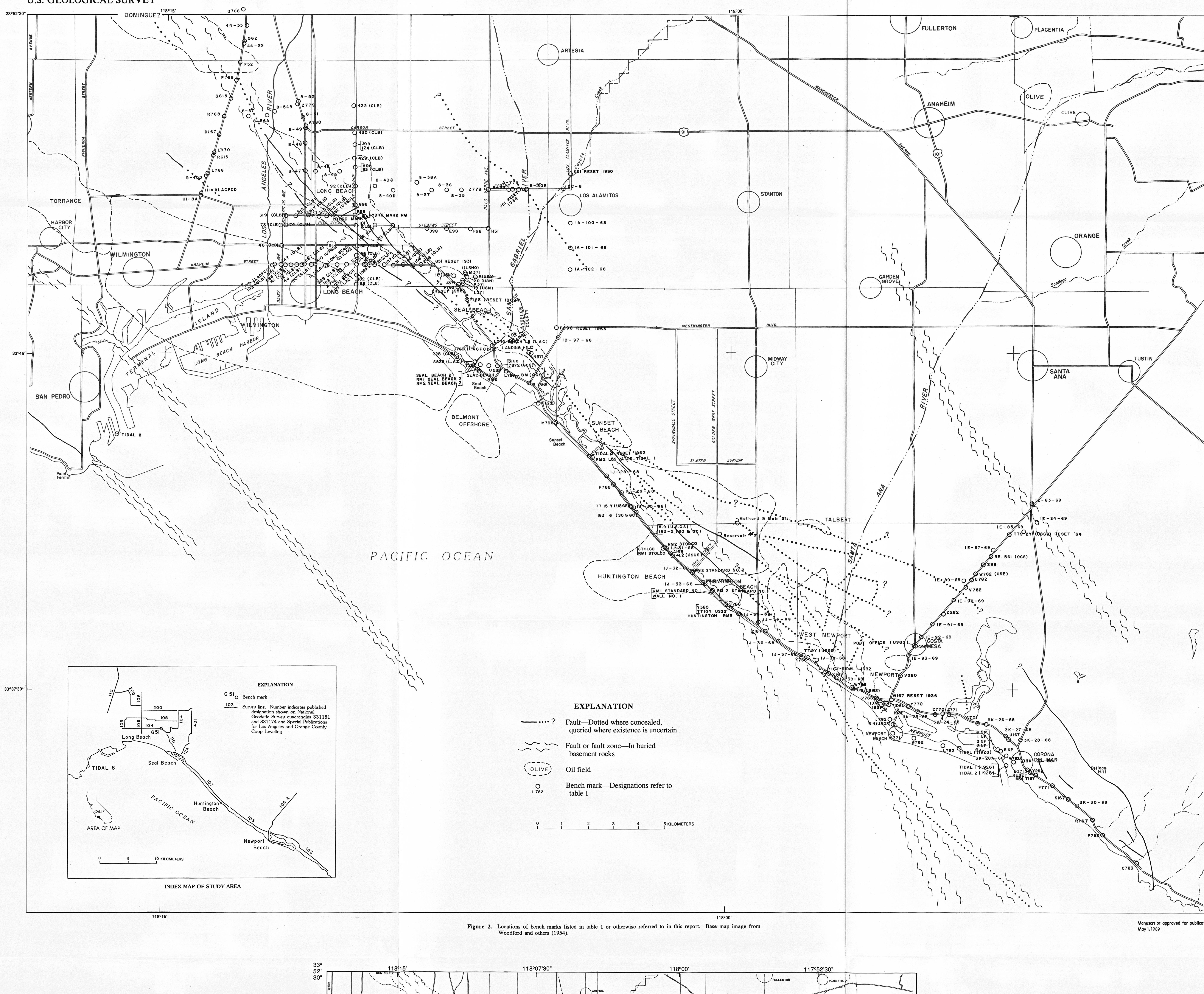

Figure 2. Locations of bench marks listed in table 1 or otherwise referred to in this report. Base map image from Woodford and others (1954).

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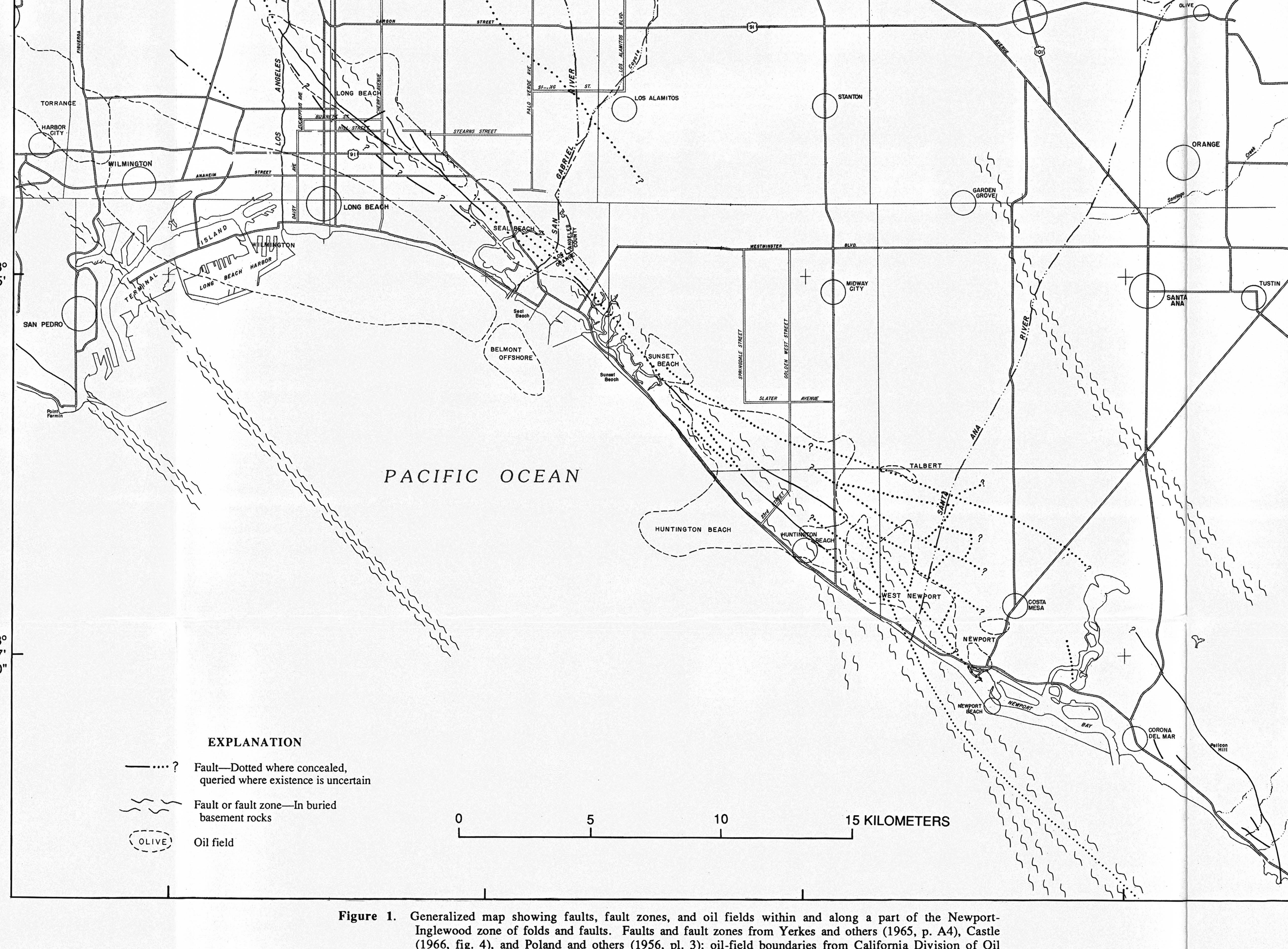

Figure 1. Generalized map showing faults, fault zones, and oil fields within and along a part of the Newport-Inglewood zone of folds and faults. Faults and fault zones from Yerkes and others (1965, p. A4), Castle (1966, fig. 4), and Poland and others (1956, pl. 3); oil-field boundaries from California Division of Oil and Gas (1961).

VERTICAL SURFACE DISPLACEMENTS ALONG A PART OF THE NEWPORT-INGLEWOOD ZONE OF FOLDS AND FAULTS, LOS ANGELES AND ORANGE COUNTIES, CALIFORNIA

By

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1989

INTRODUCTION

During the past half century, the onshore section of the Newport-Inglewood zone of folds and faults between the Dominguez oil field and Corona del Mar (fig. 1) has been repeatedly leveled to geodetic standards. These essentially fortuitous surveys are unrelated to either the tectonic framework or the urbanization of the Los Angeles basin, but were established instead because the Newport-Inglewood zone southward from the Long Beach area is roughly coincident with the coastline--and, hence, is roughly coincident with a naturally defined leveling route. Although there have been several relevelings athwart this zone north of the Long Beach area, notably in the Baldwin Hills area (Castle and Yerkes, 1976), about 25 km to the northwest, the survey density, in both space and time, diminishes markedly northward. Thus, the results of the indicated relevelings along the Los Angeles-Orange County coast have permitted the relatively detailed appraisal of historic vertical surface movements described in this report.

The Newport-Inglewood zone of folds and faults forms the surface expression of a major crustal boundary separating the Peninsular Ranges province on the east from the Continental Borderland province on the west (Castle and others, 1984, p. 8-9, pl. 1). Transcurrent fault movement along this boundary has produced not only continuing seismic activity, for which this zone is justly famous, but also folds and other structural features within the sedimentary veneer that have entrapped the petroleum deposits for which the Newport-Inglewood zone is even more famous. Although the northeast boundary of the exceptionally prolific Wilmington oil field is roughly coincident with the southeast edge of the Newport-Inglewood zone, we have deliberately excluded this area from consideration—in other than a peripheral way—simply because compaction-induced subsidence centering on the Wilmington field is viewed as a singularly spectacular example of this phenomenon and, hence, has been the subject of a series of detailed investigations (Harris and Harlow, 1947; Gilluly and Grant, 1949; Hudson, 1956; Miller, 1966; Poland and Davis, 1969; Allen and Mayuga, 1970; Castle and Yerkes, 1976).

VERTICAL-CONTROL DATA

Although several geodetic levelings were propagated northward from San Pedro beginning as early as 1897 (U.S. Geological Survey, 1898, p. 382; Gannett and Baldwin, 1908, p. 69-70), it was not until 1926 that any levelings included more than one or two marks athwart the Newport-Inglewood zone. Moreover, the 1932 levelings were the first that extended along virtually the entire length of that part of the zone considered in this report. Since 1932, survey routes along the Newport-Inglewood zone southeastward from the Dominguez oil field have been releveled, in whole or in part, no less than six times.

The index map accompanying figure 2 identifies first-order leveling routes by the line numbers given in the published reports of the National Geodetic Survey (or its predecessor, the U.S. Coast and Geodetic Survey), which list adjusted elevations or heights rather than less ambiguously defined observed elevations. The basic data used in the development of the successive vertical-displacement fields shown here consist chiefly of rod-corrected observed elevation differences—which are treated here as the equivalents of true orthometric height differences (see Vanicek and others, 1980, p. 510-513). All of the observed elevation differences in turn (table 1) have been reconstructed with respect to bench mark Tidal 8, San Pedro, as invariant in height (table 1 and fig. 2). Bench mark Tidal 8 is located adjacent to the primary tide station at San Pedro, a station that has been characterized by a history of relatively positive movement with respect to most other California tide stations (Hicks and Crosby, 1974, p. 5). Accordingly, height changes referred to Tidal 8 are biased toward the recognition of subsidence and against the recognition of uplift.

MEASUREMENT ACCURACY

Nearly all the elevation differences on which the reconstructed elevations are based (table 1) have been obtained from first-order levelings. Exceptions to this generalization consist of 1932 and 1941 values obtained from third-order levelings extending southeastward from bench mark G51, Long Beach, and 1968 and 1974 differences based on a mix of first- and second-order leveling extending eastward to near G51 and adjusted with respect to Tidal 8. The results of the 1932 and 1941 network (or partial network) levelings were adjusted with respect to bench mark G51, for which successive starting elevations depend on observed elevation differences obtained from first-order leveling emanating directly from Tidal 8.

Errors in height differences based on geodetic leveling may be categorized as (1) systematic errors, (2) those attributed to inaccurately formulated orthometric corrections, (3) blunders, and (4) random error. Those errors with which we are chiefly concerned here are blunders and random error.

Systematic errors tend to accumulate as a linear function of distance (for example, staff settlement) or height or height gradient (for example, rod or refraction error) (Vanicek and others, 1980, p. 506-507). Because errors attributable to staff settlement tend to cancel in double-run leveling (Bomford, 1971, p. 240, 243), the 1932 and 1941 single-run, third-order surveys are the only ones that may have been significantly contaminated by errors of this type. Nevertheless, even if it is assumed that this error accumulated at the exceptionally high rate of 1 mm/km, the result would be an accumulated error between Long Beach (G51) and Newport Beach of no more than about 50 mm. Similarly, because the terrain traversed by these surveys is generally close to sea level and almost nowhere exceeds heights of 50 m (table 1), height- or slope-dependent errors associated with any of the levelings considered in this study are negligible in comparison with the estimated random error. Errors attributable to inaccurately formulated orthometric correction can be dismissed in the context of this report for two reasons. (1) This investigation is directed toward an assessment of height changes rather than the heights themselves. Because most of the compared heights are based on levelings over the same route on which the gravity-dependent orthometric correction relies, and because these corrections are insensitive to temporal variations in gravity (Vanicek and others, 1980, p. 516-517), any errors in height differences associated with inaccurate orthometric corrections will be nearly completely nullified. (2) Height differences within the area of concern are measured in meters or several tens of meters. Because the orthometric correction is a function of height difference as well as the Earth's gravity field (Vanicek and others, 1980, p. 511-512), this correction is necessarily very small (in millimeters or tenths of millimeters) within the study area. It is so small, in other words, that any errors in the orthometric corrections applicable to the results of levelings over the modestly disparate, yet generally coincident routes along the axis of the Newport-Inglewood zone can be safely ignored (see below).

Blunders and random error generally can be identified and estimated, respectively, with a relatively high degree of confidence. The existence of a major blunder (usually attributable to either a whole-foot or decimeter misreading or comparable recording error in the field notes) can be searched for in the following ways: (1) The detection of above-limits circuit misclosures in any network leveling invites the suspicion of a blunder in one or more of the involved circuits. (2) Comparisons of old versus new levelings, where an even 1-ft (0.3048-m) or any unusually large and unanticipated offset occurs between adjacent marks virtually guarantees the occurrence of a blunder, particularly if either of the levelings was single run (double-run leveling nearly always precludes the occurrence of blunders). Because both the 1932 and 1941 networks extending southeastward from G51 met third-order closures, even though the circuits that define these networks locally are tied by single-line connections, it is unlikely that any major blunders have contaminated the results of the only potentially suspect levelings included with this report. Similarly, the fact that comparisons of the results of both the 1932 and 1941 levelings against later (first-order) surveys disclose no sharply defined steps or offsets also argues against significant blunders in any of these levelings.

Random error for various orders and classes of leveling traditionally has been estimated from statistical examination of section closures (that is, the differences between forward and backward runs in double-run leveling). Where the error is assumed to be approximately normally distributed, the standard deviation associated with the random error in the measured elevation difference between two bench marks L distance apart is given as $\alpha L^{1/2}$, where α and L generally are given in units of mm/km$^{1/2}$ and km, respectively. The experience of the National Geodetic Survey with first-order leveling indicates that since 1917 and prior to 1956, α was about 1.5 mm/km$^{1/2}$, whereas since 1956, it has been about 1.0 mm/km$^{1/2}$ (or less) (Vanicek and others, 1980, p. 507). Similarly, the experience of the National Geodetic Survey with second-order leveling indicates that since 1956, α has been about 2.0 mm/km$^{1/2}$ and that of the U.S. Geological Survey with third-order leveling indicates that prior to 1956, α was about 6.0 mm/km$^{1/2}$ (Vanicek and others, 1980, p. 507-508). Thus, in comparing elevations based on repeated surveys over the same or nearly coincident routes, one standard deviation in the discrepancy between successively measured elevation differences between two bench marks 50 km apart (about the length of the survey route between bench mark Tidal 8 and Corona del Mar) would be about 10 mm, where both surveys consisted of post-1955 first-order levelings (1968-74). This figure would enlarge to our worst-case value of about 35 mm, where one survey consisted of a combination of a 20-km segment of pre-1956 first-order leveling and a 30-km segment of pre-1956 third-order leveling, and the second survey consisted of pre-1956 first-order leveling (1932-33).

DISCUSSION

The results of our comparisons among successively determined observed elevations along the Newport-Inglewood zone (table 1) are presented here as a series of maps showing vertical displacements during selected periods (fig. 3, maps A-G). The indicated period depends directly on the dates of the irregularly spaced levelings propagated southeastward from Long Beach as far as Corona del Mar. The control on which these reconstructions are based differs from period to period; the bench-mark distribution constraining the reconstruction is indicated for each period.

The configuration of the vertical-displacement field shown for each period is highly generalized and clearly could be drawn in a variety of ways, and, in one case, we actually present two interpretations. Nevertheless, and however fanciful, these representations are generally far more useful than tabulated or even profiled height changes. Moreover, because all of the basic data is contained in the body of the report, the user may reconstruct not only the maps shown here, but add to this series by including still other leveling results. Our ultimate purpose, of course, is to summarize both the significance and limitations of the contoured vertical-displacement maps and to characterize the origins of these displacements as explicitly as possible.

1926-32

The displacement field based on the extremely limited number of marks common to both the 1926 and 1932 leveling is equally limited in its significance (fig. 3, map A). Probably its chief value rests in its characterization of the activity (or inactivity) along the Newport-Inglewood zone in advance of the 1933 Long Beach earthquake. Secondarily, the displacement field demonstrates the occurrence of subsidence around the flanks of the Long Beach oil field, which began production in 1921 and reached peak production of oil within two years (Ingram, 1968, p. 7, 14; see also table 2 and fig. 4, this report). In fact, however, although the isobases shown in the series of maps included with this report are based on the most objective reconstruction possible, it is likely that the 1926-32 contours should be shown as trending northwestwardly in such a way that they more closely match the outlines of the oil field.

1932-33

The height changes that occurred within the period 1932-33 consist almost exclusively of coseismic displacements that accompanied the 1933 Long Beach earthquake. This earthquake, the only $M \geq 6$ shock known to have occurred within the study area during this century (fig. 5), was identified with a predictable right-lateral focal mechanism, where the slip plane was approximately parallel to the trend of the Newport-Inglewood zone (Woodward-Clyde Consultants, 1979, Appendix E, fig. E-10).

Two interpretations of the 1932-33 displacement field are shown here (fig. 3, maps B and B.1), both of which are in reasonably good agreement with that given by Gilluly and Grant (1949, p. 468) but which enlarge upon this earlier interpretation of coseismic deformation. Regardless, the 1932-33 interpretations are generally inconsistent with what we would have predicted from what is known of the structural configuration of the now-disrupted sedimentary cover along the Newport-Inglewood zone, and with theoretical expectations and various experimental studies (see, for example, Harding, 1973). That is, the fold axes along the Newport-Inglewood zone trend in a more westerly direction than does the zone itself and, hence, in a way that is consistent with wrenching produced through right-lateral slip in the crystalline basement (Harding, 1973). The surface folding shown in the interpretation for 1932-33 (fig. 3, map B) and along the northern half of the alternative interpretation for 1932-33 (fig. 3, map B.1) trends more nearly along or even easterly of the trend of the zone and is, in this sense, clearly at variance with what we would have anticipated. Moreover, the surface folding crests eastward of the fold crests in the subsurface, particularly in the area adjacent to the Long Beach and Seal Beach oil fields (and, less definitively, adjacent to the West Newport field as well).

Compaction-induced subsidence attributable to fluid withdrawal could hardly be expected to appear as a significant feature where its recognition is based on only a one- or two-year leveling window. In fact, however, subsidence centering on the Huntington Beach oil field, which began operations in 1920 and reached peak oil production in 1933 (Hazenbush and Allen, 1958, p. 15, 25; see also table 3 and fig. 6, this report), is clearly identified in the 1932-33 comparison. Subsidence over the Long Beach oil field, on the other hand, was expressed—if at all—by no more than a modest steepening of the isobases where they straddle the field.

1933-41

The displacements that dominate the 1933-41 pattern of height changes along the Newport-Inglewood zone (fig. 3, map C) are associated largely or entirely with oil-field operations, particularly in and around the Huntington Beach field. The vertical displacements within the northern part of the study area define the east edge of the Wilmington subsidence bowl and clearly document relatively modest differential subsidence centering on the Long Beach field and, less certainly, the Seal Beach oil field as well. Although the likelihood of a tectonic contribution to the 1933-41 vertical displacement pattern cannot be categorically dismissed, nothing is disclosed in the 1933-41 displacement field that could not be reasonably attributed to oil-field operations.

1933-68

The height changes that occurred within the 35-yr period 1933-68 (fig. 3, map D) are largely consistent with what we might have anticipated. The movement pattern is again dominated by the effects of continuing oil-field operations, although there is evidence as well of modest tectonic activity. Even though we have deliberately avoided, as stated at the outset, any attempt at characterizing the movement centering on the Wilmington oil field, the subsidence domain associated with production from the Wilmington field clearly invades the northern part of the area examined in this report. The compaction associated with operations in the Wilmington oil field could, for example, be responsible for the subsidence (measured with respect to Tidal 8) over the Seal Beach oil field--either through edgewater migration or downdrag of the section adjacent to the producing part of the Wilmington field. Partitioning of the subsidence over the Long Beach oil field between that attributable to production from the Long Beach field and that associated with operations in the Wilmington field is, perhaps, even more challenging. That is, if we refer the subsidence over the Long Beach oil field to Tidal 8, it suggests that through the period 1933-68 the Long Beach field sustained subsidence associated with compaction of the underlying oil measures of the order of 0.7 m. However, because subsidence identified with operations in the Wilmington oil field extended well east of the Long Beach oil field, *differential* subsidence over the Long Beach field--and, hence, that attributable to operations within this field (table 3 and fig. 6)--may have been no more than about 0.3 m. On the other hand, subsidence over the Huntington Beach oil field, whether referred to Tidal 8 or nearby bench marks to the south, was certainly no less than 0.9 m and probably well in excess of 1.0 m through the period 1933-68.

Because this period encompasses about a third of a century, and because the bracketing surveys were both run to first-order standards, the modest downwarp of the area around Corona del Mar probably is a valid expression of tectonic deformation. However, because Tidal 8 is known to be rising with respect to other southern California tide stations (see above), the "absolute" tectonic subsidence of Corona del Mar during the period 1933-68 may have been only a fraction of that shown here.

1945-68

The 1945-68 vertical-displacement pattern (fig. 3, map E) is similar in form to that developed during the period 1933-68 (fig. 3, map E). However, and perhaps because the period 1945-68 represents a smaller time slice, this comparison discloses at least one additional association that is obscured in the 1933-68 map. Specifically, although the form remains poorly defined, differential subsidence over the Seal Beach oil field is more certainly determined for this period than it is for any other period considered in this report. Moreover, the 1945-68 comparison demonstrates that the estimated 1933-68 subsidence of 1.0 m centering on the Huntington Beach oil field is certainly realistic--if not truly conservative. Finally, the 1945-68 tectonic subsidence within and around Corona del Mar of 0.04-0.06 m is about that which would have been predicted from the 1933-68 value, a point that testifies to the accuracy of the measurements that define the vertical displacements described in this report.

1955-68

The displacements disclosed by a comparison between the 1955 and 1968 levelings (fig. 3, map F) are comparable to those that occurred within the period 1945-68. The chief and perhaps the only value of this representation lies in the greater detail brought out in the Newport-Corona del Mar area.

1968-74

The relatively short period 1968-74 (fig. 3, map G) was selected for examination chiefly because the dense distribution of data and resulting detail permit the discrimination of features that might be obscured over longer intervals.

Probably the most noteworthy change that occurred within this period, as contrasted with the earlier intervals, is the near cessation (or reversal) in the subsidence centering on most of the oil fields in this area. This cessation is attributable chiefly to water flooding associated with secondary recovery operations. For example, the rebound, which is shown as having occurred along the north edge of the Wilmington field, is almost certainly due to massive water flooding--which by the end of 1974 had amounted to nearly 5 billion bbl (California Division of Oil and Gas, 1975, p. 137). In fact, about the only place where the subsidence did not seem to be nearly completely arrested was along the south end of the West Newport field. Whether or not any tectonic activity is masked by these artificially induced movements is problematic. Nevertheless, with the exception of the continuing downwarp in the Corona del Mar area, there is no reason for believing that any measurably significant fraction of the 1968-74 displacements is other than the product of continuing oil-field operations.

CONCLUSION

The relatively simple comparisons developed in this report demonstrate that the geodetic measurements that comprise the historic vertical-control record in this area are of sufficient accuracy that they permit the detection of even very modest height changes. Nearly all of the height changes described here are either coseismic in origin or associated with oil-field operations. However, by such time as the elastic component of compaction resulting in surface subsidence has been completely recovered through water flooding or other repressurization techniques (where it is necessarily assumed that the reservoir pressures are maintained throughout the productive life of the indicated oil fields), a large fraction of any height changes beyond this time are apt to be associated with continuing aseismic tectonic activity along the Newport-Inglewood zone of folds and faults.

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Table 1. *Sequentially determined elevations for bench marks along selected lines within the onshore section of the Newport-Inglewood zone of folds and faults*
[Elevations in meters with respect to Tidal 8 at 3.392 m. Line and quadrangle designations refer to index map, fig. 2]

Line 200; Quad 331181

Bench mark	Apr. 1968-June 1969	July 1973-July 1974
8-57	9.598	9.598
8-56A	16.400	16.395
8-54B	17.432	17.421
8-52	12.249	12.235
Z779	13.404	13.390
8-51	28.126	28.113
A780	29.763	29.749
8-49	31.246	31.235
8-48	33.649	33.638
8-47	26.811	26.816
8-46	26.533	26.531
8-45	21.005	20.988
8-40C	14.236	14.219
8-40D	10.683	10.665
8-38A	7.367	7.353
8-37	7.010	6.994
8-36	6.505	6.495
8-35	6.402	6.391
8-33	5.961	5.953
8-30B	9.910	9.897
CC-6	11.489	11.475

Line 401; Quad. 331181

Bench mark	Apr. 1968-June 1969	July 1973-July 1974
1A-100-68	5.781	5.768
1A-101-68	5.116	5.099
1A-102-68	4.203	4.183
1C-97-68	6.215	6.179

Line 106; Quad. 331181

Bench mark	Dec. 1931-Mar. 1932	Sept.-Dec. 1933	June 1941-Jan. 1942	July 1945-Mar. 1946	Apr. 1968-June 1969	July 1973-July 1974
26 (CLB)	13.049	13.082	---	12.898	12.829	---
182 (CLB)	10.515	10.563	---	10.383	10.108	---
196 (CLB)	7.274	7.332	---	7.145	6.899	---
30 (CLB)	5.807	5.864	---	5.667	5.412	---
101 (CLB)	38.534	38.605	---	38.391	---	---
G98	43.486	43.566	43.395	43.347	---	---
92 (CLB)	23.337	23.431	---	---	---	---
H98	18.119	18.228	---	18.032	17.686	17.661
93 (CLB)	---	---	---	16.587	16.255	16.219
429 (CLB)	17.322	17.429	---	17.246	16.928	---
J98	19.365	19.472	---	---	---	---
124 (CLB)	19.363	---	---	19.537	---	---
430 (CLB)	20.859	20.967	---	20.466	20.222	---
432 (CLB)	20.802	20.909	---	20.805	---	---

Line 124; Quad. 331181

Bench mark	Mar.-June 1949	Dec. 1954-Jan. 1955	Apr. 1968-June 1949	July 1973-July 1974
N371	13.292	13.228	13.099	13.067
F898 Reset 1963	---	2.208	2.087	---

Line 110; Quad. 331181

Bench mark	Sept.-Dec. 1933	June 1941-Jan. 1942	July 1945-Mar. 1946	Mar.-June 1949 [11]	Dec. 1954-Jan. 1955	Apr. 1968-June 1969
Y766 Reset 1955	---	---	23.512	23.462	23.386	23.281
F168 Reset 1962	5.759	5.694	5.649	5.596	5.513	---
Long Beach L6 (LAC)	---	4.830	4.831	4.782	4.716	---
U766 (LACFCD)	---	4.804	4.807	4.757	4.690	---

Line 105; Quad. 31181

Bench mark	Dec. 1931-Mar. 1932	Sept.-Dec. 1933	June 1941-Jan. 1942	July 1945-Mar. 1946	Apr. 1968-June 1969	July 1973-July 1974
47 (CLB)	3.896	3.897	3.741	3.643	3.476	3.561
46 (CLB)	3.202	3.186	3.041	3.965	---	---
73 (CLB)	4.239	4.259	4.137	4.090	---	---
74 (CLB)	4.041	4.067	3.942	3.885	---	---
319 (CLB)	4.541	4.579	4.459	4.408	---	---
318 (CLB)	4.641	4.669	4.540	4.487	---	---
317 (CLB)	6.047	6.093	5.970	5.920	---	---
316 (CLB)	7.009	7.050	6.915	6.863	---	---
S52 (USGS) -315 (CLB)	14.491	14.540	14.391	14.337	---	---
B98	51.856	51.917	51.742	51.692	51.395	---
Hydro Mark	109.098	109.166	108.991	108.941	---	---
Hydro Mark RM	109.231	109.301	---	---	---	---
102 (CLB)	69.155	69.233	69.081	69.034	---	---
103 (CLB)	20.096	20.205	20.067	20.030	---	---
D98	8.408	8.561	8.476	8.453	---	---
E98	4.990	5.153	5.087	5.072	---	---
F98	5.024	5.189	5.133	5.124	---	---

Line 115; Quad 331181

Bench mark	Aug. 1926 [1]	Aug. 1931-May 1932 [2]	1933-1934 [3]	July 1945 [4]	Mar. 1955 [5]	Apr. 1968-June 1969 [13]	July 1973-July 1974 [14]
111-8 LACFCD	---	5.372	5.362	5.221	5.784	---	---
111-8A	---	---	---	---	---	5.713	5.728
5-40D	---	---	---	---	---	6.784	6.803
L-768	---	---	---	5.796	5.633	---	---
R-615	---	---	---	7.264	7.141	---	---
L-970	---	---	---	---	---	8.243	8.254
D-167	---	---	9.703	9.599	9.491	9.392	9.403
R-768	---	---	---	8.454	8.333	8.205	---
S-615	---	---	---	10.834	10.714	---	---
P-768	---	---	---	13.281	13.167	---	---
F-52	15.504	15.416	15.412	15.282	15.143	---	---
44-32	---	---	---	16.367	16.221	---	---
56Z	---	---	---	17.020	16.862	---	---
44-33	---	---	---	19.494	19.335	---	---
Q768	---	---	---	18.546	18.370	---	---

Line 104; Quad. 331181

Bench mark	Jan.-Aug. 1926 [6]	Dec. 1931-Mar. 1932 [7]	Sept.-Dec. 1933 [8]	June 1941-Jan. 1942 [9]	July 1945-Mar. 1946 [10]	Mar.-June 1949	Dec. 1954-Jan. 1955 [12]	Apr. 1968-July 1969	July 1973-July 1974
1-3 (LACFCD)	---	---	---	4.288	4.156	---	---	---	---
192 (CLB)	---	2.182	2.162	1.988	1.869	---	---	---	---
D51	3.896	3.756	3.766	3.618	3.522	---	3.165	---	---
568 (CLB)	---	---	---	---	7.502	---	---	---	7.283
191 (CLB)	---	10.094	10.106	9.969	9.882	---	9.566	9.528	9.616
12 (CLB)	---	11.308	11.328	11.194	11.114	---	10.821	10.915	11.001
44 (CLB)	11.705	11.569	11.590	11.459	11.382	---	11.111	11.054	11.141
567 (CLB)	---	---	---	---	11.627	---	11.364	---	11.583
190 (CLB)	---	11.241	11.267	11.141	11.068	---	10.823	10.740	10.916
A10 (USGS)	10.987	10.820	10.844	10.716	10.645	---	10.408	---	---
11 (CLB)	---	10.214	10.341	10.222	10.152	---	9.938	10.072	10.160
Long Beach C3 (LAC)	---	---	---	---	10.155	---	9.941	---	---
289 (CLB)	---	9.935	9.969	9.848	9.779	---	9.588	9.514	9.713
189 (CLB)	---	9.402	9.443	9.324	9.258	---	9.081	9.002	9.151
Z766	---	---	---	---	9.925	---	9.747	---	---
Long Beach D3 (LAC)	---	---	---	---	8.957	---	8.219	---	---
22 (CLB)	---	8.683	8.730	8.626	8.548	---	8.405	8.476	8.648
188 (CLB)	---	9.089	9.149	9.047	8.970	---	8.826	8.735	8.803
188A (CLB)	---	---	---	9.034	8.984	---	8.840	---	---
25 (CLB)	---	10.698	10.766	10.658	10.599	---	10.468	10.572	10.630
187 (CLB)	---	11.946	12.017	11.914	11.865	---	11.742	11.793	11.841
31 (CLB)	---	11.097	11.189	11.097	11.047	---	10.929	10.830	10.866
186 (CLB)	---	5.571	5.671	5.584	---	---	---	---	5.526
108 (CLB)	---	6.716	6.837	6.757	---	---	---	6.817	6.828
296 (CLB)	---	---	---	---	9.473	---	9.361	9.261	9.262
G51 Reset 1931	17.753	17.593	17.740	17.697	17.648	---	17.533	---	---
J371	---	---	---	---	---	25.299	25.221	---	---
18 (USN)	---	---	---	---	---	23.796	23.717	---	---
K371	---	---	---	---	---	24.301	24.222	---	---
19 (USN)	---	---	---	---	---	23.789	23.709	---	---
L371	---	---	---	---	---	23.713	23.632	---	---
20 (USN)	---	---	---	---	---	24.002	23.917	---	---
M371	---	---	---	---	---	24.300	24.223	---	---
1 (USNO)	---	---	---	---	---	24.356	24.270	---	---
BIXBY	24.083	23.938	24.112	24.072	24.043	---	---	---	---
H51	4.808	4.673	4.861	4.823	4.798	---	---	---	---
Z778	---	---	---	---	7.111	---	---	6.536	6.529
A779	---	---	---	---	6.985	---	---	6.695	6.657
J51 Reset 1938	8.185	8.055	8.202	---	8.178	---	---	---	---
K51 Reset 1930	---	8.006	8.058	---	8.016	---	---	---	---

Line 106A; Quad. 331174

Bench mark	Dec. 1931-Mar. 1932	Sept.-Dec. 1933	July 1945-Mar. 1946	Mar.-June 1949	Dec. 1954-Jan. 1955	Apr. 1968-June 1969	July 1973-July 1974
1E-83-69	---	---	---	---	---	9.785	9.747
1E-84-69	---	---	---	---	---	19.310	19.269
1E-85-69	---	---	---	---	---	13.047	13.022
TTS 2Y (USGS) Reset 1964	12.641	12.520	12.544	---	12.491	12.467	12.434
1E-87-69	---	---	---	---	---	10.908	10.882
RE561 (OCS)	---	---	---	---	10.902	10.877	---
Z98	10.667	10.578	10.584	---	---	---	---
W782 (USE)	---	---	15.299	---	15.264	---	---
U782	---	---	16.156	---	16.139	---	---
1E-89-69	---	---	---	---	---	19.958	19.934
V782	---	---	19.767	---	19.723	---	---
1E-90-69	---	---	---	---	---	24.326	24.304
Z282	---	---	---	---	25.211	25.164	25.142
1E-91-69	---	---	---	---	---	24.725	24.704
1E-92-69	---	---	---	---	---	25.947	25.919
Post Office (USGS)	---	---	29.606	---	29.563	29.482	---
C99	30.911	30.860	30.862	---	30.820	30.737	---
1E-93-69	---	---	---	---	---	26.455	26.418
V280	---	---	---	---	21.254	21.149	21.112
Tidal 3 1931	2.047	1.940	1.930	1.887	1.885	1.795	---
Tidal 2 1931	2.095	1.977	1.965	1.920	1.918	1.822	---
J782	---	---	1.679	1.637	1.639	1.539	1.497
6.4 (USGS)	---	1.683	1.680	1.535	1.537	1.437	---
K771	---	---	4.110	4.076	4.089	3.990	---
K782	---	---	2.509	2.474	2.489	2.436	---
L782	---	---	2.323	---	---	2.253	2.228
Tidal 1 1926	1.411	1.313	1.326	---	1.314	1.265	---

Line 107; Quad 331181

Bench mark	Dec. 1931-Mar. 1932	Sept.-Dec. 1933	June 1941-Jan. 1942	July 1945-Mar. 1946	Mar.-June 1949	Dec. 1954-Jan. 1955	Apr. 1968-June 1969	July 1973-July 1974
Landing Hill	19.095	---	19.192	---	---	---	---	---
225 (CLB)	---	---	---	1.205	1.158	---	---	---
Seal Beach RM2	---	---	---	6.843	6.801	---	---	---
RM2 Seal Beach 2	---	---	---	5.599	5.555	5.501	5.354	---
RM1 Seal Beach 2	---	---	---	5.277	5.233	5.177	---	---
Seal Beach 2	---	---	---	5.647	5.596	5.538	5.389	5.435
T280	---	---	---	---	---	2.589	2.437	2.470
U280	---	---	---	---	---	2.310	2.159	---
D168	---	2.343	2.245	2.251	2.208	2.156	---	---
L766	---	---	---	3.441	3.402	3.354	3.209	3.209
BM (OCS)	---	---	2.059	2.162	2.126	2.081	---	---
N766	---	---	---	9.857	9.819	9.779	9.639	9.619
C168	---	3.275	---	3.232	3.199	3.172	---	---
M766	---	---	---	3.524	3.489	3.459	3.328	3.303
Tidal 2 Reset 1962	---	2.283	2.219	2.230	2.199	2.167	2.022	1.988
RM2 Los Patos-Tidal 1	2.165	2.252	2.192	2.208	2.176	2.145	2.001	1.972
IJ-28-68	---	---	---	---	---	---	1.112	1.080
P766	---	---	---	3.319	3.281	3.236	---	---
IJ-29-68	---	---	---	---	---	---	2.626	2.602
TT 15Y (USGS)	4.554	4.567	---	---	---	---	---	---
IJ-30-68	---	---	---	---	---	---	3.115	3.111
163-6 (SO &GC)	---	---	---	---	4.092	4.008	---	---
163-2 (SO & GC)	---	---	---	2.459	2.397	2.247	1.906	---
8.9 (USGS) (2.5 mi. NW H.B.)	2.574	2.562	2.419	2.399	2.306	---	---	---
RM2 STOLCO	---	11.577	---	11.332	11.218	11.019	10.659	---
RM1 STOLCO	---	---	---	11.539	11.425	---	---	---
STOLCO	---	11.503	11.321	11.258	11.145	---	---	---
IJ-31-68	---	---	---	---	---	---	11.469	11.442
A168	13.103	13.063	12.844	12.794	12.668	12.481	---	---
41.2 (USGS) (1.8 mi. NW H.B.)	12.407	12.402	12.148	12.097	12.006	---	---	---
RM2 Standard No. 3	---	---	---	9.153	9.001	8.790	8.176	---
IJ-32-68	---	---	---	---	---	---	8.896	8.804
Reservoir #2	39.199	---	39.120	---	---	---	---	---
Gothard & Main Sts.	20.433	---	20.459	---	---	---	---	---
30.8 (USGS) (Coast Hwy. & 17th)	9.233	9.210	9.004	8.974	---	---	---	---
IJ-33-68	---	---	---	---	---	---	8.345	8.311
Wall No. 1	---	---	---	4.614	4.532	4.443	4.135	---
RM1 Standard No. 1	---	---	---	3.606	3.526	3.434	3.123	---
RM2 Standard No. 1	---	---	---	9.235	9.158	9.065	8.749	8.723
S766	---	---	---	8.757	8.700	8.653	8.426	8.403

Line 103; Quad. 331174

Bench mark	Dec. 1931-Mar. 1932	Sept.-Dec. 1933	June 1941-Jan. 1942	July 1945-Mar. 1946	Mar.-June 1949	Dec. 1954-Jan. 1955	Apr. 1968-June 1969	July 1973-July 1974
Y385	---	---	---	7.756	7.705	---	---	---
TT 10Y (USGS)	8.559	8.534	---	---	---	---	---	---
Huntington RM3	---	---	---	5.052	5.000	---	---	---
IJ-34-68	---	---	---	---	---	---	1.841	1.794
IJ-35-68	---	---	---	---	---	---	1.483	1.446
Z167	---	2.141	2.137	2.125	2.082	2.059	1.939	1.910
IJ-36-68	---	---	---	---	---	---	1.840	1.809
TT 9Y (USGS)	2.139	2.049	---	---	---	---	---	---
IJ-37-68	---	---	---	---	---	---	2.171	2.147
X766	---	---	---	2.141	2.095	2.092	2.018	1.997
IJ-38-68	---	---	---	---	---	---	2.571	2.546
Y167-Tidal 1 1932	---	4.885	4.908	4.895	4.854	4.854	4.773	4.744
X167	---	4.909	4.930	4.917	4.877	4.876	4.797	4.764
IJ-39-68	---	---	---	---	---	---	2.234	2.190
W766	---	---	---	2.655	2.612	2.596	2.447	2.369
7.8 (USGS)	---	2.132	---	2.125	2.082	2.068	1.919	---
V766	---	---	---	3.212	3.168	3.160	3.067	3.016
W167 Reset 1936	---	3.197	---	3.171	3.130	3.132	3.044	---
Y770	---	---	---	1.882	---	1.846	1.786	1.762
3K-23-68	---	---	---	---	---	---	2.472	2.449
Z770	---	---	---	2.753	---	2.681	---	---
3K-24-68	---	---	---	---	---	---	3.231	3.210
A771	---	---	---	4.643	---	4.623	---	---
C771	---	---	---	22.110	---	22.094	22.055	---
3K-26-68	---	---	---	---	---	---	27.355	27.337
3K-27-68	---	---	---	---	---	---	27.915	27.901
U167	---	29.152	---	29.159	---	29.152	---	---
3K-28-68	---	---	---	---	---	---	37.420	37.402
Tidal 1 1926	---	---	---	2.423	---	---	2.365	---
Tidal 2 1926	---	---	---	2.355	---	---	2.299	---
2NP	---	---	---	---	---	---	2.496	2.480
3NP	---	---	---	---	---	---	2.515	2.499
1NP	---	---	---	---	---	---	2.799	2.783
6NP	---	---	---	---	---	---	3.814	3.796
5NP	---	---	---	---	---	---	3.117	3.101
3K-28A-68	---	---	---	---	---	---	11.771	11.685
M782	---	---	---	27.967	---	27.966	---	---
3K-29-68	---	---	---	---	---	---	24.931	24.911
E771 Reset 1954	---	---	---	31.943	---	---	31.897	31.877
Y282	---	---	---	---	---	31.477	31.442	---
T167	---	26.971	---	26.967	---	---	---	---
F771	---	---	---	43.130	---	43.117	43.086	43.064
S167	---	35.685	---	35.671	---	35.608	35.548	35.520
3K-30-68	---	---	---	---	---	---	37.267	37.242
R167	---	21.355	---	21.357	---	21.333	21.300	21.276
F783	---	---	---	33.223	---	33.205	33.178	33.150
C783	---	---	---	5.476	---	5.449	5.425	5.400

[1] Starting elevation at bench mark F52 based on leveling between Tidal 8 and F52 during Aug. 1926 (NGS line (293)).
[2] Starting elevation at bench mark 111-8 (LACFCD) based on leveling between Tidal 8 and 111-8 (LACFCD) during the interval Aug. 1931-May 1932 (NGS line L-386).
[3] Starting elevation at bench mark 111-8 (LACFCD) based on leveling between Tidal 8 and 111-8 (LACFCD) during the interval 1933-34 (NGS line L-991).
[4] Starting elevation at bench mark 111-8 (LACFCD) based on leveling between Tidal 8 and 111-8 (LACFCD) during July 1945 (NGS line L-11398).
[5] Starting elevation at bench mark 111-8 (LACFCD) based on leveling between Tidal 8 and 111-8 (LACFCD) during the interval Mar.- May 1955 (NGS line L-15577).
[6] Starting elevation at bench mark D51 based on leveling between Tidal 8 and D51 during the interval Jan.-Aug. 1926 (NGS lines (293) and (291)).
[7] Starting elevation at bench mark D51 based on leveling between Tidal 8 and D51 during the interval Dec. 1931-Jan. 1932 (NGS line L-386).
[8] Starting elevation at bench mark 192 (CLB) based on leveling between Tidal 8 and 192 (CLB) during the interval Sept.-Oct. 1933 (NGS line L-991).
[9] Starting elevation at bench mark 1-3 (LACFCD) based on leveling between Tidal 8 and 1-3 (LACFCD) during June 1941 (NGS line L-9203).
[10] Starting elevation at bench mark 1-3 (LACFCD) based on leveling between Tidal 8 and 1-3 (LACFCD) during the interval July-Aug. 1945 (NGS line L-11398).
[11] Starting elevation at bench mark Y766 based on leveling between Tidal 8 and Y766 during the interval May-June 1949 (NGS line L-12981).
[12] Starting elevation at bench mark D51 based on leveling between Tidal 8 and D51 during Dec. 1954 (NGS line L-15457).
[13] Starting elevation at bench mark 111-8A based on leveling between Tidal 8 and 111-8A during the interval Apr.-Sept. 1968 (NGS lines L-21729 and L-21537).
[14] Starting elevation at bench mark 111-8A based on leveling between Tidal 8 and 111-8A during the interval Sept. 1973-Feb. 1974 (NGS lines L-23644 and L-23699).

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