GPS Survey of Control Markers on Chesil Beach
Technical Report

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Acknowledgements:

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Please let me know if I have overlooked anyone.

Executive Summary

To support future scientific surveys of Chesil Beach and the Fleet Lagoon and to assist potential management actions a network of coordinated permanent reference markers has been installed and surveyed precisely. The network is intended to function as a memorial to Alan Carr, the scientist who has made the most important contributions towards modern understanding of Chesil Beach. The markers are distributed as follows:

a) Thirty markers located at 500m intervals along the landward margin of the beach (Fleet Lagoon shoreline);

b) Four markers along the mainland shore of the Fleet;

c) Six secondary markers within the boundaries of Abbotsbury Swannery.

This report gives the results of a precise Differential Global Positioning System (DGPS) survey of the markers. It describes the methods used and assesses the accuracies achieved. Detailed national grid co-ordinates and elevations are provided for each point accurate to within at least ±3cm (majority within ±2cm). A series of maps and photos are provided within Appendix A to identify and locate the reference markers. Opportunity was also taken to collect a photographic record of the beach of the beach crest, backslope and other features at each 500m interval. Some samples of these photos are presented in Appendix B depicting notable excavated peat blocks and reactivated seepage "cans" following SSE storms of 26 and 27th October 2004. The full record of over 100 photos together with high-resolution versions of the various maps and report files are presented on a CD-ROM accompanying this report.

Two final sections discuss the potential uses that can be made of the reference markers and offer suggestions for dissemination of the information and for further studies.

1. Introduction

OVERALL PROJECT AIMS:

- To achieve a high quality network of permanent reference stations that would be available for the use of scientists for many decades to come. The control points should support beach surveys, Fleet Lagoon surveys (physical, ecological and archaeological) and potentially provide ground control for aerial photography. They should provide the spatial reference points for future monitoring of the physical and biological properties of Chesil Beach and the Fleet Lagoon;

- To create an appropriate and lasting memorial to Alan Carr;

- To contribute to ensuring the continued effective management of the beach and lagoon.

OVERALL PROJECT DESIGN

To address these aims thirty markers located at 500m intervals along the landward margin of the beach (Fleet Lagoon shoreline) and a further four markers along the mainland shore of the Fleet were installed. Each marker is formed of a heavy gauge (three inch) angle iron 2.44m in length driven some 1.5 to 2.0m into the beach/shore. In four instances existing structures were used as markers instead of the angle irons. Details of locations of markers and descriptions of individual markers are presented in Appendix A.

The intention is that a survey instrument can be set up above any of the markers with the marker surface at the apex of the angle iron serving as the survey datum. This report provides precise co-ordinates for each marker datum.

A Differential Global Positioning System (DGPS) survey was undertaken to precisely locate the markers because they were spread along a large area that has very little existing high precision survey control. Use of conventional survey techniques would significantly increase the time involved due to the need to laboriously extend the control along the beach and across the lagoon. There would also be a tendency for small survey errors to cumulate as control was extended away from initial known points requiring additional time consuming checking (or “closure”) of surveys. The GPS survey method outlined in the subsequent sections of this report overcomes many of these problems.

Why are permanent reference stations needed?

1. It is important that features of the size and importance of Chesil Beach and the Fleet Lagoon should be adequately monitored in order to better understand their behaviour and to inform their management;

2. Monitoring is especially important due to the dynamic nature of these features and their likely high sensitivities to future changes *e.g.* climate change. It enables early detection of key changes and provides a baseline against which the significance of future changes can be measured;

3. Much previous monitoring has not been continuous or consistent, due in large part to difficulties of locating and re-locating precise spatial co-ordinates from which to undertake surveys or re-surveys. The problems are a function of the size and shapes of the features and the remoteness of parts of the beach;

4. Provision of a network of permanent reference stations should facilitate more frequent and consistent future monitoring of the physical and biological properties of the beach and lagoon.

Why was it necessary to install reference stations every 500m on the beach?

1. To provide good coverage of the main portion of the beach and lagoon and to adequately record variations in conditions along its length *e.g.* variable rates of crest recession and overwashing;
2. To enable convenient sighting from base stations to intermediate locations between any pair of stations – most locations on the beach and lagoon should be no more than 300m from the nearest reference station, this is especially useful for total station instrument (electronic distance measurement) surveys. It saves time (often a critical factor with tides or adverse weather) and also reduces the tendency for small survey errors to accumulate that would exist if surveys had to be started from widely spaced initial points;
3. To allow buried, disturbed or vandalised base stations to be replaced swiftly using real-time GPS survey to relocate precise original co-ordinates. Real-time GPS has a maximum range of less than 1km, so the proposed 500m spacing should ensure that a neighbouring reference station is always within 500m of any station that is lost.

2. Summary of Results

The following table provides precise coordinates and accuracies of the marker points measured, together with estimates of their accuracies:

Point Ref	Eastings	Northings	Elev.	Description	Error estimate		
					±(mE)	±(mN)	±(mZ)
AS01	357645.966	84025.312	1.490	Nail in batten post	0.002	0.002	0.006
AS02	357733.808	84013.847	0.857	Nail in post	0.014	0.012	0.032
AS03	357524.411	83987.745	1.562	Nail in post	0.009	0.007	0.019
AS04	357474.320	83953.521	1.493	Nail in post	0.010	0.008	0.019
AS05	357243.143	83968.517	1.600	Nail in post	0.020	0.017	0.032
AS06	357544.392	84179.094	2.314	Nail in tarmac in car park	0.008	0.006	0.015
CB00	356445.796	84277.090	4.087	Corner of angle iron	0.011	0.007	0.018
CB01	356935.688	83940.109	2.857	Corner of angle iron	0.009	0.007	0.017
CB02	357335.758	83646.928	3.159	Corner of angle iron	0.009	0.007	0.018
CB03	357707.299	83354.941	2.544	Corner of angle iron	0.008	0.005	0.015
CB04	358370.674	82845.225	3.366	Corner of angle iron	0.009	0.005	0.013
CB05	358617.061	82665.010	2.851	Corner of angle iron	0.012	0.008	0.022
CB06	358926.255	82415.535	2.761	Corner of angle iron	0.014	0.007	0.017
CB07	359257.558	82160.223	2.661	Corner of angle iron	0.013	0.007	0.020
CB08	359560.925	81909.012	2.346	Corner of angle iron	0.008	0.005	0.015
CB09	359894.230	81681.663	2.219	Corner of angle iron	0.010	0.008	0.021
CB10	360199.561	81412.972	1.997	Corner of angle iron	0.010	0.008	0.018
CB11	360538.214	81125.982	2.086	SE corner of pulley block	0.013	0.009	0.022
CB12	360933.721	80796.314	2.225	Corner of angle iron	0.016	0.008	0.025
CB13	361277.158	80486.876	2.094	Corner of angle iron	0.018	0.012	0.032
CB14	361631.290	80215.475	2.294	Corner of angle iron	0.012	0.007	0.017
CB15	361995.103	79893.101	2.463	Corner of angle iron	0.021	0.009	0.026
CB16	362347.174	79595.023	2.737	Corner of angle iron	0.009	0.005	0.016
CB17	362674.150	79336.300	2.228	Corner of angle iron	0.012	0.008	0.023
CB18	362993.880	79051.528	2.825	Corner of angle iron	0.005	0.003	0.009
CB19	363306.605	78762.031	2.111	Sawn-off telegraph post	0.011	0.008	0.019
CB20	363660.253	78444.598	2.199	Corner of angle iron	0.012	0.008	0.020
CB21	363975.143	78155.564	2.803	Corner of angle iron	0.010	0.006	0.017
CB22	364295.773	77861.421	2.134	Corner of angle iron	0.011	0.008	0.018
CB23	364613.347	77641.014	2.082	Corner of angle iron	0.009	0.006	0.017
CB24	364979.282	77247.104	2.209	Corner of angle iron	0.011	0.008	0.022
CB25	365321.967	76921.028	2.575	Corner of angle iron	0.011	0.007	0.019
CB26	365729.415	76536.734	2.706	Corner of angle iron	0.016	0.007	0.019
CB27	366193.604	76090.609	2.489	Corner of angle iron	0.010	0.009	0.018
CB28	366514.449	75759.100	2.561	Bolt in cement block	0.002	0.003	0.006
CB29	366859.742	75499.511	2.326	Corner of angle iron	0.005	0.004	0.011
CB29Cr	366707.126	75364.620	12.402	Corner of angle iron	0.008	0.007	0.024
FL01	359248.816	82524.237	1.824	Corner of angle iron	0.008	0.006	0.016
FL02	360672.452	81373.896	2.148	Corner of angle iron	0.012	0.009	0.020
FL03	361630.307	80535.861	1.537	Corner of angle iron	0.006	0.005	0.012
FL04	363754.270	79084.145	0.893	Corner of angle iron	0.010	0.009	0.031
Average					0.011	0.007	0.019

AS = Abbotsbury Swannery
CB = Chesil Beach
FL = Fleet Lagoon

Plan coordinates on the United Kingdom Transverse Mercator (UKTM) projection, Airy Spheroid, OSGB (1936) datum.

Elevations referenced to mean sea level datum at Newlyn, Cornwall (Ordnance Datum Newlyn).

Accuracies refer to range of 1 standard deviation.

Users are referred to subsequent sections of this report for details of the survey and data processing techniques applied.

3. Methodology

Given the distances involved, and the requirement to tie the survey into the national coordinate system, it was decided to carry out a Differential Global Positioning System (DGPS) survey. It works on the principle that, given two GPS receivers collecting data simultaneously from a suite of satellites with one on known coordinates, (the base station), it is possible to obtain accurate coordinates of the second receiver. The line between the two points is referred to as a baseline. As the length of the baseline increases so the accuracy of the result decreases. This can be overcome by increasing the time spent taking the observations. There are no absolute times for achieving standard accuracies as they are related to a number of ungovernable factors such as satellite geometry and atmospheric conditions.

Due to the lack of any known coordinated positions in the vicinity of the survey area a decision was made to make use of the active stations within the Ordnance Survey's National GPS Network, (http://www.gps.gov.uk). This system collects data from a network of GPS receivers and makes the data available over the Internet. As the coordinates of all the OS stations are known they act as base stations. Baselines can then be observed to any number of points within the vicinity of Chesil Beach. To reduce the overall lengths of observed baselines along the beach three stations were placed within the vicinity of Chesil Beach that, once coordinated, would act as local base stations. In effect this would reduce the number of very long baselines and would consequently reduce the time required to undertake the survey. Figure 1 shows the active stations used in the survey, OSHQ, (Southampton), Taunton and Plymouth and their location with respect to the three local base stations, AS01, CB18 and CB28 selected in the vicinity of Chesil Beach. The Ordnance Survey recommends that a minimum of four hours observations are required to achieve acceptable accuracies in the order ±2cm. Table 1 shows the time spent observing baselines into the three base stations, demonstrating that the observation periods are in excess of the recommended guidelines.

Local Base Station	Date	OS Base Station	Observation Time (hrs)
AS01	5th Nov	OSHQ	4.73
		Taunton	4.73
	7th Nov	OSHQ	6.17
		Taunton	6.17
	8th Nov	OSHQ	1.72
		Taunton	1.72
	Total		**25.24**
CB18	6th Nov	OSHQ	5.59
		Taunton	5.59
	Total		**11.18**
CB28	30th Nov	OSHQ	4.69
		Taunton	4.69
		Plymouth	4.69
	1st Dec	OSHQ	5.70
		Taunton	5.70
		Plymouth	5.70
	Total		**31.17**

Table 1 Duration of baseline observations to coordinate the three local base stations

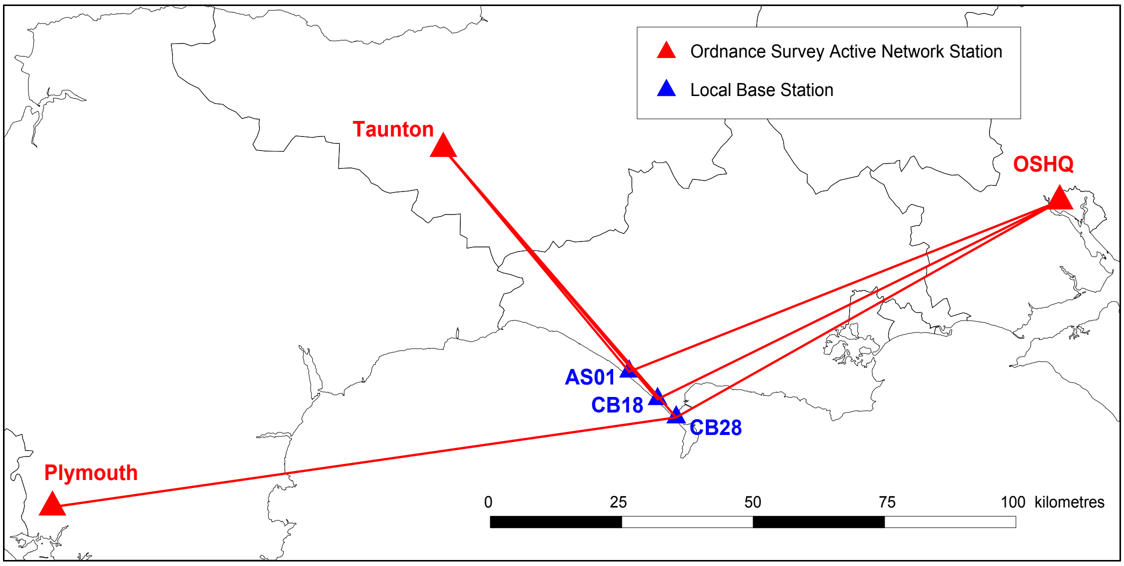


Figure 1. Three active OS GPS stations and the baselines measured to the three local base stations in the vicinity of Chesil Beach

From the two local base stations baselines of much shorter distance could then be observed to all the points in the vicinity of Chesil Beach. For points in Abbotsbury Swannery the longest baseline was in the order of four hundred metres, therefore observations were for approximately five minutes. For the points along the beach the longest baseline would be in the order of ten kilometres, therefore observations were taken for approximately fifteen minutes to ensure sufficient accuracies were maintained.

4. Processing

The data processing was carried out using GeoGenius® 2000 software developed by Spectra Precision, (now being marketed under the name of Total Control™ by Trimble). Prior to any processing the instrument heights above the station marks were entered as well as instrument phase centre offsets. These offsets are used to account for the fact that many models of instruments were used in this survey and each one has a different electrical centre as opposed to the physical centre. The phase centre offsets for the different instruments are detailed in Table 2.

	Instrument		Phase Centre Offsets (m)	
Station	**Receiver**	**Antenna**	**C1**	**C2**
OSHQ	Ashtech	700936E	0.1089	0.1274
Taunton	Leica	AT504	0.1093	0.1282
Plymouth	Leica	AT504	0.1093	0.1282
AS01, CB18 & CB28	Leica	SR 299	0.1164	0.1100
All other points	Geotracer	Mini Geodetic L1/L2	0.0365	0.0287

Table 2. Stations, receiver, antennas and their phase centre offsets

Additionally, the satellites transmit their positions so that the position of the receiver can be calculated. These *broadcast ephemeris* can be slightly inaccurate as the orbital parameters can vary due to the effects of the sun, moon and solar radiation pressure. From a global network of ground stations it is possible to correct the positions of the satellites. Approximately three to four weeks after the broadcast signal the final orbital positions, *precise ephemeris*, are made available as *.sp3 files.

Using broadcast ephemeris the accuracy of the orbit is approximately 200cm and the clock accurate approximately 7 nanoseconds, however using corrected precise ephemeris orbit is accurate to less than 5cm and the clock to less than 0.1 nanoseconds, (http://igscb.jpl.nasa.gov).

Once these additional files were incorporated into the project the baselines to the three local base stations (AS01, CB18 and CB28) were processed and adjusted using a least squares method. These three points were then marked as fixed and used to process the remaining baselines to the survey markers.

5. Accuracy of Local Base Stations

Figures C1-C6 in Appendix C give a visual comparison of the range of results obtained from the baselines observed as detailed in Table 1. Initial processing also included an additional OS Active Station at Nash Point in South Wales, however on examination the results from this station were considered to be unreliable and were therefore excluded from any final processing.

The plots show the result of each observed baseline in both plan and elevation; the numerical mean solution and a least squares solution weighted by the standard deviations of the individual baselines. This weighted least squares solution was considered to be the most accurate result and was used as the final result. The accuracies for the final result generated by GeoGenius® 2000 are given as 1 standard deviation, (i.e. that, given a normal distribution of results, there is a 67 percent probability that the correct position lies somewhere within the given range). These values are given in Table 2 below and are considered to be sufficiently accurate to proceed with processing the remaining baselines.

Station	±(mE)	±(mN)	±(mZ)
AS01	0.002	0.002	0.006
CB18	0.004	0.003	0.009
CB28	0.002	0.003	0.006

Table 2. Local base station accuracies given as one standard deviation

6. Loop Closure

Two points CB14 and CB23 were coordinated using baselines from two separate local base stations, (see Figure 2). The two separate results for each point can give an assessment of the relative accuracies of the local base stations. Table 3 shows the coordinates obtained for the two tie stations from the two local base stations and the differences between the results.

Tie Station	Base Station	Eastings (m)	Northings (m)	Elevation (m)
CB14	AS01	361631.278	80215.479	2.288
	CB18	361631.295	80215.475	2.303
	Difference	-0.017	0.004	-0.015
CB23	CB18	364613.350	77641.016	2.087
	CB28	364613.340	77641.017	2.068
	Difference	0.010	-0.001	0.019

Table 3. Coordinates for CB14 and CB23 measured independently from two local base stations AS01 and CB18, and CB18 and CB28 respectively

From Table 3 it is evident that the elevations from CB18 to both CB14 and CB23 are approximately 0.017m above those elevations observed from AS01 and CB28. There is an argument that the value of CB18 be adjusted by that amount, however it was felt that the adjustment procedure within GeoGenius® 2000 would adequately correct for this using the assessment of accuracies given in Table 2 and the loop closure values.

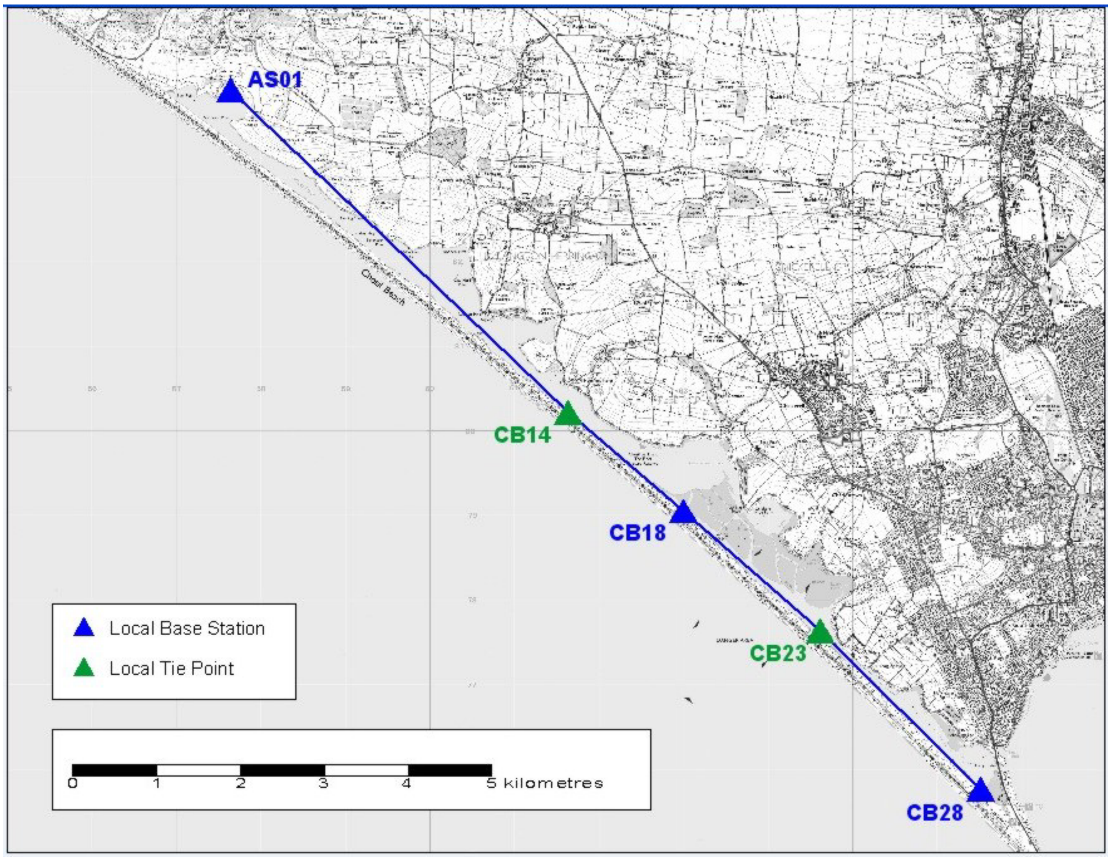


Figure 2. Location of three local base stations, two tie stations and the associated baselines

7. Accuracies

The quoted accuracies given in the Summary of Results are based on an accumulation of estimated errors that can be introduced into the survey. These can come from a number of sources and will be dealt with in turn.

<u>Instrument position</u>
When positioning the GPS instrument over a marker there is scope for error. This is essentially a human error and can be resolved into horizontal, (centring) and vertical, (instrument height), components, affecting the coordinate and elevation results respectively. This error should be small and random with a mean of zero throughout the survey. The loop closures indicate there are minimal errors in the results for the three local base stations.

<u>Satellite geometry</u>
Results for DGPS are obtained when a minimum of four satellites are observed simultaneously by both receivers. The result lies on the intersection of three spheres

at an observed distance from each of the three satellites, (the fourth satellite is used for timing correction). However, if the three satellites are in the same quadrant in the sky, then the solution can become 'loose' in that the spheres intersect at oblique angles. Small inaccuracies in the distances to the satellites can then result in large errors in plan and elevation. Most of this source of error can be overcome by ensuring that observations are taken over a reasonably long period of time. Each satellite orbit takes approximately 12 hours, which means that, given reasonable sky views, satellites will take anything up to six hours to cross the sky. To ensure that a reasonable coverage of the sky is obtained, thus reducing this source of error, observation times somewhere in the order of four hours are preferable.

Phase centre offset

The electrical centre of the antenna, (to which all baselines are measured), is not coincident with the physical centre of the antenna. If the same type of antenna is used throughout the survey then no corrections are required as the errors are constant for all instruments. However, using different antennas requires the offset values to be incorporated in the processing. These offsets are themselves subject to error but improve the accuracy when using multiple antenna types.

Atmospheric retardation

The ionosphere and troposphere slow the signal speed, the amount being dependent upon various constituents in the atmosphere. The differential method reduces this source of error by assuming that the atmosphere is the same above both GPS receivers. However it is not eliminated entirely. Greater spatial variability in, for example water vapour content, can lead to increased error, as certain paths through the atmosphere would have a larger effect than others. Shorter baselines are less susceptible to this form of error as the atmospheric changes are greater over longer distances.

Signal errors

When a static receiver records position over a period of time, the results show it to be moving in a random manner. This is due to the inherent noise of the signal. The Active Stations in the OS GPS network are fixed points but still have average 95 percent standard errors of 0.005m in plan and 0.016 in elevation. These errors are due to the inherent uncertainties in the result due to signal errors.

8. Suggestions for Uses of Reference Marker Stations

1. To enable precision surveys to be undertaken throughout the length of the beach and lagoon by a wide range of persons and organisations, including schools and colleges to *e.g.* beach profiling. Most users will be dependent upon traditional survey methods (Total station, level, or Abney level and tape) that require a known co-ordinate marker located close to any potential survey sites. It would reduce dependence on third parties and high-tech instrumentation and enable users to measure consistently from the same locations over future decades, thus enabling collection of reliable archives of surveys. Typical uses could involve beach profiling on Chesil, studies of beach flora/fauna, studies of Fleet Lagoon water levels and other physical water properties, coring of sediments and sampling or mapping of lagoon flora/fauna;

2. To provide known ground control points that are essential for checking the accuracy of any future airborne (LIDAR, CASI and air photo) and surveys e.g. highly visible temporary markers could in future be laid out on the reference stations whenever it were known that aerial surveys were being flown over the beach. The markers would then provide quality ground control for photogrammetric analysis and checking of aerial surveys;

3. To provide known ground control points and profile lines for future strategic monitoring of the beach for coastal defence purposes. The Channel Coast Observatory (www.Channelcoast.org) are appraising the feasibility of including Chesil (together with the other key SW coast beaches) within a major DEFRA funded monitoring programme;

4. To support any biological sampling as well as topographic surveys of the beach and lagoon (e.g. flora and fauna studies) without being limited to the features that could be picked up by air photos, LIDAR and CASI;

5. To allow local fast response surveys to events *e.g.* post storm surveys that are not dependent upon making expensive and time-consuming arrangements for aerial survey or reliance upon third parties and high-tech instrumentation;

6. To enable immediate use of real-time (radio-link) GPS anywhere on the beach for rapid ground surveys, or for relocation of fixed points or reference stations disturbed by overwashing, or affected by vandalism. Note that real time GPS (without custom modification) typically has a maximum range of less than 1km and so requires a network of appropriately located reference stations for most efficient use.

It should be noted that aerial surveys are extremely valuable in providing the most effective “snapshot” of the whole of the beach and lagoon on a single occasion, but ground surveys should always be required to address specific features, add detail, check remote sensing interpretations and provide more frequent coverage.

9. Further Recommendations

1. To fully realise the potential opportunities now afforded to the scientific and educational community it will be important to disseminate information about the marker system. Use of an internet website, or pages of an existing site should be the most efficient method. To be effective some care would needed in selecting appropriate keywords and registering with all commonly used search engines – that would enable users to efficiently directed to the site from search engines. Another option would be to link to/from existing heavily accessed sites that are relevant *e.g.* Jurassic Coast, Ian West’s Geology pages etc.;

2. Each marker ideally needs to be physically numbered enabling users to be absolutely sure which one they are using at any one time in the field;

3. To encourage users to undertake profiling studies across Chesil is important to undertake an initial set of profiles at each beach markers (CB0 to CB29). This would establish a valuable topographic baseline to which all subsequent surveys could be compared *e.g.* if a storm lowered a portion of the beach

crest, users could measure new profiles at relevant reference markers and then compare their results with the baseline profiles to quantify any changes;

4. Ideally, an archive of surveys should be established to collect profile data measured by users *e.g*. housed at the Ferrybridge Centre? It would, however, require information about the survey techniques applied by users to enable outline assessments to be made of accuracy and reliability of surveys. Results could be periodically be posted on the website to further advertise the value of the reference markers.

Location of

Survey Markers

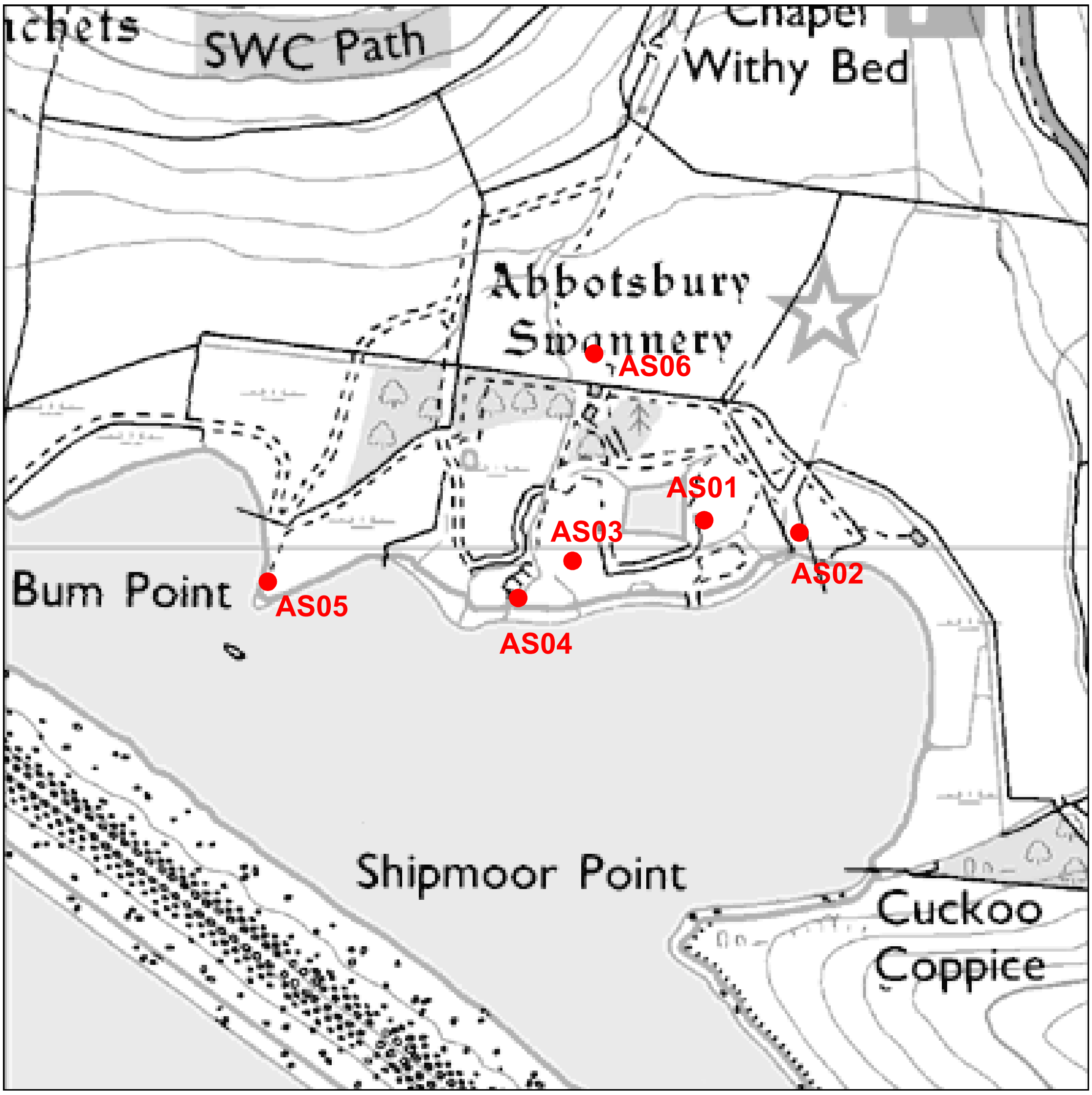


Figure A1. Locations of coordinated markers around Abbotsbury Swannery

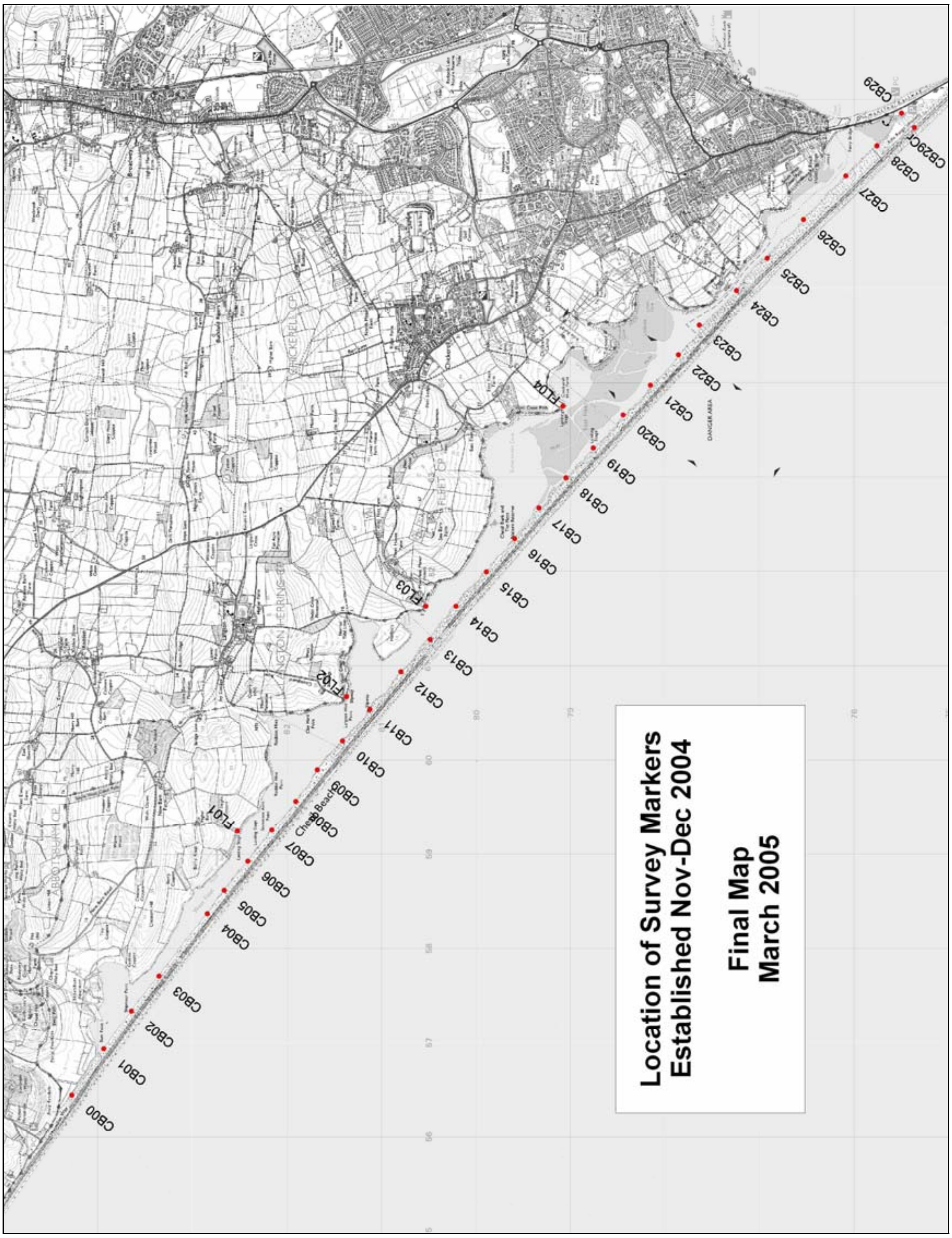
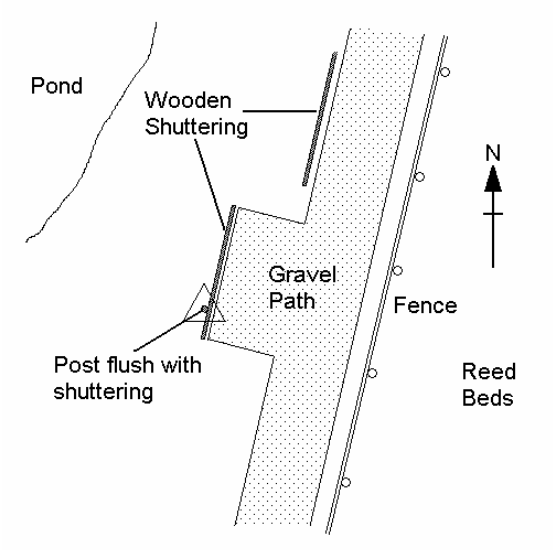


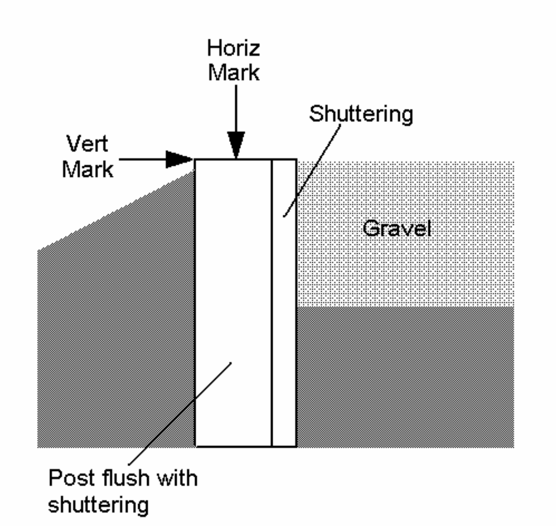
Figure A2 Location of coordinated markers around Fleet Lagoon and Chesil Beach

Description of

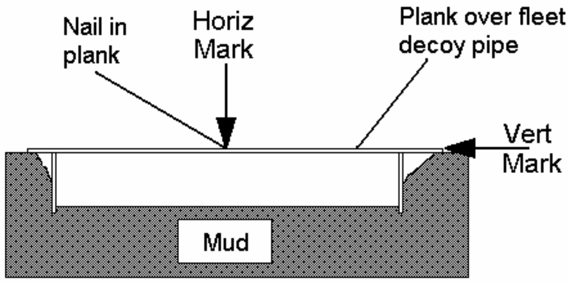
Survey Markers

Station AS01

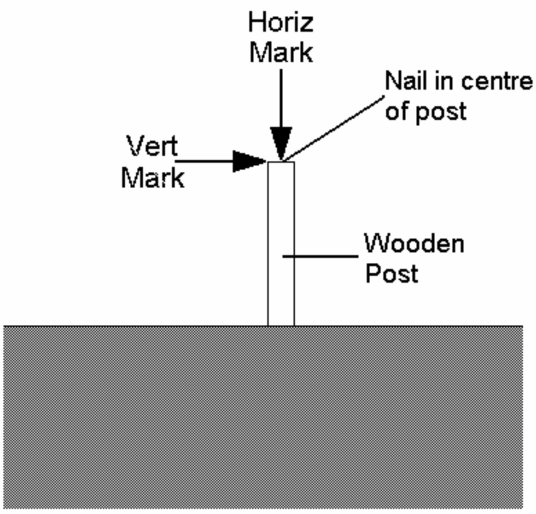




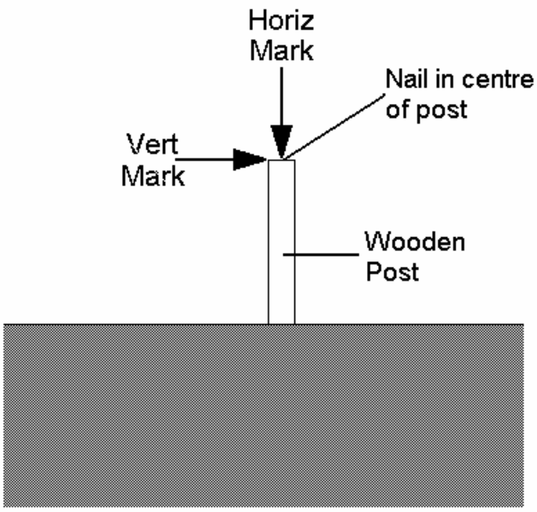
Station AS02



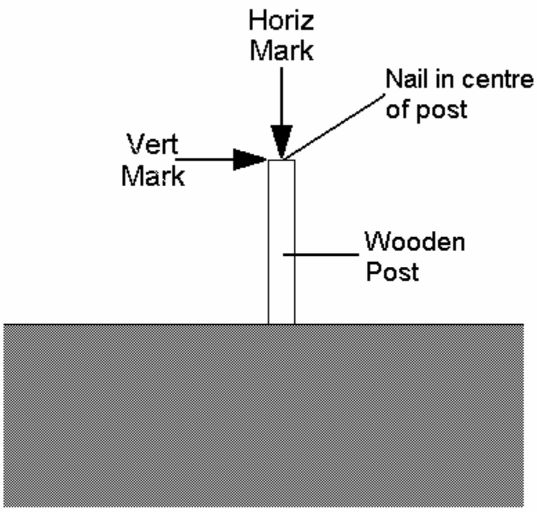
Station AS03



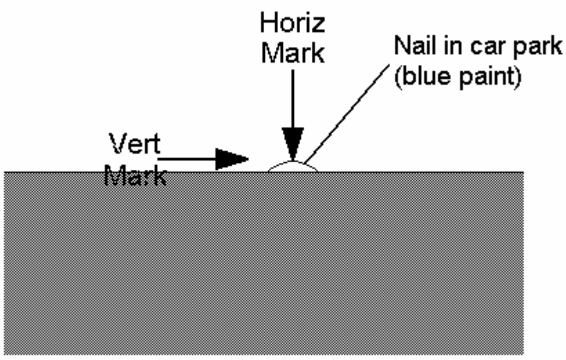
Station AS04



Station AS05

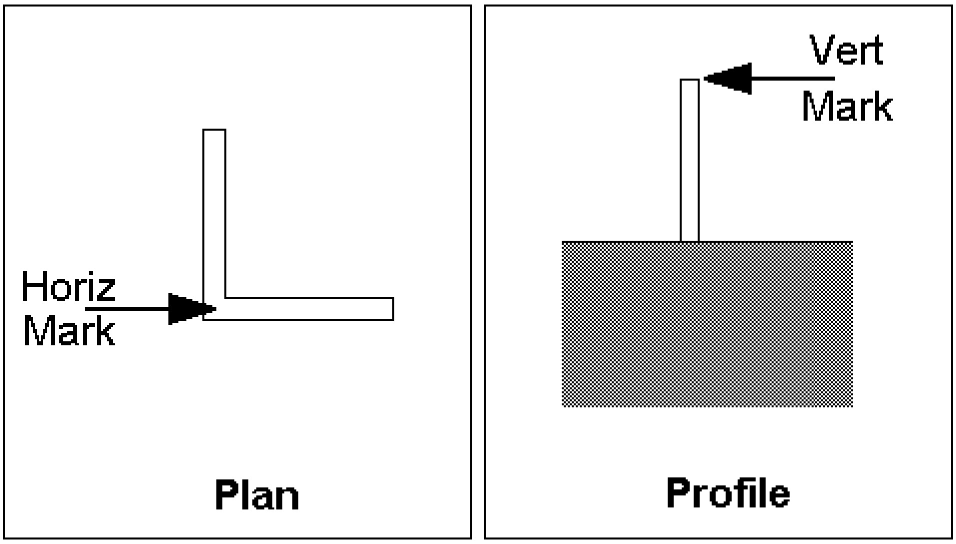


Station AS06



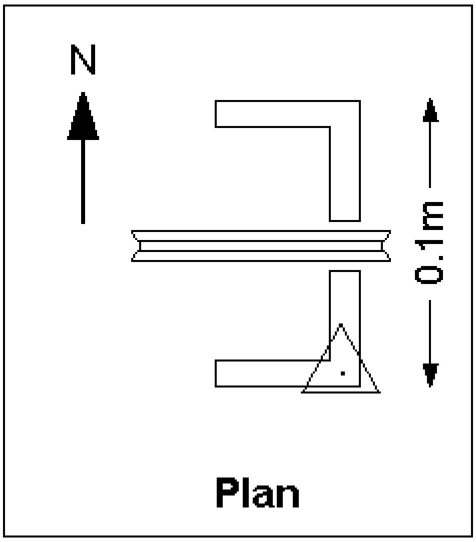
CB00, CB01, CB02, CB03, CB04, CB05, CB06, CB07, CB08, CB09, CB10, CB12, CB13, CB14, CB15, CB16, CB17, CB18, CB20, CB21, CB22, CB23, CB24, CB25, CB26, CB29, CB29Cr, FL01, FL02, FL03 and FL04

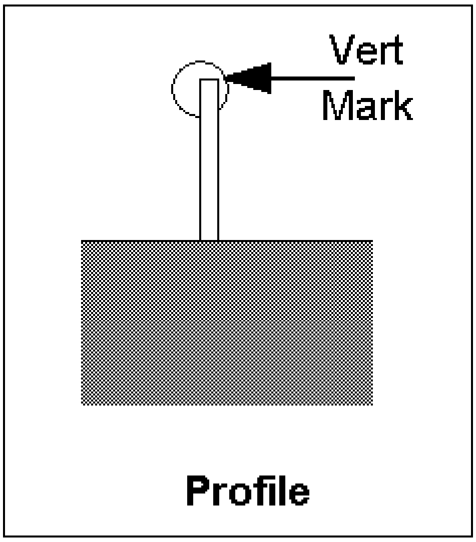
Station



3" Angle Iron

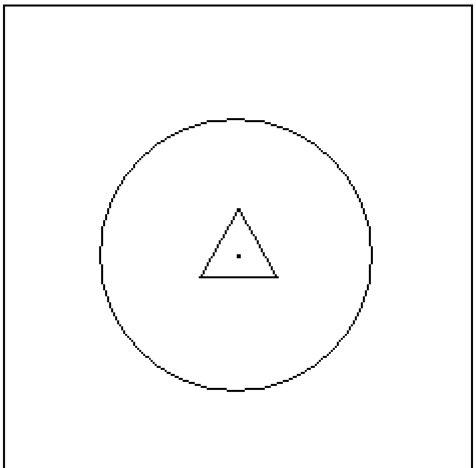
Station CB11



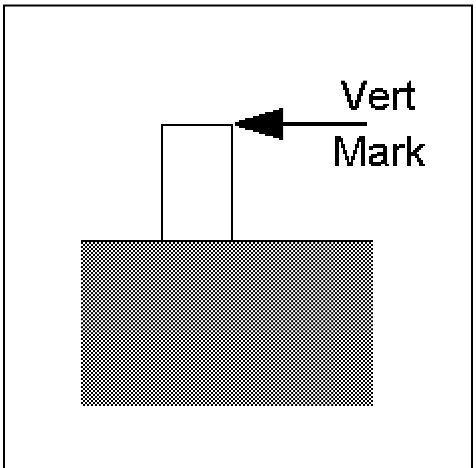


Pulley Block

Station CB19



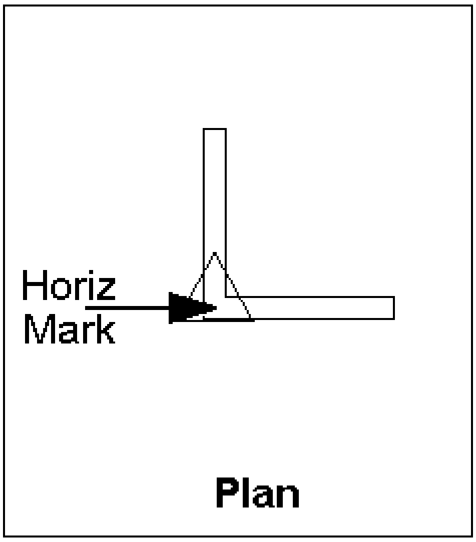
Plan

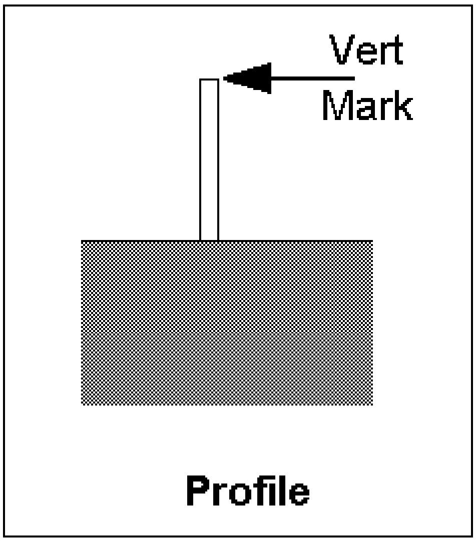


Profile

Sawn-off telegraph pole

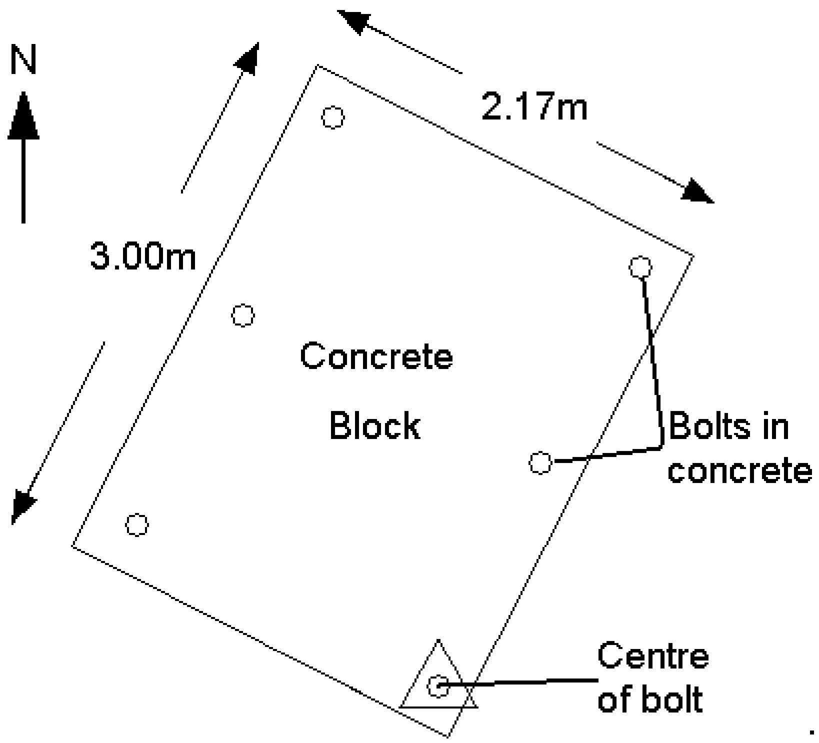
Station CB27





Existing Angle Iron

Station CB28



Plots of Base Line Results

Achieved at

AS01, CB18 and CB28

AS01

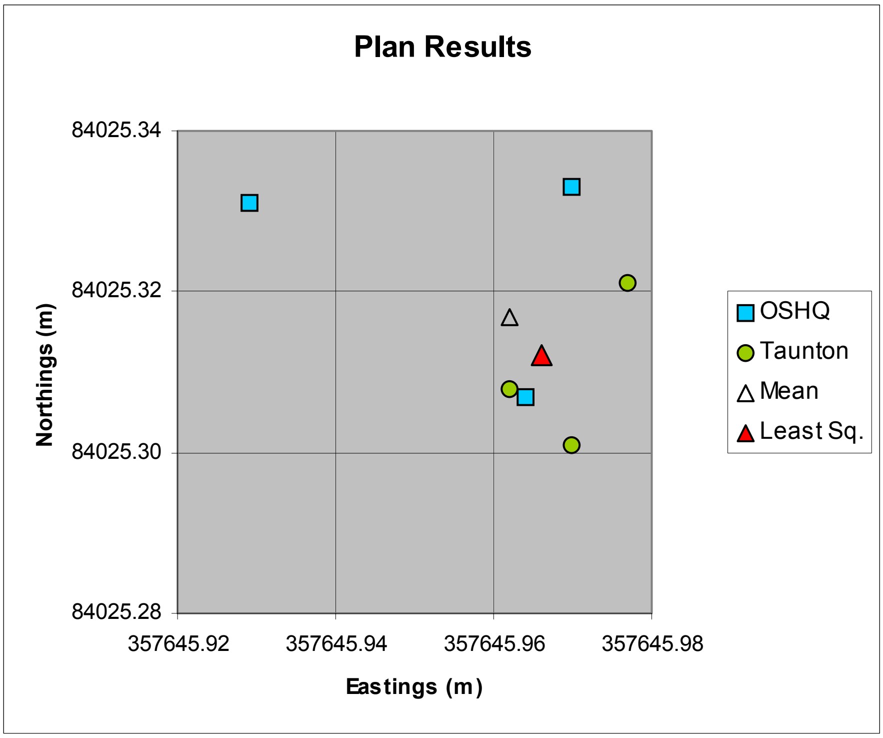


Figure C1 Baseline plan results at AS01

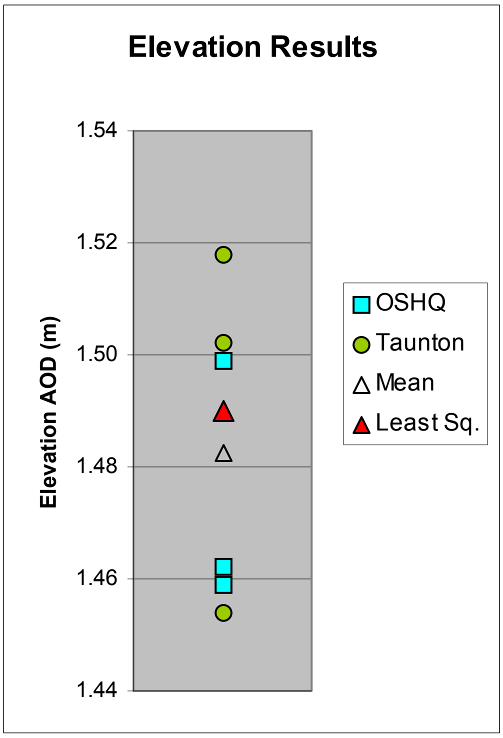


Figure C2 Baseline elevation results at AS01

CB18

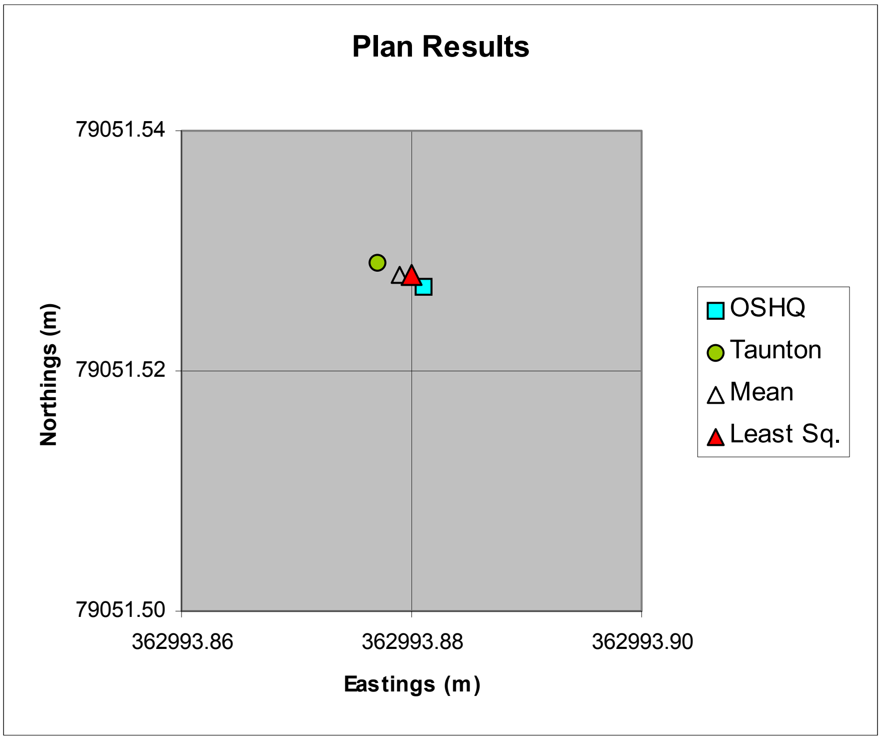


Figure C3 Baseline plan results at CB18

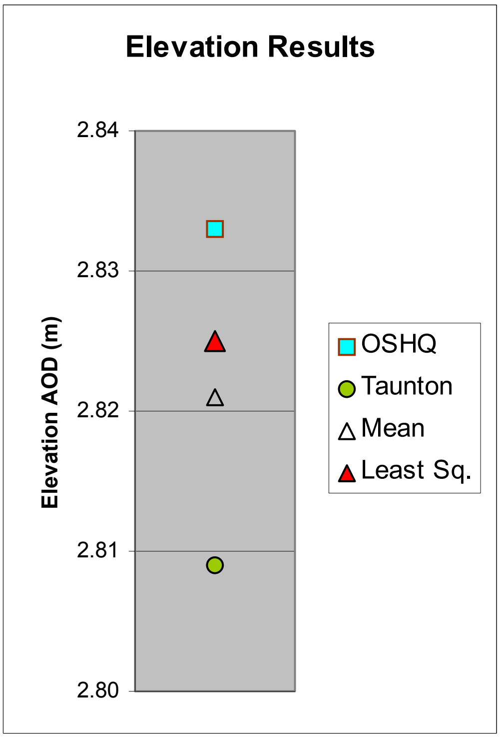


Figure C1 Baseline elevation results at CB18

CB28

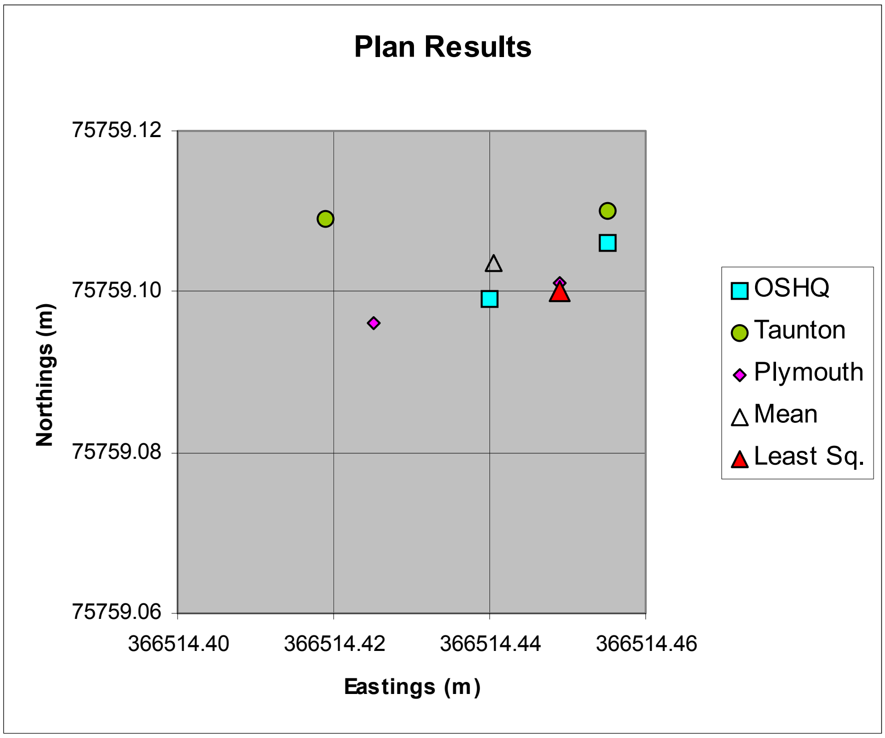


Figure C1 Baseline plan results at CB28

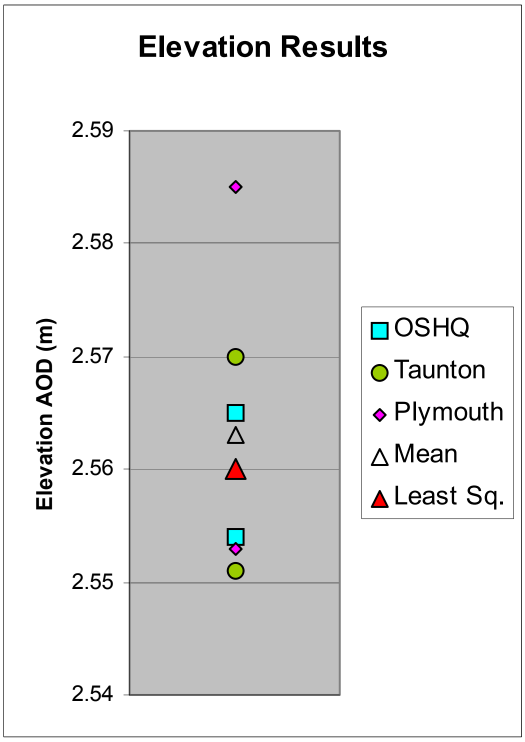


Figure C1 Baseline elevation results at CB28

Photos of

Survey Markers

and Beach

A series of photographs are presented on the CD-ROM of the following:

1. Each survey marker inserted;
2. Views NW and SE along the beach crest corresponding to each marker site
3. Features on the beach e.g. seepage “cans”

A severe storm from the SE affected the beach approximately one week prior to the 5th to 7th November 2004 surveys. This had the effect of excavating large peat blocks from the beach toe and depositing some of them along the upper beach face and crest. They can be seen in photos between CB 10 and CB 0. The extreme sea-level associated with the storm and spring high tide also appeared to have activated many of the seepage cans on the beach backslope resulting in formation of gravel fans along the Fleet shores. Can activity appeared especially marked between CB 1 and CB 6 and CB 21 to CB 25.

Active seepage can at CB 4 on 5th November 2005

Presentation showing occurrence of Chesil Peat at beach crest

A short PowerPoint presentation is included on the CD-ROM illustrating the origin of peat beds and explaining how blocks could be deposited on the beach crest: