& Grids & Datums

THE STATE OF ISRAEL

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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 State of Israel was originally printed in 2000 but contains updates to their coordinate system since then.

Archaeological evidence has un-covered the existence of man during the Paleolithic Period (Old Stone Age) in what is now modern Israel. During the subsequent Neolithic Period (New Stone Age), humans had cultivated crops and built towns, such as Jericho, by 7,000 *BC*. Israel is hilly in the North, and its highest peak is Mt. Meron at 1,125 m (3,692 ft). It is bounded on the North by Lebanon, on the West by the Mediterranean Sea, on the East by Syria and Jordan, by Egypt to the South-west, and by the Negev Desert to the South with the Gulf of Aqaba at its extreme Southern port. The State of Israel was established by decree of the United Nations on 15 May 1948.

The first serious mapping of Israel on modern lines was under-taken in 1798 by Napoleon, as an ex-tension of his survey of Egypt. A Topographic Section was formed which consisted of four officers, an astronomer, and four "intelligent soldiers." Bases were measured at Alexandria and Cairo by the "Service Topographique de l'Armee d'Egypte," and topographic maps were compiled using a 10 km grid with an origin at the great pyramids of Giza. The coastline depicted on these early French topographic maps was actually based on British Admiralty Charts. Survey work on the ground was completed late in 1801, and, by the end of 1803, compilation in Paris had reached a stage where the maps could be engraved on copper plates. The sheets were printed in 1808, but Napoleon ordered that they should remain under seal as state secrets. The maps were not finally published until 1817.

In 1865, Captain C. W. Wilson, RE (later Major General Sir Charles Wilson), surveyed the City of Jerusalem at a scale of 1:2,500. The success of Wilson's survey led directly to the establishment of an association called the Palestine Exploration Fund (PEF). November of 1871 was the beginning of the PEF surveying and mapping activities, and by 1874 Lieutenant H. H. Kitchener, RE (later Field Marshal Lord Kitchener of Khartoum), arrived to assist Lieu-tenant C. R. Conder in the first successful mapping expedition of the entire region since Napoleon's at-tempt. Conder's report speaks of oak forests and bears, wolves, wild pig, cheetah, deer, antelope, and a great

variety of game birds. The fauna were the same as reported in the Bible except for the lion, last re-corded by the Crusaders in the 12th century. The surveying and mapping was completed by 1878 and comprised 26 sheets, all based on a single Cassini-Soldner projection with a Central Meridian (λ_o) = 34° 56′ East of Greenwich. The ellipsoid of reference was the Clarke 1866. There was no Grid associated with this sheet series where each map measured 15′ from north to south and 22′ from east to west. Sir Arden-Close remarked, "It is interesting to note that the field work was done by prismatic compass and that no plane-table was used, though, in general, the country lends itself remarkably well to plane-tabling. The reason given by Conder was that the members of the party moved everywhere on horse-back, and that a plane table is an in-convenient thing to carry on a horse." Conder and Kitchener super-vised Stanford's engraving of the final maps in 1881.

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In 1883-4, Kitchener accompanied an expedition and carried out a triangulation from a base at Aqaba to the Dead Sea, connecting it with the original Palestine control frame-work near Beersheba. In December 1913, Captain S. F. Newcomb, RE was given charge of a large surveying and archeological expedition which started in Gaza and was to cover the entire Sinai Peninsula. One member of that expedition included T. E. Lawrence, later known as Lawrence of Arabia! Close remarked, "It was doubtless the experience which Lawrence gained on this expedition that justified his being commissioned into the Director-ate of Military Survey in September 1914, where he was immediately involved in the compilation of the map of Sinai." Lawrence's carto-graphic drafting work of Israel be-tween Gaza and Aqaba was per-formed in Cairo where he also interviewed prisoners, processed intelligence data from agents behind enemy lines, and produced a handbook on the Turkish Army.

Although a gridded version (referenced to the Bessel 1841 ellipsoid) of Conder's one-inch to the mile map series was used by the Egyptian Expeditionary Force during W.W. I, there was also a need for larger scale maps of the Palestine for artillery and tactical purposes. The Brit-ish Forces had no town maps of some of the key towns of Palestine. Towns situated beyond the front line, such as Gaza, Beersheba, Ramleh, and others were photo-graphed by the Aerial Squadrons and maps of those towns were made. The first map, that of Gaza, was produced on 25 January 1917, and was probably the first town-map ever made using aerial photographs. Other maps produced during 1918, such as those of Nablus and El-Kerek ,were maps that demonstrated a new solution to the problem of the use of aerial photographs for the purpose of mapping towns situated in hilly areas. Town-maps for the Palestine Front were an immediate necessity, not an academic exercise, and the war served as an immediate catalyst. The new Survey of Pales-tine department (now the Survey of Israel) was established by the Occu-pied Enemy Territory Administration after the war, and therefore inherited some good topographic maps. They were then able to concentrate on improving the triangulation network and connecting it with the French triangulation in Syria, as well as carrying out cadastral surveys for land settlement.

Under the post-WWI Mandate, Lebanon and Syria (the Levant) were protectorates of France, while Israel and Jordan, collectively called Palestine and Trans-Jordan, were protectorates of Great Britain. As a result, the northern reaches of Israel are also covered by the Levant Zone. This is a particularly difficult Grid system because it was developed by General Sevki of Syria and is based on the French Army Truncated Cubic Lambert (partially) Con-formal Conic. Earlier Turkish Otto-man topographic maps of the Levant, northern Israel, and the Palestine were on the Turkish Bonne Grid. The joins and transformations among the Levant Zone, the Turkish Bonne, and the Palestine Grid (mentioned below) are the source of de-cades of computational heartburn for cartographers; not to mention my graduate students' homework problems . . . .

John W. Hagar, formerly with DMA/NIMA, offered that the Palestine Da-tum of 1928 has its origin at station Number 2 where: Φ_0 = 31° 18′ 06.27" North, Λ_0 = 34° 31′ 42.02" East of Greenwich, the ellipsoid of reference is the Clarke 1880 where a = 6,378,300.789 meters, $^1/_f$ = 293.466004983713280, and elevation = 98.9 m. The Cassini-Soldner Civil Grid of 1933 (origin adopted is the principal point 82′M (Jerusalem)) having the geographic coordinates ϕ_0 = 31° 44′ 02.749" N, λ_0 = 35° 12′ 39.29" East of Greenwich + 04.200" E = 35° 12′ 43.490". The addition of 04.200" to the longitude is in accordance with the decision in 1928 to adopt the French value for the longitude at the points of junction 73′M and 98′M in the north, and to correct all Palestine longitudes accordingly. Palestine longitudes were originally based on those of Egypt at the Transit of Venus station, and a correction of 3.45" was indicated to the Egyptian longitudes. Imara Base (1′M or 5′DM) is the original false origin of the Grid coordinates (i.e., FN = FE = 100 km) for the Cassini-Soldner Civil Grid. Final implemented Cassini-Soldner False Easting is then 170,251.555 m, False Northing = 126,867.909 m.

A military version of this system based on the Gauss-Krüger Transverse Mercator is identical to the Civil Cassini-Soldner Grid, except for the False Easting at False Origin where 1,000,000 meters is added, and for coordinates used for the southern Sinai while it was still occupied by the Israelis, an additional 1,000,000 meters was added south of the South False Origin! Of course, that is now defunct.

Hagar further observed that, "I don't normally pay much attention to the limits of a Grid but here it might be of interest. North is the 150,000 meter Northing Grid line of the Levant Zone. This was redefined, probably as a line of latitude, when the Levant Zone was eliminated. East is the meridian of 39° E. South is a loxodrome from 19° N, 39° E to 26° 45′ N, 35° E, thence west on parallel of 26° 45′ N to 70,000 meter Easting Grid line. West is the 70,000 meter Easting Grid line. You will see that the Grid is not symmetrical east and west and thus can be extended into the Sinai which is precisely what Israel did when they occupied the Sinai." I have noticed that ellipsoidal loxodromes will warm a professor's heart, but they generally drive cartographers, and graduate students, nuts!

About 10 years ago, I was teaching my once every other year grad course in coordinate systems. On the occasion of a 3-day weekend, I assigned a computational problem for intersecting ellipsoidal loxodromes with grid lines of a constant value as are found for offshore oil leases in the Gulf of Mexico as well as the Palestine Grid limits. The problem is particularly involved be-cause it is iterative between isometric space and in this Louisiana in-stance, Gauss-Krüger space for UTM. On the first day of class after the holiday, I had the students pass their homework solutions up to me. They then nervously asked me to show the solution on the black-board. I complied, filling about three blackboards with the computational solution. One of the students in class then asserted, "Yes sir, that is correct." Stunned, I thanked the lady graduate student for the validation! (She later got an "A"

in the course). The point to all of this is that there are many "British Grids" still extant throughout the world that have boundaries de-fined by ellipsoidal loxodromes. Furthermore, shipping lanes, called Safety Fairways and Traffic Separation Schemes (TSS), are defined by end points connected by ellipsoidal loxodromes. This is one of the realities of contemporary computational cartography that the GIS Mapping Scientist may encounter in the real world.

My first job in mapping was as a junior map draftsman for Offshore Navigation, Inc. (ONI) (now out of business) in New Orleans during the early 1960s. In later decades, ONI retained me for consulting work for various coordinate system puzzles they encountered from time-to-time. In the early 1980s, ONI received a curious message from Israel and I was asked to solve the problem. Four points were given: Zikhron Yaakou, Tel Aviv, Ashdod, and Khan Yunis. Coordinates were furnished in Latitude and Longitude and in X and Y coordinates. No other explanation was offered to me (or to ONI). Objective: figure out how one set of coordinates related to the other and "solve the problem, Cliff." Knowing what the Datums and Grids of the Palestine, and particularly Israel, used, I started trying the permutation of systems. The trial-and-error solution yielded the fact that someone in Israel offered the coordinates of the four points in geodetic coordinates referenced to the European Datum of 1950 (Inter-national 1924 ellipsoid), and the co-ordinates of the same four points in Cassini-Soldner Grid coordinates in meters referenced to the Palestine Datum of 1928 on the Clarke 1880 ellipsoid. Therefore, Palestine 1928 to European Datum 1950 is : $\Delta X = -76$ meters, $\Delta Y = +64$ meters, $\Delta Z = +442$ meters. For instance, Ashdod on Palestine 1928, $\phi = 31° 50' 07.039"$ N, $\lambda = 34° 38' 17.396"$ E, and on ED 50, $\phi = 31° 50' 01.8994"$ N, $\lambda = 34° 38' 13.6922"$ E. (No elevations were offered).

In October of 1989, Dr. Ron K. Adler, director general of the Survey of Israel, offered that the "new" Usrlurim Da-tum origin at station Urim was : $\Phi_o = 31° 20' 42.687"$ North, $\Lambda_o = 34° 28' 02.835"$ East of Greenwich. The Israel New Datum is referenced to the GRS 1980 ellipsoid where a = 6,378,137 m, and $^1/_f = 298.2572215381489$. The 7-Parameter Datum shift from the Israel New Datum to WGS84 Datum are: $\Delta X = -23.500$ meters, $\Delta Y = -18.190$ meters, $\Delta Z = -17.530$ meters, Scale = $+5.43 \times 10^6$, $R_x = -0.30$ arc seconds, $R_y = -1.84$ arc seconds, and $R_z = +1.64$ arc seconds. The new Grid system is defined as being a Gauss-Krüger Transverse Mercator where $\phi_o = 31° 44' 03.817"$ N, $\lambda_o = 35° 12' 16.261"$ East of Greenwich, False Northing = 626907.39m, False Easting = 219,529.584m. The Scale Factor at Origin is 1.0000067 for the New Israel Grid. For example, on the New Israel Grid: X = 186,691.878m, Y = 666,264.4m, Z = 82.545m (height above ellipsoid), the corresponding WGS 84 Datum coordinates are: $\phi = 32° 05' 21.16923"$ N, $\lambda = 34° 51' 26.51726"$ E. h = 82.526m (height above ellipsoid).

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Update

Israel has implemented a nation-wide Kinematic GPS Continuously Operating Reference Station network. The entire country is now on a new coordinate system named Israel 2005 (IL05). A new Grid has also been implemented for cadastral purposes based on the Transverse Mercator; the selected scale factor at origin is 1.0000067. There is a 50 km shift in the Y axis and a 500 km shift in the X axis, implemented so as to keep the grid lines unchanged on large scale maps *(Steinberg, G., and Even-Tzur, G, Establishment of National Grid Based on Permanent GPS Stations in Israel, Surveying and Land Information Science, Vol. 65, No. 1, 2005, pp. 47-52).* See also: *(Ronen, H., Even-Tzur, G., Kinematic datum Based on the ITRF as a Precise, Accurate, and Lasting TRF for Israel, DOI: 10.1061/(ASCE)SU.1943-5428.0000228. © 2017 American Society of Civil Engineers).*

A fascinating account of all surveying and mapping activities in a significant portion of the 20th century is in: *(Gavish, Dov, A Survey of Palestine under the British Mandate 1920-1948, 2010, ISBN 978-0-415-59498-1, 337 pages).*

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