MOVING TO NAD '83

the new address for georeferenced data in Canada

THE CANADIAN INSTITUTE OF SURVEYING AND MAPPING

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PREFACE

This publication represents the sequel to the "Papers for the CISM Seminars on the NAD'83 Redefinition in Canada and the Impact on Users" document compiled in 1988. That document provided valuable background on NAD'83 from various perspectives to heighten the awareness of the redefinition impact. With NAD'83 coordinate values now available and officially adopted by the federal department of Energy Mines and Resources, the reality of NAD'83 adoption is here.

Provincial Surveying and Mapping agencies are expected to follow the Federal lead of official NAD'83 adoption. This will result in far reaching impacts to any agencies dealing with georeferenced data. Although users are not expected to be forced to adopt the new datum it is hoped that industry has the foresight to foster its adoption. This will facilitate the transition into an environment conducive to exchange and merging of georeferenced data.

Although no definitive method exists for the conversion of all data from NAD'27 to NAD'83 the papers contained in this document identify some alternatives and promote the preferred alternatives. Various jurisdictional strategies are outlined as they are evolving. Although final provincial strategies are not in place for all jurisdictions, the material presented in this publication will provide strategies on which users can focus. In addition as the reality of NAD'83 adoption dawns, more details on related issues surface. These issues are addressed by the various authors.

The material is divided into contributions by Federal and Provincial agencies as well as industry. The 'National Transformation' user guide is also included. All provincial government surveying and mapping agencies were approached for a contribution. The absence of papers from some provincial agencies may be an indication of their status in the NAD83 adoption exercise or perception of the magnitude of the problem.

The details of regional adoption will evolve and become more refined with time. Efficiencies of various algorithms and conversion approaches will likely improve. Users are encouraged to maintain communication with agencies involved in the conversion process in order to stay abreast of test results on accuracies and efficiencies of preferred conversion approaches.

You are invited to contact the authors directly with any comments or questions. The editor also welcomes any comments you might have.

D.C. Barnes
Editor
Councillor - Geodesy
Canadian Institute of Surveying and Mapping

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Presented at NAD83 Implementation Seminars
Sponsored by the Canadian Institute of Surveying and Mapping

Abstract

As an introduction to the topic of coordinate transformations to be discussed at CISM-sponsored NAD83 Implementation Seminars, this paper explains the fundamental differences between the NAD27 and NAD83 reference systems, and shows how much the geodetic latitude and longitude coordinates, and Universal Transverse Mercator coordinates are affected by the change in datum and by other factors. Errors in the NAD27 coordinates from these other sources are the reason why, in most cases, more than a simple datum transformation is needed for converting NAD27 data to NAD83.

Introduction

The NAD83 Project is a cooperative effort by geodetic agencies of North America to strengthen and recompute their horizontal control survey networks, and to redefine the datum to which they are referred. The project stems from discussions between the national geodetic agencies of Canada, Mexico, and the United States in 1973, recognizing the need to readjust their geodetic networks because the adopted NAD27 coordinates were not accurate enough to satisfy modern requirements.

The background and development of the NAD83 Project is given in several papers listed in the bibliography attached to this report. Much of this information was covered in the first series of CISM - sponsored seminars held in several Canadian cities during 1988 and 1989.

A milestone was reached in the Canadian NAD83 Project in June 1990 with the completion of an adjustment to integrate western and northern secondary geodetic surveys comprising 48,000 control points into the North American Datum of 1983. This, along with the July 1989 adjustment of approximately 57,000 in the eastern networks, finishes the NAD83 Secondary Integration Adjustment Project carried out by member agencies of the Canadian Control Survey Committee (CCSC).

To date, NAD83 coordinates have been computed for approximately 105,000 survey control points, but there still remains many other secondary and lower order control surveys to be integrated. In cases where the retrieval and automation of survey observations is feasible, network adjustments are definitely the preferred way to integrate these points.

There are, however, some surveys, many of them lower-order, for which coordinate recomputations from the observed data may not be feasible, because the observations cannot be retrieved and adjusted at reasonable cost. Also, many organizations manage data that is referenced geographically to NAD27 or other local or regional coordinate systems. Examples of this data are to be found in digital mapping data and geographic information systems. In these cases coordinate transformations provide a relatively simple and expedient method for bringing this data into the NAD83 reference system.

The differences between NAD27 and NAD83 are presented here to provide some background for the discussions that will follow in this Seminar on transformation methods, one of which is the National Transformation (*Junkins,1989*).

Geodetic Reference System

One reason for the differences in NAD27 and NAD83 coordinates is that they are referred to different mathematical reference systems or "datums".

Geodetic computations are carried out on the surface of an ellipsoid of revolution, which is chosen to approximate the size and shape of the Earth, or at least that part of the Earth for which a geodetic datum is being defined. In this context the size and shape of the Earth is described by another important surface in geodesy, the geoid, which is the equipotential surface of gravity which closely approximates mean sea level, and a surface that extends underneath the continents. Figure 1 illustrates the relationship between the geoid and an ellipsoid surface chosen to approximate it.

Almost all types of field survey observations are related in some way to the geoid which is too complicated a surface for geodetic computations because of its many and various undulations. However, an ellipsoid of revolution approximating the geoid is a relatively simple surface on which to carry out precise computations of geodetic distances, azimuths, and latitude and longitude.

A particular geodetic reference ellipsoid is often defined by the length of the semi-major axis, and by either the length of the semi-minor axis (the axis parallel to the Earth's axis of rotation) or by the flattening of the ellipsoid. There are many ellipsoids still in use today chosen as best fitting ellipsoids for different parts of the Earth's irregular surface.

The Clarke Ellipsoid of 1866 - Meades Ranch - NAD - NAD27

The Clarke ellipsoid of 1866 has a semi-major axis of 6378206.4 metres, and a semi-minor axis of 6356583.8 metres. It was chosen as a best fit for North America by the US Coast Survey for the New England Datum of 1879, and later retained for the U.S. Standard Datum adopted in 1901. The U.S. Standard Datum was renamed the North American Datum (NAD) when it was agreed to in 1913 by the U.S., Canada, and Mexico.

The origin, or datum point for the NAD adopted in 1913 is a marked point known as Meades Ranch, located in Kansas, USA. This was the starting point for the computation of NAD coordinates for network points in the continental triangulation network. The geodetic coordinates adopted for Meades Ranch can be traced back to the earlier New England Datum. They were computed through the triangulation that extended from the east coast at the turn of the century. Meades Ranch was chosen as the origin because it is approximately in the centre of the lower 48 states.

By the mid 1920's unacceptable errors in the NAD coordinates became apparent. In 1927, the United States began a recomputation of coordinates for their networks, retaining the Clarke 1866 ellipsoid and the NAD coordinates for the Meades Ranch origin. The recomputed coordinates were labelled NAD27, even though the recomputation took several years to finish. Figure 2 shows the extent of the triangulation in the United States included in the NAD27 adjustment.

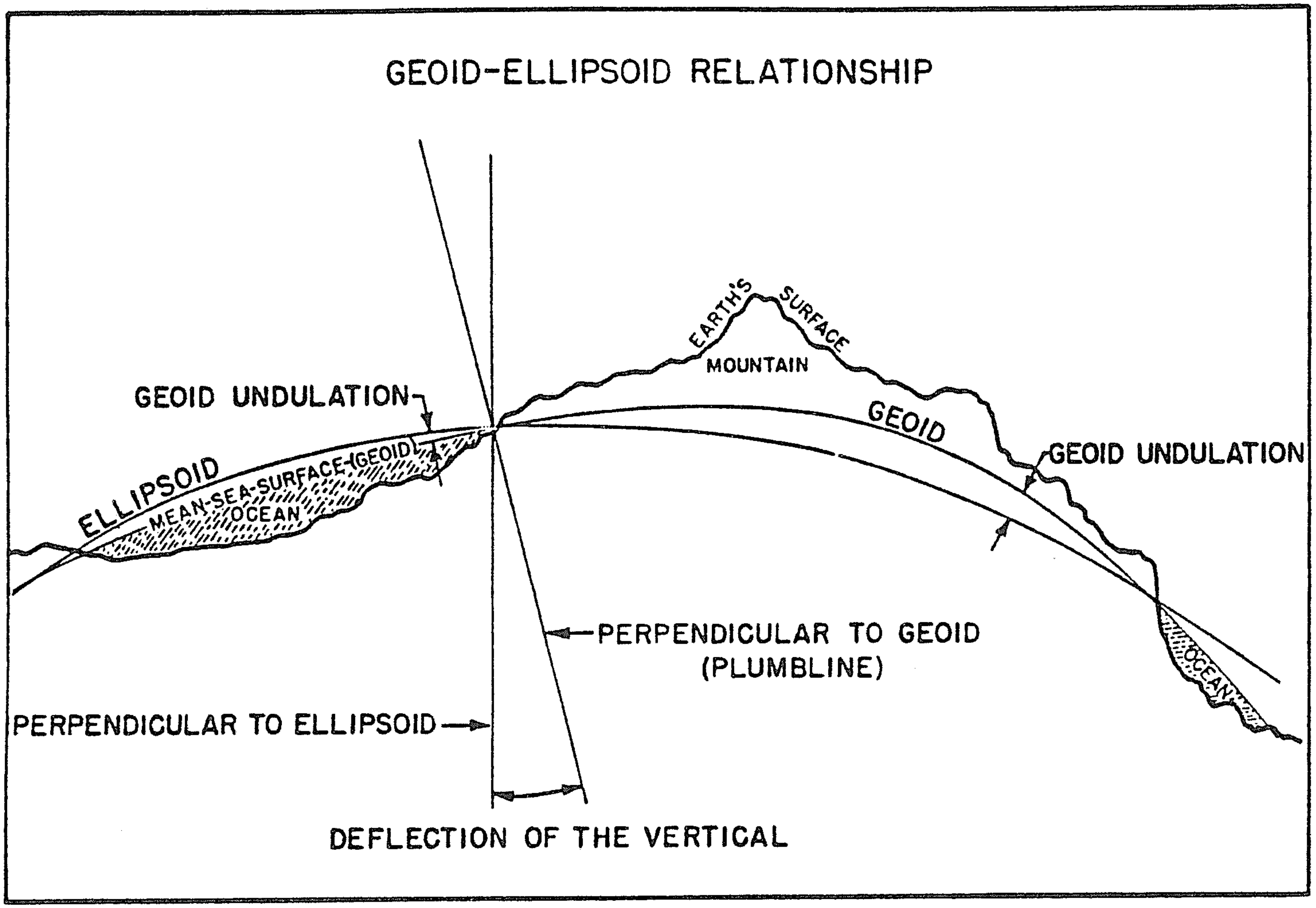

Figure 1: Geoid - Ellipsoid Relationship

Figure 1: Geoid - Ellipsoid Relationship

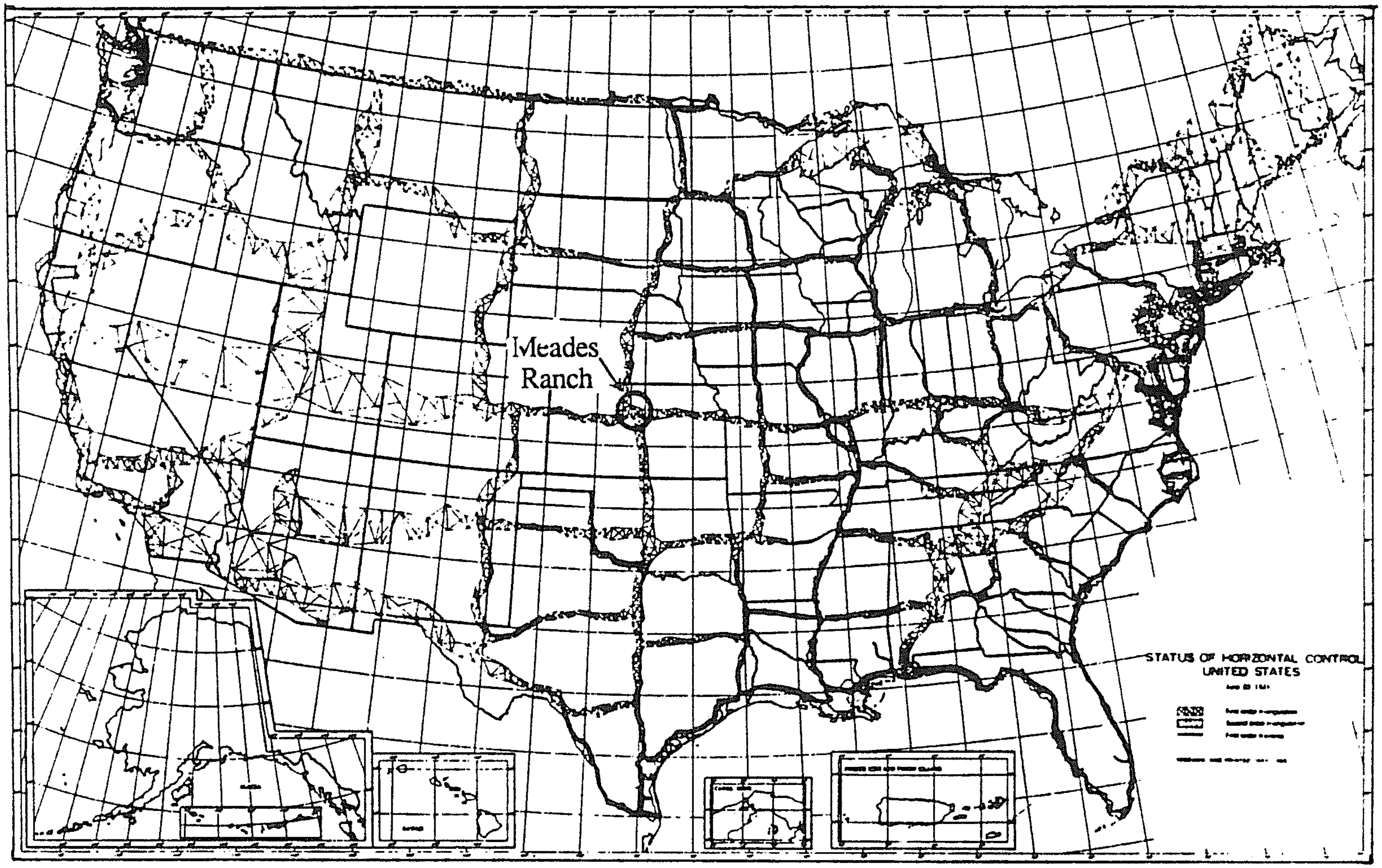

Figure 2: Extent of U.S. Networks included in the NAD 27 Adjustment

By that time, the Canadian network had been extended to southern Quebec and the maritime provinces, and included a triangulation loop in southern Saskatchewan and Alberta, and some triangulation along the southern part of the coast of British Columbia. The network also included a triangulation arc shared with the U.S. along the 49th parallel, and a triangulation connection across Lake Superior. Figure 3 shows the extent of the triangulation in Canada in 1932 when the computation of NAD27 coordinates for these networks was completed.

Distortions in the NAD27 Coordinates

As geodetic control was densified and extended to other parts of Canada over the next 50 years, random and systematic errors accumulated in the network coordinates for three main reasons. These were; geometrical weaknesses in the network, lack of an accurate geoid model, and the application of non-rigorous adjustment methods.

Geometrical Weaknesses

Until the late 1950s, taped baselines were the only source of scale for the triangulation, and although baselines were measured with accuracies estimated at between 3 and 5 parts per million, they were sparse. The establishment of baselines in the network was not dense enough to control the propagation of significant scale errors through the triangulation.

Orientation of the network was controlled through the establishment of Laplace stations at which azimuths were observed, but, like the baselines, these also were spaced too far apart to control, adequately, the propagation of azimuth error.

Because of the extent of the Canadian landmass and the need to extend control quickly to support the needs for mapping, and because it was not feasible to extend first order triangulation to some parts of Canada where the terrain is unsuitable, the general configuration of the Canadian primary framework was weak when NAD27 coordinates were computed. For example, when the NAD27 coordinates were computed for triangulation points on either side of Hudson Bay the connection between these points was circuitous and indirect depending on the triangulation arcs along the southern border of Canada to connect them. As a result, the error in the NAD27 relative positioning of points on either side of Hudson Bay is about 27 metres.

Lack of an Accurate Geoid Model

When NAD27 coordinates were computed for most of the Canadian network, there was insufficient geoid data to accurately reduce observations to the geodetic reference ellipsoid.

The Clarke 1866 ellipsoid proved to be a fairly good fit to the geoid in most of the area covered by the lower 48 States and much of Canada. However, in parts of Newfoundland, Labrador, and Baffin Island this ellipsoid is about 35 metres below the geoid. Not taking this into account has caused a systematic scale error of 5.5 parts per million in the NAD27 coordinates for networks in these areas. Smaller scale errors, amounting to 1 ppm for every 6.38 metres of geoid-ellipsoid separation that was ignored, exist in other parts of the NAD27 network and these are systematic, affecting large areas of the network.

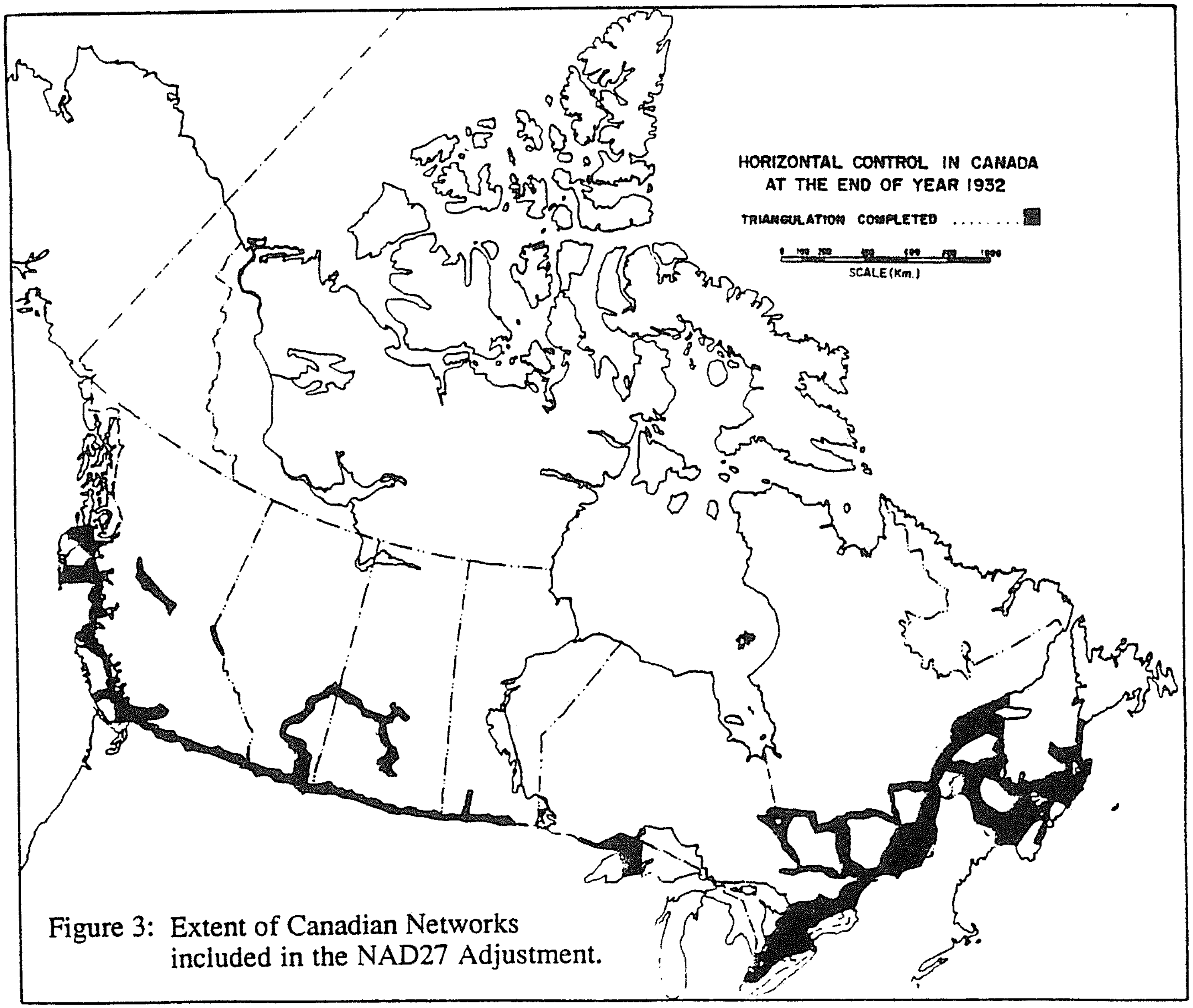

Figure 3: Extent of Canadian Networks included in the NAD27 Adjustment.

Non-Rigorous Adjustment Methods

Another source of error in the NAD27 coordinates is the application of network adjustment methods whereby the NAD27 coordinates computed in previously established networks were held fixed in least squares adjustments of a new net, measured in one or two field seasons as an extension to the existing geodetic control. This practice was a necessary expedient in both Canada and the U.S. before electronic computers made it feasible to carry out the simultaneous adjustments of thousands of stations that are done routinely today.

In 1972, Geodetic Survey initiated a project to evaluate the accuracy of networks in the Canadian horizontal framework, and to determine where EDM distances and new Laplace azimuths should be measured to strengthen the framework. Test adjustments of the strengthened networks confirmed the existence of large distortions in the NAD27 coordinates.

Readjustments were carried out on several regional networks to reduce the NAD27 coordinate distortions within the regions. Some of the major readjustments are listed below.

Prince Edward Island	1968
Newfoundland	1971
Nova Scotia	1972
Southern Ontario	1974
Northwestern Ontario	1974
Quebec (readjusted by MER in the CGQ 77 system)	1978
Maritime Provinces (readjusted by LRIS on the geocentric ATS77 datum)	1979

These readjustments improved the relative positioning accuracy of the coordinates within the regions but often resulted in some major discordances between regions, and incompatabilities with old NAD27 coordinates for networks not included in the readjustments. The problems left unresolved by regional readjustments confirmed the need for a comprehensive adjustment of all Canadian networks.

Large regional NAD27 distortions exist outside the areas of the readjustments listed above. Figure 4 shows, in metres, some of the larger distortions in the relative positioning of NAD27 coordinates for stations in the framework. The distortions shown in Figure 4 all exceed 100 parts per million of the distances between stations. Significant distortions also exist in the NAD27 coordinates for many local networks.

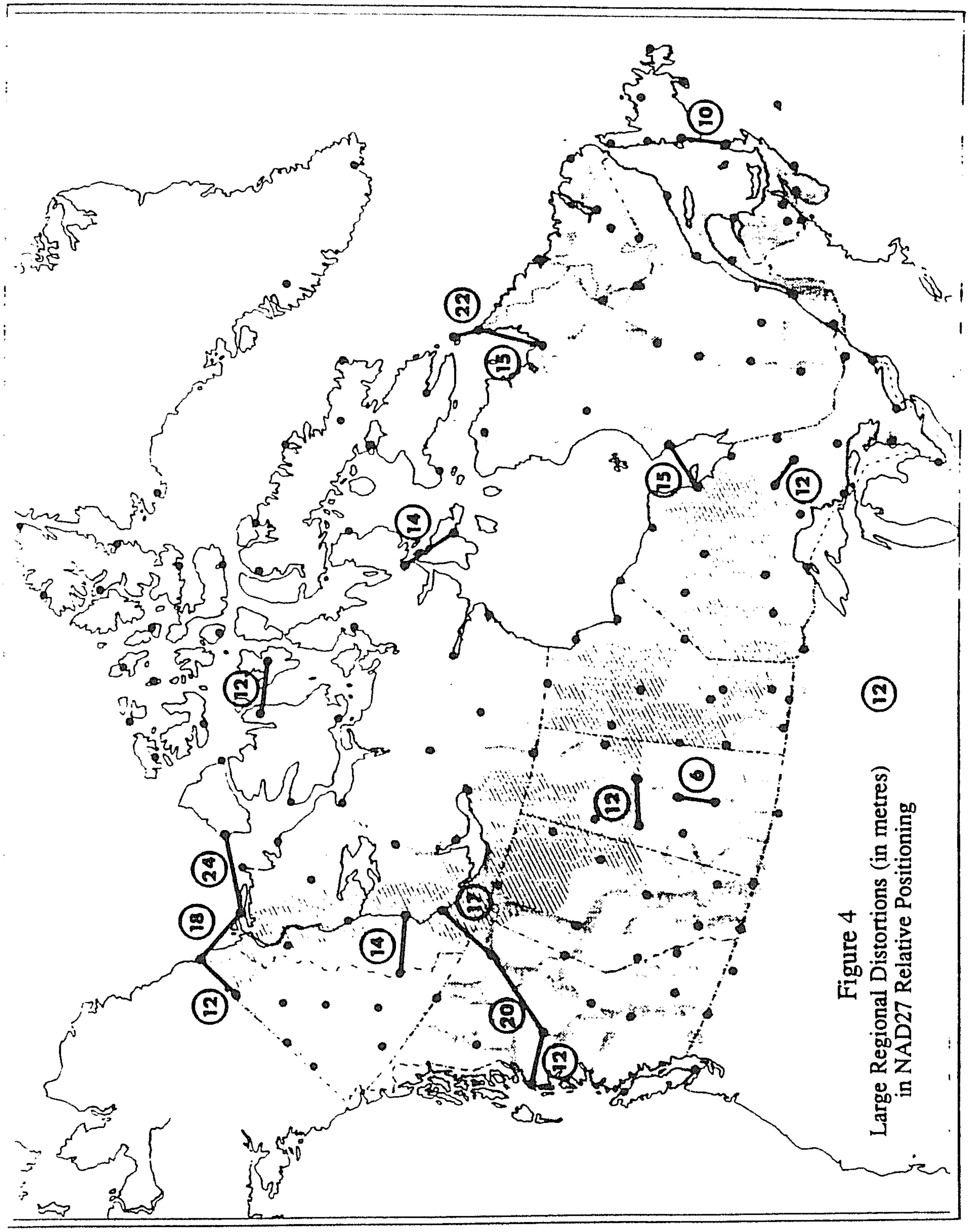

Figure 4
Large Regional Distortions (in metres)
in NAD27 Relative Positioning

NAD83 - GRS80 - WGS84

Development of the NAD83 reference system was much different than the evolution of the NAD27 coordinate system and was very much influenced by new satellite positioning technology and by accurate modelling of the geoid carried out in the late 1970s. NAD83 has no origin or datum point on the surface of the Earth and no attempt was made to define or select a reference ellipsoid that would be considered a particularly good fit to the geoid in North America.

NAD 83 Reference Ellipsoid

The ellipsoid adopted for NAD83 is the Geodetic Reference System 1980 (GRS80) adopted by the International Association of Geodesy to represent the size, shape and gravity field of the whole world *(Moritz, 1980)*. The defined semi-major axis is 6378137. metres (69.4 metres less than for the Clarke 1866 ellipsoid) and the derived semi-minor axis is 6356752.3141 metres (168.5 metres more than for the Clarke 1866 ellipsoid).

The GRS80 ellipsoid does not approximate the geoid in North America any more accurately than the Clarke 1866 ellipsoid does, but recent modelling of the geoid has provided the information to accurately reduce or relate our survey observations to the reference ellipsoid. The geoid model used in NAD83 network computations was developed by Dr. R. Rapp at Ohio State University in 1978 and is often labelled RAPP78. More accurate models are being developed and will be used for future NAD83 computations.

An important feature of the GRS80 ellipsoid is that it is defined as geocentric, that is, the centre of the ellipsoid coincides with the centre of mass of the Earth, a point that can be located relative to the surface of the Earth through the tracking of satellite orbits.

The Clarke 1866 Ellipsoid as it applies to NAD27 is not geocentric and the estimates of where the centre of the Clarke 1866 Ellipsoid is in relation to the Earth's centre of mass are subjective, depending on which set of points and coordinates on the surface of the Earth are used to estimate it.

World Geodetic Reference System 1984

As mentioned above, NAD83 has no origin on the surface of the Earth. In the 1970's approximately 500 points in the North American geodetic network were positioned in the reference frame of the U.S. Navy Navigation Satellite System using satellite Doppler techniques (About 170 of these stations are in the Canadian network). The positioning of these points made it possible to relate the geodetic network to the earth-centred terrestrial reference system designated NWL-9D. Later, in 1986, parameters were adopted to transform from NWL-9D to the World Geodetic System 1984. *(DMA, 1987)*. WGS84, shown in Figure 5, is an orthogonal X,Y,Z coordinate system with origin defined as geocentric. The NAD83 reference system is consistent with the definition of WGS84 which is the terrestrial system used in orbit computation of satellites in the Global Positioning System.

The WGS 84 Coordinate System
- Definition -*

Origin = Earth's center of mass.

Z-Axis = Parallel to the direction of the Conventional Terrestrial Pole (CTP) for polar motion, as defined by the Bureau International de L'Heure (BIH) on the basis of the coordinates adopted for the BIH stations.

X-Axis = Intersection of the WGS 84 Reference Meridian Plane and the plane of the CTP's Equator, the Reference Meridian being parallel to the Zero Meridian defined by the BIH on the basis of the coordinates adopted for the BIH stations.

Y-Axis = Completes a right-handed, earth centered, earth fixed (ECEF) orthogonal coordinate system, measured in the plane of the CTP Equator, 90° East of the X-Axis.

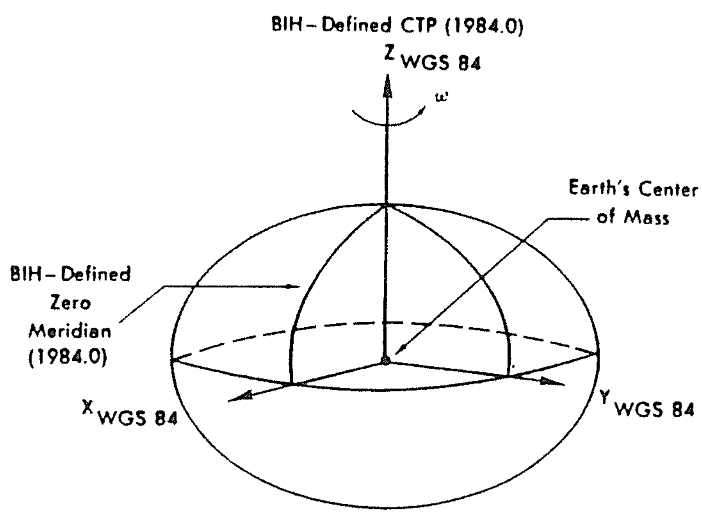

Figure 5: World Geodetic System 1984.

* Analogous to the BIH Defined Conventional Terrestrial System (CTS), or BTS, 1984.0.

NAD27-NAD83 Coordinate Differences

To simplify discussion on the NAD27-NAD83 coordinate differences we attribute them to only two factors discussed above, to the differences in the datums and to the errors in the NAD27 coordinates. There are, of course, errors in the NAD83 coordinates but these are much smaller, less systematic, and insignificant compared to the distortions in the NAD27 values.

Figure 6 is a vector diagram showing the NAD27 to NAD83 coordinate differences at locations throughout Canada. The vectors with solid lines show the shifts in geodetic latitude and longitude coordinates. The dotted vectors show the shift in the Universal Transverse Mercator coordinates corresponding to these geodetic coordinates.

Shifts in the geodetic coordinates range, in general, from about 120 metres westerly on the west coast to about 70 metres easterly in Newfoundland, and approximately 100 metres northerly in the high Arctic islands. For the corresponding Universal Transverse Mercator (UTM) coordinates there is a fairly consistent northward shift ranging from about 200 to 250 metres. The UTM vectors differ from the geodetic vectors because of the differences in how geodetic and UTM coordinate systems are defined in relation to the reference ellipsoid.

Summary

NAD83 coordinates have been computed for 105,000 stations in the Canadian primary and secondary geodetic control network. Many other surveys comprising an estimated 100,000 points still remain to be integrated.

Where feasible, these surveys should be integrated through network adjustments. Adjusted coordinates will be more accurate than transformed coordinates, and reliable estimates can be computed for their relative accuracy, based on the standard deviations assigned to the observations included in network adjustments. For these reasons, network adjustments are recommended over coordinate transformations whenever it is practical to retrieve the survey observations.

There is a need, however, for expedient methods for converting some surveys and large amounts of other NAD27-based data to the NAD83 reference system. If datum differences were the only things that influenced the NAD27-NAD83 coordinate differences, a well known set of datum transformation formulae could be used, but large errors in the relative positioning of NAD27 coordinates preclude such a simple solution.

Transformation algorithms must deal with the NAD27 coordinate distortions. The software based on these algorithms should also be easy to use and capable of transforming large amounts of data efficiently. Another prime consideration should be the adoption of one particular method as a means to promoting consistency and uniformity of transformed data throughout the country.

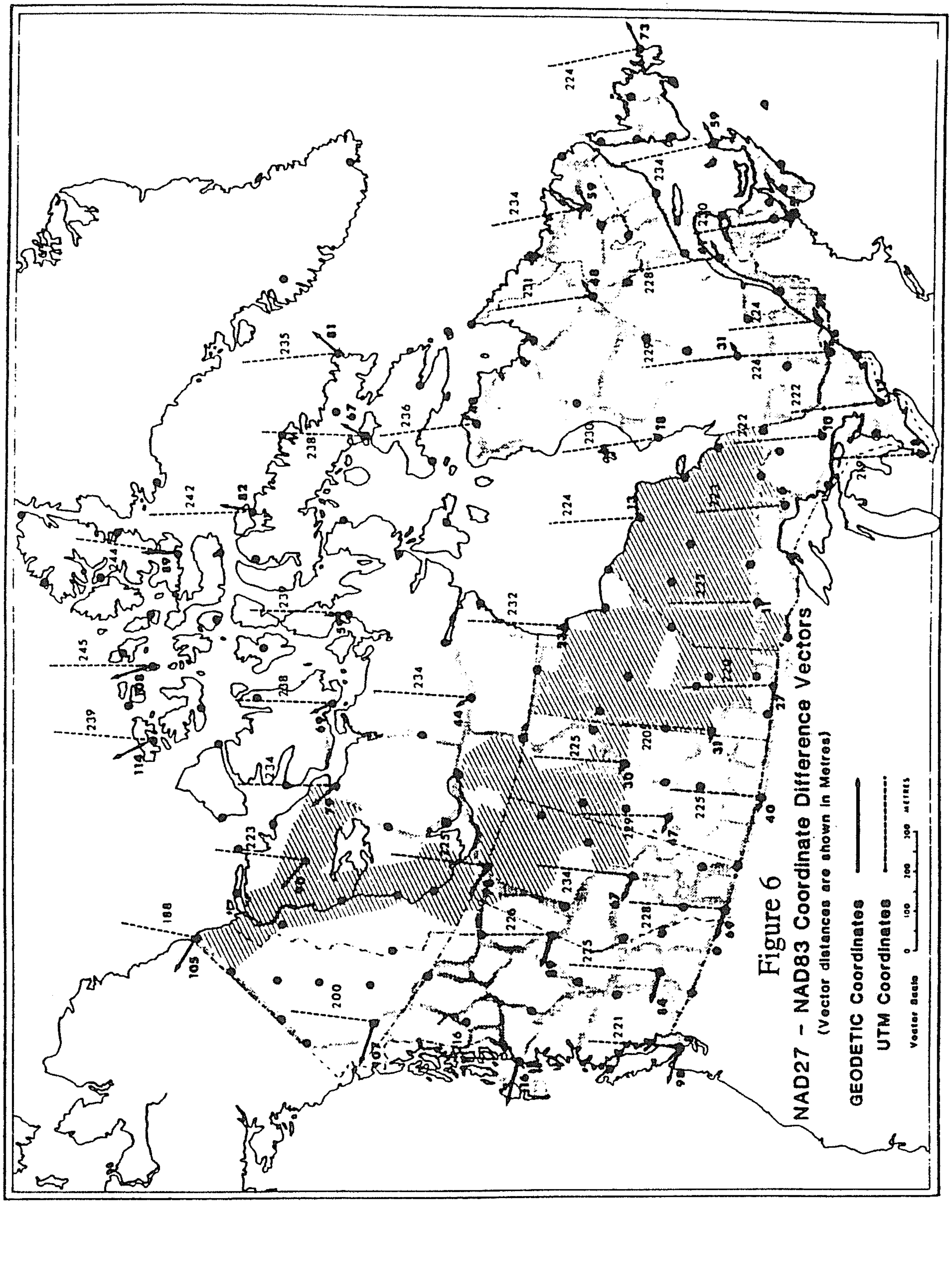

Figure 6
NAD27 – NAD83 Coordinate Difference Vectors
(Vector distances are shown in Metres)

GEODETIC Coordinates
UTM Coordinates
Vector Scale 0 100 200 300 METRES

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The NATIONAL TRANSFORMATION

for converting between NAD27 and NAD83 in Canada

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Abstract

The National Transformation to convert coordinate data between the NAD27 and NAD83 reference systems in Canada is described in this paper. Background concerning many complex processes and the data used to model the differences between the two systems is provided, with some analysis of the accuracy. The resulting model is implemented by means of a simple, automated software package to enable most users to handle their own data conversion processing. Suitability of the National Transformation for various applications is also discussed.

Introduction

In May 1990, NAD83 (North American Datum of 1983) was proclaimed as the official geodetic reference system for all products of the federal Department of Energy, Mines and Resources. This marks the availability of coordinates in this new system for all major control survey networks in Canada, replacing the NAD27 (North American Datum of 1927) system which has been in use for the past 60 years.

To assist users in the transition to this new system, the Geodetic Survey Division, in cooperation with other federal and provincial government survey agencies, is providing users with a uniform technique to predict the coordinate differences at points not coincident with established control survey stations. This technique will assist not only conventional users, such as mappers and thematic GIS data compilers, but also users concerned with offshore boundaries, such as the oil exploration industry.

This paper describes the concepts, software and data used to model the differences, and the simplified approach to implementing the model for distribution to users. The datum transformation is described first, followed by the much more complex task of modelling the distortion of the NAD27 network. An overview of the software developed specifically for this project is given, followed by a description of the data used and the results of some of the analyses. This information is provided mainly for background material.

The focus of the reader should be directed toward the latter part of the paper in which the implementation of the transformation by means of a grid shift table format is described. An accompanying document, "Program Descriptions and Users' Guide", gives more detail about the operation of this automated implementation.

The rationale for many of the decisions made during development is also presented to assist in understanding the form of the final product. Throughout the paper, the descriptions are interspersed with questions that have frequently been asked by prospective users during the development stages. This dialogue of question and response should deal with most concerns such as the decisions that were made, the suitability for a particular application, and where to obtain additional authoritative information.

Change in Reference Datum

• *What is the difference between the NAD27 and the NAD83 datums?*

The largest component of the change between NAD27 and NAD83 is due to the adoption of a new reference datum, which is geocentric and globally applicable. The reference ellipsoid for NAD83 is the GRS80 ellipsoid, the same as for the WGS84 reference datum used for the Global Positioning System (GPS). In fact, the NAD83 and WGS84 systems are essentially identical for all practical uses of geodetic control networks (Pinch, 1990; and DMA , 1987).

Because these two datums (NAD27 and NAD83) are specified differently (Pinch, 1990), a pragmatic approach was employed to determine the relationship between them based on the realization of each datum through the adjusted coordinates of selected control survey points. The only exact differences known *a priori* are the ellipsoid parameters for converting the XYZ spatial coordinates (of the Conventional Terrestrial System) to latitude and longitude.

To model this systematic change, which includes a shift in the origin at the centre of the earth of about 250 metres, a standard geodetic datum transformation (3-dimensional similarity transformation of 7 parameters) was tested. The determination of the parameters is based on comparisons of coordinate values for the precise Doppler network in Canada (~170 points), which was established coincident with existing primary control stations. This approach is not intended to produce a definitive relationship between the two datums, but rather, it is intended strictly for use with the National Transformation. It serves as a means of accounting for the large systematic datum shift and change of reference ellipsoid prior to modelling the distortions.

The testing cycle of programs - DATUM (determination of parameters), SCTRANS (application of parameters) and ESTPM (distortion modelling) - indicated that a simple set of 3 shifts worked as well as including the 3 rotation and one scale which make up the total complement of 7 parameters.

There are some rather obvious explanations for this - the most obvious of which is that there remain regional variations of ± 20 metres due to distortions in the NAD27 system.

Any improvement introduced by adding the extra four datum parameters is much smaller in magnitude than this 20 metre variation.

A second explanation is that the data used is limited to Canadian territory, which is concentrated on a small part of the globe, straddling the negative Y-axis. Thus, the Z-rotation parameter is very highly correlated to the X-shift, and the scale parameter is similarly correlated to the Y- and Z-shifts.

For these reasons, the added complexity was not considered justified in the context of the accuracy attainable, and the distortion model required to refine the transformation within this non-systematic ± 20 metres could adequately handle either approach.

• *Why can't I just apply the datum shift to my coordinates to get them into NAD83?*

The relationship between NAD27 and NAD83 is not explicitly known, due to the differences in the method of defining the two datums (Pinch, 1990). This, coupled with the variations due to distortion, led to the approximate method described above. To use it without the companion distortion model would give results that are not representative of the NAD27 system. This is because the distortions have regional trends that are seemingly random from one region to another, but are systematic within regions (Pinch, 1990; Boal and Henderson, 1988). Thus, significant advantage can be taken of the locally systematic nature of distortion.

Distortion Modelling

To model the distortion between the two systems, the original ESTPM (Estimation of Secondary Terrestrial Positions for Mapping) was selected as an appropriate tool. It had been developed specifically for this purpose (Blais, 1979), and was favoured for the continuous surface of its data model. Also, it had been in production use for more than 10 years for the integration into NAD27 of satellite survey networks. These networks covered wide areas, which precluded the use of constrained adjustment techniques into a set of values for the control survey network which contained significant local distortion.

Production use had been on an area-by-area basis, with each area being bounded by a major loop of the primary framework. No transformations were performed in the immediate neighbourhood of the high-density control, because satellite networks were generally established to densify large areas at about 80 km spacing.

• *Is the version of ESTPM used in the National Transformation the same as the one on the GHOST library that I have been using for years?*

When some detailed analyses were made of the behaviour of the ESTPM data model as applied to the national system of control networks, it was found that some fundamental assumptions of the original implementation did not apply. The two key items that indicated the need to modify ESTPM were:

1) the unusual distribution of residuals to the polynomial model when the residual interpolation feature was disabled, and

2) the unexpected localization of distortion in the intervals between control points when the residual interpolation feature was enabled.

The first problem was addressed by making changes to account for the extreme range of latitude - and thus the interval between meridians of longitude - required to cover all of Canadian territory. The units of displacement were converted from seconds to metres, and the computation plane was converted from a rectangular grid of latitude and longitude to a projection accounting for the convergence of meridians of longitude.

The second problem was a result of the large variation in the density of control survey stations throughout the country. The residual interpolation model used a weighting function (Blais, 1979) that assumed a constant value (**k**) against which the distances (**d**) to surrounding points were compared in the form

$$e^{-(d/k)^2}.$$

To briefly summarize the characteristics of this function, a point very near to a control point (i.e. $d \to 0$) would have a weight approaching one (the maximum possible value), while a point very far away (i.e. $d \to \infty$) would have a weight approaching zero. A point at a distance $d = k$ would receive a weight of ~0.4 .

It can clearly be seen that a fixed value for **k** would produce weights that are much too large in areas of high density, with the result that points that are many legs of surveying away - and thus with many opportunities to be under the influence of different distortion-producing constraints - would exert too great an influence on the residual interpolation process. Conversely, it can be shown that too small a value for **k** in areas of low density tends to localize the legitimate distortion that exists between adjacent control points to a small portion of the total interval between the points, thus producing a step-like function rather than a smooth transition.

To handle this much more complex second problem, a variable weighting approach was adopted. A value for **k** was determined for each individual control survey point, based on the typical distance to its nearest neighbour in the network. This was implemented separately in a pre-processing program named NEARPT.

Other features added to ESTPM2 include:

- more detailed reporting of data matching anomalies on input,

- sorting of data by y-coordinate to reduce the amount of computation required during residual interpolation (this change alone reduced the computing time of a single run by a factor of 25 !),

- a separate report of inconsistent residuals to aid the detection of improperly identified and/or integrated points, and

- handling of 9-character station identifiers as used in GHOST.

In developing the National Transformation, the decision was made to treat the datum transformation separately using program SCTRANS, and also to treat the plotting analysis separately, using program PLOTMB. These two aspects of the original ESTPM program were removed from ESTPM2, to alleviate the overhead of maintaining duplicate tasks in separate implementations.

Also developed as a separate application was the statistical analysis of the residuals, using program ESTAT. This utility routine uses the GHOST chi-square goodness-of-fit analysis and histogram plotting, and divides the data into a number of separate files for plotting.

• So, now can I just get this new version of ESTPM and use it with the two sets of values I have for the handful of control stations in my area, and transform my data to NAD83?

What must be realized is that the ESTPM software is only one of the components that determine the differences in coordinates at any given point, and does *not* produce unique results. The other main components are the common points selected from each system, the degree of the polynomial specified and the various residual interpolation options used, each of which is a very subjective process. To change any one would produce results that are noticeably different from the published National Transformation, thus destroying the need for users to have a consistent and reliable standard.

Data for Distortion Modelling

• If Geodetic Survey has computed this transformation, how much good will it be to me in my area where there is no federal control nearby, and I rely on regional control networks?

In addition to the more than 7,000 stations of the primary control network established by the Geodetic Survey of Canada, almost 100,000 secondary stations were included in the simultaneous integration adjustment to realize NAD83 in Canada. The survey observations for these stations were assembled in a cooperative effort involving both federal and provincial surveying agencies, through the Canadian Control Survey Committee (Pinch, 1990). Through similar cooperation of this same committee, as many of these stations as possible were used as common data points to define the distortion model between NAD27 and NAD83.

Provincial and federal survey agencies provided their currently published NAD27 values for stations within their jurisdiction to provide differences with the NAD83 values already on hand from the adjustment. At the primary control network stations, provincial values were compared to those published by Geodetic Survey to ensure that the NAD27 provided a basically consistent system amongst agencies. This exercise was a very positive one, confirming that the inter-agency communication (often assumed without question) was indeed working.

There were notable exceptions to the availability of NAD27 and NAD83 values for some provincial networks, however. The three Maritime provinces readjusted their networks on a geocentric system (ATS77) more than 10 years ago. Because of their continuing commitment to ATS77, they did not include the data for their 50,000 secondary stations in the NAD83 adjustment. Even though Quebec did include all of their secondary data in the NAD83 adjustment, they had recomputed their entire network on the NAD27 datum in the CGQ77 adjustment, which rendered it incompatible with the NAD27 system in use elsewhere in the country. Thus, in these four provinces, the distortion has been modelled based on the federal values for the primary control network only. These are the only major exceptions to the inclusion of secondary networks.

Apart from these exceptions, every effort was made to use all control survey points that were included in the NAD83 simultaneous secondary integration adjustment completed in June, 1990. Only stations considered to have NAD27 values that were grossly inconsistent with the surrounding network were removed, to prevent unwarranted bias in the distortion model. The general criteria followed was; if the coordinates were doubtful for use as reliable survey control, they would be removed and investigated by the responsible agency at a later date.

Some of the more typical situations that arose for questioning NAD27 data included:

- approximate coordinates that may have been scaled, or have preliminary or unintegrated values, which are generally indicated by the lack of significant digits after the decimal in the seconds field for latitude and longitude;

- stations for which reliable NAD27 values were not available from the controlling agency, because a current integrated adjustment had not been performed;

- inconsistent values for stations separated by only a few metres, often a result of networks overlaying each other (from different time periods), which were not integrated or maintained up-to-date.

• *If data for Quebec and the Maritimes were not included in the National Transformation, how will I transform my data in these regions?*

For the two cases of special provincial reference systems (ATS77 and CGQ77) as mentioned above, the provincial agencies will be developing separate transformations for use in these areas. Users whose data was compiled based on federal NAD27 control values, or on National Topographical System mapsheets, can use the National Transformation .

As with all other jurisdictions, users should contact the responsible agencies to obtain information about the version that is officially recognized and its relationship to the National Transformation.

• *How does this transformation work in the offshore areas where there are no control survey points established?*

To extend the definition of the transformation for users with interests in the offshore regions of Canadian territory, a few artificial control points have been added to the data set of actual control survey stations. Offshore control points were arbitrarily designated based on the nearest primary Doppler stations along the coastlines, and propagated as rays of 500 and 1000 km. The shifts at these points were assigned the same values as the shore points from which they were propagated. This simulates the relative positioning using satellite receivers that has been used extensively in offshore surveys.

• *Can I use this transformation with all of my NAD27 data?*

Although the National Transformation is universally applicable, we must remember that the NAD27 label has been generally applied to both the datum and to the coordinates of control survey points that are the realization of the datum. Because it is possible to have more than one set of coordinates referred to the same datum as a result of computations from different epochs (Junkins, 1988; Pinch 1990), the user must first determine how his NAD27 values relate to the current "official" values used in defining this transformation. Any significant discrepancy should be compensated for externally before using the National Transformation.

Accuracy of the Transformation

• *How accurately does this transformation produce coordinates in the new system?*

The purpose of this transformation is to predict what would happen if data which had been compiled in one system were to be recompiled into the other. The assumption is made that any such data would be directly connected to, or in some way derived from the primary and secondary control network stations in the immediate neighbourhood. It is also assumed that such a recompilation would uniformly distribute the distortion over the intervals between control stations.

Because knowledge of the differences between the two systems for these inter-station intervals is not generally available, a good estimate of the accuracy is not easily made. What are available are the residuals from ESTPM at the common points that were used to define the distortion model. These residuals exist since the model is not one that passes exactly through all the data points - a typical problem when working with an irregular distribution of points.

A summary by province of the RMS values of the residuals is given in Table 1. As shown in Table 2, the model predicts to within 10 cm of the actual difference for 74% of the cases, and within half a metre for 93% of the cases. Statistics and plots will be prepared to indicate similar analyses on an area by area basis across the country. These will indicate to users the areas in which they might have slightly less confidence in the use of the transformation.

As some of the provincial agencies proceed to integrate their lower-order networks by adjustment of survey observations, more information will become available indicating how well their results compare to the predicted values. In making such comparisons, an important factor that must be kept in mind is the accuracy and reliability of these lower-order networks. Any discrepancy with predicted values is a function of inaccuracies in both the predicted and computed coordinates.

This transformation should satisfy the requirements of most users whose survey data is of lower accuracy than the control networks, and for digital mapping applications at most scales. Some exceptions are dealt with in the following discussion. It will also serve well those whose data is one or more steps removed from being directly tied to the control survey network, such as geographical information system data compiled by digitizing from a map base or by remote sensing, for example.

• *But I have a very dense network in just a small area with accuracy much better than 10 centimetres!*

For municipal control surveys and other dense, high-accuracy networks, some other factors need to be considered. First, was the basic municipal/local control network included in the readjustment project and the transformation data set? If so, then a reasonable model will be provided over the area of concern, but a denser grid than the nominal 5 minutes might be required. If not, then further modelling may take place after local control surveys have been integrated. In either case, consult the responsible provincial agency for official status and plans in the area of interest.

Secondly, is there significant distortion over the area, resulting in intolerable changes to dimensions (relative positions of points)? In this case, the next question that needs to be asked is - how was the local network connected to the control network? In many cases, there may be connections to only one or two stations, indicating that a local datum change should be considered as an alternative option. If the local network is more solidly connected, then perhaps its influence is required by simultaneous readjustment of the these survey observations together with the control network. If the distortion is valid, then the user should question the accuracy of his NAD27 dimensions and why he wishes to preserve them.

• *Why are there large residuals in some areas, and if confidence is reduced, what should I do about it?*

The mathematical models used in ESTPM assume that neighbouring points are directly connected by survey observations that are free of blunders, the typical status of integrated networks. Discontinuities in the control network pose a particular problem. The smooth surface of the model may not handle this situation adequately. Users should be alerted to these areas by the indications on the plots of large residuals distributed with the transformation. If the magnitude of these residuals is intolerable for an application, it is up to the user to determine to which of the neighbouring control values their data is related, and compute local shifts. This is virtually the same situation as data compiled on control values from earlier epochs.

In all cases, if retention of relative accuracy is the prime concern, then recompilation of the survey observations into the revised survey control network is the preferred solution. Transformation is an approximate method only.

The Grid Implementation

• *My business doesn't have any powerful computers like the VAX to run ESTPM2. How am I going to be able to do this with only a desktop or personal computer? Will Geodetic Survey Transform my data for me?*

To simplify the application of the National Transformation model to users' coordinate data, the commonly used approach of generalizing the modelled differences by a regular grid was adopted. This is similar to the implementation of the NADCON system developed by the United States National Geodetic Survey for the same purpose within U.S. jurisdiction (USNGS, 1989).

The objective of this approach is to make the model available in an automated form that will run on the smallest of common personal computers, without the requirement for large amounts of memory or high speed processing demanded by a routine such as ESTPM2. As stated in the SMRSS policy document on NAD83 (Canada Centre for Surveying, 1990), Geodetic Survey will not operate as a service bureau to transform users' data. Instead, this simplified implementation is designed to make users self-sufficient.

The accompanying set of data flow diagrams illustrate the development and application of the grid representation. Diagram 1 traces the computation of datum and distortion model parameters from the initial sets of coordinates for the control survey network in both systems. Diagram 2 shows the empirical creation of the grid, its conversion to the new system, and the creation of the binary grid shift file. Diagram 3 presents the components that utilize the grid shift file to actually apply the transformation to user-supplied coordinates.

• *The transformation will be based on the Grid - this is great! I'll be able to get the shifts to my UTM coordinates and go directly to NAD83.*

It must be emphasized that all references to the term "grid" in the context of the National Transformation are meant to imply points at regular intervals (of arc) of latitude and longitude. There has not been a corresponding set of tables made up for plane coordinates (often referred to as the reference "grid") for a few reasons:

- there are several projections in common use in Canada (eg. Transverse Mercator, Stereographic, Lambert, Polyconic, etc.), and variations within each of these, making it difficult to choose any one to be definitive, and prohibitive to produce versions for all;

- if the most common plane projection (UTM) were chosen, should the grid points be selected at regular whole intervals of plane coordinates, or should they correspond to the projected values of the ellipsoidal grid? ;

- if the ellipsoidal grid were projected into corresponding plane values, the table look-up algorithm would fail since the intervals would no longer be regular. Also, the bilinear interpolation would not provide identical results on the plane as on the ellipsoid;

- if a regular grid were used in the projection plane, inconsistencies in resulting values would occur in the neighbourhood of zone boundaries, since interpolation at the same point using tables for adjacent zones would produce slightly different results.

Keeping in mind that the main objective of the grid implementation is to simplify the process and to provide a unique result for all users, the choice to define the grid in terms of ellipsoidal coordinates seems the most straightforward.

• *Then how will I handle my data, which is all in UTM values?*

To accommodate most users of plane coordinates, the Transverse Mercator projection has been built into the grid interpolation software. Values may be optionally supplied in the form of plane coordinates, which are internally converted to corresponding ellipsoidal coordinates, and the shift computed in the default ellipsoidal system. On output, the transformed values are converted back to plane coordinates - either in their default zone (which may have changed), or in their original zone, at the option of the user. Variations such as zone width, central meridian, and false eastings and northings are user selectable options.

• *Will I be able to get the transformation in both ESTPM2 and the Grid formats?*

Again for the sake of uniqueness, the grid implementation is the only form in which the National Transformation will be published. The ESTPM2 solution for a point would be slightly different than the bilinear interpolation result. Since these differences are well within the accuracy of the distortion model in most areas, no hardship will be imposed on users. Some provincial agencies have indicated their desire to densify the grid using intervals smaller than the nominal 5 minutes of arc, to better handle areas of very dense control with significant local distortion. This will be done as a subsequent exercise, once the areas requiring such treatment have been identified.

Grid Software and Data Files

The grid interpolation software for the National Transformation is actually a suite of programs, focused around the files of grid shift data. It is independent of the software and modelling techniques used to transform between two systems, and can be used with any pair of systems. All that is required are one file of coordinates in a regular grid, and its counterpart that has undergone some transformation process. It works in both directions between the two systems.

The following are brief descriptions of the programs. More detail can be found in the accompanying Software Documentation and User's Guide (Farley & Junkins, 1990).

Program **INTGRID** accepts coordinates for a point supplied by the user, performs the lookup of grid points for the appropriate quad, and interpolates within the quad to produce the shift at the point. This shift is applied to the original coordinates to produce transformed values.

Program **INTTAB** produces a tabulated printout or can be used to create a subset of the grid shift file for a selected area. The tabulation produces a two-dimensional representation of the selected area, enabling the user to more easily visualize the differences between the two reference systems. The printout is also useful for manual interpolation if only a few points require transformation. The subset provides a more manageable file for users not concerned with the entire Canadian territory.

At the heart of these two processes is the **Grid Shift File**. It is a system-specific, unformatted direct-access file with one grid point per record. As such, it is virtually unreadable by the user, and thus not easily altered by mistake. The header records included at the beginning of the file provide such information as the limits of the grid, the sizes of the grid intervals, the units of the shifts, and the names and ellipsoid parameters of the "to" and "from" reference systems. The data records each contain a pair of shifts - one for latitude and one for longitude. The coordinates of the grid point are not included - the appropriate record number in the file can be calculated from the header data.

The Grid Shift File is created by program **DIRFIL**, which reads two separate files of GHOST format coordinate records and takes the difference between the values to produce the shifts. After obtaining the necessary information through an interactive dialogue with the user, the program forms the header records, and follows them with the grid shift records. The files of grid coordinates may be windowed by the limits set by the user. Data is checked to ensure the integrity of the grid files being processed. This exercise needs to be performed only once to establish the Grid Shift File for an area, unless a user wishes to migrate the file to a different computer platform.

The utility program **READDA** allows the user to obtain a formatted printout of the Grid Shift File, with the option of listing either the complete file or only the header information. This can be useful for verifying the creation of a new file, or checking the contents of an existing file. It also is capable of converting the grid shift file between the standard binary format and an ASCII equivalent, which is useful for porting between computer platforms.

Program **GRIDPT** generates a regular grid of ellipsoidal coordinates to initiate the implementation of the grid shift approach. While it is included in the suite of programs, it is of little use to most users, since they will not have ready access to the ESTPM2 distortion model to generate the corresponding file of transformed grid values. Note also that there is no point in densifying the grid using the bilinear interpolation, since the results would be identical.

Program **GSRUG** converts between ellipsoidal and Transverse Mercator forms of the same coordinate. It is taken from the GHOST library, and is included for converting externally rather than within program INTGRID. Users who wish to convert from one standard of plane projection to another (eg. from 3°MTM to 6°UTM) while making the move to NAD83 may find this useful.

• *What computer will this software require? Will I have to buy a PC, or can I run it on my SUN Workstation?*

All of this software has been written in FORTRAN 77 code, keeping as close to the ANSI standard as possible. It has been implemented on three platforms - IBM/PC compatibles, Apple Macintosh, and Digital VAX/VMS. The same source code is used on all three with minor exceptions. Where these exceptions do occur, statements for all three systems are embedded in the source code with identifying comments. The inappropriate lines are commented out before compilation. No significant amounts of memory are required to load or execute any of the programs. The result is a package that is easily migrated to any platform with a FORTRAN compiler.

• *I don't have a large hard disk for my PC. How am I going to handle the data files for all those grid points?*

At a grid interval of 5 minutes, there are 144 points per 1°x1° area. With the vast area of Canadian territory, plus the offshore regions for which this transformation is required, a single grid file is not practical for many applications. It could take as much as 10 megabytes of disk space. To reduce the storage required on-line for users of small systems, the Grid Shift File can be windowed into smaller areas and kept to a size that fits on standard floppy diskettes.

Users wishing to create their own Grid Shift files from the two files of GHOST format coordinate records will temporarily need significant hard disk space to hold these two files, since each is about five times the size of the resulting direct access file. The windowing is easily accomplished with program DIRFIL, and only needs to be done once for each windowed area, as mentioned above.

• *If the grid files are partitioned into areas, are they discrete or will they overlap? Will I get the same results from different partitions in the overlap area, or if I use a "windowed" subset?*

All grid files can be considered a subset of a single, large master file. Since only the four points at the corners of a quad are used to determine the shift at any point within the quad, any subset containing these four points will produce identical results.

• *The possibility of "densifying" the grid was mentioned earlier. How will that be compatible with the standard grid?*

A denser grid can be produced for any regular quadrilateral area designated by a responsible agency as having significant local distortions that are not adequately handled by the standard 5 minute grid spacing. The shifts at the additional grid points that are interior to the selected quad would be computed using the same datum and distortion models and parameters. At grid points falling along the lines bounding the area, however, the linear interpolation values would be retained as indicated in Diagram 4, to ensure that all points have unique results. Notification to alert users of such specialized areas would be handled by the agency producing them.

• *This brings up the possibility of different versions. What will happen when you resolve problems with some of the control points that had to be left out, or integrate new surveys? We can't afford to update our data base annually!*

The possibility of new versions of the transformation certainly does exist, but no more so than for the control network itself. As investigations of existing NAD27 anomalies and further integration of other existing networks not yet included in NAD83 progress, the model will continue to be improved. The addition of newly performed surveys will have negligible effect on the transformation, since they will cause little change in existing NAD83 values, and there are no corresponding NAD27 values to add to the transformation model.

Every effort will be made to retain the existing values published for the shifts, unless there are overwhelming differences that the responsible agency deems significant in terms of the accuracy of the estimates. Probably most such cases could be handled locally in a similar fashion to the grid densification described above. As such changes accumulate, eventually a new version will likely be published. Again, consult the appropriate agency to obtain the official status.

This does underscore the requirement to tag all coordinate data with both the reference datum and the source of the computation on that datum, such as the date of adjustment or the version of the transformation. Such information allows the user to readily identify and resolve discrepancies among coordinates from various sources, since the tags give enough information to trace the exact relationships.

Summary

• *Why should I use this rather than just work out something simple for my own small area?*

There really aren't any methods simpler than interpolating within a grid that can handle variable differences, as required just by the change in reference ellipsoid without even considering distortion. This technique was commonly used with tables for functions of more than one variable in the days of log tables and sharp pencils.

Most federal and provincial jurisdictions, represented by their survey and mapping agencies on the Canadian Control Survey Committee of the Canadian Council for Geomatics, will officially adopt this transformation. Local variations will be smoothly integrated and become part of the overall unique specification.

Use of this standard will ensure results that are identical to those obtained by other users, thus optimizing the usefulness of the new standard reference system NAD83.

This transformation has already been prepared and is supported by the same agencies that produce and distribute NAD83 control survey coordinates. It only has to be used without any investment in development on the part of the user.

• *When shouldn't I use this transformation?*

As mentioned previously, this transformation is based on NAD27 values for control survey points as currently published by federal and provincial agencies. If data that the user wishes to transform to NAD83 is based on these values from another epoch, or are referred to a local datum or some other variation, then these differences need to be accounted for. Such inconsistencies will only be preserved in the transformed coordinates.

Quebec and the Maritime Provinces have special local systems for which a different transformation will be required. These and other federal and provincial agencies can provide assistance to determine what the differences are, and whether they might be significant for a specific application.

Transformations in general should not be used with the intent of improving the accuracy of coordinate data. Existing systematic errors and blunders will be preserved, and have the local error (inaccuracy) of the transformation added to them.

Neither this transformation nor any other should be used to migrate reliable control surveys to NAD83. The survey observations should be readjusted to properly integrate them, and to produce accuracy estimates for the resulting coordinates.

Acknowledgements

The transformation package was developed primarily by a three person team at Geodetic Survey, including Dann O'Kane, Steve Farley and this author. Dann O'Kane single-handedly compiled and analyzed the data for the more than 80,000 stations used to define the transformation - a demanding task, considering the less-than-perfect nature of the NAD27 system. Steve Farley developed the many programs for the Grid Implementation suite and utilities for the data pre-processing, analysis and plotting in the definition stage. Steve is co-author of the accompanying software documentation and users' guide.

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NATIONAL TRANSFORMATION
Accuracy Analysis

Table 1: Analysis of Variance by Region

Area	*# Stations*	*RMS* ϕ *(m)*	*RMS* λ *(m)*	*Total (m)*
Yukon & NWT	8696	0.48	0.51	0.62
British Columbia	12047	0.52	0.56	0.64
Alberta	10067	0.25	0.22	0.30
Saskatchewan	4281	0.13	0.36	0.37
Manitoba	2056	0.19	0.23	0.26
Ontario	40186	0.12	0.08	0.14
Quebec	1728	0.17	0.24	0.26
Maritimes	348	0.08	0.08	0.09
Newfoundland	2601	0.21	0.22	0.28
National	82714	0.29	0.31	0.39

Table 2: Ranges of Residuals

Magnitude (m)	ϕ %	λ %	*Total* %
< 0.1	82	82	74
< 0.25	91	91	86
< 0.5	96	96	93
< 1.0	98	98	97

NATIONAL TRANSFORMATION
Define Parameters

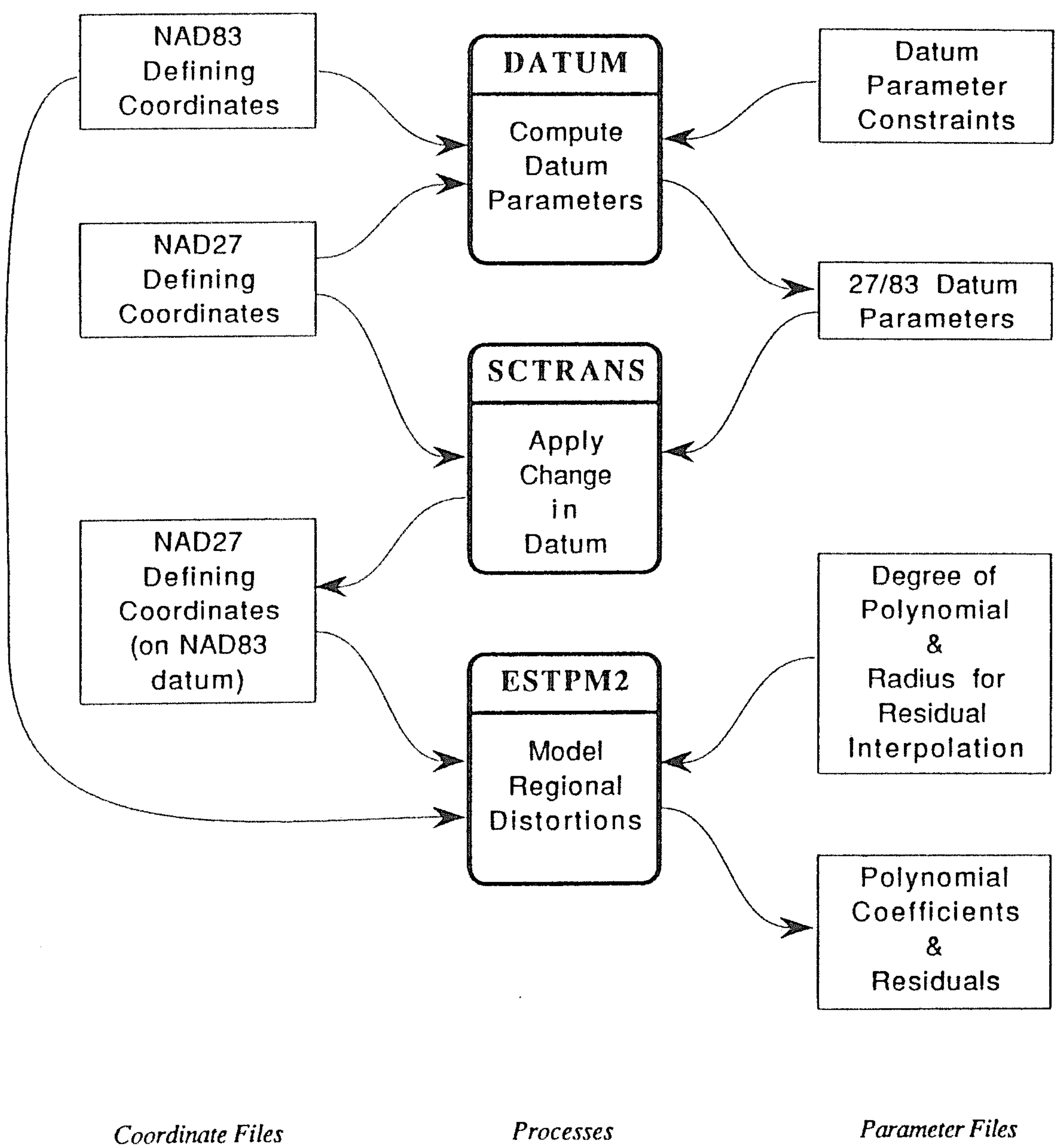


Diagram 1

NATIONAL TRANSFORMATION
Create Grid Shifts

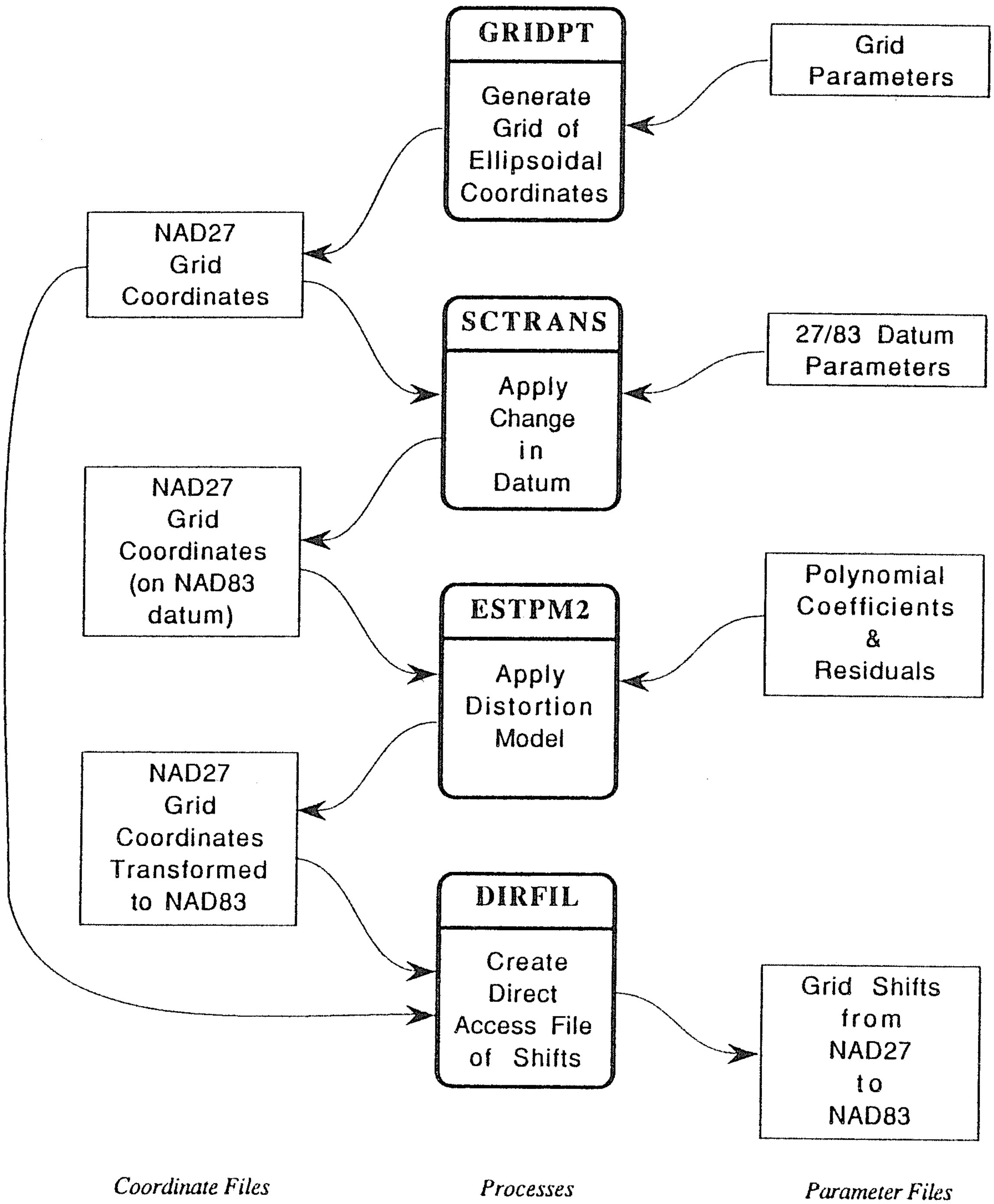
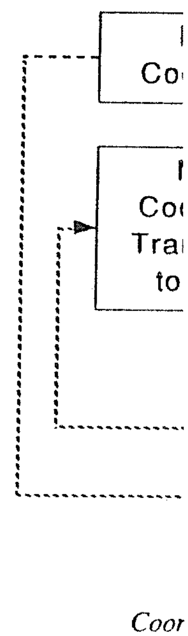


Diagram 2



NATIONAL TRANSFORMATION
Transform Coordinates Using Grid Shifts

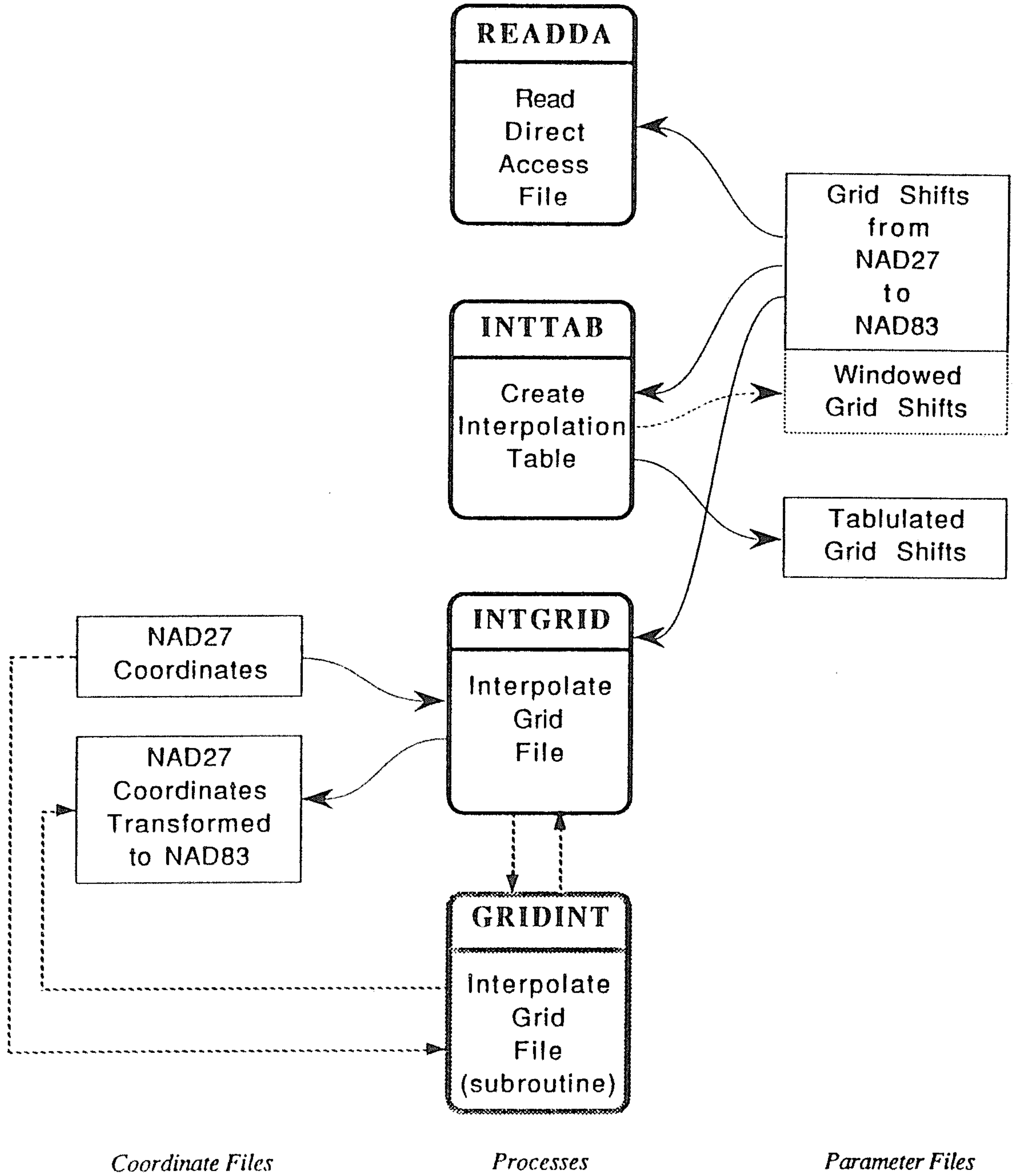
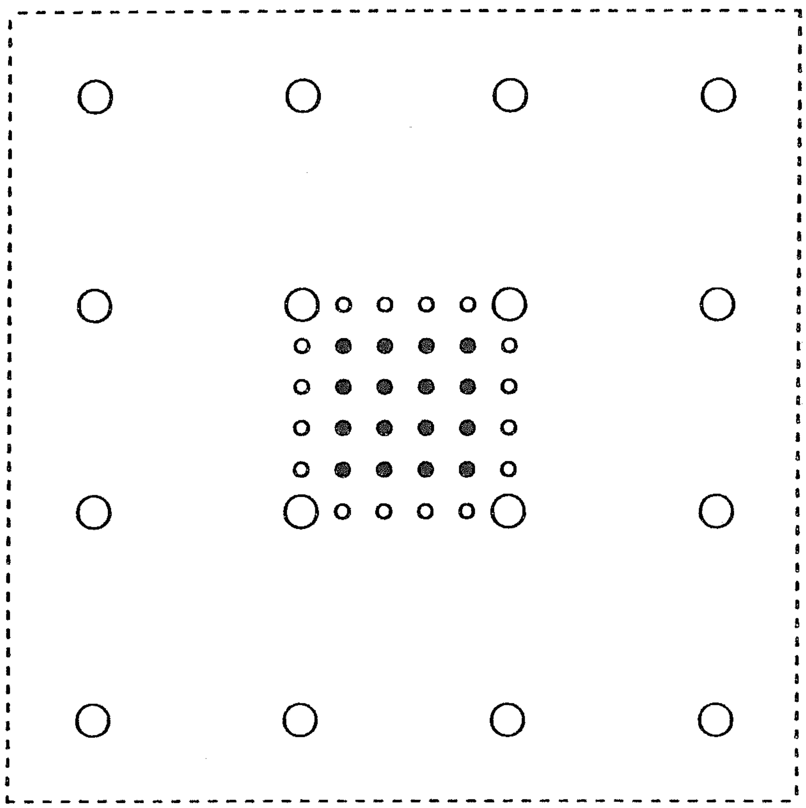


Diagram 3

NATIONAL TRANSFORMATION
Densification of Grid Within a Selected Area



Legend

- Original Grid Points
  - computed from model
- New Grid Points Within Densified Area
  - computed from model
- New Grid Points on Edges of Densified Area
  - interpolated between original grid points

Diagram 4

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THE IMPACT AND IMPLEMENTATION OF NAD83 ON NTS PRODUCTS

Daniel Brassard, Topographical Mapping Division
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ABSTRACT

A new reference datum called the North American Datum 1983 (NAD83) replaces NAD27 as the official geodetic reference system. The new datum results in considerable changes to the existing hardcopy maps and associated digital products. There will be a change in geographic coordinates by up to 150 meters in latitude and 140 meters in longitude. The Universal Transverse Mercator coordinates will also change by up to 250 meters in northing and 150 meters in easting. The Canada Centre for Mapping's (CCM) new policy on NAD 83 addresses the necessary changes to both digital and conventional products produced by CCM. This new policy allows for a progressive and cost effective implementation of NAD83.

INTRODUCTION

General

A new reference datum called the North American Datum 1983 (NAD83) replaced the North American Datum 1927 (NAD27) as the official geodetic reference system. The products in the National Topographic System (NTS) are produced based on the national datum. Any change in reference system will cause significant changes for the 13,837 maps and associated digital products of the National Topographic System. In July 1989, the Director of the Topographical Mapping Division (TMD) created a study group to resolve the NAD83 issue. This group investigated the impact of NAD83 on the products of the TMD and made many recommendations. A management review of the feasibility of the proposals produced a new policy and implementation plan.

Outline

The main points from this 1989 study and the implications for users of NTS products are discussed in this paper. To assist in the review of the NAD83 conversion, some background information related to the issue are summarized. The main areas discussed in detail are listed below.

A. The history and status of NAD83 is discussed to place in perspective the need to change to NAD83.

B. A summary of the 1989 internal TMD study on the implications of NAD83 is presented to highlight the magnitude of the problem for TMD to attempt a conversion to NAD83.

C. A summary of TMD's present implementation plan is discussed.

D. The impact of TMD's conversion/implementation plan on users of NTS digital and analogue products is briefly covered.

BACKGROUND ON THE NAD83 PROJECT

Background

The old datum for the Canadian geodetic networks was NAD27 with the reference ellipsoid being the non-geocentric Clarke 1866. This datum had evolved from the integration and recomputation of earlier Canadian, American and Mexican networks. Since 1927 new surveys have been added to the primary network as well as a network of satellite Doppler and Global Positioning System (GPS) based stations. The primary Canadian framework comprises 8,000 stations with an additional 150,000 stations in federal and provincial secondary networks. It became clear in the 1960's that significant distortions were being introduced in the newer and more accurate surveys.

Several regional recomputations succeeded in minimizing local distortions but created new discrepancies between the regions. The MAY76 adjustment was one such local change which improved the quality of NAD27 referenced data by removing many of the larger distortions in the network. An international symposia was held on the requirements for a redefinition of North American networks. It was agreed to redefine the geodetic networks on a new geocentric ellipsoid. Recomputing the networks would cut distortions and a geocentric ellipsoid would ensure compatibility with satellite based positioning. The reference ellipsoid associated with NAD83 is the Geodetic Reference System 1980 (GRS80).

Current Status of the Adjustment

For Canada the first stage of the adjustment was completed in July 1986. This adjustment integrated the 8,000 station primary network into the Continental Adjustment. The integration of secondary networks is now complete. The Eastern region Secondary Integration Adjustment resulted in NAD83 coordinates for 60,000 primary and secondary control stations. The Western and Northern regions Secondary Integrated Adjustments resulted in 34,000 and 11,000 stations respectively.

Conversion Tables

To help users in converting their data from NAD27 to NAD83, the Geodetic Survey Division, of the Canada Centre for Surveying, is preparing a conversion table. The table provides shifts between the systems for points on a regularly spaced grid at 5 minute intervals. The user could also determine the transformed value of his NAD27 coordinates by using a standard interpolation algorithm which will access the table. The values in the table will be compiled from the differences between published NAD27 and final NAD83 values. The NTS maps were mainly produced using NAD83 but since 1980, the Topographical Survey Division had been using MAY76 values for new mapping and recompilation. The shifts from MAY76 to NAD83 are different from the shifts from NAD27 to NAD83. As a result Geodetic Survey Division will produce two transformation tables. The user must correctly identify whether his data is adjusted on MAY76 or NAD27 before using the tables. In the NTS system there are about 2,467 MAY76 maps at 1:50 000 scale, none of which bear a note to that effect.

REVIEW OF THE 1989 STUDY

General

The 1989 study proceeded to review the result of the previous study, done in 1982, and then to analysis the magnitude of the various shifts. This analysis was based on a combination of final and provisional adjustment values. The study considered the impact on all of the NTS products, both graphical and digital. The magnitude of the these shifts and their practical implications were important considerations in the preparation of its recommendations. The implementation strategy was strongly influenced by the impact on NTS users, the policy Directive 1-88, and the availability of resources to implement the changes.

The 1982 Study

A previous study had been conducted by the Topographical Survey Division in 1982. This study focused almost exclusively on the conversion options for the hardcopy 1:50 000 and 1:250 000 products. It proposed three options for converting the graphical 1:50 000's.

A. Do nothing to the maps except add a note in the margin giving users the necessary data to position the new graticule and grid and to obtain correct coordinates of features. Although inexpensive it only delayed the final conversion.

B. Implement a partial conversion of the maps. This option would maintain the existing neatlines and amend the latitude and longitude of the sheet corners to new non-integer NAD83 values. The graticule and grid would be displaced to correspond to the new datum and the existing neatlines would not be moved. This allows both the geographical and grid coordinates read from the map would to be correct. New maps would diverge from existing maps since the former would be compiled on the new datum. The result would be that most of maps would have NAD27 neatlines and NAD83 values.

C. Fully convert the maps by maintaining the integer values of the sheet corners. This would require moving the map window by small amounts which would be done manually by adding or subtracting very narrow strips along sheet edges as well as repositioning the grid. This relatively costly method provides a complete solution while maintaining the integrity of the NTS system.

It was decided not to carry out a conversion program due to the lack of final NAD83 coordinate values. Based on the recommendations of the report, it was stated that NAD83 would eventually become the official datum for NTS maps and digital products.

Conversions

The shifts involved in the conversions must be assessed separately in terms of the changes to the geographic coordinates (latitude and longitude) and the plane coordinates (UTM for the NTS products). It is not possible to convert UTM coordinates directly from the shifts of the corresponding geographic coordinates. This is due to the change in ellipsoid from Clarke 1866 to GRS80. This conversion process applies equally for the NAD27 to NAD83 and the MAY76 to NAD83.

NAD27 to NAD83 Geographic and UTM

The magnitude of the shifts from NAD27 to NAD83 were assessed. To convert UTM's from NAD27 to NAD83 it is necessary to:

A. transform them to geographic coordinates in NAD27;

B. convert these to NAD83; and

C. then derive the UTM values from the NAD83 geographic coordinates.

The basis of the analysis in the 1989 study consisted of a thorough examination of data obtained from the Data Analysis and Adjustment Section of the Geodetic Survey Division. The data sets were derived from values obtained from the preliminary National Transformation of geographic coordinates at one degree intervals of latitude and longitude. This transformation included the entire Canadian landmass and the corresponding UTM coordinates. Provision for both distortion modelling and datum transformation were accommodated. Individual listings provided displacements in latitude and longitude expressed as meters and UTM differentials at each of the one degree by one degree grid points. A third listing consisted of shift vectors given as azimuth and magnitude for each point.

Summary of Findings:

A. For the geographic coordinates the shift increases in size as a function of the distance east or west of approximately longitude 88 degrees west. East of this meridian the direction is eastwards and west of it the direction is westwards. The latitude shifts range from -50 to 150 meters and the longitude shifts range from -120 to 140 meters.

B. For the UTM coordinates the shift in northings ranges from 125 to 250 meters; for the eastings the range is -150 to 130 meters. As with the geographic shifts, longitude 88 degrees is the approximate turning point for the eastings. West of this line the eastings decrease and east of it they increase.

C. Although there is a wide range in the direction and magnitude of the shifts when viewed over the entire country, the change is usually gradual across the extents of 1:50 000 and 1:250 000 maps. The exceptions will be discussed later. For 1:50 000 maps there is typically less than 2 meters difference in the shift required to move each of the four corners to its NAD83 position. Similarly for the 1:250 000 maps the typical difference is less than 10 meters.

1. **Typical UTM Shift for Adjacent 1:50 000 Maps** An evaluation was done to compare the results of the conversion on two adjacent 1:50 000 NTS sheets, 12A13 and 12A14. The changes in UTM values in meters required to convert 1:50 000 scale NTS maps 12A13 and 12A14 to NAD83 based on the exact amounts at each of the corners. The upper number of each pair is the amount to convert the NAD27 northing and the lower number is the amount to convert the NAD27 easting. The northing shift is positive northwards and the easting shift is positive eastwards. The average of the corners of 12A13 is 219.3 meters for the northing and 59.9 meters for the easting. For 12A14 the values are 218.9 and 60.7 respectively, see Figure 1. Using these average values, 12A13 would differ from 12A14 after the shift by 0.4 meter in northing and 0.8 meter in easting. For most cases this is typical of the gradual progression of the shift. However when adjacent maps are in different UTM zones one can expect a more dramatic change in the value of the shift in the eastings. For example maps in zone 18 will have their eastings change by about 26 meters but maps just west in zone 17 will be changing by 10 meters in the easting. This phenomenon is caused by the change in size of the UTM zones on NAD83 compared to NAD27. At 52 degrees latitude the zones are 14 meters wider in NAD83. The effect on the northings is less dramatic.

219.5	219.1	218.5
59.8	60.4	61.5
12A13		12A14
219.2	219.1	218.6
59.5	59.9	60.8

FIG 1: Typical UTM Shift for Adjacent 1:50 000 Maps

2. **Typical Graticule Shift for Adjacent 1:50 000 Maps** The shift required to orient the same 1:50 000 map (12A13) to the NAD83 graticule are illustrated in Figure 2.

1.3	0.4	-0.5
-57.4	-59.1	-60.8
12A13		12A14
0.8	0.0	-0.8
-57.0	-58.6	-60.5

FIG 2: Typical Graticule Shift for Adjacent 1:50 000 Maps

The upper value of each pair is the shift in latitude in meters and the lower value is the shift in longitude in meters. For the latitude shift positive is a northwards and for the longitude shift positive is westwards. The graticule shifts for 12A13 average 0.6 meter north in latitude and 58.0 meters east for longitude. For 12A14 the comparable values are -0.2 and -59.8 meters.

D. Assuming that shifts less than 0.5 mm on a map are insignificant, there are 1,400 maps at 1:50 000 scale in Ontario and eastern Manitoba as well as all of the 1:250 000 maps that will be unaffected by graticule changes. However all maps at both scales will require new grids due to the UTM shifts which are generally more than 200 meters.

MAY76 to NAD83 Geographic and UTM

The analysis of the shifts from the MAY76 datum to NAD83 used listings from the Geodetic Survey Division similar in coverage and format with those used for the NAD27 to NAD83 analysis. The difference is that the MAY76 to NAD83 data contains only the datum transformation component but not the distortion component which was not available. The distortion component is not considered to be very significant since most of the distortion was removed from the MAY76 data. NTS maps compiled on MAY76 form a significant component of the system since most new mapping and recompilations done since 1980 were based on MAY76 data. At this time, there are 2,467 MAY76 1:50 000 scale maps and 8,860 NAD27 1:50 000 scale maps. All of the 1:50 000 digitally stereocompiled maps have been done on MAY76 with the exception of a block in New Brunswick which is on NAD27. All of the 1:250 000 maps and scanned products are NAD27 with the possible exception of recent derivations which will be the same as the 1:50 000's from which they were derived.

The problem with the conversion from MAY76 to NAD83 is that the amount of shift for both the graticule and UTM coordinates is different than that for NAD27 to NAD83. Adjacent maps or digital files on different systems will theoretically have gaps or overlaps after conversion. An example is 73C12 which is on MAY76 and is adjacent to 73D09 which is on NAD27. The following values are averages of the shifts at the four corners:

Sheet	73C12	73D09
change in northings :	215 meters	221 meters
change in eastings :	-70 meters	-53 meters
change in latitude :	-2 meters	6 meters
change in longitude :	67 meters	54 meters

If these values are used to move the two graticules a gap of 8 meters in latitude and 13 meters in longitude will occur. At 1:50 000 this translates into 0.16 and 0.26 mm which is insignificant for the graphical products. To be significant the difference would have to be 25 meters or more. There are only a few areas in the entire country where this situation may arise. For the digital products, the difference between NAD27 and MAY76 presents an additional problem which will affect the scanned 1:50 000's more than any other product due to the mixture of existing manuscripts on the two systems. At each boundary between the two, there will be mathematical gaps or overlaps which will have to be resolved. As the previous example of 73C12 and 73D09 shows, common features along the north - south neatline have two values after conversion from MAY76 and

NAD27 respectively which differ by 6 meters in northing and 17 meters in easting. This could be resolved by processing both files using an affine or projective transformation after defining compromise coordinates for the common corners. The amount of misclosure could be even greater if the two maps are also in different UTM zones.

The 1:50 000 Graphical conversion Pilot Projects

A pilot project was carried out to acquire data on the cost effectiveness of two methods for the conversion of existing hardcopy maps. Four adjacent 1:50 000 sheets, namely 83H/1,2,7,8, were fully converted and data for partial conversion was estimated from the results. The partial conversion maintains the existing neatlines and amends the latitude and longitude of the sheet corners to new non-integer NAD83 values and displaces the graticule and grid to correspond to the new datum. The full conversion procedure involved shifting the window to maintain the graticule. The amount of shift required was derived from the preliminary geographical shifts (not UTM shifts) listing. The amount of shift required for each map is 60 meters in longitude which is 1.2 mm at 1:50 000 scale and 7.5 meters in latitude which is 0.15 mm at 1:50 000 scale.

To fully convert one typical map sheet by maintaining the integer values of the sheet corners required 36 person hours. The estimated savings to partially convert one typical map sheet was estimated at 7 person hours for a conversion requirement of 29 person hours. The full conversion requirements excludes the resources to add a bleeding edge needed to convert maps that:

A. fall on the leading edge of a block being converted; and

B. the graticule shift is more than 0.5 mm.

The initial savings with the partial conversion are more than offset with the resulting long term problems. New maps would diverge from existing maps since the former would be compiled on the new datum. The result would be that most of maps would have NAD27 neatlines and NAD83 values. This was considered an unacceptable compromise given the relative savings.

Based on the results of the pilot project, the cost for incorporating the conversion to standard revision contracts was estimated. The incremental effort would be a maximum of 10 to 15 hours with some additional savings on material. Other simplier approaches may further reduce these figures which were used to help estimate the conversion/ implementation costs.

Conversion of Digital Files

The conversion of digital products was found to be relatively straight forward. This conversion of digital files is greatly simplified since the UTM values change gradually. It is possible to apply a single northing and easting shift to each position reference in a particular map file based on the average shift at each of the corners. Exceptions to this approach would be:

A. at NAD27/MAY76 interfaces;

B. at zone changes; and

C. where the shift changes unevenly due to distortion in the original NAD27 data.

The method of conversion should apply an affine or projective transformation keeping the corners fixed. The projective transformation is an eight parameter transformation which needs a minimum of four control points (map corners) and corrects the data for X and Y scale factors, skewing and translation. This process would be followed by merging and clipping to new neatlines defined by the NTS whole numbers for latitude and longitude on the GRS80 ellipsoid. It was estimated that one person day and 1-3 hours of computer time is required to convert a 3D map file. Newer commercial software packages and faster workstations will likely reduce these figures.

Minimum Implementation Costs

The study provided an estimate for the conversion costs. In preparing an estimated cost the study made several assumptions:

A. all new work would be done using NAD83, also includes the eventual recompilation of 388 photomaps;

B. the conversion of digital products would be done in-house;

C. a standard non-inflated commercial labour charges for graphics work by contract was used; and

D. all maps being revised would also be fully converted.

The cost for the graphical conversion, incremental cost only used for revisions, in 1989 dollars was estimated at almost $15 million. The digital conversion of existing digital data at 1,500 person days of in-house work. This substantial cost cannot be easily accommodated over a short period of time.

Main Conclusions

The study made many conclusions and recommendations concerning the impact of NAD83. One of the main recommendations concerned the need for a NAD83 Policy statement. Other conclusion and recommendations were divided into those related to graphical products and those related to digital products.

A. Graphical Products

1. The recommended approach was the full conversion as part of the revision process.

2. Almost all of the existing 1:50 000's will have to be converted while all the 1:250 000s only require new grids, new edition numbers and credit notes.

3. Maps in the 30 year cycle (6,416 maps at 1:50 000 scale and 380 maps at 1:250 000) which will not be converted for a very long time and require an interim solution such as a conversion note printed in the margin.

4. Consideration should be given to adding a bleeding edge to prevent loss of content for NAD83 maps which adjoin NAD27 maps.

B. Digital Products

1. All of the existing digital files will have to be transformed to NAD83, both the MAY76 and NAD27, and clipped to new neatlines.

2. Most of the digital conversion is simple but some cases will have to be handled on an individual basis.

3. The aerial survey data base for maps for maps not yet in production should be adjusted to NAD83.

PROPOSED CANADA CENTRE FOR MAPPING POLICY AND IMPLEMENTATION PLAN

General

The CCM's management used the 1989 study as a initial base for developing a policy and a proposed implementation plan concerning NAD83. A draft NAD83 policy was prepared and awaits final approval before being promulgated. The proposed implementation plan provides additional details to the policy paper and requires minor refinements prior to final approval.

Policy

The policy paper is titled "Canada Centre for Mapping Management Directive 1/90 Policy on NAD83". The key points contained within the directive are listed below.

A. NAD83 will be the official datum for all CCM analogue and digital data once all the coordinates and datum transformations are available.

B. Conversion to NAD83 will be done as part of a longterm conversion program tied to the revision cycle.

C. Maps not scheduled for revision in the next 15 year revision cycle will not be converted until they are digitized.

D. All digital products are to be converted to NAD83.

E. The northern Aerial Survey Data Base (ASDB) and other aerial-triangulation data will be transformed to NAD83.

F. CCM will publish information explaining the conversion and listing UTM shifts each of the 1:50 000 and 1:250 000 maps of NTS series.

Implementation

The implementation plan attempts to provide the details to allow the NAD83 policy to be implemented with the available resources. The main points in this implementation plan.

A. Effective immediately all new and revision mapping, and aerial triangulation adjustments will use NAD83.

B. Effective 1 Apr 91 all revision contracts will incorporate NAD83.

C. Effective 1 Apr 91 all digital data structuring contracts for 1:250 000 and 1:50 000 data will be converted to NAD83.

D. Effective 1 Apr 91 all requested digital data, both 1:50 000 and 1:250 000, will be converted to NAD83 before distribution.

E. The completion date for the publications explaining the conversion to NAD83 and listing UTM shifts is 1 Oct 91. The data for conversion to NAD83 would be in the form of a delta easting, delta northing, delta latitude and delta longitude based on the mean for the centre of the sheet. These means would only result in very minor differences which could not be measured on the maps. The MAY76 products will be highlighted in the publications.

F. The conversion publications will be available through the Canada Map Office for use by users.

This implementation plan allows a systematic conversion of both analogue and digital data to NAD83 given available resources.

IMPACT ON DIGITAL AND ANALOGUE USERS OF 1:50 000 AND 1:250 000 NTS PRODUCTS

General

In general, the progressive change from NAD27, or MAY76, to NAD83 should cause only minor problems for users. The transformed digital data will be available on in a relatively short time frame while the maps will be converted over a longer period of time.

Analogue Maps

The changes associated with a conversion to NAD83 generate shifts which are generally too small to be a major concern to users. Until the information publications are published, users will be unable to make any of the required conversion. New products will all be NAD83 and the compilation date will be a useful means of temporarily determining the datum:

A. maps compiled before 1980 will likely be NAD27;

B. maps compiled between 1980 and 1990 will likely be MAY76; and

C. maps compiled after 1990 will be NAD83.

Users requiring very precise coordinates will be required to verify the datum of the product and apply the necessary conversions for many years.

Digital Data

The existing digital data will available on NAD83 commencing 1 Apr 91. Until that date, users can either accept the NAD27 or MAY76 based data or attempt to transform it themselves using the precise shifts from Geodic Survey Division. All new digital data will be in NAD83.

SUMMARY

The conversion of the NTS 1:50 000 and 1:250 000 NTS series of digital and analogue products is a major undertaking. CCM is committed to the use of NAD83 and new products will use NAD83. With the available resources the conversion of exisiting analogue and digital products will occur over many years. Analogue products will be converted on revision or recompilation and conversion publications will be available. Existing digital products will be converted initially on an as requested basis.

The shifts involved with the conversion to NAD83 will only impact users requiring very high precision at the limit of the accuracy of the product. Most users will find that the conversion to NAD83 will not effect their operations.

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IMPLEMENTATION OF NAD83 IN A REGULATORY ENVIRONMENT

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CANADA OIL AND GAS LANDS ADMINISTRATION

ABSTRACT

This paper discusses the implementation of NAD83 on Canada's frontier lands in an oil and gas regulatory environment. Regulatory, technical and user group considerations are presented as is a planned time frame for implementation. Concerns expressed by oil and gas industry representatives with respect to the effect of transformation to NAD83 on oil and gas rights, geophysical and geological data points, and well names and locations are addressed. Cooperation and coordination of the implementation of NAD83 with industry and the frontier lands petroleum resource management administrations are discussed.

INTRODUCTION

The Canada Oil and Gas Lands Administration (COGLA) and its sister organizations, the Canada-Newfoundland Offshore Petroleum Board (CNOPB) and the Canada-Nova Scotia Offshore Petroleum Board (CNSOPB), manage the exploration for and exploitation of petroleum resources in the frontier lands. Frontier lands are lands under federal jurisdiction, namely the Yukon and Northwest Territories and offshore Canada's eastern, western and northern coasts, as defined in the Canada Petroleum Resources Act (refer to Fig. 1). COGLA also has some responsibility for Public Lands, mainly the mineral rights underlying federal lands in the provinces.

Frontier oil and gas exploration and development activities are regulated by these administrations. Included in the mandate of these organizations is the collection and curation of vast amounts of data resulting from industry oil and gas activity on frontier lands. These data are derived from geophysical, geological and environmental surveys and from the drilling of exploratory and development oil and gas wells. This information is used by the organizations' engineers, geologists and geophysicists for their regulatory tasks and, in addition, form a national inventory of resource information.

Oil and gas companies working on frontier lands are required to obtain authorization from the petroleum resource management agencies prior to commencing any work. Besides regular reporting while the work is ongoing, the companies must also submit copies of reports, maps, information and data resulting from the work. It is essential that geographic locations are accurately defined and referenced to a common datum or survey system. The datum employed must be clearly identified in order to prevent mixing of data referenced to different datums.

Any changes to the existing regulatory requirements and operating environment are expensive in terms of human and financial resources. Changes must therefore be made on sound technical grounds and in consultation with all parties concerned. Given the above and the fact that the transformation from NAD27 to NAD83 has been officially endorsed by the federal government (gazetted May, 1990), it falls on the various federal agencies to implement the transition.

Three factors to consider are:

1) Legislative and regulatory considerations;
2) Technical considerations; and,
3) User community.

In the context of NAD83 implementation the petroleum resource management administrations (COGLA, CNOPB, CNSOPB) are primarily concerned with geographic coordinates as they relate to oil and gas rights, geophysical and geological data points and well locations.

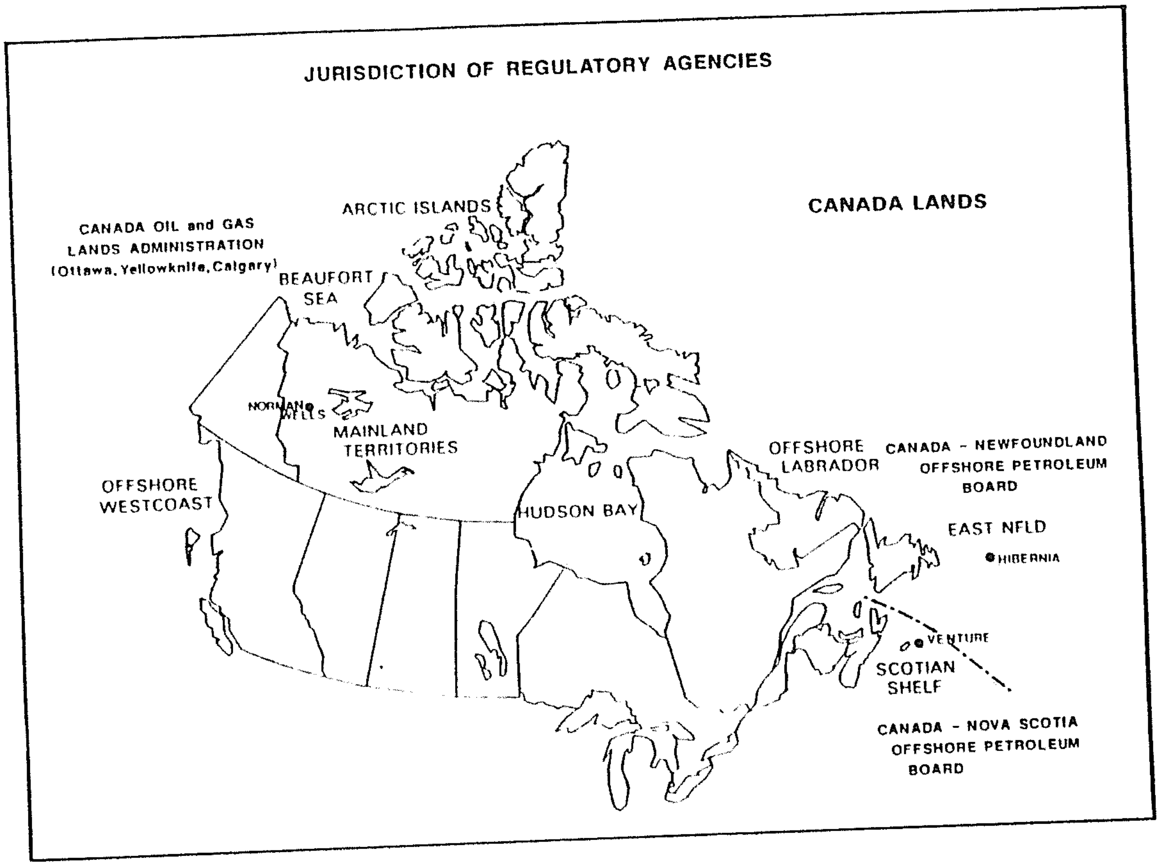


Fig.1 Areas of jurisdiction of the petroleum resource management agencies on the frontier lands.

FRONTIER OIL AND GAS RIGHTS

Implementation of a new survey datum has potentially serious effects for the descriptions of the various exploration licences, significant discovery licences, production licences and other proprietary interests in the frontier lands. The location of these properties has been determined by a grid system established in the 1950's as a major component of the Canada Oil and Gas Land Regulations (COGLR) and amended from time to time thereafter.

Use of a fixed grid system based on latitude and longitude provided a theoretical but practical means of distinguishing boundaries in areas where survey control was sparse or non-existent. The regulations also provided for an obligation on the part of the licence holder to pay for and conduct a legal survey once a prospect had demonstrated potential for commercial production. Such surveys also operated to position the grid in the immediate area of the discovery and could have predictable effects on neighbouring grids that had not yet benefited from such a survey. At the time, the drafters of the regulations envisaged that a network of legal survey control would soon materialize. Given that only a few of the discoveries from the remote frontier regions have been developed for commercial production it can be easily appreciated why this has not materialized. The grid system does constitute a fair, equitable and reasonably accurate land rights regime for oil and gas exploration in the frontiers.

This grid system, defined in COGLR, specifically references the required coordinates to the North American Datum of 1927 (NAD27). That specific reference will have to be modified by a reference to NAD83 once it becomes effective throughout Canada.

Various issues need to be addressed in this respect. Not the least of these is to bring the entire regulation respecting the grid system and surveys into the modern era under specific legislation, the Canada Petroleum Resources Act. Similar regulations are required for the Newfoundland offshore and Nova Scotia offshore areas under the respective accord legislation.

Initial consultations in the early 1980's between the Surveyor General's office and the oil and gas industry emphasized that locations of boundaries (and wells) could be considered as shifted with the application of the new datum. Generally, this effect would have been favoured by industry given the other benefits arising from the implementation of the new system. However, there was a perceived reluctance to alter boundary descriptions on any licences where discoveries had been made. The matter was reviewed again at an industry-government workshop in 1985. This workshop concluded with a recommendation that the datum shift take place with provision for remedial action to be applied on request of any party, particularly where resources had been discovered.

The drafting of proposed remedial practices for inclusion in the regulations quickly highlighted the difficulties inherent in this recommendation. There was also a lack of authority in the statute (CPRA) to resolve the problem by way of new regulation. Most importantly, the existing regulations clearly intended that the boundaries would not be altered. Accordingly a decision was made to recommend a regulation that recognized and maintained the NAD27 positions of any rights existing on the date the new system is implemented. This would require that special descriptions be prepared by the Surveyor General's office in order to express the positions of the licences referenced to NAD83. These special descriptions would form an attachment to the licence documents and be recorded in the registry of such rights. At the same time, it was recognized that special descriptions would also be required for adjoining parcels owned by the Crown when these were offered for bids, to address any problems arising from gores or overlaps.

For the time being, it is considered unnecessary to modify other administrative record systems, at least until the special descriptions of existing rights are in place. Until full integration of these fractional areas is possible, COGLA proposed to simply identify each such licence area with a NAD27 label in its computer systems.

Other changes being recommended at the same time in the proposed new regulations will include:

1) eliminating the requirement for a "legal" survey;
2) eliminating the references to circumstances under which a survey is required; this aspect is covered more appropriately under the relevant operating regulations issued pursuant to the Oil and Gas Production and Conservation Act; and,
3) improved definition of the grid system.

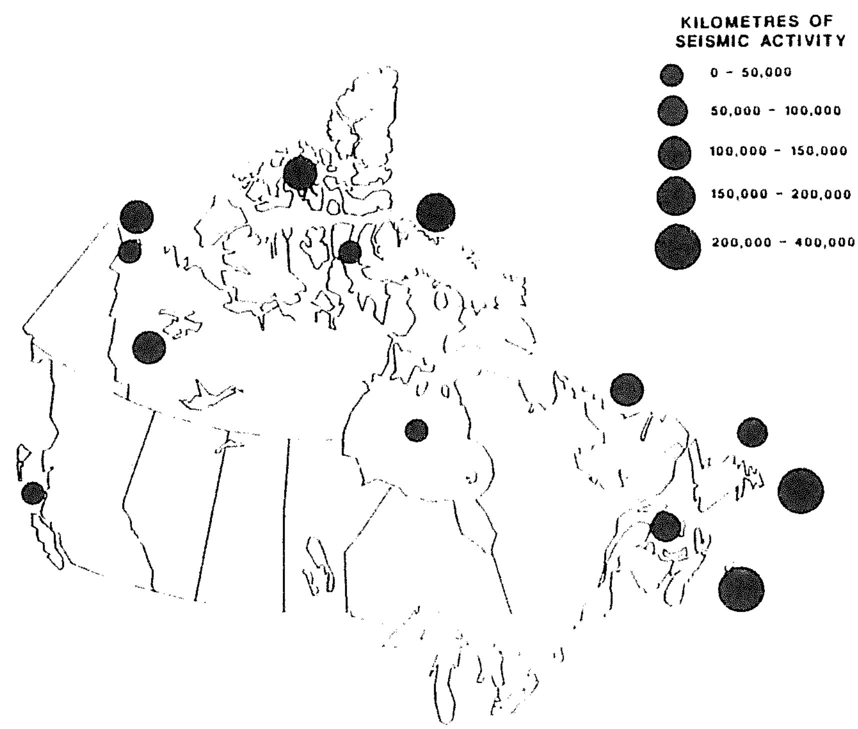
Consideration is being given to specifying a "unit" (1/16 of a "section") as the smallest land quantum for issuance purposes instead of a "section" (section is defined in the regulations). Thought is also being given to the advisability of issuing an updated hectare table.

GEOPHYSICAL AND GEOLOGICAL PROGRAMS

The data points acquired under geophysical and geological programs consist of the geographic locations of geological and geotechnical samples, geophysical shotpoints, gravity and magnetic stations, and environmental sample locations.

Implementation of NAD83 with respect to new geophysical, geological, geotechnical and environmental programs is relatively simple from a regulatory standpoint. After the date of implementation, chosen by the regulatory agencies in consultation with industry, all reporting will be required in NAD83.

For the frontier lands alone, there are already an estimated 30 million seismic shot point locations (refer to Fig. 2). To date COGLA has been able to capture about half of these in digital form on its Shot Point Location System. Many of the remainder only exist on older NAD27 maps. Some of these shot point locations will eventually be digitized from the maps and then transformed to NAD83.



SEISMIC COVERAGE ON FRONTIER LANDS

Fig.2 Representative map showing seismic data density on the frontier lands.

COGLA is planning to use an algorithm, under development by the Geodetic Survey Division of the Canada Centre for Surveying, to transform its digital data points to NAD83. This transformation method is based on tables of grid shifts with an algorithm for interpolating between grid points.

The methodology will have to be tested against the real data to determine its suitability. The main concern will be maintaining the relationships between coordinate locations transformed using different methods.

Data points may fall into categories of differing accuracies. The coordinates that exist for any given point must be accepted since there is no way to determine the accuracy of older surveys. Current surveys are positioned using either the Global Positioning System (GPS), radio positioning systems or any combination of survey methods. Regardless of which survey method is used the derived positions will be reduced directly to the NAD83 datum. Problems may arise when older data sets (NAD27) are transformed to NAD83. Two transformation options exist:

1) NAD27 data may be transformed to NAD83 using the grid table and interpolation algorithm.
2) Old position data may also be reduced directly to NAD83 from the original survey notes. However this can be considered an impossible task due to the large number of data points involved.

In the end, deriving NAD83 coordinates by different methods must not change the existing relationship of data sets to each other. The following example illustrates this problem. Wells are often drilled on seismic shotpoint locations. If the NAD27 coordinates of the seismic shotpoint are now transformed using the grid table and interpolation algorithm, and the location of the well is transformed by reduction from the original survey data, the relationship as defined by the transformed coordinates must not have changed from that defined under the NAD27 coordinates. Similarly transformed NAD27 coordinates must agree with NAD83 coordinates derived from a recent survey (GPS or other) for common data points. Any differences in either case must be reconciled.

The transformation from the NAD27 datum to the NAD83 datum will hopefully be invisible or of minor consequence to the geophysical user. The effect of the transformation on mapped structures, for example, will become clearer when testing of the algorithm begins. A sampling of interpretative prospect contour maps that have been produced using NAD27 data will be digitized and transformed to NAD83. Even though the datum change component of the transformation is mathematically defined, the effect of the removal of the distortion component is not clear. A comparison of the original NAD27 map with the transformed product will determine whether or not any significant differences come to light.

A concern is the continuing use of NAD27 maps and data. It cannot be stressed enough that data sets used must be compatible. The resources to transform all existing data are simply not available. Therefore the possibility of human error in mixing data referenced to different datums will continue to exist and must be guarded against. The consequences of mixing data referenced to different datums will cause points to be positioned incorrectly leading to potentially expensive mistakes.

The "Geophysical and Geological Programs on Frontier Lands - Guidelines for Authorizations and Reports" will direct the use of NAD83 commencing with programs active on or commencing after April 1, 1991. This date is tentative and will depend on the outcome of discussions between regulatory agency and industry representatives.

OIL AND GAS EXPLORATION, PRODUCTION AND DEVELOPMENT WELLS

Since the 1985 industry-government workshop, there has been some discussion on the effects of transformation of existing well locations to NAD83. Several aspects must be kept in mind. The accuracy of the positioning for the various wells is dependent on the method initially used to position that well. The surveys are thus repeatable to within the accuracy of the original survey, both for onshore and offshore well locations. For discovery or producing wells the legally accepted location of the well relative to oil and gas rights is extremely important as it may affect the extent to which the operator has rights to the discovered oil or gas.

About 2000 wells have been drilled on frontier lands, offshore and onshore (refer to Fig. 3). For many of the wells drilled within the last twenty years, original survey notes, satellite positioning data and/or legally registered surveys are available. COGLA's Engineering Branch has decided that wells drilled prior to the implementation of NAD83 will have their locations referred to the new datum by reduction from the original survey notes or positioning information whenever possible. This will allow for the greatest possible accuracy. Where this is not possible, a transformation algorithm will be applied to the NAD27 co-ordinates.

One area of concern expressed by industry in meetings held in late 1989 and early 1990 was the question of what would happen to the official well name and the unique well identifier (UWI) on transformation. For frontier lands, the well name and UWI are dependant on geographic location and therefore both could be changed on transformation. Industry data systems rely on well name and/or the UWI for identification of the well. COGLA has therefore decided that for recording purposes, the NAD27 referred name and UWI will not be changed. All records and data base systems will be modified to record both the NAD27 and NAD83 referred values. Wells drilled after the implementation of NAD83 will have only those values recorded.

The reporting and recording of well locations after NAD83 implementation is relatively simple compared to the problems associated with land rights as discussed earlier. Drilling operations are regulated through the Canada Oil and Gas Drilling Regulations issued under the authority of the Oil and Gas Production and Conservation Act. Details of reporting requirements are contained in "Drilling for Oil and Gas on Frontier Lands - Guidelines and Procedures", a new edition of which is planned for the fall of 1990. Modification of the latter will be sufficient to implement NAD83. The date for implementation will probably be in the spring of 1990 but will be decided upon after discussions between regulatory agency and industry representatives.

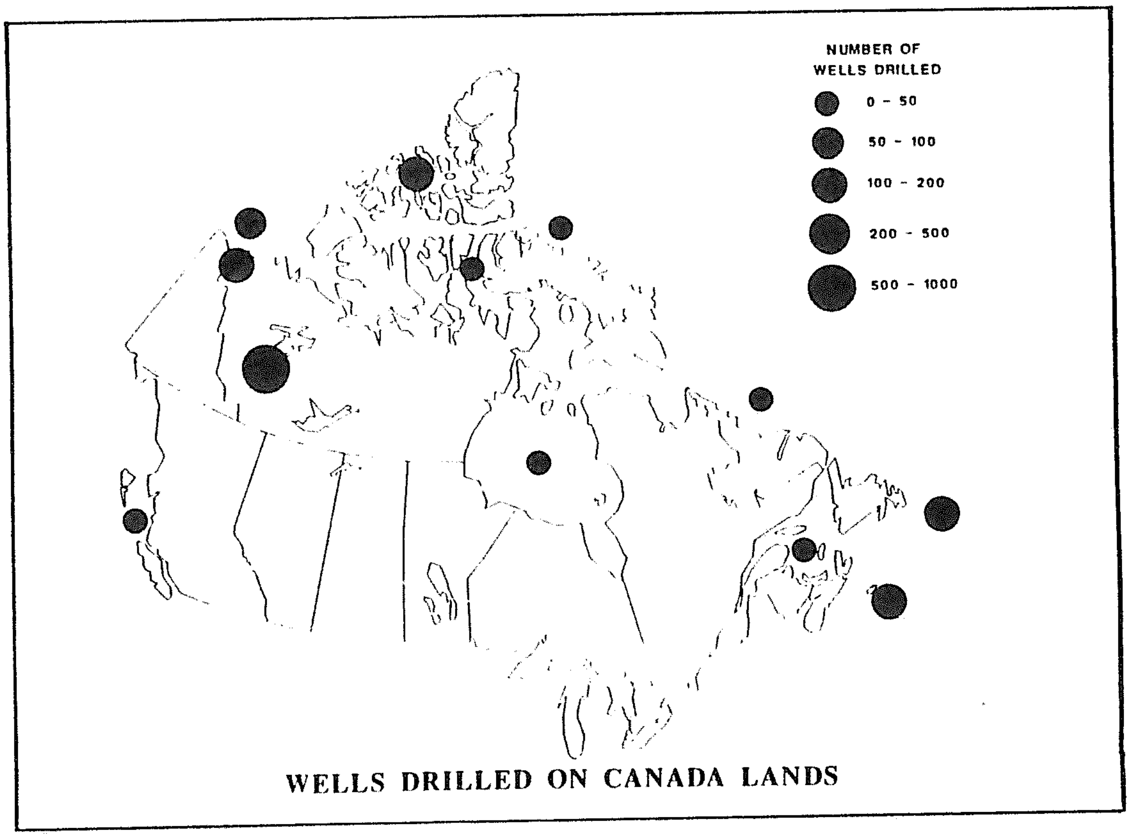


Fig.3 Map showing locations of wells drilled on frontier lands

CONCLUSIONS

From the regulatory standpoint implementation will likely occur in the spring of 1991.

Coordination between the various branches within COGLA must be finalized. Implementation of NAD83 for the Rights Management Branch is tied to proposed new regulations to replace the Canada Oil and Gas Land Regulations. For the Resource Evaluation and Engineering Branches implementation is linked to program authorizations and reporting guidelines.

Coordination with industry and the other petroleum resource management administrations, (the Canada-Newfoundland Offshore Petroleum Board and the Canada-Nova Scotia Offshore Petroleum Board), is essential. Furthermore the mechanisms for keeping the user community abreast of developments must be sustained. All these factors are essential to the successful implementation of NAD83 in the working environment. The dates specified above are tentative and will depend on the outcome of discussions between industry representatives and the staff of the three petroleum resource management administrations.

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Geodetic Survey Division, Canada Centre for Surveying The National Transformation For Converting Between NAD27 and NAD83, 1990 (?).

Jones, Harold E. and Gray, David H. Offshore Legal Surveys - Datums and Charts. Presented at Colloquium IV, Lake Louise, Alberta, 1986.

ADOPTION OF NAD83

AND THE

SURVEY OF CANADA LANDS

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ABSTRACT

This paper describes the effect of adoption of NAD83 on the survey of Canada Lands.

Eleven Coordinated Survey Areas managed by the Legal Surveys Division will be readjusted and coordinates of monumented points in these areas will be expressed in terms of NAD83.

New regulations are being prepared for the survey of rights to oil and gas in the territories and the offshore referring all rights to NAD83.

INTRODUCTION

Surveys of Canada Lands are performed and dealt with through the authority assigned the Surveyor General by the Canada Lands Surveys Act and several other authorities including the Yukon Quartz Mining Act, the Canada Mining Regulations and the Canada Oil and Gas Land Regulations.

The Surveyor General is also Director of the Legal Surveys Division of the Canada Centre for Surveying and discharges his responsibility through the work of that division. The division consists of a headquarters unit at Ottawa and nine regional offices each under the direction of a Regional Surveyor.

The bulk of the division's efforts are directed toward the management and regulation of surveys of surface rights in Indian reserves and national parks in the provinces and in Crown Lands in the two territories. The Surveyor General also regulates subdivision surveys of private lands in the territories and surveys of subsurface rights in Canada Lands both on land and in the offshore. The division also prepares legal descriptions of land for inclusion in legal documents on request from federal departments.

Traditionally, cadastral surveys are not referred to a particular datum or coordinate system, but have generally relied on markers placed on or near the boundaries for the exact determination of these. This has changed to some extent during the past 20 or 30 years with the advent of high precision measuring techniques and equipment permitting great precision in determining the position of points on the surface of the Earth both relative to one another and to a coordinate system.

For surveys regulated by the Surveyor General the use of coordinate systems has been applied primarily in two cases: to the survey and definition of parcels in areas of high activity in so-called Coordinated Survey Areas and to the definition of the extent of rights to gas and oil in the territories and in the offshore.

COORDINATED SURVEY AREAS

Section 28 of the Canada Lands Surveys Act provides for the establishment of coordinated survey areas (C.S.A.s) within which all new legal survey monuments placed must be connected to a framework of reference points. The location of monuments are determined and expressed in terms of a system of coordinates specified for the C.S.A.

The Act does not specify a particular datum to be used for all C.S.A.s. In all cases where a C.S.A. has been established under this authority, the coordinate system used has been one related to NAD27. The systems used in the North are the Universal Transverse Mercator and the Territorial Plane Coordinate Systems. In Alberta and British Columbia, to be compatible with the provincial systems, we have used the Alberta 3° Transverse Mercator System and the British Columbia Polyconic System.

Within a C.S.A. the location of monuments placed prior to the establishment of the area may be determined and expressed in terms of the coordinate system in accordance with the instructions of the Surveyor General.

Where the position of a monument that has been determined in this manner is lost, the coordinates of the monument are, in the absence of evidence to the contrary, proof of its position.

Twelve C.S.A.s have been proclaimed on Canada Lands, of which 11 with a total of approximately 800 control survey monuments, are still actively used. Tens of thousands of monumented points have been coordinated within these areas.

Effective immediately, any new C.S.A. proclaimed will be related to NAD83. The division will institute a program to change existing C.S.A.s to NAD83 based reference systems. As C.S.A.s are multi-user systems, this change-over must be performed in consultation with other users of the systems.

It may be noted that due to the distortions present in NAD27 coordinates and to the difference in parameters of NAD27 AND NAD83 it will not be possible to deal with this by a simple translation. Each C.S.A. will have to be readjusted into the NAD83 values for the primary control, probably reinforced with additional G.P.S. measurements at some existing survey control monuments. New coordinates will then be generated for any control survey monument that exists or has existed in the past. Each individual survey will then have to be adjusted into this framework. This task is a massive and complex one and may not be completed for several years. In the meanwhile the existing systems will be used.

CANADA OIL AND GAS LAND SURVEYS

The existing Canada Oil and Gas Land Regulations relate rights to the NAD27. The system of subdivision is one of straight line boundaries and is fully explained in the regulations.

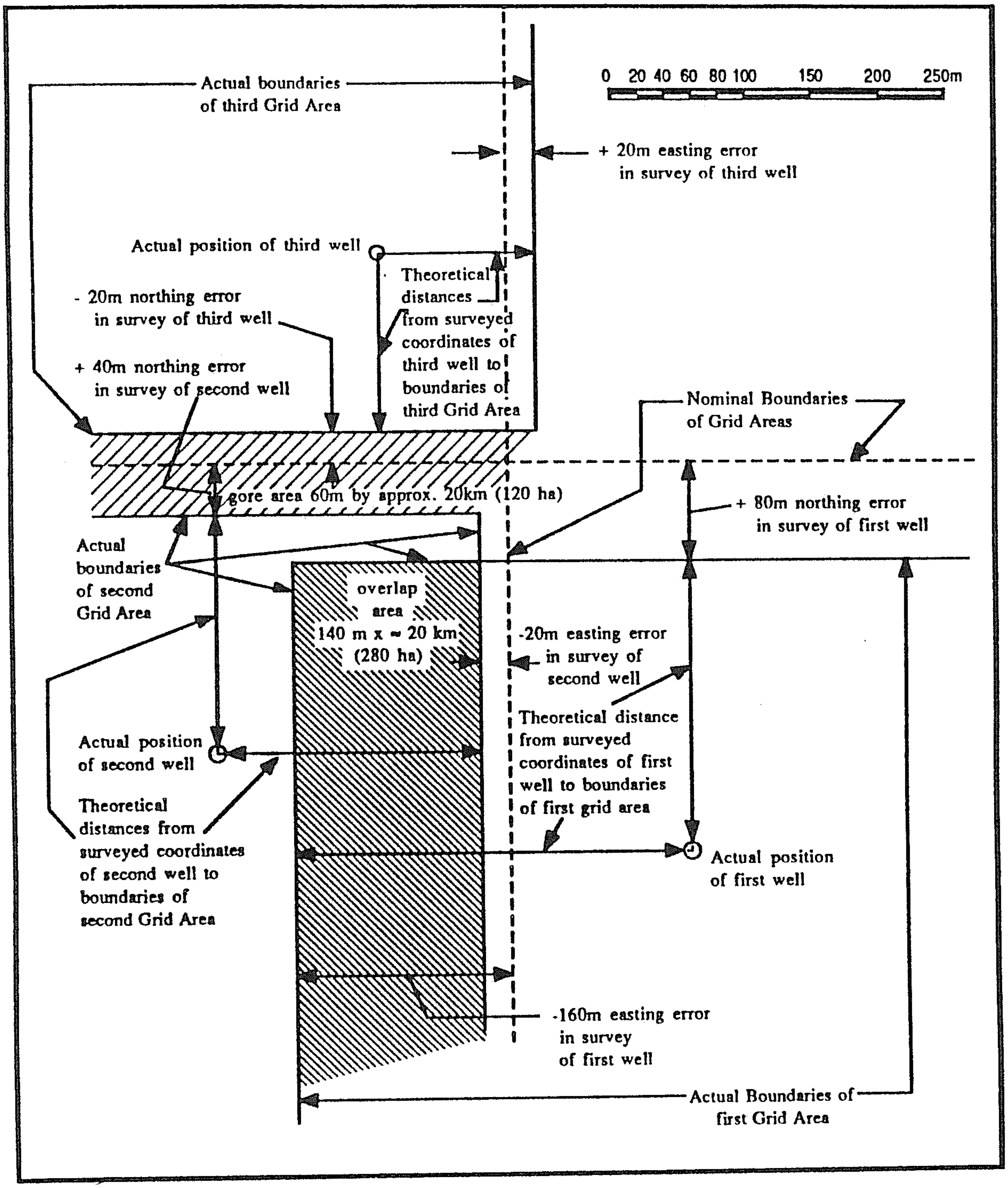
Lands administered under the Canada Oil and Gas Land Regulations are those of the offshore and the Yukon and Northwest Territories.

With early exploration in the offshore taking place as far as 6-800 km from the nearest geodetic control and with the the capability of the survey systems of the day it was unsure that the location of a borehole could be determined to an accuracy of better than 100 m and there was also the possibility that significant blunders may go undetected. For this reason, and to protect the owners of the gas and oil rights, the existing regulations provide that the boundaries of a grid area become fixed in accordance with a plan of legal survey approved by the Surveyor General regardless if the boundary fixed by the survey is found later not to be in the position required by the regulations. The position of the boundaries are related by computed theoretical dimensions from the drilling structure attached to the bed of the sea. Similarly, the boundaries of an adjacent grid area would be fixed by the first legal survey of a well in that grid area. Any overlap resulting from inaccuracies or blunders are deleted from the subsequently established grid area. Figure 1 illustrates how gores and overlaps may develop in adjoining grid areas fixed by legal survey. It may be noted, that while these gores and overlaps do exist in the offshore, we have little knowledge of their magnitude as each survey is performed independently and the location of the borehole, to which the boundaries are referenced, is virtually inaccessible once the drilling rig has been removed from the site.

With development of satellite positioning systems and adoption of NAD83, positions in the offshore may be determined with great accuracy, and new regulations have been drafted dealing with the division of land and the survey of wells, structures and other facilities.

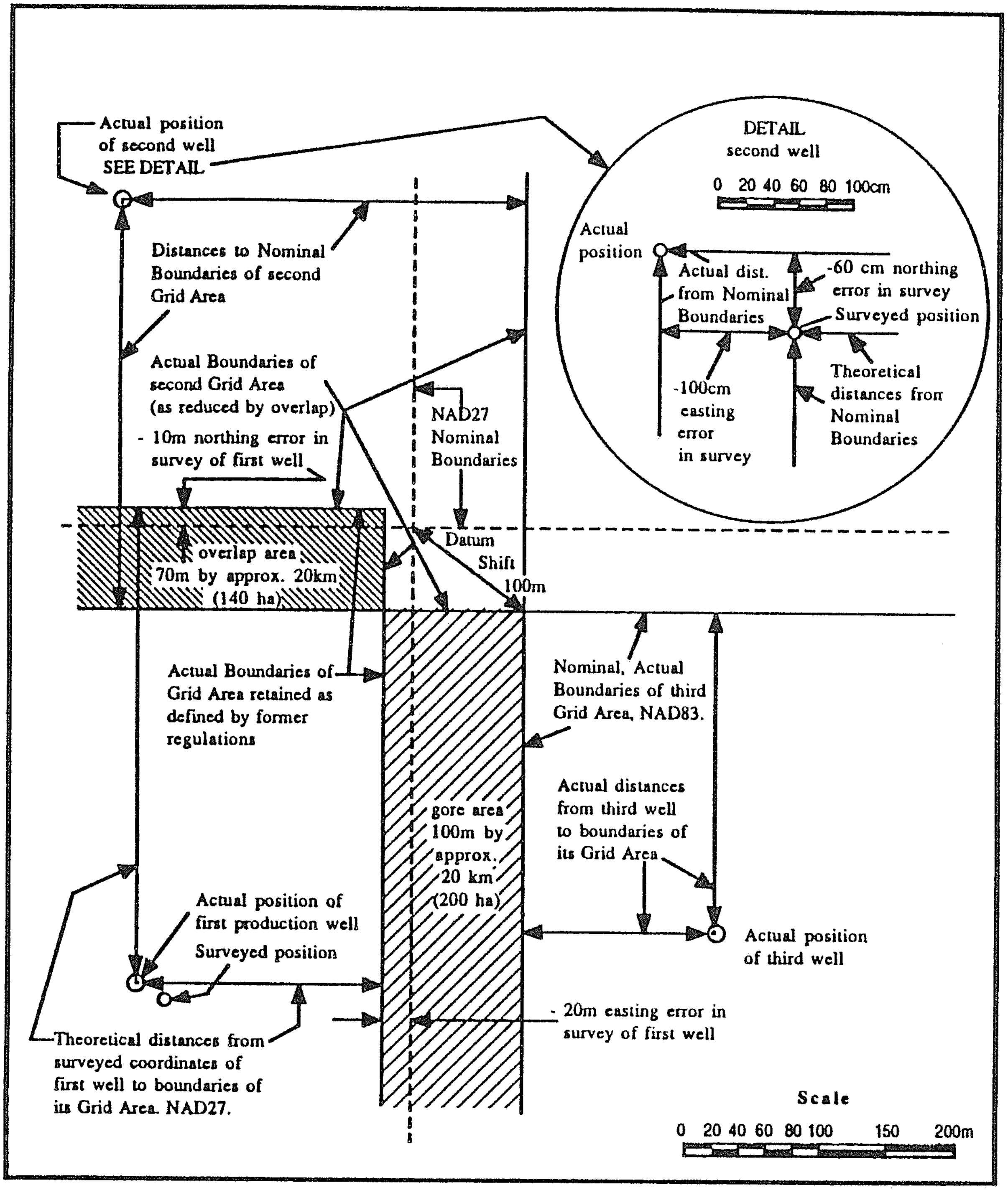
The draft regulations identify the extent of rights to be granted by reference to NAD83. Boundaries will be defined only in terms of latitude and longitude. Surveys will not fix boundaries but will determine the location of the well in respect to the theoretical boundaries of the grid area and to the location of other wells to a

Figure 1



Gore and overlap areas which would be produced by large survey errors of three consecutive production well surveys in adjoining Grid Areas, where the actual boundaries of Grid Areas are defined in accordance with existing Canada Oil and Gas Land Regulations.

Figure 2



Gore and overlap areas which would be produced by retaining rights in Grid Areas defined by the Canada Oil and Gas Land Regulations based on NAD27, upon adoption of the anticipated Canada Oil and Gas Land Division and Survey Regulations based on NAD83.

required accuracy.

Adoption of the NAD83 grid will shift boundaries in the offshore by 60 to 120 metres and will create gores and overlaps between rights granted. The draft regulations provide that any rights granted under the new regulations will be subject to any overlap with existing rights. Figure 2 illustrates the effect of these overlaps.

Once the new regulations come into effect the overlaps will have to be accounted for in the issue of rights. It will therefore be necessary to recalculate the location of boundaries of existing rights and express this in terms of NAD83. In very few cases have boundaries in the offshore been fixed by legal survey and the overlap will therefore consist simply in the datum shift. In the few cases where the boundaries have been fixed the shift may be considered to have 2 components: the datum shift and the error in survey. While the datum shift may be readily computed, the error in survey will be virtually impossible to assess unless the site of the well is reoccupied.

EXISTING LEGAL DESCRIPTIONS

There are hundreds of legal descriptions in existence which are based on NAD27.

While the presence of the new datum does not affect the validity of these descriptions, our ability to determine where the described parcels are on the ground requires the continued availability of a framework of control monuments realizing NAD27. It will therefore be necessary to maintain NAD27 in a data bank or at least to be able to recreate the NAD27 values for some time. We foresee that some of the more important descriptions will be amended to refer t o NAD83.

NATIVE CLAIMS

The Western Arctic (Inuvialuit) Claim is the only major comprehensive land claim affected by the adoption of NAD83.

The land selections of this claim are referred to boundaries of grid areas as defined by the Canada Oil and Gas Land Regulations and therefore to NAD27. The selections are being surveyed by establishing a 3rd order control framework and by establishing the boundaries from this.

Land selections for other claims are either feature related or described by reference to NAD83.

CONCLUSION

Adoption of NAD83 will create a considerable amount of extra work for the Legal Surveys Division in the immediate future. In the long run great benefits will be achieved both from the homogeneous control framework and from new positioning technology being developed.

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Legal Surveys Division. Manual of Instructions for the Survey of Canada Lands, Second Edition 1979, Energy Mines and Resources Canada, Ottawa

Jones, Harold E. and Gray, David H. Offshore Legal Surveys - Datums and Charts. Presented at Colloquium IV, Lake Louise, Alberta, 1986

NAD-83

THE CANADIAN HYDROGRAPHIC SERVICE PERSPECTIVE

(WHAT HAVE WE DONE? WHAT DO WE DO NEXT?)

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ABSTRACT

The implementation of NAD 83 will require the eventual re-publishing of some 1575 charts and chart insets that are in the inventory of the Canadian Hydrographic Service. In 1985 it was estimated that 22.6% of them would need reconstruction or resurvey to define the latitudes and longitudes, 68% would just need a new border with new latitude and longitude grid lines, and 9.4% were deemed acceptable the way they are. In 1986, the NAD 83 coordinates of the 8000 primary stations were published, allowing CHS to compute the shifts between NAD 27 and NAD 83 needed to redefine the latitude and longitude borders and grid points. Production of charts on NAD 83 began in 1987.

The historical background, current status, and future outlook of conversion of charts (West Coast and Western Arctic) within Pacific Region's jurisdiction are presented. The impact on data management, publications related to charts, and problems associated with having some charts on NAD 83 and some on NAD 27 during the transition period are discussed. The impact on field surveys is briefly described.

1. NAUTICAL CHART PRODUCTION

1.1 HISTORY

The conversion of Canadian Hydrographic Service charts to NAD 83 began in earnest in 1985, with a request from the Director General (then Steven MacPhee) to have David Gray of CHS Nautical Geodesy prepare a report on the implications for surveys and charting. In his report (prepared for CHS management meeting, Dec. 1985, reprinted in LIGHTHOUSE, April, 1986) David concluded that:

1. Publication of Charts on NAD 83 is necessary due to the fact that mariners using GPS and Electronic Charts will have continuous positioning, accurate to 0.2 miles or better, yet some charts are old and off datum in relation to these postioning accuracies. Compatibility and consistency will be ensured through the use of NAD 83. Also CHS is committed to provide the International Hydrographic Organization (IHO) with datum shift values between chart datum and NAD 83.

2. The criterion that the displacement in position of surveyed points from charted to NAD 83 be less than 0.2 mm was used to determine that 22% of published charts require total reconstruction or resurvey to define the geographic grid. These charts are on a variety of datums other than NAD 27. Some of these are Astronomic, Shoran, US Standard Pre-NAD27, while others, are unkown. Another 68% can simply be converted by re-drawing the grid and border lines by applying a datum shift, based on adjusted control in the area. Only 10% pass the criteria that a position on NAD 83 plots within 0.2 mm of the same point on NAD 27.

3. The estimated time frame for conversion will be dictated by the normal CHS printing cycle - whenever a chart comes up for Reprint or New Edition the conversion can be undertaken. At best it will take at least 10 years to complete the task.

Publication of New Charts on NAD 83 began in 1986. With the release of the NAD 83 coordinates of the 8000 primary survey points in Canada, Nautical Geodesy was given the task of computing and maintaining a data base of shifts between NAD 83 and NAD 27 and the chart base for all charts and insets. These shifts are provided to the cartographers in order to compile charts on NAD 83 and to place notes explaining the differences between NAD 83 and NAD 27 (or other datum) on the charts.

By March 31 1987, all New Editions of charts were to be either drawn on NAD 83, or if recompiled on NAD 27, were to have the explanatory notes applied so that mariners using a NAD 83 positioning system could apply the correct shift to plot positions on NAD 27.

1.2. CURRENT STATUS - PACIFIC REGION

Pacific Region is responsible for about 300 charts of the West Coast, Western Arctic, Mackenzie River, and a few large lakes. To date, 18 charts have been published on NAD 83, and another 12 are expected to be published in the next year. At the current rate of 10 per year, another 28 years should see the job done!

At this point an explanation of chart production policy and procedures is in order:

1. The mandate is to provide charts for safe navigation. Thus it is more important to update charts by showing changes critical to navigation (new shoals, moved navigation aids etc.) than it is to spend many dollars and man hours completely reconstructing charts just to get them on NAD 83. As stock of any chart runs out, there are three replacement options - create a New Chart, publish a New Edition, or simply Reprint the original. A New Chart is the first publication of a Canadian chart embracing an area not previously charted to the scale shown, or embracing an area different from any existing Canadian chart. A New Edition is a new issue of an existing chart containing amendments essential to navigation in addition to those issued in Notices to Mariners and making existing editions obsolete. A Reprint is a new printing of the current edition of a chart incorporating no amendments of navigational significance other than those previously promulgated in Notices to Mariners. It may also contain amendments from other sources provided they are not essential to navigation. Previous printings of the current edition remain in force, and it is the users responsibility to keep their charts up to date through Notices to Mariners.

2. Updating the existing chart scheme has been ongoing for many years, driven by the need to convert existing charts to a metric/bilingual format, and to reduce the number of charts slightly by providing coverage of coastal waters at scales of 1:40 000 and 1:80 000. Any New Charts planned to fulfill these requirements will be produced on NAD 83. Some planned New Charts in this category are also the reason for new surveys in some areas.

3. As stock of any chart runs out it may be reproduced as a Reprint, which, by definition would not be done on NAD 83. A New Edition may or may not be done on NAD 83, depending on the amount of compilation or reconstruction required. If the chart is digital and in the automated system, it will likely be converted to NAD 83. If it was manually produced it will likely remain on NAD 27. A sticky wicket here is that converting an existing chart changes the coordinates of the four corners, so that by strict definition, it would now be a New Chart - which creates more work prior to production than a Reprint or New Edition. Reprints have the advantage

of not having to pull old stock off dealers shelves.

Obviously many years will pass before all charts are finally published on NAD 83. Mariners will have to deal with NAD 27 charts adjoining NAD 83 during this transition period, therefore the following notes (see figures 1-2 for example) are added to all newly printed charts:

CHART DRAWN ON NAD 83

HORIZONTAL DATUM: North American Datum 1983 (NAD83). Positions on NAD27 must be moved 0.65 seconds southward and 4.88 seconds westward to agree with this chart.

CHART DRAWN ON NAD 27

HORIZONTAL DATUM
This chart is drawn on North American Datum 1927 (NAD27). Positions on NAD 83 must be moved 0.65 seconds northward and 4.88 seconds eastward to agree with this chart.

On small scale charts such as chart 3001, Vancouver Island at a scale of 1:525 000 where the shift is not plottable, the following notes will appear:

HORIZONTAL DATUM: This chart is drawn on North American Datum 1983 (NAD 83) which, at this scale is equivalent to NAD 27.

or

HORIZONTAL DATUM: This chart is drawn on North American Datum 1927 (NAD 27) which, at this scale is equivalent to NAD 83.

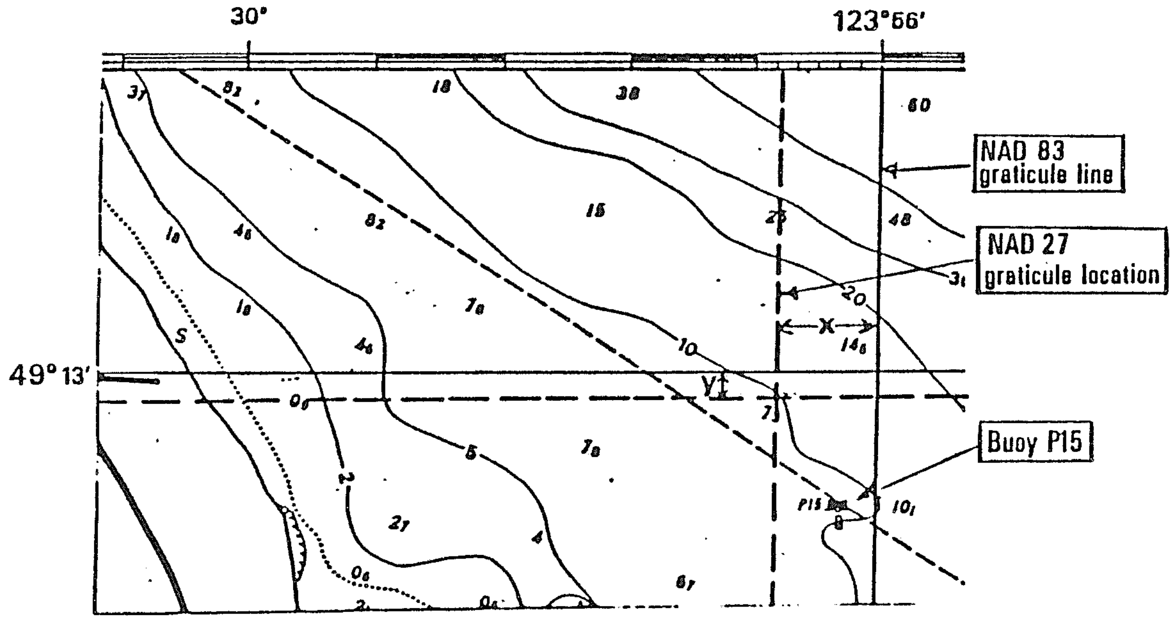
1.3 CHARTING SUMMARY TO DATE - PACIFIC REGION

By December 1990 63% of the west coast charts will either be drawn on NAD 83 or will have the horizontal datum note added. By December 1991, it is estimated that 80% will be updated:

WEST COAST CHARTS 1990-91

	DEC. 1990	DEC. 1991
CHARTS ON NAD 83	18	35
CHARTS ON NAD 27 (OTHER) WITH HORIZONTAL DATUM NOTE	108	125

CHART DRAWN ON NAD 83



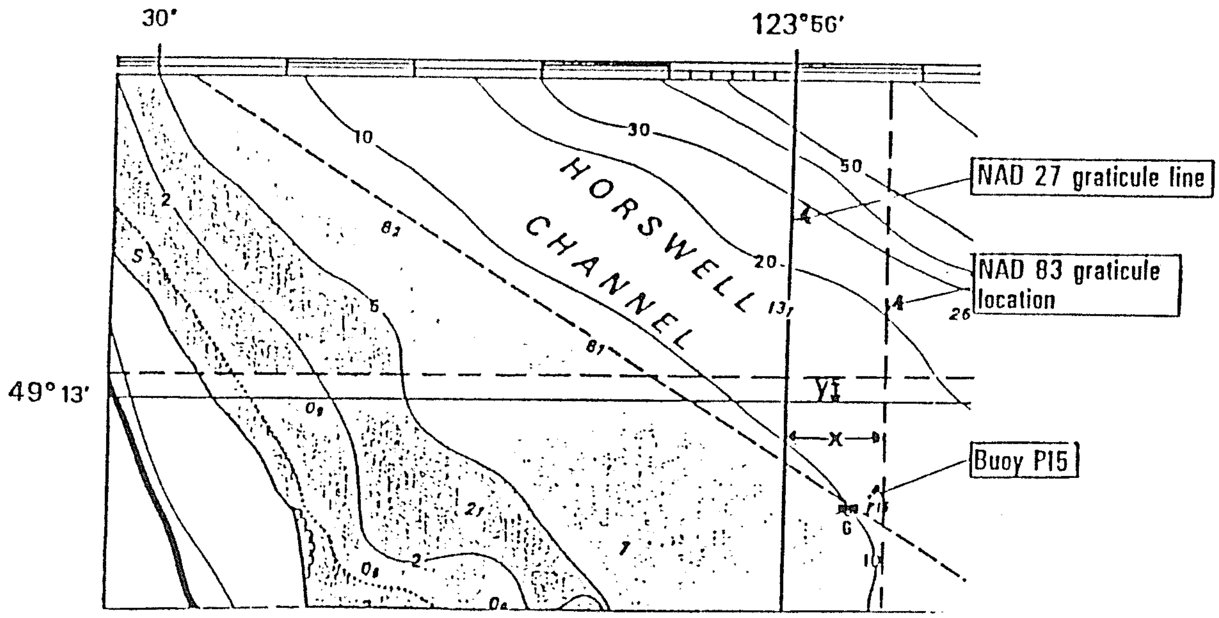
HORIZONTAL DATUM: North American Datum 1983 (NAD 83). Positions on NAD 27 must be moved 0.65 seconds southward and 4.88 seconds westward to agree with this chart.

In this case
y (0.65) seconds must be subtracted from the NAD 27 latitude position value and x (4.88) seconds must be added to the NAD 27 longitude position value prior to plotting.

Ex: NAD 27 values of buoy P15	**49° 12′ 56.″50 N**	**123° 55′ 57.″00 W**
	minus 0.65	**plus 4.88**
NAD 83 values to be used for plotting	**49° 12′ 55.″85**	**123° 56′ 01.″88**

FIGURE 1

CHART DRAWN ON NAD 27



HORIZONTAL DATUM
This chart is drawn on North American Datum 1927 (NAD 27). Positions on NAD 83 must be moved 0.65 seconds northward and 4.88 seconds eastward to agree with this chart.

In this case
y (0.65) seconds must be added to the NAD 83 latitude position value and x (4.88) seconds must be subtracted from the NAD 83 longitude position value prior to plotting.

Ex: NAD 83 values of buoy P15	49°12′55.″85 N plus 0.65	123°56′01.″88 W minus 4.88
NAD 27 values to be used for plotting	49°12′56.″50	123°55′57.″00

FIGURE 2

This leaves 60 charts to be updated in the next 5-7 years, depending on depletion of existing chart stocks.

Conversion of Western Arctic charts has been put on hold pending final adjusted coordinates of control. To date, no Arctic charts are on NAD 83, however 14 have the horizontal datum note, leaving about 100 charts to be updated.

These figures and the time frame have been estimated for Pacific Region only. The time frame for conversion in the other regions was not researched at this time.

Some charts (both Western Arctic and Pacific Coast) are not currently drawn on NAD 27, but are on a local datum, astronomic datum or some "orphan" datum. These areas will have to be re-surveyed before they can be published on NAD 83.

Canada-wide, 30% of all charts are non-datum. A good example are the MacKenzie River Charts which were constructed on the circa 1960 topo maps. The presently accepted NAD 27 for the River is based on post 1969 Aerodist and doppler surveys. There is no systematic shift between pre 1969 chart datum and post 1969 NAD 27. Differences vary from an estimated 0.3 to 0.5 nautical miles. The following note will accompany such charts until such time as new surveys are done:

> HORIZONTAL DATUM: Positions plotted from navigation systems such as GPS, SATNAV, LORAN-C, OMEGA, may be in error by by "X" miles because the horizontal reference datum for this chart is unknown. Positioning methods such as range and bearing should therefore be used.

2. INFORMATION MANAGEMENT - CHARTS AND RELATED PUBLICATIONS

Having a mixture of NAD 27 and NAD 83 for the foreseeable future creates a bit of a data management nightmare. Any time geographic positions are changed or published in documents such as Sailing Directions, Orders-in-Council, International Boundary documents, the List of Lights, etc. care will have to be taken to avoid confusion. A good example of how problems can occur can be illustrated by the List of Lights. Positions of all lighted navaids are listed along with the largest scale chart the aid is plotted on, and the year the light was erected or last altered. This publication is produced by the Ministry of Transport (MOT) with many light positions simply taken off the largest scale chart. At present the book doesn't indicate the datum of positions, so it is possible, for example, to have 10 lights on a given chart all positioned on NAD 27. Now suppose a new NAD 83 chart is produced and a new light erected, and positioned on NAD 83 using the chart. The List of Lights will now have 10 lights with NAD 27 positions and one with NAD 83 coordinates. (See figure 3).

SAMPLE FROM LIST OF LIGHTS ILLUSTRATING POSSIBLE PROBLEMS.

DISCOVERY PASSAGE

Name	Position Latitude N. Longitude W.	Colour of Light	Char	Elev in m. above water	Nominal Range	Character of apparatus	Description of structure Height in metres above ground	Year Est and last altr'd	Remarks Fog Signals
Tyee Spit range	50 02 53 4 125 15 26	Y	Q	2 2	—	Electric	Circular mast, white daymark, red vertical stripe.	1980 1987	Flash 0.3 s; eclipse 0.7 s Visible in line of range.
	196°34' 38.3 m from front.	Y	Q	5 2	—	Electric	Circular mast, white daymark, red vertical stripe.	1980 1987	Flash 0.3 s; eclipse 0.7 s Chart:3540
Duncan Bay Fog Signal	W. corner of shipping wharf. 50 04 30 5 125 17 14	—	—	—	—	—	—	1961	Whistle - Blast 3.5 s; silence 26.5 s Privately maintained Chart:3540
Steep Island	W. side of Island. 50 04 45 125 15 06	W	Q	6 4	—	Electric	White circular tower, red band at top.	1962 1975	Flash 0.3 s; eclipse 0.7 s Chart:3540
Race Point	On E. extremity of point. 50 06 48 6 125 19 24.8	G	Q	23 5	—	Electric	White circular tower, green band at top.	1943 1988	Flash 0 3 s; eclipse 0.7 s Chart:3539
Maud Island South	50 07 41 125 20 26	R	Fl	6.1	—	Electric	White circular tower, red band at top.	1984	Flash 0 5 s; eclipse 3.5 s Chart:3539
Maud Island	On rock, W. side of Island, Seymour Narrows. 50 07 50 5 125 20 47	R	Q	8 5	—	Electric	White circular tower, red band at top.	1907 1983	Flash 0 3 s; eclipse 0.7 s Chart:3539
Wilfred Point	On point. 50 07 50 9 125 21 26 7	G	Q	6.7	—	Electric	White circular tower, green band at top.	1968 1988	Flash 0.3 s; eclipse 0.7 s Chart:3539
Brown Bay	50 10 00 125 22 01 5	G	Fl	6 0	10	Electric	White circular tower, green band at top.	1988	Flash 0.5 s; eclipse 3.5 s Chart:3539
Separation Head	50 10 45 125 21 11	R	Fl	6 5	—	Electric	White circular tower, red upper portion.	1985	Flash 0.5 s; eclipse 3.5 s Chart:3539
McMullen Point	On point. 50 14 45 4 125 23 44	W	Fl	8 5	5	Electric	White circular tower, green band at top.	1962 1986	Flash 0.5 s; eclipse 3.5 s Chart:3539
Cinque Islands	W. side of Island. 50 17 43 8 125 23 58 6	R	Fl	6 7	—	Electric	White circular mast, red and white triangular daymark.	1970 1986	Flash 0.5 s; eclipse 3.5 s Chart:3537

Handwritten annotations: Maud Island position (50 07 50 5 / 125 20 47) and year 1907 / 1983 circled — "Definitely NAD 27"; Brown Bay position (50 10 00 / 125 22 01 5) and year 1988 circled — "NAD 83 or NAD 27 ?"; Brown Bay Chart:3539 circled — "NAD 83".

FIGURE 3

More typically, it will be sometime before the Light List is updated, therefore the positions given in the List will be different from the plotted position on a NAD 83 chart. Most lights have been surveyed by CHS and are in the CHS control data bank, so computing NAD 83 positions will not be difficult. But publishing all light positions on NAD 83 will not end the confusion, because there will still be a mix of NAD 27 and NAD 83 charts. Suffice to say - problems such as these will cause nothing but trouble and confusion for cartographers and surveyors for years to come, to say nothing of the poor Mariner!! During revisory surveys this past season re-positioning lights, buoys, and soundings on a NAD 83 chart using NAD 27 control files was trouble enough!

3. THE IMPACT ON FIELD SURVEYS

The ramifications of NAD 83 on field hydrography are minimal but important. Now that the primary and secondary coordinates are available on NAD 83, CHS Pacific intends to survey on NAD 83 in 1991. All computer programs (control, launch data gathering, and data processing software) that deal with geographic coordinates and projections are currently being upgraded to work in both NAD 83 and NAD 27. The Geodetic Surveys of Canada survey control adjustment package, GHOST, will remain in use as our main control adjustment program.

Since the new ellipsoid does not fit mean sea level as well as it did with the NAD 27 datum, measured distances will have to be reduced to the new ellipsoid, not to mean sea level. Upgrading the distance reduction program has already been done to output either ellipsoid or mark to mark distances, depending on the requirements of the network adjustment.

Until GPS replaces conventional geodetic positioning techniques, hydrographers will continue to recover monuments in the ground and extend new control from them. The positions of the starting monuments will have to be on NAD 83. With luck a given survey area will tie in to Geodetic or Provincial Control already adjusted. Another task, prior to heading out in the field, will be to research all existing observations with ties to primary or secondary NAD 83 control, enter those observations into GHOST, and readjust our own networks. Furthermore, there should be an even stronger policy in the CHS to tie all future work to higher order NAD 83 control points. Advantages to doing so will be: (1) consistency in adjoining networks, (2) better reductions of measurements to the ellipsoid because deflections of the vertical will be known at GSC satellite positioned points, and (3) CHS measurements will be of more value to other agencies. One danger that exists: if old surveys are simply transformed to NAD 83 and not readjusted, the old distortions may be carried along in the transformation. Surveyors must be wary of this!

Due to the number of years involved until all charts are NAD 83; field work will be required in both NAD 27 and NAD 83 for the forseeable future. Particularly when revisory work is required for a NAD 27 chart. The transformation programs will be major tools in our inventory.

4. CONCLUSIONS

Conversion of charts to NAD 83 is most necessary due in part to GPS, and electronic charts being used more and more for navigation. The need for precise charts and digital data is paramount to enable mariners to navigate more precisely through busy routes, closer to headlands or banks, in order to save fuel or fish more efficiently. However the cost of reproducing all charts as soon as possible in a systematic fashion would be astronomical. The printing cost alone for 5000 copies of a four colour chart (not including cartography costs, the paper they are printed on, or the distribution costs) is about $5000. Depending on the chart's annual sales, each new printing requires between 1500 and 15 000 copies! For some years to come, Mariners and other users of Nautical Charts and publications will have to live with a mix of NAD 83 and NAD 27.

The task of converting all charts to NAD 83 would be somewhat easier if all data were in digital format, if every cartographer had a graphics work station, and if all charts could be produced by automated processes. However, it is only in the last few years that field surveys have become fully automated, and the question of converting analogue Field Sheets to digital format always sparks a lively discussion within CHS. Given the large number of analogue Field Sheets currently in our Hydrographic Data Centre, the task of digitizing them all is enormous and daunting. Some argue that doing digital surveys within a long term plan would be more economical and efficient than conversion of old Field Sheets. Others argue that with Electronic Charts and sophisticated integrated positioning systems becoming common navigating tools, digital chart files are a must.

In reality, the number of automated work stations currently on hand, are but a few - again a function of cost and available capital. The only reasonable method is to tackle the job of conversion whenever a chart normally comes due for a Reprint or New Edition. Some of these can be prepared by digital methods, while the majority will require manual cartographic methods for some time to come. Each job will be examined on an individual basis to determine the best route to take.

As David Gray so aptly put it: "All charts are of equal value in the eyes of the author when setting priorities for datum conversion, for he will not be satisfied that the project is complete until the last chart is done. But the real world just isn't that way." This author agrees wholeheartedly!

Finally - they did this in 1927 - without computers!! Would that have made life harder or easier? Will we have to do this again in 60 years when space technology provides real time dynamic positioning to the millimetre?

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IMPLEMENTATION OF NAD83 IN BRITISH COLUMBIA

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Abstract

One of the major projects underway at the Surveys and Resource Mapping Branch (SRMB) of the British Columbia Ministry of Crown Lands is that of the establishment and maintenance of the new NAD83 geodetic reference system for British Columbia. With the adoption of NAD83 now official, this paper provides an overview and status of the project and offers heightened awareness of the impact of NAD83 on all direct and indirect users of geodetic control.

Introduction

On May 23, 1990, and May 24, 1990, the federal and provincial (B.C.) governments announced the adoption of the NAD83 (North American Datum of 1983) geodetic reference system in their respective jurisdictions. The NAD83 system will replace the NAD27 (North American Datum of 1927) system which has been in use for the past 60 years. The large distortions in the NAD27 system will be removed and the NAD83 system will be internally consistent as well as consistent with the satellite survey techniques now being implemented.

The existing geodetic reference system, called NAD27, is being replaced by NAD83 in B.C. over the next two years through cooperation with the rest of Canada, under the auspices of EMR Canada's Canada Centre for Surveying (Geodetic Survey Division). Various articles describing the components of this international project (North American countries from Greenland to Panama) have been written. A good overview of the canadian perspective is available in a 1988 paper by the Federal Government.[1] As well, the status and plans for B.C. have been presented to various audiences, including the 1988 CISM seminars on NAD83 and its impact on users, where Mr. Gordon Wilkinson's paper provides excellent background.[2] Readers of this article are therefore referred to the Wilkinson paper for a historical description of the project in B.C.

Why NAD83

NAD27, established through surveys across Canada with considerable care and within the limits of accuracy that the technology of the day had to offer, adequately served its intended purpose up to the early 1960's.[3] The 1927 geodetic reference system cannot meet modern day demands of current and future position-related activities.[4] The new NAD83 geodetic reference system is intended to meet these needs. Changes resulting from NAD 83 are therefore critical to future economics in the production and use of land-related information. As an example, over $2 billion were spent in 1986 alone in one province (Alberta) on programs which have a direct land-related (ie: positionaly related) component and rely heavily on the geodetic reference system.[5]

The following reasons are often cited as motivation to ensure conversion of all land-related data holdings (both public and private) to NAD83.

- Proliferation of local coordinate systems impede overlaying and edge-matching of information gathered from various sources (for example, utilities companies and municipalities). Universal compatibility is the foundation of true Geographic Information Systems (GIS). NAD83 provides for a homogeneous, global, survey control network on which all geo-referenced data can be made universally compatible.

- Distortions in the NAD27 datum based survey control coordinates result in added costs for surveys due to reliability concerns.

- Advent of Global Positioning System (GPS) technology has spurred myriad applications based on a universal (global) coordinate system (that is compatible with NAD83).

- Future Active Control System (ACS) will be based on geocentric coordinate system consistent with the new NAD83 datum. Thus, data collected tomorrow from cheap, hand-held, receivers by practically any citizen, will yield coordinates directly consistent with the NAD83 datum.

- The current Terrain Resource Information Management (TRIM) 1:20,000 mapping is already on NAD83. All future Federal Government mapping will also be undertaken on NAD83.

- The Canadian Government declared, on May 23,1990, NAD83 as the official datum for Canada. The British Columbia Government followed immediately and announced adoption of NAD83 on May 24,1990.

- Transformation of NAD83 compatible coordinates to old NAD27 datum based coordinates is an imprecise procedure due to the un-modelable distortions inherent in the NAD27 system.

- NAD83 conversion offers an opportunity to users to rationalize and computerize their current operations and clean-up their data resources.

- Low-cost user-friendly intelligent graphics work stations, in the future, will become common and users will demand from government agencies on-line access to consistent geographic data sets for their displays and decision-making.

- Costs associated with the maintenance of Integrated Survey Area control points will be reduced due to more homogeneous survey control networks on NAD83.

- Conversion software, from NAD27 coordinates to NAD83 coordinates, has been developed by the Federal Government so as to provide NAD27 users a means for data conversion.

- More control points will be available on NAD83 than on NAD27. New points will be computed on NAD83 only by both Federal and Provincial Governments because transformation to NAD27 (once surveyed under NAD83) is an inexact science. Old NAD27 coordinates will be phased out by the mid-1990's.

In order to understand the requirements for NAD83, the need to understand the uses for geodetic control at first is obvious. The following definition of geodetic control is set forth for these purposes. Thereafter, the translation of the definition to the actual situation in British Columbia is presented to offer contextual understanding of geodetic control usage in the province.

Geodetic Control - Definition

Geodetic Control, often referred to as Survey Control, can be compared to the steel skeleton which supports a building. As a steel skeleton supports a building, Geodetic Control, through its provision of an accurate coordinate system, supports all position-related activities. Position-related activities include, but are not limited to:[6]

·Development and operation of computerized land-related information systems

·Topographical and resource mapping

·Cadastral (real properties) mapping

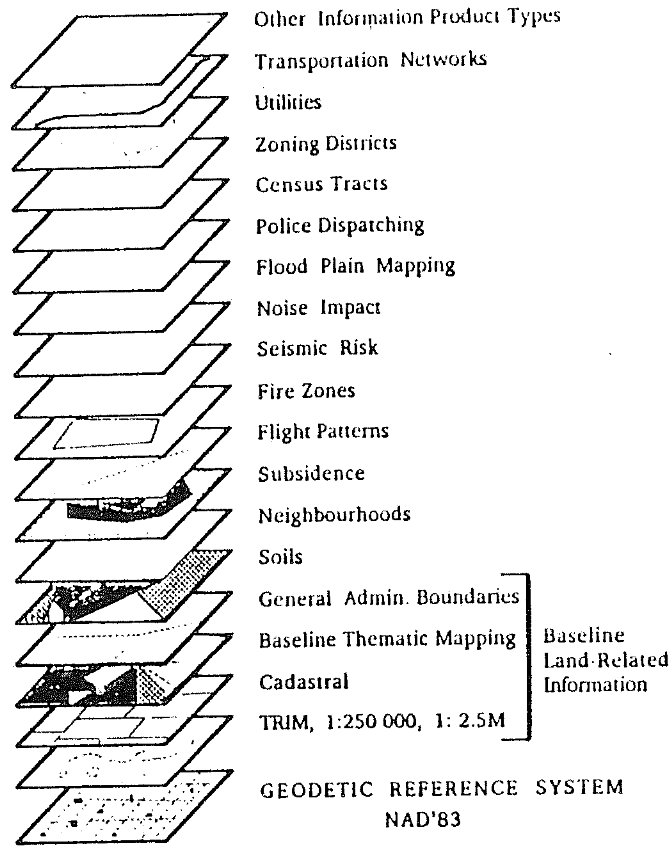

Figure 1. Secondary and Tertiary Products Based on a Geodetic Reference System.[8]

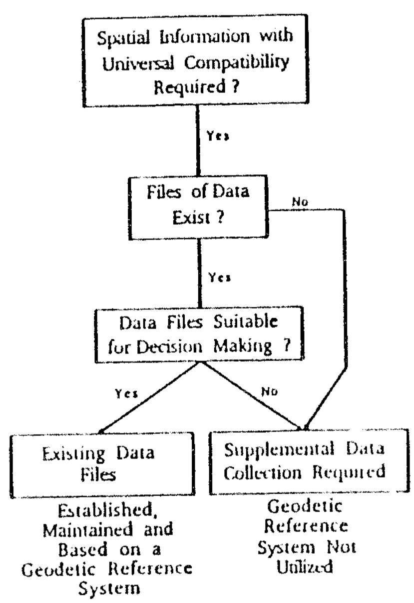

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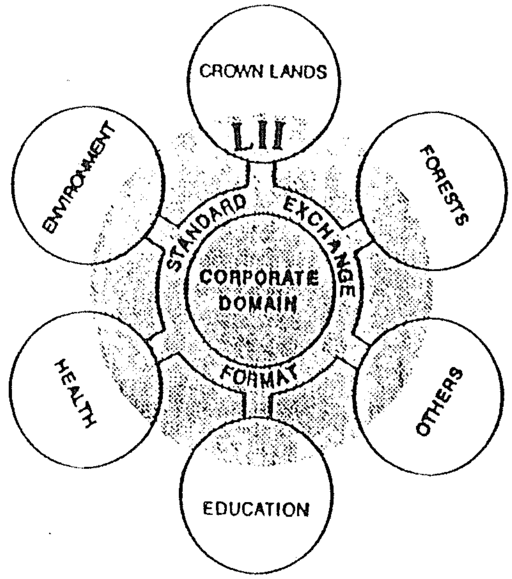
Figure 2. The Land Related Decision Process.[7]



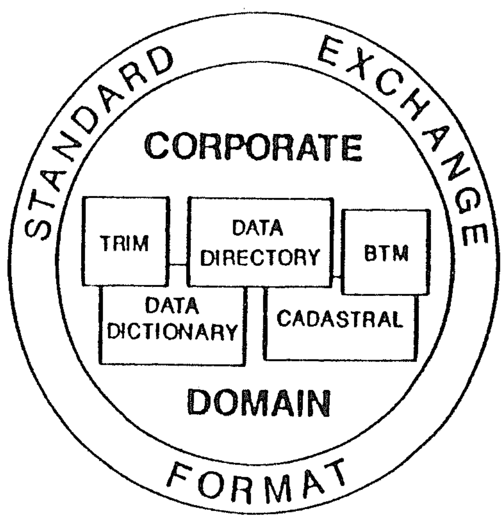


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Figure 3. The Land Information Infrastructure (L.I.I.). The L.I.I. facilitates the sharing and exchange of land related data. The Corporate Domain at the hub of the L.I.I. consists of baseline data that can be utilized by a number of user agencies. The Standard Exchange Format will provide the means through which data is exchanged between ministries.[8]

·Integrated engineering projects (planning, reconnaissance and construction)

·Exploration for and recovery of natural resources

·Coordinating positions of surface and subsurface installations for future location and protection

·All forms of navigation (water, air, land)

In the same way that the multi-storied building requires a substantial foundation and an accurately positioned steel framework, modern positional applications (e.g. Geographic Information Systems or GIS's) require a precise coordinate system framework (Figure 1). It is also obvious from the preceding that secondary and tertiary users of the geodetic reference system avoid costs of compatibility with other information products when attempting to aggregate or compare data and information. Figure 2 illustrates this point.[7]

Geodetic Control - Application

The Ministry of Crown Lands has the mandate to manage the geodetic reference for subsequent geographic positioning and navigation. Further, the Ministry is tasked to secure geographically referenced baseline data fundamental to the GIS requirements of British Columbians engaged in managing natural resources and municipal infrastructure, and to manage a corporate GIS framework within which GIS's can evolve within government ministries while maximizing opportunities for data sharing.

As well, the geodetic reference management requirement within the Ministry also derives from legislation under the Land Survey Act and the Petroleum and Natural Gas Act. These Acts are fundamental to the cadastral fabric of the province and to exploration activities in the petroleum and natural gas industries, respectively.

In British Columbia, the Land Information Infrastructure (L.I.I.) is a concept whereby land-related activities can be supported through a (largely) computer-based medium.[8] Integral to this medium is the need for universal (data) compatibility, entailing a standard base referencing system with standard technology and a standard access system for the exchange of land-related information. Given such a medium, baseline land-related information - that is the information system forming the base land-related data describing the B.C. water and land masses - may be linked to subject data bases containing location based information to facilitate integrated business decisions using GIS technology (Figure 3).

The implementation of this L.I.I. in the province is being directed by the Land Information Strategic Committee and it is envisaged that the benefits of this program will extend to local governments and the private sector in the form of more timely and accurate data exchange as well as the provision of better land information.[9]

Survey Control provides the basic geodetic reference system necessary for an accurate and consistent framework in the L.I.I. NAD83 is the standard for modern georeferencing needs within this L.I.I.

NAD83 Establishment

NAD83 is being established by re-adjusting all of the continental (North American) horizontal survey control data gathered to date (1900's to 1980's) in a rigorous manner. The adjustment is being performed on a geocentric ellipsoid definition of the Earth called GRS'80 (Geodetic Reference System 1980). This ellipsoid definition is globally based (not just best fitted to North America as in the old NAD27 definition) and is consistent (i.e. coincident) with the satellite based definitions of the Earth (e.g. WGS84 or World Geodetic System 1984) which is used for satellite-based surveying with the Global Positioning System (GPS).

The Canadian effort is spearheaded by Geodetic Survey Division (GSD) of EMR Canada in Ottawa. Apart from the national "framework" data, the provinces have contributed "secondary" data to Ottawa for simultaneous (i.e. rigorous) adjustment of Canadian data by Ottawa. For B.C., this means that all non-ISA (Integrated Survey Areas) horizontal survey control data are included in the Ottawa adjustment. For data management purposes, GSD first completed the Eastern Canada adjustment and then completed the Western Canada adjustment. This methodology utilizes the GHOST software and the Helmert Blocking technique to least squares adjustment.

With the completion of the Western Canada adjustment, B.C. will now integrate the remainder of the geodetic control onto this NAD83 framework. Thus, the ISA's will be incorporated by the weighted stations adjustment technique simulating the simultaneous, rigorous method of adjustment. By the end of 1992, all geodetic control in B.C. should be thus converted onto NAD83.

As the above work progresses in converting the ISA's onto NAD83, network weaknesses will be identified and targeted for strengthening using conventional geodetic surveying or GPS means. NAD83 should yield distortion-free geodetic control coordinates that have relative accuracies in the order of a few centimetres in urban networks (ISA's) and less than 1 metre relative accuracy in rural regions (i.e. non-ISA's). This is a vast improvement over

NAD27, whereby, regional distortions of several metres may be found in B.C. Perhaps, the most important improvement with NAD83 will be on the question of reliability in coordinates. That is to say, a far greater confidence will be attached to the NAD83 coordinates than was previously possible due to the nature of the simultaneous and weighted station adjustment techniques used in Ottawa and Victoria, respectively.

Impacts/Transforming to NAD83

NAD83 will result in coordinate shifts of 50 to 150 metres in geographic coordinates (mainly west south-westerly) and in excess of 200 metres in UTM coordinates (mainly north north-westerly) in B.C. Table 1 shows the shifts for selected points around the province. Note that the shifts vary in size due to the distortions in NAD27. For example, across southern B.C. (south of 52· latitude), the variations are up to 25 metres (Frost and Lucky) and across the whole province, variations as high as 45 metres may be found (Frost and Goat Ridge). These differences point out the dangers in using a simple mean shift of selected common points when transforming NAD27 coordinates to NAD83 coordinates. No doubt such a method may be sufficient for low accuracy requirements over areas of small extent.

To account for variation of relative position due to distortion between two adjustment systems, additional modelling parameters must be considered.[10] Geodetic Survey Division (Federal Government) has now developed software to do just this.[11] The software and techniques developed at GSD are being promoted as a national standard so as to provide uniformity and consistency in NAD27 to NAD83 coordinate conversions. SRMB is working closely with GSD to ensure that the software meets provincial needs. We have adopted the software as our standard and are ensuring its availability to all interested users.

The GSD transformation software consists of two program packages: SCTRANS/ESTPM and the GRID ALTERNATIVE. The SCTRANS/ESTPM package is known as the National Transformation. The GRID ALTERNATIVE is an easily implementable transformation, provided as a stand-alone package and as a callable subroutine. The program SCTRANS applies a seven parameter transformation to perform the datum transformation and absorb a portion of the distortion. The program ESTPM computes a polynomial distortion model to account for most of the remaining distortion between the two adjustment systems. The combination of SCTRANS and ESTPM produces a transformation with good relative accuracy but the process is computationaly intensive. This technique does not lend itself well to use with very large data files such as a GIS or digital mapping files.[12]

Station
FROST
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MACPHERSON
GLEN
DOUGLAS
LUCKY
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GRAND
BRIDGE
FRASER
FERGUSON
TALTAPIN
CECIL
GETHING
FORT
KWOK
ANDREWS
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Station	Latitude	Longitude	dLat (sec)	dLong (sec)	Differences in UTM Coords dN (m)	dE (m)	Dist (m)	Brg (deg)
FROST	49 04 18	115 11 10	-0.1	3.6	213.3	-77.8	227.0	340
KELLY	49 08 21	117 25 36	-0.3	4.0	210.9	-79.6	225.5	339
DISH	49 20 37	119 40 19	-0.4	4.3	208.7	-81.3	223.9	339
MACPHERSON	50 55 55	118 19 06	-0.3	4.2	212.2	-78.1	226.2	340
GLEN	51 22 25	116 52 09	-0.1	4.0	215.9	-77.7	229.5	340
DOUGLAS	48 29 35	123 20 48	-0.7	4.7	199.1	-95.6	220.9	334
LUCKY	49 04 30	125 17 29	-0.7	5.1	200.4	-98.8	223.5	334
BARR	49 15 49	121 33 33	-0.6	4.6	200.0	-95.3	221.6	335
GRAND	49 19 17	123 03 27	-0.6	4.7	200.1	-95.7	221.8	334
BRIDGE	51 32 37	120 43 27	-0.3	4.6	205.9	-94.0	226.3	335
FRASER	51 58 26	122 13 48	-0.3	5.0	207.2	-96.9	228.7	335
FERGUSON	54 02 48	122 53 36	-0.2	5.4	210.5	-98.8	232.5	335
TALTAPIN	54 23 14	125 20 25	-0.3	5.9	209.5	-101.0	232.6	334
CECIL	56 24 55	120 35 24	-0.2	5.3	203.5	-96.3	225.2	335
GETHING	56 02 05	122 26 02	-0.2	5.5	206.2	-96.8	227.8	335
FORT	58 48 58	122 24 20	-0.4	5.3	195.5	-87.0	214.0	336
KWOK	59 16 16	120 39 11	0.1	5.4	206.7	-91.2	226.0	336
ANDREWS	59 55 38	122 56 21	-0.6	6.4	187.6	-98.9	212.1	332
SHUSHARTIE	50 46 51	127 48 33	-0.7	5.8	195.4	-115.5	227.0	329
CALVERT	51 32 38	127 57 13	-0.6	5.9	196.8	-115.1	228.0	330
IKEDA	52 16 42	131 06 04	-0.8	5.9	197.8	-108.4	225.6	331
TOW HILL	54 04 28	131 47 55	-1.0	5.9	188.3	-102.5	214.4	331
RUPERT	54 18 02	130 10 37	-1.0	6.2	186.0	-109.5	215.9	330
WILLIAMS	54 24 11	128 16 24	-0.7	6.2	192.3	-113.1	223.1	330
GOAT RIDGE	56 16 37	126 48 30	-0.4	6.7	196.7	-119.9	230.4	329
JUNCTION	56 46 28	129 52 53	-0.8	6.2	189.1	-103.2	215.4	331
COAL	59 59 17	127 01 23	-0.7	5.7	182.5	-92.4	204.6	333
ALBERT	59 58 09	129 16 32	-0.8	6.0	182.8	-92.7	205.0	333
DAWSON	59 59 20	132 31 17	-1.0	6.3	181.9	-91.2	203.5	333
PONDE	59 51 43	135 00 34	-1.1	6.6	180.2	-92.9	202.8	333

Table 1. Differences between NAD83 and NAD27 coordinates at selected primary framework stations in British Columbia.[2] (NAD83 - NAD27)

GSD has developed the GRID ALTERNATIVE to reduce the computation time and provide a solution which can be easily implemented within an established system. The GRID ALTERNATIVE consists of a table of shifts between the two adjustment systems on a regular arc-minute grid (for example, every 5 arc minutes). The table of shifts is computed by GSD from the SCTRANS/ESTPM package solution. A simple standard algorithm to interpolate at positions within the grid is provided. The facility for some users to generate a more dense grid may also be included. For example, as the ISAs are adjusted and integrated onto NAD83 a denser, more refined grid will be formulated for these areas. The GSD software is in standard FORTRAN77 code and runs on a variety of computers, including a PC. The datum shift for a point within the grid is established by bilinear interpolation. Bilinear interpolation exhibits several properties dealing with topology. The transformation surface is continuous and the grid boundaries are co-linear. Continuous features will thus remain continuous within the grid and across grid boundaries. Linear features will be distorted, i.e. conformality is not preserved.

When selecting a transformation method, the preferred method to achieve the highest relative accuracy is to recompute or readjust the observations using weighted stations adjustment techniques. Original observations may not be available to users, therefore other transformation techniques must be used.

Many software packages exist to compute transformations for plane coordinates, most of which use a similarity transform. These transformations are applicable to small areas only since nonlinear distortions exist between NAD27 and NAD83. Dense control with the coordinates known in both systems is also required in the area to properly define the transformation. Non-conformance of these solutions with the solutions from the National Transformation is also a significant issue since multiple sets of NAD83 transformed coordinates will be generated for the same (common) points. The GRID ALTERNATIVE software will work well in small areas where dense control exists if there are no large distortions in the NAD27 framework. The existing control can then be put to use in checking the accuracy of the transformation (simply by comparing the transformation generated coordinates for an existing station with its actual, rigorous adjustment derived, coordinates). In areas of sparser control, the GRID ALTERNATIVE should be used over other methods. This will provide implicit agreement with the National Transformation

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and prevent problems arising from inadequately defined transformation parameters. The SCTRANS/ESTPM suite of programs should be used in areas requiring the highest relative accuracy. The SCTRANS/ESTPM programs form the basis of the National Transformation use of the SCTRANS/ESTPM suite will ensure that all users will always produce the same transformed values for the same points, a distinct advantage in reducing potential sources of confusion and disagreement. In all cases, caution must be exercised to ensure large nonlinear distortions in the underlying NAD27 coordinates are not adversely affecting the transformation. Under certain circumstances, no transformation method will provide adequate results (due to these unmodelable distortions affecting the solution).

To gain an indication of the accuracy of any transformation, techniques such as inspecting predictions at common points and reserving common points from the computations should be used. The term "common point" refers to a marker for which the coordinates are known in both systems. Users will then be able to assess whether the method selected achieves the desired results. Transformation errors are extremely difficult to quantify and they are cumulative with errors in the initial coordinates. Users must implement proper checking procedures to be confident of their results.

The GSD has organized a series of workshop sessions in conjunction with CISM and the provincial surveying and mapping agencies to introduce the transformation software to users this fall and winter and discuss implementation issues. The SRMB will be involved in the Federal Government workshop sessions. In addition, a number of information/workshop sessions may be run throughout the province as the need arises to discuss the transformation issues and general issues concerning the conversion to NAD83. A policy and users guide has been developed to assist users in the NAD83 conversion process, a summary of which is presented below.

Surveys and Resource Mapping Branch Policy

The Geodetic Control Unit of SRMB will be readjusting all Integrated Survey Area networks using the adopted NAD83 coordinates from the Continental Readjustment. All other provincial control stations not included in the Continental Readjustment will be recomputed if the original observations are available. SRMB will limit its assistance to outside Branches and Ministries to providing expert advice and suggestions in order to promote common and proper standards adoption. A number of private software developers should also be able to assist in implementing the transformation programs. A network of contractors is also expected to develop which will specialize in performing and checking the transformations. The following statements are formulated as Branch policy.

1. The NAD83 coordinates for provincial, non-ISA, control stations will be released to the public on October 1,1990.The ISA control station coordinates on NAD83 will be released on a staggered basis from 1991 to mid-1992. NAD27 coordinates in the CSDB will be phased out over a five year period upon release of NAD83 coordinates. No new coordinates on NAD27 will be produced over this five year phase-out period.

2. The National Transformation approach utilizing the SCTRANS/ESTPM package from Geodetic Survey of Canada shall be the provincial standard for converting non-geodetic control data and those provincial data holdings not suited to rigorous re-computation of original measurement data. The GRID ALTERNATIVE, consisting of a grid table of shifts as computed from the SCTRANS/ESTPM package, may be used as the most convenient implementation tool. Selection of approach shall be based on a proper evaluation of the precision and reliability achieved as compared to needs. Both the National Transformation and the GRID ALTERNATIVE shall be made available to all users from October 1, 1990.

3. The GSC software, primarily the GRID ALTERNATIVE, will be used for transforming existing SRMB digital mapping data on an as needed basis, provided that adequate relative accuracy can be achieved with the transformation. The SCTRANS/ESTPM program package will be used for problem areas. Cartographic, representation and other topological questions will be addressed by a suitable method thereafter. The hard copy maps held by SRMB will be over printed with a grid shift to reflect the NAD83 coordinate shift on an as needed basis. Generally, new mapping undertaken at SRMB will be done using NAD83 coordinates.

4. SRMB will promote NAD83 adoption through publication of articles and papers in various journals and newsletters, through seminars and information sessions and in general through its client base. SRMB will not undertake to perform actual conversions of client data resources, due to its limited resources and the nature of the conversions (which require an in-depth understanding of the client's data resources).

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Additional information or assistance on the above matter can be obtained by contacting Amin Kassam at (604)387-8438 for NAD83 coordinates and coordinate transformation issues and Roger Balser at (604)387-9321 for mapping (e.g. topology) issues. Further explanation of policy regarding map data is provided below.

Conversion of map data / New mapping

SRMB has the mandate to produce all topographic base mapping within the province. The Branch also establishes all specifications and procedures regarding the production of those base map products. Guiding these specifications and provision of data is the realization that GIS's require that the digital data adhere to stringent structural requirements. A major factor influencing the decision to convert data is how the data to be converted would be used. Increasingly, the demand is for data to drive GIS applications. A major portion of the data holdings of the branch is in paper form and thus conversion to NAD83 would involve the development of a digital file as well. The conversion decision is then based on the accuracy, timeliness and integrity of the data.

The method of conversion for hard copy will be through the recalculation of the geographic (ellipsoidal) position of the sheet corners and the overprinting of the Universal Transverse Mercator (UTM) grid to reflect the NAD83 coordinates. This will result in the sheet corner latitudes and longitudes not being even numbers. The advantage of this approach is that the location will be exact and the sheet edges will match. This will be done during the revision cycle or on a project by project basis.

In the case of digital data, the branch is in the process of developing a methodology for the digital conversion of map files. The methodology will be based upon the Grid Alternative software as integrated into a package that will read an existing file format, apply the conversion factors and then rewrite the output values to a new file of the same format. The clipping of data to a proper sheet edge based on NAD83 coordinates will be done as a post process. The Request For Proposal (RFP) for this software development is currently underway and an operational package is expected by December, 1990.

New mapping projects are being undertaken with NAD83 coordinates where they are available. The Terrain Resource Information Management (TRIM) program is a 1:20,000 scale digital mapping project designed to completely map the province by 1997. This is being undertaken with NAD83 coordinates. This base will form the georeferenced framework for the activities of other ministries. Thus there will be a natural migration to the new reference datum. This is currently taking place where TRIM data is available.

NAD83 Maintenance

While NAD27 served us for 60 years, it is difficult to visualize replacement of NAD83, given its geocentric and satellite-derived ellipsoid datum. Certainly, changes up to a few metres are inevitable due to continental drifts (upto 10 cm a year), more precise surveys (using GPS for example), and better realization of the geodetic reference frame (through, for example, better alignment of survey control networks with very long baseline interferometry derived reference frames). What this points towards is the idea of dynamic survey control networks. The idea that points (coordinates) can be fixed permanently and held errorless, is no longer valid (at least for geodetic users). Coordinates of points have to be considered as **attributes** of the permanent marker, just as the location description or sketch is but an attribute of the physical marker. Thus, when we think of coordinates, we should think in four-dimensions, that is x, y, z, and t (for time) or latitude, longitude, height and time. We now potentially have the tools -powerful computers, enhanced communications technology and satellite surveying - to implement a real-time, dynamic geodetic reference system.

The advent of GPS technology means that special order surveys can be performed cheaply, where first, second or third order surveys previously required inordinate amount of effort across difficult terrain. By the time 24 hour satellite coverage is achieved in 1992, GPS will offer a practical survey option for most static and kinematic requirements. Thus, reduced receiver costs, enhanced software, high precision and reliability will combine to make GPS cost-effective. SRMB is proposing to meet this challenge by partnering with the surveying and mapping community in creating an enabling environment for the most effective use of this new technology. We are currently establishing a GPS basenet in the province (around Vernon). This Basenet will provide a new means for validating GPS systems on a precisely measured basenet, thereby providing scale control for our survey control networks (just as EDM Baselines provide similar scale control for EDM systems). Thus, integration of NAD83 conventional survey control with GPS surveys will be enabled in a proper (controlled) manner. In addition, SRMB is working closely with the GSD in the establishment and integration of GPS occupied federal first order level bench marks throughout the province (every 30 km. along primary levelling routes). These accurate 3-dimensional points will not only permit easier access to an accurate 3-d geodetic reference system, but will also allow better definition of the geoid in the province. The geoid is important to heighting with GPS due to the difference between GPS derived ellipsoid height and the spirit levelling derived orthometric height (often referred to as elevation above mean sea level).

Another initiative being launched at SRMB that will impact NAD83 maintenance is the Active Control System (ACS) utilizing GPS technology. Essentially, the ACS will permit

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users of GPS technology to derive NAD83 compatible coordinates in a direct way (i.e. without occupying much existing survey control) and through cost-effective means. It is interesting to note that the ACS is a **continuous** system in that its stations - Active Control Points (ACP's) - are continuously enhancing their own coordinates due to increased observational redundancy over time and changes in the reference frame (as noted previously). Hence the idea of dynamic coordinates as the future network maintenance scenario once again.

The networks maintenance scenario being adopted at SRMB, is that of dynamic coordinates and weighted stations adjustment. The methodology was first put forward by GSD and is currently being detailed under the auspices of the Canadian Control Survey Committee (comprising of the provinces, GSD, and Canadian Hydrographic Service).[13] Given that the NAD83 Readjustment will yield a consistent set of coordinates and associated covariance information (statistical predictions of coordinate accuracies), the network maintenance on NAD83 will attempt to retain rigour in the integration of new surveys by holding existing stations weighted and not fixed and errorless. In theory, with proper weighting of old stations and new observations, NAD83 should not accrue any distortions over time. Practically speaking, however, small distortions will occur over time due to the impracticality of including all the covariance information with each new adjustment. Only a limited set of adjustment points and associated covariance information will be input to the adjustment of each new survey. Thus, 'refresh' adjustments over regions such as large urban areas will be performed from time to time so as to release the pent up tensions within the control in a given area. These changes will be small on any given refreshing, thereby avoiding large, wholesale changes as in an entirely new adjustment for B.C.

Conclusions

The new NAD83 datum has been adopted and implementation has begun. The Federal Government and the provinces have jointly adopted a national method for transforming coordinates from NAD27 to NAD83. As such, all users need to review their own situations and assess the best method(s) for converting to NAD83. SRMB, in cooperation with GSD and CISM, is promoting workshop sessions to assist users in this endeavour.

NAD83 offers a homogeneous and global datum that meets modern users needs for land-related activities. Its compatibility with GPS technology opens up exciting new opportunities - as with the ACS - to establishing and maintaining **continuous** geodetic control networks, whereby real-time positioning is effected and control point coordinates are treated as dynamic, four-dimensional coordinates. As well, greater opportunities in GIS are being effected through the adoption of this consistent, reliable and accurate geodetic reference system.

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THE IMPLEMENTATION OF NAD 83
IN
BRITISH COLUMBIA

IMPACT ON MAPPING PROGRAMS
AND
IMPLICATIONS FOR LAND INFORMATION DATA MANAGEMENT

Presented by: Roger Balser, Ministry of Crown Lands

NAD 83 IMPLEMENTATION SEMINAR

NOVEMBER 1,1990
TSAWWASSEN INN, 1665 56 St., DELTA, BRITISH COLUMBIA

ABSTRACT

The Province of British Columbia has officially adopted the new reference geodetic datum referred to as NAD83 as of May 24, 1990. This has been done in recognition of the fact that the requirement for data sharing and integration, through technology such as Geographic Information Systems (GIS), and modern techniques used in position location, such as Global Positioning Systems (GPS), will be playing an ever increasing role in the provision of timely and accurate georeferenced data. There are other strong technical persuasions for adopting NAD83 which have been presented in papers such as 'NAD83 Project - Status and Background' (1) or 'Implementation of NAD83 in British Columbia'(2). Not only has the datum changed, but likewise, the mapping industry has changed from one of more conventional cartography to the 'data/information integration' industry. Holders of data , both government and industry, must address this issue in an active, business driven manner to ensure that the migration of georeferenced data from NAD27 to NAD83 is done in a manner that users of the data can accept and accommodate and that is consistent with the provision of georeferenced data for GIS processing. This paper will present some of the options and recommendations envisaged by the Ministry of Crown Lands, Surveys and Resource Mapping Branch, regarding this change in datum and its impact.

1.0 INTRODUCTION

The mandate of the Surveys and Resource Mapping Branch (SRMB) is to provide topographic base mapping and to coordinate the development of Geographic Information Systems (GIS) within the province. The corner stone for the mapping activities is the geodetic control framework. This framework is what provides the coordinate reference system for map projections. Thus with the adoption of NAD83 as the geodetic control framework, mapping and other activities with a georeferenced component will follow suit. The period of migration to full implementation of NAD83 for the geodetic framework, other than Integrated Survey Areas (ISA) is October 1990. The period of migration for map and georeferenced data will depend on many factors that each organization must evaluate. Some of the considerations to be addressed will be value of the data, frequency of update, quality of the data, and conformance with other provincial standards for shared data.

There are essentially two types of mapping products that must be considered; these are hard copy or paper maps and digital or computer map files. Within the province there are significant data holdings in both of these environments. It must be recognized that the data is held by many ministries with in government such as Crown Lands, Forests, Environment, Transportation and Highways, Energy, Mines and Petroleum Resources. As well there are the Municipalities and private sector companies to be considered.

2.0 NAD27 AND NAD83 DIFFERENCES

The relationship between NAD27 AND NAD83 in terms of the cartesian coordinates (X and Y) on the Universal Transverse Mercator (UTM) projection, or any projection for that matter, is not a simple linear shift (3). This places considerable constraints on any specific transformation package that would be applied to a digital data set and also relates directly to the accuracy that would be associated with over printing of a grid on any paper map. In order that some standards and consistency be introduced into the digital transformation process, the Ministry has worked closely with the federal government in the development of a national transformation package that would be available for adoption by any requester (2). When considering the type of transformation to be applied it must be borne in mind that the absolute shift in UTM coordinates is in the order of 200 metres in a northerly direction(2). The relative shift between points in the same map sheet is much smaller and is the order of some 2 metres across a 1:20,000 map sheet. The relative position accuracy between these points would be in the order of 14 metres at the 90% confidence level. Therefore the relative shifts through the transformation to correct for network distortion may or may not be significant in some particular applications. Where the transformation does become critical is in maintaining the integrity of the digital data.

The British Columbia Geographic System (BCGS) which defines the limiting boundaries for map sheets will continue as it is presently defined. Thus the geographic sheet corners will remain even units of latitude and longitude. The effect of this is that the area of coverage for a given map sheet in NAD27 will differ from that of the same sheet in NAD83. This is caused by the northerly shift of approximately 200 meters. To maintain the same area of coverage, the sheet corners will have uneven geographic numbers. This is the classic problem of edge ties between adjoining maps due to the shift of geographic location.

3.0 CONVERSION OF DATA

The main question being posed by organizations who hold georeferenced data seems to be whether or not to convert that data from NAD27 to NAD83. I believe that in reality the question is more one of **when** should the data be converted. There is no question that NAD83 is here to stay. New mapping and georeferenced data base information systems will be developed utilizing NAD83. The government and industry as a whole is moving consistently, if not always in step, toward an environment where data can be 'easily' shared. One of the keys to this migration will be the development of broadly accepted standards for that common georeferencing base. In British Columbia the major scales that will be the responsibility of the Ministry will be 1:2,000,000; 1:250,000; 1:20,000 (TRIM), 1:5,000; 1:2,5000 and larger. Specifications have either been written or are in the process of being drafted for each of those scales. These specifications will reflect NAD83 as the reference datum. The concept of an atlas of these map scales is being developed. The foundation for this process is the Terrain Resource Information Management (TRIM) project. TRIM is a 1:20,000 digital mapping project with the intent of producing province wide coverage at a scale of 1:20,000 specifically to support the emerging application developments taking place in GIS. This product is based on NAD83. The emerging acceptance of TRIM and the fact that this scale is the foundation for the resource based management infrastructure of the province will provide a strong influence in the decision to migrate to NAD83.

There are several requirements that must be addressed when considering the conversion of data. There can be no gaps at map sheet edges created by the conversion. The conversion must maintain the integrity of the data. Integrity in this case refers to the quality of the data in terms of connectivity and continuity. The final requirement is that the integrity of data on map sheet edges be maintained.

3.1 Hard Copy / Paper Maps

There is a considerable data holding that is in a hard copy or paper map format. I feel that some of the most difficult conversion decisions will be centred on this data source. One of the main considerations will be whether to convert the data to a digital format or to simply update the geographic and grid information on the map to reflect the NAD83 conversion. It is inevitable that many of these data sets will eventually be required in an integrated data sharing environment based upon computer technology and applications. One of the major considerations will be the update cycle for the data and a second consideration will be the availability of a georeference base data set from the atlas.

The method of actual conversion of hard copy where it is deemed appropriate and necessary will be through the recalculation of the geographic position of the sheet corners and the overprinting of the UTM grid to reflect the NAD coordinates. This will result in the sheet corner latitudes and longitudes not being even numbers. The advantage of this approach is that the location will be exact and the sheet edges will match.

3.2 Digital Files

With the advent of computer aided drafting (CAD) mapping in the late 1970s, there was a migration from traditional paper maps to digital computer files. There are now significant data holding in computer form. It is this data that will most likely be migrated from NAD27 to NAD83. However before transforming this data there will be several issues to be addressed. What is the revision cycle for the data? Perhaps it would be more cost effective to merely wait for the natural update process to replace the data. Is the data compatible with other data sources that would lend it acceptable for data sharing in a corporate sense? Sharing data would lessen the cost of migration for all parties.

In any event there will be large quantities of data that will need to be transformed. One of the major considerations controlling this transformation is how to protect the integrity of the digital data in terms of its content and accuracy and relationship to any attribute data that may be stored in associated files. The characteristics of the transformation must be such that it reflects the distortion of the coordinate change as well as addressing the simple datum change. It must also respect the fact that when dealing with map sheets there are edge tie conditions that must insure the continuity of data across those edges. The Geodetic Survey Division of the Canada Centre for Surveying has developed a methodology based upon the Grid Alternative (2). This is a bi-linear transformation that utilizes parameters extracted from a table of grid values based on a 5 minute by 5 minute grid of points. A NAD27 value is passed to the program that then determines the proper grid cell, extracts the parameters from the bi-linear transformation, applies the transformation and output the proper NAD83 value.

The Ministry has issued a Request for Proposal (RFP) to develop a software package that will integrate the Grid Alternative subroutine into a main program that will read a data set from an existing map file format in NAD27 and output a map file in the same format in NAD83 coordinates. The RFP calls for the delivery of that software by January 1991. The first delivery of the software will operate on Intergraph files. The test data set will be Cadastral files from the Surveyor General Branch of the Ministry. Once tested this software will be made available.

A major data set that will become increasingly relied upon for thematic data input to GIS is satellite imagery. One of the problems associated with satellite data is fitting it to ground coordinates. The satellite follows a natural orbit that conforms more closely to NAD83. This will render the georeferencing of satellite data a much less operationally intense process. The output from the processed/classified satellite data will then be compatible with the georeference base map.

4.0 ROLE OF THE BC-ATLAS

One of the main problems facing organizations is the question of the ability to integrate data for the purpose of integrated resource management (IRM). The major problems to be faced when transforming data from NAD27 to NAD83 will not be the transformation itself, but rather the reconciliation of the differences in the georeferencing base. The attempt to migrate data from an old base that was digitized for a sole requirement to a new multipurpose base will result in conflicts of boundary location that will have to be resolved. For example an inventory boundary may follow a creek. The position of that same creek may vary amongst data sets dependent upon where the digitizing originated. The migration to NAD83 will force organizations to rationalize this variance and hopefully to adopt a common georeferencing base. This common base will be the focus of the corporate data set within government as identified in the Corporate Land Information Strategic Plan (CLISP) (4). The Ministry will provide data sets to published specifications for the scales 1:2,000,000; 1:250,000; 1:20,000 (TRIM); 1:5,000 and larger.

5.0 POLICY

The following will form the basis of the policies/procedures for the SRMB topographic mapping with respect to the adoption of NAD83.

- NAD83 is the official datum for all graphical and digital products. This will occur as the NAD83 values become available.

- Existing products will be converted to NAD83 on an as needed basis. This will be true for either paper or digital products.

- Emphasis will be placed on NAD83 coordinates in the provision of new map data.

- Appropriate header and legend information will be provided for any converted data.

- The Ministry will accelerate the provision of base georeferencing data an NAD83 through the BC-Atlas concept of the CLISP project.

- The ministry will provide expertise and advice on the conversion of data as required.

- All new maps will follow the existing BCGS mapping grid, maintaing whole numbers for the latitudes and longitudes of the sheet boundaries; coverted maps will have recomputed values.

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NAD'83 - MAPPING IN ALBERTA

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The mere mention of NAD'83 (North American Datum 1983) can bring a frown or a smile from someone in the mapping community within Alberta. Although many questions still remain to be answered, the overall advantages of converting from NAD 27 to NAD 83 seem to indicate that, in the long term, the conversion should take place. This paper will discuss some of the outstanding philosophical and technical issues that remain to be addressed, such as coordinate conversion/ graphics conversion, master coordinate file for converting, and compatibility with other users. The advantages and disadvantages of converting will be reviewed, along with the timing and other issues related to NAD 83.

The approach that the Surveying and Mapping Branch, Land Information Services Division is planning to take to address these outstanding mapping issues will also be discussed, and will hopefully lead to the development of solutions to address these issues.

INTRODUCTION

Discussions regarding the conversion to a new North American Datum from the presently used NAD 27 (North American Datum 1927) have been going on amongst the surveying and mapping community since the early 1970's. The new datum adopted by international agreement is called the NAD 83 (North American Datum 1983). The technology changes that have taken place within the mapping community, have helped to change attitudes towards the seemingly unmanageable task of converting to NAD 83. The evolution of digital mapping has provided the cartographer with more effective methods to gather, store, and display information, and has opened the door to opportunity with the increasing application being developed utilizing digital data. The GPS, (Global Positioning System) for example, can be utilized to determine an accurate position of features in the digital file, and is a key component of the AVL (Automated Vehicle Location) system which utilizes a digital file as its base. The issues have not changed and still require solutions, but the balance between converting to NAD 83 versus staying with NAD 27 has taken a positive change in direction.

ADVANTAGES TO CONVERTING

It is argued that in certain organizations/ applications, converting to NAD 83 will not provide any advantages. Although the advantages will certainly vary in numbers from organization to organization, anyone who is interested in the benefits of receiving and/or providing data to/from another system can find advantages to NAD 83.

The advantages to mapping begin with the increased accuracy the control network will provide. Local area shifts within the control network will correct approximated shifts of up to 10m over a 100 km distance. Although these corrections may not have much effect on smaller municipalities, the advantages realized by provincial organizations will be significant.

With the increasing need for sharing of data between users federally, provincially, and locally, a need has risen for digital data to be in a standard format that allows for easy exchange of data between differing vendor systems. To date, the requirement for conversion of datums during exchange of data has not been a problem, however, the scenario in the future could be different if both NAD 27 and NAD 83 are present. This conversion would only add to the computing time required to exchange data when the datums were different. This change would be most noticeable between users exchanging data and utilizing the same vendor systems. The advantage of exchanging data efficiently and effectively with other users is one that will be realized by all.

Another plus to NAD 83 is the capability to take advantage of new opportunities being brought about by new technology. AVL (Automated Vehicle Location) systems utilize a digital transportation network in conjunction with the GPS to form the major part of its system. The GPS is developed to generate coordinates utilizing the NAD 83. Distributors of the digital data will not be faced with the incompatibility problem of differing datums if NAD 83 was the standard being used.

DISADVANTAGES OF CONVERTING

The most talked about disadvantage is the cost. Although cost is a concern, the advantages to converting to NAD 83 should justify, in the long term, the initial costs. The exact cost of converting will be dependent on what methodologies and specifications are adopted to convert and also, the size and complexity of the system being converted. Depending again on the methodology chosen to convert to NAD 83, a certain amount of delay in completing presently planned program schedules will likely be required. This could be minimized if additional resources from what is normally expended on the program can be made available. A disruption of established services could also occur, depending on how the conversion is done.

ISSUES/ALTERNATE SOLUTIONS

The mapper is challenged by three (3) major issues when developing the specifications and procedures to convert existing NAD 27 products to NAD 83; compatibility, timing and edge features. Separate consideration must also be given to conventional mapping products as well as digital mapping products. Although in many instances the conventional product is derived from the digital data, the procedures and specifications may have to differ when addressing the same issue for conventional and digital.

Compatibility

The idea of a standard geo-referenced base to ensure compatibility amongst the users of digital mapping data has been advocated since the development of digital base mapping programs in the early 1980's. The retention of this philosophy presents a major challenge when developing procedures to convert digital mapping data to NAD 83. Hundreds of thematic mapping users have purchased standardized digital base maps and developed digital thematic systems referenced to the bases. The two (2) data sets must be converted using the same software in order to maintain the compatibility. Absolute accuracy is not the issue, but rather computing the same coordinate value is. With the different vendor system involved, this may not be an easy task. Vendor solutions will have to be developed with compatibility in mind. An alternative to separate vendor solutions may be the development of a standard conversion program that would run in conjunction with a standard interchange format such as CCOGIF, (Canadian Council on Geomatics Interchange Format). Processing could be done at each site or possibly at a central site set up to convert digital data to NAD 83. Each site would have the requirement to run CCOGIF software. The latter alternative may provide the best opportunity to maintain compatibility.

The same issue is evident when looking at conventional mapping, but in a different sense. Compatibility, as far as relationships go, is a lesser problem due to the relational accuracy of conventionally developed systems. The major issue will be the requirement to re-develop the thematic overlay to correspond to the new generated base maps' window. Manual methods may prove to be very time consuming and costly. An alternative to manual compilation may be to take the opportunity to convert to digital and generate a hard copy product from the converted digital data. Choosing the latter provides more long term benefits.

Timing

If conversion is going to take place, what should the schedule look like? Converting as quickly as possible does have its advantages, but is it feasible? The gradual approach will work in some areas but may not be acceptable or may just cause too many problems. The big advantage of converting as quickly as possible is that administration of two (2) systems will be minimized. Data conversion from one datum to another when exchanging data from one user to another would also be minimized. Although this may appear to be the best approach, consideration must be given to what the cost would be, and the elapsed time required to achieve. An alternative approach would be to phase in the conversion over an extended length of time, eg. implement conversion as part of the update/ maintenance process. This method may have less of a disruptive effect short term, but will certainly require increased administration and processing of data when exchanging amongst users. Another alternative would be combination of the first two (2). A schedule could be established for the conversion of existing data. Any new data created during the schedule would utilize NAD 83 and only the NAD 27 files would be distributed to other users. NAD 83 files would only be distributed when all files had been converted. This would require storage of duplicate sets of the same data in the different datums.

Conventional mapping has to deal with the timing issue, but again from a different view. To convert all printed maps within a short time period would be ideal, but probably not feasible due to resources and cost. Phasing in the publishing of converted maps through the maintenance program may prove to be the best alternative. Users of the maps would have to live with the situation that some features along two (2) of the maps' edges would not appear when joining adjacent maps produced with different datums. A solution to the unmapped data along the edges would be to carry the NAD 27 maps sheets until the NAD 27 window area is covered with converted NAD 83 map sheets. The smaller scale maps would be less affected by this, due to their scale.

Edge features

An issue that is unique to both conventional and digital mapping is the problem that will be created when borders for map sheets or files shift by approximately 200m. Linear features may be merged and clipped automatically in most cases when transforming digital files to NAD 83, however the text that is affected by the shift will have to be adjusted manually in the digital file. Software to perform this task automatically is in an infancy stage and will not provide any significant assistance. This task, although not difficult to perform manually, will be quite time consuming and tedious.

Conventional mapping will have to deal with the addition and transfer of both linear and textual features when transforming map sheets to NAD 83. The only mapping systems that will not have to deal with this issue are ones that have developed their system using a land feature for a border, such as hydrography or the township system. An example of that in Alberta would be the Parcel Mapping Program where the digital files are defined on a township basis.

IMPLEMENTATION APPROACH

The procedures and specifications developed and used to implement NAD 83 will vary from organization to organization depending on their specific needs. The Surveying and Mapping Branch, Land Information Services Division, is in the process of reviewing its needs and the needs of its users in order to develop and put in place procedures and specifications for converting the Provincial Digital Base Mapping programs and conventional mapping bases. The Surveying and Mapping Branch has advocated for some time the standard base policy, and is attempting to develop procedures that will allow for the retention of this policy after conversion has been completed. The ever increasing requirement for sharing of data amongst users supports the importance of achieving this goal. Surveying and Mapping also would like to develop procedures that would allow for conversion of the digital base maps in as short a time period as possible. It is felt that converting the digital base maps in a short period of time would have the least impact upon the users of the data. Procedures for repositioning of textual features along the borders of digital and conventional base maps are being planned and developed with efficiency and effectiveness in mind. Surveying and Mapping believes that the most effective way to achieve the end goals is by communicating with the users and identifying as many of the issues in the user community as possible. By knowing the issues, policies and procedures can be developed to focus on addressing the major issues and making the conversion to NAD 83 as smoothly as possible. Surveying and Mapping is planning to have a schedule, in place by April 1991, for the development of procedures and specifications to convert the digital and conventional mapping data.

CONCLUSION

1992 is fast approaching. Policies and procedures to address all the issues surrounding the conversion of conventional and digital base maps, from NAD 27(North American Datum 1927) to NAD 83 (North American Datum 1983), are not in place. To meet tomorrow's needs and opportunities, the question of whether the conversion should take place at all, is a diminishing one. By working together and communicating our needs, the mapping community, be it conventional or digital, can develop procedures and specifications that will address the main issues and minimize the efforts required to convert to NAD 83.

LAND INFORMATION SERVICES DIVISION

RECOMMENDED

NAD83 ADOPTION APPROACH

FOR NON GRAPHICS DATA

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Abstract

May of 1990 saw the official Federal adoption of the North American Datum of 1983 (NAD83). After significant preparation the values of Federal control point positions are now available on NAD83. This paper will overview the implementation plans in Alberta for the adoption of the new datum. Discussion is directed toward Provincial plans for dealing with coordinate or tabular non graphic data. Methodology and timing as well as some other peripheral issues related to the NAD83 adoption are also addressed.

Introduction

The Canadian Federal Government has recently completed an international exercise that redefined the mathematical surface to which we relate all of our horizontal positioning. During the course of this datum redefinition, all of the national survey control framework was re-adjusted. This has resulted in new coordinate values for the national geographical referencing framework. Whereas the nationally adopted values for primary geodetic control used to be available referenced to the North American Datum 1927 (NAD27) the published values are now available in the North American Datum 1983 (NAD83) system.(1) An announcement on May 23, 1990 by Energy, Mines and Resources, officially adopted NAD83 in the Federal jurisdiction. The official adoption of NAD83 by the provincial surveying and mapping agencies is a decision that has been left to the respective provinces. Although the timing regarding the adoption of NAD83 will not be consistent across the country (i.e. different provinces are likely to adopt NAD83 at different times), indications are that all provinces will probably adopt the new datum.

The most rigorous method of adopting the new datum would be to recompute or recompile all of the existing data on NAD83. This however is not practical in all cases. Where recomputation is not practical, an approximation of NAD83 values can be derived by using various transformations. In order for different datasets based on NAD27 to maintain their consistency after the transformation, it is recommended that the same methodology be used in their respective conversions to NAD83. The approach that is expected to be promoted and endorsed in Alberta as the basis for all transformations is the "National Transformation", developed by the Canada Centre for Surveying. This "National Transformation" is discussed in more detail elsewhere in this publication. (2)

Why Adopt NAD83 ?

Several reasons and advantages have been stated in the literature (1) for the adoption of NAD83. Some of these are itemized in Appendix 1. Many of the advantages pertain to those users requiring relatively accurate and reliable position information. The improved accuracies of NAD83 will undoubtably be a benefit to these users. Existing distortions in NAD27 range from decimetres up to many metres, depending on the region and situation.

A significant number of users of position data may not be concerned about the improvements in positional accuracy however, and may be content with NAD27. Those users are probably custodians of geographic information systems (GIS) with large volumes of data,which is referenced with lower positional accuracy. The coming of age of these information systems necessitates the merging of different sets of information through a common spatial referencing system. An ability to overlay and merge various infrastructure datasets will significantly increase the value of the individual datasets. In order to merge this data in a meaningful way with other information, a common spatial reference system is necessary. NAD83 is this nationally adopted standard reference system.

Further, in the transformation of any GIS to the nationally adopted spatial reference system, care must be taken to follow an approach consistent with other geographic information systems to ensure continued compatibility.

Scope of Shifts

The magnitude of the coordinate shift between NAD27 and NAD83 values varies throughout the province. The differences between NAD27 and NAD83 values can be attributed to two sources. These two sources are the effects of the redefinition and the readjustment. In other words there is a shift component due to the new datum definition and another component due to the distortion removed by the readjustment. Tables 1 and 2 reflect the numerical differences between datasets of positions referenced to the two datums.

Table 1 shows the relationship, sorted by rural 1:250,000 map sheets, between the two datum values for points on which NAD83 values exist. Although some anomalies are evident, the average Northing and Easting shifts are in the neighborhood of 200+ meters and 60+ meters respectively. The map sheets that reflect high standard deviations are evidence of either pockets of high distortion or may contain markers with non integrated data. This table reflects the raw differences in coordinates between identical points on NAD27 and NAD83 reflected in 10TM coordinates.

Table 2 shows the relationship between the same two datasets with the effect of the datum difference removed. In other words the NAD27 values have had a datum shift to NAD83 applied prior to comparison with the published

1:250k MAPSHEET	MIN SHIFT NORTHING	AVG SHIFT NORTHING	MAX SHIFT NORTHING	STANDARD DEVIATION	MIN SHIFT EASTING	AVG SHIFT EASTING	MAX SHIFT EASTING	STANDARD DEVIATION	VECTOR COUNT
48110	213.903	215.248	215.942	0.639	-71.570	-68.661	-67.305	1.295	18
48112	214.907	215.261	215.717	0.241	-75.672	-72.580	-71.837	0.947	15
49110	209.843	218.388	220.630	1.153	-79.233	-69.338	-67.146	1.204	265
49112	213.891	217.023	220.682	1.074	-73.359	-72.141	-69.926	0.562	462
49114	213.383	219.620	224.839	1.522	-76.347	-73.075	-66.808	1.016	354
50110	210.086	220.339	222.655	1.475	-79.188	-69.571	-68.356	0.932	352
50112	218.122	221.888	224.273	1.976	-73.412	-71.922	-70.615	0.561	338
50114	215.988	223.440	234.715	1.323	-74.706	-71.507	-67.580	1.099	308
50116	214.618	220.632	226.203	3.634	-74.200	-67.389	-64.813	3.247	7
51110	220.663	222.113	222.975	0.734	-70.695	-68.940	-66.063	1.173	285
51112	221.612	223.631	224.267	0.468	-71.803	-71.020	-69.166	0.511	335
51114	210.539	223.563	230.613	1.193	-79.593	-71.160	-62.176	0.951	971
51116	127.241	216.758	222.639	12.678	-75.298	-71.750	-60.689	2.504	53
52110	210.212	220.874	223.268	3.197	-79.180	-66.641	-64.134	3.937	213
52112	222.550	223.039	224.268	0.190	-71.682	-70.441	-67.471	0.705	306
52114	-797.681	216.499	224.713	80.439	-300.117	-72.940	-68.907	18.083	161
52116	218.010	222.254	237.120	1.808	-90.097	-73.100	-67.488	3.464	238
52118	195.728	221.196	255.457	6.593	-99.833	-71.822	-37.003	5.791	73
53110	210.843	222.042	223.115	1.313	-79.121	-65.431	-63.877	1.948	313
53112	221.991	223.286	223.815	0.449	-71.168	-69.815	-67.153	0.573	734
53114	223.158	224.026	225.782	0.477	-71.347	-70.533	-69.224	0.457	361
53116	218.506	224.624	227.324	0.793	-84.835	-72.199	-70.284	1.073	360
53118	-294.715	220.124	236.276	29.603	-378.390	-75.596	-67.452	17.387	312
54110	211.673	222.128	223.929	1.440	-79.216	-67.367	-64.235	1.449	193
54112	222.885	223.879	224.621	0.373	-70.927	-69.660	-68.105	0.615	91
54114	220.091	223.902	225.124	1.120	-73.329	-70.475	-69.310	1.072	206
54116	217.691	222.051	226.244	2.764	-76.459	-73.262	-71.193	1.315	110
54118	216.770	220.512	225.071	1.771	-81.395	-77.784	-72.817	1.677	172
55110	172.608	222.021	224.205	4.736	-92.889	-66.504	-63.834	2.624	114
55112	221.661	224.083	225.158	0.647	-71.606	-69.485	-65.837	1.460	111
55114	221.001	222.861	224.508	0.836	-75.099	-72.855	-71.277	0.990	149
55116	219.051	221.065	223.283	0.981	-77.659	-76.093	-73.997	0.863	146
55118	214.815	217.916	221.019	1.054	-85.072	-77.635	-77.104	0.545	270
56110	220.008	221.046	222.153	0.286	-66.935	-65.242	-61.296	0.744	490
56112	128.437	221.209	224.438	10.303	-70.977	-68.264	-63.817	1.257	84
56114	191.870	223.915	228.076	3.557	-92.308	-72.382	-69.169	2.726	96
56116	221.577	222.822	227.150	1.285	-77.820	-77.059	-74.311	0.775	142
56118	213.431	219.035	222.812	2.800	-80.706	-78.275	-77.289	0.843	95
57110	219.292	220.944	222.177	0.909	-65.730	-63.666	-60.645	1.691	185
57112	219.811	221.740	222.579	0.492	-69.512	-66.931	-64.142	1.304	98
57114	221.201	222.587	224.745	0.634	-74.785	-71.772	-69.102	1.608	103
57116	220.881	222.163	224.102	0.605	-77.714	-76.277	-73.603	0.931	120
57118	212.956	219.483	223.014	2.988	-81.381	-78.690	-77.264	1.092	97
58110	219.546	220.514	221.793	0.456	-65.375	-64.466	-62.389	0.658	107
58112	219.190	220.614	221.438	0.342	-69.717	-66.982	-65.367	1.111	91
58114	220.739	221.716	222.103	0.313	-73.306	-70.617	-67.990	1.225	93
58116	221.096	221.923	222.788	0.485	-77.042	-74.406	-71.812	1.239	105
58118	219.335	222.128	223.473	1.069	-78.260	-75.600	-73.456	1.257	102
59110	219.305	221.603	222.970	0.765	-67.030	-65.851	-64.959	0.442	95
59112	220.064	221.104	221.499	0.300	-69.092	-67.193	-65.728	0.758	101
59114	220.064	221.206	221.891	0.367	-81.150	-71.456	-67.860	3.220	101
59116	220.171	221.481	222.659	0.595	-79.268	-73.469	-71.697	1.317	131
59118	219.084	221.187	223.137	1.132	-74.222	-73.043	-71.763	0.572	104
60110	221.940	232.362	242.783	14.738	-80.326	-72.872	-65.419	10.541	2
60112	219.683	220.386	221.246	0.732	-68.095	-67.502	-66.894	0.514	4
60114	219.268	219.444	219.535	0.153	-70.923	-70.457	-69.790	0.593	3

NAD 83 10TM VALUES MINUS NAD 27 10TM VALUES

(METRES)

TABLE #1

1:250k MAPSHEET	MIN SHIFT NORTHING	AVG SHIFT NORTHING	MAX SHIFT NORTHING	STANDARD DEVIATION	MIN SHIFT EASTING	AVG SHIFT EASTING	MAX SHIFT EASTING	STANDARD DEVIATION	VECTOR COUNT
48110	3.637	4.975	5.669	0.634	3.644	6.272	7.662	1.153	18
48112	4.650	5.003	5.480	0.248	0.079	2.917	3.469	0.838	15
49110	-0.803	7.813	9.966	1.069	-4.178	5.612	7.511	1.085	265
49112	3.561	6.502	10.002	0.998	2.340	3.375	5.848	0.559	462
49114	2.828	9.108	14.155	1.480	-0.314	2.825	8.975	0.999	354
50110	-0.716	9.492	11.649	1.397	-4.185	5.375	6.517	0.851	352
50112	7.429	10.976	13.248	1.809	1.834	3.693	4.649	0.472	338
50114	5.035	12.418	23.771	1.309	1.281	4.421	8.681	1.185	308
50116	3.926	9.710	15.421	3.634	2.135	9.027	11.597	3.281	7
51110	9.403	10.739	11.570	0.715	4.539	6.130	8.731	1.014	285
51112	10.440	12.376	13.060	0.532	3.867	4.650	6.092	0.401	335
51114	-0.596	12.304	19.218	1.247	-3.773	4.756	14.092	0.976	971
51116	-84.202	5.369	11.076	12.680	1.133	4.746	16.123	2.564	53
52110	-1.606	8.997	11.512	3.215	-4.198	8.346	10.597	3.925	213
52112	10.613	11.295	12.592	0.256	4.028	5.202	7.799	0.594	306
52114	-1009.337	4.758	12.812	80.432	-223.829	3.172	7.262	18.061	161
52116	6.303	10.476	25.334	1.810	-13.734	3.401	8.989	3.465	238
52118	-16.197	9.316	43.452	6.547	-22.728	5.193	40.214	5.799	73
53110	-1.261	9.814	10.767	1.274	-4.164	9.493	10.872	1.843	313
53112	9.744	11.029	11.562	0.333	4.299	5.857	8.141	0.495	734
53114	10.876	11.841	13.543	0.432	4.713	5.460	6.594	0.374	361
53116	6.498	12.420	15.018	0.732	-8.351	4.497	6.216	1.040	360
53118	-506.841	7.778	24.116	29.589	-301.278	1.455	9.843	17.381	312
54110	-1.139	9.452	11.200	1.497	-4.414	7.665	10.544	1.350	193
54112	10.395	11.210	11.758	0.301	4.790	5.885	7.186	0.484	91
54114	7.386	11.324	12.641	1.208	2.943	5.680	6.932	1.116	206
54116	4.979	9.404	13.656	2.867	0.372	3.337	5.328	1.299	110
54118	3.873	7.827	12.469	1.828	-4.043	-0.638	4.090	1.602	172
55110	-40.576	8.871	11.249	4.756	-17.778	8.543	10.997	2.599	114
55112	8.356	10.971	12.143	0.737	4.209	6.084	9.506	1.323	111
55114	8.105	9.766	11.192	0.763	1.187	3.215	4.652	0.861	149
55116	6.143	7.959	9.960	0.875	-0.845	0.498	2.357	0.742	146
55118	1.452	4.832	7.704	1.090	-8.214	-0.584	-0.080	0.543	270
56110	6.353	7.395	8.612	0.341	8.276	9.930	13.567	0.677	490
56112	-85.241	7.654	11.078	10.325	4.846	7.318	11.672	1.143	84
56114	-21.493	10.352	14.439	3.541	-16.325	3.680	6.659	2.643	96
56116	8.202	9.306	13.518	1.219	-1.147	-0.432	1.999	0.646	142
56118	-0.362	5.474	9.176	2.816	-3.429	-1.233	-0.387	0.725	95
57110	5.168	7.000	8.360	1.007	9.512	11.502	14.244	1.579	185
57112	5.710	7.756	8.632	0.534	6.325	8.649	11.237	1.177	98
57114	6.999	8.599	10.947	0.713	1.519	4.297	6.726	1.462	103
57116	6.686	8.154	10.317	0.704	-0.926	0.303	2.722	0.806	120
57118	-1.033	5.469	8.780	2.950	-4.119	-1.633	-0.054	0.983	97
58110	5.257	6.044	7.106	0.405	9.562	10.672	12.553	0.599	107
58112	4.545	6.173	7.189	0.402	6.118	8.626	10.029	0.999	91
58114	6.337	7.286	7.870	0.371	2.999	5.451	7.863	1.104	93
58116	6.721	7.476	8.453	0.508	-0.269	2.131	4.485	1.112	105
58118	4.730	7.664	8.982	1.113	-1.310	1.415	3.687	1.281	102
59110	4.191	6.680	8.129	0.794	7.920	9.311	10.248	0.494	95
59112	4.981	6.209	6.662	0.305	6.747	8.427	9.679	0.657	101
59114	4.976	6.321	7.008	0.457	-4.919	4.596	7.986	3.138	101
59116	5.075	6.573	7.977	0.709	-2.973	3.059	4.597	1.363	131
59118	3.957	6.274	8.438	1.217	2.608	3.954	5.407	0.600	104
60110	6.804	17.114	27.424	14.581	-5.056	2.298	9.652	10.400	2
60112	4.526	5.264	6.138	0.753	7.689	8.078	8.538	0.370	4
60114	3.750	3.943	4.045	0.168	5.150	5.547	6.112	0.503	3

NAD 83 10TM VALUES MINUS 10TM NAD 27 VALUES TRANSFORMED* TO NAD 83

(METRES)

* TRANSFORMED USING PROGRAM SCTRANS

TABLE #2

(preliminary) NAD83 values. This basically will give an idea of the magnitude of the distortion to be removed from the NAD27 values by the readjustment. We can see that there are varying degrees of distortion existing in the survey control fabric, but on average it ranges from 7 to 17 meters across 1:250,000 map sheets. This dataset reflects about one third of the provincial survey control data, and although this general pattern is expected in the remaining secondary data there will be pockets following this trend to varying extents. The magnitude of the differences will be a function of the distortion existing on NAD27 and the extent of the area over which we make the comparisons. In particular the municipal control is expected to have absolute shifts of the same order of magnitude as shown in the rural areas, but with the magnitude of the relative shifts significantly reduced. The magnitude of the distortion will likely be similar however if expressed in parts per million.

Timing and Transition

Alberta is moving towards the adoption of NAD83, and work has been underway in support of this task for several years. An official policy statement is expected in 1991 regarding the adoption of NAD83. The transformation from NAD27 to NAD83 will be a significant task for all users. In the adoption of the new datum, agencies such as the Land Information Services Division (LISD) of Alberta Forestry, Lands and Wildlife will likely have transition periods during which all of the surveying and mapping products will be converted to NAD83. This transition period is due to the interdependence of various surveying and mapping products and the need to complete the conversion on some, prior to being able to address others. This suggests the need for a transition period in which information will be made available for certain products in both reference systems. For example, the conversion of mapping products and coordinate values of tertiary data (e.g. legal corners) is dependent on the availability of NAD83 values on survey control points. Thus the adoption of NAD83 for these products will not commence until the NAD83 values for control points are finalized. As a result of the Division having the same entity represented on two or more products in different reference systems, an attempt will be made to provide coordinates for survey control for a limited time period on both datums.

In the case of the Alberta survey control markers, the target date for having NAD83 values available is mid 1992. After this date the official published values distributed will be NAD83. Users however, will be able to order NAD27 values as special requests on points that existed prior to the adoption of NAD83. For points established after the official adoption of NAD83 by LISD only NAD83 values will be available. Users wishing NAD27 values on these points will have to convert the published NAD83 values to NAD27 themselves.

The exact timeframe of the transition period for LISD products is not known at this time. The availability of the service to respond to special conversion requests for NAD27 values will be the exception after the adoption of NAD83 in mid 1992. The turnaround time on delivery of this service will be a function of demand and will be treated as a lower priority than responding to requests for data on NAD83. As a result, slower response to requests for data on NAD27 can be expected. As the transition period progresses it is anticipated that the existence of entities represented on two or more LISD products on different datums will disappear. As products within the LISD that contain Alberta Survey Control information are converted to NAD83, the service to provide NAD27 values will be stopped.

NAD83 values are currently available on the national geodetic framework points as well as on some secondary stations in Alberta. Approximately two thirds of the thirty three thousand markers in the Provincial survey control fabric still remain to be readjusted. It is expected that the remaining readjustment will influence the results of the values currently available on NAD83 in Alberta. Therefore, although NAD83 values are available for some Alberta Survey Control points, it is likely that they will be revised somewhat, with the addition of the remaining secondary fabric. Therefore, the existing NAD83 values should be treated as provisional in Alberta until NAD83 is officially adopted here.

Although these values are provisional, every attempt will be made to make them available to users for testing purposes. Users will be warned of the preliminary nature of these values and the dangers of inadvertently mixing data from records on different datums. That is to say that there will be mixes of points within areas for which only some may have NAD83 values. Hence potential problems may arise in comparing between points on different datums. An attempt will be made to clearly mark information as to datum origin, and users are advised to maintain this datum attribute in their use of the data.

Mechanics of Adoption

As previously mentioned, the most rigorous method of accommodating the shift from NAD27 to NAD83 is by a recomputation/readjustment of all of the raw data, on the new datum. This readjustment process will only apply to the Alberta survey control fabric at LISD.

Other divisional datasets (e.g. Alberta Township System(ATS)) have neither the raw data available in a convenient form, nor the funds to recompute using original data. The next available option in converting to NAD83 is to perform an approximate adjustment or transformation on the data. This transformation approach would apply to datasets whose initial accuracy is such that the errors introduced by a transformation would not significantly downgrade the data. In order that consistency be maintained between datasets that are converted to NAD83 using this approach, a common transformation should be used. This approach is likely more cost effective than readjustment.

In Alberta, the "National Transformation" approach is seen as the tool that may serve as the basis for data handled through a transformation rather than readjustment, recomputation or recompilation. In order that georeferenced information remain compatible for GIS purposes after conversion to NAD83, the "National Transformation" will likely be promoted as the transformation tool to be used in this Province.

In basic terms the "National Transformation" refers to a process adopted at Geodetic Survey Division (GSD) intended as a national transformation standard. It is to be used where data on NAD27 is to be transferred to NAD83 or vice versa, through a process other than readjustment. Through a procedure that models the relationship between NAD27 and NAD83, a series of shifts between the two systems will be generated at regularly spaced intervals throughout Canada. Initially the shift will be calculated on the basis of a 5 minute by 5 minute geographic grid. A particular interpolation algorithm will then be used to interpolate the NAD27 to NAD83 relationship for each point in question. This interpolation approach will yield identical values for interpolated points falling on the boundaries between adjacent grid areas, regardless of which of the adjacent areas is used as the basis for interpolation.

Although reliable accuracy estimates on the transformation results are not available from the transformation process, the accuracies will be a function of both the control density on which the model was based and the magnitude of distortions in the particular area. Points for which NAD83 values are known, may be withheld from the process for the purpose of evaluating the quality of the conversion. Such an evaluation however, only gives an indication of quality for that particular micro-region.

"National Transformation" Considerations

As with most solutions, there are some side effects and other issues that are raised in the use of the "National Transformation". The transformation results will be a function of the NAD27 and NAD83 values used to define the model. That is to say, the two different datum values for several points will describe the relationship of the systems.

In Alberta, the NAD83 values on which the transformation was predicated were derived from the July 1990 secondary adjustment carried out by Geodetic Survey Division (GSD) Energy Mines and Resources Canada. This adjustment included all of the data pertaining to the primary networks as well as selected secondary data. In Alberta this accounted for about one third of the Provincial survey control fabric. The NAD27 values on which the transformation was predicated were those that were published in the Provincial record in June 1990. Some exceptions may have existed for points with minor differences in position between the Federal and Provincial record. The point is that the transformation was derived from NAD27 values as they exist now. If marker positions have been revised over time due to movement or distortion rectification, and users have datasets based on values other than those used in the transformation definition, there may be anomalies in their dataset transformations (i.e. May '76 values etc.). The magnitude of these anomalies will be a function of the differences between the NAD27 position used for the transformation and those adopted by the users in their application. For the most part these differences will likely be minor.

Conversely the NAD83 values defining the transformation model may be subject to change in the form of actual changes to the NAD83 values for particular points due to revisions or upgrades. In Alberta the intent is to have the positions of the remaining two thirds of the secondary network (not included in GSD's July '90 adjustment) influence the transformation so that each region is properly modelled. This will result in changes to the grid of predicted shift values and provide different transformation results. The result of these possibilities is that the transformation will have to be labeled with a version or date attribute and users must be cognizant of the implications of this attribute. Due to LISD's intention to add significant amounts of information to the dataset controlling the transformation model in Alberta, the possibility exists of "significant" changes in transformation results, after the data addition. Furthermore, in order to take advantage of the refinement afforded by the addition of this control data, particularly in the municipalities, the gridded shifts will be computed on a denser spacing. The spacing of the computed shifts will likely vary throughout the province but generally will be more dense where the control is more closely spaced, and conversely less dense where the control is more widely spaced. The net result is that due to the addition of data and the revised grid density after the completion of the Alberta survey control readjustment in mid 1992, transformation results will be different from current provisional ones. Therefore any NAD27 to NAD83 transformations executed prior to mid 1992 will only be preliminary. The "official" Alberta version of the transformation will not be available until after mid 1992. In fact, over the time of its use the dataset governing the transformation may change with the revisions and modifications to NAD83. The question will then become: When do revisions to the control fabric become significant enough to warrant regenerating the grid of shifts?

Another consideration in this transformation is that the control point values, as derived through the transformations, will not be identical to the published values. This is due to the residual smoothing that takes place in computing the grid, which accepts the influence of surrounding control points in a particular region. The amount of difference between the published values and transformed values for control points will depend on several factors. It is expected however that the differences will be greatest in areas that constitute transition zones between areas of varying control point densities. Once the "official" version of the transformation is available in Alberta, the magnitude of the differences will be publicized.

Adoption of NAD83 by ATS

Although the specific method, process and software have not been identified for converting the Alberta Township System Coordinate File (ATS) to NAD83, it is certain that the ATS file will be converted and NAD83 will become the datum on which the ATS coordinate file will be published. As the estimated completion date for the readjustment of the provincial survey control network is mid 1992, the conversion of the ATS file to NAD83 is expected to follow within approximately one year.

Since the ATS file has been released in several versions over the past six years, it is important for users of this file to be aware that the version which will be converted to NAD83 will be the current version as of the conversion date. It is also important to realize that the framework control readjustment not only addresses the adoption of a new datum, it addresses distortions in the control network itself. The specific implication with respect to the ATS file is that users who have determined positions relative to an older version of the ATS file and then transform those coordinates to NAD83 will quite conceivably find their data not to be in registration with the NAD83 ATS file. In fact, if it is a requirement that the user data be in registration with the NAD83 ATS file there may be a requirement to go through two conversions. The first would be to convert the data to the current ATS version and the second would be to convert to NAD83.

The effort to convert the ATS file to NAD83 will be significant since the file contains in excess of 800 000 coordinate pairs. As well, this file is used extensively throughout Land Information Services Division in nearly every base mapping program. The conversion of the digital map bases may involve following the two step process identified above if relationships between all map features with respect to the ATS fabric are to be maintained after the conversion to NAD83.

User Impact

It is hoped that all users will adopt NAD83. The method that is used in this adoption is left to the user. If users wish to maintain the ability to exchange and merge georeferenced data without creating discontinuities provincial users are encouraged to adopt the provincially accepted transformation approach. The gridded dataset and associated interpolation software of the "National Transformation" operate on geographic coordinates. This necessitates that users who have data in a particular map projection form must convert their data first to Latitudes and Longitudes prior to running the software. This will likely create a large overhead. The capability to operate on geographic coordinates instead of map projection coordinates was implemented due to the existence of several different map projections being used across the county. Rather than build in transformations for a myriad of projections, this software was built to operate on the more universal geographic coordinates.

Consideration will likely have to be given to generating a transformation standard in Alberta that operates on plane coordinates.

Users must be aware that the transformation process is only an approximation of the true picture. The effect of the approximation is to smooth out the distortions and not exactly replicate the relationship between the two systems. This will result in a certain amount of smoothing, and "spikes" that may exist in NAD27 when transformed to NAD83 may be somewhat moderated. The result however is not a reliable transformation for which accuracy estimates can be predicted. This will be confirmed by the inability of the transformation to replicate published values of control stations. Agencies attempting to continue working on NAD27 may be able to tolerate the inconsistencies in transformed data, in the absence of checking against control, due to the smoothing effect of the transformation. When connections are made to control markers using published values however, significant problems may surface due to shortcomings in the transformation process.

Currently the "National Transformation" process works in a batch mode. This may be more or less beneficial than interactive, depending on the application. Users should however, take this into account when planning their conversion approach.

Other User Considerations.

In addition to the larger problem of transforming data between the two systems, there are a couple of other considerations that are worth addressing.

Although the adoption of NAD83 creates the first major problem of dealing with coordinates of spatially referenced data changing, it is a sign of things to come. In the future, although the changes in coordinates will not likely be of the same magnitude as the NAD27 to NAD83 shift, we will likely see continued coordinate changes due to marker movement and/or position upgrades.As we deal more frequently with data in digital form these changes in position will become more evident through the use of automated processing. In order to minimize the impact of these coordinate changes on our databases, the positions need to be somewhat desensitized. The position components of entities in our databases must be relegated to "attributes". This philosophy in database design will reduce the impact of coordinate revisions on our databases. Depending on the reason for the coordinate value change and the magnitude, it may or may not be of concern to users.

The tried and true software packages that we use in our data processing tasks having NAD27 datum parameters embedded in the code, need to be modified for use with NAD83. This is not likely a large task but necessitates tracking down the source code and modifying it as required. Modifications in the software structure enabling datum definitions to be input as "control" parameters may simplify the problem in the future and make software more versatile. Somewhat related to this issue is the matter of associating datum definitions with coordinate qualifiers. As with the software packages, we are used to having to deal with only coordinates referenced to one datum. Although some other jurisdictions have more than one reference datum for their spatial referencing systems, Alberta has retained NAD27 since its inception. It is imperative now, with the existence of NAD27 and NAD83, that an attribute be attached to all coordinate information to define the datum to which it is referenced.

Summary

Preliminary NAD83 values have been calculated for approximately eleven thousand markers in Alberta. These values can be made available to users for testing purposes. The remaining survey control markers in the province will have NAD83 values available in the middle of 1992.

It is expected and planned that the "National Transformation" will serve as the basis for transforming LISD's non graphics tertiary data. In the process of finalizing the transformation some modifications to the "National Transformation" will take place. These modifications include; a) incorporating the remaining secondary to influence the gridded shift computation, and b) modifying the grid density in and around built up areas.

Although no users will be forced to adopt NAD83, it is hoped that for the sake of consistency, the adoption of NAD83 will be universal throughout the user community. Furthermore, as users adopt NAD83 it is recommended that a standard in transformation be used. This will minimize inconsistencies introduced by transformation dissimilarities.

No transformation process is perfect. Some of the issues pertaining to the use of the National Transformation have been raised. Users should be aware of these concerns when implementing this approach.

Assistance will be provided through LISD providing advice on the adoption of NAD83 to users. Although Mid '92 will signal the initial stages of NAD83 adoption in Alberta, less significant revisions in coordinates will continue into the future. This will necessitate users preparing to function with coordinate values subject to change. User databases should be designed with this consideration in mind.

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A P P E N D I X 1

Some Reasons and Advantages of Adopting NAD 83

The use of a "local" or non standard reference system precludes the merging, matching and overlaying of datasets from various sources. Universal compatibility of graphic reference systems is the foundation of any GIS application. NAD83 provides the national standard for georeferenced data.

Distortions in the NAD27 based coordinate reference system make for inaccuracies in the reference fabric. This results in either; a) costly resurveys to provide a local upgrade in position quality or, b) project surveys integrated with provincial control not reaching their full accuracy potential.

The space based positioning techniques of today operate in a geocentric system. The Global Positioning System (GPS) in particular is NAD83 based. This implies the direct compatibility of GPS derived positions with NAD83. Examples of some applications to which this is significant are; vehicle navigation, in flight photocentre positioning etc.

The future Active Control System which will enhance the efficiency of GPS and provide a direct link of positioning to the adopted provincial reference fabric, is based on NAD83.

NAD83 has been declared the official datum for Canada by the Federal department of Energy, Mines and Resources Canada.

To continue working on NAD27 will require continual transformations from NAD83. This transformation process is imprecise due to the inability to accurately replicate the NAD27 distortion. Further, the more data compiled on NAD27, if and when the decision is made by a user to adopt NAD83, the larger the transformation task will be.

The availability of reliable accuracy estimates on NAD27 based coordinates is lacking. With the awareness of the accuracy qualifiers on georeferenced information increasing, users will need data regarding the accuracy to which infrastructure positions are stated. One of the side benefits to NAD83 is the availability of position accuracy estimates providing the basis for estimating positional accuracy for infrastructure (land information entities).

Saskatchewan NAD83 Status Report

October 1990

CSMA NAD83 Implementation Strategy

G.W. Meggitt

Saskatchewan Central Surveying and Mapping Agency

CSMA NAD83 Implementation Strategy

Saskatchewan through the Saskatchewan Central Survey & Mapping Agency is coordinating closely with EMR Canada in all aspects of NAD83 implementation.

An announcement of the official adoption of NAD83 by Saskatchewan is planned for 1991. CSMA will take a leadership role in making users aware of the benefits of adopting NAD83.

The basic CSMA topographical and cadastral data sets will be converted starting in 1991 with priorities according to user requirements.

Data in both the NAD27 and the NAD83 system will be available to users for at least 5 years. This will allow users to set their own time frame for adoption of NAD83.

Starting in 1991 all new data will be generated in the NAD83 system, including hard copy maps produced by CSMA.

It is proposed to convert data by transformation using the national ESTPM and bilinear algorithms and parameters to be supplied by Geodetic Survey Division, EMR Canada.

Activities

1 Geodetic Control

Several Saskatchewan control networks are being prepared for integration (by Ghost adjustment) into the NAD83 framework in 1990.

This integration exercise will begin the network maintenance procedures which will continuously add to the 6,844 stations computed from the National Secondary Integration Project in 1990 July.

Weighted station adjustment calculations will be completed for the above stations when the variance-covariance data is made available from Geodetic Survey Division.

Other coordinates will be converted by transformation and not by adjustment. In these cases the residuals between the transformation coordinate values and the "true" NAD83 values at the control points will be calculated using the software to be supplied by Geodetic Survey Division. The residuals will be assessed to determine their significance and any further necessary processes.

After satisfactory transformation testing, users will be advised how to use these transformations to transform any user specific data.

2 Topographical Mapping - Coordinate values in NAD27 will be converted by bilinear transformation by the same methods proposed by the Topographical Mapping Division, EMR. During 1990 a cooperative approach to NAD83 conversion will be negotiated with the Topographical Mapping Division.

3 Cadastral Mapping - Coordinate values in NAD27 will be converted mainly by the EMR bilinear program, but in areas with a high density of control points used to define the ESTPM parameters, ESTPM may be used. During 1990, development work will be undertaken to test conversion processes.

The Significance of Coordinate Accuracies Derived from Transformations.

The coordinate value noise or accuracy level of the topographical data for the photogrammetrically compiled digital nominal scale 1:50,000 maps is, say at best, 0.1 mm at 1:50,000 map scale or 5 metres on the ground and upto 25 metres for digitally scanned map data.

Being aware of some uncertainties in coordination due to occasional unresolved bad misclosures, the overall cadastral coordinate accuracy is stated as being about 2 metres relative to the coordinate grid. The relative accuracy between monuments is generally much better. In the case of cadastral coordinates derived by calculation from measurements on legal plans of survey connected to control points, the relative accuracy should be better than about 1/5,000 or, for example, one cm on a 50 metre line. An objective is to maintain the same official coordinate values for the same point in all GIS data sets; in particular for legal monuments that also happen to be control points, in both cadastral maps and the geodetic data base. For such points the transformation residuals at control points will need to be no more than one or two cms in order to maintain the integrity of the cadastral coordinate calculations i.e. 1 in 5,000 relative accuracy. It remains to be seen, after testing, if this objective will be possible.

For future cadastral surveys being integrated into the framework, this problem will not arise as coordinates of new points will be calculated directly from control points with NAD83 coordinates.

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NAD83 IN ONTARIO: PRE-ADOPTION CONCERNS AND POLICIES

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ABSTRACT

The present concerns and plans of the Ontario Ministry of Natural Resources with respect to the official adoption of NAD83 in Ontario will be addressed in this paper. Both the graphical (GIS) or mapping concerns as well as the non-graphical (control surveying) or geodetic concerns will be dealt with in varying degrees of detail. The history of the horizontal control network within the province will be briefly addressed so that the events leading to the present situation can be understood.

BACKGROUND

Within Ontario, the Ministry of Natural Resources is the provincial agency charged with the responsibility of storing, analyzing and validating horizontal control networks within Ontario, thus ensuring they meet the established provincial standards and specifications. However, many agencies establish control within the province. A major contributor to the network within Ontario, of course, is the Geodetic Survey Division of Energy, Mines and Resources, Canada, whose first order framework spans the province. Much of the network also consists of control established across the province by the Ministry of Transportation, Ontario (MTO), whose mandate it is to construct and maintain the system of highways throughout the province.

Since approximately 1980, the Geodetic Services Section has been collecting control survey information from the control establishing agencies within Ontario, including MTO, as well as many municipalities and other sources. In addition to horizontal control sources external to the Ministry of Natural Resources (MNR) another major contributor is the control established for the Ontario Basic Mapping (OBM) program of MNR, whose objective it is to map the entire province at differing scales, 1/20,000 for Northern Ontario, 1/10,000 for Southern Ontario, and 1/2,000 for municipal mapping. Thus control established for these OBM projects is also spread across the province in distinct areas where OBM mapping has occurred.

The distribution of the horizontal control in Ontario, which results from the fact that there are in total over forty establishing agencies, is demonstrated in Figure 1.

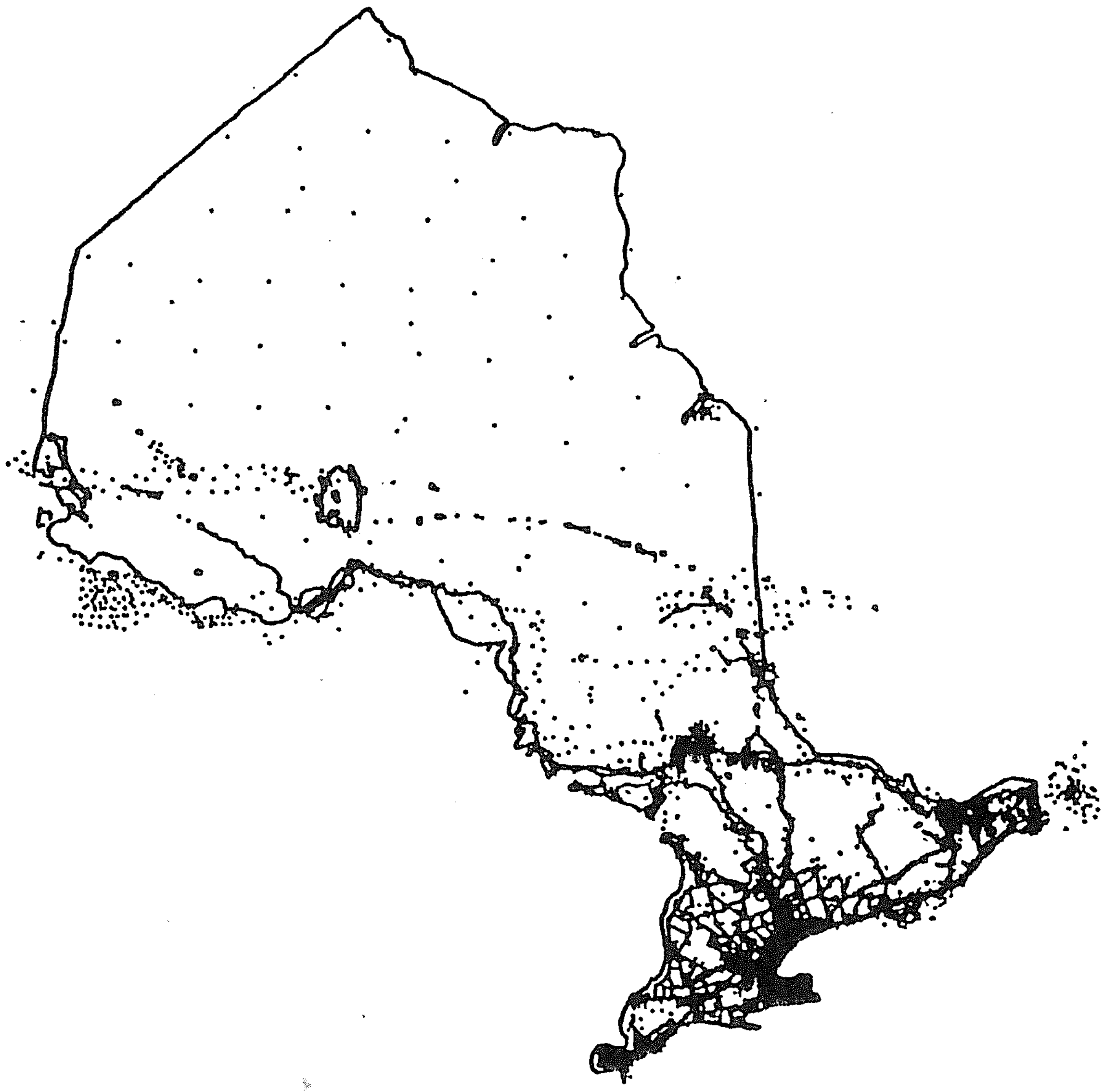

Figure 1: The Horizontal Control Network in Ontario [after Vanicek, et al., 1987]

All projects which were submitted to MNR for loading into the provincial data bank COSINE [Jiwani, 1981] were analyzed using the least-squares adjustment package MANOR [Barber, et al., 1979]. MANOR allows for a constrained adjustment approach only, as weighted station capabilities are presently not incorporated in the package. As such, the networks submitted were constrained to the existing control already in the network in the area. Obviously, this piece-wise constrained adjustment approach for the densification/extension of the network in Ontario resulted in ill-fit conditions in a number of areas of the province. However, this was the generally accepted method at the time. This effect combined with the distortions present in the "classical definition" of the horizontal geodetic datum used for NAD27 resulted in a network with inherent problems and distortions in various areas. Due to these problems, two different major adjustments on the NAD27 datum were undertaken. These least squares-adjustments of the network essentially formed the coordinate reference frame (or datum) for control survey work or mapping within the province of Ontario. The two adjustments are [Kelly and Marshall, 1988]:

> MAY76 adjustment; a NAD27 based minimum distortion coordinate system generated by the Geodetic Survey Division of EMR in an attempt to remove the scale distortion inherent in NAD27 on a national basis, and

74 adjustment; the truly official horizontal coordinate system in Ontario. It is entirely based on NAD27 but it is a result of a regional readjustment carried out in 1973 to distribute inherent NAD27 distortions throughout a small region and consequently provide better consistency of scale in the isolated region of the re-adjustment.

Thus, there are two coordinate systems based on the NAD27 datum which carry some form of official status within Ontario for various activities. Control established by MTO is officially released and employed by them in the 74 adjustment system. As well, the Ontario Ministry of Consumer and Commercial Relations (MCCR) requires mapping done as part of their POLARIS property mapping project to be completed using the 74 adjustment coordinates. However, MNR uses the MAY76 system for the OBM project.

However, no matter whether the MAY76 or 74 adjustment coordinate system is used these coordinates are the product of a constrained adjustment technique with the subsequent artificial distortions resulting in the network. In addition to these local distortions, the datum definition for NAD27 is also not entirely rigorous. Therefore, MNR realizes whole heartedly the problems inherent in the continued use of the NAD27 system and the two adjustments carried out upon this datum.

NAD83 - GENERAL POLICIES AND CONCERNS

The North American Datum of 1983 or NAD83 as it is more commonly referred to represents a significant step forward for geo*referencing and the geodetic control reference system of this continent. It includes both the redefinition of the reference ellipsoid and readjustment on this new reference surface. As such it is a geocentric system which is compatible with the Global Positioning System (GPS - a relatively new satellite surveying system). In addition it is a consistent system due to the fact that all available control survey observations from across the continent are adjusted using Helmert Blocking which is equivalent to a simultaneous adjustment of all data at once, rather than in a piece-wise fashion as had been the case since NAD27 was adopted in 1932.

In May of this year, at the joint Canadian Institute of Surveying and Mapping and Canadian Geophysical Union (CISM/CGU 90) meeting the Minister of Energy, Mines and Resources, Canada, the Honourable Mr. Jake Epp, announced that his Ministry was officially adopting NAD83. This announcement, followed by subsequent policy statements from the Canada Centre for Surveying and the Canada Centre for Mapping have indicated that the provinces are expected to follow suit and work cooperatively with the federal government in adopting NAD83 on a provincial basis. Presently, the federal government is in the process of making available to the provinces some of the tools necessary to implement NAD83. It is anticipated that the first edition of the National Transformation should be released before the end of the 1990 calendar year.

The Ontario Ministry of Natural Resources recognizes the inherent advantages in the NAD83 system and is working towards adopting it officially within Ontario. A staff member from the Geodetic Services Section of MNR is a member of the Canadian Control Survey Committee (CCSC) and the Network Maintenance Subcommittee of the CCSC. These are national committees dealing with NAD83, its adoption and other related topics. The Ontario Ministry of Natural Resources is working cooperatively with members of the federal government on these issues. However, it is the position of MNR that the policies and procedures for adopting NAD83 must be in place prior to moving towards official adoption for Ontario. Some of the areas of concern being examined by provincial or national committees include the integration of tertiary (municipal) and other new control surveys into the NAD83 system, the suitability of the National Transformation for provincial mapping needs, and the use of local transformations.

As one must realize, the move to NAD83 has a large and broad ranging impact on the surveying and mapping activities of everyone across the province. Thus, the Ministry decided to postpone the official proclamation of NAD83 through the required Order-in-Council until a full NAD83 Implementation Plan has been devised for Ontario addressing those complex issues high-lighted above. It is presently hoped that this would be accomplished within approximately a one year time frame. Until the time which NAD83 is officially adopted, the only coordinate values officially recognized by MNR and generally available for unrestricted use from the provincial data bank COSINE will be NAD27 coordinates referred to either the 1974 or 1976 adjustments.

NAD83 STATUS

The Ontario Ministry of Natural Resources (MNR) received the secondary integration simultaneous adjustment of the primary and secondary horizontal control data earlier this year. Geodetic Survey Division of EMR (GSD) officially calls this the Secondary Integration Helmert Block Adjustment (SIHBA). The final iteration of SIHBA for eastern Canada results in what is known as the fifth (5th.) pass SIHBA coordinate set. The loading of the fifth pass SIHBA coordinates into COSINE has been completed.

A study has been completed by Dr. Wassef of the University of Toronto comparing these NAD83 coordinates (SIHBA - 5th. pass) loaded in COSINE with the NAD27 coordinates already stored in the data bank [Wassef, 1990]. This study was designed to measure the compatibility of the two systems and required that:-

(i) mathematical procedures be formulated to examine the coordinate shifts at all horizontal control stations in any given area within Ontario;

(ii) mathematical procedures be designed to assess the degree of compatibility or conformality between the NAD27 and NAD83 coordinates of any particular point;

(iii) qualitative and/or quantitative procedures be formulated to advise on which point or points should be identified as incompatible with the requirements of a number of applications to be identified by MNR.

The results of this analysis will help MNR in determining the location of problem areas in the network and may also serve as a check on the conclusions of Dr. Wassef's report on the comparison of the constrained NAD83 set of coordinates, known as ONT86, to the NAD27 coordinates held in the data bank. The resultant software from the study is presently being loaded on the Branch's VAX computer for testing and implementation purposes.

New control survey work which results in new stations being added to the Horizontal Control Network in Ontario which have not been included in the 5th. pass SIHBA will be integrated into the network at a later date in NAD83 form. All additional networks being loaded into COSINE are still being loaded in NAD27 coordinate form by the constrained adjustment technique. Integration of all data not found in the SIHBA NAD83 coordinate set will be undertaken at a later time making consideration for the recommendations of the Network Maintenance Subcommittee of the Canadian Control Survey Committee (CCSC) with respect to integration of secondary and tertiary control not included in the Secondary Integration Helmert Block Adjustment (SIHBA) least-squares adjustments for NAD83.

NAD83 ADOPTION ISSUES AND CURRENT POLICIES IN ONTARIO

The Geodetic Survey Division (GSD) of EMR anticipates that all of the covariance information and any associated software should be available for the SIHBA fifth pass NAD83 coordinate set very soon. Once Geodetic Services has obtained this and has also undertaken full compatibility tests of the SIHBA fifth pass coordinates as facilitated by the software produced by Dr. Wassef's current study, it is anticipated that these coordinates will almost surely be the coordinates adopted by Ontario for the new official datum of NAD83.

GSD also plans to publish the National Transformation Parameters and Software along with the covariance information prior to the end of this year. In addition, studies will be undertaken to determine the suitability of the National Transformation Parameters and Software for use in Ontario.

The reasons for delay in adopting NAD83 as the official datum in Ontario are multi-faceted. Firstly, the Ontario Ministry of Natural Resources (MNR) felt that the province should not officially adopt NAD83 until it was the official datum of the federal government. Now that this has occurred, extensive testing to evaluate the National Transformation for its suitability to the needs of Ontario must be undertaken once it is available. If the National Transformation Parameters and Software prove acceptable for the needs of Ontario, then the adoption of NAD83 can proceed. However, if further research and development must be undertaken to gain transformation parameters suitable for the needs of Ontario, further delays will be incurred as the transformation parameters must be available for users when NAD83 is officially adopted in the province.

The Order-In-Council proclaiming the official adoption of NAD83 is in draft form. However, the official proclamation will not take place until all of the concerns mentioned above have been addressed to the satisfaction of MNR.

A comprehensive plan for the implementation of NAD83 in Ontario is being investigated by the NAD83 Implementation Plan Subcommittee (NIPS) of the Ontario Committee on Control Surveying (OCCS). Currently, the OCCS has suggested to NIPS that a particular consultant be considered to develop the plan, and that the members of NIPS work cooperatively with this consultant. The adoption plan and any other recommendations of this Subcommittee will be evaluated and acted upon to ensure that MNR is comfortable in putting forth its recommendation to Council to adopt NAD83 as the official datum for Ontario. The terms of reference of the NAD83 Implementation Plan Subcommittee (NIPS) of the Ontario Committee on Control Surveying (OCCS) give a general indication of the activities of this Subcommittee over the foreseeable future. These key areas of the terms of reference may be summarized by the statement of purpose for the Subcommittee which is as follows:-

> i) Establish a framework for and provide direction to the development of a comprehensive Implementation Plan for the adoption of North American Datum 1983 (NAD83) as the official horizontal control datum for Ontario;

ii) Recommend the services of a consultant (or consultants) to actually prepare the Implementation Plan and prepare terms of reference for the services of said consultant(s);

iii) Review the progress of the preparation of the Implementation Plan and recommend the approval of the final draft of the consultant's report;

iv) Secure comment and advice from the surveying and mapping community on the usefulness and practicability of the Implementation Plan through prior circulation of the Plan and the conducting of a Workshop at the Association of Ontario Land Surveyors (AOLS) Annual Meeting;

v) Recommend approval, circulation and promotion of the "official" NAD83 Implementation Plan.

As indicated previously, the only coordinate values bearing official status within Ontario, are the MAY76 and 74 adjustment values based on the NAD27 datum. As well, as was also previously indicated, all loading of new horizontal control surveys into the COSINE data bank is proceeding using the constrained adjustment technique on the NAD27 datum. However, after the point which the

Secondary Integration Helmert Block Adjustment (SIHBA) fifth pass coordinates for Eastern Canada on NAD83 were loaded into COSINE, the Ontario Ministry of Natural Resources has distributed these coordinates upon special request to agencies carrying out research or to contractors involved in GPS surveys for the province. When these NAD83 coordinates are issued a disclaimer is attached which states that the coordinates are of a preliminary nature only, and may not reflect final NAD83 coordinate values to be adopted at a later date. In addition, the user is reminded that they are to be used for the stated purpose only, and that these NAD83 coordinates are not to be further disseminated. One might question why these coordinates, which represent the first official release of NAD83 coordinate values for Eastern Canada, would be labelled as preliminary. However, it should be noted that the Network Maintenance Subcommittee of the Canadian Control Survey Committee (CCSC) is recommending a weighted station adjustment approach using the GHOST [Beattie, 1984] program for integration of the remaining secondary and tertiary control within Ontario. This weighted station approach would allow the existing NAD83 coordinate values to vary in accordance with the variance-covariance information provided. Thus, until a plan for the integration of the remaining secondary and tertiary control is devised for Ontario, the possibility of the weighted station approach necessitates the issuing of any NAD83 coordinates from the SIHBA with the preliminary coordinate warning.

Presently, the covariance information available for the SIHBA fifth pass for Eastern Canada is available only in the form of the profile for each of the blocks forming part of the adjustment. The Geodetic Services Section of MNR has yet to receive this information from the Geodetic

Survey Division (GSD) of EMR, Canada. However, when it is made available, it will necessitate that the MNR begin use of the geodetic least squares adjustment package GHOST, as this is the software package that is required to compute the variance-covariance information from the profiles of the lowest level blocks (as used by Geodetic Survey Division, EMR). The Ontario Ministry of Natural Resources is awaiting the completion of software from the GSD that will compute the variance-covariance information for stations between blocks. When GHOST has been implemented in Ontario, and this other software package is fully developed and tested by GSD for distribution to the provinces, it is anticipated that MNR will distribute variance-covariance information for the NAD83 SIHBA coordinates once this information is computed by MNR. A time frame cannot be attached to the completion of this action because it is dependent upon the release of the new software package currently being developed and tested by GSD which will compute the variance-covariance information between blocks for the SIHBA.

Depending upon the methods adopted by Ontario for the integration of the remaining secondary and tertiary control not included in SIHBA, NAD83 coordinate values for these stations may be issued with or without variance-covariance information. The major factor in this decision will be whether the GHOST software package provided by GSD is used for this task, or whether Ontario continues to use MANOR exclusively.

Finally, in terms of geodetic concerns, the Network Maintenance Subcommittee of the CCSC is recommending that the provinces support the federal government in the development of a dynamic network scenario. In this scenario, the provinces would integrate new survey work into the existing network using a weighted station adjustment approach using GHOST. This would allow for the variability of coordinates on existing stations in accordance with their appropriate variance-covariance information. Thus, coordinates assigned to stations which have already been released to the public would be changing. The Network Maintenance Subcommittee is proposing that the distributed network in a province be compared to the ever changing dynamic network, and that when the coordinate values between the distributed network and the dynamic network are significantly different, then consideration be given to replacing the distributed network values with the dynamic network values. The current criteria suggested by the Network Maintenance Subcommittee for the determination of significantly different is the rigorous 95% confidence displacement ellipse. The reason why this approach is being suggested is that it will avoid the necessity of ever having to carry out a large scale national or international readjustment of the horizontal survey networks again some years down the road. It is hoped that as new data is added, it will be allowed to impact the old existing survey fabric so that a cohesive system is formed. This approach precludes the use of the constrained adjustment technique and assumes that the user realizes that errors are associated with the existing control as well as the new. MNR is committed to assisting the federal government in this endeavour. As such this will further necessitate the adoption and use of the GHOST program within Ontario. However, the province still withholds the right to determine which criteria can be used to determine what is a significant difference between the distributed coordinate values and the dynamic coordinate values, and if there will be any updating of NAD83 coordinate values in the province on a systematic basis or not.

On the mapping side of things, the Ontario Ministry of Natural Resources is eagerly awaiting the first release of the National Transformation. At the time of the writing of this paper, its release is pending. MNR will undergo extensive testing of the software for its suitability for the Ontario Basic Mapping (OBM) program. The main objective of the OBM program is to produce a Digital Topographic Database. The problems of transforming the Database to NAD83 are quite different from those when only graphical products are considered. It is anticipated that the National Transformation Software may be useful for the 1/20,000 and 1/10,000 digital scale mapping, but concern runs high in determining its suitability for 1/2,000 digital mapping, given that accuracies are anticipated to be somewhat better than one metre for the Software. However, the question is how much better than one metre accuracy can we expect. In addition to this concern, it should also be realized that all OBM mapping is carried out on the MAY76 coordinate definition of the NAD27 datum. The first release of the National Transformation software will address only the 74 adjustment, the official NAD27 coordinates across the country and their transformation to NAD83 or vice versa. The federal government anticipates addressing the issue of a MAY76 to NAD83 (and reverse) transformation within no more than one year from the date of the first release of the National Transformation.

The Ontario Ministry of Natural Resources is recommending to all GIS and related database developers or users, that they retain the survey observations and their associated accuracies used to obtain coordinate information. In this way they will be able to maintain the full accuracy and integrity of their database by readjusting their coordinate values to the published NAD83 coordinates released by MNR. No matter which transformation technique one considers, the accuracy of the coordinates is further impacted by the accuracy of the transformation. In the case of some sewer, road and water infrastructure management systems (SIMS, RIMS and WIMS), this could prove intolerable. Therefore, whenever possible MNR is suggesting that the readjustment process be favoured over transformation, as a transformation must always be considered an additional source of error to the system.

Finally, for those users which have not retained the observations used to establish coordinate values for GIS or other related databases, as well as for the large scale municipal mapping needs at scales of 1/2,000 or larger, the Ontario Ministry of Natural Resources will be investigating the National Transformation, its possible modification, or other alternative measures to meet the needs of these users.

CONCLUSIONS

The Ontario Ministry of Natural Resources recognizes the inherent advantages in the NAD83 system and is working towards adopting it officially within Ontario. To this end MNR is participating in the Canadian Control Survey Committee (CCSC) and the Network Maintenance Subcommittee of the CCSC. In addition, the NAD83 Implementation Plan Subcommittee (NIPS) of the Ontario Committee on Control Surveying (OCCS) is charged with the responsibility of developing a comprehensive plan for the implementation of NAD83. It is hoped that the questions and concerns of this paper can be answered and dealt with in an approximate time frame of one year, so that Ontario can progressively be one of the first provinces to officially adopt NAD83.

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SOFTENING THE IMPACT OF THE REDEFINITION

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ABSTRACT

The readjustment and redefinition of the 1927 North American Datum has reached a significant milestone with the recent completion of the secondary integration by the federal government. With the completion of this phase, all first order and a substantial number of second order surveys have now been integrated. In the next one to two years, most provincial agencies are expected to be well under way with the integration of the remaining control networks. With this ground-breaking effort now complete, the work of transforming the vast amount of spatial information stored in automated mapping and geographic information systems can begin.

Generation 5 Technology Ltd. has a client base with databases ranging from a few hundred spatial objects to hundreds of thousands of objects. These databases are being utilized in applications ranging from traditional municipal mapping, to agricultural assessment, to facilities management. Generation 5 will be providing the support

necessary to assist its clients in making the transformation to NAD83. In doing so, issues such as provincial status, timing, cost, resource impact, required accuracy, alternative techniques, application, and others must all be evaluated in order to provide each user with the best possible solution.

This paper outlines Generation 5 Technology's approach, and identifies alternatives available to its user base. These alternatives range from simple coordinate shifts, through scaling and rotation of axes, to complex polynomial modelling. The advantages and disadvantages of each approach are presented, with an emphasis on the utility of the grid interpolation technique of the National Transformation.

Introduction

With advances in positioning technology, particularly in the last ten to fifteen years, it has become apparent that an improved reference datum is required to take full advantage of the high quality surveys which are now possible. As well, the huge increase in the use of Geographic Information Systems and the proliferation of a vast variety of data for these systems has resulted in the need for standardization of the data to facilitate exchange between different users. An important element of this standardization is a solid geodetic base upon which to exchange other data layers. While there are certainly other reasons for the redefinition, these are the two with the greatest impact on the Geographic Information System and the Automated Mapping System communities.

However, it is important to realize that while the adoption of NAD83 will be welcomed, and the ability to work with data from a variety of sources without encountering problems involving spatial inconsistencies will be a great relief, the effort which will be required to reach this goal is enormous. The volume of spatially referenced data currently available is staggering, and it is growing constantly. As a result, very careful consideration must be given to the most effective way to take advantage of these changes.

Generation 5 Technology Ltd. is a software development firm specializing in CAD and GIS technologies and their application in the surveying and mapping sector. With the implementation of NAD83 imminent, Generation 5 is evaluating techniques for aiding both users of its Geo/SQL GIS package, and the popular AutoCAD package, in transforming their existing data.

Impact on Users

In the short term, the impact of the redefinition on most users will be fairly minimal. The computation of virtually all coordinates will continue to be based on the NAD27 datum until such time as provincial bodies have completed the integration of their own control networks. As government agencies begin to utilize the datum in their day to day operations, private users will begin to make the switch to NAD83.

In the medium to long term, it seems probable that many users will be evaluating the application of NAD83 in their operations. Three major factors will affect the degree to which they will adopt NAD83:

1. The most significant factor is now, and will continue to be, the perceived need to make the change from NAD27. The vast majority of users of geographic information systems and automated mapping systems are not yet aware of the implementation of NAD83 or of the impact that it may have on them. Only their dealings with members of the surveying and mapping sector will serve to increase this awareness. As has been noted by many other authors, the success of the industry in demonstrating the reasons for the redefinition and the methods by which users may take advantage of it will be critical in determining its acceptance.

   However, it seems likely that most users will not see the benefit of an improved geodetic foundation for their data as sufficient reason for undertaking the transformation unilaterally. The vast majority of users are quite satisfied with data as currently available. Most users will be reactive in their adoption of

NAD83, transforming data only as required in order to integrate information referenced to the new datum. As mentioned, only the availability of NAD83 coordinates, primarily from government agencies, will begin this process.

2. The second factor affecting user adoption of NAD83 is the cost of transforming existing data. When evaluating the potential benefits of adopting NAD83, the cost of doing so will be the most important limiting factor. To date, little effort has been made to determine what the costs will be in terms of man hours and C.P.U. time. The coming availability of software from the Geodetic Survey of Canada for the conversion of coordinate data should allow some estimates to be made. However, the costs for transforming graphics and related products will remain to be evaluated.

   There is no doubt that the conversion of geographically referenced data currently available will incur a huge cost. This will also act to cause the adoption of NAD83 to be gradual over the next five to ten years.

3. The final factor involves the availability of the hardware and particularly the software tools for the transformation of existing data. The available hardware is certainly adequate for this manipulation. Personal computers currently provide processing capabilities available only on mini and mainframe platforms as little as eight to ten years ago. As time goes on, this processing power will only increase, helping to reduce the costs of data conversion.

   Software is becoming increasingly available for the transformation of data and will continue to appear. The Geodetic Survey's grid interpolation software should greatly simplify the transformation of coordinate data. It is hoped that this software will provide the standard technique for transforming this type of data, ensuring consistent accuracy for the majority of users. At this time, however, no clear standard has emerged for transforming more complex graphical data. Due to the wide variety of proprietary systems currently storing this kind of information, the emergence of such a standard may not occur for some time.

Role of Generation 5 Technology

In order to describe the approach of Generation 5 Technology in assisting its user base transform to NAD83, it is necessary to understand the way in which the Geo/SQL system handles spatial data. As has been implied above, there are two major types of digital data which must be transformed. The first are coordinate data, whether they be simple lists of coordinates, or a portion of a complex database record. The second type of data is actual graphical or map data, containing different types of line work, text labelling, etc. This type of data exists in virtually all automated mapping systems, and also serves as a foundation for many GIS packages.

The transformation of simple coordinate data to NAD83 is relatively easy, with a wide variety of methods of varying complexity available to perform the task. The grid interpolation method to be provided by the federal government provides an excellent opportunity for a simple, standard method for transforming coordinate data for all possible users. In contrast, the transformation of graphical data tends to be much more difficult. Computations can be more intensive, with special handling of different entity types often required. Text entities, placed interactively, often have to be relocated by an operator as well, adding manual effort to the computational effort.

The Geo/SQL Geographic Information System handles spatial information in an intelligent spatial database, rather than as a graphical drawing file. The user effectively begins with a blank page and constructs a custom map out of any basic graphical or attribute entities required. The storage of these graphical entities is accomplished by beginning with a points file, upon which a number of topological indices are constructed. Line entities are stored as pointers to the point entities which comprise them, while polygon objects are stored as a number of pointers to the line entities which comprise them. In this way, any change to the location of a point entity is automatically reflected in changes to any complex object of which that point is a member.

The Geo/SQL system works on the principle of a single seamless database for the entire area of interest. Since all of the fundamental point entities for any spatial database are stored in a single file, operations like changes in map projections or datum are a simple matter of performing the appropriate mathematical manipulations on all records in the file. Because of the seamless nature of the database, there are no problems with edge matching between different portions of the database. All of these calculations can be performed in batch mode, with no user interaction required. At the same time, because the topology of the data is stored in the database, problems due to compromised topological integrity should be virtually eliminated. For the transformation to NAD83, Generation 5 plans to provide a variety of different options, ranging from simple horizontal translations to complex polynomial modelling. Based upon the specific requirements of individual users, Generation 5 will recommend the most appropriate approach.

As noted above, the adoption of NAD83 by users will be very dependant upon the availability of NAD83 referenced data from government agencies, and the user's need to integrate this data. As a result, Generation 5 will also be acting reactively in providing these services to its client base. While its users will be kept informed of the progress and implications of the redefinition, Generation 5 will in no way be encouraging its users to begin transforming their data unless there is strong reason to do so.

Potential Solutions for Users

Generation 5 has been evaluating a variety of techniques for the transformation of coordinate data from NAD27 to NAD83, in order to provide its users with the largest variety of options possible. In this way, the client's specific application and future needs will determine the most appropriate transformation method. Potential solutions include:

1. Simple X,Y Shift - for many applications, an approximation of the coordinate difference between NAD27 and NAD83 is sufficient. These shifts can be obtained by comparing the coordinates of a few local control stations. For a small region, coordinate shifts can be determined for three or four control points, and the resulting shifts in X and Y will be relatively constant across the region. While errors in the range of half a meter may be introduced, this is within the necessary tolerance for many applications. These corrections are easily added to the coordinates to be transformed, in a very fast, approximate transformation.

2. 2-D Similarity Transformation - with this type of approximation, four parameters are calculated to estimate a datum transformation (two translations, one rotation, and one scale.) These parameters can be estimated using the a program like DATUM, available from the Geodetic

Survey of Canada, and applied to the coordinates to be transformed using the companion program SCTRANS. Both of these programs are currently being evaluated in order to determine if they can be ported to the PC platform. Again, this technique would be relatively fast, but with an accuracy suitable for only certain applications.

3. 3-D Similarity Transformation - this approximation uses seven parameters to estimate a datum transformation (three translations, three rotations, and one scale). These parameters can again be calculated and applied using the programs DATUM and SCTRANS. These seven parameters are those usually used to define a datum transformation and are also available directly from the Geodetic Survey. This technique would provide an accurate datum transformation, while still running reasonably quickly on a typical PC.

4. 2-D Affine - while the above methods estimate only the global parameters for a datum transformation, the distortions inherent within the control network itself must also be accounted for. The six parameters of this transformation include two translations, two rotations, and two scales, and apply the same datum transformation as well as providing some estimation of the linear distortion in the network. In some cases, experience may show that some approximation of these distortions may be necessary in particular areas. It is anticipated that methods 3 and 4 will process at approximately the same speed, so that the choice of methods will be dependant primarily on the need to model network distortion.

5. Polynomial Modelling - the use of a polynomial model in conjunction with one of the above datum transformations will allow much better estimation of the non-linear network distortions. The use of the polynomial minimizes the discontinuities between different coordinate sets, and unlike the above techniques, may allow different areas to be joined together with minimal errors at their boundaries. This is particularly important when data from adjoining areas must be shared. The program ESTPM, also available from the Geodetic Survey, can be used following a datum transformation to apply this polynomial model. It is important to note that while this technique is very powerful, it also requires a good understanding of the effect of different polynomial factors. Some care must be taken in the use of ESTPM, since different parameters will generate different results.

   While the combination of a global datum transformation with a regional polynomial model would result in a very accurate transformation, the processing time for such a technique would be prohibitive for most users. While the time for the datum transformation might be reasonable, the addition of the time for the polynomial modelling step, which would be far more computationally intensive, would place this technique beyond the means of most GIS users.

6. Grid Interpolation - While the above technique can be useful, consistent results are not guaranteed. It is conceivable that two adjacent municipalities, using the above technique and the same parameters, might still have some unmodelled distortion at their database boundaries.

This could make integration of data across the boundaries difficult. Therefore, the use of the grid interpolation technique to be provided by the Geodetic Survey of Canada may be preferable for cases where high accuracy is required. This is particularly true in areas where control is sparse, which is the case in much of Canada. While many of the above methods may be sufficient in areas of dense control, difficulties may occur in other areas. This technique interpolates between a uniform grid of control points at 7.5 minute spacing across the country. In addition to the above polynomial modelling, these grid points have been generated by the ESTPM program with an additional step involving residual interpolation to further refine the distortion modelling.

While the performance of this technique remains to be demonstrated, there is no doubt that it should run on a PC platform reasonably quickly. The greatly increased accuracy must also be considered. Work at the Geodetic Survey has shown that the full ESTPM package cannot run on the PC platform due to memory limitations. The residual interpolation phase also requires the specification of parameters relating to the covariance function to be used. The knowledge of the appropriate parameters is beyond that of most potential users.

Once the grid interpolation routines become available, Generation 5 Technology will begin to evaluate these options more fully, both in terms of accuracy and computational effort. This evaluation will first require that these routines be ported to the PC. It is anticipated that most of the intermediate options will involve excessive computation when compared to either the very simple approximations or the fast interpolations based upon the complex estimation of the full ESTPM package.

Based upon these findings, Generation 5 will be in a position to offer it's client base the most appropriate techniques for their transformations, based upon considerations of accuracy, cost, and application.

Conclusions

Generation 5 Technology Ltd. is committed to providing solutions to its clients wishing to transform their data to NAD83. A wide variety of techniques exist for performing this task, and Generation 5 is confident that appropriate alternatives can be found for all users. As time goes on, and NAD83 becomes more and more widely accepted, these techniques can only improve, while the associated costs diminish.

NAD27 to NAD83 Conversion in ARC/INFO

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ARC/INFO offers a variety of methods for moving between different coordinate systems. The TRANSFORM command converts coverage coordinates by either an affine or projective transformation. The PROJECT command offers a flexible interface for converting coverage coordinates between terrestrial projections (i.e. Lambert Conic and Transverse Mercator). However, NAD27 to NAD83 conversion is a rather unique case due in part to the change in ellipsoid from Clarke 1866 to GRS80 but primarily due to the systematic errors implicit in the NAD27 datum. As such, there is no exact formula for transformation of coordinates between NAD27 and NAD83. Energy, Mines and Resources Canada (EMR) provides a program for conversion using a high order polynomial approximation for coordinate transformation. A user with access to all the control points and observations used for the simultaneous adjustment and a rigourous least squares adjustment package could perform a full adjustment of coordinate locations.

Regardless of what conversion method is used, at some point it becomes inefficient to convert all coordinate data using rigourous adjustment. Especially at large scales, the relative accuracy of intermediate point, vertex and text data can be maintained using less rigourous approaches. For conversion of NAD27 to NAD83 data in the USA, the National Geodetic Survey provides two types of data files with both NAD27 and NAD83 locations for control points. The first type actually consists of two data files of geographic coordinates (latitude and longitude); a file of NAD27 coordinate values and a file of NAD83 coordinate values. These two data files are used by the CONTROLLINK command in ARC/INFO to create link features between NAD27 and NAD83 points. The second type provides NAD27 and NAD83 geographic coordinates (latitude and longitude) for each 7.5 minute quadrangle corner. This data file is used by the QUADLINK command in ARC/INFO to create link features between NAD27 and NAD83 points. Both file types are formatted ASCII files with the following structure;

CONTROLLINK Data Files

Column	NAD27 File	NAD83 File
1 - 12	Station Identifier (QIDQSN)	Station Identifier (QIDQSN)
14 - 43	Station Name	Station Name
45 - 58	Latitude (dd mm ss.sssss)	Latitude (dd mm ss.sssss)
61 - 75	Longitude (ddd mm ss.sssss)	Longitude (ddd mm ss.sssss)
78 - 88	State Plane Northing (metres)	State Plane Northing (metres)
91 - 101	State Plane Easting (metres)	State Plane Easting (metres)
103 - 106	State Plane Zone	State Plane Zone
108 - 118	Meridian Convergence	Meridian Convergence
121 - 129	Point Scale Factor	Point Scale Factor
131 - 138	Elevation (metres)	Elevation (metres)
140 - 145	NAD27	Geoid Height (metres)
147	Station Quality 1 - First order (1:100,000) 2 - Second order I (1:50,000) 3 - Second order II (1:20,000) 4- Third order (1:10,000 or 1:5,000)	Station Quality 1 - First order (1:100,000) 2 - Second order I (1:50,000) 3 - Second order II (1:20,000) 4- Third order (1:10,000 or 1:5,000)

QUADLINK Data Files

Column	Description
5 - 30	Name of quad corner
40 - 51	Latitude for NAD27 (dd mm ss.sss)
56 - 68	Longitude for NAD27 (ddd mm ss.sss)
74 - 85	Latitude for NAD83 (dd mm ss.sss)
90 - 102	Longitude for NAD83 (ddd mm ss.sss)

For ARC/INFO coverages in Canada, these data file formats can be mimicked using coordinates obtained from EMR or link coverages can be created from scratch using the same coordinates. Once the link coverage is created, the ARC/INFO ADJUST command is used to transform coverage features. Geographic coordinates (i.e. latitude and longitude) are required for both the CONTROLLINK and QUADLINK commands. The reason for using geographic coordinates is that a single link coverage can be used for the entire USA. Depending on the application, geographic, lambert conic or transverse mercator coordinates could be used for link coverage coordinates (note that if geographic coordinates are used, coordinates must be in decimal degree format).

The ADJUST command in ARC/INFO performs coordinate transformation by building a triangulated irregular network (TIN) from link starting points and using the x and y coordinate shifts as surface values for the TIN (i.e. two surfaces, a delta-x surface and a delta-y surface). The coordinate shift for any point in the convex hull of the TIN is computed separately for x and y using bivariate quintic interpolation. The result is a smooth interpolation of x and y shifts between points while maintaining the x and y shifts at the given control points. Therefore the more points used for the adjustment, the more accurate the adjustment (a complete adjustment would have a link for every coordinate shift in the coverage). ADJUST moves all coverage features including vertices, points and text so that once the coordinate transformation is performed, the coverages are ready for use in the new datum. It is important that all coverage coordinates fall within the convex hull of the link coverage so that a coordinate translation is defined for every coverage location.

Some important considerations have to be made using any adjustment, especially an adjustment with different coordinate shifts for each location. Unlike a similarity transformation, parallel and perpendicular lines are not preserved in the transformation. Moreover, parametric curves (i.e. circles, circular arcs, elliptical arcs, transition curves, etc.) will change shape because each vertex on the curve will have a different translation. Depending on the application, these features may have to be recreated from original observations.

Map library tiling structures based on a transverse mercator grid will also have to be reconceptualized. The coordinate shifts in some areas can be severe (up to about 200 metres in northing and up to about 20 metres in easting), so applications utilizing coordinate grid map tiles will have to be modified. A good interim solution could store the transformed NAD27 tiles (i.e. the old tiles with new NAD83 coordinates) in a map library and modify applications to utilize EXTRACT rather than GETTILE to retrieve grid coverages. In general, it is better to tile libraries by internal coverage features rather than by imposing an external coordinate grid structure.

NAD27 to NAD83 conversion offers a unique challenge to organizations with existing digital data bases. Although ARC/INFO provides a multitude of tools for coordinate transformation, the method of conversion of choice will depend on the accuracy requirements of applications within these organizations.

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The National Transformation

Program Descriptions
and
User Instructions

for

Software Package

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**** NO WARRANTY ****

Although these programs have been tested, neither the author nor the crown gives any warranty as to the accuracy of the functioning of the programs or the accuracy of the related program material and the users of such programs and related materials shall use them at their own risk.

Grid Implementation of The National Transformation between NAD27 and NAD83

GENERAL DESCRIPTION

Purpose

The grid interpolation system has been developed as a simplified implementation of the National Transformation between NAD27 and NAD83. The National Transformation employs complicated computations for datum conversion and distortion modelling, and imposes too heavy a computational burden for most users. This alternative allows computation on basic personal computers, and the efficient processing of very large amounts of data on standard time-sharing systems.

Although descriptions in this documentation repeatedly refer to NAD27 and NAD83, this suite of software is independent of reference systems and the techniques used to model differences between them. It can be used to implement any other combination of systems, areas, grid densities, and transformation software.

Derivation of Grid

The nominal grid points from one system have been passed through the National Transformation software to produce a corresponding grid file in the second system. By comparing these two files, the shifts between systems at each grid point are determined. Assuming that there is no significant irregular variation within each quad defined by the grid, a bilinear interpolation algorithm is used to determine the shift at any selected point within the quad.

Types of Coordinates

All computations use ellipsoidal coordinates - i.e. the familiar geographical system of latitude and longitude. The user has the option of supplying values either in this form, or as UTM coordinates, which will be transformed to the corresponding ellipsoidal values for computation, and then converted back to the UTM system for output.

Description of Grid

The grid of points on which the system is based is defined in terms of ellipsoidal coordinates. The points are specified at regular intervals, although the interval need not be the same for both latitude and longitude. The bilinear interpolation takes place within these quads on the curvilinear surface.

The basic quad size selected for general coverage has a grid interval of 5 minutes in both latitude and longitude. This corresponds to approximately 9 km in latitude, and the longitude interval is diminished by the cosine of the latitude, or approximately 6 km at latitude 49 degrees.

For areas of dense population and/or survey control, certain jurisdictions may choose to specify the grid at smaller intervals to accommodate local variations in the control network. Such grids would supersede the basic grid in those areas.

Any attempt to convert the coordinates of the ellipsoidal grid to UTM (or other plane projection) coordinates and then employ the bilinear interpolation algorithm would produce slightly different results. The differences diminish as a denser grid is selected, since the smaller quads become closer to their plane approximations. However, to preserve uniqueness, only the ellipsoidal grid is used.

The look-up algorithm for grid files requires that a full quad be used. Any attempt to use an irregular area will produce unpredictable results.

Methods of Use

The system can be used in one of three basic methods:

1) A file of coordinates supplied by the user is processed in its entirety, producing a corresponding file of transformed coordinates;

2) As a subroutine to the user's system, coordinates are passed one point at a time and corresponding shifts are returned to the system;

3) A tabulation of shifts at grid points can be produced to be used for manual reference and computations.

Interactive submission of coordinates is not supported, since formatted files are easily created with elementary text editors, and most users will have too much data to enter "on the go".

Transformations can be made in either direction between the two systems.

SOFTWARE and DATA FILES

Language

All routines are written in FORTRAN 77, and have been kept as free from system-dependent features as possible. This facilitates the migration of the software among various computer platforms.

Computers

Versions of the software have been developed for the Digital VAX/VMS family of computers, for IBM/PC compatible micro-computers and the Apple Macintosh computers. The same source code is used on all three with minor exceptions. Where these exceptions do occur, statements for all three systems are embedded in the code with identifying comments. The inappropriate lines are commented out before compilation. The result is a package that is easily migrated to any platform with a FORTRAN compiler.

Migration

The following steps are required to migrate the software and data to a new system:

1) make any necessary changes to file access statements in the source code;

2) re-compile the source code on the new system;

3) convert sequential files of grid coordinates to system-specific direct-access files.

Data Files

To completely cover the country with a 5-minute grid requires approximately a half-million points, which would require several megabytes of disk storage. The coverage is broken down into blocks of more manageable sizes. The basic criterion for determining a block size is that the binary file of grid shifts must fit onto a floppy disk, for transfer between users.

The ASCII sequential files of grid coordinates in each system, which are used to create the binary files of shifts, are much larger for each block. It is assumed that most users will have hard disk systems that can be used to re-combine fragmented sequential files for conversion to binary direct-access format.

File Formats

There are only two file formats with which the user must be concerned:

1) GHOST format geographic coordinate records, and

2) Universal Transverse Mercator (UTM) Grid coordinate record.

Geographic coordinate record:

Columns	Field Description
3	Code used to identify type of data on the record
4 - 6	Type used to identify the record with class of observation
7 - 15	Station number (unique identifier)
16 - 30	Station name
32	Station classification
33 - 38	Associated network
40	Latitude north/south indicator
41 - 42	Latitude degrees
43 - 45	Latitude minutes
46 - 54	Latitude seconds
55	Longitude east/west indicator
56 - 58	Longitude degrees
59 - 61	Longitude minutes
62 - 70	Longitude seconds
71 - 79	Orthometric height
80	Orthometric height indicator

Although the complete record specification has been given, only the latitude and longitude are used for points being transformed. The station number field is used during the construction of the grid shift file to check for matching pairs of coordinates. No other information is required.

Universal Transverse Mercator (UTM) Grid coordinate record:

Columns	Field Description
3	Code used to identify type of data on the record
4 - 6	Type used to identify the record with class of observation
7 - 15	Station number (unique identifier)
16 - 30	Station name
51 - 52	UTM zone number
57 - 68	Easting
69 - 80	Northing

Although the complete record has been listed only the zone,easting, and northing are used for points being transformed.

Program Operation

To make the running of the transformation software as simple as possible, all programs are controlled through the use of similar basic menus, providing an interactive dialogue with the user. The menus consist of:

1) A brief description of a file or an option to be selected;

2) A letter enclosed in square brackets which is used to select the file or option to be modified;

3) The default / user selected option or file;

The user may choose an option by entering the letter for that option followed by a carriage return. After the option has been modified the revised menu is displayed. This will continue until the user selects the option to continue running the program or exits from the program. The following is an example taken from program INTGRID, running on the VAX computer:

```
Program INTGRID Menu

Transformation direction         [D] NAD27   -> NAD83
Input coordinate file            [I] NAD27.DAT
Transformation grid file         [G] GRID.DAC
Input coordinate type            [C] GEO              Default options and file
Output list                      [O] INTGRID.LIS      names
Transformed coordinate file      [N] INTGRID.NEW
Missing coordinate file          [M] INTGRID.MIS
Missing to output list           [L] No
Transform coordinates            [T]
Exit from program            [CR][Q]

Select a menu item

I                                                     Select option to be modified
                                                      by entering letter followed
                                                      by carriage return
Enter file name    [CR] to exit

TEST.DAT                                              User's file name followed by
                                                      carriage return


Program INTGRID Menu

Transformation direction         [D] NAD27   -> NAD83
Input coordinate file            [I] $1$DUA1:[STEVE.TRANSF]TEST.DAT;2
Transformation grid file         [G] GRID.DAC
Input coordinate type            [C] GEO              Modified menu
Output list                      [O] INTGRID.LIS
Transformed coordinate file      [N] INTGRID.NEW
Missing coordinate file          [M] INTGRID.MIS
Missing to output list           [L] No
Transform coordinates            [T]
Exit from program            [CR][Q]

Select a menu item                                    The user may continue
                                                      to select options or exit
```

Detailed Descriptions

The following pages are a description of the software and the related inputs and outputs. Reference can be made to the accompanying sample sessions, listings of input/output files, and structure chart to visualize the relationships among these items.

Although structure charts are included for each program which show the calling relationships for all subroutines, detailed descriptions of each subroutine are not given in this document. Source code for all routines is distributed along with the executable and data files.

Program: **GRIDPT**

Purpose: To generate a regular set of grid coordinates from limit information supplied by the user.

Input(s): Grid limits entered by the user:

1/	lower latitude limit of grid	Deg Min Sec
2/	upper latitude limit of grid	Deg Min Sec
3/	lower longitude limit of grid	Deg Min Sec
4/	upper latitude limit of grid	Deg Min Sec
5/	latitude grid interval	Deg Min Sec
6/	longitude grid interval	Deg Min Sec

Output(s): A sequential ASCII file of standard GHOST coordinate (code 4) records

- one record per grid point, containing point identifier, latitude & longitude
- identifiers are seven characters, defined as follows:
  - characters 1-2 latitude degrees
  - character 3 sequential alpha character for each increment within the degree of latitude
  - characters 4-6 longitude degrees
  - character 7 sequential alpha character for each increment within the degree of longitude
- points are ordered from the lower latitude and longitude limits as follows:
  - at each longitude increment along a latitude to upper longitude limit
  - at each latitude increment to upper latitude limit

Process(es):

- Points are defined by the following algorithm:

for each increment of latitude from lower limit to upper limit

for each increment of longitude from lower limit to upper limit

write a record with point identifier and coordinates

repeat longitude increment

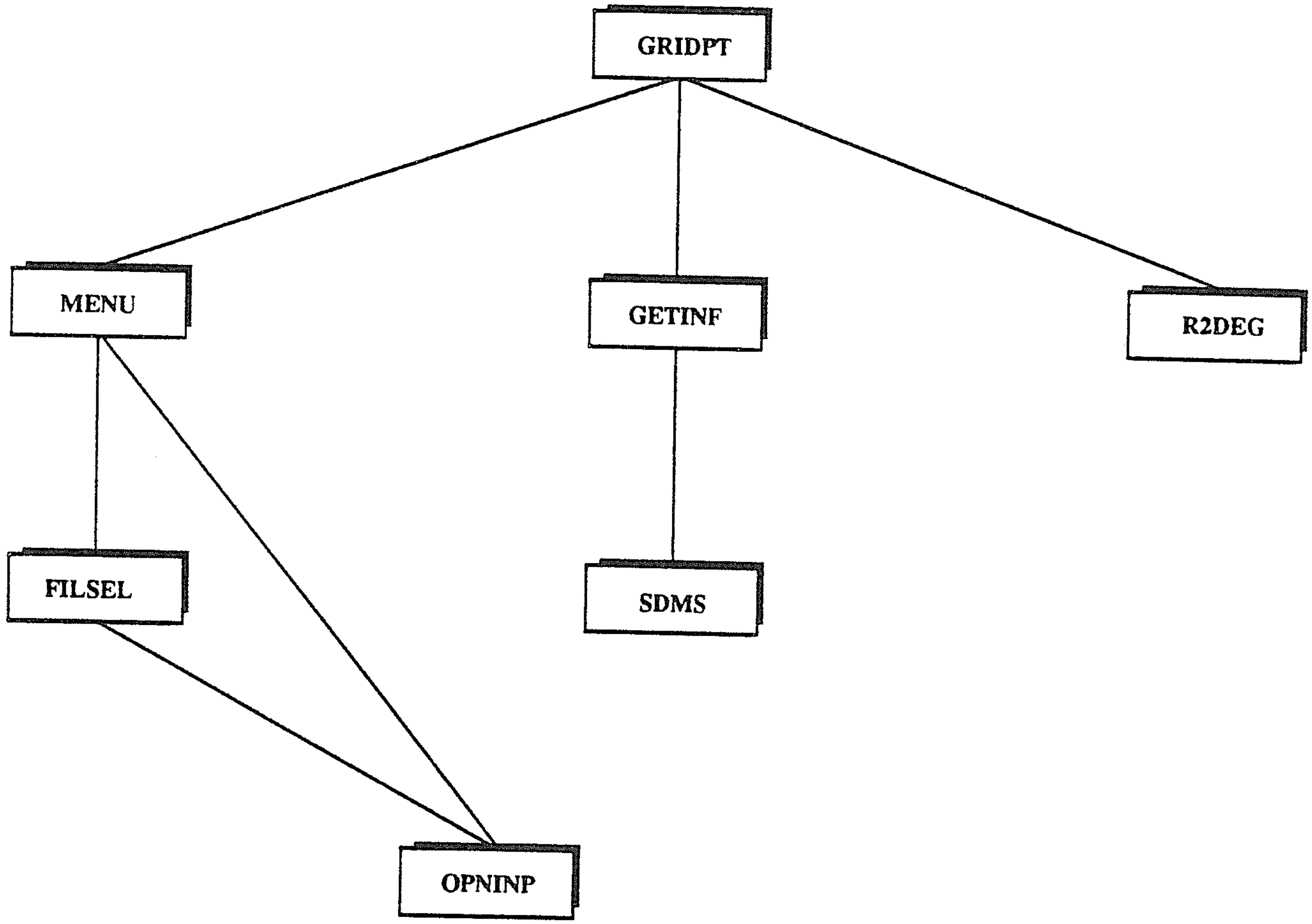
repeat latitude increment

Sample run of program GRIDPT on the VAX

```
$ RUN  GRIDPT

  National Transformation

  Program GRIDPT Menu

  Output File Name              [O] GRIDPT.LIS        Default  file  name
  Run GRIDPT                    [G]
  Exit from program          [CR][Q]

  Select a menu item

G                                                     Select  option  by  entering
                                                      a  letter  followed  by
                                                      carriage  return

                        National Transformation
                        ***********************

                         Program GRIDPT V1.0
                         *******************

 ENTER LOWER LATITUDE IN DEG,MIN,SEC
66  0  0

 ENTER UPPER LATITUDE IN DEG,MIN,DEC
68  0  0                                              Values  are  entered  in  free
                                                      format  separated  by  a  Blank,
 ENTER EAST LONGITUDE IN DEG,MIN,SEC                  Comma,  or  Slash

128  0  0

 ENTER WEST LONGITUDE IN DEG,MIN,SEC
130  0  0

 ENTER GRID SPACING FOR LATITUDE IN DEG,MIN,SEC
0  5  0

 ENTER GRID SPACING FOR LONGITUDE IN DEG,MIN,SEC
0  5  0

     Grid Information

   [1]   Lower   Lat      66   0   0.000
   [2]   Upper   Lat      68   0   0.000
   [3]   East    Long    128   0   0.000
   [4]   West    Long    130   0   0.000
   [5]   Grid    Lat       0   5   0.000
   [6]   Grid    Long      0   5   0.000

 Do you want to change any values  [Y/N/Q]
N
END PROGRAM GRIDPT
```

The following is a part of the grid file produced:

4	66A128A	66	0	0.00000	128	0	0.00000
4	66A128B	66	0	0.00000	128	5	0.00000
4	66A128C	66	0	0.00000	128	10	0.00000
4	66A128D	66	0	0.00000	128	15	0.00000
4	66A128E	66	0	0.00000	128	20	0.00000
4	66A128F	66	0	0.00000	128	25	0.00000
4	66A128G	66	0	0.00000	128	30	0.00000
4	66A128H	66	0	0.00000	128	35	0.00000
4	66A128I	66	0	0.00000	128	40	0.00000
4	66A128J	66	0	0.00000	128	45	0.00000
4	66A128K	66	0	0.00000	128	50	0.00000
4	66A128L	66	0	0.00000	128	55	0.00000
4	66A129A	66	0	0.00000	129	0	0.00000
4	66A129B	66	0	0.00000	129	5	0.00000
4	66A129C	66	0	0.00000	129	10	0.00000
4	66A129D	66	0	0.00000	129	15	0.00000
4	66A129E	66	0	0.00000	129	20	0.00000
4	66A129F	66	0	0.00000	129	25	0.00000
4	66A129G	66	0	0.00000	129	30	0.00000
4	66A129H	66	0	0.00000	129	35	0.00000
4	66A129I	66	0	0.00000	129	40	0.00000
4	66A129J	66	0	0.00000	129	45	0.00000
4	66A129K	66	0	0.00000	129	50	0.00000
4	66A129L	66	0	0.00000	129	55	0.00000
4	66A130A	66	0	0.00000	130	0	0.00000
4	66B128A	66	5	0.00000	128	0	0.00000
4	66B128B	66	5	0.00000	128	5	0.00000
4	66B128C	66	5	0.00000	128	10	0.00000
4	66B128D	66	5	0.00000	128	15	0.00000
4	66B128E	66	5	0.00000	128	20	0.00000
4	66B128F	66	5	0.00000	128	25	0.00000
4	66B128G	66	5	0.00000	128	30	0.00000
4	66B128H	66	5	0.00000	128	35	0.00000
4	66B128I	66	5	0.00000	128	40	0.00000
4	66B128J	66	5	0.00000	128	45	0.00000
4	66B128K	66	5	0.00000	128	50	0.00000
4	66B128L	66	5	0.00000	128	55	0.00000
4	66B129A	66	5	0.00000	129	0	0.00000
4	66B129B	66	5	0.00000	129	5	0.00000
4	66B129C	66	5	0.00000	129	10	0.00000
4	66B129D	66	5	0.00000	129	15	0.00000
4	66B129E	66	5	0.00000	129	20	0.00000
4	66B129F	66	5	0.00000	129	25	0.00000
4	66B129G	66	5	0.00000	129	30	0.00000
4	66B129H	66	5	0.00000	129	35	0.00000
4	66B129I	66	5	0.00000	129	40	0.00000
4	66B129J	66	5	0.00000	129	45	0.00000
4	66B129K	66	5	0.00000	129	50	0.00000
4	66B129L	66	5	0.00000	129	55	0.00000
4	66B130A	66	5	0.00000	130	0	0.00000
4	66C128A	66	10	0.00000	128	0	0.00000
4	66C128B	66	10	0.00000	128	5	0.00000
4	66C128C	66	10	0.00000	128	10	0.00000
4	66C128D	66	10	0.00000	128	15	0.00000
4	66C128E	66	10	0.00000	128	20	0.00000
4	66C128F	66	10	0.00000	128	25	0.00000
4	66C128G	66	10	0.00000	128	30	0.00000
4	66C128H	66	10	0.00000	128	35	0.00000
4	66C128I	66	10	0.00000	128	40	0.00000



Structure Chart for Program GRIDPT

90 - 10 - 11

Program: **DIRFIL**

Purpose: To create an unformatted, direct-access file of grid shifts within a window specified by the user.

Input(s): Two sequential generic ASCII files:

1) list of coordinates for grid points in "System from"
   - defined from program **GRIDPT**

2) list of coordinates for grid points in "System to"
   - computed by applying the transformation to File 1) above

Output(s): One system-specific unformatted direct-access file with 12 Header Records, followed by Data Records:

Header Records:
1/ number of header records
2/ lower latitude limit of grid
3/ upper latitude limit of grid
4/ lower longitude limit of grid
5/ upper longitude limit of grid
6/ latitude grid interval
7/ longitude grid interval
8/ units of shift values
9/ system from
10/ system to
11/ ellipsoid from
12/ ellipsoid to

Data Records:

- one record per grid point, containing shifts in latitude & longitude at each grid point

- points are ordered from the lower latitude and longitude limits as follows:
  - at each longitude increment along a specified latitude until upper longitude limit is reached
  - at each latitude increment until upper latitude limit is reached

cont'd next page...

Process(es):

- reads one record from each file and confirms that they correspond to the same point
- check for a valid pair of points by

  checking unique identifier

  check point is within limits

  check grid increments are correct
- computes differences in latitude & longitude between the two sets of coordinates
- writes differences to direct access file

Sample run of program DIRFIL on the VAX

```
$ RUN  DIRFIL


  National Transformation

  Program DIRFIL FILE Menu

  Input File Name - System To      [T] NAD83.DAT
  Input File Name - System From    [F] NAD27.DAT
  Output File Name                 [O] DIRFIL.LIS
  Direct Access Grid File Name     [G] GRID.DAC
  Run DIRFIL                       [D]
  Exit from program            [CR][Q]

  Select a menu item


D


 ENTER LOWER LATITUDE IN DEG,MIN,SEC
66  0  0

 ENTER UPPER LATITUDE IN DEG,MIN,DEC
68  0  0

 ENTER EAST LONGITUDE IN DEG,MIN,SEC
128  0  0

 ENTER WEST LONGITUDE IN DEG,MIN,SEC

130  0  0

 ENTER GRID SPACING FOR LATITUDE IN DEG,MIN,SEC
0  5  0

 ENTER GRID SPACING FOR LONGITUDE IN DEG,MIN,SEC
0  5  0


 DO YOU WANT COORDINATE DIFFERENCES TO BE
 IN SECONDS OR METRES

    SECONDS         [S]
    METRES          [M]
S
```

Default options and file names

Select option to be modified by entering letter followed by carriage return

Values entered in free format separated by Blanks, Comma, or Slash

cont'd next page...

```
 Select Datum From

Select ellipsoid     [S]
Default (NAPD80)    [CR]
Define ellipsoid     [D]
List ellipsoids      [L]
Quit                 [Q]

L
  1 CLARKE 1866             6378206.4000 6356583.8000
  2 INTERNATIONAL           6378388.0000 6356911.9461
  3 BESSEL                  6377397.1550 6356078.9628
  4 KRASSOVSKIY             6378245.0000 6356863.0188
  5 EVEREST                 6377276.3450 6356075.4131
  6 CLARKE 1880             6378249.1450 6356514.8695
  7 AUSTRALIAN NATIONAL     6378160.0000 6356774.7192
  8 FISCHER (MERCURY)       6378166.0000 6356784.2836
  9 FISCHER(ASIA)           6378155.0000 6356773.3205
 10 HOUGH                   6378270.0000 6356794.3434
 11 AVGERAGE TERRESTRIAL    6378135.0000 6356750.3049
 12 NWL9D                   6378145.0000 6356759.7695
 13 NWL10F (WGS72)          6378135.0000 6356750.5200
 14 NAD83 (WGS84)           6378137.0000 6356752.3142

Select ellipsoid     [S]
Default (NAPD80)    [CR]
Define ellipsoid     [D]
List ellipsoids      [L]
Quit                 [Q]

S
Enter number of ellipsoid

1
  1CLARKE 1866          6378206.40006356583.8000

  Select Datum To

Select ellipsoid     [S]
Default (NAPD80)    [CR]
Define ellipsoid     [D]
List ellipsoids      [L]
Quit                 [Q]

 14 NAD83 (WGS84)           6378137.0000 6356752.3142

    Grid Information

  [1]   Lower  Lat     66  0  0.000
  [2]   Upper  Lat     68  0  0.000
  [3]   East   Long   128  0  0.000
  [4]   West   Long   130  0  0.000
  [5]   Grid   Lat      0  5  0.000
  [6]   Grid   Long     0  5  0.000
  [7]   Data   Type   SECONDS
  [8]   Datum  From   NAD27
  [9]   Datum  To     NAD83

Do you want to change any values  [Y/N/Q]
N
PROCESSING RECORD    620

   625 RECORDS PROCESSED

END OF DIRFIL
```

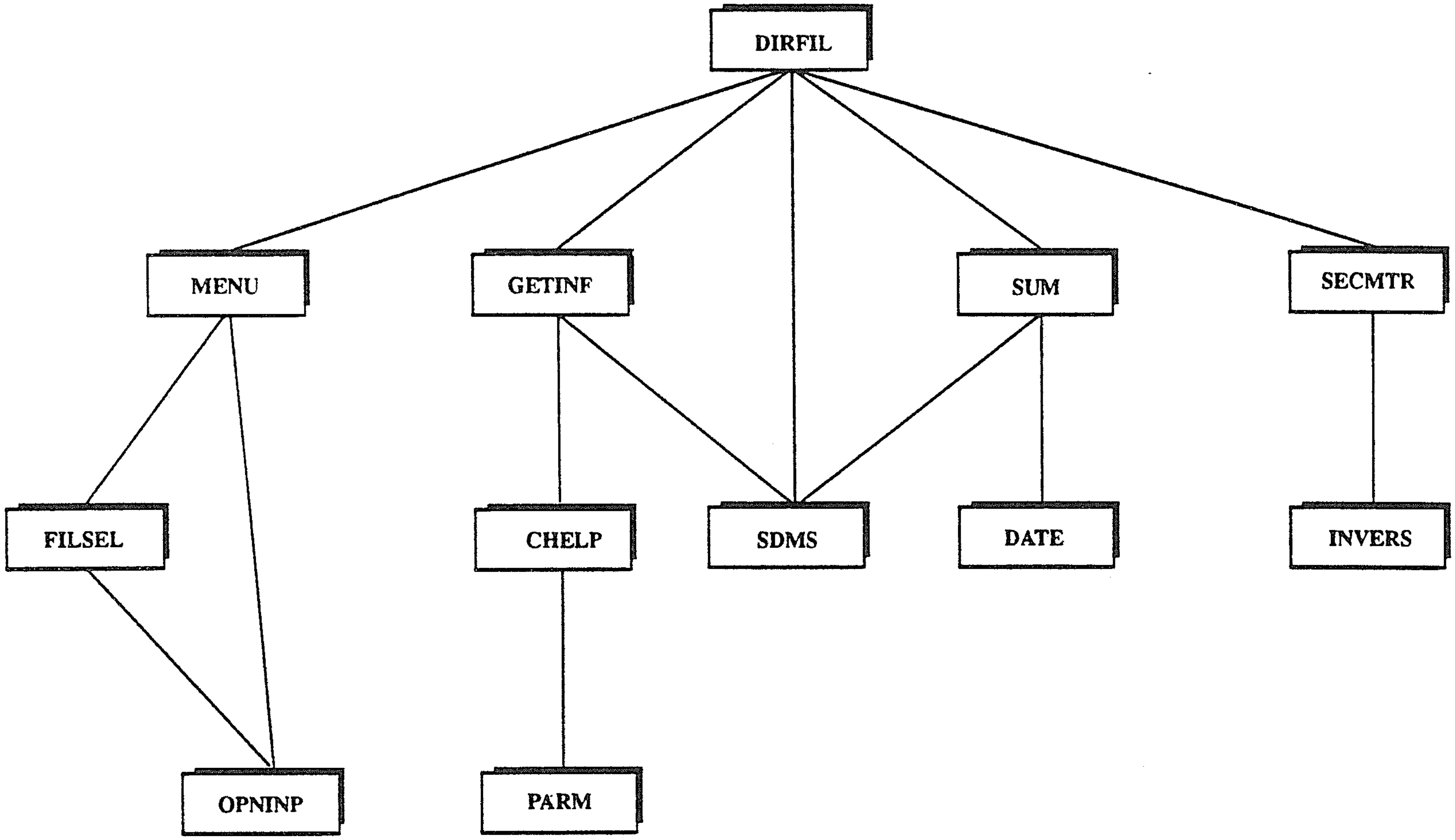
Note NAPD80 is the same as NAD83/WGS84

Ellipsoids defined in program

carriage return

List of output file DIRFIL.LIS:

```
$ TYPE  DIRFIL.LIS
                  National Transformation Version 1.0
                  ===================================

      Summary of Program DIRFIL                Date  16-OCT-90
      =========================

  Coordinate file for System To    :  NAD83.DAT

  Coordinate file for System From :  NAD27.DAT

  Output list                      :  DIRFIL.LIS

  Direct Access Grid File          :  GRID.DAC


      Grid Information
      ================

  Number of Header Records      :   12

  Lower Latitude                :   66  0  0.000

  Upper Latitude                :   68  0  0.000

  East Longitude                :  128  0  0.000

  West Longitude                :  130  0  0.000

  Grid Latitude                 :    0  5  0.000

  Grid Longitude                :    0  5  0.000

  Units of Grid Shifts          :  SECONDS

  System To                     :  NAD83     A =  6378137.000  B =  6356752.314

  System From                   :  NAD27     A =  6378206.400  B =  6356583.800


  Direction of Transformation :  NAD27    -> NAD83

  Number of Records in Grid   :     625
```



Structure Chart for Program DIRFIL

90 - 10 - 02

Program: **READDA**

Purpose: To read a direct-access file produced from program DIRFIL to obtain the grid information and a list of grid shifts.

Input(s): One direct access file output from DIRFIL.

Output(s): A file containing the grid information stored on the 12 header records at the beginning of the direct access file. The grid shifts may optionally be listed.

Header Records:

1/ number of header records
2/ lower latitude limit of grid
3/ upper latitude limit of grid
4/ lower longitude limit of grid
5/ upper longitude limit of grid
6/ latitude grid interval
7/ longitude grid interval
8/ units of shift values
9/ system from
10/ system to
11/ ellipsoid from
12/ ellipsoid to

Data Records:

- one record per grid point, containing shifts in latitude & longitude in seconds at each grid point
- points are ordered from the lower latitude and longitude limits as follows:
  - at each longitude increment along a specified latitude until upper longitude limit is reached
  - at each latitude increment until upper latitude limit is reached

Process(es):

- reads and writes out the 12 header records
- reads and lists the grid shift records if requested
- converts between direct-access (binary) file and a formatted sequential (ASCII) file so that the grid shift file can be migrated to different computer platforms.

Sample run of program READDA to get Header record information on the VAX

$ RUN READDA

```
National Transformation

Program READDA FILE Menu

Convert Between BIN / ASC        [C] No

Input File Name                  [G] GRID.DAC
Input File Type                      Binary

Output File Name                 [N]
Output File Type

Listing File Name                [O] READDA.LIS
List Data Shift Records          [L] No
Run READDA                       [R]
Exit form program            [CR][Q]

Select a menu item
```

Default options and file names

No output file created if conversion is not requested

Select option to be modified by entering letter followed by carriage return

L

```
National Transformation

Program READDA FILE Menu

Convert Between BIN / ASC        [C] No

Input File Name                  [G] GRID.DAC
Input File Type                      Binary

Output File Name                 [N]
Output File Type

Listing File Name                [O] READDA.LIS
List Data Shift Records          [L] Yes
Run READDA                       [R]
Exit form program            [CR][Q]

Select a menu item
```

R

END OF PROGRAM READDA

Partial list of output file READDA.LIS:

```
$ TYPE  READDA.LIS

                   National Transformation Version 1.0
                   ===================================

        Program READDA                Date    4-DEC-90
        ==============

   Convert Between BIN / ASC  [C] No

   Input File Name            [G] GRID.DAC

   Input File Type                Binary

   Output File Name           [N]

   Output file Type

   Listing File Name          [O] READDA.LIS

   List Grid Shift Records    [L] Yes


      Record #

          1      HEADER     12
          2      S LAT         66.000000
          3      N LAT         68.000000
          4      E LONG       128.000000
          5      W LONG       130.000000
          6      N GRID         0.083333
          7      W GRID         0.083333
          8      TYPE       SECONDS
          9      FROM       NAD27
         10      TO         NAD83
         11      FELLIPS    A=  6378206.400      B=  6356583.800
         12      TELLIPS    A=  6378137.000      B=  6356752.314
         13        0.216010        7.117390
         14        0.206350        7.126100
         15        0.194650        7.130050
         16        0.180710        7.131080
         17        0.166640        7.134480
         18        0.155040        7.144220
         19        0.145770        7.158230
         20        0.137980        7.173780
         21        0.130660        7.189550
         22        0.123840        7.204390
         23        0.116690        7.218470
         24        0.109210        7.231910
         25        0.101570        7.244870
         26        0.093920        7.257530
         27        0.086390        7.269980
         28        0.079090        7.282320
         29        0.072060        7.294600
         30        0.065340        7.306810
         31        0.058920        7.318960
```

Sample run of program READDA to convert a Binary file to ASCII on the VAX

$ RUN READDA

```
National Transformation

Program READDA FILE Menu

Convert Between BIN / ASC       [C] No

Input File Name                 [G] GRID.DAC
Input File Type                     Binary

Output File Name                [N]
Output File Type

Listing File Name               [O] READDA.LIS
List Data Shift Records         [L] No
Run READDA                      [R]
Exit form program           [CR][Q]

Select a menu item
```

Default options and file names

C

Convert Binary to ASCII option

```
National Transformation

Program READDA FILE Menu

Convert Between BIN / ASC       [C] Yes
Create a Binary or ASCII File   [F] ASCII

Input File Name                 [G] GRID.DAC
Input File Type                     Binary

Output File Name                [N]
Output File Type

Listing File Name               [O] READDA.LIS
List Data Shift Records         [L] No
Run READDA                      [R]
Exit form program           [CR][Q]

Select a menu item
```

Create an ASCII or Binary file option

O

Enter file name   [CR] to exit

ASCII.LIS

Name of output list file

```
  National Transformation

  Program READDA FILE Menu

  Convert Between BIN / ASC        [C] Yes
  Create a Binary or ASCII File    [F] ASCII

  Input File Name                  [G] GRID.DAC
  Input File Type                      Binary

  Output File Name                 [N]
  Output File Type

  Listing File Name                [O] $1$DUA1:[STEVE.TRANSF]ASCII.LIS;1
  List Data Shift Records          [L] No
  Run READDA                       [R]
  Exit form program            [CR][Q]

  Select a menu item


N

 Enter name of the new BIN / ASC grid file

GRID.ASC                                                Name of ASCII grid file

  National Transformation

  Program READDA FILE Menu

  Convert Between BIN / ASC        [C] Yes
  Create a Binary or ASCII File    [F] ASCII

  Input File Name                  [G] GRID.DAC
  Input File Type                      Binary

  Output File Name                 [N] GRID.ASC
  Output File Type                     ASCII

  Listing File Name                [O] $1$DUA1:[STEVE.TRANSF]ASCII.LIS;1
  List Data Shift Records          [L] No
  Run READDA                       [R]
  Exit form program            [CR][Q]

  Select a menu item


R
END OF PROGRAM READDA
```

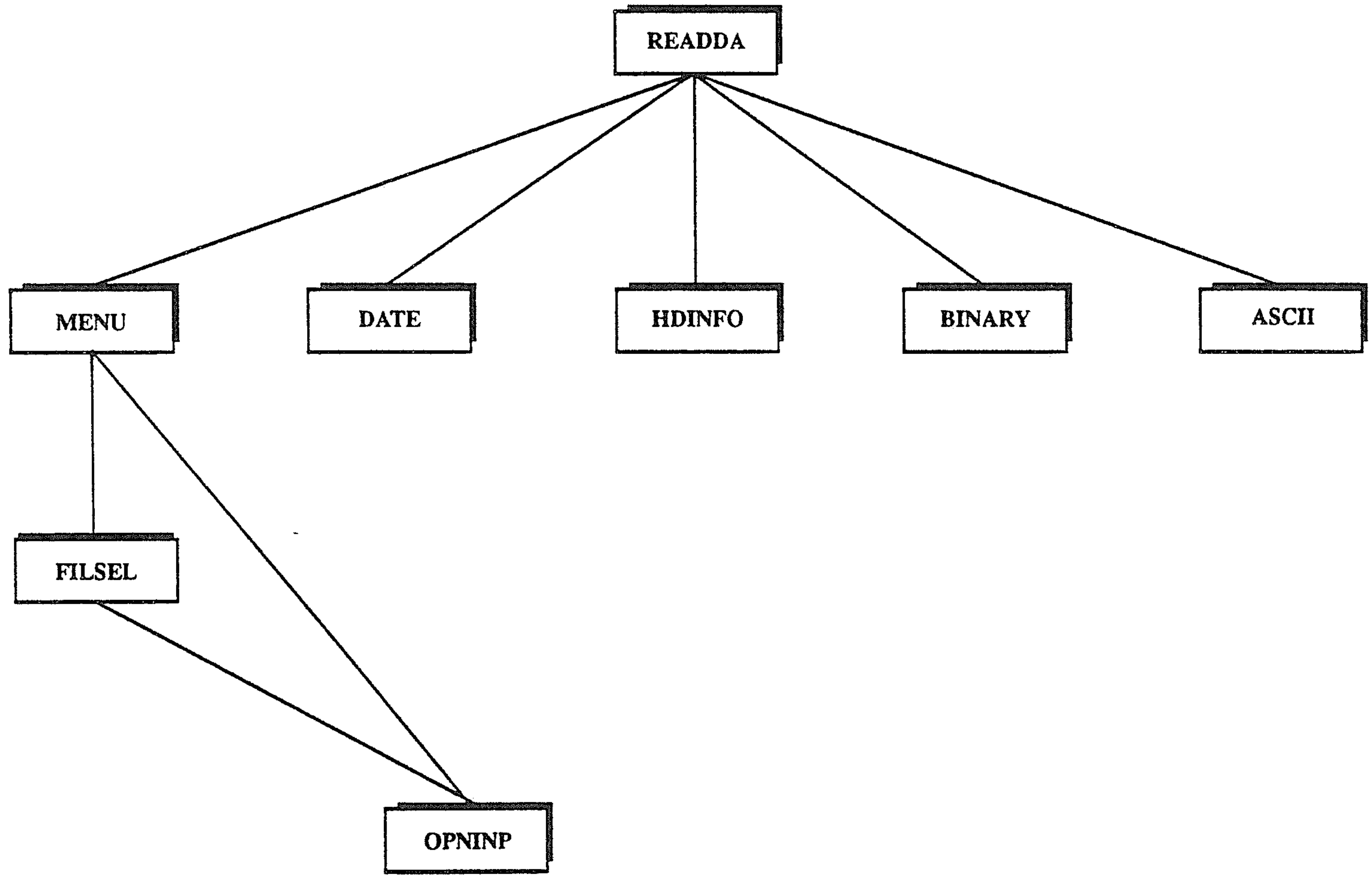
Note: A similar session can be used to convert the ASCII file back to binary by selecting the [F] menu item which toggles the appropriate file types.

Partial list of output file GRID.ASC:

```
$ TYPE  GRID.ASC

HEADER          12
S LAT    66.000000
N LAT    68.000000
E LONG  128.000000
W LONG  130.000000
N GRID         300.000
W GRID         300.000
TYPE    SECONDS
FROM    NAD27
TO      NAD83
 6378206.400 6356583.800
 6378137.000 6356752.314
   0.216010   7.117390
   0.206350   7.126100
   0.194650   7.130050
   0.180710   7.131080
   0.166640   7.134480
   0.155040   7.144220
   0.145770   7.158230
   0.137980   7.173780
   0.130660   7.189550
   0.123840   7.204390
   0.116690   7.218470
   0.109210   7.231910
   0.101570   7.244870
   0.093920   7.257530
   0.086390   7.269980
   0.079090   7.282320
   0.072060   7.294600
   0.065340   7.306810
   0.058920   7.318960
   0.052830   7.330900
   0.047260   7.342240
   0.042950   7.350560
   0.036520   7.350220
   0.033910   7.338860
   0.031160   7.328240
   0.202430   7.079730
   0.188360   7.087350
   0.174190   7.095330
   0.160750   7.104940
   0.148910   7.117640
   0.139490   7.134580
   0.132450   7.155050
   0.126970   7.177030
   0.122110   7.198640
   0.117300   7.218910
   0.111860   7.237630
   0.106650   7.254610
   0.101060   7.270310
   0.095210   7.285040
   0.089210   7.299060
   0.083170   7.312580
   0.077140   7.325740
   0.071180   7.338670
   0.065300   7.351410
   0.059470   7.364020
   0.053610   7.376450
   0.047430   7.388600
   0.040180   7.399960
   0.029920   7.409190
   0.013790   7.414110
```

List of output file ASCII.LIS:

```
$ TYPE ASCII.LIS
                    National Transformation Version 1.0
                    ===================================

      Program READDA              Date    4-DEC-90
      ==============

   Convert Between BIN / ASC   [C] Yes

   Create a BIN  / ASC File    [F] ASCII

   Input File Name             [G] GRID.DAC

   Input File Type                 Binary

   Output File Name            [N] GRID.ASC

   Output file Type                ASCII

   Listing File Name           [O] $1$DUA1:[STEVE.TRANSF]ASCII.LIS;1

   List Grid Shift Records     [L] No

       638 Records in file
```



Structure Chart for Program READDA

90-11-29

Program: **INTGRID**

Purpose: To determine shifts and apply them to a set of input coordinates to transform them between systems.

Input(s): Sequential file of ellipsoidal or UTM coordinates.

Output(s):

1/ File of transformed coordinates in same order as submitted

- sequential file of GHOST format coordinate records, with all fields preserved intact except coordinate fields

2/ printout report file with headers, dates, processing summary, etc.

3/ file of coordinates not transformed

Other File(s): Direct-access file of grid shifts (as created by **DIRFIL**) is referenced, but not modified

Process(es):

- reads one record at a time from the input file
- converts UTM plane coordinates to ellipsoidal coordinates as required
- check whether coordinates are within grid file limits
- calls routine **GRIDINT** to compute transformed value
- writes transformed value to file

The program computes the addresses of the corners of the quad containing the point to be transformed. It will find the quad for any point inside the grid provided it does not fall exactly on the upper limit of either latitude or longitude.

Sample run of program INTGRID on the VAX

```
$ RUN  INTGRID


  National Transformation

  Program INTGRID

 Enter name of transformation grid file

GRID.DAC
```

Enter name of direct access file

```
  National Transformation

  Program INTGRID

  Grid Information
```

Grid information taken from direct access file

```
 S LAT      :  66  0  0.000        N GRID     :   0  5  0.000
 N LAT      :  68  0  0.000        W GRID     :   0  5  0.000
 E LONG     : 128  0  0.000        TYPE       : SECONDS
 W LONG     : 130  0  0.000        FROM       : NAD27
                                   TO         : NAD83

  Program INTGRID Menu

  Transformation direction        [D] NAD27   -> NAD83
  Input coordinate file           [I] NAD27.DAT
  Transformation grid file        [G] grid.dac
  Input coordinate type           [C] GEO
  Output list                     [O] INTGRID.LIS
  Transformed coordinate file     [N] INTGRID.NEW
  Missing coordinate file         [M] INTGRID.MIS
  Missing to output list          [L] No
  Transform coordinates           [T]
  Exit from program            [CR][Q]
```

Default options and file names

```
  Select a menu item

I
```

Select option to be modified by entering letter followed by carriage return

```
 Enter file name    [CR] to exit

TEST.DAT
```

File of coordinates to be transformed

cont'd next page...

```
National Transformation

Program INTGRID

Grid Information

S LAT     :  66  0  0.000        N GRID    :   0  5  0.000
N LAT     :  68  0  0.000        W GRID    :   0  5  0.000
E LONG    : 128  0  0.000        TYPE      : SECONDS
W LONG    : 130  0  0.000        FROM      : NAD27
                                 TO        : NAD83

Program INTGRID Menu

Transformation direction       [D] NAD27   -> NAD83
Input coordinate file          [I] $1$DUA1:[STEVE.TRANSF]TEST.DAT;2
Transformation grid file       [G] grid.dac
Input coordinate type          [C] GEO
Output list                    [O] INTGRID.LIS
Transformed coordinate file    [N] INTGRID.NEW
Missing coordinate file        [M] INTGRID.MIS
Missing to output list         [L] No
Transform coordinates          [T]
Exit from program          [CR][Q]

Select a menu item

T
    PROCESSING RECORD #      7


            5 POINTS TRANSFORMED

            5 POINTS OUTSIDE OF GRID

           10 RECORDS PROCESSED

END PROGRAM INTGRID
```

Modified menu

Transform coordinates

Program summary

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List of output file INTGRID.LIS:

```
$ TYPE  INTGRID.LIS

                                 National transformation Version 1.0
                                 ===================================

                      Department of ENERGY, MINES, and RESOURCES
                       GEODETIC SURVEY of CANADA Program INTGRID              DATE  16-OCT-90
                      ===========================================


      Coordinate file to be transformed  : $1$DUA1:[STEVE.TRANSF]TEST.DAT;2

      Coordinate data type               : GEO

      Transformation grid file           : grid.dac

      Output list                        : INTGRID.LIS

      List of transformed coordinates    : INTGRID.NEW

      List of coordinates not transformed: INTGRID.MIS

      List missing coordinates to output : No

      Direction of transformation        : NAD27   -> NAD83


      Grid Information
      ===============

      Number of Header Records     :   12

      Lower Latitude               :   66  0  0.000

      Upper Latitude               :   68  0  0.000

      East Longitude               :  128  0  0.000

      West Longitude               :  130  0  0.000

      Grid Latitude                :    0  5  0.000

      Grid Longitude               :    0  5  0.000

      Units of Grid Shifts         :  SECONDS

      System To                    :  NAD83     A =  6378137.000  B =  6356752.314

      System From                  :  NAD27     A =  6378206.400  B =  6356583.800


                  5 POINTS TRANSFORMED

                  5 POINTS OUTSIDE OF GRID

                 10 RECORDS PROCESSED
```

-OCT-90

List of input file TEST.DAT:

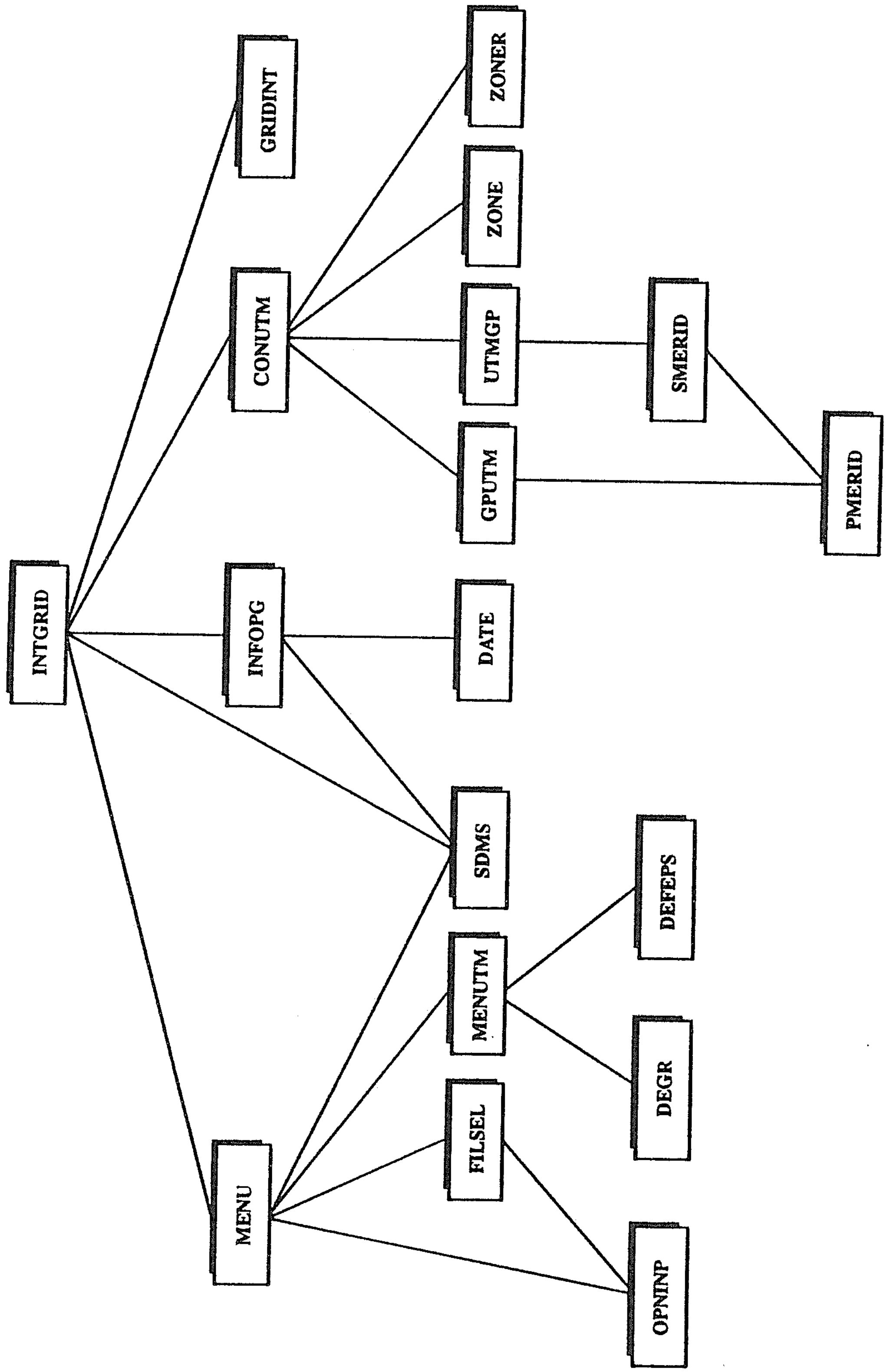
```
$ TYPE   TEST.DAT
  4   1                                      66 00 00         128 00 00
  4   2                                      66 00 00         129 00 00
  4   3                                      66 00 00         130 00 00
  4   4                                      66 30 30         128 30 30
  4   5                                      67 00 00         130 00 00
  4   6                                      67 20 00         129 20 00
  4   7                                      67 30 00         128 00 00
  4   8                                      68 00 00         128 00 00
  4   9                                      68 00 00         129 00 00
  4   10                                     68 00 00         130 00 00
```

List of output file INTGRID.NEW:

```
$ TYPE   INTGRID.NEW
  4   1                                      66  0 0.216010 128  0 7.117390
  4   2                                      66  0 0.101570 129  0 7.244870
  4   4                                      66 3030.168310 128 3037.387980
  4   6                                      67 20 0.211560 129 20 8.070450
  4   7                                      67 30 0.342290 128  0 7.926480
```

List of output file INTGRID.MIS:

```
$ TYPE   INTGRID.MIS
  4   3                                      66 00 00         130 00 00
  4   5                                      67 00 00         130 00 00
  4   8                                      68 00 00         128 00 00
  4   9                                      68 00 00         129 00 00
  4   10                                     68 00 00         130 00 00
```



Structure Chart for Program INTGRID

90 - 10 - 02

Subroutine: **GRIDINT**

Purpose: To transform supplied coordinates between systems by interpolating between values from a table of grid shifts.

Input(s): Ellipsoidal coordinates and direction of shift are supplied as formal parameters

Output(s): Transformed coordinates are returned as formal parameters

Other File(s): Direct-access file of grid shifts (as created by **DIRFIL**)

Process(es):

- determines quad in which point resides
- obtains grid shifts for appropriate points from direct access file
- computes shift at input point by bilinear interpolation with respect to the four grid points
- applies shifts to input coordinates to produce transformed coordinates

Program: **INTTAB**

Purpose: To produce a hard copy tabulation of grid shifts in a selected area or create a new grid shift file from the original direct-access file.

Input(s): Direct-access file of grid shifts (as created by **DIRFIL**) is referenced, but not modified

Output(s):

1/ File of tabulated grid shifts

2/ Windowed grid shift file

Process(es):

- obtain area for interpolation from interactive user
- read direct access file and produce a file of tables for the defined area
- window out an area in the direct-access file and create a smaller direct-access file

Sample run of program INTTAB on the VAX

```
$ RUN  INTTAB

  National Transformation

  Program INTTAB Menu

  Output listing                    [O] INTTAB.LIS
  Transformation grid file          [G] GRID.DAC
  Windowed grid file                [F] NEWGRID.DAC
  New grid file                     [N] NO
  Window grid file                  [W] NO
  Print grid table                  [P] YES
  INTGRID Table                     [T]
  Exit from program             [CR][Q]

  Select a menu item
```

Default options and file manes

```
N
```

Select option to be modified by entering letter followed by carriage return

```
  National Transformation

  Program INTTAB Menu

  Output listing                    [O] INTTAB.LIS
  Transformation grid file          [G] GRID.DAC
  Windowed grid file                [F] NEWGRID.DAC
  New grid file                     [N] YES
  Window grid file                  [W] YES
  Print grid table                  [P] NO
  INTGRID Table                     [T]
  Exit from program             [CR][Q]

  Select a menu item
```

Modified menu

```
P
```

Select print table option

```
  National Transformation

  Program INTTAB Menu

  Output listing                    [O] INTTAB.LIS
  Transformation grid file          [G] GRID.DAC
  Windowed grid file                [F] NEWGRID.DAC
  New grid file                     [N] YES
  Window grid file                  [W] YES
  Print grid table                  [P] YES
  INTGRID Table                     [T]
  Exit from program             [CR][Q]

  Select a menu item
```

```
T
```

Continue running program

```
WORKING
```

List of output file INTTAB.LIS:

$ TYPE INTTAB.LIS

```
 The program will use the nearest grid points
 beyond the limits supplied by the user if the
 defining points do not fall on a grid line in
 the grid file.

 Enter lower latitude in Deg,Min,Sec
66  33  30
 Enter upper latitude in Deg,Min,Sec
67  33  30
 Enter east longitude in Deg,Min,Sec
128  45  0
 Enter west longitude in Deg,Min,Sec
129  50  0

                    Window Limits

        User entered limits          Program will use

 Lower lat     66 33 30.000000          66 30  0.000000
 Upper lat     67 33 30.000000          67 35  0.000000
 East long    128 45  0.000000         128 40  0.000000
 West long    129 50  0.000000         129 50  0.000000

 Do you want to change any values  (Y/N)
N


WORKING

    222 Records in new file

 END PROGRAM INTTAB
```

Program selection of limits

Limits entered by user and the limits to be used by the program

List of output file INTTAB.LIS:

```
$ TYPE  INTTAB.LIS

                        National transformation Version 1.0
                        ===================================

          Department of ENERGY, MINES, and RESOURCES               PAGE    1
           GEODETIC SURVEY of CANADA Program INTTAB                DATE 23-NOV-90
          ============================================

FILE INFORMATION
================

Transformation grid file    :  GRID.DAC

Windowed grid file          :  NEWGRID.DAC

Output list                 :  INTTAB.LIS


Grid Information                             Windowed Grid File
================                             ==================

Number of Header Records    :   12

Lower Latitude              :   66  0  0.000        66 30  0.000

Upper Latitude              :   68  0  0.000        67 35  0.000

East Longitude              :  128  0  0.000       128 40  0.000

West Longitude              :  130  0  0.000       129 50  0.000

Grid Latitude               :    0  5  0.000

Grid Longitude              :    0  5  0.000

Units of Grid Shifts        :  SECONDS

System To                   :  NAD83    A =  6378137.000  B =  6356752.314

System From                 :  NAD27    A =  6378206.400  B =  6356583.800
```

cont'd next page...

List of output file INTTAB.LIS continued:

```
WINDOW INFORMATION
==================

Window the grid file        :  YES

                  Window Limits

        User entered limits          Program will use

Lower lat    66 33 30.000000          66 30  0.000000
Upper lat    67 33 30.000000          67 35  0.000000
East long   128 45  0.000000         128 40  0.000000
West long   129 50  0.000000         129 50  0.000000

      222 Records in new file
```

cont'd next page...

Department of ENERGY, MINES, and RESOURCES
GEODETIC SURVEY of CANADA Program INTTAB

Latitude and longitude SHIFTS are in SECONDS Lat/Long

Add shifts to NAD27 to get NAD83

LONGITUDE (Deg Min)

LATITUDE (Deg Min)	129 40	129 35	129 30	129 25	129 20	129 15	129 10	129 5	129 0	128 55	128 50	128 45	128 40
67 30	0.189 8.242	0.199 8.227	0.209 8.212	0.217 8.197	0.224 8.182	0.232 8.166	0.239 8.150	0.247 8.134	0.254 8.118	0.262 8.102	0.270 8.085	0.277 8.069	0.285 8.052
67 25	0.181 8.179	0.191 8.167	0.201 8.153	0.211 8.139	0.218 8.124	0.226 8.110	0.234 8.095	0.242 8.080	0.250 8.065	0.257 8.049	0.265 8.034	0.273 8.019	0.280 8.004
67 20	0.172 8.108	0.183 8.102	0.193 8.093	0.203 8.083	0.212 8.070	0.221 8.057	0.229 8.044	0.237 8.030	0.245 8.016	0.253 8.001	0.261 7.987	0.268 7.972	0.276 7.958
67 15	0.156 8.007	0.169 8.009	0.181 8.010	0.192 8.009	0.203 8.005	0.213 7.998	0.223 7.989	0.232 7.979	0.240 7.967	0.248 7.954	0.256 7.940	0.264 7.926	0.271 7.912
67 10	0.141 7.920	0.152 7.915	0.163 7.913	0.174 7.913	0.186 7.915	0.198 7.917	0.210 7.918	0.222 7.915	0.233 7.910	0.242 7.902	0.251 7.891	0.259 7.879	0.267 7.866
67 5	0.129 7.862	0.138 7.852	0.146 7.843	0.156 7.836	0.166 7.832	0.177 7.830	0.189 7.832	0.203 7.835	0.217 7.837	0.230 7.838	0.241 7.834	0.252 7.827	0.260 7.818
67 0	0.118 7.817	0.126 7.805	0.133 7.794	0.141 7.783	0.149 7.774	0.158 7.766	0.168 7.761	0.180 7.759	0.193 7.760	0.208 7.763	0.223 7.766	0.237 7.767	0.249 7.764
66 55	0.108 7.776	0.115 7.764	0.122 7.752	0.129 7.740	0.137 7.728	0.144 7.718	0.152 7.708	0.162 7.701	0.172 7.697	0.185 7.695	0.199 7.697	0.215 7.700	0.230 7.703
66 50	0.099 7.737	0.106 7.724	0.113 7.712	0.120 7.700	0.127 7.688	0.133 7.676	0.140 7.665	0.148 7.655	0.156 7.646	0.166 7.639	0.178 7.636	0.191 7.635	0.207 7.638
66 45	0.092 7.698	0.099 7.686	0.105 7.674	0.112 7.662	0.118 7.650	0.125 7.637	0.132 7.625	0.138 7.614	0.145 7.602	0.153 7.592	0.162 7.584	0.172 7.578	0.184 7.575
66 40	0.086 7.661	0.092 7.649	0.099 7.636	0.105 7.624	0.112 7.611	0.118 7.598	0.124 7.586	0.131 7.573	0.137 7.561	0.144 7.548	0.151 7.537	0.159 7.526	0.168 7.517
66 35	0.080 7.623	0.087 7.610	0.093 7.597	0.100 7.584	0.106 7.570	0.112 7.557	0.118 7.543	0.124 7.530	0.131 7.516	0.137 7.503	0.143 7.489	0.150 7.476	0.158 7.464
66 30	0.075 7.582	0.082 7.568	0.088 7.553	0.094 7.539	0.100 7.524	0.106 7.510	0.112 7.495	0.118 7.480	0.124 7.465	0.130 7.451	0.137 7.436	0.144 7.422	0.151 7.408

Latitude and longitude SHIFTS are in SECONDS Lat/Long

Add shifts to NAD27 to get NAD83

LONGITUDE (Deg Min)

LATITUDE (Deg Min)	129 50	129 45	129 40
67 30	0.166	0.178	0.189
	8.267	8.255	8.242
67 25	0.156	0.169	0.181
	8.197	8.190	8.179
67 20	0.141	0.158	0.172
	8.104	8.109	8.108
67 15	0.125	0.141	0.156
	8.005	8.005	8.007
67 10	0.119	0.130	0.141
	7.937	7.927	7.920
67 5	0.113	0.121	0.129
	7.886	7.874	7.862
67 0	0.104	0.111	0.118
	7.842	7.830	7.817
66 55	0.094	0.101	0.108
	7.801	7.789	7.776
66 50	0.086	0.093	0.099
	7.761	7.749	7.737
66 45	0.079	0.085	0.092
	7.723	7.710	7.698
66 40	0.073	0.079	0.086
	7.686	7.674	7.661
66 35	0.068	0.074	0.080
	7.649	7.636	7.623
66 30	0.063	0.069	0.075
	7.610	7.596	7.582

66 35	0.068	0.074	0.080
	7.649	7.636	7.623
66 30	0.063	0.069	0.075
	7.610	7.596	7.582

Department of ENERGY, MINES, and RESOURCES
GEODETIC SURVEY of CANADA Program INTTAB

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Latitude and longitude SHIFTS are in SECONDS Lat/Long

Add shifts to NAD27 to get NAD83

LONGITUDE (Deg Min)

LATITUDE (Deg Min)	129 40	129 35	129 30	129 25	129 20	129 15	129 10	129 5	129 0	128 55	128 50	128 45	128 40
67 35	0.199	0.207	0.215	0.222	0.230	0.237	0.245	0.252	0.260	0.267	0.275	0.282	0.290
	8.310	8.295	8.279	8.263	8.247	8.230	8.213	8.195	8.177	8.159	8.141	8.122	8.104
67 30	0.189	0.199	0.209	0.217	0.224	0.232	0.239	0.247	0.254	0.262	0.270	0.277	0.285
	8.242	8.227	8.212	8.197	8.182	8.166	8.150	8.134	8.118	8.102	8.085	8.069	8.052

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GEODETIC SURVEY of CANADA Program INTTAB

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DATE 23-NOV-90

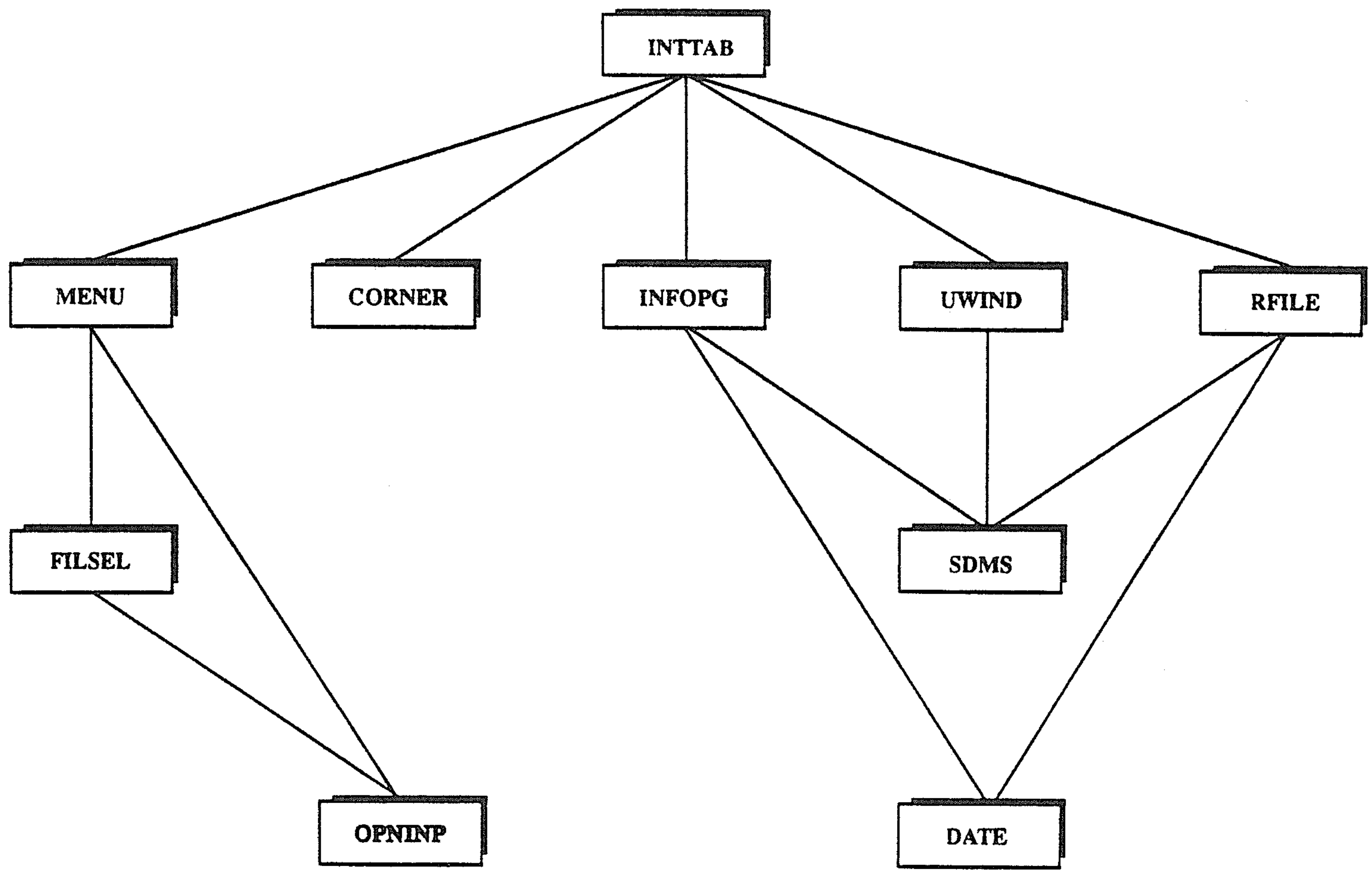
Latitude and longitude SHIFTS are in SECONDS Lat/Long

Add shifts to NAD27 to get NAD83

LONGITUDE (Deg Min)

LATITUDE (Deg Min)	129 50	129 45	129 40
67 35	0.176	0.187	0.199
	8.337	8.324	8.310
67 30	0.166	0.178	0.189
	8.267	8.255	8.242

INTTAB



Structure Chart for Program INTTAB

90 - 10 - 02

Program: **GSRUG**

Purpose: To do a transformation between geographic coordinates (ellipsoidal latitude and longitude) and Universal Transverse Mercator Grid coordinates (UTM), in either direction.

The program functions for north and south latitudes. Longitudes are positive west of Greenwich.

Input(s): Geographic coordinates or UTM's supplied by one of the following methods:

1) sequential file of points to be processed as a batch

2) coordinates enter interactively at the terminal

Output(s): Files of transformed coordinates in same order as submitted:

- sequential file of records
- printout report file with headers, dates, processing summary, etc.
- transformed values listed to terminal

Process(es):

- obtains coordinates from interactive user

  OR

  reads one record at a time from the input file

- converts UTM plane coordinates to ellipsoidal coordinates or ellipsoidal to UTM as required

- writes transformed value to file or terminal

Note: This program is taken from the GHOST library. More detailed documentation is available.

Sample run of program GSRUG on the VAX

```
GHOST > GSRUG

  Using directory [STEVE.TRANSF]


  < G S R U G  Initiated >

  Select ellipsoid     [S]
  Default (NAPD80)     [CR]
  Define ellipsoid     [D]
  List ellipsoids      [L]
  Quit                 [Q]
```

Note NAPD80 is the same as NAD83/WGS84

Carriage return to select default NAD83

```
   14 NAD83 (WGS84)        6378137.0000 6356752.3142

  Enter a title for the output listing max 80 chars

SAMPLE GSRUG TRANSFORMATION GEOGRAPHIC TO UTM
```

User entered title

```
  Choose options

  Zone width            [Z]        6
  Scale factor          [S]   0.9996
  False easting         [E] 500000.00
  False northing        [N]      0.00
  Central meridian      [C]
  Compute UTM           [U]
  Compute geographics   [G]
  Input from file       [F]
  List to file          [L]
  Save on file          [V]
  Exit from program [CR][Q]
F
```

Default options and file names

```
  Enter file name    [CR] to exit

GEO.DAT
```

File of coordinates to be transformed

```
  Choose options

  Zone width            [Z]        6
  Scale factor          [S]   0.9996
  False easting         [E] 500000.00
  False northing        [N]      0.00
  Central meridian      [C]
  Compute UTM           [U]
  Compute geographics   [G]
  Input from file       [F]$1$DUA1:[STEVE.TRANSF]GEO.DAT;1
  List to file          [L]
  Save on file          [V]
  Exit from program [CR][Q]
L

  Enter file name    [CR] to exit

GEO.LIS
```

Name of output list

```
 Choose options

 Zone width           [Z]         6
 Scale factor         [S]    0.9996
 False easting        [E] 500000.00
 False northing       [N]      0.00
 Central meridian     [C]
 Compute UTM          [U]
 Compute geographics  [G]
 Input from file      [F]$1$DUA1:[STEVE.TRANSF]GEO.DAT;1
 List to file         [L]$1$DUA1:[STEVE.TRANSF]GEO.LIS;1
 Save on file         [V]
 Exit from program [CR][Q]
V

 Enter file name    [CR] to exit
```

GEO2UTM.NEW **File of transformed coordinates**

```
 Choose options

 Zone width           [Z]         6
 Scale factor         [S]    0.9996
 False easting        [E] 500000.00
 False northing       [N]      0.00
 Central meridian     [C]
 Compute UTM          [U]
 Compute geographics  [G]
 Input from file      [F]$1$DUA1:[STEVE.TRANSF]GEO.DAT;1
 List to file         [L]$1$DUA1:[STEVE.TRANSF]GEO.LIS;1
 Save on file         [V]$1$DUA1:[STEVE.TRANSF]GEO2UTM.NEW;1
 Exit from program [CR][Q]
```

Menu with final modifications before computing new coordinates

```
U
```

Compute UTM values

```
[ 61914   mix        ]N67 21 49.369950 W107 33 45.276420 cm=105  0 W
                      n=    7474198.504 e=     389962.789 Zone=  13
[ 61911   kite       ]N67 57  3.868310 W107 28 10.817220 cm=105  0 W
                      n=    7539476.239 e=     396560.922 Zone=  13
[ 61912   lame       ]N67 34 34.451590 W107 24 10.089060 cm=105  0 W
                      n=    7497602.184 e=     397738.317 Zone=  13
[ 61916   oboe       ]N67  0 35.071120 W107 34 53.003160 cm=105  0 W
                      n=    7434799.264 e=     387516.620 Zone=  13
[ 61913   ekalulia   ]N67 34 59.278420 W108  0 55.894160 cm=111  0 W
                      n=    7499446.288 e=     626965.877 Zone=  12
[ 61915   nero       ]N67 16  4.809900 W108  3 13.292890 cm=111  0 W
                      n=    7464269.640 e=     627011.289 Zone=  12
[ 759007  759007     ]N67  7 46.636410 W112  4 20.656560 cm=111  0 W
                      n=    7446231.083 e=     453491.525 Zone=  12
[ 759008  759008     ]N67 16 52.314880 W112  7  7.565790 cm=111  0 W
                      n=    7463162.114 e=     451785.161 Zone=  12
[ 759009  759009     ]N67 24 33.333580 W112  5 13.827190 cm=111  0 W
                      n=    7477412.604 e=     453396.623 Zone=  12
[ 759010  759010     ]N67 32 51.463720 W112  6  5.957430 cm=111  0 W
                      n=    7492847.508 e=     453049.923 Zone=  12
[ 759011  759011     ]N67 41 27.261140 W112  5 20.614380 cm=111  0 W
                      n=    7508809.343 e=     453867.404 Zone=  12
[ 759012  759012     ]N67 46 41.552660 W112 12 58.322900 cm=111  0 W
                      n=    7518641.231 e=     448673.440 Zone=  12
[ 719302  71 a 2     ]N67 34 51.789230 W108 36 50.876990 cm=111  0 W
                      n=    7498110.922 e=     601520.570 Zone=  12
[ 719303  71 a 3     ]N67 41 38.576290 W108 50 54.866710 cm=111  0 W
                      n=    7510336.943 e=     591110.956 Zone=  12
```

```
Choose options

Zone width            [Z]         6
Scale factor          [S]    0.9996
False easting         [E] 500000.00
False northing        [N]      0.00
Central meridian      [C]
Compute UTM           [U]
Compute geographics   [G]
Input from file       [F]
List to file          [L]$1$DUA1:[STEVE.TRANSF]GEO.LIS;1
Save on file          [V]$1$DUA1:[STEVE.TRANSF]GEO2UTM.NEW;1
Exit from program [CR][Q]
                                                   Carriage return to exit
End Gsrug

< G S R U G  Completed >
```

List of input file GEO.DAT

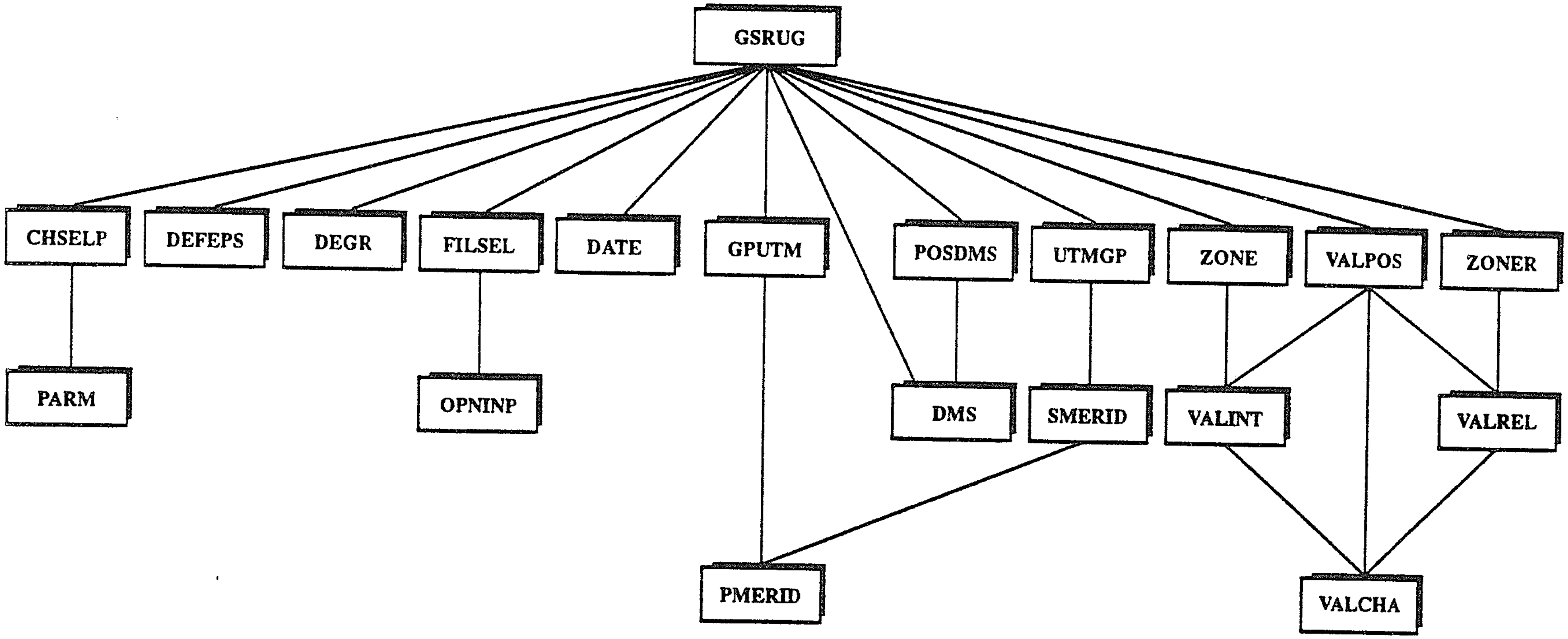
GHOST > **TYPE GEO.DAT**

4	61914	mix	1	183	67	21	49.36995	107	33	45.27642
4	61911	kite	1	183	67	57	3.86831	107	28	10.81722
4	61912	lame	1	183	67	34	34.45159	107	24	10.08906
4	61916	oboe	1	183	67	0	35.07112	107	34	53.00316
4	61913	ekalulia	1	183	67	34	59.27842	108	0	55.89416
4	61915	nero	1	183	67	16	4.80990	108	3	13.29289
4	759007	759007	2		67	7	46.63641	112	4	20.65656
4	759008	759008	2		67	16	52.31488	112	7	7.56579
4	759009	759009	2		67	24	33.33358	112	5	13.82719
4	759010	759010	2		67	32	51.46372	112	6	5.95743
4	759011	759011	2		67	41	27.26114	112	5	20.61438
4	759012	759012	2		67	46	41.55266	112	12	58.32290
4	719302	71 a 2	2		67	34	51.78923	108	36	50.87699
4	719303	71 a 3	2		67	41	38.57629	108	50	54.86671

List of output file GEO2UTM.NEW

GHOST > **TYPE GEO2UTM.NEW**

4	61914	mix	13	389962.789	7474198.504
4	61911	kite	13	396560.922	7539476.239
4	61912	lame	13	397738.317	7497602.184
4	61916	oboe	13	387516.620	7434799.264
4	61913	ekalulia	12	626965.877	7499446.288
4	61915	nero	12	627011.289	7464269.640
4	759007	759007	12	453491.525	7446231.083
4	759008	759008	12	451785.161	7463162.114
4	759009	759009	12	453396.623	7477412.604
4	759010	759010	12	453049.923	7492847.508
4	759011	759011	12	453867.404	7508809.343
4	759012	759012	12	448673.440	7518641.231
4	719302	71 a 2	12	601520.570	7498110.922
4	719303	71 a 3	12	591110.956	7510336.943



Structure Chart for Program GSRUG

90 - 10 - 02

THE CANADIAN INSTITUTE OF SURVEYING AND MAPPING

THE CANADIAN INSTITUTE OF SURVEYING AND MAPPING
ASSOCIATION CANADIENNE DES SCIENCES GÉODÉSIQUES ET CARTOGRAPHIQUES

Founded in 1882, the CISM is Canada's leading, non-profit organization focusing on the surveying and mapping industry. With over 3000 Canadian and foreign members and subscribers, the CISM serves a multi-disciplinary community as the preeminent organizers of technical, scientific, professional, and research, activities.

The Institute has members from private industry, all levels of government and educational institutions. Through its quarterly publication, annual national conferences, topical symposia, awards, grants, and scholarships, the CISM is an ideal forum for the exchange of knowledge in:

- land surveying
- photogrammetry
- cartography
- engineering surveying
- remote sensing
- geodetic surveying
- hydrography
- mining surveying
- geophysical surveying
- geographic information systems
- spatial information management

For over 100 years, the Institute has played an important role in the development of Canada. From the surveys of Western Canada for land settlement, to working closely with government and industry in mapping the second largest country in the world, the CISM has helped Canada become a world leader in surveying and mapping.

The Canadian Institute of Surveying and Mapping is proud of its heritage and, through the support of its enthusiastic membership, continues the tradition of excellence to meet the future needs of the geo-scientific communities.

BECOME A MEMBER AND RECEIVE:

- CISM *JOURNAL* ACSGC, an internationally respected surveying and mapping quarterly publication:

  refereed scientific and technical papers
  industry news
  general news
  new products
  book reviews

- discounts on registration to conferences, symposia, meetings, workshops and seminars
- discounts on proceedings, books and publications
- mailing list service, access and special rates (3000 members/subscribers; 15 000 general data base)
- mail distribution service, special rates on general or targeted distribution
- notices of conventions, symposia, meetings, workshops and seminars, nationally and internationally
- access to a network of professional contacts, locally through your branch and nationally through conferences and the CISM *JOURNAL* ACSGC
- opportunities for continuing education
- opportunities for professional development
- annual directory
- recognition of achievement through awards
- opportunity to be a leader in your profession
- discounts for and opportunity to attend the premier surveying and mapping exhibitions
- referral service, surveying and mapping information
- discounts on professional memorabilia
- insurance, group plan

L'ASSOCIATION CANADIENNE DES SCIENCES GÉODÉSIQUES ET CARTOGRAPHIQUES

THE CANADIAN INSTITUTE OF SURVEYING AND MAPPING — ASSOCIATION CANADIENNE DES SCIENCES GÉODÉSIQUES ET CARTOGRAPHIQUES

Fondée en 1882, l'ACSGC est le premier organisme national à but non lucratif du domaine des levés et de la cartographie. Comptant plus de 3 000 membres et d'abonnés canadiens et étrangers, l'ACSGC dessert une communauté multi-disciplinaire en tant que principal du organisateur d'activités techniques, scientifiques, professionnelles et de recherche.

Les membres de l'Association proviennent du secteur privé, de tous les niveaux de gouvernement et des établissements d'enseignement. Par l'entremise de sa publication trimestrielle, de conférences nationales annuelles, de symposiums thématiques, de prix, de subventions et de bourses d'études, l'Association est la tribune idéale pour l'échange de connaissances en:

- arpentage
- photogrammétrie
- cartographie
- levés d'ingénierie
- télédétection
- levés géodésiques
- hydrographie
- levés miniers
- levés géophysiques
- systèmes d'information géographique
- gestion d'information à référence spatiale

Depuis plus de 100 ans, l'Association joue un rôle important dans le développement du Canada. Des levés de l'Ouest canadien pour la colonisation, jusqu'à l'étroite collaboration avec le gouvernement et l'industrie pour la cartographie du deuxième plus grand pays au monde, l'ACSGC a aidé le Canada à devenir un leader mondial en levés et en cartographie.

L'Association canadienne des sciences géodésiques et cartographiques est fière de son héritage et, grâce à l'appui de ses membres enthousiastes, poursuit sa tradition d'excellence pour rencontrer les besoins futurs des communautés géo-scientifiques.

AVANTAGES D'ETRE MEMBRE; VOUS RECEVEZ:

- CISM JOURNAL ACSGC, publication trimestrielle qui jouit d'une excellente réputation sur le plan international:
  - articles scientifiques et techniques soumis
  - nouvelles de l'industrie
  - informations générales
  - nouveaux produits
  - critiques de livres
- réductions sur les inscriptions aux conférences, colloques, réunions, ateliers de travail et séminaires
- réductions sur les rapports, livres et publications
- service d'envoi, accès et tarifs spéciaux (3000 membres/abonnés base de 15000 données générales)
- service de distribution du courrier, tarifs spéciaux sur la distribution générale ou ciblée
- notification des congrès, colloques, réunions, ateliers de travail et séminaires se déroulant sur le plan national et international
- accès à un réseau de contacts professionnels, localement par l'intermédiaire de votre Section, et sur le plan national grâce aux conférences et à la revue CISM JOURNAL ACSGC
- possibilités de formation continue
- possibilités de développement professionnel
- répertoire annuel
- reconnaissance des réalisations grâce aux récompenses
- possibilité d'être un chef de file dans votre profession
- réductions, de même que possibilité d'assister aux plus importantes expositions en matière de sciences géodésiques et cartographiques
- service de références, informations relatives aux sciences géodésiques et cartographiques
- réductions sur les souvenirs professionnels
- plan d'assurance groupe

UES

MEMBERSHIP IN CISM IS YOURS . . . READ ON . . .

MEMBERSHIP IN CISM

- brings you the CISM *Journal* ACSGC, four times a year
- keeps you abreast of new development in the surveying and mapping sciences
- helps you develop and maintain contacts with other professionals in your field and in related sciences
- helps strengthen the surveying and mapping community in Canada
- entitles you to member discounts on purchase of CISM publications and on registering for CISM conferences and seminars

HOW YOU MAY BECOME A MEMBER

The following types of membership are offered:

Member

The requirement is involvement in the practice of surveying and mapping or an interest in the development and advancement of the surveying, mapping and associated sciences

Student Member

The requirement is enrolment as a full-time student at a recognized university or technical college in a program of studies in the surveying, mapping or related sciences.

Sustaining Member

Applies to any corporation, organization or person that is interested in, or supports, the objects of the Institute.

APPLICATION FOR MEMBERSHIP

I hereby make application for admission to the Institute as a

GST # R122381403		Sustaining		Student	
☐ Member	$95.00	☐ Member	$230.00	☐ Member	$40.00
+ 7% GST	6.65	+ 7% GST	16.10	+ 7% GST	2.80
Total	101.65	Total	246.10	Total	42.80

and, agree to abide by the constitution and by-laws of the Institute.

FACULTY CERTIFICATE

I certify that the applicant is a full time student in the ____________ Program at ____________ University/College

Signed ____________

Name ____________

Title

Full Name (Print) ____________

Home Address ____________

____________ Postal Code ____________ Tel. (Home) ____________

Work Address ____________

____________ Postal Code ____________ Tel. (Work) ____________

Mailing Address: ( ) Home ( ) Work

Professional and Technical Qualifications (circle)

1. Surveying Engineer
2. Commissioned Land Surveyor
3. Professional Engineer
4. Geodesist
5. Cartographer
6. Hydrographer
7. Photogrammetrist
8. Remote Sensing Specialist
9. Technologist
10. Student
11. Other (specify)

Field of Interest (number according to degree, 1,2,...)

( ) Cartography
( ) Control Surveying
( ) Engineering Surveying
( ) Geodesy
( ) Hydrography
( ) Land Information Management
( ) Land Surveying
( ) Mining Surveying
( ) Photogrammetry
( ) Remote Sensing
( ) Other (Specify)

Education: ( ) High School ( ) Technical/Community College ( ) University

Preferred Language: ( ) English ( ) French

Signature ____________ Date ____________

Please attach payment to application form and forward to:

Canadian Institute of Surveying and Mapping, PO Box 5378, Station F, Ottawa, Canada K2C 3J1

UN STATUT DE MEMBRE DANS L'ACSGC VOUS INTÉRESSE . . . CONTINUEZ A LIRE . . .

LES MEMBRES DE L'ACSGC

- reçoivent la revue CISM *Journal* ACSGC régulièrement quatre fois par année
- sont tenus au courant des nouvelles techniques et des progrès réalisée dans les domaines des sciences géodésiquies et cartographiques
- établissent et maintiennent des contacts avec ceux qui oeuvrent dans leurs disciplines et dans d'autres sciences connexes
- aident à renforcer la communauté des sciences géodésiques at cartographiques au Canada
- profitent d'une reduction de prix pour des publications de l'ASSGC et pour le prix d'inscription aux congrès et séminaires de l'ACSGC

COMMENT DEVENIR MEMBRE

Vous pouvez adhérer à l'association selon les catégories suivantes:

Membre

Le prérequis exige une implication au niveau de la pratique des levés et de la cartographie ou un intérêt dans le développement et l'avancemnt des sciences géodésiques, cartographiques ou connexes.

Membre étudiant

Le prérequis exige l'inscription à titre d'étudiant à plein temps à une université reconnue ou un collège technique dans un programme d'études dans les sciences géodésiques, cartographiques ou connexes.

Membre de soutien

Si en qualité de société, d'organisme ou d'individu vous êtes intéressé à supporter les objectifs de l'association.

FORMULE D'ADHÉSION

Je demande, par la présente, à faire partie de l'association à titre de:

No de TPS R122381403

Membre		Membre de soutien		Membre étudiant	
☐ Membre	95.00$	☐ de soutien	230.00$	☐ étudiant	40.00$
+TPS de 7%	6.65	+TPS de 7%	16.10	+TPS de 7%	2.80
Total	101.65	Total	246.10	Total	42.80

et, si ma demande est acceptée, je consens à respecter la constitution et les règlements de l'association.

CERTIFICAT DE LA FACULTE

Je certifie que le candidat est un étudiant à plein temps dans le

_______________ programme

à l'Université\Collège _______________

Signé _______________

Nom _______________

Titre

Nom et prénom (lettres moulées) _______________

Adresse (résidence) _______________

_______________ Code _______________ Tél. (résidence) _______________

Adresse (bureau) _______________

_______________ Code _______________ Tél. (bureau) _______________

Adresse postale: ( ) Résidence ( ) Bureau

Compétences professionelles et techniques (encerclez la ou les compétences)

1. Ingénieur topographe
2. Arpenteur-géomètre
3. Ingénieur breveté
4. Géodésien
5. Cartographe
6. Hydrographe
7. Photogrammètre
8. Spécialiste en télédétection
9. Technologue
10. Étudiant
11. Autre (spécifiez)

Domaine d'intérêts (numérotez selon les priorités 1,2,...)

( ) Cartographie
( ) Levés de contrôle
( ) Ingénierie des levés d'arpentage
( ) Géodésie
( ) Hydrographie
( ) Gestion de l'information foncière
( ) Arpentage légal
( ) Arpentage minier
( ) Photogrammétrie
( ) Télédétection
( ) Autre (spécifiez)

Etudes ( ) Secondaires ( ) Techniques ( ) Universitaires

Langue préférée ( ) Français ( ) Anglais

Signature _______________ Date _______________

Prière de joindre le paiement à la formule d'adhésion et envoyer à:

L'Association canadienne des sciences géodésiques et cartographiques (ACSGC)
C.P. 5378, Succursale F, Ottawa, Canada K2C 3J1