Republic of Bénin

In the 15th century, the site of the most organized kingdom of West Africa was at Abomey until the Portuguese came to the region in 1485. The kingdom of Great Bénin exerted great influence in the 17th century; the French established a trading presence in Cotonou (1851) with King Gezo. Temporarily suspended, the French reestablished former rights at Porto-Novo in 1863, and protection was extended to various other political entities along the coast and in the interior. Dahomey eventually was made an overseas territory of France in 1946, and it became independent in 1960. Dahomey's name was changed to Bénin in 1975. Bénin is bordered on the west by Togo (644 km), on the south by the Atlantic Ocean (121 km), on the east by Nigeria (773 km), and on the north both by Niger (266 km) and by Burkina Faso (306 km). The lowest point is the Atlantic Ocean, the highest point is Mount Tanekas (641 m), and Bénin is slightly smaller than the state of Pennsylvania. Although the country is mostly flat to undulating plains, there are some hills and low mountains.

When the federation of the eight territories constituting former French West Africa came into being in 1904, the *Annexe de l'Institut Géographique National á Dakar* (Senegal) became responsible for the official mapping. At the time, the IGN Annex, Dakar was known as *Service Géographique de l'Afrique Occidentale Française* – SGAOF (Geographic Service of the French West Africa). Topographic mapping of Bénin by SGAOF was largely at the scales of 1:200,000 and 1:500,000. The methods originally used were rapid ground mapping (using planetable and alidade with graphical triangulation). The Clarke 1880 was the ellipsoid of reference for these series. In December 1945 the *Cabinet du Directeur, Institut Géographique National* in Paris issued an instruction concerning the systems of projection to be utilized in French West Africa. The instruction detailed that a Gauss (Gauss-Schreiber Transverse Mercator) system of projection was to be used for the group of regular map compilations and related works that included geodesy, topography, photogrammetry, and cartography for a range of scales that included 1:200,000. All of the map series were to be cast on the International Map of the World sheet system based on the graticule. In particular, *Fuseau Dahomey* was defined with a central meridian, λ_o = 0° 30' East of Greenwich, a scale factor at origin, m_o = 0.999, and both False Easting and False Northing equal to 1,000 km. The limits of the Dahomey Zone grid were defined between 3° West to 4° East. The ellipsoid of reference was defined as the Hayford 1909 (International) where *a* = 6,378,388 m and 1/*f* = 297. The detailed measures that were to be taken by the Colonial Inspector Generals in charge included training their staffs to use the new tables of projection.

Within five years, French coordinate systems changed to UTM throughout the world with the exceptions of Madagascar (*PE&RS*, February 2000) and Reunion. In terms of far-reaching developments in grid system usage, this was spectacular! D. R. Cockburn and W. L. Barry of Army Map Service translated the IGN Instruction dated 20 September 1950:

> "1. The General Directorate has decided to abandon the projection systems now in use in the French Overseas Territories and Departments and to utilize henceforth, in all these territories, a new projection system called the Universal Transverse Mercator (*Mercator Transverse Universelle*), having a unique definition.
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> In-so-far as Madagascar is concerned, the use of the Laborde Projection will be continued without change. Similarly for Reunion, the Gauss system, in which the triangulation of the island has been computed, will be retained. With the exception of these two particular cases, the U.T.M. projection will from now on be the only official projection in the French Overseas Territories and Departments.
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> Consequently I.G.C. instruction No.1212, dated 12 December 1945, is rescinded.
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> 2. The new projection is a Gauss conformal projection applied to zones of 6° of longitude in width. These zones, identical to those of the 1:1,000,000 International Map of the World, are indicated on the attached index map.
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> 3. For a long time, views have been expressed in the international meetings of geodesists in favor of a universal projection system, which would be adopted by all the countries of the world. Inspector General Tardi proposed himself at the General Assembly of the International Association of Geodesy at Edinburgh (1936), a Gauss projection in 6° zones for the African continent, which is the same as the UTM projection. These views remained the dead issue for a long time. Before 1940, each country was quite satisfied with its own projection system and was reluctant to undertake the enormous task of converting coordinates into a universal system. They were especially reluctant to modify their quad printing plates. However, during the course of the last war, the extension of military operation to vast regions of the globe, the strategic deployments on a great diversity of war-fronts entailed the creation of a great number of projection systems (in 1945, over 100 of these systems were in use). As a result, a state of utter chaos ensued and considerable expense was entailed for the computation of the transformation and the adaptation operations. Consequently, the prospect of a universal projection system aroused much interest in the post war period.
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> The United States was very much in favor of the project and to facilitate its adoption by the various countries, Gauss projection tables (called a UTM projection) were computed and published. These tables were computed in the sexagesimal angular division system. The American agencies also computed the same tables on a centesimal system.
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> The Institut Géographique National, when asked to adopt the new projection in December of 1949, did not hesitate in agreeing to its use for French Colonial regions with certain exceptions which are explained below. In point of fact, it was entirely possible to adopt this new projection for the major part of the colonial possessions at a very small cost. However, a problem arose for its use in France proper and in North Africa. For France itself, a 6° belt UTM projection leads to very extreme scale changes, i.e., extreme from the point of view of civilian use.
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> 4. Actually, it was not merely in a spirit of international cooperation that the Institut Géographique National agreed to the new projection but also because it offers incontestable practical advantages. In December 1949, the situation was as follows:

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After long conferences in which various proposals were suggested, we finally adopted the solution proposed by General Laborde for our overseas possessions at the end of 1945. this solution was as follows: A Gauss system (double projection) on the international Ellipsoid with φ_o equaling 0° in French East Africa and French West Africa. For the smaller regions (Guadeloupe, Martinique, Reunion, etc.) the value of φ_o is equal to the mean latitude of the territory, φ_o being the latitude of the central point. This procedure leads to the establishment of separate tables for each value φ_o.

Tables for the conversion of geographic coordinates into rectangular and vice versa (tables which would produce the centimetric precision necessary for geodetic computations) had not been set up at the end of the year 1949 with the exception of tables covering a few small regions. Although this is a very pressing urgency, the Institut Géographique National, due to limit *(sic)* means, has neither the facilities for computing the tables rapidly nor for editing them without detriment to other equally urgent tasks.

Considering on one hand the small number of stations to be converted into the new system (for astro points the work involved is insignificant) and considering that the dimensional variations of the sheets already published would be less than the standard size, the Institut Géographique National has agreed to rapidly extend the UTM projection in these territories being aware of the following factors:

> That the United States was in a position to immediately deliver to us as many copies as was necessary of the tables computed on the sexagesimal system and contracted to compute the same tables on the grad system; that the United States was able to undertake the conversion of coordinates into the system using data obtained from electronic computing machines.

5. In point of fact, the UTM projection as it has been already adopted (or in the course of being adopted) by a number of countries is not absolutely "Universal." This would have been the case if a uniform ellipsoid had been chosen for all the countries. However, the difficulties entailed in changing ellipsoids is common knowledge and because of this, the basics of the ellipsoids in use for the various continents have been retained. Accordingly, the Clarke 1866 ellipsoid has been kept in use for North America; the International Ellipsoid has been adopted for South America and the Pacific regions, and the Everest Ellipsoid has been chosen for the East Indies and the adjacent regions. So as to fulfill a request made by the British who have already computed vast geodetic nets on the Clarke 1880 Ellipsoid, the Institut Géographique National has adopted this ellipsoid for the entire African continent. In addition, this ellipsoid was used for French geodetic work previous to 1945.

6. The UTM projection may be defined as having the following intrinsic properties:

It is a Gauss conformal projection, a direct projection of the ellipsoid on the plane. Linear values are maintained on the prime meridian of the projection with the exception of a scale-reduction which is defined by the following coefficient: $k_o = 0.9996$.

The zones have an overall width of 6° in longitude (3° on each side of the central meridian). The zones coincide with those of the 1:1,000,000 International Map. The Greenwich meridian is at the limit of two zones (zone numbers 30 and 31). These basics will suffice to define the projection for any given ellipsoid.

7. The new UTM projection differs from the Gauss projection adopted at the end of 1945 in the sense that it is a direct projection of the ellipsoid on the plane instead of being an indirect projection employing the intermediary of a sphere upon which the ellipsoid is first applied before projecting it on the plane.

The new projection retains the linear values on the central meridian of each zone to the approximate scale factor. The former projection did not retain linear values on this meridian.

In toto, the basics of the two projections are, at least within the limits of the proposed narrow zones, absolutely comparable and considered from the view point of practical application it is impossible to give preference to either one or the other. The only advantage of the former projection is that of adapting itself more simply to the extension of latitudinal belts and that this predicament will not arise for overseas geographic services.

8. Covering memo No. 1 in reference to the implementation of the new projection program is to be effective immediately. *Director, Institut Géographique National.*"

The instruction quoted above was accompanied with some specific procedures for all of the French colonies, territories, and departments. With respect to French West Africa (and Bénin), IGM explained that AMS agreed to compute the UTM coordinates of all astro points that were observed as control for the 1:200,000 scale topographic maps.

In January and February of 1952, Hydrographic Engineer Bourgoin of the French Navy directed a port survey of Cotonou in support of a new wharf. The survey included depth soundings, current measurements, measurement of the period, direction, and amplitude of the tide, observations of the characteristics of the local sea, soundings in the adjacent lagoon, and granularity determinations of the bottom. A local coordinate system was devised with the origin of X = 10,000 m and Y = 1,000 m at the church steeple. The Cotonou Lighthouse was calculated to have the coordinates X=10,241.75 m and Y=508.01 m. This local grid was oriented by tachéomètre (used at the time in Europe for cadastral surveying and distance measurement with subtense bar) to star observation, and scale was provided by a 50-meter triangulation baseline. No geodetic coordinates were given for the origin point.

A Franco-German protocol of 9 July 1897 delimited a boundary between German Togo and the French possessions of Dahomey and Soudan (presently Upper Volta). The affirmed convention boundary utilized the lagoon eastward from Île Bayol to the Mono river and then follows the river northward to the 7th North parallel, thence various jogs, thalwegs, and meridians to the tripoint with Upper Volta (now Burkina Faso). Straight lines were defined according to French topographic mapping and are therefore cast on the Gauss-Schreiber Transverse Mercator projection. Note that the thalweg is the "thread of the stream" and is not always equidistant between the two river banks.

The Bénin-Burkina Faso boundary is demarcated by the Mékrou and Pendjari rivers for about 85 percent of the distance. Be-

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tween the rivers, the boundary follows the Chaîne de L'Atacora for about 25 miles to the tripoint with Niger. This boundary (and that with Niger), was determined most recently by a French statute of 27 October 1938 and re-established on 4 September 1947.

The Lagos area of Nigeria was ceded to the United Kingdom by a local monarch in 1861. With the expansion inland of both Bénin and Nigeria, the Anglo-French convention of 10 August 1889 delimited a boundary between the territories from the gulf of Guinea northward to the parallel of 9° N. The Anglo-French agreement of 19 October 1906 and amendments made by the demarcation protocol of 20 July 1912 determined the final boundary between the two countries. Using numerous beacons (survey monuments), thalwegs of rivers, and straight lines on French 1:200,000-scale topographic maps, the boundary ends at the tripoint beacon with Niger.

In April 1959, the SGAOF name was changed to *Service Géographique, Dakar – SG, Dakar* (Geographic Service, Dakar) and in January 1961, to its present name. Topographic mapping of Bénin by IGN has been largely at the scale of 1:50,000. In the late 1940s and early 1950s, IGN compiled a small amount of topographic mapping at 1:20,000 scale and in the early through mid-1950s produced a small amount of mapping at 1:100,000 scale. After World War II the French adopted aerial photogrammetry controlled by astronomical points as the means for surveying at the scales of 1:50,000 and 1:200,000. The reader is reminded that when comparing mapping technology of the 1950s to the present, a shirt-pocket consumer grade GPS receiver is about five times more accurate than a classical "astro point."

The closest major classical datum to the Republic of Bénin is the Minna Datum of 1927. The origin is at station L40, which is the north end of Minna Base in the town of Minna, Nigeria where Φ_o = 09° 39' 08.87 N, Λ_o = 06° 30' 58.76" East of Greenwich, and the ellipsoid of reference is the Clarke 1880 where a = 6,378, 249.145 m and $1/f$ = 293.145. In 1987, NIMA published the transformation parameters from the Minna Datum of 1927 to WGS84 Datum as $\Delta a = -112.145$ m, $\Delta f \times 10^4 = -0.54750714$, $\Delta X = -92$ m ±3 m, $\Delta Y = -93$ m ±6 m, and $\Delta Z = +122$ m ±5 m, and this was a mean solution of six stations. In 1990, C.U. Ezeigbo published his solution of 11 stations for a Bursa-Wolf seven-parameter transformation as $\Delta X = -92.9$ m ±1.6 m, $\Delta Y = -116.0$ m ±2.3 m, and $\Delta Z = +116.4$ m ±2.4 m, $R_x = -0.3"$ ±1.1", $R_y = +3.0"$ ±1.7", $R_z = +2.2"$ ±1.5", and scale = +1.00002 $\pm 0.6 \times 10^{-5}$. This solution is intriguing because one station appeared to be between Lagos and Cotonou, according to the small-scale survey sketch by Prof. Ezeigbo.

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