F.R. Hassler, Superintendent of the U.S. Coast Survey, pictured in 1841.

History of Geodetic Surveying

by Joseph F. Dracup

The United States began geodetic surveys later than most of the world's major countries, yet its achievements in this area are immense and unequaled elsewhere. Most of the work has been done by a single agency. That agency began as the Survey of the Coast in 1807, was identified as the Coast Survey in 1836, was renamed the Coast and Geodetic Survey in 1878 and, since about 1970, has been the National Geodetic Survey, presently a division in the National Ocean Service, NOAA.

This four-part series is a look at the geodetic work of the Coast and Geodetic Survey, which has been with us, under one name or another, for nearly 190 years, along with the scientific accomplishments, technological developments, major and other interesting events, ancedotes, and the contributions made by the people of each period.

Part I concerns the early years of geodetic surveying in this country. Subsequent issues will cover:

- Part II—Laying the Foundations of the Networks, 1843-1900
- Part III—Building the Networks, 1900-1940
- Part IV—Dawn of a New Era, 1940-1990.

Part I
The Early Years: 1807-1843

The early period was dominated by Ferdinand R. Hassler, who developed the plan, gathered the instruments and technical books, made all the primary observations himself, and set the standards of excellence that became the hallmark of geodetic surveys in the United States.

Early Geodetic Surveys

The British/French Controversy

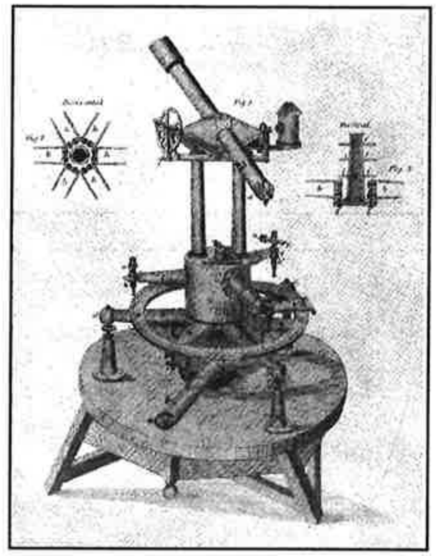
The first geodetic survey of note had been observed in France during the latter part of the 17th century and the early 18th century. Jean Picard began an arc of triangulation near Paris in 1669-70 and continued the work southward until his death about 1683. His work was resumed by the Cassini family in 1700 and completed to the Pyrenees on the Spanish border prior to 1718, when the northern extension to Dunkirk on the English Channel was undertaken.

The survey created a major controversy, for the results indicated that the earth was a prolate ellipsoid, which contradicted Issac Newton's 1687 postulate that it was an oblate figure. To settle the hue and cry that followed, the French Academy of Sciences in Paris proposed in 1733 that the length of the meridian be measured near the equator and compared with that obtained in France. Later it was decided to do the same in the Arctic region. The Torne River valley north of Tornio in Lapland, on the Swedish-Finnish border, was chosen as the northern site; observations were begun in 1736 and completed two years later. The results showed conclusively that one degree of the meridian was longer in Lapland than at Paris and proved Newton's postulate to be correct. The expedition to Peru (to a location in present-day Ecuador) departed in 1735 and returned nine years later with results that confirmed the Lapland finding, i.e., one degree of the meridian is shorter at the equator than in France.

These truly remarkable efforts by the French and their associates were carried out with instruments which would seem very primitive in comparison with equipment available 50 years later, though they were the best then available. Furthermore, the observations were secured under extreme conditions especially in the high Andes of South America. In Peru, the angle observations were made with quadrants having 2-3 feet radii and two telescopes—one fixed, the other moveable—and equipped with micrometers for finer readings, the latter used perhaps for the first time. The horizon was closed on each set of observations and usually involved six or seven angles. The average closing error was on the order of 2 minutes, indicating the accuracy of each angle at 20″ to 30″. Baselines in Peru were measured using wooden rods, each 20 feet long, and were standardized daily or more often with an iron toise (about 6.4 English feet) that was carried along and kept in the shade. The baseline in Lapland was measured over the frozen Torne River using a similar, although longer (33-foot), apparatus.

Great Britain

Great Britain began geodetic surveys in 1784 under the direction of Major General William Roy. A site for the first baseline, about five miles in length, was selected on Hounslow Heath in what is present-day west London. The initial measurement was made using rods of Riga pine. Large errors were noted between measurements made, depending on whether the rods were wet or dry, and so the line was remeasured with glass tubes constructed by Jesse Ramsden. After 1791, baselines were measured with 100-foot steel chains. Jesse Ramsden's theodolite, with a 3-foot circle reading to 1″ built in 1787, was used for the angle observations and, despite its 300 lbs. or so weight, good progress was obtained in the triangulation, including a connection between Dover and France in 1787. Roy died in 1790 and, after a delay of about one year, the triangulation was resumed and completed in 1822. (Between 1936 and 1950 a new, denser network with ties to several points of the earlier triangulation was observed.)



Twenty-four inch theodolite No. 2, made in England by Troughton in 1814. (Reproduced in Centennial Celebration of the United States Coast and Geodetic Survey 1916 *from the* Transactions of the American Philosophical Society, 1825, *and reproduced here with the permission of the National Geodetic Survey, NOS, NOAA.)*

Ramsden's Direction Theodolite

Ramsden's direction theodolite is among the four or five greatest technological advances ever in geodetic surveying. Prototypes continue in use in almost all countries. In the field of general surveying, however, the invention (in around 1790) by the French of the repeating theodolite is of equal importance, because it is the basis for the instrument which most surveyors have employed. Despite their almost universal use in the private sector, repeaters have been shown to be less accurate than direction instruments. Although in theory the opposite is the case, in practice, repeaters' more moveable parts and the mechanical motions required to operate them contribute to larger error sources. As for the French, as you might expect they still preferred repeating theodolites for higher order surveys, and continued to use them as late as 1963 when a new connection was made between Portsmouth, England and Cherbourg, France. Instruments employed that year were repeating types, presumably reading to 1″ with eye pieces having moveable cross hairs, so that as many as 10 readings could be obtained from each pointing. One point of interest. The new Portsmouth/Cherbourg connection was only possible because Bilby towers were available.

First Level Datum

As might be anticipated, The Netherlands established the first level datum in 1682 and carried out surveys along rivers and some shorelines between 1797 and 1812. However, the first geodetic leveling was not begun until 1875. By contrast, Great Britain started their geodetic leveling in 1841 and completed it about 20 years later. In almost all instances, geodetic levelings were undertaken after the triangulation was well on its way or completed.

By 1800, most of the countries of Europe had drawn up plans or were on their way to establishing triangulations. By 1842, these triangulations spanned the continent from the Mediterranean Sea on the south to the Arctic regions on the north, and from Ireland, England and the Atlantic Ocean on the west to the interior of Russia on the east.

Hassler Leads U.S. Effort

The United States entered this world of geodesy in 1807 and, while 25 years passed before the primary work could be initiated, its achievements were soon recognized by much of the world. At the beginning and along the way for 25 years, however, there were many trials and tribulations to be overcome. The country was very fortunate indeed that a man of the caliber of Ferdinand R. Hassler was selected to lead the effort, for one of lesser resolve would have given up early, given the many and difficult problems. Hassler was 37 years old when he was named the first superintendent of the Survey of the Coast and 62 when he began the first major triangulation in 1832. There were many depressing and disillusioning periods for him in the intervening years.

1807: Survey of the Coast Created

Geodetic surveying began in the United States on February 10, 1807 with the creation of the Survey of the Coast by Congress during the presidency of Thomas Jefferson. Hassler, a Swiss-born geodesist who had conceived the plan for the agency, was placed in charge and served in that capacity on and off until his death in 1843. Nothing was accomplished for several years because appropriated funds were not released due to political opposition and unsettled conditions in Europe, the source of needed equipment. Finally in 1811, $25,000 was disbursed and Hassler immediately went to England to have instruments made to his design and specifications, and to purchase other equipment and scientific books. He remained there during the War of 1812, returning in 1815.

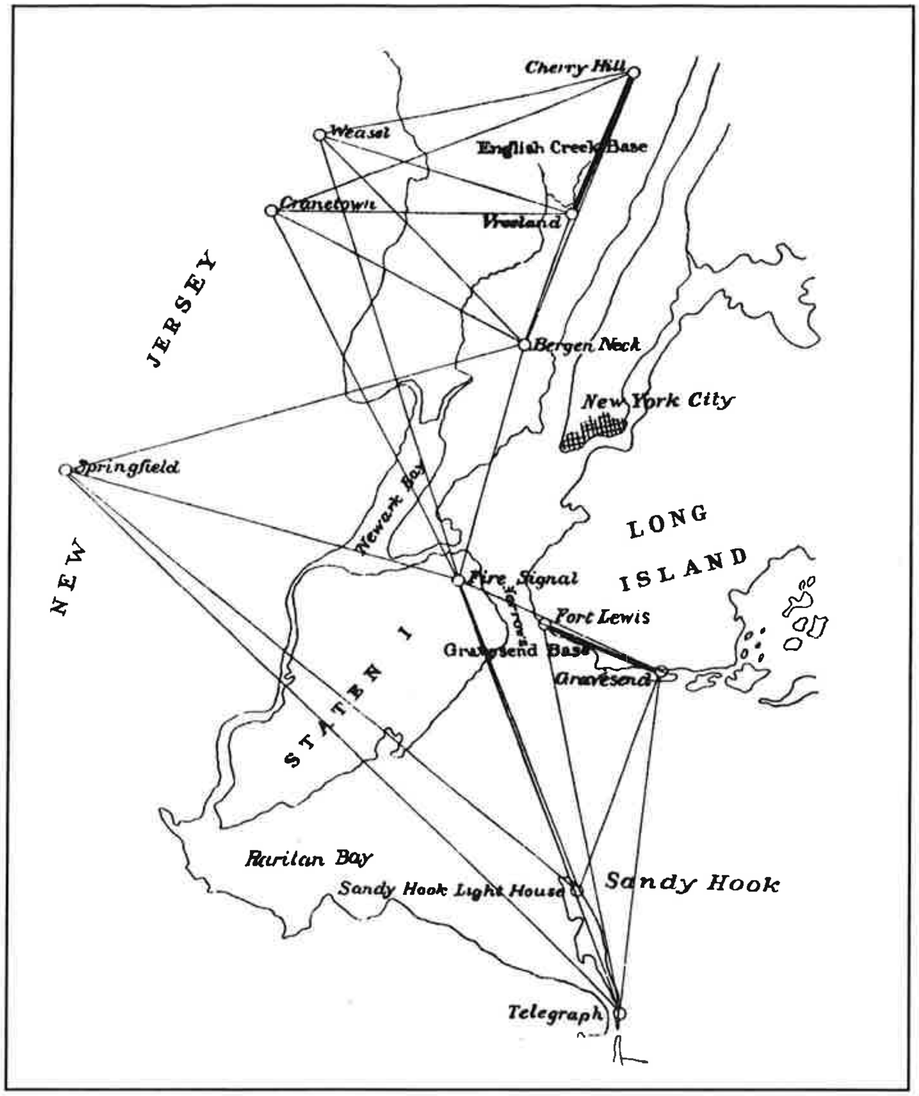
First Field Surveys

First field surveys were carried out in 1816-17 near New York City, where a small scheme of triangulation consisting of 11 points, scaled by two measured baselines, was accomplished to an accuracy that would approach present day second-order, Class I. Hassler performed the reconnaissance to select the station sites, directed the baseline measurements, and observed all the angles with the recently acquired 24-inch theodolite, built by Edward Troughton of London to Hassler's specifications.

The first point occupied for geodetic observations in the U.S. was identified as WEASEL, located on a low mountain about two miles south of Paterson, New Jersey on July 16, 1817. It was marked by a 6″ deep drill hole filled with sulphur. In 1934, it was reported that the top of the mountain had been blasted off, destroying the station. Blasting is one of the very few ways to obliterate a mark of this type. None of the original stations are thought to exist today, although WEASEL and SPRINGFIELD were included in the primary triangulation southward from New York City observed in 1838. Station CHERRY HILL, one end of the baseline at the northern end of scheme, near Englewood, New Jersey was destroyed by subdivision construction in the late 1970s, only a few days before personnel were scheduled to move the point to a protected area. In 1987, the American Society of Civil Engineers placed a plaque at the approximate location of original station CRANETOWN, north of Montclair, New Jersey, noting the site as a National Historic Civil Engineering Landmark.

Hassler Dismissed

Almost immediately on its completion, politics reared its ugly head once again and Hassler was dismissed. For about 15 years he tried his hand at several occupations before being reappointed to his position in 1832. First he worked as an assistant on the U.S.-Canada northeast boundary surveys, then made an unsuccessful attempt at farming in a remote site on the St. Lawrence River, where his wife left him. After that he took a position as a gager at the New York Custom House, followed by a period of unemployment during which he wrote several books on advanced mathematics and devel-



Hassler's first field work, 1816-17.

oped the polyconic map projection still used today. Finally, in 1830, he received an appointment as superintendent of the new Office of Weights and Measures. This office remained in the Coast and Geodetic Survey until 1901, when it was spun off to become the National Bureau of Standards. This was a dark period for both Hassler and American geodesy.

Hassler Reappointed

Once back on the job, Hassler immediatedly began geodetic surveys on Long Island, New York that have continued, more or less unabated, until today. The instruments and equipment that Hassler had made or purchased were more than adequate for the task at hand. This was attested to by a French astronomer who said in 1832 that at the time of construction, the instruments were 20 years in advance of the science of Europe. Having the best of tools is no guarantee, of course, of the best of results. In surveying, "best" means the most accurate and to reach that goal requires, in addition to the instrumentation, trained and conscientious personnel and proper observing procedures. The sum total of all the requirements can be broadly categorized as standards of accuracy, and Hassler set standards of the highest accuracy for these early surveys that remain the hallmark of American geodetic work. He made all the observations at the primary stations himself, while at the same time training his assistants James Ferguson and Edmund Blunt on the secondary surveys so that they could step in when necessary to do his job—which they did. The first station occupied was BUTTERMILK on June 11, 1833. It still exists and is located on what is now the Rockefeller estate in Westchester County, New York.

The Great Theodolite

Prior to October 18, 1836, the observations were made using the 24-inch theodolite. On that day and until his death in 1843, Hassler employed a 30-inch instrument that he proudly called the Great Theodolite. Designed by Hassler and built by Troughton, this, the finest instrument of its day, was used first at station WEST HILLS on the northern shore of Long Island, a point that remains in place even now. The Great Theodolite's weight of 300 lbs. was of little concern to Hassler, who had used a 36-inch Ramsden theodolite, an instrument of similar weight, in the trigonometrical survey of Switzerland. He simply strengthened the oversize carriage used for transporting the 24-inch instrument, a fairly heavy piece in itself, weighing perhaps 200 lbs.

Two characteristics of the Great Theodolite are seldom mentioned. Firstly, it was designed as a repeating instrument, and, second, it had a 24-inch vertical circle. Hassler employed it in the direction mode as did others later, until it was destroyed in 1873. Presumably, the final construction was as a direction theodolite.

Hassler's Methods

The two baselines measured for the 1816-17 survey at Gravesend Bay near present-day Coney Island (4.7 miles) and at Englewood, New Jersey (5.8 miles), were not considered accurate enough nor probably long enough to scale the primary triangulation then underway. Both bases were measured with iron chains, each link one meter in length. Accordingly, Hassler measured his only primary baseline at Fire Island on the south shore of Long Island in 1834 using four two-meter iron bars laid end to end. It was not a direct measurement. In order to take advantage of the level beach, the principal measurement followed a route from WEST BASE somewhat southerly of the direct line to a point about 255 meters west of EAST BASE. The point was connected to EAST BASE by angle and distance with the distance between the terminals obtained by computation.

Hassler's methods were acclaimed by several scientific societies, but as always the real proof of the pudding lies in the agreements with the nearest baselines as computed through the triangulation. The checks were excellent, about 1:100,000 with the MASSACHUSETTS base, EPPING base (Maine) and KENT ISLAND base (Maryland), measured in 1844, 1857 and 1844 respectively and to about the same accuracy with nearby EDMI lines later observed in the 1970s.

Hassler's base apparatus was used for the MASSACHUSETTS and KENT ISLAND bases. The EPPING base was measured with Bache-Wurdemann compensating equipment. The base is 8¾ miles in length and marked at the terminals by red sandstone monuments 4 feet high and about 1 foot square with a rounded top, and at intervals of 2,000 meters by stoneware cones. Records state that the marks are lost, though it is unlikely that much of an effort was made to find them, especially the intermediate ones. With today's equipment it wouldn't take a huge effort to settle the question once and for all time.

The FIRE ISLAND base was computed through the triangulation to the line WEST HILLS-RULAND on the north side of Long Island, a line Hassler called his mountain base, from which the triangulation east and north and to the south was extended. This triangulation eventually ran from Calais, Maine southward to Dauphin Island near Mobile, Alabama then westward to New Orleans, Louisiana: a distance of 1,623 miles, with the field work done between 1833 and 1898.

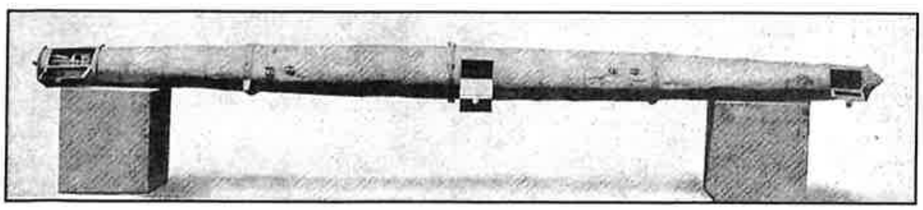
Massachusetts Commonwealth Survey

The Coast Survey was not the only agency establishing triangulation at the time. In 1830 the Massachusetts legislature decided to prepare maps of the Commonwealth based on a trigonometric survey. Colonel James Stevens was placed in charge and began operations including the measurement of a 7.4 mile base line along the Connecticut River, near Northampton.

The measurement was carried out with compensating apparatus 50 feet in length designed by Dr. Joseph Rice. (The first application of the compensation principle had been by the Ordnance Survey of Ireland on the Lough Foyle base in 1827.) Rice's use of the compensation principle was about 15 years ahead of its use in the Coast Survey, albeit his work was known there. No other information is available about Rice and little is known about his apparatus although the methodology was reported in one or two scientific journals.

A theodolite on loan from the Coast Survey was used for angle observations until its recall in 1834. After that time an instrument of the Massachusetts surveyors' own design was employed.

Stevens resigned in 1834 and Simeon Borden, formerly an assistant, took over with the bulk of the work still to be done. The survey was completed in 1838. The results were not published until 1846 and the positions were given as tangent plane coordinates based on the location of the points in one of five zones. This was the first use of plane coordinates on a large scale in America. In 1935 it was reported that little use was made of the coordinate system, a situation not too different from that found today.



Bache-Wurdeman compensating base apparatus. (Reproduced in Centennial Celebration of the United States Coast and Geodetic Survey 1916, *and reproduced here with the permission of the National Geodetic Survey, NOS, NOAA.)*

A Series of Name Changes

Hassler began using the title Superintendent of the Coast Survey in his 1836 report to the Secretary of the Treasury, the year the bureau was transferred to that department. This usage continued until 1865 where that and subsequent reports to 1877 show United States Coast Survey. In 1878 Congress changed the name to U.S. Coast and Geodetic Survey (C&GS); in 1899 the U.S. was dropped. In the 1970s, the C&GS became the National Ocean Survey (NOS), later renamed the National Ocean Service (NOS) with the geodetic functions assigned to the National Geodetic Survey (NGS), presently a division in NOS.

The End of the Beginning

Hassler continued observing the triangulation southward and after about 10 years only had reached southern New Jersey, involving but 24 stations. Upon completing the observations at station BURDEN he traveled to a station site in Delaware where during a severe storm he fell trying to protect his instruments and was badly injured. He returned to his home in Philadelphia where he died on November 20, 1843.

Thus we reach the end of the beginning. The groundwork for laying the foundation was done. By the turn of the century, triangulation would span the nation north to south from Maine to Louisiana, east to west from New Jersey to California, over the Great Lakes, and with work underway through the middle of the country between the Rio Grande and Canada.