International
Association
of Oil & Gas
Producers

Surveying & Positioning Guidance note 1

Geodetic awareness guidance note

Revision history

Version	Date	Amendments
1.1	22 August 2008	Error in false northing southern hemisphere corrected on page 5
1.0	22 May 2007	First release

Contents

1 Introduction to geodetic awareness
2 Basic principles of geodesy
3 Types of coordinate reference systems
4 Typical survey errors & consequences of geo-reference integrity failures
5 Recommended reading

1 Introduction

This guidance document is aimed at individuals with an exploration & production (E&P) background but a limited knowledge of geodesy. Its primary objective is to introduce and highlight the importance of geodesy as a discipline, whilst raising awareness of the concepts surrounding Coordinate Reference Systems (CRS). A secondary objective is to provide an appreciation of the risks and consequences of failing to understand the importance of geodesy and CRS in the E&P business. The document will also highlight the existing, more detailed OGP guidance notes, that are available on the OGP's website (see http://info.ogp.org.uk/geodesy/).

Geodesy forms part of a wider group of geosciences commonly known as geomatics. In simplistic terms, geomatics is the science and technology of gathering, analysing, interpreting, distributing, and using geographic information. This note will concentrate on the spatial referencing aspect. The science of geodesy, which underlies geomatics, is derived from the Greek for 'earth' (γη = γαια = gea) and 'I divide and measure' (δαιϖ = deo). Its literal meaning is *dividing, distributing and measuring the earth* and refers back to ancient Egyptian land surveying techniques. For the purposes of this document, the term 'surveyor' will be used where the terms 'geodesist' or 'geomatician' are often used.

The majority of the information that is of importance to the E&P business is only meaningful when associated with a location on – or near – the surface of the earth. The word 'near' includes the sedimentary basins and hydrocarbon reservoirs that essentially drive this dynamic industry. Spatial data (data pertaining to the location and spatial dimensions of geographical entities) runs through all E&P business processes like a thread: from the acquisition of permits, through exploration, appraisal, development and production, up to and including decommissioning and remediation. This spatial data is expressed explicitly via the use of CRS, but inadequate control of these CRS can lead to potentially serious risks for business, reputation, and Health, Safety & Environment (HSE) . The added value of geodesy to the E&P business lies in the assurance of the integrity of spatial data and the mitigation of the associated risks resulting from potential integrity violations.

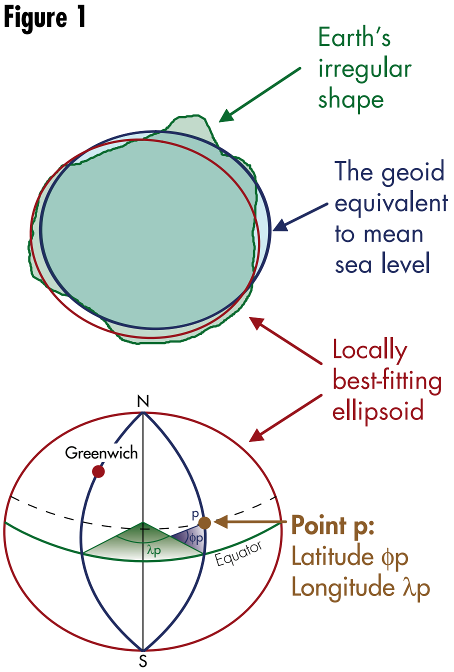
2 Basic principles of geodesy

Coordinates and Coordinate Reference Systems

Coordinates belong to a coordinate system. A Coordinate System (CS) describes the mathematical rules governing the coordinate space including: the number of axes, their name, their direction, their units, and their order. When coordinates are used to describe position on the earth, they belong to a Coordinate Reference System. A coordinate reference system (CRS) is a coordinate system which is referenced to the earth. The referencing is achieved through a datum (details to follow).

The surface of the earth is irregular (see Figure 1) and is therefore difficult to calculate on directly. Instead, surveyors use a model of the earth for their calculations. Numerous models exist and any one model may have several variations in position or orientation relative to the earth. Each variation leads to a different CRS. In general, if the coordinate reference system is changed then the coordinates of a point change. Consequently, coordinates describe location unambiguously only when the CRS to which they are referenced has been fully identified. OGP has created a database of these CRS to regulate and minimise the risk of applying the wrong systems or component parameters. See OGP guidance note 7 (*Using the EPSG geodetic parameter dataset*).

Figure 1



The Earth and the geoid

Helmert (1880) defined geodesy as 'the science of the measurement and mapping of the earth's surface'. As most of the Earth's surface is shaped by gravity, the determination of the geometric aspects of the Earth's external gravity field, the geoid, is a key element of geodesy as a science.

The surface of the earth with its topography is far too irregular to be a convenient basis for computing position. Surveyors reduce their observations to the gravitational surface, which approximates mean sea level. This equipotential surface is known as the geoid. It is approximately spherical, but because of the rotation of the Earth, there is a slight bulge at the equator and flattening at the poles. In addition, because of the variations in rock density that impact the gravitational field, there are many local irregularities. These factors make the geoid a complex surface.

Ellipsoids (also known as spheroids)

To simplify computing of position, the geoid is approximated by the nearest mathematically definable figure, the ellipsoid. The ellipsoid is effectively a 'best fit' to the geoid. However, there are numerous ellipsoids available, each of them uniquely named and defined either based on their semi-major axis, semi-minor axis or, more usually, a ratio of these axes called 'inverse flattening'.

Approximation of the geoid by a reference ellipsoid could traditionally only be done locally, not globally, and this limitation led to the existence of many ellipsoids, each with a different size and shape. Some of these ellipsoids approximated different parts of the surface of the geoid, whereas others expressed the increasing knowledge about the earth's shape and size over time. Now many of these ellipoids have become obsolete, whilst other have become enshrined in national mapping systems, such as the Airy ellipsoid from 1830, which still forms the basis of the British National Grid. A few important ellipsoids are highlighted in Figure 2 – note they sometimes have aliases and a date reference which can be confusing (hence the evolution of the OGP's EPSG dataset).

In summary, ellipsoids determine shape and provide a best fit of the geoid. The importance of ellipsoids will be discussed in more detail in “Geodetic Datums” below.

Figure 2

Ellipsoid name	Semi-major axis (equatorial radius)	Inverse flattening
Bessel 1841	6,377,397.155m	299.1528128
Airy 1830	6,377,563.396m	299.3249646
International 1924	6,378,388.000m	297.0000000
WGS84	6,378,137.000m	298.257223563

Geodetic Datums

A geodetic datum defines the position and orientation of the reference ellipsoid relative to the centre of the earth, and the meridian used as zero longitude – the prime meridian. The size and shape of the ellipsoid are traditionally chosen to best fit the geoid in your area of interest. A local best fit will attempt to align the minor axis of the ellipsoid with the earth’s rotational axis. It will also ensure that the zero longitude of the ellipsoid coincides with a defined prime meridian. The prime meridian is usually that through Greenwich, England, but historically, countries used the meridian through their national astronomic observatory. This best fit is centred on a position on the earth’s surface within the area of interest, *eg* the Helmert Tower at Potsdam, near Berlin, was used for the European Datum 1950 (ED 50). A geodetic datum is inextricably linked to the generation of geographical coordinates.

Geographical coordinates (latitude and longitude)

The position of a point relative to a geographical coordinate reference system is described on the CRS ellipsoid and is generally expressed by means of geographical coordinates: latitude (ϕ)and longitude(λ), as shown in Figure 1. These are angular expressions related to the equator and the prime meridian, usually, but not always, the meridian passing through Greenwich, London (these being the 0° references for the N–S/E–W directions respectively). For example, a typical position would be expressed as Latitude 57°30’15”N, Longitude 3°40’20”W. Note that a position with a latitude south of the equator or longitude west of the prime meridian is sometimes shown as negative, *eg* -3°40’20”. It is very important to appreciate that latitude and longitude are not unique and are therefore entirely dependent on the chosen geodetic datum (see following section). Conversely, any given values of latitude and longitude can refer to any geodetic datum.

Heights above the ellipsoid are not of much practical use because it is easier to measure height from or to the geoid. This will be discussed later on. In summary, as with any other type of coordinate, geographical coordinates in themselves do not describe position unambiguously: the associated CRS must be identified.

Without knowledge of the geodetic datum, the latitude and longitude of a point will have an inherent ambiguity of up to 1500 metres, this being the maximum positional effect caused by the irregular shape of the geoid. An ambiguity of this magnitude may be disastrous for achieving E&P business goals; it may even lead to very severe HSE incidents by *eg* drilling into a shallow gas pocket believed to be hundreds of metres away.

Each of the many models (ellipsoids) may have several determinations of its reference to the earth, each resulting in a different geodetic datum. For example, the International 1924 ellipsoid is referenced to the earth at Potsdam for the European 1950 datum, but also referenced to the earth near Rome for the Monte Mario 1940 datum used in Italy. Because of the irregularities of the geoid, a point has coordinates referenced to European datum that differ by several metres from coordinates referenced to Monte Mario datum, despite both datums using the same ellipsoid. Similarly, if the model is changed (a different ellipsoid adopted), even when the reference point is retained, coordinates of positions away from the reference point will differ. For more detail see OGP guidance note 13: *Advisory note on derivation of geodetic datum transformations*. Other types of CRS will be discussed later.

Latitude and longitude are NOT unique

The illustration opposite (Figure 3) shows the Eiffel Tower in Paris. Note that although the WGS 84 and ED 50 coordinates share the exact same latitude and longitude values (48°51’29”N, 2°17’40”E), they do not represent the same physical point on the earth’s surface (the yellow dot representing the correct location). In this example the difference between the two coordinate reference system positions is approximately 140 metres. This demonstrates that latitude and longitude are not unique without the associated CRS being identified.

Figure 3

Global Positioning System (GPS)

The use of GPS is now widespread within the E&P industry and its applications are far ranging. GPS is a worldwide navigation system operated by the US Department of Defence and formed by a constellation of 24 satellites (see Figure 4) and their ground stations. GPS receivers use these satellites as reference points to calculate positions accurate to a matter of metres, on or above the Earth’s surface. These “black box” units generate a 3D coordinate, which can be used for navigation (amongst other numerous purposes) and ultimately determine your position in terms of a latitude and longitude. In addition, they compute a height above the ellipsoid for that associated position.

The coordinate reference system used by the GPS system is known as WGS 84. The WGS 84 CRS has its own ellipsoid, confusingly also known as WGS 84. There is no single datum origin point for the WGS 84 datum and geographic coordinates are derived from a world adjustment of several geodetic markers surveyed by GPS.

At time of writing, there are alternatives to GPS on offer such as GLONASS (the Soviet equivalent of GPS which also uses its own global CRS, known as Parametry Zemli 1990 or PZ90) and the European Space Agency is planning a new commercial system called Galileo which is scheduled to be fully operational by 2010. Satellite derived positions such as those from GPS are often transformed to a local CRS. It is these transformations that harbour potential risk from a geodetic perspective.

Figure 4

Coordinate transformations

In order to merge points such as surface well locations (whose geographical coordinates are referenced to one particular CRS) with other points based on a different CRS, one of the two datasets must be transformed. It is possible to measure and calculate the displacements, rotations and scale differences between them. There are numerous different methods of transforming coordinates and more detail can be found in OGP guidance notes 7 & 13. Various E&P companies adopt different CRS to store geo-referenced data in their corporate databases. It is therefore quite common to have to transform data sets to suit the recipient’s prescribed CRS, prior to sharing data with other operators or submitting information to regulatory bodies.

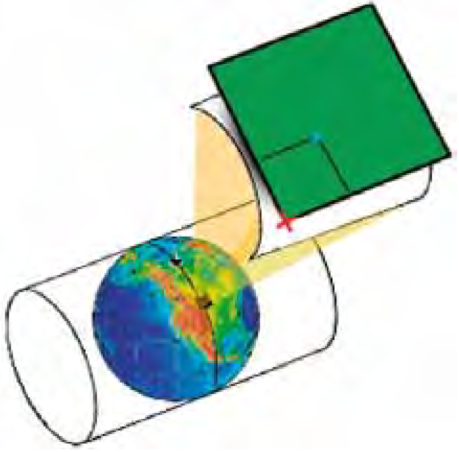
Note: colloquially a coordinate transformation may be referred to as a ‘datum transformation’. This usage is not strictly correct: it is the coordinates, not the datum, that are being transformed.

3 Types of Coordinate Reference Systems

Projected Coordinate Reference Systems (provide "grid" coordinates)

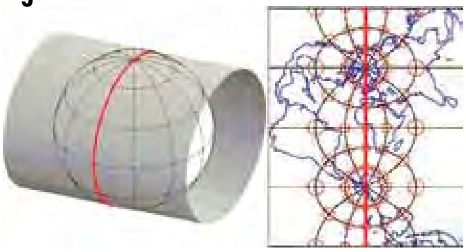
A projected coordinate reference system is a flat, two-dimensional representation of the Earth. It is a mathematical map of geographical coordinates onto a plane surface, so that calculations of distance and area are more easily performed. These projected CRS's are usually expressed in metres as Easting and Northing. A graticule (lattice of lines of equal latitude and longitude) cannot be projected onto a plane without distortion. This is similar to removing an orange peel and trying to force it onto a flat surface – it tears, bends and distorts (see Figure 5). When one property is preserved, others are distorted. For instance, in Figure 5, note that the grid distance on the map is not equal to the actual distance on the earth's curved surface. The difference in these lengths will vary over the map's extent; distances are true (equal) only along the central meridian. Map projection methods have been formulated so that distortion of one or more characteristics (area, shape, direction, distance, *etc*) is controlled (see Figure 6).

Figure 5



The most commonly encountered map projection methods in the E&P industry preserve shape (the technical term is 'conformal'). Several map projection methods such as the Lambert Conic Conformal and Transverse Mercator have this property. Projected coordinate reference systems incorporating these map projection methods contain distortion in distance and area. A Lambert Conic Conformal projection uses a cone, whereas a Transverse Mercator projection is a conformal cylindrical projection. The latter can be visualised by imagining the map plane wrapped around the earth (ellipsoid) in the form of a cylinder tangential to the equator (see Figure 6). One meridian, usually at the centre of the mapped area, will be defined to be the longitude of the projection origin. It is easily seen that only closely around this meridian the projection is reasonably distortion free. The subject of projections is far ranging and as such more details can be found in OGP guidance note 7.

Figure 6



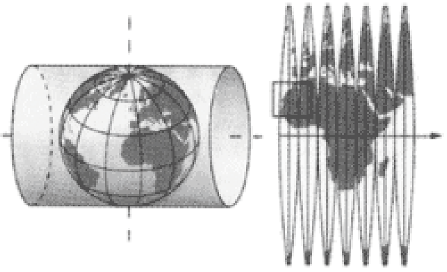
Universal Transverse Mercator Projection

The most common map projection used in the E&P industry is the Universal Transverse Mercator (UTM) projection. Introduced by the US Army Map Service in the 1950s, it uses a series of 60 individual zones (defined to be 6 degrees of longitude wide) to cover the world (see Figure 7). The point at which the central meridian in each zone intersects the equator has been given the coordinates Easting = 500,000, Northing = 0 metres. For the southern hemisphere the same point has the coordinates: Easting = 500,000, Northing = 10,000,000 metres. This prevents map coordinates from ever be coming negative, which reduces potential errors in its use.

Many people mistakenly believe UTM to be superior or a synonym for other map projections. This is a common misconception. UTM is simply an internationally agreed map projection system covering the whole world except the poles. Indeed UTM is not the only zoned grid system in use.

It is important to note that any one map projection, including UTM, may be applied to any geodetic datum. Therefore, projected CRS must be properly identified to avoid any ambiguity. As grid coordinates are derived from geographical coordinates, they too describe location uniquely only when the geodetic datum is identified. Grid convergence must also be accounted for especially when dealing with azimuth observations in operation such as directional drilling. See the section entitled "True, Grid and Magnetic North bearings" for more details.

Figure 7



Individual zones of 6 degrees each

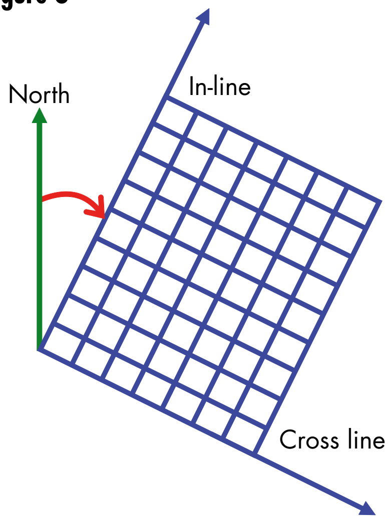
Local Grids (or Engineering Coordinate Reference Systems)

In the case of small scale projects (a few square kilometres) it is sometimes convenient to use an Engineering Coordinate Reference System, also known as Plant Grid or Local Grid. The application areas of such grids are mainly production plant, industrial or residential compounds. Engineering CRS are commonly based on a simple flat-earth approximation of the earth's surface, and the effect of earth curvature on feature geometry is ignored.

Seismic Bin Grids

Seismic bin grids and seismic cubes also ignore earth curvature, but are a bit more sophisticated. Whilst it has been common practice to survey marine seismic lines on the projected CRS, seismic interpretation software allows manipulation of the data without any knowledge of the geodetic datum and map projection upon which it has been shot. A bin grid inherits the properties of the CRS upon which it was implicitly or explicitly constructed, including any map projection distortion. For this reason grid convergence (explained later) and distortion must be managed. The bin grid is the relative coordinate framework, which defines a matrix of evenly spaced points referred to as the bin nodes (see Figure 8). These nodes are the points to which groups of traces are referenced. To be able to relate the bin grid coordinates to their map grid coordinates an affine transformation (a transformation that preserves lines and parallelism) is used. Bin grids based on projected coordinate reference systems are still subject to scale factor and grid convergence. It must be appreciated that bin grids are distorted when converting from one projected CRS to another. In-lines and cross-lines can be distorted by up to 0.15% so checks must be implemented to manage any errors, *eg* up to 15 metres over 10km, 30 metres over 20km. There is more guidance on bin grids in OGP Guidance Note 2, *Use of bin grids and coordinate reference systems in workstations*, and the UKOOA document entitled *P6/98 Data Exchange Format-3D Seismic Binning Grids* (http://www.info.ogp.org.uk/geodesy/P6.pdf)

Figure 8



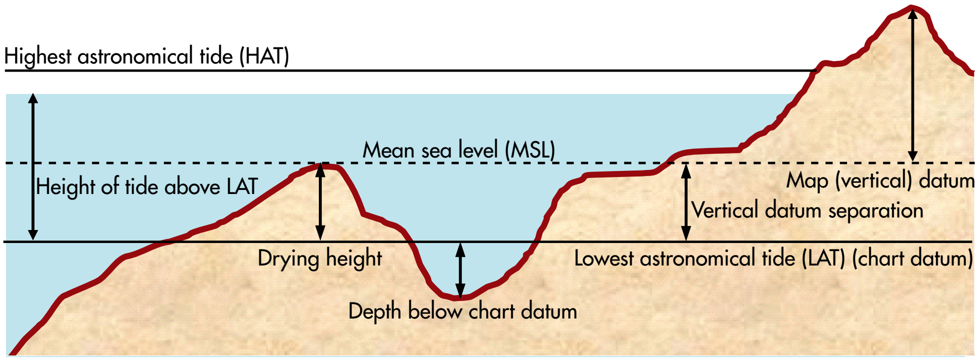
Vertical Coordinate Reference Systems (for height references)

Two types of height are recognised: ellipsoidal height and gravity-related height. Heights may be referenced to the geoid or, as part of a 3-D geographic CRS, to an ellipsoid. Ellipsoidal heights cannot exist by themselves; they form the vertical component of a 3-dimensional geographical CRS that has a defined geodetic datum. Ellipsoidal heights are measured perpendicularly to the surface of the relevant ellipsoid.

Gravity-related heights are measured in the direction of the earth's gravity field. They are referenced to a vertical coordinate reference system (see Figure 9). This is a one-dimensional CRS based on a vertical datum and a vertical coordinate system. The vertical datum defines a surface perpendicular to the gravity field from which heights are referenced. Typically, the reference surface will be associated with sea level. Because ocean tides cause water levels to change constantly, the sea level is generally taken to be the average of the tide heights at some particular place over some specified period. For example, in Great Britain, the vertical datum is based on the average sea level at Newlyn between 1915 and 1921. From an offshore perspective, where the determination of under keel clearance is essential, the vertical datum will often be associated with Lowest Astronomic Tide (LAT). For engineering purposes, MSL is often more appropriate. LAT over extended areas will be found at varying distances from MSL as tidal dynamics cause changes in the tidal range. It is therefore not a level surface except locally.

Labelling of depths is also critical as can be seen later. More details on tides can be found at http://www.pol.ac.uk/home/insight/tidefaq.html.

Figure 9

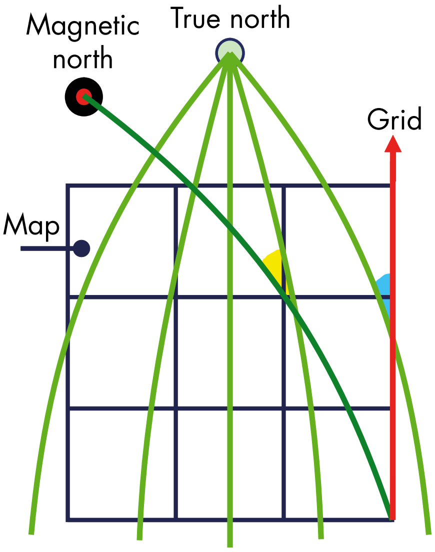


True, Grid and Magnetic North bearings

Directional measurement (*eg* a 45 degree bearing on a compass) is often taken for granted and forms the basis for many geo-referenced integrity related errors. True north is the direction towards the geographic North Pole and is the direction of all meridians on a geographic coordinate reference system (see Figure 10). Grid north, however, is based on the chosen projected coordinate reference ('grid') system. True north and grid north coincide along the longitude of origin of a map but grid north diverges from true north as you move away from the origin. Grid convergence is the angle between grid north and true north and thus also varies depending on position and distance from the chosen projection origin. In addition to varying in magnitude, grid convergence varies in a positive/negative sense, both north/south of the latitude of origin, and east/west of the longitude of origin. If bearings are converted from one (map) grid to another, one must also account for the difference in rotation between the two projected coordinate reference systems.

Finally, magnetic north is the direction sensed by a compass; the direction of the horizontal component of the Earth's magnetic field at a particular point on the Earth's surface. A compass will align itself in the direction of the field with the positive pole of the compass pointing to the magnetic north.

Figure 10



Magnetic north is a point located hundreds of kilometers from the North Pole (currently in Northern Canada) and it is not stationary. Declination is the horizontal angle between magnetic north and true north. The declination in a given area will change slowly over time, possibly as much as 2-25 degrees every hundred years or so, depending upon how far from the magnetic pole it is. For this reason when quoting any magnetic bearings, the date and declination used must be quoted. For example, at 57° N, 3° E on the 12th September 2006 the declination = 1° 44’ W changing by 0° 9’ E/year.

Magnetic bearings are especially important for drilling and specifically directional drilling operations and are often a source of error if not sufficiently referenced. It is important to note that, like geographical coordinates, bearings can be quoted in many different formats *eg* 56°15’ 23” (sexagesimal), which is equivalent to 56.2564° in decimal format. Some software packages employ a so-called ‘packed decimal’ notation where *eg* 56.1405789 should be read as 56°14’ 05.789”. There are also angular units of measure in use such as the gon or grad, which divide a full circle into 400 divisions as opposed to 360°.

Labelling of spatial data

There are numerous ways to mislabel or misinterpret coordinates *eg* incorrect coordinate reference system quoted, incorrect identification of elements of a coordinate reference system (such as ellipsoid or map projection), incorrect transformation parameters, coordinate transformation claimed but not applied, coordinate transformation applied twice, coordinate transformation applied with the wrong sign convention. For this reason, all coordinates should be properly labelled with as a minimum the following information:

> Drilling unit as-built position (rotary table) = 58°00’000”N 2°00’000”E , 440889.2mE, 6429293.8mN
>
> All coordinates based on European Datum 1950, International 1924 Ellipsoid, with projected grid coordinates based on Universal Transverse Mercator zone 31N with a Central Meridian of 3°E (UTM Zone 31N)

As with geographical and map grid coordinates, to avoid ambiguity, heights or depths require clear identification of vertical coordinate reference system including datum and units. For example, the water depth for the rig detailed above (note that surveyors and drillers often work in different units) should be as following:

> Water depth at the Rotary Table = 95.1 metres below LAT datum.
> (equivalent to 314.1 feet below MSL, where MSL is 0.65m above LAT due to tidal dynamics)
>
> Water depths surveyed by the M/V Explorer on 6th May 2006. NB 1m = 3.280839895 International Feet
>
> NB – for “dropped objects” planning, the rotary table lies 25.0 metres above MSL at normal drilling draft.

More details on requirements for unambiguous coordinate reference system definition can be found in OGP guidance note 5.

Horizontal and vertical coordinate reference system definitions for most widely used systems encountered in the E&P industry are tabulated in the EPSG Geodetic Parameter Dataset (see http://www.epsg.org/). It may be useful to label coordinates by cross-reference to the relevant CRS code from this dataset. Details of the dataset content may be found in OGP guidance note 7.

When GPS (which uses the WGS 84 CRS) has been used for positioning, and the subsequent work is conducted in a different CRS, it is critical to ensure that details of the transformation used to convert GPS coordinates to local coordinates are recorded. Transformation details may be in the EPSG dataset and like CRS details may be cross-referenced to that dataset.

4 Typical survey errors & consequences of geo-reference integrity failures

Most geo-reference integrity failures arise from incorrect assumptions, poor or non-existent labelling of coordinates or a lack of awareness of the geodetic complexities. Many individuals are not aware for instance, that latitude and longitude are not unique. In addition, there are several E&P software packages that are regularly used to process or manipulate spatial data yet do not take into account the subtleties surrounding CRS. For example, some applications cannot distinguish between true north and grid north (which introduces rotational issues when loading well position logs).

The table on the next page highlights the implications of what can go wrong when geodetic issues are not given due diligence (these examples are not readily found in the public domain):

Operation	Scenario	Root Cause	Business Impact
Appraisal well planning	Whilst merging two separate 3D seismic datasets observed on different CRS, a cumulative error was made of 250 m due to incorrect and coordinate transformations.	• Lack of knowledge of the proper transformation method. • Use of different geology and geophysics (G&G) software packages that did not handle CRS data properly. • Lack of quality control (QC).	• Resources spent on investigating error. • Expensive reprocessing which took 3 months. • Knock on effect on subsequent operations e.g well planning or drilling sequence.
Jack-up rig positioning	During a rig move in the North Sea. The surveyor went off shift, leaving his engineer to look after the navigation. The engineer did familiarise himself with the software, but didn't realise he had inadvertently changed the reference ellipsoid. Surveyor arrived back on shift whilst approaching location, navigation appeared fine so rig was positioned and moored up accordingly. Radar checks on a local platform revealed inconsistent positions. The wrong ellipsoid had been used i.e Everest was applied instead of International.	• The projected grid coordinates generated by the navigation software were incorrect. • By selecting the wrong ellipsoid, the software generated incorrect geographical and subsequently the wrong grid coordinates. • No offshore survey representative present to perform relevant QC.	• Rig 1.5 km off location, in another company's block. • Anchor handling vessels recalled to site. • Rig had to be repositioned. • Cost: $750,000. • Reputation issues. • Government reviewed license arrangements.
Land based drilling	Well drilled on the wrong Geodetic Datum in the Middle East (Egypt). New well came too close (within 200m) to the adjacent licence block. A 500m buffer had been legally established but this erroneous spud location fell within the buffer.	• Inadequate knowledge of Geodesy. • Wrong CRS adopted. • Lack of sufficient planning and QC.	• Well data had to be given free of charge to the competitor in the adjacent licence. • Loss of competitive intelligence. • Legal implications.
Platform drilling	Directional drilling contractor drilled 12 new wells from a production platform. The meridian grid convergence was incorrectly applied in the directional software. Bottom hole locations were not hit resulting in 12 dry wells.	• Convergence correction was of the wrong magnitude and sign conventions. • Latitude setting on the North Seeking Device was also incorrect.	• Loss of capital expenditure ($2 million). • Contractor received a non conformance report. • New campaign on drilling had to be recommenced.
Construction	A proposed position for a new subsea manifold was issued via an E&P operator on the ED50 datum. The Subsea Installation contractor wrongly assumed that these coordinates were related to the WGS84 datum and positioned accordingly. The pile driven manifold was therefore positioned 136 metres away from the intended location. Error only discovered when a pre-lay survey vessel did not find the manifold in the expected position.	• Incorrect assumptions were made (common geodetic problem). • The CRS was not properly identified. • European Petroleum Survey Group (EPSG) codes were not used to identify the two CRS systems. • No offshore survey representative present. • Staff not competent to perform task i.e had not received correct awareness training	• Significant delay to project. • Re-routing of pipeline approach. • Reputation issues with government & environmental bodies. • Contract dispute with installation contractor. • Contract Variation issued at as cost of $500,000.
Data conversion	A small E&P operator had recently purchased a mature field from another company containing several development wells. All corporate datasets for this field had been merged into the new companies existing database. Top-hole locations for each of the wells were correctly transformed taking into account the different UTM zones that the previous operators CRS had used. However, the bottom-hole positions were found to be in error by 65 metres.	• A 3° difference in grid headings between the two UTM zones and this had not been accounted for in the azimuth references within the down-hole deviation logs. • The anti-collision software did not alert the well planners to the close proximity of nearby well path when drilling a new sidetrack as the azimuth references were in error by 3°.	• The rig inadvertently drilled through a neighbouring well bore causing extensive damage to the well and numerous reservoir problems. • A relief well had to be drilled as a contingency. • Massive cost implications and if the error had not been found earlier, other wells may have been drilled to the wrong subsurface locations.

The availability and usage of spatial data in society is increasing almost exponentially. The increased amount of spatial data on the E&P professional's desk offers many new opportunities, but the geodetic awareness of both these professionals and software vendors alike has not developed accordingly. Vigilance is therefore more required than ever before to prevent spatial data integrity violations compromising E&P business decisions.

5 Recommended reading

Existing OGP Surveying and Positioning Guidance Notes, publication number 373, can be found on http://info.ogp.org.uk/geodesy.

Number	Content
2	Use of Bin Grids and Coordinate Reference Systems in Workstations
3	Contract Area Definition
4	Use of the International Terrestrial Reference Frame (I.T.R.F) as Reference Geodetic System for Surveying and Real-time Positioning
5	CRS Definition
7	Coordinate Reference System Definition • Part 1: Using the EPSG Geodetic Parameter Dataset • Part 2: Coordinate Conversions and Transformations including Formulas
10	Geodetic Transformations Offshore Norway
13	Advisory Note on Datum Transformation Evaluation and Use
14	Coordinates Reference Systems in Reserves Unitisation Agreements
16	Quality Control of Proposed Well Co-ordinates

Books

- *Datums and Map Projections*, Illiffe and Lott, Whittles Publishing 2007

Websites

- GPS Tutorial & FAQ http://www.trimble.com/gps/index.shtml

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