GRIDS & DATUMS

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THE KINGDOM OF NORWAY

The Grids & Datums column has completed an exploration of every country on the Earth. For those who did not get to enjoy this world tour the first time, *PE&RS* is reprinting prior articles from the column. This month's article on the Kingdom of Norway was originally printed in 1999 but contains updates to their coordinate system since then.

Norway was settled in the Middle Stone Age (*circa 7000 B.C.*), and by the 9th century A.D., the Norse expeditions began which colonized the islands off Scotland, Ireland, Iceland, and Greenland. Trondheim was the Norwegian capital until 1380. Kristiania, founded in 1050, became the capital in the 14th century and was renamed Oslo in 1924. The Kingdom occupies the western part of the Scandinavian Peninsula. It is bounded on the west by the Atlantic Ocean, on the north by the Arctic Ocean, on the north east by Russia and Finland, on the east by Sweden, and on the south by the Skagerrak and Denmark. Because of the numerous fjords and small coastal islands, the Kingdom has one of the longest coastlines in the world. Norway claims the islands of Svalbard and Jan Mayen in the Norwegian Sea.

The earliest modern map of Nor-way was the map of Scandinavia drawn by Claudius Clavus in Italy about 1425. Several other maps were compiled of the entire peninsula, but the first national cartographer of Norway was Melchoir Ramus who mapped the southern coast from 1689 to 1693. German foresters were employed in the eighteenth century to map the land resources of the Kingdom after the Scandinavian wars. The excellent quality of the work and the need for military maps of Norway after the many years of war with Sweden prompted the establishment of the Norges Graændsers Oppmåling (Norwegian Border Sur-vey) on 14 December 1773. Attached to the military, the initial attempts of the NGO at mapping by planetable and alidade without basic control were inevitably deemed unreliable. In January of 1779, General Von Huth directed that subsequent map-ping be based on astronomically determined points and classical triangulation surveys. Initial longitude determinations were based on fire signals, gunpowder explosions, and pendulum clocks. This was found too inaccurate, and in the winter of 1779-1780, a baseline was measured on Lake Storsren using wooden sur-vey bars. By 1784, a triangulation arc was surveyed between Kongsvinger and Verdal. Additional triangulation work continued, and the survey was adjusted in 1810. The geographical position of Bergen was compared to another determination from a triangulation arc from Lindesnes. The difference in longitude was 9" and that error was considered satisfactory at the time. From 1791 to 1803 a series of hydrographic charts were published from the surveys of Lt. F. C. Grove of the Royal Danish Navy. Printed in Copenhagen from copper plates, the "Grove Charts" were used for navigation for about 100 years.

A re-organization of surveying and mapping within the government in 1805 combined military and eco-nomic objectives in the same department. The Norske Topographiske Oppmåling (Norwegian Topographic Survey, or NTO) passed among several ministries including Defense, Interior, Finance, Customs

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and Trade, and finally back to Interior. In 1823, all operating funds were suspended. The first 50 years of survey and mapping work had not been reproduced in large quantities because maps were generally considered a military secret. The first map printed was a county map of Smaalenenes that was published in 1826 at a scale of 1:200,000. In fact, two of the NTO surveyors obtained permission to have it engraved and printed in Paris at their own expense. In 1833, the organization´s name was changed to Norges Geografiske Oppmåling (Geographical Survey of Norway, or NGO). By 1854, NGO obtained the expertise and equipment to publish their own maps. The first series of published maps were cast on the Cassini-Soldner projection and were referenced to the Svandberg 1805 ellipsoid where the semi-major axis (a) = 6,376,797.0 meters and the reciprocal of flattening ($^1/_f$) = 304.2506. Presumably, this was based on the Oslo Observatory Datum (of 1810?) where: Φ_o = 59° 54´ 44.00″ North, Λ_o = 10° 43´ 22.5″ East of Greenwich. However, the defining azimuth to Husbergoen was not observed until 1869. The sheets had no printed grid, and were cast on the graticule such that they measured 20´ of latitude and 1° of longitude. The sheets started at 58° North and were evenly spaced longitudinally from Oslo Observatory. This lasted until 1844 when the ellipsoid was changed to the Bessel 1841, and then the series was continued through 1890. This strange series of map sheets was actually a common design for the time.(The Grove Charts were based on the Cassini-Soldner projection also). In 1891, the Cassini-Soldner projection was replaced by the polyhedric projection. As I have pointed out in past columns, the polyhedric is mathematically equivalent to the system commonly used for computational photogrammetry, which is the local space rectangular. The U.S. equivalent was merely based on a different aphylactic projection, the polyconic.

Prof. Hamsteen became the new director of the survey in 1832, and a new triangulation commenced in 1834 from Kristiania (Oslo) to Trondheim covering most of southern Norway. The Russian-Scandinavian geodetic survey extended from Swedish Lapland to Fuglenes at Hammerfest in Norway from 1845-50. The Fuglenes Datum of 1850 origin is where: Φ_o = 70° 40´ 11.23″ North, Λ_o = 23° 40´ 12.8″ East of Greenwich. The ellipsoid of reference is the Bessel 1841, but some of the original manuscript computations must surely be on the Walbeck 1819, which was the standard for the Russians at that time. The defining azimuth was to station Jedki. By 1874, the NGO was transferred from the General Staff to the Army Department. The Triangulation Division started a second-order triangulation in 1880, and adopted a network adjustment philosophy in 1903. Computations in geodetic coordinates were introduced in 1891. The Gauss-Krüger Transverse Mercator system for Norway was initiated in 1916 and is based on the Oslo Observatory Datum of 1844. The ellipsoid of refer-ence is the Bessel 1841 where the semi-major axis (a) = 6,377,397.155 meters and the reciprocal of flattening ($^1/_f$) = 299.1528128.

Terrestrial photogrammetric experiments started in 1907, and phototheodolites were purchased in 1910. In 1920, a Zeiss Stereoautograph was purchased for the compilation of terrestrial photography, although the plane table and alidade was still used to supplement detail for holidays in the photo coverage. All topographic mapping was performed with aerial photographs after 1933. By 1936, a Zeiss C-1 Universal Stereoplanigraph was in production at NGO.

The military Grids used for Norway through World War II were the Northern European Lambert Conformal Conic Zones I-III. These were complicated systems that had Grid boundaries defined by other Grid systems, by the graticule, and by numerous ellipsoidal loxodromes. Although easy to compute nowadays, these Grids were part of the nightmare for U.S. Army Topographic Engineers in the 1940s.

After WW II, the Oslo Observatory Datum of 1844 was transformed to the European Datum of 1950 (ED50) through the Northern Block Adjustment of 1949-51. The U.S. Coast & Geodetic Survey performed the computations on the International Ellipsoid where: a = 6,378,388 meters, and $^1/_f$ = 297. The modern Norwegian triangulation south of approximately 62° latitude was connected to the Central European Net using the principal triangulation arcs of Sweden and Denmark. Flare triangulation over the Skagerrak was used between Denmark and Norway. The Norwegian triangulation north of approximately 62° latitude was subsequently included in the European Datum as a supplementary adjustment of the Northern Block from September 1951 through June 1952. The only exception to the standard Universal Transverse Mercator (UTM) Grid zones in the entire world is for the southern half of Nor-way, where the zone exceeds 3° from the Central Meridian! This exception accommodates the southern half of the Kingdom in one "V 32" zone. During this same period, Norway adjusted their new civilian datum NGO 1948, and they retained the Bessel 1841 ellipsoid with the point of origin still at the Oslo Observatory.

Svalbard is a group of nine main is-lands north of Norway that officially became a territory of the Kingdom on 14 August 1925. The most famous is-land of the group is Spitzbergen, and the main economic activity is coal mining. The coordinate systems of Svalbard include the Thumb Point Datum of 1948 origin where: Φ_o = 79° 03´ 58.97″North, Λ_o = 2° 48´ 15.36″East of Greenwich, and is referenced to the Bessel 1841 ellipsoid. The Hedgehog Datum origin is where: Φ_o = 76° 57´ 53.210″North, Λ_o = 17° 19´ 52.500″ East of Greenwich, and is referenced to the Clarke 1880 ellipsoid. The New Spitzbergen Datum of 1948 consisted mainly of re-computing Hedgehog Datum coordinates on the Bessel 1841 ellipsoid. Other observations that were recomputed in that same epoch included the Isachson triangulation of 1909-10, the Polish 1934 Expedition triangulation, the Cadastral system of the Svalbard Commissioner, several points of the Italian Hydrographic Expedition, and the Dahl Grid system. Note that this strategic island group was the subject of a treaty 5 years prior to becoming a Norwegian territory, and the signatories totaled 41 sovereign nations. Considering the number of countries participating, the number of local datums for so small an area is not surprising.

Jan Mayen is an island northwest of Norway that was annexed on 8 May 1929. The island is slightly larger in area than Washington, D. C., there are no permanent inhabitants, and the only occupation is for manning a weather station and a Loran C base station. In 1949, the Norsk Polarinstitutt established the only classical coordinate system for the island as the

Nordlaguna Datum of 1949 origin where: $\Phi_o = 71° 00′ 46.79″$ North, $\Lambda_o = 08° 27′ 51.3″$ West of Greenwich. The local Nordlaguna Grid is based on the Datum origin with a Gauss-Krüger Transverse Mercator where the scale factor at origin, mo = 1.0, the central meridian (C. M.), $\lambda_o = 08° 30′$ West of Greenwich, the False Easting (Y axis) at C. M. = 50 kilometers, and the False Northing (X-axis) = 7,800 kilometers. Note that the transposition of the axes labels is common in Europe.

In January of 1986, all mapping activities in the Kingdom were consolidated under the new banner of Staatens Kartverk (Norwegian Map-ping Authority) in Hønefoss. By 1990, the concern for establishing a coordinate system that was consistent for European offshore hydrocarbon exploitation resulted in the "North Sea Formulae." The published parameters to shift from ED50 to ED87 are 4th degree 15-coefficient multiple regression equations. The published parameters for transforming from the "new" European Datum of 1987 to the World Geodetic System of 1984 Da-tum has a specific subset of relations referred to as the "WGS84*SEA." The parameters are: $\Delta X = –82.981m$, $\Delta Y = –99.719m$, $\Delta Z = –110.709m$, $R_x = –0.5076$, $R_y = +0.1503$, $R_z = +0.3898$, scale = –0.3143 where the rotations are in micro radians and the scale factor is in parts per million (10^{-6}). For example; from ED87 coordinates: N = 52°, 8 = 02°; the WGS84*SEA co-ordinates are: N = 51° 59′ 57.0927″, and 8 = 01° 59′ 55.1400″. The number of each country's terrestrial points used in the solution was based on a proportion of comparative North Sea coastline lengths. This transformation system was a consensus of agreement among Norway (26), United Kingdom (43), Denmark (12), Germany (9), and the Netherlands (13).

A transformation algorithm was developed by the Norwegians to go between the NGO1948 Datum and the ED50. This series of transformations were developed as "block" transformations based on specific areas. All of the 2D shifts are on the conformal plane of the UTM Grid, which was the rationale used by the US-C&GS (on contract to AMS) to compute and adjust the Northern Block of the ED50. With 12 different blocks de-fined for the Scandinavian Peninsula, the implementation is non-trivial.

The Norwegian government is commercially marketing a datum shift solution similar to the Canadians and the British. A software pack-age is available (for a price) that will implement coordinate transformations based on the EUREF89 Datum. The package is called "WSKTRANS," and it works on two levels. On the national level, the formula is based on approximately 500 of the old first-and second-order triangulation stations. The accuracy is guaranteed to within 1 meter. On the county level, a network of GPS stations called "Landsnett" has been observed at a 5-km spacing such that the formula used in WSKTRANS has a positional transformation accuracy of about 2-cm. The Norwegians now tout their Stamnett 1997 system, which is a final adjustment of 930 stations distributed throughout the country on the EUREF89 Datum. The Stamnett is roughly equivalent to the HARN system for North America, and it is the basic framework used to establish the Landsnett. No information is avail-able on what Geoid model is used with the WSKTRANS package, nor on whether the package is a 2D or a 3D solution.

Update

Whether you are a professional developer or a "regular" user, the Norwegian Mapping Authority site provides you with information on how to download and use their open and free maps and geospatial data.

The following data sets from the Norwegian Mapping Authority are available as free downloads:

- Topographical land data from 1:50 000 – 1:5,000,000 (N50, N250, N500, N1000, N2000, and N5000 vector and raster images)
- Administrative/ property boundaries
- Road networks including addresses
- Place name data
- Historical maps
- National elevation models

To download the data sets you must register (except for historical maps). Data sets must be used according to the Norwegian Mapping Authority's terms of use[1].

You can download data sets from their main download page[2] or from their historical maps site[3] (texts in Norwegian only). We advise you to check their site, especially if you are unsure about further procedures and the knowledge required to make full use of their data sets.

If you are you interested in purchasing other geospatial data, please contact the Norwegian Hydrographic Service for marine geospatial data or one of their distributors for topographical land or property data[4].

For Professionals

The map data sets are released in a form that is as close to the original as possible. This provides professional developers with as much free rein as possible to develop their own products and services based on the Norwegian Mapping Authority's data.

Topographic vector data, boundaries, road data and place names are provided in SOSI and GeoJSON formats. The elevation models are provided as DEM's. N50-N5000 topographical land data can be found in ESRI File Geodatabase format, and in addition the N50 data is available in raster format as MrSID.

At the moment, professional developers and GIS workers will benefit the most from many of our open data sets. It is our goal that the map data can be used to develop new solutions, which can be useful to many users.

(http://www.kartverket.no/en/data/Open-and-Free-geospatial-data-from-Norway/, June, 2017.)

1 http://www.kartverket.no/en/data/Terms-of-use/
2 http://data.kartverket.no/download/
3 http://www.kartverket.no/en/Maps--Nautical-Charts/Historiske-kart/
4 http://www.kartverket.no/en/Bestille/Order-Geospatial-data/

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