ROYAL OBSERVATORY, HONG KONG

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AN APPLICATION OF HARMONIC METHOD TO TIDAL ANALYSIS AND PREDICTION IN HONG KONG

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1. INTRODUCTION

Since the 40s, tidal predictions for Hong Kong have been computed by the U.K. Institute of Oceanographic Sciences. In 1983, a computer program for tidal analysis and prediction was acquired by the Royal Observatory Hong Kong from the Institute of Ocean Sciences, Canada. This program was successfully modified for application in Hong Kong in 1986. As a result, the Royal Observatory started to produce tidal predictions and publish Tide Tables for Hong Kong since 1987.

The technique used in making these predictions is known as the Harmonic Method. In this approach, tide records of sufficient length and good quality at the locations of interest are analysed to determine the amplitudes and phases of the harmonic constituents. The results are then used to deduce the predicted tides from astronomical predictions (the predicted orbital parameters of the Moon and the Sun) for the year of interest.

This note gives a brief account on the technique and its underlying principles. The accuracy of the tidal prediction for North Point and Quarry Bay produced for 1983-1988 using this method is also presented.

2. PERIODICITY OF TIDES

2.1 The Origin of Tides

Watts (1959) described 7 factors which influence the water levels at a coast or in a harbour. They can be broadly categorized as:

(a) meteorological forcing;
(b) gravitational forcing;
(c) climatological modulation; and
(d) topographic modulation.

While the change in local meteorological conditions such as wind and surface atmospheric pressure are short-lived and usually irregular both in time and magnitude, the variation of the gravitational force on the Earth's ocean is very periodic. The meteorological components of the variation is of interest to the study of storm surge and sea waves. The response of tides to the gravitational forcing in various seasons and at different localities is the subject matter of tidal prediction. The effects of fluctuation in meteorological conditions are treated as noise in the regime of tidal prediction.

2.2 Tidal Force and Tidal Potential

Under a hypothetical equilibrium condition, the resultant force field due to the gravitational attraction of the Moon and the centrifugal force (Fig. 1) resulting from relative revolution of the Moon-Earth system, draws the oceans on the Earth into an ellipsoid with the major axis pointing towards the Moon. As the Earth rotates under the water ellipsoid, periodic rise and fall of water level will be observed at points fixed on Earth (Fig. 2). The tangential component (horizontal if observed on Earth) of the resultant force (Fig. 1) produces the tidal acceleration. A similar force is exerted by the Sun on the Earth's ocean with a magnitude about half of the Moon's contribution. The observed periodic tidal motion of the oceans is a result of the orbiting movement of the Sun, the Moon and the Earth.

To avoid the complicated arithmatics in handling vector quantities, $\mathbf{F}_T$, (tidal forces), a scalar potential function, V_T, known as the tidal potential is introduced.

$$\mathbf{F}_T = -\text{grad } V_T \qquad (2.1)$$

$$V_T = V_M + V_S \qquad (2.2)$$

where V_M and V_S are the potential due to the Moon and the Sun respectively.

It can be shown (Pugh, 1987) that, the equilibrium tidal height H is given by

$$gH + V_T = \text{constant} \qquad (2.3)$$

where g: acceleration of gravity at the Earth's surface

At a point P on the Earth surface, the gravitational potential due to the Moon (similarly for the Sun) is given by,

$$V = \frac{G\,M_m}{r_m}\sum_{k=2}^{\infty}\left(\frac{R}{r_m}\right)^k P_k(\cos\theta_m) \qquad (2.4)$$

where
- G : universal gravitational constant
- M_m : mass of the Moon
- R : Earth's radius
- r_m : distance between centres of the Moon and the Earth
- $P_k(x)$: Legendre polynomials
- θ_m : angle subtended by P and the centre of the Moon at the centre of the Earth (Fig. 3)

θ_m (similarly for θ_s) is a function of the coordinate of the point of interest (P) and the declination and the local hour angle of the Moon (Sun). To simplify the computation of equation (2.4), Doodson (1921) considered all terms in the summation for values of k up to 4 and expressed the potential as a summmation of harmonics. The arguments (μ) of the harmonics are related to astronomical parameters (τ,s,h,p,N'and P') as follows.

$$\mu = I\tau + Js + Kh + Lp + MN' + NP' \qquad (2.5)$$

where
- τ : the lunar time
- s : the mean longitude of the Moon
- h : the mean longitude of the Sun
- P : the longitude of the lunar perigee
- N': the negative of the longitude of the lunar ascending node
- P': the longitude of the perihelion

The integers I,J,K,L,M and N are called the Doodson numbers. For a value of k up to 4 in expression (2.4), the Doodson numbers take values between -6 and +6. Each combination of the 6 Doodson numbers (viz. I,J,K,L,M,N) is said to define a constituent. Groups of constituents with the same I form the tidal species. In Doodson's development, 4 species have been identified, i.e. the long period (I=0), diurnal (I=1), semidiurnal (I=2), terdiurnal (I=3). Conventionally, the constituents are given names to denote their tidal species and origins. Some of the more common ones are introduced below.

Long period
SA : solar annual (including seasonal modulation)
SSA: solar semi-annual (including seasonal modulation)

Diurnal
O1 : lunar diurnal term modulated by variations in lunar declination
M1 : lunar diurnal term modulated by variations in lunar distance
P1 : solar diurnal term modulated by variations in solar declination
S1 : radiational
K1 : luni-solar diurnal term modulated by variations in lunar and solar declination

Semidiurnal
N2 : lunar semidiurnal term modulated by variations in lunar distance
M2 : principal lunar semidiurnal
L2 : lunar semidiurnal term modulated by variations in lunar distance
T2 : solar semidiurnal term modulated by variations in solar distance
S2 : principal solar semidiurnal
R2 : solar semidiurnal term modulated by variations in solar distance
K2 : luni-solar semidiurnal term modulated by variations in lunar and solar declination

Terdiurnal
M3 : lunar terdiurnal caused by variations of lunar attraction over the Earth's surface (asymmetry of the tidal bulge)

2.3 Seasonal Variation

The seasonal variation of meteorological parameters such as wind, temperature and pressure induces long period oscillations in water levels. These variations are closely related to the solar declination and are roughly in phase with the solar constituents SA and SSA, having periods of 1 year and 0.5 year respectively.

2.4 Shallow Water Effects

As waves generated by ocean tides progress into shallow water, bottom friction and other non-linear physical processes come in effect. The distortion can be expressed as additional shallow water constituents. The angular speed of these shallow water constituents are given by the linear combination of those of the gravitational constituents.

2.5 Tidal Pattern

The response of the oceans to various tidal forcing is complicated. The multitude of tidal patterns exhibited at various localities can be grouped into three broad categories. Tidal patterns displaying roughly 1 cycle per day are said to be diurnal while those running at 2 cycles per day are said to be semidurnal. Patterns encompassing both features are known as mixed. Dietrich (1963) quantified this classification by introducing a ratio,

$$F = \frac{A(K1) + A(O1)}{A(S2) + A(M2)} \tag{2.6}$$

where A( ) is the amplitude of the constituent in the bracket. K1 and O1 are the most significant constituents with periods of one day. S2 and M2 are those with periods of half day. The tides are said to be

a) semidiurnal if $0 < F \leq 0.25$
b) mixed if $0.25 < F \leq 3.00$
c) diurnal if $F > 3.00$

3. THE HARMONIC METHOD

3.1 Harmonic Analysis

The basis of harmonic analysis is the assumption that a tidal record can be approximated by a finite series,

$$H(t_i) = \sum_{k=0}^{m} A_k \cos(\sigma_k t_i - \alpha_k) + e(t_i) \qquad (3.1)$$

where
$H(t_i)$: tidal height at the ith hour (t_i)
σ_k : angular speed of the kth constituent ($= \mu_k$)
A_k : amplitude of the kth constituent
α_k : phase lag of the kth constituent
$e(t_i)$: residue level at t_i

Spectral analyses of tidal records by other workers [see Godin (1972)] show that the assumption is viable apart from the very low frequency portion of the spectrum. The objective of harmonic analysis is to determine (or estimate) the amplitude and phase lag for a number of selected constituents.

3.2 Selection of Constituents

Although the tidal variation is a continuous function of time, in practice, the tidal records being analysed are finite sequences of readings sampled at regular intervals (usually one hour). This fact imposes limitations in the selection of constituents for inclusion in equation (3.1).

The finite resolution in time scale implies that oscillations with periods shorter than two sample intervals are not detected. Therefore for hourly observations, oscillations with frequencies exceeding 0.5 cycle/hour are not discernible. This restriction is known as the Nyquist criterion.

The finite duration of the tidal records results in the broadening of the spectral lines, i.e. the shorter the duration of observation, the more difficult it is to resolve constituents of similar frequencies. Analogous to the treatment of optical spectra, the Rayleigh criterion (3.2) is employed to define the extent to which 2 constituents can be resolved in tidal analysis. To resolve two neighbouring constituents, the following requirement on the duration of observation must be met.

$$|\sigma_{k+1} - \sigma_k| \; T > 1 \qquad (3.2)$$

where σ_k : angular speed of the kth constituent

T : record length

The criterion requires the minimum phase shift between the 2 constituents over the recording period to exceed 1 cycle. For neighbouring constituents failing to meet this requirement, only one of the two can be analysed.

To select the constituents to be included in the analysis, computed components of the tidal potential under the hypothetical equilibrium condition are taken as indicators of the importance of the corresponding constituent. In accordance with the computation by Cartwright and Edden (1973), 45 astronomical constituents are selected in the RO tidal analysis scheme. They are the diurnal and semidiurnal constituents with potential amplitude greater than 0.0025, M3 and some other important frequency components. For the shallow water constituents, only 101 of those resulting from low order interactions between significant astronomical constituents are chosen. The frequencies and the corresponding Doodson numbers of these 146 constituents are given in Table 1. The Doodson numbers of the shallow water constituents are obtained by linear combinations of those of the main constituents from which the former are derived.

When a tidal record is analysed, a set of constituents are selected from these 146 pre-selected ones in accordance with their relative significance and the Rayleigh criterion (3.2). The minimum record length for inclusion of each of the 146 constituents is listed in Table 2.

3.3 Determination of Amplitudes and Phase Lags

Having selected the constituents and hence fixed the angular speed (σ_k) in equation (3.1), the job remaining is to determine the amplitude (A_k) and phase (α_k). This is accomplished by using the least square fit method. Equation (3.1) can be expressed as

$$h_i = Z_o + \sum_{k=1}^{m} [C_k \cos\sigma_k t_i + S_k \sin\sigma_k t_i] + e_i \qquad (3.3)$$

where A_k : $(C_k^2 + S_k^2)^{1/2}$

$\tan\alpha_k$: S_k/C_k

h_i : $H(t_i)$

e_i : $e(t_i)$

Z_o : Mean sea level (amplitude of Z0)

For minimum $\sum_{i=1}^{n} e_i^2$ (where the index runs over the whole tide record of hourly observations),

$$nZ_o + \sum_{k=1}^{m} \left(\sum_{i=1}^{n} \cos\sigma_k t_i\right) C_k + \sum_{k=1}^{m} \left(\sum_{i=1}^{n} \sin\sigma_k t_i\right) S_k = \sum_{i=1}^{n} h_i \qquad (3.4a)$$

$$nZ_o + \sum_{k=1}^{m} B_1(j,k) C_k + \sum_{k=1}^{m} B_2(j,k) S_k = \sum_{i=1}^{n} h_i \cos\sigma_j t_i \qquad (3.4b)$$

$$nZ_o + \sum_{k=1}^{m} B_3(j,k) C_k + \sum_{k=1}^{m} B_4(j,k) S_k = \sum_{i=1}^{n} h_i \sin\sigma_j t_i \qquad (3.4c)$$

where $j = 1, \ldots, m$ in (3.4b) and (3.4c); and

$$B_1(j,k) = \sum_{i=1}^{n} \cos\sigma_j t_i \cos\sigma_k t_i$$

$$B_2(j,k) = \sum_{i=1}^{n} \cos\sigma_j t_i \sin\sigma_k t_i$$

$$B_3(j,k) = \sum_{i=1}^{n} \sin\sigma_j t_i \cos\sigma_k t_i$$

$$B_4(j,k) = \sum_{i=1}^{n} \sin\sigma_j t_i \sin\sigma_k t_i$$

The system of 2m+1 linear equations is solved by Cholesky factorization.

3.4 Greenwich Phase Lag

In the foregoing calculations, the variable $\sigma_k t_i$ is defined as the phase of the local astronomical argument. However, due to historial reason, it is customary in tidal analysis to define this argument as at the Greenwich meridian. The corresponding phase lag (g_k) is given by

$$g_k = \mu_k^\circ - \alpha_k \qquad (3.5)$$

where μ_k° is the astronomical argument of the kth constituent at the Greenwich meridian at t = 0 (which is taken to be the centre hour of the tidal record).

The μ_k's are calculated from the 6 Doodson numbers of the corresponding constituents and values of the astronomical variables in (2.5). In particular,

$$\mu_k^\circ = I\tau + Js + Kh + Lp + MN' + NP'|_{t=0} \qquad (3.6)$$

The astronomical variables at t=0 are calculated by taking the first order terms in their power series expansions given in the Explanatory Supplement to the Astronomical Ephemies and the American Ephemeris and Nautical Almanac (Her Majesty's Nautical Almanac Office, 1961). The time origin of the expansion is taken to be Epheremis Time (ET) 00 hour on 1 January 1976. The values of the astronomical variables at this origin are taken from the Astronomical Ephemeris for 1976 (Her Majesty's Nautical Almanac Office, 1974).

3.5 Correction for Satellite Modulation

Due to the limited spectral resolution of the tidal records, the analysed amplitude and phase of the selectd constituents are masked by neighbouring minor constituents. These minor constituents are known as the satellites. The analysed signal for each constituent is in fact due to a spectral band consisting of the main constituents and its surrounding satellites which together form a cluster. Each cluster is defined by the first three Doodson numbers (I,J,K) which is invariant for all constituents in the cluster. To extract the true amplitude and phase of the main constituent, it is assumed that the ratio of the amplitudes between the main constituent and its satellites of the same cluster are the same as those of the corresponding constituents in the computed equilibrium tide. It is further assumed that the phase is approximately constant within the cluster. Denoting the analysed amplitude and phase as A_k' and g_k', the true amplitude and phase are calculated as follows

$$A_k = f_k A_k' \qquad (3.7a)$$

$$g_k = g_k' + b_k \qquad (3.7b)$$

where

$$f_k = ((1 + \Gamma_c)^2 + \Gamma_s^2)^{1/2} \qquad (3.7c)$$

$$\tan b_k = \frac{\Gamma_s}{1 + \Gamma_c} \qquad (3.7d)$$

and $\Gamma_c = \sum_j |r_{kj}| D_{kj} \cos(\mu_{kj} - \mu_k + \delta_{kj})$

$$\Gamma_s = \sum_j |r_{kj}| D_{kj} \sin(\mu_{kj} - \mu_k + \delta_{kj})$$

(with subscript j denoting the jth satellite of the kth constituent). Furthermore,

$r_{kj} = \bar{A}_{kj}/\bar{A}_k$ (ratio of the amplitudes of constituent and its satellite in the equilibrium tide)

$$D_{kj} = \frac{\sin(n(\sigma_{kj} - \sigma_k)/2)}{T\sin((\sigma_{kj} - \sigma_k)/2)} \qquad \text{(T: record length in hours)}$$

For satellites arising from second order terms in the expansion of the tidal potential,

$$\delta_{kj} = 0 \qquad r_{ky} > 0$$
$$= \pi \qquad r_{kj} < 0$$

For satellites arising from third order terms in the expansion of the tidal potential,

$$\delta_{kj} = \pi/2 \qquad I = 1,\ 3 \text{ and } r_{kj} > 0$$
$$= 3\pi/2 \qquad I = 1,\ 3 \text{ and } r_{kj} < 0$$
$$= -\pi/2 \qquad I = 0,\ 2 \text{ and } r_{kj} > 0$$
$$= \pi/2 \qquad I = 0,\ 2 \text{ and } r_{kj} < 0$$

For shallow water constituents, the amplitude and phase correction factors are given by

$$f_k = \pi_j\ f_j^{|c_j|}$$

$$b_k = \sum_j b_j\ c_j$$

where the subscript j denotes the gravitational constituents from which the shallow water constituent is derived. c_j is the coefficient of linear combination used for calculation of the angular speed of the shallow water constituents. The multiplication runs over all gravitational constituents from which the shallow water constituent is derived.

3.6 Tidal Prediction

The final results of the harmonic analysis, A_k and g_k are related to the tidal height at time t as follows

$$H(t) = \sum_{k=0}^{m} f_k A_k \cos(\mu_k + b_k - g_k) \qquad (3.8)$$

where f_k, b_k, μ_k are all time dependent.

Also, in equation (3.8) μ_k is the phase of the tidal potential at Greenwich at time t measured from the origin defined in section (3.4), that is 00 hour ET on 1 January 1976. It is calculated from

$$\mu_k(t) = \mu_k(t_o) + (t - t_o)\sigma_k \qquad (3.9)$$

where t_o = 00 hour ET on 1 January 1976

From equations (3.7c), (3.7d), (3.8) and (3.9) the tidal heights are predicted from the amplitudes and Greenwich phase lags of the set of selected constituents obtained in the harmonic analysis of the existing tidal records. The details of the numerical techniques used in locating the high and low waters are given in Foreman (1977).

4. ANALYSIS AND PREDICTION OF TIDES AT QUARRY BAY

4.1 Tide Observation at Quarry Bay

In January 1951, an automatic tide gauge was installed at Arsenal Yard in Hong Kong. It was then moved to North Point in October 1952 (Watts 1959). Since then North Point was taken as the standard port. In 1985, reclamation at North Point necessitated the relocation of the tide gauge there to Quarry Bay. The set-up at Quarry Bay is similar to that at North Point. It is sited at a location approximately half a kilometre to the east of the North Point tide gauge. The tidal conditions at both locations are almost the same. Comparison of records from both tide gauges for the period September 1985 to March 1986 showed no noticeable difference. From 1986 onwards Quarry Bay became the standard port of Hong Kong. Tidal records from both gauges, particularly for the purpose of harmonic analysis and prediction, are treated as from one gauge. For the sake of brevity, these two tide gauges will be referred to as Quarry Bay in the subsequent discussion pertaining to the tidal characteristics of both locations.

Tides at Quarry Bay are of the mixed type with semidiurnal tides predominating. Using analysed values of O1, K1, M2 and S2 for Quarry Bay in the years 1975 and 1976, the calculated F value was found to be 1.18 confirming mixed tides. Fig. 4 shows a typical tide record at Quarry Bay for the month October 1987. Tides were diurnal on the 1st and gradually changed to semidiurnal on the 4th and onwards. Tides became diurnal again on the 14th to 16th. The cycle repeated in the second half of the month with seimidiurnal tides on the 18th to 26th, diurnal tides on the 28th to 30th and mixed tides on the other days. The predominance of semidiurnal tides is reflected by the number of days of semidiurnal tides occurring in the years 1975 and 1976 as listed in Table 3. It can be seen that, on average, tides are semidiurnal (including mixed tides) for 95% of time in a year.

Tide heights are referred to the Hong Kong Chart Datum which is the reference level used for tidal measurements and is 0.146 m below the Principal Datum of Hong Kong.

4.2 Analysis of Tide Data

The hourly tide heights of each year in 1961 - 1988 at Quarry Bay are analysed using the harmonic method. The number of available hourly data in each of these years are given in Table 4. The amplitude and phase of some major constituents analysed for each year are listed in Table 5. The inter-annual variation of these parameters is probably due to the interference of non-tidal noise such as storm surges or changes in coastline and depths in Victoria Harbour.

4.3 Prediction

To remove the inter-annual variation in the amplitudes and phases, 19-year vector averages are calculated for each constituent. In the calculation, the amplitude and phase of each constituent are taken to be the magnitude and direction of a vector. A period of 19 years is chosen to filter out the oscillation associated with the nodal cycle. Vector mean values of the major constituents for ten running 19-year periods are included in Table 5.

Residue analysis of the results of the least square fit indicated that the noise level in the tide records of the period 1961 - 1979 was the lowest among the 19-year periods. The vector mean constituent set of this period was chosen to be the basis for verifying the usefulness of the Harmonic Method in predicting the tides at Quarry Bay. The amplitude and phase of the constituents in this set are given in Table 6. After discarding the constituents of less than 1 mm, this constituent set is used to predict the tides at Quarry Bay in 1983 - 1988. The average root mean square errors for hourly tide heights, heights and times of the extreme waters for these six years were found to be 0.14 m, 0.15 m and 35 minutes respectively, as shown in Table 7. As the average standard deviation of the hourly tide heights in these 6 years is 0.50 m, the residue of these prediction therefore represented about 8% of the variance in the observed tide heights.

4.4 Conclusion

The harmonic method for tidal analysis and prediction as used in Hong Kong was described. The method has been applied to analyse the data of Quarry Bay in 1961 to 1988 to extract tidal constituents. 19-year vector means of the constituents were calculated to predict the tides at the location in 1983 - 1988. It was demonstrated that tides at Quarry Bay can be predicted with reasonable accuracy using the Harmonic Method.

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APPENDIX

Glossary

Chart Datum (CD): The level to which soundings or tide heights are referenced.

Diurnal Inequality: The difference in height between two successive high waters in a day.

Diurnal Range: The difference in height between mean higher high water and mean lower low water.

Diurnal Tide: A tide with one high water and one low water in a day.

Ebb Tide: The period of tide between high water and the succeeding low water (equivalent to falling tide).

Equilibrium Tide: The hypothetical tide generated by the tidal forces in the absence of ocean dynamics.

Flood Tide: The period of tide between low water and the succeeding high water (equivalent to rising tide).

High Water (HW): The maximum height reached by a rising tide.

Higher High Water (HHW): The higher of the two high waters in a day. The single high water occurring daily when tide is diurnal is taken as a higher high water.

Highest Astronomical Tide (HAT): The highest level predicted to occur under average meteorological conditions and under any combinations of astronomical conditions.

Higher Low Water (HLW): The higher of two low waters in a day.

Low Water (LW): The minimum height reached by a falling tide.

Lower High Water (LHW): The lower of two high waters in a day.

Lower Low Water (LLW): The lower of two low waters in a day. The single low water occurring daily when tide is diurnal is taken as a lower low water.

Lowest Astronomical Tide (LAT): The lowest level predicted to occur under average meteorological conditions and under any combinations of astronomical conditions.

Mean High Water (MHW): The average height of the high waters over a long period of time.

Mean Higher High Water (MHHW): The average height of the higher high waters over a long period of time.

Mean Higher Low Water (MHLW): The average height of the higher low waters over a long period of time.

Mean Low Water (MLW): The average height of the low waters over a long period of time.

Mean Lower Low Water (MLLW): The average height of the lower low waters over a long period of time.

Mean Range of Tide: The difference in height between mean high water and mean low water.

Mean Sea Level (MSL): The average height of the sea surface over a long period of time.

Mean Tide Level (MTL): The arithematic mean of the mean high water and mean low water.

Mixed Tide: A type of tide with a large inequality in either the high or low water heights.

Neap Tide: A tide of decreased range occurring near the time when the sun and moon are at right angles to each other as measured at the centre of the earth. The tidal constituents M2 and S2 are out of phase by 90 degrees to each other. The difference between high and low waters is small.

Nodal Cycle: A period of approximately 18.61 years required for a cycle of the regression of the lunar ascending node.

Secondary Port: A port where predicted times and heights of high and low waters are obtained by applying time and height differences to the predicted values for the standard port.

Semidiurnal Tide: A tide with two high and two low waters in a tidal day with comparatively little diurnal inequality.

Spring Tide: A tide of increased range occurring near the time when the sun and moon are in opposition or conjunction, i.e. at full or new moon. The tidal constituents M2and S2 are in phase with each other. The high waters occur near local noon or midnight and are higher than average. On the other hand, the low waters are lower than average.

Standard Port: The major port where continuous and accurate observations of sea levels are conducted and daily predictions of the times and heights of high and low waters are evaluated from analysed data.

Tidal Day: Equivalence of Lunar Day and consists of 24 hour and 50 minutes.

Tidal Range: The difference in height between consecutive high and low waters.

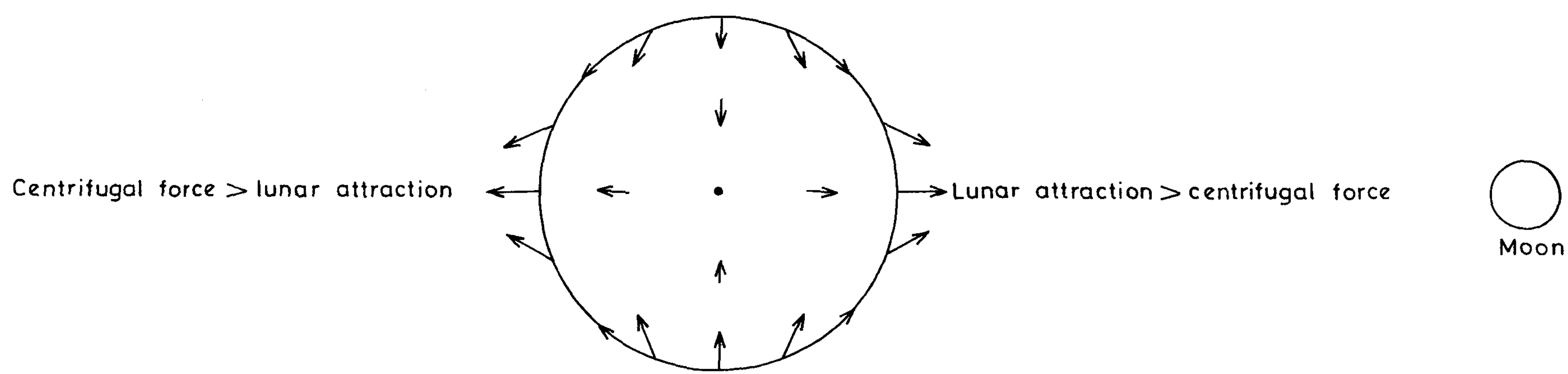

Fig. 1 The distribution of tidal forces on the Earth's surface

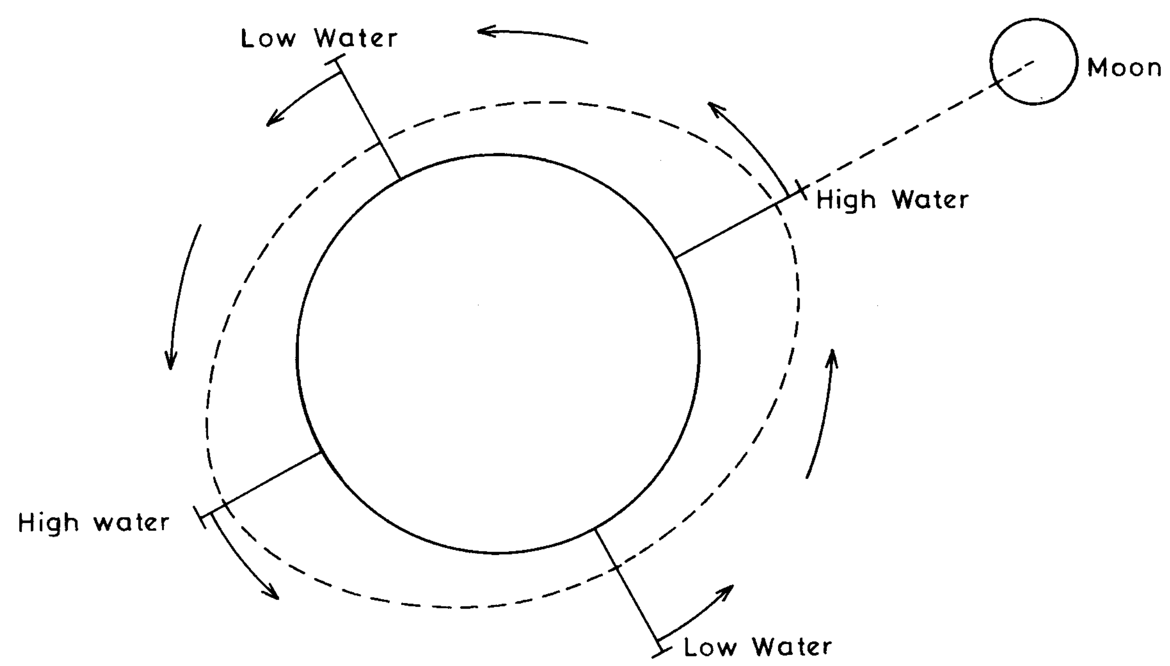

Fig. 2 Effect of Earth's rotation and the equilibrium envelope on locally observed tide levels

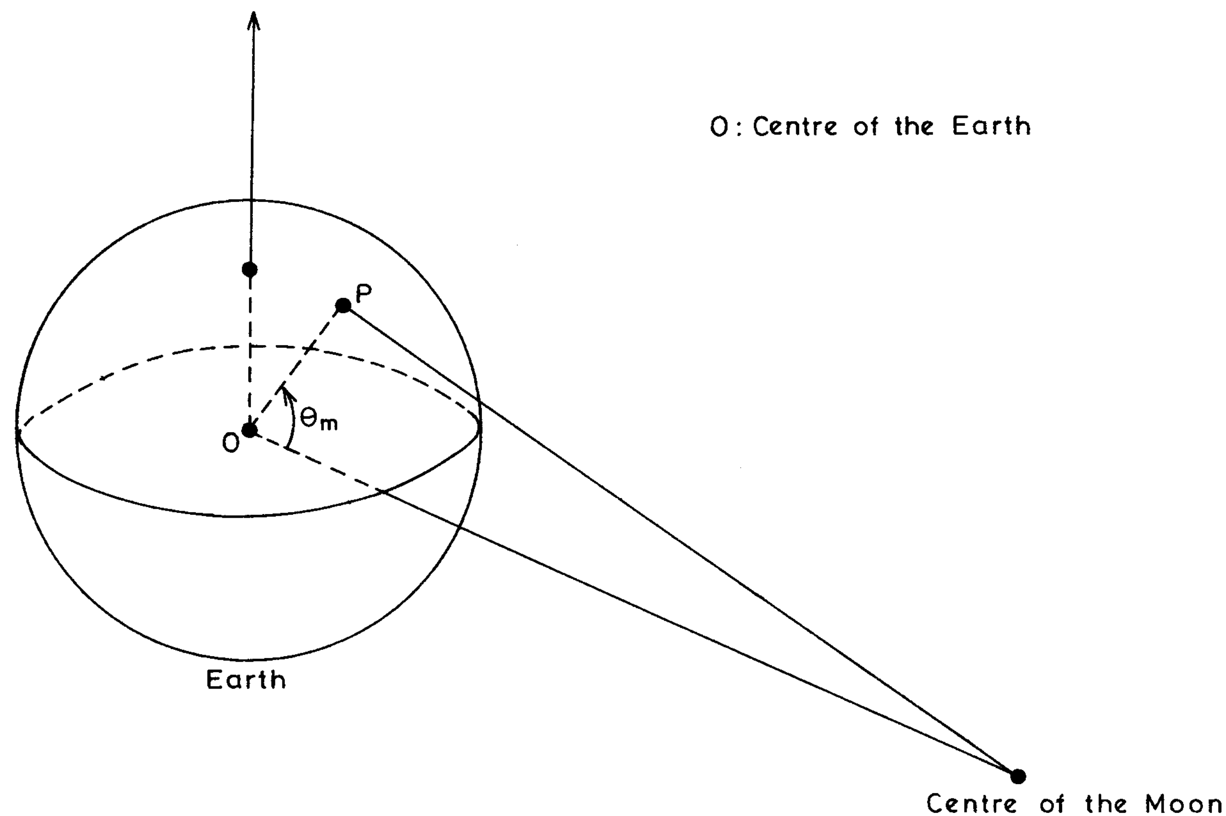

Fig. 3 Tidal potential

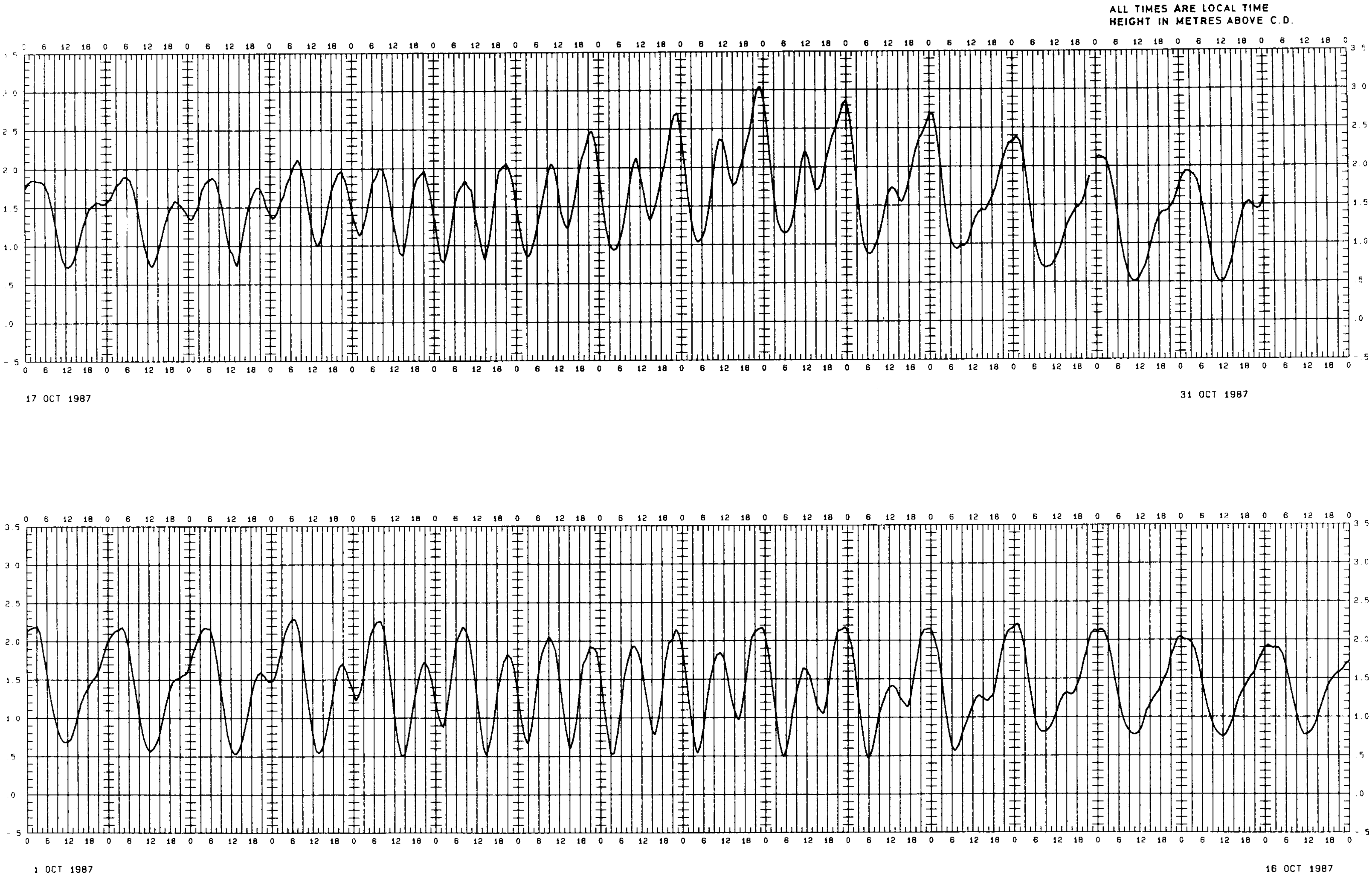

Fig. 4 Tide record of Quarry Bay (October 1987)

Table 1 List of Selected Constituents

	Constituent	Origin	Frequency (cph)	Doodson Numbers
1	Z0	G	0.0000000000	0 0 0. 0 0 0
2	SA	G	0.0001140741	0 0 1. 0 0 -1
3	SSA	G	0.0002281591	0 0 2. 0 0 0
4	MSM	G	0.0013097808	0 1 -2. 1 0 0
5	MM	G	0.0015121518	0 1 0. -1 0 0
6	MSF	G	0.0028219327	0 2 -2. 0 0 0
7	MF	G	0.0030500918	0 2 0. 0 0 0
8	ALP1	G	0.0343965699	1 -4 2. 1 0 0
9	2Q1	G	0.0357063507	1 -3 0. 2 0 0
10	SIG1	G	0.0359087218	1 -3 2. 0 0 0
11	Q1	G	0.0372185026	1 -2 0. 1 0 0
12	RHO1	G	0.0374208736	1 -2 2. -1 0 0
13	O1	G	0.0387306544	1 -1 0. 0 0 0
14	TAU1	G	0.0389588136	1 -1 2. 0 0 0
15	BET1	G	0.0400404353	1 0 -2. 1 0 0
16	NO1	G	0.0402685944	1 0 0. 1 0 0
17	CHI1	G	0.0404709654	1 0 2. -1 0 0
18	PI1	G	0.0414385130	1 1 -3. 0 0 1
19	P1	G	0.0415525871	1 1 -2. 0 0 0
20	S1	G	0.0416666721	1 1 -1. 0 0 1
21	K1	G	0.0417807462	1 1 0. 0 0 0
22	PSI1	G	0.0418948203	1 1 1. 0 0 -1
23	PHI1	G	0.0420089053	1 1 2. 0 0 0
24	THE1	G	0.0430905270	1 2 -2. 1 0 0
25	J1	G	0.0432928981	1 2 0. -1 0 0
26	2PO1	S	0.0443745198	1 3 -4. 0 0 0
27	SO1	S	0.0446026789	1 3 -2. 0 0 0
28	OO1	G	0.0448308380	1 3 0. 0 0 0
29	UPS1	G	0.0463429898	1 4 0. -1 0 0
30	ST36	S	0.0733553835	2 -5 4. 1 0 0
31	2NS2	S	0.0746651643	2 -4 2. 2 0 0
32	ST37	S	0.0748675353	2 -4 4. 0 0 0
33	ST1	S	0.0748933234	2 -4 4. 2 0 0
34	OQ2	G	0.0759749451	2 -3 0. 3 0 0
35	EPS2	G	0.0761773161	2 -3 2. 1 0 0
36	ST2	S	0.0764054753	2 -3 4. 1 0 0
37	ST3	S	0.0772331498	2 -2 -2. 0 0 0
38	O2	S	0.0774613089	2 -2 0. 0 0 0
39	2N2	G	0.0774870970	2 -2 0. 2 0 0
40	MU2	G	0.0776894680	2 -2 2. 0 0 0
41	SNK2	S	0.0787710897	2 -1 -2. 1 0 0
42	N2	G	0.0789992488	2 -1 0. 1 0 0
43	NU2	G	0.0792016198	2 -1 2. -1 0 0
44	ST4	S	0.0794555670	2 -1 4. 1 0 0
45	OP2	S	0.0802832416	2 0 -2. 0 0 0
46	GAM2	G	0.0803090296	2 0 -2. 2 0 0
47	H1	G	0.0803973266	2 0 -1. 0 0 1
48	M2	G	0.0805114007	2 0 0. 0 0 0

Table 1 (Cont'd)

49	H2	G	0.0806254748	2	0	1.	0	0	-1
50	MKS2	S	0.0807395598	2	0	2.	0	0	0
51	ST5	S	0.0809677189	2	0	4.	0	0	0
52	ST6	S	0.0815930224	2	1	-4.	1	0	0
53	LDA2	G	0.0818211815	2	1	-2.	1	0	0
54	L2	G	0.0820235525	2	1	0.	-1	0	0
55	2SK2	S	0.0831051742	2	2	-4.	0	0	0
56	T2	G	0.0832192592	2	2	-3.	0	0	1
57	S2	G	0.0833333333	2	2	-2.	0	0	0
58	R2	G	0.0834474074	2	2	-1.	0	0	-1
59	K2	G	0.0835614924	2	2	0.	0	0	0
60	MSN2	S	0.0848454852	2	3	-2.	-1	0	0
61	ETA2	G	0.0850736443	2	3	0.	-1	0	0
62	ST7	S	0.0853018034	2	3	2.	-1	0	0
63	2SM2	S	0.0861552660	2	4	-4.	0	0	0
64	ST38	S	0.0863576370	2	4	-2.	-2	0	0
65	SKM2	S	0.0863834251	2	4	-2.	0	0	0
66	2SN2	S	0.0876674179	2	5	-4.	-1	0	0
67	NO3	S	0.1177299033	3	-2	0.	1	0	0
68	MO3	S	0.1192420551	3	-1	0.	0	0	0
69	M3	G	0.1207671010	3	0	0.	0	0	0
70	NK3	S	0.1207799950	3	0	0.	1	0	0
71	SO3	S	0.1220639878	3	1	-2.	0	0	0
72	MK3	S	0.1222921469	3	1	0.	0	0	0
73	SP3	S	0.1248859204	3	3	-4.	0	0	0
74	SK3	S	0.1251140796	3	3	-2.	0	0	0
75	ST8	S	0.1566887168	4	-3	2.	1	0	0
76	N4	S	0.1579984976	4	-2	0.	2	0	0
77	3MS4	S	0.1582008687	4	-2	2.	0	0	0
78	ST39	S	0.1592824904	4	-1	-2.	1	0	0
79	MN4	S	0.1595106495	4	-1	0.	1	0	0
80	ST9	S	0.1597388086	4	-1	2.	1	0	0
81	ST40	S	0.1607946422	4	0	-2.	0	0	0
82	M4	S	0.1610228013	4	0	0.	0	0	0
83	ST10	S	0.1612509604	4	0	2.	0	0	0
84	SN4	S	0.1623325821	4	1	-2.	1	0	0
85	KN4	S	0.1625607413	4	1	0.	1	0	0
86	MS4	S	0.1638447340	4	2	-2.	0	0	0
87	MK4	S	0.1640728931	4	2	0.	0	0	0
88	SL4	S	0.1653568858	4	3	-2.	-1	0	0
89	S4	S	0.1666666667	4	4	-4.	0	0	0
90	SK4	S	0.1668948258	4	4	-2.	0	0	0
91	MNO5	S	0.1982413039	5	-2	0.	1	0	0
92	2MO5	S	0.1997534558	5	-1	0.	0	0	0
93	3MP5	S	0.1999816149	5	-1	2.	0	0	0
94	MNK5	S	0.2012913957	5	0	0.	1	0	0
95	2MP5	S	0.2025753884	5	1	-2.	0	0	0
96	2MK5	S	0.2028035475	5	1	0.	0	0	0
97	MSK5	S	0.2056254802	5	3	-2.	0	0	0
98	3KM5	S	0.2058536393	5	3	0.	0	0	0
99	2SK5	S	0.2084474129	5	5	-4.	0	0	0

Table 1 (Cont'd)

100	ST11	S	0.2372259056	6	-3	2.	3	0	0
101	2NM6	S	0.2385098983	6	-2	0.	2	0	0
102	ST12	S	0.2387380574	6	-2	2.	2	0	0
103	2MN6	S	0.2400220501	6	-1	0.	1	0	0
104	ST13	S	0.2402502093	6	-1	2.	1	0	0
105	ST41	S	0.2413060429	6	0	-2.	0	0	0
106	M6	S	0.2415342020	6	0	0.	0	0	0
107	MSN6	S	0.2428439828	6	1	-2.	1	0	0
108	MKN6	S	0.2430721419	6	1	0.	1	0	0
109	ST42	S	0.2441279756	6	2	-4.	0	0	0
110	2MS6	S	0.2443561347	6	2	-2.	0	0	0
111	2MK6	S	0.2445842938	6	2	0.	0	0	0
112	NSK6	S	0.2458940746	6	3	-2.	1	0	0
113	2SM6	S	0.2471780673	6	4	-4.	0	0	0
114	MSK6	S	0.2474062264	6	4	-2.	0	0	0
115	S6	S	0.2500000000	6	6	-6.	0	0	0
116	ST14	S	0.2787527046	7	-2	0.	1	0	0
117	ST15	S	0.2802906445	7	-1	0.	2	0	0
118	M7	S	0.2817899023	7	0	0.	0	0	0
119	ST16	S	0.2830867891	7	1	-2.	0	0	0
120	3MK7	S	0.2833149482	7	1	0.	0	0	0
121	ST17	S	0.2861368809	7	3	-2.	0	0	0
122	ST18	S	0.3190212990	8	-2	0.	2	0	0
123	3MN8	S	0.3205334508	8	-1	0.	1	0	0
124	ST19	S	0.3207616099	8	-1	2.	1	0	0
125	M8	S	0.3220456027	8	0	0.	0	0	0
126	ST20	S	0.3233553835	8	1	-2.	1	0	0
127	ST21	S	0.3235835426	8	1	0.	1	0	0
128	3MS8	S	0.3248675353	8	2	-2.	0	0	0
129	3MK8	S	0.3250956944	8	2	0.	0	0	0
130	ST22	S	0.3264054753	8	3	-2.	1	0	0
131	ST23	S	0.3276894680	8	4	-4.	0	0	0
132	ST24	S	0.3279176271	8	4	-2.	0	0	0
133	ST25	S	0.3608020452	9	-1	0.	2	0	0
134	ST26	S	0.3623141970	9	0	0.	1	0	0
135	4MK9	S	0.3638263489	9	1	0.	0	0	0
136	ST27	S	0.3666482815	9	3	-2.	0	0	0
137	ST28	S	0.4010448515	10	-1	0.	1	0	0
138	M10	S	0.4025570033	10	0	0.	0	0	0
139	ST29	S	0.4038667841	10	1	-2.	1	0	0
140	ST30	S	0.4053789360	10	2	-2.	0	0	0
141	ST31	S	0.4069168759	10	3	-2.	1	0	0
142	ST32	S	0.4082008687	10	4	-4.	0	0	0
143	ST33	S	0.4471596822	11	3	-2.	0	0	0
144	M12	S	0.4830684040	12	0	0.	0	0	0
145	ST34	S	0.4858903367	12	2	-2.	0	0	0
146	ST35	S	0.4874282766	12	3	-2.	1	0	0

G: Constituents of gravitational origins

S: Constituents due to shallow water effects

Table 2 Record length required for extraction of the constituents

Constituent	Length of record (hour) required for constituent inclusion
Z0	13
SA	8766
SSA	4383
MSM	4942
MM	764
MSF	355
MF	4383
ALP1	764
2Q1	662
SIG1	4942
Q1	662
RHO1	4942
O1	328
TAU1	4383
BET1	4383
NO1	662
CHI1	4942
PI1	8767
P1	4383
S1	8767
K1	24
PSI1	8767
PHI1	4383
THE1	4942
J1	662
2PO1	4383
SO1	4383
OO1	651
UPS1	662
ST36	764
2NS2	662
ST37	4942
ST1	38778
OQ2	4942
EPS2	764
ST2	4383
ST3	3938
O2	38778
2N2	4942
MU2	764
SNK2	4383
N2	662
NU2	4942
ST4	3938

Table 2 (Cont'd)

OP2	4383
GAM2	11326
H1	8767
M2	13
H2	8767
MKS2	4383
ST5	4383
ST6	4383
LDA2	4942
L2	764
2SK2	4383
T2	8767
S2	355
R2	8767
K2	4383
MSN2	4383
ETA2	662
ST7	4383
2SM2	4383
ST38	38778
SKM2	764
2SN2	779
NO3	662
MO3	656
M3	25
NK3	77556
SO3	4383
MK3	656
SP3	4383
SK3	355
ST8	764
N4	662
3MS4	4942
ST39	4383
MN4	662
ST9	4383
ST40	4383
M4	25
ST10	4383
SN4	764
KN4	4383
MS4	355
MK4	4383
SL4	779
S4	355
SK4	4383
MNO5	220
2MO5	328
3MP5	355
MNK5	662
2MP5	4383
2MK5	24

Table 2 (Cont'd)

MSK5	355
3KM5	4383
2SK5	178
ST11	358
2NM6	662
ST12	779
2MN6	662
ST13	4383
ST41	4383
M6	26
MSN6	764
MKN6	779
ST42	4383
2MS6	355
2MK6	4383
NSK6	764
2SM6	355
MSK6	4383
S6	386
ST14	220
ST15	331
M7	656
ST16	4383
3MK7	24
ST17	355
ST18	662
3MN8	662
ST19	4383
M8	26
ST20	764
ST21	4383
3MS8	355
3MK8	4383
ST22	764
ST23	779
ST24	4383
ST25	31
ST26	30
4MK9	28
ST27	28
ST28	662
M10	13
ST29	764
ST30	662
ST31	651
ST32	779
ST33	28
M12	13
ST34	355
ST35	651

Table 3 Number of days of diurnal and semidiurnal tides at North Point

Year	Diurnal tide		Semidiurnal tide	
	No. of days	Percentage	No. of days	Percentage
1975	21	5.8	344	94.2
1976	10	2.7	356	97.3
1975 & 1976	31	4.2	700	95.8

Table 4 Number of available hourly tide data at Quarry Bay (1961 -1988)

Year	Number of hourly data available
1961	8737
1962	8477
1963	8712
1964	8640
1965	8712
1966	8760
1967	8139
1968	8712
1969	8734
1970	8755
1971	8751
1972	8784
1973	8733
1974	8759
1975	8760
1976	8784
1977	8752
1978	8712
1979	8760
1980	8701
1981	8571
1982	7585
1983	8145
1984	6809
1985	8448
1986	8656
1987	8437
1988	8741

Table 5 Amplitude and phase of some major constituents at Quarry Bay*

Constituent : SA

Period : 365.2595 days

Year	Amplitude (m)	Phase (deg)
1961	.1331	297.52
1962	.1283	298.65
1963	.1212	291.32
1964	.1536	296.09
1965	.0788	305.30
1966	.0583	276.73
1967	.1305	285.53
1968	.1354	288.03
1969	.1018	286.44
1970	.1462	317.24
1971	.1123	307.82
1972	.0754	303.80
1973	.1261	285.09
1974	.1594	309.37
1975	.1335	323.45
1976	.0933	286.47
1977	.1640	299.02
1978	.1162	294.62
1979	.1031	268.76
1980	.1121	294.43
1981	.1140	303.17
1982	.0267	323.71
1983	.1334	292.45
1984	.1189	327.32
1985	.0776	286.20
1986	.1104	277.00
1987	.0871	297.54
1988	.1023	324.69
1961-1979	.1165	296.98
1962-1980	.1154	296.82
1963-1981	.1146	297.04
1964-1982	.1095	297.70
1965-1983	.1084	297.48
1966-1984	.1098	298.82
1967-1985	.1109	298.95
1968-1986	.1096	298.65
1969-1987	.1072	299.30
1970-1988	.1069	301.18

* Please see para. 4.1

Table 5 (Cont'd)

Constituent : SSA

Period : 182.6211 days

Year	Amplitude(m)	Phase(deg)
1961	.0513	47.65
1962	.0519	84.38
1963	.0425	92.78
1964	.0767	64.26
1965	.0357	71.52
1966	.0709	54.08
1967	.0493	24.09
1968	.0594	347.45
1969	.0561	106.66
1970	.0780	71.72
1971	.0639	23.78
1972	.0046	349.92
1973	.0603	86.29
1974	.0688	81.95
1975	.0747	76.06
1976	.0623	27.97
1977	.0269	32.86
1978	.1005	27.93
1979	.0980	60.84
1980	.0891	60.22
1981	.0682	96.46
1982	.0545	36.13
1983	.0858	70.63
1984	.0593	21.63
1985	.0514	63.36
1986	.0482	39.57
1987	.0765	87.40
1988	.1184	57.14
1961-1979	.0522	56.74
1962-1980	.0542	57.50
1963-1981	.0546	58.57
1964-1982	.0554	56.14
1965-1983	.0558	56.71
1966-1984	.0566	54.40
1967-1985	.0555	54.86
1968-1986	.0558	55.54
1969-1987	.0582	60.49
1970-1988	.0625	58.21

Table 5 (Cont'd)

Constituent : MSF

Period : 14.7653 days

Year	Amplitude(m)	Phase(deg)
1961	.0099	171.41
1962	.0110	19.80
1963	.0252	42.49
1964	.0243	43.85
1965	.0194	88.67
1966	.0131	98.32
1967	.0136	97.81
1968	.0052	285.53
1969	.0138	346.54
1970	.0176	13.68
1971	.0025	143.43
1972	.0206	52.30
1973	.0106	244.45
1974	.0207	58.17
1975	.0177	46.13
1976	.0173	128.23
1977	.0265	101.74
1978	.0290	171.23
1979	.0307	175.51
1980	.0182	182.09
1981	.0338	87.18
1982	.0272	110.44
1983	.0303	134.34
1984	.0201	85.50
1985	.0161	148.37
1986	.0337	27.66
1987	.0294	76.51
1988	.0332	60.43
1961-1979	.0088	83.39
1962-1980	.0086	86.26
1963-1981	.0102	89.40
1964-1982	.0107	97.33
1965-1983	.0114	107.38
1966-1984	.0114	107.04
1967-1985	.0114	110.38
1968-1986	.0110	102.04
1969-1987	.0127	99.12
1970-1988	.0144	97.44

Table 5 (Cont'd)

Constituent : O1

Period : 1.0758 day

Year	Amplitude (m)	Phase (deg)
1961	.2946	249.88
1962	.2864	249.98
1963	.2925	249.65
1964	.2896	250.13
1965	.2905	249.31
1966	.2900	250.21
1967	.2877	250.91
1968	.2884	250.05
1969	.2938	250.60
1970	.2919	250.97
1971	.2891	251.12
1972	.2892	250.50
1973	.2880	250.63
1974	.2836	250.27
1975	.2875	250.53
1976	.2863	250.54
1977	.2884	250.50
1978	.2891	250.19
1979	.2879	250.00
1980	.2864	249.77
1981	.2843	250.10
1982	.2858	250.85
1983	.2807	251.76
1984	.2834	251.81
1985	.2841	251.19
1986	.2932	249.81
1987	.2951	250.57
1988	.2900	251.26
1961-1979	.2892	250.31
1962-1980	.2887	250.31
1963-1981	.2886	250.32
1964-1982	.2883	250.38
1965-1983	.2878	250.46
1966-1984	.2874	250.59
1967-1985	.2871	250.64
1968-1986	.2874	250.59
1969-1987	.2878	250.61
1970-1988	.2876	250.65

Table 5 (Cont'd)

Constituent : K1

Period : 0.9973 day

Year	Amplitude (m)	Phase (deg)
1961	.3597	299.55
1962	.3621	299.65
1963	.3574	299.50
1964	.3587	299.02
1965	.3585	299.46
1966	.3572	299.46
1967	.3534	299.13
1968	.3553	299.07
1969	.3552	299.37
1970	.3539	299.92
1971	.3583	299.52
1972	.3568	299.83
1973	.3601	299.37
1974	.3606	299.31
1975	.3599	299.53
1976	.3593	299.72
1977	.3584	299.50
1978	.3585	299.44
1979	.3546	299.77
1980	.3557	299.10
1981	.3552	299.36
1982	.3520	300.38
1983	.3425	300.85
1984	.3477	300.81
1985	.3526	299.27
1986	.3631	298.68
1987	.3605	299.84
1988	.3570	299.48
1961-1979	.3578	299.48
1962-1980	.3576	299.45
1963-1981	.3572	299.44
1964-1982	.3569	299.49
1965-1983	.3561	299.58
1966-1984	.3555	299.65
1967-1985	.3552	299.64
1968-1986	.3558	299.61
1969-1987	.3560	299.66
1970-1988	.3561	299.66

Table 5 (Cont'd)

Constituent : M2

Period : 0.5175 day

Year	Amplitude (m)	Phase (deg)
1961	.3990	267.00
1962	.4001	267.37
1963	.4025	266.13
1964	.4038	267.37
1965	.4035	267.06
1966	.4011	268.26
1967	.3924	267.30
1968	.3994	265.85
1969	.3978	266.41
1970	.3967	268.25
1971	.3866	268.43
1972	.3943	267.68
1973	.4005	268.24
1974	.3944	268.29
1975	.3938	268.53
1976	.3916	268.55
1977	.3938	268.34
1978	.3943	268.79
1979	.3936	268.14
1980	.3941	267.72
1981	.3892	268.69
1982	.3883	268.66
1983	.3737	269.72
1984	.3797	268.00
1985	.3830	267.01
1986	.3866	265.84
1987	.3891	268.04
1988	.3877	269.17
1961-1979	.3968	267.68
1962-1980	.3965	267.72
1963-1981	.3959	267.78
1964-1982	.3952	267.92
1965-1983	.3936	268.04
1966-1984	.3923	268.09
1967-1985	.3914	268.02
1968-1986	.3911	267.95
1969-1987	.3905	268.07
1970-1988	.3900	268.21

Table 5 (Cont'd)

Constituent : S2

Period : 0.5000 day

Year	Amplitude(m)	Phase(deg)
1961	.1584	297.73
1962	.1607	298.00
1963	.1590	295.94
1964	.1591	296.93
1965	.1611	296.76
1966	.1583	297.32
1967	.1575	296.29
1968	.1580	296.26
1969	.1578	296.78
1970	.1562	298.07
1971	.1592	298.01
1972	.1591	298.69
1973	.1584	297.34
1974	.1553	298.10
1975	.1561	297.49
1976	.1562	297.92
1977	.1565	296.57
1978	.1559	296.73
1979	.1562	297.46
1980	.1589	295.86
1981	.1558	297.48
1982	.1568	297.60
1983	.1496	297.03
1984	.1513	296.53
1985	.1544	295.53
1986	.1595	295.45
1987	.1567	296.72
1988	.1548	298.78
1961-1979	.1578	297.28
1962-1980	.1579	297.18
1963-1981	.1576	297.16
1964-1982	.1575	297.24
1965-1983	.1570	297.25
1966-1984	.1565	297.24
1967-1985	.1563	297.15
1968-1986	.1564	297.10
1969-1987	.1563	297.13
1970-1988	.1561	297.23

Table 5 (Cont'd)

Constituent : M3

Period : 0.3450 day

Year	Amplitude(m)	Phase(deg)
1961	.0118	341.98
1962	.0143	351.55
1963	.0138	345.87
1964	.0145	337.87
1965	.0165	339.19
1966	.0176	331.54
1967	.0153	328.93
1968	.0137	335.55
1969	.0121	328.67
1970	.0114	349.77
1971	.0150	353.62
1972	.0156	346.53
1973	.0173	342.87
1974	.0170	332.80
1975	.0150	325.73
1976	.0142	326.40
1977	.0113	331.53
1978	.0120	337.00
1979	.0118	352.86
1980	.0131	348.12
1981	.0157	345.97
1982	.0173	346.96
1983	.0165	338.94
1984	.0160	345.39
1985	.0150	332.42
1986	.0136	331.51
1987	.0131	345.30
1988	.0132	344.44
1961-1979	.0140	338.75
1962-1980	.0141	339.07
1963-1981	.0142	338.81
1964-1982	.0144	338.97
1965-1983	.0145	339.03
1966-1984	.0145	339.39
1967-1985	.0143	339.51
1968-1986	.0142	339.71
1969-1987	.0142	340.19
1970-1988	.0143	340.91

Table 5 (Cont'd)

Constituent : MU2

Period : 0.5363 day

Year	Amplitude(m)	Phase(deg)
1961	.0182	217.25
1962	.0181	217.61
1963	.0189	217.98
1964	.0188	215.14
1965	.0207	213.69
1966	.0196	217.39
1967	.0208	211.76
1968	.0194	211.93
1969	.0199	217.92
1970	.0180	217.65
1971	.0209	212.37
1972	.0194	214.42
1973	.0205	209.46
1974	.0203	219.87
1975	.0190	216.41
1976	.0219	211.57
1977	.0189	212.98
1978	.0210	208.72
1979	.0222	219.37
1980	.0195	216.22
1981	.0189	217.14
1982	.0198	214.40
1983	.0195	219.07
1984	.0178	221.00
1985	.0205	211.44
1986	.0206	216.30
1987	.0223	221.21
1988	.0222	224.65
1961-1979	.0198	214.85
1962-1980	.0199	214.80
1963-1981	.0199	214.79
1964-1982	.0199	214.61
1965-1983	.0200	214.81
1966-1984	.0198	215.16
1967-1985	.0199	214.85
1968-1986	.0199	215.10
1969-1987	.0200	215.62
1970-1988	.0201	216.02

Table 5 (Cont'd)

Constituent : MS4

Period : 0.2543 day

Year	Amplitude(m)	Phase(deg)
1961	.0174	22.04
1962	.0182	28.53
1963	.0180	30.82
1964	.0166	15.08
1965	.0178	19.85
1966	.0174	13.92
1967	.0203	11.30
1968	.0196	19.37
1969	.0181	10.13
1970	.0172	13.64
1971	.0204	14.34
1972	.0208	13.35
1973	.0177	4.37
1974	.0187	9.95
1975	.0195	18.23
1976	.0215	16.80
1977	.0219	14.49
1978	.0207	12.89
1979	.0234	15.96
1980	.0215	18.45
1981	.0205	14.45
1982	.0227	11.27
1983	.0222	12.33
1984	.0201	352.85
1985	.0226	11.40
1986	.0222	16.19
1987	.0205	15.45
1988	.0214	15.51
1961-1979	.0191	15.98
1962-1980	.0193	15.84
1963-1981	.0195	15.14
1964-1982	.0198	14.17
1965-1983	.0201	14.02
1966-1984	.0201	12.66
1967-1985	.0204	12.53
1968-1986	.0205	12.80
1969-1987	.0205	12.61
1970-1988	.0207	12.88

Table 6 Vector mean amplitude and phase of the constituents at Quarry Bay* in 1961 - 1979

Constituent	Frequency (cph)	Amplitude (m)	Phase (deg)
Z0	.00000000	1.3644	360.00
SA	.00011407	.1165	296.98
SSA	.00022816	.0522	56.74
MSM	.00130978	.0067	154.89
MM	.00151215	.0028	291.35
MSF	.00282193	.0088	83.39
MF	.00305009	.0046	20.14
ALP1	.03439657	.0012	217.56
2Q1	.03570635	.0068	215.24
SIG1	.03590872	.0061	234.98
Q1	.03721850	.0543	228.27
RHO1	.03742087	.0112	227.08
O1	.03873065	.2892	250.31
TAU1	.03895881	.0041	39.72
BET1	.04004044	.0035	269.54
NO1	.04026859	.0186	276.28
CHI1	.04047097	.0034	271.96
PI1	.04143851	.0064	288.36
P1	.04155259	.1133	293.72
S1	.04166667	.0046	351.12
K1	.04178075	.3578	299.48
PSI1	.04189482	.0026	219.56
PHI1	.04200891	.0038	299.42
THE1	.04309053	.0041	324.28
J1	.04329290	.0138	319.23
SO1	.04460268	.0041	231.76
OO1	.04483084	.0070	22.99
UPS1	.04634299	.0004	61.50
ST36	.07335538	.0007	255.91
2NS2	.07466516	.0007	200.15
ST37	.07486754	.0016	305.58
OQ2	.07597495	.0011	206.09
EPS2	.07617732	.0041	187.12
2N2	.07748710	.0119	230.58
MU2	.07768947	.0198	214.85
SNK2	.07877109	.0003	132.97
N2	.07899925	.0837	251.36
NU2	.07920162	.0138	256.04
OP2	.08028324	.0037	75.66
H1	.08039733	.0060	269.65
M2	.08051140	.3968	267.68
H2	.08062547	.0007	280.16
MKS2	.08073956	.0020	318.25
LDA2	.08182118	.0025	316.40
L2	.08202355	.0078	283.78
2SK2	.08310517	.0011	17.33
T2	.08321926	.0101	291.57
S2	.08333333	.1578	297.28

* Please see para. 4.1

Table 6 (Cont'd)

Constituent	Frequency (cph)	Amplitude (m)	Phase (deg)
R2	.08344741	.0031	134.80
K2	.08356149	.0456	296.59
MSN2	.08484549	.0008	249.32
ETA2	.08507364	.0036	313.83
2SM2	.08615527	.0007	299.57
SKM2	.08638343	.0011	316.53
MO3	.11924206	.0081	351.77
M3	.12076710	.0140	338.75
SO3	.12206399	.0076	26.73
MK3	.12229215	.0133	41.28
SK3	.12511408	.0068	101.12
ST8	.15668872	.0018	37.51
N4	.15799850	.0028	241.96
3MS4	.15820087	.0038	94.68
MN4	.15951065	.0118	288.76
ST40	.16079464	.0023	106.82
M4	.16102280	.0323	322.15
SN4	.16233258	.0024	334.53
MS4	.16384473	.0191	15.98
MK4	.16407289	.0066	39.96
S4	.16666667	.0017	24.91
SK4	.16689483	.0017	107.23
2MK5	.20280355	.0026	264.57
MSK5	.20562548	.0015	339.78
2SK5	.20844741	.0007	343.52
2MN6	.24002205	.0021	114.14
ST41	.24130604	.0006	41.97
M6	.24153420	.0037	150.80
2MS6	.24435613	.0033	221.41
2MK6	.24458429	.0011	210.77
2SM6	.24717807	.0022	287.55
MSK6	.24740623	.0004	250.38
3MK7	.28331495	.0004	207.84
ST18	.31902130	.0003	21.43
3MN8	.32053345	.0009	63.09
M8	.32204560	.0012	84.12
ST20	.32335538	.0007	93.78
3MS8	.32486754	.0018	131.56
3MK8	.32509569	.0009	140.07
ST22	.32640548	.0001	157.56
ST23	.32768947	.0005	150.45
ST24	.32791763	.0007	196.10
M10	.40255700	.0018	210.18
ST29	.40386678	.0020	236.24
ST30	.40537894	.0034	269.74
ST31	.40691688	.0007	319.83
ST32	.40820087	.0017	332.69
M12	.48306840	.0002	177.54
ST34	.48589034	.0003	262.33

Table 7 Root mean square errors of the prediction for Quarry Bay* in 1983 - 1988

Year	Hourly height (m)	Extreme waters	
		Height (m)	Time (min)
1983	.1438	.1462	34.3
1984	.1408	.1510	34.3
1985	.1338	.1410	33.4
1986	.1331	.1382	36.3
1987	.1298	.1431	35.2
1988	.1635	.1767	34.7
Mean	.1408	.1494	34.7
Maximum	.1635	.1767	36.3

* Please see para. 4.1