THE NAD83 PROJECT - BACKGROUND AND STATUS

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May, 1989

ABSTRACT

The last general recomputation or readjustment of North American geodetic networks was done during the period 1927-1932 and was designated North American Datum of 1927 (NAD27). By 1972, the need for another general readjustment of North American networks had been recognized, and strengthening of the network by means of additional electronic distance measurements and satellite Doppler positioning began. Discussions among the national survey organizations of North America and Denmark (for Greenland) led to the recomputation and new datum definition known as the North American Datum of 1983 (NAD83).

The availability and accuracy of modern satellite positioning techniques, and the high probability of their more widespread use in the future for all types of surveying and navigation, together with the rapid development of computerized geographic information systems, made it desirable to adopt a compatible geocentric reference system for the recomputation project. The NAD83 Earth-centered system is significantly different from NAD27 and many existing land-related information databases will require conversion to NAD83.

This paper outlines the steps leading up to the redefinition, describes the method of network adjustment, presents the status of the integration of secondary and primary networks, and outlines user support that will be available from the Geodetic Survey Division.

1. INTRODUCTION

1.1 Participants

The North American Datum 1983 (NAD83) Project is a cooperative effort by the geodetic agencies of North and Central America to strengthen and recompute their horizontal control survey networks, and to redefine the datum to which they are referred. These networks provide the foundation for mapping, charting, navigation, and land-related information systems. Project participants include the Danish Geodetic Institute, the Geodetic Survey of Canada, the U.S. National Geodetic Survey, the U.S. Defense Mapping Agency and the Dirección General de Geografia del Territoria Nacional of Mexico.

1.2 Information Seminars

Some eight technical information seminars have been held across Canada over the past year, aimed primarily at the surveying and mapping community. The papers presented at these seminars have been bound and are available from the Canadian Institute of Surveying and Mapping (CISM), Ottawa. A second series of seminars is being scheduled to meet the needs users will have for computational procedures for NAD83 integration.

The Canadian Council on Surveying and Mapping (CCSM) supports the CISM initiative, and is urging CCSM member agencies to sponsor seminars or briefing sessions aimed at data managers outside the surveying and mapping community. This paper has been prepared for a briefing session for data managers within the federal government, who need to be aware of the implications of NAD83.

2. PROJECT BACKGROUND

2.1 Creation of NAD27

The national survey network in Canada was begun in 1905, and was computed on what was known as the Canadian Datum. In 1913 Canada and Mexico agreed to base their networks on the United States' network, to which they were strongly tied, and to refer to the datum as the North American Datum.

By the mid-1920s, the problems of computing new surveys to fit the existing network clearly indicated the need for an overall recomputation of the existing primary triangulation. The Canadian networks were sparse, comprising the arc along the 49th parallel, some area surveys in southern Ontario and Quebec, and a loop in New Brunswick. A recomputation was carried out during the period 1927-1932, resulting in the 1927 North American Datum (NAD27) which is still the official datum in Canada.

2.2 Extent of the Canadian Horizontal Geodetic Networks

Since the NAD27 adjustment, surveys have been added to the primary network, an extensive network of satellite Doppler stations has been established within, or extended from, the primary network, and some stations have been added using the more recent Global Positioning System (GPS) satellites. The primary Canadian framework comprises some 8000 stations. Federal and provincial secondary networks comprise an additional 150 000 stations.

2.3 Need for General Recomputation

As the survey networks were extended and densified, the new surveys were computed to fit the existing surveys. In the 1960s this process resulted in the introduction of significant distortions in the newer, and often more accurate, surveys. Recomputations of extensive networks such as those in Southern Ontario or the Maritime provinces, minimized the local distortions but created discordances between recomputed areas.

Analyses of the regional readjustments confirmed the obvious - that a comprehensive readjustment of horizontal networks was needed. Hence, in 1972 a systematic evaluation of the primary network in Canada was begun. Because the same conclusion was being drawn by geodetic agencies in the U.S.A. and Mexico, preliminary plans for a North American readjustment were discussed in 1973. Following two international symposia on the redefinition of North American networks (in Fredericton, N.B. in 1974 and in Arlington, Va. in 1978), Canada and the U.S.A. formally agreed to the redefinition of their geodetic networks on a new geocentric datum. The recomputation of the networks would eliminate distortions and the choice of a geocentric datum would ensure compatibility with satellite-based positioning.

3. NAD83 - DATUM AND COMPUTATIONS

3.1 New Datum

The datum or reference surface used for NAD27 geodetic computations is the Clarke 1866 ellipsoid which was regarded as a best fitting computational surface for the shape of the Earth (The Geoid) in North America. The origin or datum point for NAD27 is the triangulation station "Meades Ranch" in Kansas. This origin is on the surface of the Earth and was chosen because it is located at the approximate geographical centre of the conterminous U.S.A. (the lower 48 states).

For the NAD83 Project, a new datum was adopted which lends itself to accurate computations of 3-dimensional positioning for surveying and navigation by satellite methods. The datum or reference frame for NAD83 is the World Geodetic System 1984 (WGS84) adopted by the U.S. Department of Defense for satellite orbit computations in both the U.S. Navy Navigation Satellite System (NNSS or "TRANSIT" system) and the newer Navstar Global Positioning System (GPS). The reference ellipsoid associated with NAD83 is Geodetic Reference System 1980 (GRS80) adopted by the International Association of Geodesy (Moritz, 1980).

Further details on World Geodetic System 1984 and parameters defining and relating it to GRS80 and NAD83 are given in a technical report published by the U.S. Defense Mapping Agency (DMA - TR 8350.2)

3.2 Adjustment Computations

For greatest accuracy, geodetic networks are almost always established with redundant observations and computed by the method of least-squares. The least-squares network adjustments being carried out for the NAD83 Project involve the simultaneous solution of hundreds of thousands of equations using computer programs and strategies developed for this purpose.

Canadian participation in the NAD83 network adjustment computations is being carried out in 2 stages. The first stage was finished in July 1986 when the Geodetic Survey of Canada (GSC) and the U.S. National Geodetic Survey (NGS) completed a simultaneous adjustment of the primary network in Canada and the primary and secondary networks in the United States. Because the secondary networks in the United States were included in the July 1986 Continental Adjustment, NGS was able to begin publication of NAD83 coordinates in late 1986 following analysis of the results. In Canada, however, only the primary network, comprising 8000 stations,

was included in the July 1986 adjustment. The integration of secondary networks is now underway as a cooperative project by federal and provincial control survey agencies represented at semi-annual meetings of the Canadian Control Survey Committee formed under the CCSM.

To facilitate the NAD83 integration adjustments of secondary networks and to accommodate the different plans and schedules of provincial agencies for secondary integration, the national network was divided into Eastern, Western and Northern Regions. The Eastern Region Secondary Integration Adjustment was completed in May 1989, resulting in NAD83 coordinates for 60 000 primary and secondary control survey stations in Ontario, Quebec and Newfoundland, and for about 400 primary stations in the Maritimes. Networks in the four Western provinces comprising 34 000 stations will be integrated simultaneously with 11 000 stations in the Yukon and Northwest Territories and NAD83 coordinates for the Western and Northern Regions will be available by the spring of 1990.

Following the regional secondary integration adjustments there will still remain many thousands of lower-order survey points to be integrated by provincial agencies and other organizations, using network adjustment methods or coordinate transformations.

4. PUBLICATION OF RESULTS

4.1 Adoption

Publication of results will begin with an Order-in-Council informing all federal departments and agencies that NAD83 is now the official datum for all federal surveying, mapping, charting and GIS applications. Similar proclamations are expected from each participating province; some may precede the federal announcement.

4.2 National Geodetic Data Base (NGDB)

Upon completion of the secondary integration computations, the NAD83 coordinate values for all primary and secondary stations will be loaded into Geodetic Survey's National Geodetic Data Base (NGDB). Station descriptions are kept up to date by the establishing agency, federal or provincial, and therefore not all descriptions will be on the NGDB. Users are advised to consult the establishing agency to get up-to-date descriptions before they try to find stations in the field for reoccupation. On-line access by users will begin once NAD83 values have been loaded into the NGDB. The NAD83 coordinates will also be available from provincial control survey agencies for points within their jurisdictions.

NAD27 coordinate values will remain available on request, but not necessarily on-line, after the publication of NAD83. It is our intention not to add new surveys to this system, nor to update NAD27 in any way. Gradually, its use will diminish as maps and charts are published in the NAD83 system. In the United States, individual State legislation calls for a 5-year transition period during which NAD83 will be implemented and NAD27 phased out.

5. USER SUPPORT

5.1 Preliminary Coordinates

Since late 1986, provincial agencies have had access to the preliminary NAD83 coordinates resulting from the Continental Adjustment (for the primary network). These values have been used to verify secondary networks, and to assess the impact of the coordinate differences on various applications and products. In addition, the values have been issued on request to major users to enable them to begin preparations for conversion of their data. Geodetic Survey also used the preliminary results to begin development of a national transformation between NAD27 and NAD83. This was done in response to a request for a method of converting the coordinates of unmarked boundaries, such as those defining offshore leases.

5.2 Coordinate Transformations

To take advantage of the NAD83 system, many users may be faced with the task of transforming their data from its existing system to NAD83. Transformation methods increase in complexity from simple shifts, through scaling and rotation of reference axes, to distortion modelling and local refinements for overdetermined systems. Some differences may be known *a priori* , such as when the relationship between two datums is specified. Other differences may need to be computed.

The most common and elementary transformation involves the simple addition of constant values to effect a translation of the origin of the coordinate system. Such a shift is usually determined by taking the mean shift of selected common points, and assuring that the range of these shifts does not vary significantly. This type of transformation is generally applicable to mapping plane coordinates, to ellipsoidal coordinates, and to geocentric Cartesian coordinates.

However, to account for variation in relative positions due to distortion between two control survey adjustment systems, additional modelling parameters must be introduced. This is done to distribute distortion smoothly among common control points, so that it is not localized where one local datum shift model meets another.

5.3 National Transformation

Geodetic Survey Division is preparing a representative transformation to convert coordinates of data points between the NAD27 and NAD83 systems, for use in situations where, for example, recompilation of the original observed survey data is not feasible and hence network adjustments are not feasible. This transformation is based on published NAD27 values, and on values for NAD83 which are being computed by the simultaneous adjustment of the primary network together with the secondary control networks in the provinces and territories.

This transformation is computed in two parts, and includes both a datum transformation and NAD27 distortion modelling. Geodetic Survey will be distributing parameters for this transformation, plus the corresponding software, and recommending it for all situations in which consistency with surrounding control survey networks is of greatest importance. Use of this unique transformation will ensure that different users will always produce the same new values for the same points, a great advantage in reducing potential sources of confusion or disagreement.

To facilitate the use of this national transformation, Geodetic Survey will produce a table of shifts between the systems, for points on a regularly spaced grid. A simple standard algorithm for interpolating among the grid points will also be provided, and both the table of shifts and the interpolation routine will be made available in automated format. All software for the national transformation is in standard FORTRAN77 code, and runs on a variety of computers, including a simple PC.

6. IMPACT AND BENEFITS OF NAD83

6.1 Impact

Following the adoption of NAD83 as the new geodetic reference system for Canada, federal and provincial mapping agencies will be using it as the foundation for all new maps and charts. The effect that NAD83 will have on various users of geodetic control and other position-dependent data will depend, in part, on the magnitude of the coordinate shifts from NAD27 to

NAD83. Figure 1 shows estimated shifts from NAD27 to NAD83 for geodetic coordinates and for Universal Transverse Mercator (UTM) coordinates.

Shifts in the geodetic coordinates range from about 120 metres westerly on the West Coast, to 70 metres easterly in Newfoundland and approximately 100 metres northerly in the high Arctic Islands (McLellan 1978). For UTM coordinates, there is a fairly consistent northward shift ranging from 200 to 250 metres. The reason why the "UTM shifts" differ from the geodetic coordinate shifts is that the UTM northings are affected by the differences in the dimensions of the Clarke 1866 and GRS80 ellipsoids.

6.2 Benefits

To assess the benefits of the NAD83 project, it is necessary to look beyond the primary users of control survey data to the secondary and tertiary users, for example, those who depend on the geodetic reference system for GIS applications. Their data, originally produced for single-purpose functions, becomes much more valuable if it is positionally compatible with other data. NAD83 will make this compatibility possible. Costs which would have otherwise been incurred to create compatible data sets are thus avoided by the availability of NAD83.

Positioning systems now under development will use the NAD83 datum, thus making data gathering and data management easier and more compatible. Prototype Global Positioning System (GPS) satellites are now broadcasting their positions in the NAD83 reference frame. NAD83 coordinates will be used to rectify data from remote sensing satellites such as SPOT before it is provided to users.

Future integration of surveys performed using GPS satellites will be greatly facilitated by the adoption of NAD83. Control surveys in both urban and rural areas are now being done using signals from the prototype satellites. Accuracies of two or three parts per million are being routinely achieved, and the integration of such new survey projects with the continental network will serve to further enhance the quality of NAD83 coordinates.

In 1988, Geodetic Survey began using GPS to tie primary bench marks to the horizontal network at 30-km spacing along levelling routes in southern Canada, thus making NAD83 and primary horizontal network points more accessible to users. Other GPS activities are reported in various papers presented at the CISM-sponsored seminars.

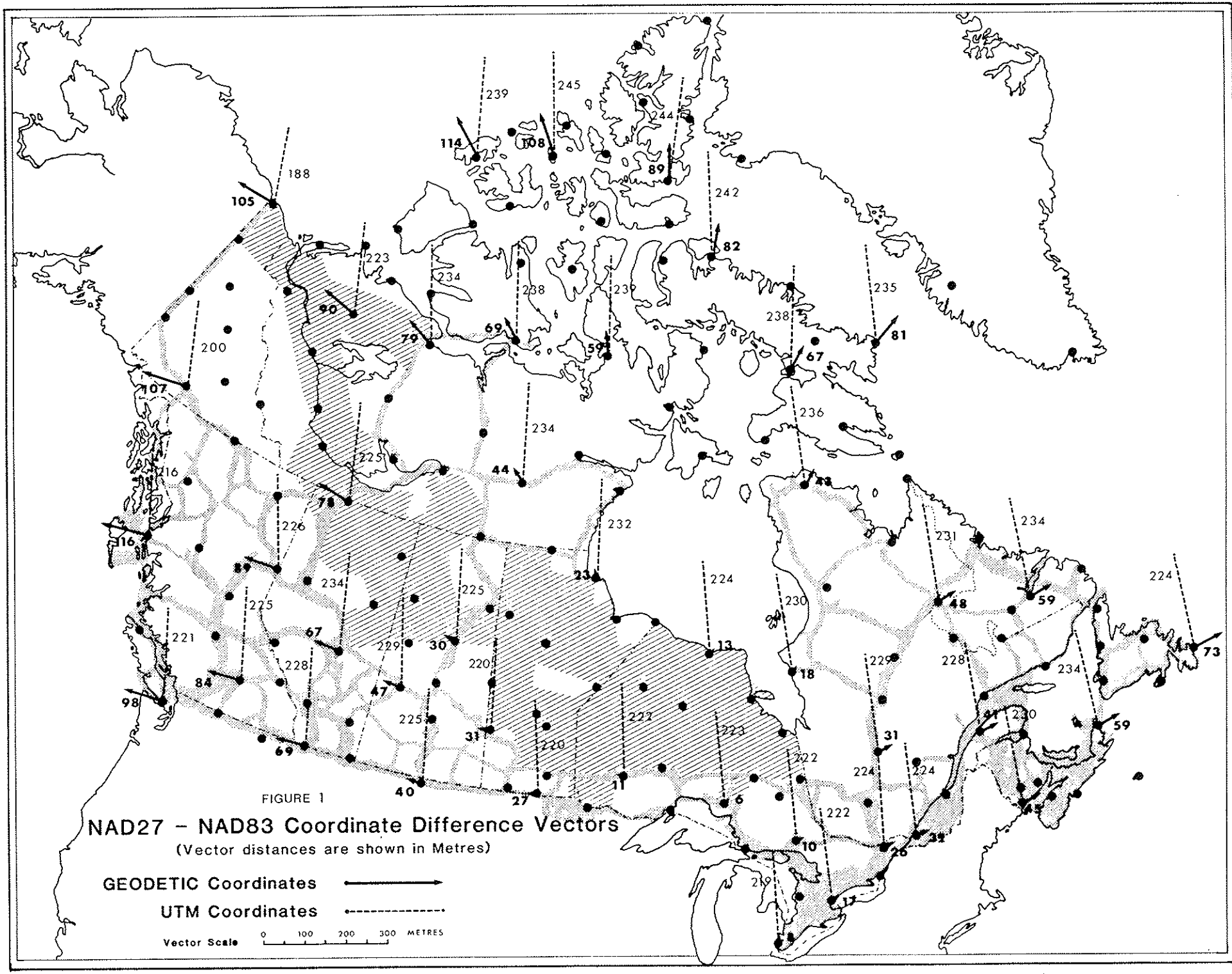

FIGURE 1

NAD27 – NAD83 Coordinate Difference Vectors

(Vector distances are shown in Metres)

GEODETIC Coordinates ——————

UTM Coordinates ----------

Vector Scale 0 100 200 300 METRES

7. SUMMARY

The last continental adjustment was completed about 60 years ago, initiating the NAD27 coordinate system which until recently satisfied most requirements for geodetic control. NAD27 does not meet the accuracy required today by national and provincial mapping and charting programs and other uses. NAD83, on the other hand, lends itself to the future maintenance of an accurate and consistent control survey system capable of supporting future satellite surveying, mapping, and GIS needs.

There will be costs to the NAD83 conversion which only individual users, who know their own operations, can assess. Geodetic Survey will support conversion efforts by continuing to take part in seminars, by providing, on request, data, information and advice, and by developing the national coordinate transformation described above.

Computation of NAD83 coordinates for primary and most secondary control was completed this May for eastern Canada networks, and will be completed by the spring of 1990 for western and northern networks. Integration of new projects, of some remaining secondary networks, and of lower-order networks will follow. Steps are being taken to provide for official adoption of NAD83 through orders-in-council in the several jurisdictions involved.

By 1992, GPS will provide a worldwide positioning capability 24 hours per day for all surveying and navigation purposes. There is no doubt, for those who are willing to make the changeover to NAD83, the benefits will be real.

References and Bibliography

Boal, J. D. and J. P. Henderson (1988) *The NAD83 Project - Status and Background.* Geodetic Survey of Canada paper for CISM Seminars on NAD83.

Defence Mapping Agency (1987) *Department of Defense World Geodetic System 1984.* DMA technical report 8350.2, Washington, D.C., September 30, 1987.

Junkins, D.R. (1988) *Transforming to NAD83.* Geodetic Survey of Canada paper for CISM Seminars on NAD83.

McLellan, C.D. (1978) *Status of the Readjustment Project in Canada*, paper presented at the Second International Symposium on Problems Related to the Redefinition of North American Geodetic Networks, Washington, D.C., April 24-28, 1978.

Moritz, H. (1980) *Geodetic Reference System 1980*, The Geodesist's Handbook, Bulletin Géodésique, Vol. 54, No. 3, 1980.

O'Brien, L.J. (1985) *NAD83 Redefinition and Readjustment of North American Geodetic Networks.* Geodetic Survey of Canada, EMR, Ottawa, January 1985.

Papers for the CISM Seminars on the NAD83 Redefinition in Canada and the Impact on Users.

Parent, C. (1987) *NAD83: Nouveau datum horizontal et recompensation des réseaux géodésiques nord-américains.* Arpenteur-géomètre, vol. 14, no. 4, novembre 1987, pp. 11-16.

Parent, C. and M.C. Pinch (1988) *NAD83 Secondary Integration*, CISM Journal ACSGC, Vol. 42, No. 4, Winter 1988, pp. 331-340.

Proceedings of the International Symposium on Problems Related to the Redefinition of North American Geodetic Networks, Fredericton, New Brunswick, Canada, May 20-25, 1974, The Canadian Surveyor, December 1984, Vol. 28, No. 5.

Proceedings of the Second International Symposium on Problems Related to the Redefinition of North American Geodetic Networks, Arlington, Virginia, U.S.A., April 24-28, 1978, U.S. Government Printing Office, Washington, D.C. 20402 (Stock number 003-017-0426-1).