Grids & Datums

Kingdom of Saudi Arabia

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"The first concrete evidence of human presence in the Arabian Peninsula dates back 15,000 to 20,000 years. Bands of hunter-gatherers roamed the land, living off wild animals and plants. As the European ice cap melted during the last Ice Age some 15,000 years ago, the climate in the peninsula became dry. Vast plains once covered with lush grasslands gave way to scrubland and deserts, and wild animals vanished. River systems also disappeared, leaving in their wake the dry river beds (*wadis*) that are found in the peninsula today. This climate change forced humans to move into the lush mountain valleys and oases. No longer able to survive as hunter-gatherers, they had to develop another means of survival. As a result, agriculture developed – first in Mesopotamia, then the Nile River Valley, and eventually spreading across the Middle East. The development of agriculture brought other advances. Pottery allowed farmers to store food. Animals, including goats, cattle, sheep, horses and camels, were domesticated, and people abandoned hunting altogether. These advances made intensive farming possible. In turn, settlements became more permanent, leading to the foundations of what we call civilization – language, writing, political systems, art and architecture. Located between the two great centers of civilization, the Nile River Valley and Mesopotamia, the Arabian Peninsula was the crossroads of the ancient world. Trade was crucial to the area's development; caravan routes became trade arteries that made life possible in the sparsely populated peninsula. The people of the peninsula developed a complex network of trade routes to transport agricultural goods highly sought after in Mesopotamia, the Nile Valley and the Mediterranean Basin. These items included almonds from Taif, dates from the many oases, and aromatics such as frankincense and myrrh from the Tihama plain. Spices were also important trade items. They were shipped across the Arabian Sea from India and then transported by caravan. The huge caravans traveled from what is now Oman and Yemen, along the great trade routes running through Saudi Arabia's Asīr Province and then through Makkah and Al Madīnah, eventually arriving at the urban centers of the north and west. The people of the Arabian Peninsula remained largely untouched by the political turmoil in Mesopotamia, the Nile Valley and the eastern Mediterranean. Their goods and services were in great demand regardless of which power was dominant at the moment – Babylon, Egypt, Persia, Greece or Rome. In addition, the peninsula's great expanse of desert formed a natural barrier that protected it from invasion by powerful neighbors" (*Embassy of Saudi Arabia, 2008*).

The kingdom is bordered by Iraq (814 km), Jordan (728 km) (*PE&RS*, December 2006), Kuwait (222 km), Oman (676 km) (*PE&RS*, March 2007), Qatar (60 km) (*PE&RS*, January 2008), UAE (457 km) (*PE&RS*, February 2001), and Yemen (1,458 km) (*PE&RS*, August 2003). With a coastline of 2,640 km, Saudi Arabia's lowest point is the Persian Gulf (0 m); although they prefer to call it the *"Arabian Gulf,"* and the highest point is Jabal Sawdā́ (3,133 m). With regard to international boundary treaties with Saudi Arabia, land agreements appear to exist with Jordan, UAE, Iraq, and Oman. For Limits in the Seas, continental shelf boundaries have been signed with Iran and Bahrain. In both cases, the principle of equidistance has been followed, more or less (*Office of the Geographer, U.S. Department of State*).

During the early part of the 20th century, the Survey of India, while under British rule, extended some of their triangulation arcs into the Arabian Peninsula – as I recall from my own readings in recent years. In 1910, the British War Office published topographic maps of Arabia in four sheets at 32 miles to the inch (approximately 1:2,000,000 scale). The British Directorate of Military Survey produced maps at a scale of 1:253,440 (1 inch = 4 miles), along the Red Sea from surveys in 1915-1917 (*Foreign Maps, TM 5-248, 1963*). In 1933, Saudi Arabia granted the first concession for oil exploration to an American company – ESSO, and the Arabian-American Company was founded: ARAMCO.

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The earliest geodetic surveying of any importance were the ARAMCO surveys that started in the 1930s. The original datum is Umm Er Rus at point 506 Umm Er Rus, $\Phi_o = 26° 19' 04''$ North, $\Lambda_o = 50° 07' 50''$ East, and the defining astronomic azimuth to Station 511 Midra Jinubi from south is: $\alpha_o = 82° 34' 32.64''$. The ellipsoid of reference is the Clarke 1866 where: a = 6,378,206.4 meters and $^1/_f$ = 294.9786982, and elevation = 149.7 (units unknown). The grid system associated with this datum is the ARAMCO Gauss-Krüger Transverse Mercator Zones 1-10 where each zone is a 2° belt with central meridians (λ_o) from 37°E to 55°E, scale factor at origin (m_o) = 0.9999, False Easting = 150 km, False Northing = 100 km, and False Northing Latitude at Origin = 12°N for each zone. According to John W. Hager, "As best I can remember, the ARAMCO surveys ran from south of the former Kuwait-Saudi Neutral Zone to about the Qatar-Saudi boundary. There were several arcs but they were never adjusted as a whole."

Thanks again to Hager, "In 1954 there was a SHORAN survey in northeast Saudi Arabia by the name of Carmine performed by Worldwide Aerial Surveys. (Worldwide was a combination of Aero

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Services Corporation and Fairchild Aerial Surveys created to handle large projects.) The purpose was to provide mapping photography for 1:250,000 scale mapping. From my experience with similar work in Iran, I would estimate that the trilateration network yielded positions of the ground control stations to better than 10 meters and positions of the photo nadir points at better than 50 meters. The boundaries between Saudi Arabia and Kuwait, and Saudi Arabia and Iraq were in dispute and there were two Neutral Zones as a result. Finally all the parties got together and resolved the problem. One result was point Ain el Abd (HIRAN 2) φ = 28° 14' 06.171"N, λ = 48° 16' 20.906"E."

Another datum according to Hager is the Selwa Datum at ARAMCO Station 915, Φ_o = 24° 44' 06.270"N, Λ_o = 50° 48' 08.381"E, and the defining astronomic azimuth to an unknown station is: α_o = 351° 05' 24.456". The ellipsoid of reference is also the Clarke 1866, elevation = 5.7295 (units unknown) at Khor Ed Duan. Hager continued, "About 1957, Aero Services Corporation out of Philadelphia (later Aero Service Division of Western Geophysical in Houston), did a trilateration net using the MRA 1 Tellurometer. It ran along the coast from about latitude 27°N south to Fort Tarut and Ra's Tann rah. The following season the trilateration net was continued south with the purpose of establishing the boundary between Saudi Arabia and Bahrain. This portion ran into trouble with numerous ambiguities in the readings. The fact that a number of the lines were over water probably did not help matters. Army Map Service, with advice from the Tellurometer Corp. was able to straighten things out and get a satisfactory solution."

Again, thanks to Hager, "Ain el-Abd (1964) at Point 'A', Ain el-Abd, Φ_o = 28° 14' 06.968"N ±0.076" (P.E.), Λ_o = 48° 16' 27.868"E ±0.044"(P.E.), and the defining astronomic azimuth from north to 127(AMI) is: α_o = 307° 07' 34.85" ±0.08"(P.E.), **Clarke 1880** ellipsoid, height = 52 meters. The point is described as ARAMCO "Q" or AMINOIL 43, a 2-inch iron pipe embedded in concrete set in the ground, located beside a natural spring named *Ain el-Abd*." Considering the probable errors of the observations and the choice of ellipsoid, my guess is that this point was originally an Astro Station by the British Royal Navy.

Established in 1925 and used during WWII for portions of the Arabian Peninsula, the Mecca-Muscat Zone was established by the British General Staff, Geographic Section and was known as one of the "British Grids" where the projection was the fully conformal *secant* Lambert Conical Orthomorphic. The Latitude of Origin (φ_o) = 45°N, the Central Meridian (λ_o) = 23°E, the Scale Factor at Origin (m_o) = 0.99907, the False Easting = 1,000 km, and the False Northing = 600 km. This ersatz datum used the Clarke 1880 ellipsoid where a = 6,378,300.78 meters, $^1/_f$ = 293.466308. I am informed by NGA that the current version of *GeoTrans* will now accommodate the British Definition parameters for defining a Lambert zone. From every public source available, it appears that all unclassified military mapping is on the Clarke 1880 ellipsoid, and the UTM Grid is utilized.

On 12 October 1966, the first comprehensive geodetic survey of Saudi Arabia was commenced by a consortium of British, French, Dutch, Japanese, and Saudi Arabian companies that completed a 15,000 km survey in 45 months. For this survey, the *Rub' al Khali* – the Empty Quarter – was excluded. The network incorporated 702 traverse stations and about 2,500 benchmarks. All were permanently monumented, paneled, and recorded on strip photography flown at 1:30,000 scale. All the routes were traversed to First-Order specifications and double-run leveled. All the routes were leveled to Second-Order standards except for the line connecting Jeddah, Al Riyādh, Az Zahrān (Dhahran), and Ain el Abd, along which First-Order leveling and relative gravity observations with Worden meters were taken. The traversing and leveling lines followed the same routes as closely as the terrain permitted and common stations or height connections were established at frequent intervals rarely exceeding 100 km. In addition, a flare triangulation net was planned between the 47 primary stations using five of the traverse sections as baselines. Six tide gauges were installed; four beside the Red Sea and two in the Persian Gulf, and simultaneous tidal observations were taken for a year initially. Two standardization bases were established with Geodimeters to calibrate the Tellurometers used for traversing. In all, 189 Laplace stations were observed for azimuth control and geoid computations.

'"Field operating conditions in Saudi Arabia still preserve some unique features. The size of the country and the limited supplies obtainable in provincial towns made the logistic support of mobile field parties a vital task. The scheduled services of Saudi Arabian Airlines were used to fly in personnel, fresh food, and spares. For most of the length of the Red Sea coast there is a narrow coastal plain with patches of *sebkah* salt flats. Behind this the mountains of *Al Hejāz* and *Asīr* rise to a ridge elevation of between 1,000 and 3,000 m. East of the ridge the igneous rocks and lava flows of the Western Shield gradually become submerged beneath the sand plain with just occasional hill ranges outcropping. Further east a series of westward facing sedimentary escarpments, the largest of these being the *Tuwaiq* escarpment of Jurassic limestone, break up the monotony of the plains. These escarpments in turn dip beneath the sands of the *Rub' al Khali*, the *Dahna*, and the *Great Nefud*, which provide the conventional image of the desert with huge longitudinal sand dunes often vivid orange in color. Beside the Persian Gulf, low sandy hills descend gently to the *sebkahs* along the coast. Across this obstacle course a network of paved roads is being extended at the rate of 1,000 km a year, but only a few thousand kilometers had been completed at the time of the survey. The climate is harsh and immoderate but not often disagreeable. The summer months are predictably hot and fortunately – because of the heat haze – quite unsuitable for geodetic observations. The winter can be surprisingly cold with light frosts in the early mornings, and snow on occasions. In spring and autumn, storms bring rain and flash floods. In November 1967 the rainfall all over the country was exceptionally heavy and brought all the field parties to a temporary halt. It is always windy; a hot sand blast in summer, penetratingly cold in winter. Sandstorms blew tents away and even brought a tower down. The diurnal temperature range is enormous, and one removes layers of clothing progressively during the morning only to replace garment after garment during the afternoon" (*J. Leatherdale, The Geodetic Survey of Saudi Arabia, Chartered Surveyor, December 1970*).

In a later paragraph of Leatherdale's paper on page 273, he provides insight to the common question regarding the proper ellipsoid to associate with the Ain El Abd Datum of 1970. "The initial computations of the traverse net were made on European Datum as defined by the geographical coordinates of the HIRAN 2 station at Ain El Abd near the Kuwait Neutral Zone border. Deviation and separation were not defined. Trigonometric heights were calculated and adjusted to the leveling net at all bench mark connections. Distances were reduced first to sea level and later to spheroid. Initial values for the geodetic positions of the traverse stations were calculated without adjustment for azimuth or closure, by the Gauss mid-latitude formula extended to fifth order terms." On page 274 Leatherman continues, "At an early stage we expected that the separation of the reference spheroid of European Datum from the geoid in Saudi Arabia would be inconveniently large. It was agreed that the adjustment should be carried out in terms of European Datum and that the adjusted coordinates would be transformed to a new 'best fitting datum' for the International spheroid in Saudi Arabia by the method given by Weightman in *Bulletin Géodésique*, *No. 85, 1967*. The geoid-spheroid separation varied from –6m to –68 m and the range of the deviation components was 32" in meridian and 45" in prime vertical. Three alternative definitions of best fitting were considered: to minimize the separations, or the deviations, or both simultaneously. It was considered more meaningful and more useful to minimize the separations. Being smoothed quantities they provide a better representation of the overall pattern, and by minimizing the separations, the scale errors are also minimized. The adopted best fitting datum has been designated the Ain El Abd (1970) Datum. Any readjustment of European Datum positions in this area would affect the relationship between the datums but not the final coordinates." The ellipsoid of reference for the Ain El Abd Datum of 1970 is the International 1924 where: a = 6,378,388 meters, $^1/_f$ = 297.

In 1995, J. Anthony Cavell, now deputy director of the LSU Center for GeoInformatics (C4G), developed an oblique Mercator Grid (Hotine Rectified Skew Orthomorphic projection), for Saudi Arabia. The defining parameters are: Central Scale Factor (k_o) = 0.99919, Center Latitude (φ_o) = 22° 30'N, Central Line through: φ_1 = 17°N, λ_1 = 51°E, φ_2 = 31°N, λ_2 = 36°E, False Easting (x_o) = 4,000 km, False Northing (y_o) = 500 km, and the ellipsoid of reference is the WGS 84 where: a = 6,378,137 m, $^1/_f$ = 298.257223563. A test point is: φ = 16°N, λ = 43°E; X = 1,455.596.409 m, Y = 2,162,102.853 m.

According to *TR 8350.2*, the transformation parameters **from** the Ain el Abd 1970 Datum **to** the WGS 84 Datum are: ΔX = –143m ±10m, ΔY = –236m ±10m, ΔZ = +7m ±10m. Nine stations were used to derive the parameters which were published in 1991.

The contents of this column reflect the views of the author, who is responsible for the facts and accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the American Society for Photogrammetry and Remote Sensing and/or the Louisiana State University Center for GeoInformatics (C^4G).