INTEGRATED LAND SURVEYS

Final Report to the Canadian Council on Geomatics

January 2002

Dr Brian Ballantyne

Table of contents

Recommendations 4

Executive Summary 5

Part I – Introduction

1. Purpose & overview 8
2. Definitions 9

Part II – Current provincial & federal requirements

1. Federal – Canada Lands 12
2. British Columbia 15
3. Alberta 16
4. Saskatchewan 18
5. Manitoba 19
6. Ontario 20
7. Quebec 21
8. Newfoundland 21
9. New Brunswick 22
10. Nova Scotia 23
11. Prince Edward Island 24
12. Trends 25

Part III – Costs & benefits: Asserted & actual

1. Views of the surveying community 27
    a. In praise
    b. Reservations
    c. What of standards?
    d. Who are the stakeholders?
2. Meta-analysis 31
    a. New Zealand
    b. Australian Capital Territory
    c. Ontario
    d. Maritime Provinces
3. Case studies 34
    a. Capital Regional District
    b. Calgary
    c. Invermere, British Columbia
    d. Somewhere in Canada
4. Synthesis 39

Part VI – National standards

1. Should integration become more rigorous? 44
2. Criteria 45
3. Integration accuracy & land use 46
4. Specifications 50
5. When should integration be required? 51

Part V – Conclusion 52

References
1. Acknowledgments 54
2. Bibliography 54
3. Legislation 57

Appendices
1. Questionnaire for stakeholders 58
2. Views of CCOG members 59

Recommendations

That the Canadian Council on Geomatics encourage the integration of all new parcels to the Canadian Spatial Reference System using the following principles:

1. Integration of a land survey to NAD83(CSRS) should be mandatory in creating any new parcel of land to which attaches a legal interest (freehold or easement):
- if GPS is not being used and the parcel is within five (5) km of a NAD83(CSRS) monument, or,
- if GPS is being used, but then provided that any post-processing so as to allow the coordinate information to enhance the spatial database will be done by the regulator, if desired by the land surveyor.

The only exception would occur if no more than two new parcels are being created by the survey, both of which lie completely within a larger parcel which had previously been integrated to the CSRS, and the total area of new parcels is less than one ha.

2. User fees to access active control information should be reduced, as an incentive to land surveyors, and based upon the rationale that if there is a public benefit to value-added spatial databases, then the costs of active control should be borne by the public.

3. User fees that accompany the submission of plans of survey to the land titles or registry systems should be waived, if the plan is integrated to CSRS and if the fee is used to subsidize the digital mapping process.

4. If surveyors submit integrated land surveys to regulators, then the costs to the surveyors of accessing the value-added spatial database should be reduced.

5. The regulator that requires integrated surveys must ensure that the information is used to improve the spatial infrastructure databases.

6. The standard to which land surveys are integrated to NAD83(CSRS) must be a function of parcel location and land use, with the connections qualified by the surveyor to meet the following minimum relative accuracy @ 95%:

High-density commercial or industrial parcel	2 cm
High-density residential parcel	5 cm
Any other urban or suburban parcel	10 cm
Rural parcel smaller than 10 ha in area	50 cm
Rural parcel larger than 10 ha in area	2 m

7. Consultation and strategic alliances must take place with five groups of stakeholders - land surveyors, municipalities, land developers, resource extractors, and aboriginal peoples.

Executive summary

Narrowly speaking, integration of land surveys means merely the referencing of parcel boundaries to a robust control framework. The overwhelming consensus is that the framework ought to be the NAD83 within the Canadian Spatial Reference System. NAD83(CSRS) is represented by active control systems, by high precision networks, and by many provincial survey control monument systems. In a broader sense, integration refers to the geo-spatial management system that sets the requirements and standards for integration, maintains the control framework, and uses the coordinate values to upgrade cadastral mapping. Such mapping, in turn, is used for many purposes, ranging from keeping track of infrastructure to providing evidence of location when re-establishing boundaries. The requirement to integrate is set either by the provincial or federal regulator, by the municipality, or by the surveying association, depending on the jurisdictions wherein a survey lies.

On Canada Lands, integration is required when a legal survey falls within one km of any established federal or provincial control point, or within a designated Coordinated Survey Area. In either instance, the desirable connection for the survey is to tie at least two of the legal survey monuments to at least two established control points. There are currently 11 Coordinated Survey Areas established on Canada Lands, although the control monuments within many are not being maintained. Provincially, integrated survey areas have been established in British Columbia and in New Brunswick, while Alberta, Quebec, Newfoundland, Nova Scotia and Prince Edward Island have provisions for tying surveys to their respective control systems. Ontario is proposing amendments to their Regulations to allow for integration. The datum used across the various jurisdictions ranges from older frameworks such as NAD27 and ATS77 to the more current systems of NAD83 and NAD83(CSRS). In most cases the maximum allowable distance for tying to a coordinate monument is one to 1.5 km. The closure errors acceptable for integrated surveys are reasonably consistent in the 1:5,000 range for traverse closures, and N(20″) or √N(20″) for bearing misclosures, where N are the number of traverse stations.

With the increase in GPS use, most provinces are moving towards improving or upgrading their coordinate reference systems so as to be compatible with the CSRS. This trend has two evident modes. The first finds the various jurisdictions maintaining few of the traditional, densely spaced control monuments, in favour of establishing High Precision Networks (HPN). HPN spacing varies from about two km in urban areas (Calgary, Victoria), to 20-40 km on a regional or provincial basis. The second trend finds jurisdictions (such as Quebec) establishing and encouraging the use of active control points, as represented by the Canadian Active Control System (CACS). The HPN and the Active Control Points, being less dense than traditional control networks, both encourage the use of GPS techniques and the mastery of adjustment methodology.

The strong consensus from municipalities and surveyors in private practice is in favour of integration. Both parties see many benefits to integrating parcel boundaries within digital databases, both from the perspective of first generation and subsequent surveys, and as allowing many uses to be made of the enhanced spatial data infrastructure. However, the respondents were not without reservations about integration. Concerns were expressed about its being the slippery slope towards the use of coordinates in place of monuments; about the requirements for submission of digital plans as being rather onerous; about the surveyor as data-gatherer not being compensated by the regulator for contributing to the value-added databases; and about increased distance to control monuments, as denser networks are phased out, resulting in additional field time and thus costs. Any proposal on national standards, requirements and conditions respecting integration can take its benefits as givens, but must be wary of the reservations.

Data on the costs and benefits are consistent in reporting savings of 25-40% of the cost of surveying to land surveyors. The absolute savings are more modest on second generation and subsequent surveys - in the order of $300-400 per survey, or $3 per parcel per year. There are two conclusions to be drawn from the attempts at cost-benefit analysis of integration. The first is that rigorous data on the financial costs and benefits of integrating land surveys is scarce. The second is that the significant benefits – both financial and non-quantifiable – accrue further along the value-added chain, as the spatial data infrastructure is augmented with land survey information.

The case studies reveal that administration of control networks and of integrated land surveys is devolving to municipalities (such as Calgary) and to surveying associations (such as the Alberta Land Surveyors' Association), respectively; that strategic alliances are helping to establish HPN and active control, both of which have merit; and that there are true benefits to integrated land surveys, not the least of which is that they allow for the digital submission of plans in the same reference framework as the municipal spatial database. Other benefits illustrated by the cases include the detection of blunders, the ease of locating buried services, and the reduction of emergency services' response times.

Integration to assist in re-establishing boundaries can often be justified by land surveyors. Moreover, integrated land surveys in support of other services or products can be justified, provided four criteria are met. First, there must be genuine consultation by the provincial and federal regulators of integration with all the stakeholders – surveyors, municipalities, land developers, resource extractors (such as the mining, logging, and petroleum and natural gas sectors) and aboriginal peoples. Second, regulators of integration must offer enhanced access to spatial data and reduced user fees to the data-gatherers, as represented by land surveyors. Third, all new parcels should be integrated to the CSRS according to the size of the subdivision and depending upon the surveying technique that is used. Fourth, the standards for integration should be a function of parcel location and land use.

The proposed standards require integration to NAD83(CSRS) in creating any new parcel of land to which legal interests attach. If GPS is not being used, then any parcel within five km of a NAD83(CSRS) monument should be integrated; if GPS is being used, then all parcels should be so integrated, although the regulator should assist the land surveyor (upon a request from the latter) with any post-processing. This requirement should ensure that the coordinates of the majority of new parcels will be captured and used to enhance spatial databases, and recognizes two trends. The first is the increasing use of GPS and of active control. The second is that the five km distance is only slightly double the current distance within which parcels must generally be integrated. Indeed, some land surveying associations are in the midst of a debate on doubling the distance to control monuments, within which integration is required. If no more than two new parcels are being created, both of which lie within a larger parcel that is integrated to NAD83(CSRS), and the total area of the new parcels is less than one ha, then integration should be dispensed with.

The standard to which land surveys are integrated to NAD83(CSRS) must be a function of parcel location and land use, with the connections qualified by the surveyor to meet the following minimum relative accuracy @ 95%:

High-density commercial or industrial parcel	2 cm
High-density residential parcel	5 cm
Any other urban or suburban parcel	10 cm
Rural parcel smaller than 10 ha in area	50 cm
Rural parcel larger than 10 ha in area	2 m

This taxonomy reflects the relationship between the accuracy of integration and the use to which the parcel that is being created will be put. Land use determines the standard, because the value of a parcel of land is directly related to its use, and thus to its zoning or land use classification.

Part I - Introduction

1. Purpose and overview:

Surveys which set out or re-establish rights in land (variously known as land, cadastral, legal, or boundary surveys) are integrated to high accuracy reference systems in various parts of Canada according to differing criteria and standards, and with varying degrees of acceptance by the land surveying profession. Integrated surveys "are already the norm in many parts of many provinces and the territories, and can serve to provide geo-referenced data for use in cadastral mapping and in land information systems" (Ballantyne et al, 1999).

The Canadian Council on Geomatics endorsed the following resolution at its 1999 Annual Meeting:

- Whereas positioning technologies continue to improve and are now becoming practical;
- Whereas NAD 83 CSRS provides a homogeneous high accuracy reference system;
- Whereas cadastral databases are being built that could benefit from integrated surveys;
- Whereas a need exists to increase the use and acceptance of integrated surveys by the land surveying profession; therefore,
- Be it resolved that Michael O'Sullivan, Surveyor General of Canada, lead a project … to:

1. Identify the benefits of integrated land surveys;
2. Determine the target applications; and
3. Develop national standards for integrated surveys.

This report undertakes to fulfill that resolution. Its purpose is to consider the case for establishing national standards for integration. To that end, it examines the state of, and trends in control systems, the existing standards for integration, and the costs and benefits of integrated surveys. Given those descriptive findings, the analytical aspect of the study justifies the introduction of, and then proposes requirements, conditions, and specifications for a more rigorous, nation-wide regime of integration. The methodology employed was to review the legislation and standards of practice that require integration, to interview either orally or in writing a selection of stakeholders from among the regulators and the private sector, to meta-analyze other relevant studies, and to use case studies.

The report is set out in five parts. The remainder of Part I defines integration, and reviews both the spatial reference system in Canada and the integration of land surveys to that system. Part II describes the current requirements for integration across the provinces and territories and on Canada Lands, and identifies trends in integration and in reference systems. Part III analyzes the real and perceived costs and benefits of integration, from interviews with members of the surveying community, from a meta-analysis of four significant studies, and from four case studies. Part IV sets out the conditions that should attach to more rigorous integration, and proposes national standards and requirements for integration.

2. Definitions:

Integration of land surveys (or integrated land surveys) refers to the surveys being geometrically related, or at least relatable, to one another, such that they can be put into a common system of coordinates. Thus, loosely speaking, the ordinary cadastral fabric is integrated to a large degree, through the ties that are made from a survey to those nearby. However, the term is not ordinarily used in that way. In fact, such a usage would make it redundant. Further, such accretive integration can only succeed very locally. Over a larger area, positional ambiguities are liable to creep into the cadastral fabric, if it is left to itself, due to cumulative measurement uncertainties within surveys and, especially, as survey ties to survey; due to geodetic considerations, to discrepancies between different surveys covering the same area, and to the inevitable presence of the occasional blunder or area of sub-standard work. The fabric, on its own, tends towards a "mass of adjoining and inter-locking surveys," presenting many practical difficulties (Pawson, 1964).

Properly speaking, integration refers to the tying of land surveys to an *external* reference framework which is meant to be, and is regarded as, accurate over large areas. In this way, positional ambiguities in the cadastre may be largely prevented and resolved: Integration irons out the wrinkles in the fabric. A distinction must therefore be made with the mere geo-referencing of surveys by virtue of tying into the existing township or lot fabric.

Integration of land surveys, then, means the referencing of parcel boundaries to a robust control framework, in which the lot corners are given coordinates. Having refined the definition of integration in one respect, it must now be broadened in a different direction. Narrowly, integration means the tying of land surveys to control. In a broader sense, integration refers to the geo-spatial management system that sets the requirements and standards for integration, maintains the control framework, and uses the coordinate values to upgrade cadastral mapping. Such mapping, in turn, is used for many purposes, ranging from keeping track of infrastructure to providing evidence of location when re-establishing boundaries. The requirement to integrate is set either by the regulator, by the municipality, or by the surveying association. This study focuses on integration in the narrow sense, while also discussing the relevant bits from the broader definition, including the setting of standards, requirements, and conditions, and the monitoring of compliance. Thus, "integration", "integrated surveys", and "integrated land surveys" are used indiscriminately throughout this report, letting context indicate whether the narrow or the broad sense is meant.

There has been some confusion over the symbiotic relationships between coordinates-only to define boundaries, deferred monumentation of boundaries and integrated surveys

(Ballantyne et al, 1999). Conceptually, integrated surveys do represent an intermediate step between the use of monuments and the use of coordinates-only, insofar as monumented boundaries are integrated to close tolerances within a spatial reference system: The coordinates that are derived for the locations of the monuments can then be used as evidence in re-establishing the monuments. This has led some to suggest forgoing the placement of monuments in the first place. However, there is no necessary progression from integration to coordinates-only, practically. The latter is of only peripheral concern here.

Integrated surveys must be related to a spatial reference system. The overwhelming consensus is that the framework ought to be the Canadian Spatial Reference System (CSRS), owing to the robustness of the system. Robustness is a function of the accuracy to which the control framework is known, the accuracy to which the parcel boundaries are referenced to the framework, and the extent to which the framework is maintained.

Traditionally, access to a national spatial reference system was provided through the use of ground-based monumented geodetic control points, each established with precise coordinates. The Geodetic Survey Division (GSD) of NRCan has established and maintained a national network of points, initially for mapping and surveying, and more recently to reference geo-spatial data. With additions from provincial programs, this framework has been expanded to close to 200,000 control points across Canada. These coordinates were based on a datum such as the national NAD27 datum and NAD83 datum. The disadvantage of these traditional networks is in the accumulation of measurement errors made in their construction, although the networks were established to the accuracy allowed by the equipment and techniques of the time. Most provinces are working towards the adoption of NAD83(CSRS) coordinates to allow the integration of provincial networks with the CSRS.

The CSRS is a national framework for spatially referencing horizontal and vertical coordinates established as a result of technological advances including the Global Positioning System (GPS), within which the GSD and the provinces all maintain their own data. There are several layers to the CSRS hierarchy, of which the top two are respectively, the Very Long Baseline Interferometry (VLBI) network and the Canadian Active Control System (CACS). The VLBI network consists of five Canadian observation sites located at Whitehorse, Yukon; Yellowknife, Northwest Territories; Penticton and Victoria, British Columbia; and Algonquin Park, Ontario. This radio astronomical technique allows inter-station distances on a global scale to be determined with sub-cm accuracy. The CACS network consists of a sparse network of continuously operating GPS satellite tracking stations across Canada. Used in conjunction with the VLBI network data, a consistent global reference frame is maintained.

One means of accessing the reference system is through traditional monumented control networks tied to the CSRS. The Canadian Base Network (CBN) is a high accuracy GPS-based network of monuments set by GSD in cooperation with provincial agencies. In conjunction with the VLBI and CACS networks, the CBN – consisting of a few hundred highly stable markers across Canada – provides the national backbone of monumented control points within the CSRS frame. Some provincial control survey agencies have established High Precision Networks (HPN) of their own via additional GPS-based control monuments, in order to provide improved access to the reference system. In more populous areas of some provinces, regional control networks are providing access to the same standard reference frame by establishing a large number of densely monumented points tied to the high precision network. At each level of network, the access to the reference system is via monumented control. Surveys that are to be integrated are referenced to established monuments by occupying at least one control point.

Most recently, with the improvement in GPS technology, it has become possible to reference the control network directly. Through precise GPS satellite positioning relative to the CSRS, or differential GPS corrections based on an active control point, a direct link may be established with the CSRS. In this manner, integration can be achieved without the need to maintain a vast number of control monuments. However, there are significant costs to obtaining a good geo-position by directly referencing the CSRS. The Canadian Differential GPS service (CGDPS), for instance, only allows accuracies of 1-10 m at the moment, although improvements in methodology might allow for positioning to within 20cm.

Part II - Current provincial & federal requirements

This section provides the current requirements of integrated surveys by synthesizing the relevant legislation at the federal and provincial levels, along with relevant guidelines and policies set by the provincial surveying associations. Integration varies in several respects across Canadian jurisdictions. Depending upon the jurisdiction, integration may be required, or merely recognized (the coordinates derived are accorded some evidentiary weight), or not recognized. The criterion for the requirement of integration may be one of proximity with control monuments, or of falling within one of certain designated areas. Integration is variously governed by legislation (mostly regulations), by rules of land surveyors associations, and even influenced by municipalities, sometimes in combination. As an example of the latter, many municipalities in Ontario now require that plans of subdivision be integrated.

1. Federal - Canada Lands:

Requirements for surveys conducted on Canada Lands are set out in the *Canada Lands Surveys Act*. The Act's definition of Canada Lands includes the offshore, and any lands belonging to the Crown in right of Canada that are situated in the Yukon Territories, Northwest Territories, Nunavut, or in any National Park of Canada and any lands that are surrendered lands or reserves as described in the *Indian Act*.

a. Coordinated Survey Areas

The *Canada Lands Surveys Act* allows for integrated surveys, but uses the term coordination in place of integration. Section 28(1) allows the Minister of Natural Resources to establish or alter a Coordinated Survey Area within any lands dealt with in the Act. It specifies that all new monuments and those monuments that are relevant to newly placed monuments are to be referenced to control points specified for that purpose and are to be expressed in terms of the system of coordinates for that Area, in accordance with the Surveyor General's instructions. Further, all monuments placed prior to the establishment of the Area may have their positions determined and are also to be described in accordance with the Surveyor General's instructions. The final subsection of section 28 allows that in these Areas, for any monument that is lost, the coordinates of the monument may act as proof of its position in the absence of contrary evidence.

The *Manual of Instructions for the Survey of Canada Lands* (as of 1996) lists eleven Coordinated Survey Areas: two located in the Yukon Territories at Ross River and Whitehorse; three in the Northwest Territories at Hay River, Inuvik, and Yellowknife; two in Nunavut at Iqaluit and Rankin Inlet; and four in National Parks at the townsites of Banff and Field, Jasper and Lake Louise. In Part D – General Instructions, the Manual states the requirements for legal surveys that fall at least partially within one of these Areas. Such surveys shall be connected to Coordinated Control Monuments (CCM) – defined as control stations that form part of a provincially or federally established control network. Federally established control points use the NAD83 datum. However, the control monuments are not well maintained and are in various states of disrepair. In some CSA's (such as Whitehorse) the CCM's are virtually ignored in favour of using active control. Conversely, in some CSA's in Nunavut, the CCM's are relied upon extensively.

Section 82 of the Manual goes on to state that:

> Connections shall be made from at least two well-separated monuments of the legal survey to:
>
> - the two Coordinated Control Monuments that best straddle the survey;
> - all Coordinated Control Monuments within the perimeter of the survey; and
> - all Coordinated Control Monuments within 150 m of the survey.
>
> Bearings for the survey are to be derived either from one or more pairs of Coordinated Control Monuments or from monuments of a survey previously integrated in the Area.

Also, surveys within Coordinated Survey Areas should be tied to existing boundary monuments previously tied to the existing control.

Official plans submitted for surveys in Coordinate Survey Areas must show all relevant Coordinate Control Monuments. It is assumed that the control monuments are errorless and any discrepancies in calculated coordinates are to be proportionally distributed in each part of the survey. The return of the plan must include the coordinate datum used, the date of the coordinates, and a listing of all the relevant control monuments and boundary monuments found or established.

b. Other Canada Lands

Integration with a spatial reference system is also a consideration for other surveys completed on Canada Lands. The General Instructions section of the Manual requires that when a survey is conducted within 1 km of existing federal or provincial survey control markers, the survey must be connected from at least two well separated monuments of the legal survey to at least two of the control markers that straddle the survey. If only one control marker is within the one km distance requirement, then the lone control point will suffice, but it should be tied to at least two of the monuments of the survey.

For a subdivision survey of a parcel that was previously integrated with federal or provincial control points, new connections to the control network from the new monuments are not necessarily required. However, connections are to be made to control points that lie within or near the parcel being subdivided in order to confirm the integrity of the survey fabric. In instances where connection is made to an existing control point, the return of survey plan shall contain the coordinate datum used, the date of coordinates, and a listing of relevant control monuments and boundary monuments as is required in Coordinated Survey Areas.

For the majority of new land claims surveys, spatial positioning is required for all parcels unless otherwise indicated in the Statement of Work. The positions of all monuments are to be integrated within the CSRS via CACS, geodetic control markers, or any other approved control markers. The increasing use of GPS technology by industry allows the requirement that surveys be geo-referenced to NAD83(CSRS): GPS technology allows this to be done at little additional cost, especially for surveys of parcels located in rural and remote areas.

For eastern Canada, if no local control exists and the survey is to be done by GPS, the requirement is for two cm local (relative) accuracy and 50 cm or better network (absolute) accuracy (network accuracy is-the absolute accuracy of the coordinates for a point at the 95% confidence level, with respect to the reference frame of the CSRS). This accuracy standard applies when using the CACS to integrate the survey into the CSRS.

However, surveys of new Indian Reserves in southern Canada are normally performed under provincial regulations. As such, provincial integration requirements are normally followed as long as they are at least equivalent to the accuracy requirements in the Manual of Instructions.

For Lands Claims surveys in the North, the following accuracy requirements form part of the contract. The minimum internal accuracy of all surveys shall meet the following relative accuracy standards:

- if the distance in meters between two survey stations or monuments is less than 1km, then the maximum allowable error of the semi-major axis at the 95% confidence level is 0.02 m + (80 ppm) x (distance).
- if the distance in meters between survey stations or monuments is greater than 1km, then the maximum allowable error of the semi-major axis at the 95% confidence level is 0.085 m + (15 ppm) x (distance).

Each survey shall be integrated into the CSRS according to the type of survey. For Rural Settlement Land including Isolated Boundaries the network accuracy is to be 2 m; for Site Specific and Community Settlement Land the network accuracy is to be 5 m. An Accuracy Report, to be submitted with the survey, must provide a summary of the internal and network accuracy of the survey. It must also refer to details, such as least square adjustment results, traverse closure reports between control points (i.e. points in the survey network, typically GPS stations), to support the summary. The summary must include the following:

- Local accuracy of control points (e.g. GPS control points) that are 10 km or less relative to each other.
- Local accuracy of control points which are greater than 10 km in relation to each other.
- Average network accuracy of GPS control points that are positioned using the CACS.

2. British Columbia:

The *Land Survey Act* allows the Surveyor General to make regulations designating portions of the province as Integrated Survey Areas (ISA). The first ISA was designated in 1967 in Surrey. There are now 47 ISA located throughout the province with the most recent being the City of Terrace constituted as ISA No 55 on June 11th, 1999. For each ISA, the Surveyor General must file in the local land title office a plan of the integrated survey area showing the locations and coordinate values of all control monuments.

In an ISA, all original monuments established by a survey and all those previously established that are pertinent to the survey of a parcel must be tied to the nearest coordinate control monuments in accordance with procedures set out by the Surveyor General's General Survey Instructions. Any such original monument defined by coordinates in an ISA may have the coordinates considered as evidence of its true position on the ground.

Part 3 – Division 2 of the General Survey Instructions establishes the rules for ISA surveys. All legal surveys completed within or partially within an ISA must be integrated with control surveys in the vicinity of the area under survey. Bearings must be obtained if possible by direct observations between any two inter-visible control monuments. Barring that, bearings may be derived from a traverse between two control monuments. A survey must be tied to no fewer than two control monuments using appropriate procedures to ensure compatibility with prior adjoining integrated legal surveys and that the accuracy meets closure requirements. Closure must not exceed 1:5,000 +/- 2 cm on the coordinates of the closing monument and the bearing misclosure must not exceed (20") x (root of N), where N are the number of angles in the traverse.

Division 3 details preparation requirements for survey plans. A plan must show all ties made to control monuments and the measurements as required under Division 2. A note must be present stating that bearings are derived from observations between identified control monuments and indicate the ISA number.

The control monuments used in the legal surveys in ISA's are established on instructions from the Surveyor General as described in Part 2 of the General Survey Instructions. Control surveys must be integrated with the Provincial and Federal Geodetic (Survey Control) Networks with coordinates based on the North American Datum approved by the Surveyor General. The official plans and consolidated coordinate listings on record in the local land title offices are now using the NAD83(CSRS) datum and all survey plans submitted in these areas are to be prepared using NAD83(CSRS) derived bearings.

There is one proposed ISA pending constitution (Williams Lake) - the survey is complete with only administrative details yet unfinished. Only a few municipalities are actively maintaining their physical ISA. Urban active control systems are being implemented in the Greater Victoria and Lower Mainland areas, and the province recognizes that there is a transition occurring between control systems. The traditional geo-referencing system consisting of survey monuments is slowly being replaced by the use of GPS to tie to less dense HPN or to various ACS. It is anticipated by the Office of the Surveyor-General that as GPS technology becomes more prominent, reliance on physical control will diminish and activity in the integrated survey program will be reduced. The program of maintaining monuments in the ISA will be phased out over the next few years. As the expertise and capability of the land surveying community allow it to embrace GPS methodology, the use of ISA monuments will decline

In the interim, the Office of the Surveyor General recognizes that continued development and maintenance of conventional Integrated Survey Areas is desirable in many cases. The Surveyor General will consider applications on a case-by-case basis from land surveyors wishing to conduct surveys within ISA using GPS. Surveyors using GPS for all or a portion of a survey will be required to follow specific procedures and to provide additional information on survey plans. Exceptions to the requirement that all land surveys within an ISA be integrated are allowed, if various conditions are met. Strict compliance might be impracticable, as where more than three traverse hubs would be required for each tie to the integrated control monuments and the distance to the nearest integrated control monument exceeds 1 km. In addition, it is proposed that new right-of-way, easement, posting or reference plans wholly within a plan or plans previously integrated, where the bearings for the present survey are derived from grid bearings, should not have to be integrated.

Finally, the new General Survey Regulations, which guide the preparation of plans pursuant to the *Land Act*, require that at least one corner of new parcels be expressed in UTM NAD83(CSRS) coordinates, if DGPS has been used. UTM coordinates can also be derived from recreational-grade GPS in some circumstances.

3. Alberta:

All regulations under the *Surveys Act* were repealed in March 1999, and the standards were shifted to the Alberta Land Surveyors' Association *Manual of Standard Practice*. The Manual describes an integrated survey as "any survey, the data from which forms part of the geographical positioning system." The Act defines a geographical positioning system as a set of databases coordinated by the Director of Surveys that contain the geographical positions of survey control markers, land survey monuments and photogrammetric control points. The provincial survey control points used for integration are established under the authority of the Director and only become valid points in the geographical positioning system upon confirmation of the coordinates by the Director.

Section C-5 of the Manual of Standard Practice sets out the requirements for integrated surveys. Every survey for a plan that is to be registered must be integrated with survey control if at least two monuments found or placed by the survey are within one km of any two survey control markers. For all other surveys, the surveyor shall make field measurements connecting the survey to all survey control markers situated within one km of any monument found or placed by the survey.

Integration with survey control means obtaining sufficient measurements for the survey in relation to the survey control markers to allow the derivation of grid bearings and computation of a closure, starting at a survey control marker and proceeding along the shortest path through the survey to a second survey control marker. Closure must not exceed the greater of 25 mm or the product 0.00014 x D, where D is the direct distance between the two survey control markers used for the closure.

For deferred monumented surveys under section 43 of the *Surveys Act* (RSA 1980) there must be sufficient survey control markers available in the vicinity of the survey such that no property corner is in excess of two km from each of at least two survey control markers. Further, no property corner shall be established that is beyond 200 m from at least one reference monument or survey control marker. Plans for non-monumented surveys must show all survey control markers, reference monuments, found monuments, and re-established monuments valid to the survey, along with their respective coordinate positions. Coordinate positions and the location of all deferred monuments must also be shown on the plan.

The accuracy requirements for section 43 surveys have been a matter of discussion between the Alberta Land Surveyors' Association Standards Committee and the Director of Surveys Branch. The key issues of discussion are:

- the requirement for at least two survey control markers to be within two km of surveyed corners, precluding almost all rural surveys from meeting requirements due to typical control spacing of 10 to 20 km;
- that establishing new control specifically for section 43 purposes is contrary to provincial policy unless the new control points are to be in support of High Precision Networks;
- the development of a test statistic and methodology for the placement of reference markers in section 43 surveys. Existing control will only support surveys up to two km distant, using the proposed test statistic.

Under Part D – General Requirements for Plans, the Manual of Practice recognizes that as of June 1, 1994, the datum for spatially referenced data in Alberta has been NAD83. This is the datum that will be used on all plans of survey submitted if the plan information relates to grid bearings or coordinates. With the proliferation of high precision GPS surveys, the Geodetic Control Section of the Director of Surveys adopted NAD83(CSRS) coordinates for a subset of the Alberta Survey Control Markers (ASCM) in August 1999. After December 2000, only NAD83(CSRS) coordinates will be computed for new ASCMs. Requirements for NAD83 coordinates will be transformed from the NAD83(CSRS) as required. The Director issued new standards, specifications, and guidelines for such use of GPS in March 2000.

4. Saskatchewan:

New standards are being worked on in conjunction with the adoption of the new *Land Surveys Act*. The new Act specifically refers to integrated surveys and allows for the creation of regulations. The new Act will not be in force until mid-2001 and some sections may still be changed prior to bringing the Act into force.

Section 94 of the present *Land Surveys Act* provides that the Minister may instruct the Controller of Surveys to establish survey control in any area in the province for the orderly development of existing and subsequent surveys performed in accordance with the Act. The Controller of Surveys is to prepare maps, plans and records to facilitate the development of survey control and upon confirmation that these requirements are met, the Minister is empowered to declare an area to be a survey control area. The presence of survey control in a survey control area may be considered as evidence of the position of a lost or obliterated monument. The Lieutenant Governor in Council may prescribe the manner in which surveyors are to relate surveys to the survey control.

However, no such regulations have been prescribed to instruct surveyors in dealing with survey control. There is also no requirement elsewhere in the legislation (as of March 2000) for integrated surveys. There are no current standards for Integrated Survey Areas. The standard for legal surveys is that closures must meet an accuracy of 1:5,000.

Although the potential of section 94 has not been realized, integration of land surveys exists in Saskatchewan in three, albeit limited forms. Firstly, survey control is in place in Saskatchewan for activities other than legal surveys, and the latter are connected to the former to some extent. The provincial geodetic control network is administered by the Geodetic Surveys Branch of SaskGeomatics. The Branch provides data and advice to users in all sectors regarding provincial control survey standards, distributes control survey data, oversees the conversion to NAD83, makes provisions for technical expertise in GPS, and coordinates efforts with federal geodetic surveys. Road surveys must connect to all geodetic control points that lie within 800 m of the survey. Surveys in areas with no existing cadastral fabric (northern Saskatchewan) must connect to geodetic control at mapping accuracy levels. Regulations under the new Act are not complete, but it is expected that more land surveys will have to be connected to geodetic control.

Secondly, surveyors integrate their surveys on their own initiative, to some extent. Surveyors with GPS connect to control and use coordinates for subsequent legal surveys; but do not show coordinates on the legal survey plan. Some survey firms establish local control nets in conjunction with subdivision surveys. Most survey firms have the equipment and expertise to perform integrated surveys. Thirdly, the use of the provincial cadastral base is widespread, including most government departments, the utility companies, pipeline companies, mining companies, the Prairie Farm Rehabilitation Agency.

In the wider sense of the term, integration of legal surveys is soon to be adopted. In January 2000, SaskGeomatics stated in a press release that it is undertaking the Land Titles Automated Network Development Project (LAND Project) that will automate the province's paper-based land titles system and integrate it with Geographic Information System (GIS) technology.

5. Manitoba:

Integrated surveys are not addressed in provincial legislation. Nonetheless, integration of surveys is required for survey plans prepared in connection with Treaty Land Entitlement surveys or plans prepared for the Provincial Director of Surveys. There is no general set of instructions for these surveys and requirements are issued on a project basis.

The *Manual of Good Practice* of the Association of Manitoba Land Surveyors formerly dealt with integrated surveys. The stated purpose of the guidelines was to assist in the provision of survey data for the use in the development of a province-wide land parcel and survey monument positional database. Distinctions were made between urban and rural surveys each with its own specifications. Urban surveys were to be integrated when two existing parcel monuments - that had already been tied to the survey reference framework datum (and known as integration monuments) - were within 50 m of the survey. In instances where only one integration monument was within the 50 m radius, but additional integration monuments were available within 400 m, then the survey was to be connected to the monument within 50 m and to at least one of the others within 400 m. Rural surveys that were within 800 m of a Geodetic Control Survey Monument were to be tied to geodetic control; at least two monuments from the cadastral survey being tied with angle and distance to the Geodetic Control Monument. When direct measurement could not be achieved, a traverse was to be made. Rural right-of-way surveys were to be integrated, with preference given to obtaining ties to control at each end of the project and additional ties along the length of the project to prevent intervals between ties from exceeding 1 km.

However, the Association repealed the section of the Manual dealing with integration in March 1999. The only provisions of the sort are the pending ones of the Property Registry which, in its forthcoming Instructions for Survey and Plans, has a requirement for Right of Way Plans that fall within 1.6 km of a geodetic control monument to be tied in. There are no other directives that deal with integrated surveys in either urban or rural settings. Although there is now no requirement to integrate land surveys, there is a recommendation that surveys be integrated, but only if a disproportionate amount of work would not be involved. That is, integration is not regarded as justified unless it is feasible.

The province initiated the Manitoba Spatial Reference Network (MSRN) in 1998 to provide increased access to CSRS values. The MSRN is a GPS-based network consisting of some 250 monuments, roughly on 40 km grid spacing. The MSRN is part of the

NAD83(CSRS) datum. Since June 1990, the City of Winnipeg has its own system based on NAD83. It has not been updated owing to the property mapping not being maintained.

6. Ontario:

Section 62 of the *Surveys Act* allows the Lieutenant Governor in Council to make regulations establishing, governing and regulating systems of coordinate surveys. The Ontario Coordinate System Regulation 1028 provides the details for the system in use. Coordinates for a point in this system are required to be based on the NAD27 datum.

Regulation 42/96 made under the *Surveyors Act* prescribes and governs performance standards for the practice of cadastral surveying. It defines a coordinate survey as a survey for the purpose of establishing the location of points on the surface of the earth by geographic or grid co-ordinates. Bearings for coordinate surveys must be derived from monuments. A plan for a survey integrated with a coordinate survey must include notes that indicate the distances are adjusted and that the coordinate survey represented is based on a stated projection, zone and datum. Similarly, bearings derived from a coordinate survey must be indicated on the plan as grid bearings that have been derived from horizontal control monuments with stated values. Closure error for field data must not exceed 30 mm for the first 30 m, 3 mm per 30 m for the next 300 m, 3 mm per 30 m for the next 240 m, and 1:5,000 for any traverse in excess of 570 m.

The Association of Ontario Land Surveyors Integrated Surveys Task Force was formed to prepare a Regulation that would require integrated surveys. The Task Force generated and presented a series of proposed amendments to Regulation 42/96 and a companion Interpretative Guide at the 1999 AGM of the Association that would provide for this implementation. The amendments to the Regulation have not yet been adopted.

The amendments provide a definition of a coordinate system as a positioning system related to the earth by a known datum and realized by a set of coordinates related to monumented points at a given time (such as NAD27, NAD83, NAD83(CSRS98)). A known control point is given to mean a stable monumented point with coordinates that are stored and made available by a federal, provincial or municipal control survey authority. The proposed amendment would require Ontario Land Surveyors undertaking a survey to integrate it with a coordinate system by determining the coordinates in the coordinate system of every angle and corner on a line or boundary.

Coordinates so defined must be accurate to 10 m or better unless the survey is made in preparation of a subdivision under the Planning Act and is located within one km of a known control point which would require the coordinates to be accurate to one m or better. These are minimum accuracy requirements and the Interpretative Guideline notes that coordinates should be accurate to 10cm or better where practical. Plans submitted must note the coordinate system used and show the coordinates of at least one point related to the survey.

7. Quebec:

Quebec has about 1,800 monuments in its High Precision Network. In addition, there are about 90,000 monuments in the official geodetic network, about half of which have been readjusted. The intention this year is to add 85 monuments to the HPN, to increase the number of control points for traditional surveys by 500, and to increase the number of active control points from five to eight. There are some 3.3 million legal parcels in the province, with 40,000 new parcels created each year. Parcels have been integrated to the geodetic network (systeme de coordonnees planes du quebec – SCOPQ) since the start of the Cadastral Reform Program in 1985. All land surveys within 500 m of a control monument must be integrated. Hence, most rural parcels are not tied to control, and no coordinates exist for parcels that are outside the reformed land database that is maintained by the Ministere des Resources Naturelles. Cadastral reform intends to integrate to the databases about 1.5 million parcels; half of which had been renovated (integrated) by 2000.

The purposes of reform are to ensure that each parcel in the province has a unique identification number and is graphically represented in the database. Each parcel in the database is represented by a polygon and is located using pairs of coordinates. However, the coordinates have no legal value. Article 977 of the *Civil Code* says that "the limits of land are determined by the titles, the cadastral plan, and the boundary lines on the land, and by any other useful indication or document, if need be." The coordinates exist in the database to support the graphical description.

8. Newfoundland:

Under authority of the *Land Surveyors Act*, the Association of Newfoundland Land Surveyors may regulate and establish standards for the practice of land surveying. The Association Bylaws provide the requirements for survey integration in section 12 – Minimum standards.

All land surveys are to be completed in accordance with the bylaws. Where inconsistencies between requirements may be encountered during work involving provincial or federal agencies, then the most rigorous standards are to be applied. All surveys are to be tied or referenced to the provincial monuments of the provincial referencing system whenever possible. The general rule is to provide a tie to the reference system when the survey that is being completed is within 1.5 km of a provincial monument. The current provincial referencing system is based on the NAD83 datum. Angular misclosure must not exceed (20") x (N), where N are the number of angles in the traverse. Closure for any traverse must not exceed 0.03m + (0.0001) x (D), where D is the distance traversed in metres.

All plans of survey must include a straight line bearing and distance from one of the control points to a property monument, being the point of commencement of the survey, or the coordinate values (NAD83) of the point of commencement. Further, all provincial control monuments tied to in the survey must have their coordinates and UTM zone number provided.

The Geodetic Surveys program has established approximately 7,000 permanent survey markers with precise positions for the reference of topographic mapping, land surveys, and engineering surveys. The positions are integrated with the Geodetic Survey of Canada. The current method of control survey is the Global Positioning System (GPS) utilizing precise survey methods.

9. New Brunswick:

The *Surveys Act* requires that a system of coordinates for locating points on the earth be established and maintained. Schedule A of the Act defines the datum and map projections to be used, and section 4 says that under the coordinated survey system, the surveyor must set out bearings of boundary lines in terms of grid azimuths and distances in metres. Also, any survey plan under the coordinate survey system must describe a parcel of land using the coordinates of the parcel monuments. Service New Brunswick (SNB) is responsible for the maintenance of the Provincial survey framework. Over 24,500 monuments were established in the control survey framework from the late 1950s until 1998, which are now referenced to NAD83(CSRS98). From 1994 to 1999, SNB, in cooperation with the Geodetic Survey Division and the other two Maritime Provinces, established the New Brunswick High Precision Network. The NBHPN is based on GPS, is referenced to NAD83(CSRS98), and consists of some 130 monuments at a nominal spacing of 20 km.

The *Surveys Act* also makes provision for the Lieutenant Governor in Council to declare portions of the Province as integrated survey areas. For areas declared, the Director of Surveys must file in the Registry Office a plan setting out the coordinate monuments established. Once an integrated survey area is constituted, all subsequent surveys that establish legal monuments pertaining to Crown lands, subdivisions as required under the *Community Planning Act*, and parcels of land which the owners request to be included must be tied to the coordinate monuments.

Regulation 84-77 (previously 72-160) established the City of Saint John as an integrated survey area (ISA). This is the only ISA in the province. The Director of Surveys Instructions allows a surveyor to tie his legal survey to control points in a variety of manners such as triangulation (two control points), trilateration (two control points), or resection (three control points), and then tying the parcel monuments to other control points not previously used in a closed traverse. The manner of tie in is dependent on surveyor preference and the availability of control points. In addition, Regulation 74-149 requires that a condominium plan shall be prepared in accordance with *Surveys Act* regulations and the Director of Surveys instructions even if the condominium project is located outside an ISA.

Angular misclosure shall not exceed (20") x (root of N), where N is the number of angles, length variances shall not exceed 1:7,500 +/- 0.015 m, and traverse misclosure must not exceed 1:5000 +/- 0.03 m. All plans must include a table showing coordinate values for coordinate monuments used in the survey, for every monument or lot corner, and all other coordinate monuments whose position falls within the area of the plan must be shown. All plans of survey prepared under the *Condominium Properties Act* or the *Air Space Act* in any part of the province are done under the Director of Surveys Instructions, and must be tied to the control framework.

In addition, the *Standards Manual* for New Brunswick Land Surveyors states the requirements for surveys that must be tied to survey control monuments. Every survey conducted should be connected to the New Brunswick Coordinate Monuments if:

- the nearest pair of usable control monuments is within 1.5 km,
- it will require less than seven setups to complete the connection, and
- the cost of the connection won't be prohibitive.

Any survey that cannot meet these requirements may be connected to a coordinate monument of any surveying or mapping agency (federal or provincial). When a survey is tied to the New Brunswick Coordinate System, the coordinate values of all coordinate monuments and parcel corners should be indicated on the plan of survey.

Thus, land surveys are integrated to the control framework under either of two models. The first model is administered under the *Surveys Act*. The second model is administered under the by-laws of the Association of New Brunswick Land Surveyors. Over 95% of surveys are now integrated.

GPS may be used to determine coordinates of control points for a legal boundary survey. When referencing the HPN, the accuracy of the coordinate values must be 0.02 m + 5 ppm relative to the nearest control point. When referencing the older ATS77 Network points, the accuracy of the coordinate values must be 0.02 m + 5 ppm relative to any control monuments from the Network used in the survey. For all surveys, angular misclosure must not exceed (30") x (root of N), where N is the number of angles measured between points of angular control. Closure error is a function of length of traverse. It must not exceed 0.05 m for the first 100 m, 0.02 m per 100 m for any distance between 100 and 400 m, and 0.01 m per 100 m plus 0.1 m for any distance beyond the first 500 m.

10. Nova Scotia:

Section 8 of the *Land Surveyors Act* allows that the Lieutenant Governor in Council may make regulations prescribing standards for land surveying. The Land Surveyors Regulation 188/88 provides the details for the system in use including integration of surveys with a coordinate referencing system. Unless hardship and extraordinary expense can be shown, each survey must be referenced to the Nova Scotia Coordinate System via a measured bearing and distance to one or more control monuments. Astronomic bearings are permitted but all other bearings must be grid bearings derived from two or more monuments of the Nova Scotia Coordinate System. Closure requirements are the same for all surveys. Angular closure may not exceed (30”) x (N), where N is the number of angles measured in the traverse. Error of closure of a traverse after angular adjustment must not exceed 1:5000 plus 30 mm.

The control system contains approximately 23,000 points in the ATS77 datum framework. As well as maintaining this network, the province in cooperation with the other Maritime Provinces and the federal government is creating the regional Maritime High Precision Network (HPN) referenced to the Canadian Base Network. In Nova Scotia the HPN was established using GPS methods and currently has 153 stations with coordinates in the NAD83(CSRS) datum.

The standards of the Association of Nova Scotia Land Surveyors indicate that bearings shall be derived from astronomic observations referred to the appropriate central meridian of the Nova Scotia Co-ordinate Survey System or from two suitably spaced co-ordinate monuments of the Nova Scotia Co-ordinate Survey System, with the following exceptions:

- a surveyor is permitted to use a magnetic bearing in the case of surveys to retrace the boundaries of uncultivated lands where no immediate transfer of ownership or development is foreseen other than for forest utilization.
- A surveyor is permitted to use a magnetic bearing reference as the best possible meridian obtainable at the time of survey but only in situations where undue hardship and expense can be shown to exist for the determination of astronomic or grid meridian and provided at least two angular ties are made to permanent visible points.

11. Prince Edward Island:

The *Land Survey Act* recognizes the Prince Edward Island Coordinate System (PEICS) is the system instituted by the Geodetic Survey of Canada for defining and stating positions in the province. The coordinates were established to depend on and conform to the national system and were referenced using the NAD27 datum. Since the early 1970's PEI has had a network of over 4000 reference points spanning the entire province. Generally, a pair of inter-visible monuments can be found no greater than one km from any particular property and land surveyors have always made every effort to tie in their surveys to the network. There is also a HPN referenced to NAD83(CSRS), consisting of 27 monuments at a spacing of 20 km

There are no regulations providing details for completing ties to the provincial coordinate system. Of interest, in 1971 the Legislature passed another version of *the Land Survey Act* that provided for integrated survey areas very similar to New Brunswick legislation. However, this Act was never proclaimed and integrated survey areas are not a component of the survey fabric in PEI. The existing legislation states that any survey to be submitted to the Chief Surveyor lying within 1.5 miles of any reference point is to be tied in to the network.

The Act prohibits any survey from being received for filing by the Chief Surveyor if any part of that survey lies within 1.5 miles of a coordinate station, unless all corners and directions of boundaries included in the survey are shown in terms of coordinates. This prohibition is only effective if an Order in Council by the Lieutenant Governor in Council subjects an area of the province or a municipality to it. However, within such an area, the Chief Surveyor is not to accept even a survey no part of which falls within 1.5 miles of any coordinate monument, if some means to tie it in to the PEICS is achievable but no tie was made.

However, in the past, the Chief Surveyor only conducted a preliminary examination of plans. Currently, plans are not filed with the Chief Surveyor. Typically, surveyors do integrate surveys and publish coordinate values for every monument. Although there are no minimum standards on closures, land surveyors strive to achieve the highest achievable accuracy with the technology at hand (about 1:20,000).

12. Trends:

Integration requirements vary across the 10 provinces and Canada Lands, and vary within provinces, as represented by the demands of various municipalities (such as those in Ontario), the existence of Coordinate Survey Areas and Integrated Survey Areas (as on Canada Lands, and in Saint John, respectively), and the establishment of areas of active control (as in the Capital Regional District). Hosts of government agencies, and in at least two cases (Alberta, New Brunswick) the provincial surveying associations, administer the requirements.

There are currently 11 Coordinated Survey Areas established on Canada Lands. At the provincial level, integrated survey areas exist in British Columbia and New Brunswick, while Alberta, Quebec, Newfoundland, Nova Scotia and Prince Edward Island have provisions for tying surveys to their respective control systems. Ontario is proposing amendments to their Regulations to allow for integration.

The data used across the various jurisdictions ranges from older frameworks such as NAD27 and ATS77 to the more current systems of NAD83 and NAD83(CSRS). In most cases the maximum distance acceptable for tying to a coordinate monument is one to 1.5 km. Acceptable closure errors for integrated surveys are 1:5,000 for traverse closures, and (20”) x (N) or (20”) x (root of N) for bearing misclosures, where N is the number of angles in the traverse.

With the recent increase in GPS use, most provinces are moving towards improving or upgrading their coordinate reference systems so as to be compatible with the Canadian Spatial Reference System. There are two apparent modes to this trend. The first finds the various jurisdictions maintaining few of the traditional, densely spaced control monuments, in favour of establishing High Precision Networks. HPN spacing varies from about two km in urban areas (Calgary, Victoria), to 20-40 km on a regional or provincial basis. The second trend finds jurisdictions (such as Quebec) establishing and encouraging the use of active control points, as represented by CACS. The less dense HPNs and the Active Control Points both encourage the use of GPS techniques and the mastery of adjustment methodology.

There are four trends that affect integration, even without a national standard being adopted. First, the use of active control will increase, particularly in urban areas. Second, the use of sophisticated GPS equipment and techniques will increase, although perhaps not as much in high-density areas. Third, the devolution of responsibility for the control network and other aspects of land surveying will continue, with surveying associations, municipalities, and aboriginal peoples assuming more of the burden of administering integration. Fourth, spatial databases will continue to grow in sophistication, although perhaps not in uses. At least three of these trends bode well for more rigorous integrated land surveys; devolution of responsibility, admittedly, only affects integration in a neutral sort of way.

Such devolution does suggest, however, that compliance with any integration standard must be monitored by the regulatory agency which requires integration, or with the agency to which monitoring has been devolved and assumed. To wit, if LSD requires that surveys on Canada Lands must be integrated to the CSRS, then it must be responsible for monitoring compliance. Or, if the ALSA Manual of Standard Practice requires integrated parcels but a plan of survey lies within Calgary, then Calgary must ensure compliance. The agency whose spatial database is being improved should bear the responsibility of administration.

Of course, many municipalities, for instance, might not have the ability (either the technical competence or the financial resources) to monitor and ensure compliance with integration requirements. There may well be the need and the potential to form joint ventures and consortia, with clearly defined areas of responsibility, as in the Capital Regional District. Suffice to say that no one model should apply to the diversity of jurisdictions that is Canada. Witness the active role of the province of Quebec, as opposed to the active role of the ANBLS or the ALSA, as opposed to the active role of municipalities in Ontario. These diverse arrangements have arisen because of differences in political will, economic culture, and legislative mandate.

Any case for national integration standards can adopt four premises. The first premise is that nation-wide cadastral data infrastructure is contemplated. A second premise is that inter-provincial mobility will result in surveyors working willy-nilly across provinces and territories. A third premise is that Canada Lands are recognized as holding a unique place in the debate, and that the data-set on such lands is national in scope. A fourth premise is that the Canada-wide DGPS program will be warmly welcomed by the surveying community and other users of spatial data, thereby leading, in conjunction with the ending of selective availability, to consistent practices across Canada

Part III – Costs & benefits: Asserted & actual

1. Views of the surveying community

Over 35 interviews (in person, by telephone, by e-mail) were held with surveying and mapping experts in most of the provinces and territories (see the questionnaire in Appendix 1). Half of the respondents came from the private surveying sector; the remainder came from government (primarily municipalities). The majority of surveying firms that are represented are multidisciplinary, but rooted in cadastral and land development. Other areas of involvement included construction, control, and mineral claims. Their views are summarized here, and are primarily classed according to those in praise of integration, and those with reservations about it. Views as to standards and stakeholders round out this Part. On the presumption that CCOG knows its own mind, the benefits, costs and stakeholders associated with integrated land surveys that were identified by CCOG member have been relegated to Appendix2.

a. In praise:

Most respondents acknowledged that benefits to GIS developers and users within governments are obvious and easily demonstrable. It was also noted that engineering design and construction users within municipalities benefit from accurate ground mapping, which includes cadastral information in digital form as a basis on which to produce their designs. The process of managing land acquisitions and dispositions, as well as costing for property and materials, is greatly aided by digital mapping.

The surveyors appeared to regard integration within a municipality as not an onerous requirement (for themselves), because clients understand that integration is simply a requirement of approving the subdivision - to be met like all others. In other words the cost is simply passed on to the client, and clients do not object. Some surveyors preferred working in an integrated system. This means that they would, cost permitting, tend to integrate their legal surveys more often than not. Those firms that have much experience with integration report that retracement is made easier, as well as the comparing of their work with that of other surveyors. Having amassed a digital database of their survey dealings in a certain area allows firms, when their cadastral dataset is overlaid (e.g., on large scale topographic mapping), to assess prospective jobs with a good degree of certainty. In this way, the integrated survey (database), as augmented with other data, proves to be a strategic asset to firms. Firms interviewed report that integration allowed them to compile a database of coordinated surveys that they can retrace easily even (as some New Brunswick firms) many years after the initial survey.

The cost of surveying connections to the control network and processing the created parcel data is estimated at 10 - 20 percent over the basic survey cost. Surveyors universally either discount the significance of this expense, seeing it as a means of meeting the specification for a survey and, therefore, a cost that is passed on to the client. Otherwise, they view integration as a normal part of their surveying and, indeed, their *business* process; for instance, some firms consider the requirement (actual or anticipated) to submit plans digitally and working 'on grid' as second nature. In particular, those firms that use GPS extensively tend to regard the extra effort to integrate a legal survey as minimal and take the training of staff in their stride. There appears to be a pool of spatially educated talent available both for municipal and private users of digital mapping.

One municipality which overlays its cadastral layer with its orthophoto base uses the resulting product, which it can reproduce and present at various scales and for various planning purposes, for public meetings and strategic planning. For instance, having an accurate means of viewing topographic detail superimposed on the parcel fabric has allowed it to work with the POLARIS project (property mapping in Ontario) to identify prospective problems with boundaries (e.g. encroachments) early on in the compilation process.

b. Reservations:

One surveyor reported that there is some desire by those who deal with geographic data to recognize coordinates as irrefutable. Users, other than surveyors, appear not to have an understanding of the application to property. A common opinion expressed in the interviews was that automation and coordinates have steadily encroached, and will continue steadily to encroach, upon the way surveys are researched, performed, and archived. The issue of what the coordinate values then represent – what their evidentiary value is - appears to be the cause of some considerable anxiety for the profession.

Although coordinates represent data well, some surveyors were concerned that others surveyors favour integrated surveys as allowing them to survey from their desktop. The prospect of coordinates which would be preferred and upheld as the best evidence of a boundary and regarded as a final arbiter of a point's position worries those who gravitate, in the evidentiary hierarchy model, towards favouring monuments found in place. Several surveyors interviewed expressly referred to the hierarchy and reaffirmed that coordinates should, like all measurements, remain the least preferred type of evidence.

Several surveyors spoke about working with coordinates since the inception of the Saint John ISA and feeling, early on, that having coordinates represent boundaries was the best option. However, they related a change of heart and a more cautious attitude towards the use of coordinates, perhaps because we have a tendency to make mistakes even in the most advanced numerical system: "Coordinates are a terrific tool but, if push comes to shove, we will side with the monument in the ground." The critical skill and contribution of surveyors is still the *application* of the technology - the means of ascertaining the location of the boundary.

Some private sector surveyors did raise issue with the requirement to submit digital plans. They felt that that mandatory digital submission is out of line in general, unless the surveyor gets paid (or otherwise compensated) for the trouble. Assuming that the digital data has a public value, then the view was expressed that it was not fair for the public to take that value at the expense of the surveyor and, ultimately, the surveyor's client.

Other surveyors had reservations about municipalities allowing digital plans to be viewed by parties apart from the client. One municipality that requires digital submission is committed to *not* releasing any of this type of information. Private surveyors seem to bristle at the thought that the city can require a digital plan from them where, in the past, paper copies were acceptable, for two reasons. First, the municipalities do not subsidize the initial acquisition of digital data. Second, they do not pay royalties for the value-added use of the product. Evidence of this intellectual property quandary was reported by one surveyor, who rebuffed a city employee upon the latter releasing information based on a digital real property report (RPR) to a landowner whose interest in contacting the city was in avoiding the cost of an RPR. In general, this remains a critical unresolved issue. For their part, the municipalities who responded expressed no desire to pay for the digital parcel data from surveyors. They appear to view it as a requirement of city policy, if not a statutory requirement that this information be delivered to them, in the required (i.e. digital) format

Some respondents were critical of physical monuments and suggested that where the framework is composed of a network of control monuments, entropy asserts herself and wreaks havoc. Especially in the north, unstable ground and the action of frost often displaces the carefully positioned beacons. In other areas (notably, Ontario), unless integration of the survey was mandated, surveyors told of the profit margins not permitting integration as a matter of course. Another concern about the current standards for integration related the fact that easements, while not requiring integration, yet still must be positioned for practical purposes. Several surveyors commented on this gap in the requirements, and the consequent gap in the digital cadastre that is created.

c. What of standards?

Many respondents felt that working with integrated legal surveys requires a 'common sense' approach and a good understanding of coordinates. The existing accuracy standards applying to integrated surveys are universally acceptable to all interviewees for purposes of legal surveys. Some municipalities purported to have achieved better accuracies. Some respondents noted that, depending on the distance from the control points used in a particular survey, or on seasonal and ground conditions, the specified accuracy is more difficult to meet. Conversely, in built-up areas where control points are densely located, the achievable accuracy is better than the specification.

Even if not designated as an integrated survey area, municipalities tend to require that new land development schemes (severances and plans of subdivision) be integrated with geodetic control and that the coordinate data, in the form of a digital file, be submitted. The rigour of the integration varies, from essentially simply tying one end of the subdivision to control, to fully integrating and balancing the parcel fabric between two sets of control points. One municipality gives the developer the option of integrating the survey voluntarily or paying a set fee for this operation to the city - the funds coming from the bond posted as part of the subdivision/servicing agreement. The requirement of a coordinate file is specified in draft plan requirements, or in the subdivision agreement. Where a municipality requires new subdivisions to be integrated into control, it generally does not have its own specifications, but relies on the standard set by the provincial surveying association. These standards could be improved, from the viewpoint of municipalities, if they called for integration of 'street furniture' - i.e., utility cabinets, access holes, and municipal plant that can be located within new subdivisions. Municipalities noted that checking digital cadastral data that are received from surveyors is onerous, but is a necessary burden to ensure system integrity.

The six cm tolerance allowed in the Saint John ISA in New Brunswick was referred to. It was talked about as a reasonable safeguard against the proposition of recalculating and upsetting published coordinate values on a continual basis - something which, as with mathematical changes in the reference framework, changes the numbers and is, therefore, likely to confuse the public. One comment referred to a demographic issue: the median age of surveyors in his province was around 50 years of age. This informs the professional capacity aspect of integration. Not all surveyors are necessarily 'GPS-ready' and conversant with the technical requirements of integrated surveys or, at any rate, are not yet proficient at the level required to assure the integrity of the system.

Some surveyors were opposed to making integration more onerous, by requiring traverses to more distant, less dense control monuments. This view echoes that at the ALSA AGM in Calgary (April 1998), at which a proposal was defeated to require that surveys be integrated if within two km, as opposed to the current requirement to integrate within one km (ALSA, 1998):

> Concerns were expressed with respect to increasing costs of surveys as a result of running lines, extending control ties, and filing digital plans at land titles. It is important when considering these changes that thought is given to client relations. Most clients will not want to pay the extra cost. It was further suggested that if integration up to two km is so important to the municipalities, perhaps the municipalities should pay for desecration of the existing [control] monuments. It was further suggested that it is important that the clients fully understand the benefits to the public and the member ship should not assume that clients will be opposed to increased costs.

d. Who are the stakeholders?

Those identified as preferred allies to have at the table when determining standards include GIS users in municipalities (urban and rural), provincial and federal governments; First Nations; engineers; land developers; land registration staff; utilities; resource companies; consumer interest groups; architects; and planners. In the category of groups who would stand some education in the principles of integrated land surveys, real estate lawyers were mentioned, as well as the general public. It was mentioned that others may be interested in the education aspect once NAD83(CSRS) becomes fully implemented in the aspect of wanting to do their own positioning.

Not surprisingly, those interviewees working with municipalities expressed the 'applications' side of the issue. Integration enables them to provide value and reduce cost to their agency in particular and to the constituency generally. However, one strand of thinking that was expressed bears an important caution for surveyors: that integration of the legal aspect - the cadastre by itself - "is not where it's at...the value of what surveyors do is in how it relates to other spatial [artifacts]." This stresses the need to work with groups other than surveyors when developing standards, protocols and, importantly, assessing value and negotiating costs for the information which surveyors provide to the 'value-added' users.

2. Meta-Analysis:

This Part reviews four recent studies on the merits of integrated land surveys – two from Canada and two from offshore - to see if the conclusions are supported by the evidence, and to look for replication across, or discrepancies between studies. Are there exemplars from other systems that can inform the proposals in this present study, or do the studies provide some cautionary tales?

a. New Zealand:

A study of the value of the New Zealand geodetic system calculated that central government had established 60,000 control monuments at a cost of some $250 million over about 120 years. In addition, land surveyors have established many of their own permanent reference marks, the costs of which have been borne by the clients at the time of subdivision. The annual cost of maintaining the geodetic network is $3 million. The analysis suggested that the geodetic system was one contributory stage in "obtaining security of tenure and, especially, in reducing costs when transacting real property" (Hoogsteden & Hannah, 1999). However, the only evidence in support of the assertion is that the cost of title insurance was avoided in New Zealand, unlike the situation in the United States. This is a weak argument, because there is no apparent relationship between an integrated land survey and an assessment of the legal interests in land.

Without further explanation, the study proceeds to assert that the land titling and surveying system "enables accurate and reliable transfers of property to take place speedily and efficiently." And yet, in the absence of surveys to re-establish boundaries and to place improvements relative to those boundaries, which surveys are unknown in New Zealand when parcels are bought and sold, there is the very real potential for encroachments to remain undetected. Returning to the argument that integrated land surveys obviate the need for title insurance, the study concludes that the effective cost-savings per year to New Zealand property owners ranges from $99 to $118 million. Finally, the study concludes that if the survey system is an equal partner (along with the title system) in the cost-savings, then integrating parcels to the geodetic network saves $50 million per year.

However, there is no empirical relationship established between the geodetic system, the absence of title insurance, and the risk of encroachments. Indeed, in many parts of North America (such as Canada) parcels have been integrated to a control system, and yet real property reports have been common. Now, of course, in many provinces, title insurance appears to be supplanting such surveys, even in the face of ties to control. There is no evidence that integration eliminates the need for title insurance, because each provides different things. The former allows a parcel to be referenced to a control framework and thus for a databases to be enhanced, and says nothing about competing rights in the parcel. Conversely, title insurance says nothing about the location and topology of the parcel within the cadastre; it merely gives lenders some assurance. To suggest that savings can be passed from one to the other ignores the absence of causation. To augment the argument by introducing the principle of security of tenure adds little, without supporting evidence.

Finally, the study uses earlier findings from the Australian Capital Territory to suggest that subsequent surveys can be performed more economically if parcels have been tied to control. By accepting without analysis the Australian assertion of 20% lower survey costs, the New Zealand study calculates that savings to land surveyors from integration amount to $44.6 million per year. Furthermore, savings to the building and construction sector are said to be at least $4 million per year, again in the absence of data. Certainly, the study appears undeterred by the very real (and acknowledged) difficulties in getting any empirical data in asserting these sundry benefits.

b. Australian Capital Territory:

The New Zealand study based its assumptions on a 1990 cost-benefit analysis of establishing integrated land surveys in the Australian Capital Territory (ACT). The ACT study calculated that the costs of integrating some 98,000 parcels included the costs of establishing a control network (placing monuments, surveying and adjusting), of connecting the cadastral blocks to the network, and of calculating, adjusting and drafting the parcels. These costs were $112 per parcel, which, it was assumed, would be borne by the state. The information used for calculating the costs was derived from the actual cost incurred for comparable activities undertaken by the Australian Surveying and Land Information Group.

However, the benefits of integrating the parcels appear to be less well supported by data. For instance, although the study asserts that there are savings in the cost of surveys and administrative processes, and that there are benefits from increased security of tenure, it admits that benefits are "relatively small" (Angus-Leppan et al, 1990). Indeed, the argument that security of tenure would be enhanced is particularly speculative, and appears to go like this: Integrating land surveys means that fewer boundary monuments are lost. Less loss means fewer discrepancies between early and subsequent surveys. Fewer discrepancies in surveys mean less uncertainty about the spatial extent of the parcel. Less uncertainty means fewer boundary disputes. Fewer disputes means enhanced market value. Greater market value means lower interest rates on mortgages. Finally, fewer boundary disputes means fewer building encroachments. There are at least two significant difficulties with the argument. First, there is no intuitive link between many of the if-then propositions. Second, little empirical evidence is given to support the propositions. In fact, what evidence is adduced - that in the absence of integration there had not been a boundary dispute in the ACT for 20 years - serves only to undermine the argument.

Moving onto cost savings, the study admits that there are no savings (only costs) for the first generation of surveys to be integrated to control monuments. However, for second generation and subsequent cadastral surveys, savings of 25% are estimated, which would amount to savings of $300,000 per year within the ACT. This estimated saving must be put into perspective. First, there is no indication of how the 25% estimate was calculated. Second, given typical surveying costs of $6.9 million per year within the ACT, the estimate amounts to a saving of 4.5% per year. Third, given the cost of integrating and the number of parcels, it would take some 37 years to recoup the costs. Finally, the study assumes that, although the costs will be borne by the state, the surveyor and the client will reap any savings.

c. Ontario:

The Report of the Task Force on Integration in Ontario (1990) found that integration of surveys is the most cost-effective way of keeping a planimetric and property map data base current and at the accuracy standard required by users. It found that although many municipalities had taken the initiative of integrating land surveys, few had any information on benefits and costs, and most acknowledged the difficulty of cost-benefit analyses. Indeed the City of St. Catherines said that analyses in the absence of empirical data are "disappointing and they are now distrusted as self-serving sophistry."

Thus, the Task Force attempted a cost-effectiveness analysis by comparing two hypothetical one square km blocks, each of which contained 800 parcels. Community A had no control network and did not integrate land surveys; Community B had third-order control monuments in a 500m grid and required that parcels be integrated. Over a five-year period, savings of $2,400 per year were estimated in Community B, through easier maintenance of planimetric and property mapping and faster engineering surveys.

However, to normalize the meta-analysis with the ACT study, let's delete mapping from the Ontario simulation. If only the costs of establishing a control network and of integrating parcels are offset against the saving in subsequent surveys, then the saving of $3 per parcel per year is identical between the two studies. The Ontario costs of $85 per parcel are slightly less than the ACT cost of $112 per parcel, meaning that only 28 years would be required to recoup the costs in the Ontario analysis. Although the findings are in the same order of magnitude, the critique of the estimates is also similar. The Ontario study estimated that engineering surveys of parcels that had been integrated would be 30% cheaper (which compares closely to the ACT estimate of 25%). Yet the assumption was supported by no empirical data. Given the relatively small savings over the five years, a subtle reduction in the estimate has the potential to significantly erode the savings or, indeed, to result in a net cost in the integrated community.

The danger of such unsubstantiated assumptions are borne out by the one municipality - the City of Etobicoke - that did provide a cost-benefit analysis to the Ontario Task Force.

Etobicoke calculated $2.7 million of benefits over a ten-year period, which included better accuracy, reductions in staff and time, more efficient production and updating of drawings, faster referencing, and faster response times for emergency vehicles. Costs of establishing a dense control network were said to be only $2.3 million, for an apparent saving to the municipality of $40,000 per year. However, more careful probing reveals that Etobicoke did not include the costs of maintaining the network nor did they include the cost to the land surveyor in integrating land surveys.

d. Maritime Provinces:
Finally, the Task Force on Control Surveys in the Maritime Provinces reported that the survey control framework is a "cost-effective societal investment." This finding was based on evidence from two sources. The first source was professional opinion: Land surveyors asserted that the control system allowed them to reduce fieldwork on subdivision and re-establishment surveys by 20-60%, depending upon the job. The volume and uniformity of this anecdotal evidence was very persuasive. Less clear is the supposed link between tying to control and avoiding litigation. To wit, one Nova Scotia land surveyor said that because some 95% of land surveys are referenced to control, there are fewer uncertain boundaries, and thus "less reliance on an expensive legal system to adjudicate." The second source of evidence was the opinions of property mapping managers, who were equally keen about the benefits of maintaining referential integrity through integration.

What is also unclear is the methodology used to determine that the control network was cost-effective. Certainly, the Task Force estimated that establishing a High Precision Network would cost New Brunswick some $400,000 per year over at least seven years, with proportional costs to Nova Scotia and Prince Edward Island. These costs were to be borne entirely by government, although the savings of 20-60% were to be enjoyed by land surveyors. Furthermore, surveyors and administrators within the Saint John Integrated Survey Area reported that there are higher costs associated with working in the ISA than without.

3. Case Studies

This Part examines in detail four municipal jurisdictions so as to demonstrate the benefits of tying to the control network, and to determine any factors that might influence the future of integration in Canada.

a. Capital Regional District:
The Capital Regional District (CRD) of British Columbia spans 13 municipalities, three electoral areas, and eight First Nations on southern Vancouver Island. It has an area of 2,420 square km, and a population of 340,000. In 1998, a Memorandum of Agreement (MOA) was entered into between the CRD and Geographic Data BC to establish a GPS-based geo-spatial referencing system in support of land surveying, engineering, mapping, land information management and other related uses.

The context for the MOA was that, over time, some 4,000 geodetic control monuments had been established in the CRD, although the density-distribution of the monuments was not uniform. Not surprisingly, the monuments tended to be concentrated in the more developed and urban parts of the CRD. Land surveys in many of the municipalities in the CRD must be integrated to the control monuments, owing to the existence of Integrated Survey areas (ISA) and under the Integrated Survey Program (ISP). In addition, the control monuments have been used to geo-reference various mapping schemes, including orthophoto imagery, 1:20,000 scale topographic and planimetric mapping under the Terrain Resource Information Management Program (TRIM), and large scale engineering drawings. For the most part, the control monuments consist of brass plugs embedded in concrete.

The further context for the MOA was that since 1992 much of the Geo-Spatial Reference (GSR) throughout British Columbia had been upgraded to the BC Active Control System (ACS). In 1997, Geographic Data BC stopped its support of physical geodetic monumentation consisting of densely spaced brass plugs, and committed to providing Municipal GSR through ACS technology.

Among other things, the MOA has resulted in the provision of two Active Control Points (ACP) in November 1999, and a 130-station High Precision Network. The Active Control Points are located at Canadian forces base Esquimalt, and at Pacific Geoscience Centre of the Geological Survey of Canada. GPS data from the two ACPs are supplied to the latter organization to allow them to continue to monitor plate tectonics in the area.

The High Precision Network (HPN) was established in two densities. Within the rural area of the CRD the control monuments are spaced at 10 km; within the municipalities that make up greater Victoria, the spacing is in a two km grid. The NAD83(CSRS) horizontal coordinates of each monument are accurate to one cm at the 95% confidence level. Seventy-one of the HPN monuments were among the 4,000 pre-existing control monuments. The remaining HPN monuments are new. This reuse of monuments allowed the existing network to be readjusted and new coordinates to be derived for all the monuments in November 2000. However, owing to changes in coordinates of up to 12 cm for the old monuments, and to their not being maintained, users are being advised to rely only on the HPN monuments, and to only use the other monuments for low accuracy work. Thus, the control monuments within the CRD are graded as A, B, C, or D according to their accuracy, with the same classes but different standards applying for urban areas and for rural. Only Class A and B monuments are recommended for land surveys. For instance, in the urban setting, Class A monuments allow users to achieve accuracies of 0.02 to 0.05 m; Class B monuments allow accuracies of 0.05 to 0.5 m.

Four principles were significant in the project. First, maintenance costs are to be recovered through user fees for the real-time GPS service. Second, the municipal governments were the key stakeholders. Third, the private sector was given the contracts to do the high-precision surveying to establish the HPN and readjust the remaining monuments. Fourth, the ACS was compared against the HPN, and found to provide horizontal coordinates that agree to within a few cm.

A Real-Time Kinematic (RTK) system was offered to land surveyors and others in early 2001. This allows those who use GPS to avoid traversing using conventional techniques and equipment. RTK techniques give instantaneous positions accurate to within a few cm, similar to the accuracy of non-kinematic GPS with longer occupation times and post-processing. To obtain high accuracy results using Real Time Kinematic, GPS users should be within 15 km of one ACP.

In comparison to the physical control monuments, it is asserted that the ACS in the Capital Regional District will save money, will be compatible with the province-wide system, will provide uniform coverage throughout the CRD, will allow for faster data capture, will promote economic development, and will allow for better emergency response services. Various non quantified, and in some cases non-quantifiable benefits have been posited for the ACP/HPN system, including:

- Requires less maintenance (human and fiscal resources)
- Provides a common reference system for the CRD
- Supports other programs such as 911 uses
- Allows hybrid surveying of GPS and conventional equipment
- Improves the accuracy, consistency, currency and completeness of positional information.

Most of these assertions have to do with the supposed advantage of ACS/HPN over dense control monuments, rather than the benefits of integration per se. If one accepts that integration is good, and that ACS/HPN makes integration better, easier, and/or cheaper, then integration and ACS/HPN are mutually supportive.

b. Calgary:

Calgary currently has a HPN of 210 monuments, to which some three-quarters of currently conducted land surveys are integrated. The federal government established the first survey control network in Calgary in 1927, with a first-order triangulation network along Glenmore Trail. In 1963, the network was expanded. By 1995, 8,200 control monuments had been installed, of which 2,000 had been destroyed in the development process. Most of the monuments were brass plugs or smooth-wall pipe in concrete. At that time, the province of Alberta changed the reference datum to NAD83, and withdrew from the surveying and mapping agreement with Calgary that had included the maintenance of the network. At the same time, the Canadian Active Control System and the Canadian Base Network were being established and promoted. Further, there was large-scale distortion in the existing city network, owing to instability of the monuments and a lack of adjustment tools.

Calgary therefore decided that it was neither economically feasible nor practical to maintain the existing network. It embarked upon a pilot project to evaluate GPS accuracies, to determine the type of spatial referencing system required to allow integrated legal surveys using GPS, and to look into the transition from the existing monumented system to an active control system. The pilot project used nine control monuments and found mean horizontal accuracies of 5 mm relative to adjacent monuments, and 1 cm relative to fiducial stations.

The City then developed a HPN using 200 new control monuments spaced in a one mile (1.6 km) grid that following the DLS sectional system. Horizontal coordinates for each monument are relative to the NAD83(CSRS) coordinates assigned to four existing CBN monuments. The accuracy at the 95% confidence level relative to adjacent stations is about 7mm. As of mid-2000, the coordinates for all HPN monuments and for 800 of the older monuments are available from the city's web-site. The 800 are only those other control monuments that have been tied directly to the HPN monuments and are intervisible with the local HPN monument. There is no charge for access, although the land surveyor must sign a waiver/indemnification agreement and remain in good standing regarding digital plan submissions.

There are some 800 plans of subdivision submitted to the city each year for approval, containing about 8,000 new parcels. About 25% of tentative plans are integrated; whereas over 75% of the registered plans (which establish new property boundaries) are integrated to the HPN. Although those subdivisions that are not integrated tend to lie within one km of an HPN, the land surveyor then argues that there are enough common boundaries between the new parcels and a previously integrated parcel to obviate the need for integration to the HPN. The result is that the new parcels are put into the city's cadastral map only with more difficulty and to less precision. That is, the city finds it easier to update its cadastral database, and finds that the results are more reliable, when integrated surveys are used.

And therein lies the rub. The city, as a creature of the *Local Government Act*, is constrained in what it can require of surveyors and developers. Both digital plan submission and integrated land surveys are done either by the grace of the surveyor, or because the ALSA has made it part of its Manual of Standard Practice. However, because practice review by the Association is less efficient (not all plans are inspected) than inspection upon registration in the land titles system, surveyors are often able to argue with the City of Calgary against full integration of all new parcels. That is, the City lacks the big stick that could compel integration, and ALSA's stick is only wielded periodically.

c. Invermere, British Columbia:

Invermere is a District and Town in the Columbia River valley of southeastern British Columbia, which has an area of 900 ha and a population of 2,900. It is not within an Integrated Survey Area (ISA) and thus there is no requirement that land surveys now be integrated to a control network. However, an informal High Precision Network (HPN) was established in 2000/2001 in Invermere so as to allow an analysis to be made in a real-world setting of integrated land surveys.

The Invermere HPN consists of three primary control monuments, referenced to the Invermere Active Control Point (ACP) that is maintained by the province, and 43 secondary control monuments referenced to the three primary monuments. The total cost to establish the control network was $16,170, and consisted of the cost of fieldwork, post-processing, monumentation and equipment rental. Admittedly, there has been no maintenance of the network. A re-establishment survey was done and tied to control, so as to give an estimate of the costs of integrating land surveys.

Integrating to three HPN monuments added 30 minutes to the re-establishment survey. Integrating to the Invermere ACP using DGPS and post-processing added 110 minutes to the land survey, which included gathering and downloading data, trawling through the internet, post-processing, and reducing baseline distance to ground distance using a scale factor. One significant conclusion was that integrating to the HPN was preferable to using active control for three reasons. The first reason was that less time was required. Second, because ACP data is sold in hourly blocks, there is the potential to be required to purchase two-hours of data despite observing for only 15 minutes. Third, accuracy is a function of distance from active control. Given that ACPs are not located in every town nor spaced in a grid, there is potential to seriously degrade accuracy. For instance, if the accuracy is 2 cm +/- 1 ppm, and if the distance of the land survey is 300 km from the ACP, then the integration accuracy is only +/- 32 cm.

The other significant conclusion was that a consortium of municipal and provincial government agencies are best placed to provide HPN and, if desired, ACP, owing to the costs of implementation and maintenance. Moreover, the benefits to be realized accrue primarily to the public in the form of better infrastructure mapping, and not necessarily to the land surveyor nor to the surveyors' clients. Indeed, some regional surveyors who are conversant with the use of GPS were critical of integration as being inconvenient and of providing benefits primarily outside land surveys. Of course, it was not feasible to examine the extent to which integration assisted the search for evidence when re-establishing boundaries, because none of the Invermere parcels have heretofore been tied to a control network. This supports the evidence, from the interviews and the meta-analysis, of the real benefits of integration being in value-added products and services, and in reestablishing boundaries.

d. Somewhere in Canada (location not specified, to limit liability):

A land surveyor surveyed, calculated and monumented five subdivision plans over a three year period. The plans of survey were duly registered, which created 300 parcels. Lots were sold and hundreds of houses were built, sold and occupied. The entire development was laid out on the basis of a single control tie, shown on the subdivision plan for the first phase. On each subsequent plan, it was merely stated that bearings were referenced to two control monuments. No mention was made of plan numbers on which one might discover the original control ties. This was a combination of two non-standard practices. First, the plans that relied on the single control tie were merely adjacent to each other. Second, on the second and subsequent plans the surveyor failed to indicate which previous plans were to be used as reference. This makes it time consuming and frustrating to calculate coordinates for any plan after the original plan was registered.

Integrated by a single control tie shown on one plan, the five plans were produced and registered and a sixth was being submitted for registration when an error was discovered. Although each plan, and corresponding phase of the subdivision, tied in neatly with the preceding and subsequent phases of the development, all of the plans as well as the boundary monuments and improvements such as houses, garages, fences, etc. were systematically 1.2 m out of position. The entire development had somehow been laid out 1.2 meters south of where it was intended to be. The lots and blocks generally agreed in the interior of these subdivisions, and the houses were generally laid out correctly with respect to their immediate boundaries. At the perimeter, however, there was a 1.2 m. vacant sliver on the north side. More alarmingly, on the south side there was an encroachment onto the neighboring landowner by the same amount.

The geometry of the development was such that there was limited opportunity to tie the successive surveys to other existing legal monuments. The surveyor performed all of his internal checks and proceeded, convinced that nothing was amiss. To a large extent, the subdivisions were isolated from the external world. In this context, it is easy to see how a blunder in the original plan could be perpetuated, without the independent check to another control marker. Of course, the problem would have been avoided if the surveyor had evaluated all boundary evidence and had used good survey practice. (i.e. not based on adjacent surveys on a single tie)

However, independent control ties, observed anew from each phase of the subdivision, were the single best way to detect the blunder. Existing monuments that might have alerted the surveyor were either missing or presumably were unreliable. The existing cadastral base mapping in the area was based on original 75-year-old plans of survey and was not sufficiently reliable to expose the problem. By relating all of the six plans to a single control tie, the surveyor was discarding one tool that might have prevented the entire situation. Correct integration will reveal that while one's subdivision closes internally, it is not located on the proper parcel, whether it is a district lot, township lot, subdivision lot, or quarter section.

4. Synthesis:

In concluding his commentary on the use of GPS in land surveying, Pinch (2000) identified an increasing concern over the integration of land surveys. Given that the real benefits appeared to be in enhancing the spatial data infrastructure (and not to land owners) he suggested that the key questions were:
- What are the costs and benefits to integration?
- Are the costs significant?
- Who pays the costs?
- Who benefits?

A reviewer of the article agreed that these were fundamental questions which many survey regulators across Canada have been struggling to answer. This study has confirmed what is implicit in Pinch's questions and the reviewer's lament - that there is a disparate bunch of information out there about integrated land surveys.

Although the benefits of integration are very real to most land surveyors, they are rather small in absolute financial terms, and so integration should not be promoted merely as a financial boon to surveyors. Benefits to value-added databases that comprise the spatial infrastructure, such as maps, are great, but are extraordinarily difficult to economically quantify and can be some distance removed from the land survey. Enhancing security of tenure is not supported as a benefit by the evidence.

The interviews revealed that the very strong consensus among municipalities and surveyors in private practice is in favour of integration. Both parties see the very many benefits to integrating parcel boundaries within a digital database, both from the perspective of first generation and subsequent surveys, and as allowing many uses to be made of the enhanced spatial data infrastructure. The presence of proprietary GIS in the private sector is a good indication that integration, the information from which is made freely available, has genuine public value, and is not just an arcane boondoggle.

However, the respondents were not without reservations. Concerns were expressed about integration being the slippery slope towards the use of coordinates in place of monuments, about the submission of digital plans as being rather onerous, about the surveyor as data-gatherer not being compensated by the regulator for contributing to the value-added databases, and about increased distance to control monuments resulting in additional field time and thus costs. The concern about profit margins appears to conflict with praising the value of the private GIS. Perhaps integration is only economic if the firm hoards its data, for competitive advantage? On the other hand, perhaps if everyone integrates and shares information, then everyone benefits – which is essentially the intended effect of mandatory integration.

And that leads into game theory: there's a temptation for individual firms to defect, to try to avoid integrating their own surveys, while benefiting from the integrated surveys of everyone else. Based on these interviews, therefore, it appears that any proposal on national standards, requirements and conditions for integration can take the benefits as given but must be wary of the reservations.

Data on the costs and benefits from previous studies are consistent in reporting savings of 25-40% (the latter is the median value from the Maritime Task Force) to land surveyors on second generation and later surveys. More significantly, however, the absolute savings are modest - in the order of $300-400 per survey, or $3 per parcel per year.

We can draw two overall conclusions from these studies. The first is that rigorous data on the financial costs and benefits of integrating land surveys is scarce, as acknowledged by three of the studies. The second is that the significant benefits – both financial and non-quantifiable – accrue further along the value-added chain, as the spatial data infrastructure is augmented with land survey information. As the former Surveyor General of British Columbia said: "... the value of integrated surveys as an enhancement to or substitute for the cadastral survey structure was oversold by some of the original proponents. They could never have been justified for this purpose alone. Only if used as a base for the whole municipal infrastructure can the costs be justified" (Ontario, 1990). To put this constraint in context, however, some land surveyors in the private sector extol the virtues of integration to assist them in reestablishing boundaries and in establishing in-house digital mapping systems; indeed, some have set up their own control frameworks.

The case studies suggest that administration of integrated land surveys and control networks is devolving to some surveying associations and municipalities, respectively. Strategic alliances are helping to establish HPN and active control, both of which have merit, or so it is asserted. There are true benefits to integrated land surveys, not the least of which is that they allow for the digital submission of plans in the same reference framework as the municipal spatial database. Other asserted benefits include the detection of blunders, and the reduction of emergency services' response times. Finally, the case studies demonstrate some resistance from land surveyors to integration.

Most regulators have accepted that densely monumented control networks are not cost-effective over the short term. For instance, the control network of the LRIS program in the Maritime Provinces had a ratio of benefits to costs over a 25-year period of only 0.61; annual benefits only exceeded annual costs after 16 years of the project (Zwart, 1980). This phenomenon has been recognized in many jurisdictions. Recently, maintenance of all the Maritime Provinces control monuments has ceased in favour of a few HPN monuments. Ontario reduced maintenance funding in the 1980's. Calgary has put its resources in 200 monuments in a HPN. Alberta maintains only 1003 ASCM's that have published NAD83(CSRS) values. British Columbia favours active control points in municipal areas. The Legal Surveys Division of NRCan is not maintaining CSA monuments, and so on.

However, that various jurisdictions are moving away from dense control networks doesn't necessarily prove that they are right to do so. After all, they *did* put in the dense control in the first place; on the same sort of reasoning that proves the contrary – that the dense control *was* a good idea. Arguably, GPS has made it obsolete.

There is also a surfeit of unsubstantiated assertions, presumed benefits, and analysis in the absence of data, about the costs and benefits of integration. Hoogsteden & Hannah (1999) identified some of the problems associated with determining the benefits of a control network, and of subsequent ties to the network by land surveys. First, integration has public-good properties, such as a tendency to monopoly and significant capital costs. Second, the costs incurred by land surveyors in first-generation surveys must be offset by the benefits realized by surveyors in second-generation surveys. Third, data on the costs and benefits to the private sector are not available. Fourth, although the costs to the public sector of establishing and maintaining the control system are available, the benefits realized by the public sector are difficult to unravel. Finally, many of the benefits, such as value-added cadastral databases, may be many steps removed from the actual integration of land surveys.

Thus, various submissions to the Ontario Task Force on Integration acknowledged that although integration had taken place over many years in their respective jurisdictions, "the monetary value of these benefits is unknown" (LSD, 1989). The overwhelming theme was that most of the benefits, such as better maps which resulted in faster responses by emergency vehicles, or enhanced detection of survey errors, or allowing many different uses of the same coordinate information, could not be reduced to financial savings. To attempt to do so was characterized as "self-justifying sophistry."

This debate illustrates well how problematic it is to attribute the costs and benefits of integration to either the public or the private sector. For a HPN (as in New Brunswick) or an active control system (as in the Capital Regional District of British Columbia) there are high establishment costs to the state. At the same time, less dense monumentation should result in lower maintenance costs to the state, but in higher equipment purchase costs and user fees to the private sector. Conversely, although for a denser network of control monuments the maintenance costs to the state are high, the private sector can continue to use conventional equipment and techniques.

Thus, the findings suggest a subtle shift in on-going costs away from the state and towards the private sector (in the form of lower maintenance costs to the former, and higher user charges to the latter). Moreover, the private sector is being encouraged (if not implicitly forced) to incur significant capital costs in equipment, although the subsequent ongoing costs in terms of less field time might be lower than continuing with conventional techniques. The disparity between non-conventional and conventional techniques will only be heightened if the requirement to integrate is made more onerous. An influential group of land surveyors at the 1998 AGM of the ALSA asserted that such a requirement would increase the amount of field time and thus the cost to the land surveyor, with no assurance that the cost could be entirely passed on to the client.

So, why advocate continued integration? First, there is a demand for value-added databases. For instance, AltaLIS in Alberta now gets access for mapping purposes to the CAD files of all survey plans registered in the land titles system. There is significant demand for the use of an accurate, uniform, cadastre as a result of advances in information system technology, in particular GIS technology. Municipal, provincial, federal and private organizations are now planning, analyzing and performing many of their functional activities using this technology, and the cadastre is often the core of these systems. Moreover, demand for this information will likely increase. As but one example, the annual ESRI User Group Meeting for Southern Alberta had approximately 140 attendees at its first meeting in 1997. In 2001, over 300 users attended. These users need a continuous database of known accuracy that meets their needs, set within a common reference framework.

Second, integration provides another means for searching for original monuments that have been integrated, or provides superb evidence of the monument's original location in its absence. Surveyors in the Maritime Provinces have explicitly recognized this benefit. Third, integration allows the use of coordinates-only to define parcel corners, in the absence of monumentation. Integrated land surveys are an intermediate step in the direction of abandoning monumenation for new parcels. This is not to advocate the use of coordinates-only, but merely to note that the integration of all new parcels to the CSRS is a necessary, albeit not a sufficient condition for their adoption.

However, there is no evidence (at least in the Canadian context) that integration serves to prevent boundary disputes, to repel the visitation of title insurance, to enhance parcel values or to reduce encroachments, as is averred in some offshore studies. Thus, integrated surveys must not be justified on these grounds.

Part IV – National standards

1. Should integration become more rigorous?

The trend to more frequent, more rigorous and more accurate integration in Canada should continue. Indeed, the trend should be encouraged, for various reasons, but subject to a couple of conditions. The conditions are necessary because the data-gatherers - the surveyors who are at the coal-face of the debate - have some serious reservations. Among the institutional issues to be addressed is the gap between powerful GPS technology and physical control monuments. Although many land surveyors have the expertise and the resources to operate sophisticated dual-frequency GPS equipment and are familiar with the intricacies of radio links, a not-insignificant group of surveyors are content to use either rudimentary GPS equipment, or conventional theodolites, EDMs, tapes, and so forth.

Experience from New Brunswick is that the first group is not interested in having control monuments restored or maintained, because they have established local base stations. Such stations correspond to local, private active control systems. The second group is keen to have control monuments maintained because they are relied upon in the process of conventional traversing. Indeed this gap in professional expertise was identified by the Association of New Brunswick Land Surveyors, which was concerned that sparse control monuments would have an impact for those surveyors who have single-frequency GPS receivers (ANBLS, 1996). The need to use GPS in a traverse mode, and to use field-based reference stations meant an increase in the time and thus the cost of doing a survey. This increase had the potential to affect the competitiveness of such surveyors.

All of this is not to say that integration should not become more rigorous across Canada. Given the significant benefits, standards should be made more consistent, and integration should be required more frequently. It is to say, however, that the pursuit of such policies by survey regulators at the municipal, regional, provincial and federal levels must be accompanied by both genuine consultation and a quid pro quo between regulator and surveyor. Consultation must take place across at least five distinct groups. Those leading the debate should be the surveying, mapping, and geodetic regulators in the provincial, territorial and federal governments, as represented by CCOG. The second group consists of municipalities and local communities that, in many cases have been demanding and relying upon of integration for some time. In those cases, the sentiment from land surveyors was that integration was tolerated, if not necessarily embraced, as simply another condition of doing business. Moreover, many non-surveyors, such as engineers, continue to use coordinate locations in those communities, which considerably broadens the usefulness of dense control.

Third, users of value-added databases must be consulted. Such users include land developers (as represented by the Urban Development Institute, associations of house-builders and URISA), realtors, real property lawyers, and the resource extraction industry. One representative of the latter group is the Canadian Association of Petroleum Producers

(CAPP), which has recommended, for instance that all member companies in Western Canada continue to operate in NAD27 (CAPP, 1999). Although CAPP has tentatively determined that the costs of implementing NAD83 outweigh the benefits, it would be keen to discuss any proposal that all pipeline easements should be integrated to NAD83(CSRS), as was indicated at a recent workshop sponsored by the Association of Canada Land Surveyors (ACLS).

The fourth group to be consulted should be aboriginal peoples, given that surveying accuracy, demarcation, and techniques should be a function of the kind and purpose of land tenure. Certainly in the North, the evidence suggests that land surveys are a function of land tenure, such that the need to integrate a parcel to be used for diamond mining should outweigh the need to integrate to a similar standard a parcel used for trapping. Finally, land surveyors, as represented by the ten provincial surveying associations, by the Canadian Council of Land Surveyors (CCLS) and by the ACLS must have their fears assuaged. These fears focus on the need to spend more time in the field, the need to purchase expensive equipment, the need to hone skills.

The best way to relieve those fears is for regulators to offer something back to land surveyors, in return for surveyors providing integrated coordinates for parcels. Such consideration might take the form of:

- Reducing user charges for active control data.
- Reducing user charges when digitally lodging plans, as represented, for instance by the $100 pure mapping fee that is levied against each plan registered in digital form in the Alberta land titles system and which is passed on to a third party.
- Eliminating post-processing time to the surveyor, with the regulator doing the work
- Reducing costs of access to the databases available from the regulators, which have had their value enhanced through the provision of integrated land surveys.

Such quid pro quo flies in the face of the trend to less state subsidy and higher user charges, but should go a long way to getting the surveying community firmly on-side. Of course, surveyors who availed themselves of the regulators' assistance with post-processing would be required to do adequate fieldwork, such that sufficient observation periods, PDOP, and satellites, for instance, were used. Thus the costs of more rigorous integration would be shared somewhat between the land surveyor (in the field) and the regulator (in the office). In the theme of quid pro quo, in 2001 the Geodetic Surveys Division of NRCan eliminated the expense of purchasing a database subscription to access CSRS information, such as precise GPS orbits and clock corrections, and replaced it with a one-time fee of $40.

2. Criteria:

When should integration be required, and to what standards? Given the reasons for and conditions accompanying a more rigorous regime of integration, is there a pressing need for national standards? On the face of it, consistency of standards across a country with as many jurisdictions as Canada appears to be contradictory. Consistency is not a sufficient reason in and of itself. However, an obvious piece of evidence in favour of national standards is that NAD83(CSRS) provides a homogeneous high accuracy reference system that is available across the country, and that GPS and adjustment methodology are being mastered by an increasing number of land surveyors. As one commentator asserted: NAD83(CSRS) “is the obvious choice for a national standard”, although its use is not widespread in provinces such as Alberta and Ontario.

If an integrated survey system is to continue to remain valuable, four criteria must be met. It must be accessible, permanent and stable. It must help to define newly created parcel boundaries. It must assist in re-establishing parcel boundaries in the case of disturbance or dispute. It must meet the requirements of the expanded body of users who wish to use data that is based upon survey system information. The following standards are proposed to ensure that the integrity of an integrated survey system is maintained.

Standards must satisfy three sets of needs: those of the user, those of the supplier and those of society. The needs of society are reflected in legislation and in the level of public good generated by the system. The needs of the user are reflected in their quality, cost and timeliness requirements. The needs of the survey community are to meet all of the above at a cost which, given the price a user is prepared to pay, will return an acceptable profit.

In terms of an Integrated Survey Specification, the management of quality is of paramount importance. Quality is defined in a specification by identifying criteria that relate to network design and planning, instrumentation to be used, and field and office procedures that promote efficiency and reliability, and which facilitate the classification of surveys. The management of quality is achieved by implementing quality assurance practices and procedures that are intended to maximize the chances that a product or service will satisfy a user's requirements at a reasonable cost. These procedures are generally augmented by quality control procedures used to verify the level of quality achieved, and if it is inadequate, to detect the source of the problem and remedy it, if possible.

Quality management, in the context of land surveys, is concerned with assuring an agreed level of accuracy and reliability of boundary information. The focus is therefore on procedures for defining, measuring and verifying the quality of an integrated survey. These are derived from a set of best practices from within Canada and internationally where applicable.

3. Integration accuracy & land use:

Typically, accuracy standards for horizontal coordinates take one of two forms. First, they can be based on the ratio of the relative positional error (Relative Fraction of 1:5,000) of a pair of control stations to the horizontal separation of the points, often at the 95% confidence level, as is the case for surveys on Canada Lands. Second, they can use a standard allowable distance plus a ratio of the horizontal separation of two control stations (e.g., 0.03 m + (0.0001) x (D), where D is the distance between the stations in metres) as is used in Newfoundland. As these ratios change, the classification of the survey changes. These criteria have in the past been determined by what the land surveying community considers achievable.

With the dramatic increase in the use of GPS for land surveys it would appear that the current accuracy standards could be improved within some regions as it is possible to measure relative position using GPS carrier phase data routinely to 0.005 - 0.010 m + 1-2 ppm. With careful observation procedures, and appropriate data processing, precision in the order of 0.01 ppm have been achieved for scientific GPS surveys. This is significantly better than the most "1st Order" accuracy standards.

However, this raises the question of whether the public needs surveys to be performed to the level of accuracy achievable by today's technology. The 1999 report to CCOG (Ballantyne *et al,* 1999) concluded that this is not necessary. While the public generally desired an accurate cadastre, some 40% of respondents would accept residential boundaries at an accuracy of ±0.10 m or more. It is with these results in mind that the general classification of surveys are proposed in Table 1:

Class	Minimum Relative Accuracy @ 95% confidence level
A	2 cm
B	5 cm
C	10 cm
D	50 cm
E	2 m

Table 1: Proposed Accuracy Specification

In order that this classification can be readily understood the following definitions have been developed to indicate the relationship between the class of a survey and the intention of a cadastral parcel to which the survey relates. The classification assumes that Municipal, Provincial or Federal organizations maintain registers that define land use within their jurisdictions. Land use is the primary driver for the determination of survey classes, because the value of a parcel of land is directly related to its use, and therefore to its zoning or land use classification.

Class A: A high-density commercial or industrial area, or an area that is intended to be as a result of a survey.

Class B: A high-density urban area that is not intended to be commercial or industrial, or is intended to be a high density residential area as a result of a survey, or a commercial or industrial area within a rural area.

Class C: A medium or low density urban/suburban area that is not intended to be a high density urban area, nor a commercial or industrial area; or is intended to be a medium or low density urban/suburban area as a result of a survey.

Class D: A rural area with surveyed parcels of less than 10 hectares that is not intended for residential, commercial or industrial purposes.

Class E: Surveys of rural and remote areas not to be used for residential, commercial or industrial purposes with parcels larger than 10 hectares.

Easements and Right of Way Surveys: The class of survey required for Easement or Right of Way surveys would depend upon the type of land over which the survey traverses. In all probability, an Easement or Right of Way survey could contain a number of areas that require a different survey classification. To determine if accuracy specifications have been met for these surveys where adjacent marks have been determined using different classes of survey, compare to the lowest class of survey.

It is apparent from these accuracy requirements that various survey techniques must be used in order that the full range of survey classifications can be implemented in a cost-effective manner. Other factors to consider include: network design; instrumentation; field procedures and monumentation; office reduction procedures; calibration and result validation procedures. Aside from these accuracy aspects, there are a number of other factors, primarily environmental, that must also be considered when choosing an appropriate survey methodology. For example, multipath effects caused by extraneous reflections from nearby metallic objects within a high-rise commercial area make the use of GPS for Class A surveys inappropriate.

All survey plans must indicate the class of survey that has been performed. Plans must also list the coordinates of all new witness marks placed as part of the survey. The coordinates must be in terms of the NAD83(CSRS) datum. Digital Traverse sheets of all surveys that have used traditional survey techniques are to be submitted to the regulator that requires integration. Traverse sheets must tabulate adjusted coordinates in terms of the origin and datum of the survey. The method of adjustment of all traverses must be shown. If a Least Squares adjustment is used, then the coordinate report should tabulate the adjusted coordinates in terms of the origin and datum and the relative horizontal error ellipses for each station. If a GPS survey has been undertaken, then the coordinate report submitted with the survey must list the baseline observations and parameters included in the adjustment, the absolute and standardised residuals, the variance factor, and the relative error ellipse/ellipsoid information.

A Report is to be submitted with each land survey, signed by the Surveyor responsible for the work. If the survey is undertaken using a theodolite, then the report should include:

- The purpose for which the survey was conducted;
- How the origin of bearings and coordinates were derived;
- Details of old marks found, and the reasons for relying on them or not;
- Details of old marks searched for but not found;
- Details of relevant marks not searched for and reasons why not;
- Definition methodology;
- Details of any conflicts with existing survey and title records, and how each was resolved;
- Details of any orientation and scale adjustments and the reason for them;
- Details of equipment and methods used in the survey, including methods used to ensure compliance with the prescribed standards of accuracy;
- Details of methods used to determine natural boundaries;
- An explanation of any material difference between boundaries and occupation;
- Details of any existing Right of Way or Easement that is to be surrendered or released; and
- References to correspondence with the Director of Surveys, or the Registrar of Titles, or any person acting under their authority, relating to the survey.

For GPS based surveys, the Survey Report should also include:

- A discussion of the observation plan, equipment used, satellite constellation status, and observables recorded;

- A description of the data processing performed, which should also note the software used (version number, etc.), the techniques employed (including ambiguity resolution), and error modelling;
- A summary and detailed analysis of the minimally constrained and the constrained Least Squares network adjustments performed;
- The identification of any data or baseline solutions excluded from the network with an explanation as to why it was rejected;

- Details of the transformation model used, or derived, and any GPS/Geoid height information that was determined; and

Data files, including observations, computed baselines, network adjustments, and coordinates, if not submitted with the project report, should be archived for inspection and future analysis, as should all field sheets and other reconnaissance information.

4. Specifications:

Most surveyors within municipalities can do land surveys in urban/suburban settings using Pseudo Kinematic GPS techniques and can achieve the accuracy requirements specified for those areas (Alberta, 2000). If multipath effects are minimal for Class B surveys, then it is likely that the same GPS techniques can be employed if appropriate observing techniques for each baseline are implemented. This is dependent on such things as baseline length, number of visible satellites, PDOP range, and whether modern or conventional static GPS techniques are to be used. If environmental conditions dictate that GPS is not appropriate, traditional survey techniques can then be employed.

Class A surveys will likely continue to be undertaken using a theodolite and EDM. Aside from the high probability of multipath effects degrading the GPS positions obtained, baselines are also going to be considerably less than that which is acceptable if accuracy is to be maintained (noise factor). Class D and E surveys can be undertaken using a combination of traditional static GPS surveying and Pseudo Kinematic techniques. Static survey techniques can be used to provide an adequate number of witness marks at an appropriate accuracy within the survey (based on the witness mark criteria in Table 2). The remainder of the survey can then be performed using Pseudo Kinematic techniques. This combination of techniques will allow the survey system requirements to be met at a cost that will not be prohibitive to a client.

To assist with the connection of a survey to the NAD83(CSRS) datum, the Canadian Active Control Network (CACS) should be used if feasible. The 3D NAD83(CSRS) network within which CACS sits has a positional accuracy of about 0.01 m. For survey projects using GPS phase measurements and requiring the highest precision, introducing CACS precise ephemerides in the data processing will reduce all orbit related errors in GPS baseline determinations to less than 0.1 ppm. These errors can reach 3 parts per million or more when ephemerides broadcast by the satellites are used. Furthermore, by including observational data from the CACS in the data processing, a direct tie to the national spatial reference frame is established.

Scale and orientation are provided by the precise ephemerides without occupation of any control points, thereby increasing the efficiency of field operations and data processing. Depending on the GPS software, further advantages may be realized by using precise ephemerides, such as improved cycle slip detection and fixing capability, enhanced carrier phase ambiguity resolution, and better a posteriori error estimates. Recent tests, combining CACS data and precise ephemerides, has shown static positioning precision at the cm level in each of the three-dimensional components for distances up to 600 km when appropriate software and adequate procedures are applied.

5. When should integration be required?

In many jurisdictions, such as on Canada Lands in Western Canada, a majority of the surveys are performed using a total station, and not using GPS. In other jurisdictions the use of dual frequency GPS is not common. In still other jurisdictions, such as within the urban canyons of Calgary, GPS use of any kind is rare. Thus, the requirement for integrated land surveys should depend upon the proximity to NAD83(CSRS) control monuments, and upon whether GPS or a theodolite is used.

Given these two relationships, integration of a land survey to NAD83(CSRS) should be mandatory in creating any parcel to which attaches a legal interest (Crown land, fee simple land, or an easement):

- if GPS is not being used, and the parcel is within five (5) km of a CSRS control monument, or

- if GPS is being used, provided that any post-processing so as to allow the coordinate boundary information to enhance the spatial database is done by the regulatory agency.

The only exception would occur if no more than two new parcels are being created by the survey, both of which lie completely within a larger parcel which had previously been integrated to the CSRS, and the total area of new parcels is less than one ha..

Part V - Conclusion

Considering that rigorous data on the financial costs and benefits of integrating land surveys is scarce, much weight should be given to the opinions of those surveyors with practical experience of the benefits of integration, which opinions seem to be generally very positive. This is not to say that there is not some self-contradiction in the attitude of surveyors towards integration. Many like it, some don't like it, and others merely tolerate it. Possibly they like working in an area where the cadastre is already integrated, but don't like having to do the integration themselves. Perhaps the benefits of integration (to surveyors) remain unappreciated until the integration starts to pay off in second- and later-generation surveys, or where a non-integrated local cadastre has not (yet) deteriorated. Then surveyors in an area where integration is new and/or was introduced pro-actively (before the local cadastre deteriorated) might be grudging in their acceptance.

In most cases, surveyors integrate new parcels when encouraged or required to do so by an approving (municipal) or regulatory (federal or provincial) body. However, many surveyors also readily admitted that integration is a true boon to them, and some have built in-house GIS or cadastral mapping systems based upon integrated data. Owing to GPS use not being widespread throughout the surveying community, integration is much better accepted where dense control monuments continue to exist. However, there is a trend to more sophisticated use of GPS by the private sector, and to sparser and active control monumentation by the public sector.

Although integration is a public good, the economic value of the good is difficult to calculate. Moreover, high-accuracy and rigorous integration should not be justified on the basis of improving the response times of emergency vehicles. To do so requires a spurious argument, one that abuses a “motherhood” issue. Only a callous fiend would not care if ambulances, police, and fire-trucks arrive too late. However, getting them to the scene of an emergency without delay seems to require only a 10 m level of accuracy and (perhaps more importantly) a correct topology of the road system in whatever electronic guidance is used. Reverting to grid-style road systems in urban and suburban areas, as opposed to the currently popular mazes of cul-de-sacs, would probably go a long way towards solving such navigation problems.

The issue of maintenance of dense control comes up repeatedly in this economic context. One commentator suggested a cost of $3,500 to $5,000 to install and survey new HPN monuments, ignoring the cost of getting the data into the network. And yet, control monuments are largely immune to everyday accidents, and hardly an attractive target for vandals. The damage, then, appears to be mostly caused by construction equipment. There are two effective responses. The first is to assign the costs of replacing the monument to the developer responsible for its destruction. The second is to place the monuments more thoughtfully, out of harm’s way. Perhaps this problem of maintenance is a function of attitude, whereby the destruction of control monuments in the development process is taken lightly, and therefore happens frequently.

The principal purpose of dense control is to allow integration, and the difficulty in accounting for the benefits of integration is acknowledged. The benefits are broad and diffuse (like those of all kinds of mapping and accounting) and allow for intelligent land use and infrastructure planning. There are implications that dense control really *is* a good idea: In some jurisdictions, land surveyors establish local control nets on their own initiative. In other jurisdictions, surveyors using GPS establish local base stations, which are little more than dense control points (well, denser than an HPN) which are positioned for GPS use instead of for lines-of-sight within a terrestrial network. These examples from the private sector suggest that dense control is no example of government profligacy.

At the same time, many levels of government are scrutinizing all regulations that impede development, and will look askance at any requirements for integration that require the private sector to absorb significantly higher operating or capital costs (through field time, office time, and equipment purchases). Thus provincial and federal regulators have an important role to play in assisting municipal and regional governments in upgrading reference systems to NAD83(CSRS). Integration will only truly flourish when cadastral (and thematic) data-sets are upgraded concurrently with upgrades to the geo-referencing system. Provincial and federal regulators also have a role to play in enhancing the national infrastructure that is required to regulate, archive and disseminate (perhaps through some sort of licensing arrangement) integrated information. The level of involvement will be a function of the extent to which municipalities (many of which now use integrated data) have the resources to monitor and ensure compliance.

References

1. Acknowledgments:

Critiques of the August 2001 penultimate report, which comments were generally integrated: Geoff Banham, Ron Berg, Jim Dobbin, Gordon Garrard, Roger Gaudet, Jacques Grondin, Leo-Guy Leblanc, Brian Maloney, Chuck Salmon, Peter Sullivan, Larry Zimmerman.

Critiques of the September 2000 draft report, which provided invaluable direction: Ron Berg, Serge Bernard, Jim Dobbin, Paul Egesborg, Roger Gaudet, Mike Michaud, Gord Olsson, Chuck Salmon, Peter Sullivan, Larry Zimmerman.

Insights from written and oral interviews with over 35 experts, representing private-sector land surveyors, and federal, provincial and municipal survey regulators and mappers.

Research assistance: Mike Inniss, Andrew Hunter, Khaleel Khan, JC Lanciault, Mark Merner.

2. Bibliography:

Alberta. Director of Surveys & Technical Services Branch. Investigation of s.43 subdivisions. 2000.

Alberta. Director of Surveys & Technical Services Branch. Standards, Specifications and Guidelines for Establishment and Maintenance of Alberta Survey Control using GPS. 2000.

Alberta. Director of Surveys & Technical Services Branch. Website. (August 28th, 2000) www.gov.ab.ca/env/land/dos/

Alberta Land Surveyors Association (ALSA). Report of the Study Group on the Coordinate Based Cadastre. February, 1999.

ALSA. Report of Proceedings of the Proceedings of the Eighty-ninth Annual General Meeting. 1998.

ALSA. Manual of Standard Practice. 1999.

Association of Manitoba Land Surveyors. Manual of Good Practice. 1999.

Association of Newfoundland Land Surveyors. Association ByLaws.

Association of New Brunswick land Surveyors (ANBLS). Discussion paper for the New Brunswick Geographic Information Corporation. June 1996.

ANBLS. Standards Manual for New Brunswick Land Surveyors. 1998.

Angus-Leppan, P.E. & P.A. Report on the Cost Benefit Analysis of Establishing a Cadastral Coordinate System in the A.C.T. October, 1990.

Association of Ontario Land Surveyors. Report of the Integrated Surveys Task Force.1999.

Ballantyne, Khan & Conyers. Coordinates in Context: Technical, Social and Legal Implications of using Coordinates-only to Define Boundaries. Final Report to the Canadian Council on Geomatics. 1999.

Ballantyne, Khan, Conyers & Merner. Technical, Social and Legal Implications of Defining Boundaries Using Coordinates-Only: An Abridgement of the CCOG Report. *Geomatica.* 54(1). 2000.

Banham. Accuracy Requirements for Section 43 Surveys – Draft Report. Geodetic Control Section, Director of Surveys Branch, Alberta. 2000.

Brash, Gosling & Grenkie. Report on Integrated control network for cadastral surveying. April, 2001.

British Columbia. Office of the Surveyor General. Website (August 28th, 2000) www.elp.gov.bc.ca/clrs/surveyor_general

Canadian Association of Petroleum Producers. Coordinate integrity in the Third Millenium – User Handbook. May 1999.

City of Calgary. Request for Proposal. Design, installation, observations and adjustments for the Calgary High Precision Control Network. July 31,1996.

Craymer. Integration of Local Surveys into the Canadian Spatial Reference System. Presented at the Public Works & Government Services Canada – Survey Contracting & CACS Seminar.1998.

Dobbin. Regulation of the Land Surveying Profession in Canada. MSc Thesis, Graduate Academic Unit of Geodesy & Geomatics Engineering, University of New Brunswick. January, 1999.

ESRI. National Integrated Lands System, Parcel Consortium, and ESRI Form Partnership. ESRI ARC News. Summer, 1999.

Geodetic Survey Division. Accuracy Standards for Positioning Version 1.0. Geomatics Canada. 1996.

Geodetic Survey Division Website. (August 28th, 2000)
www.geod.nrcan.gc.ca/index_English_text_based.html

Gillis, Hamilton, Gaudet, Ramsay, Seely, Blackie, Flemming, Carlin, Bernard & LeBlanc. The Selection and implementation of a new Spatial Reference System for Canada's Maritime Provinces. *Geomatica.* 54(1). 2000.

Grant. A Dynamic Datum for a Dynamic Cadastre. Presented at the New Zealand Australia Cadastral Conference. Wellington. 1995.

Hamilton & Doig. Report of the Task Force on Control Surveys in the Maritime Provinces. Report to the Steering Committee. March 1993.

Hoogsteden & Hannah. Of capital importance: Assessing the value of the New Zealand geodetic datum. Final report to Land Information New Zealand. March 1999.

Kassam, Hlasny, Warman & Lloyd. BCACSm – The modernization of British Columbia's Municipal Geo-Spatial Reference System. Paper presented to the GIS 2001 Conference. Vancouver. February 2001.

Legal Surveys Division. Integrated surveys on Canada Lands. Canada Centre for Surveying. September 1989.

LINZ, 2000. "Cadastral Survey Guidelines", version 3.
www.linz.govt.nz/services/surveysystem/cadastral/csg_index.html
linz.govt.nz/services/landonline/fact_sheet_3.html

Nova Scotia Land Use Committee. A Coordinate Referencing Policy for the Province of Nova Scotia. Control Survey Task Group, Land Information Systems Advisory Committee. 1995.

Nova Scotia Land Information Services Website (August 28th, 2000)
www.gov.ns.ca/homa/land/

Ontario. Task Force on Integration of Surveys in Ontario. Report to the Surveys, Mapping and Remote Sensing Branch, Ministry of Natural Resources. March 1990.

Pawson. Article in: *The Canadian Surveyor.* 18(4). September 1964.

Pinch. Commentary on GPS in land surveying. *Geomatica*. 54(2). 2000.

Quebec Cadastral Reform. http://www.mrn.gouv.qc.ca/cadastre/info/en2.asp

Roberge. La representation graphique des lots dans le cadastre du Quebec. Geomatique. 25(3). October 1998.

SaskGeomatics Website. (August 28th, 2000)
http://www.sgd.gov.sk.ca

Williamson. A Modern Cadastre for New South Wales. Unisurv S-23, 1983. Report from School of Surveying, The University of New South Wales. 1983.

Zwart. A Re-Evaluation of the Concept of Integrated Survey Systems. MSc Thesis, Department of Surveying Engineering, University of New Brunswick. 1980.

3. Legislation:

Canada Lands Surveys Act
Manual of Instructions for the Survey of Canada Lands, 3rd Edition

British Columbia	Land Survey Act General Survey Instructions Regulation Integrated Survey Area Regulations

Alberta Surveys Act

Saskatchewan Land Surveys Act

Manitoba Surveys Act

Ontario	Surveys Act Surveyors Act

Newfoundland Land Surveyors Act

New Brunswick	Surveys Act Integrated Surveys Area Regulation – Surveys Act Directors of Surveys Instructions
Nova Scotia	Land Surveyors Act Land Surveyors Regulations
Prince Edward Island	Land Survey Act Land Survey Act, 1971 (never proclaimed)

Appendix 1:

Integration of Surveys
Questionnaire for Stakeholders

1) Name
Position/Title
Type of Work

3) What is the *requirement* for integration in your jurisdiction?

4) What is the *practice* of integration in your jurisdiction?

5) What are the standards / precision that must be met?
- actual
- preferred by you

6) What is *your* definition of Integration?

7) What is your opinion of integration?
a) examples of benefits (actual, not expected)
b) examples of costs (actual, not expected)

8) What is your opinion of the Integrated Survey Area model?

9) Comment on whether the following purposes are - achievable? - achieved? through the integration of surveys.
- for retracement / re-establishment?
- to prevent disputes?
- to facilitate mapping?
- any other purposes?

10) What are your concerns relative to integration?

11) Who are the key players (organizations, professions) that should be involved in developing standards for integration?

Appendix 2 – Views of CCOG members

Members of the Canadian Council on Geomatics individually identified various features of integrated land surveys, which have been aggregated here according to benefits, costs, preferences, and stakeholders:

Benefits:

- Accurate cadastral reference maps for those municipalities which took the initiative to effectively integrate survey control and legal survey plans in their map compilation process.
- The only benefits might have been in the areas of cadastral mapping and GIS in Ontario. Other benefits have not been realized, owing to non-homogeneous, monumented geodetic control networks that, for the most part, are not maintained. To the extent that the points are geo-referenced, they can be used in a GIS. Retracement of boundaries using these values is problematic given the work required to re-establish a network that was questionable in the first place.
- There are sufficient connections between geodetic and cadastral surveys to produce digital cadastral maps in Saskatchewan. These connections have helped to resolve hundreds of problems with township plans or legal surveys where the information shown on the plan did not match the monument positions - or where surveys of different vintage disagree. The connections have also helped to determine the correct width of road allowances along correction lines (where the ties across the correction line were not documented on township plans or field notes). The connections have also resolved problems with 20 or so geodetic points where the point was misidentified as a reference point rather than the geodetic monument.
- Because all plans registered in Alberta are used in maintaining the provincial cadastral mapping, there is a very accurate mapping base. Consider the situation where a particular block exists in the cadastral base map. Although the relative measurements within the block are accurate, there is a systematic error throughout the cadastral base map so that the entire block actually is 30 cm farther north on the ground than the cadastral mapping indicates. A surveyor performs a survey and submits a plan that includes the block in question. If the survey plan is not integrated, then the cadastral mapper cannot eliminate this error in the base map. If the plan is contained in its entirety within the limits of the block, then the mapper will not even be alerted to the 30 cm error. If a tie is made to a point on the other side of the street to the north, then the mapper may realize that there is a 30 cm error between opposite sides of the street, but is the error in the existing cadastral map, or is the error in the new survey? This can only be resolved with extensive calculations, additional fieldwork, or a combination of both. However, if the new survey plan is integrated, then the cadastral mapper instantly knows that the new plan is located in the correct location and that the existing cadastral base map must be adjusted to accommodate the coordinate values of the new map.

- Surveyors use integrated surveys to help in re-establishing boundaries, for blunder detection, and to establish new boundary corners on township surveys in unsurveyed territory.
- Data sets can be maintained on Canada Lands where Cadastral Fabric information is integrated with other parcel based information. It is imperative that as much of the survey information as possible is integrated so as to be able to provide a useful GIS. In those areas where there was no systematic integration, the survey information is integrated at the local (Indian Reserve, Park) level. For example, exterior boundaries of existing Canada Lands have been geo-referenced in one form or another (GPS ties, Mapping and scaling boundaries using existing mapping etc.…)
- As the manager of the boundary component of the Property Rights Infrastructure on Canada Lands, LSD is able to manage the Canada Lands Surveys System more efficiently and effectively as its client base is shifting to the various First Nations and Aboriginal groups across the country.
- Integrated survey information on a homogeneous platform enables the consolidation and dissemination of survey information to and from various sources. This saves the effort required to re-observe the data. Often the published value of particular evidence is the only available evidence of its observed location.
- The New Brunswick digital property map database is updated daily, with registered plans of surveys that contain coordinate values for all parcel corners. Most plans are coordinated to the survey framework.
- A province-wide database of land survey plans; for example, as maintained by the ANBLS and which is accessible to members.

Costs:

- The cost of installing a control monument ranges from $50 to $500. To contract a horizontal and vertical control survey among 15 monuments costs $300 - $500 per monument. To do a single replacement conventionally costs $1200 to $2000.
- Estimates of the cost of integrating a residential subdivision in an urban area varied: one half hour of field crew time; 10-20 % of the cost of the entire survey; fixed cost of $1,000.
- A private sector company was contracted to place a 2nd order horizontal and 3rd order vertical control network in Iqaluit (then Frobisher Bay). Some monuments had disappeared before the crew left the site.
- Geo-referencing Indian Reserves from existing mapping cost $50,000. Validating some of the information and providing additional information on the exterior boundaries cost $25,000. The accuracy of this geo-referencing exercise is very limited because of its dependence on the accuracy of existing mapping in the area.
- In eastern Canada, the cost of geo-referencing the exterior boundaries of Indian Reserves by tying in local boundary monuments to control using GPS was $500,000 over five years. The estimated cost of geo-referencing Indian Reserves in British Columbia is $650,000.
- If the tie in was poor on the original survey, and on re-survey the monuments are found to be undisturbed, then lawyers have difficulty dealing with different

coordinates for the same property corner if coordinates were quoted in the deed. This problem stems mostly from misconceptions in the legal community on such concepts as achievable accuracies in land surveying, and the hierarchy of boundary evidence in the resolution of boundary uncertainties.

- There is the potential for unsophisticated land surveyors to re-monument the same corner using coordinates from different control monuments. The result is a series of boundary monuments within a small radius.
- There still exists some resistance to this within the profession. In Alberta there was an attempt in 1998 to expand the integration radius from 1 to 2 km. This was defeated because not all surveys are being done with GPS yet, even in remote areas. For example, in Northern Alberta there is so much existing traverse information from oil field activity that many surveys are done using conventional total station methods. Many of the comments came from the most progressive survey companies that use GPS extensively who felt that making extra connections to control did increase their costs.

Preferred requirements and standards:

- A general survey instruction that better reflects the use of GPS for cadastral surveys and the integration of cadastral surveys.
- If the coordinate values are to be used as evidence for retracement surveys, then a high standard is dictated. This high standard can only be justified if the control framework is reliable, easy and inexpensive to access, and sustainable. If positioning technology could get to the point where it can quickly deliver one cm accuracy within the CSRS in real time, we should insist on this standard. It is short sighted to set standards based solely on today's technology – given the fast pace of its evolution. Using lesser standards will eventually lessen the usefulness of the derived data. Rural areas have a habit of becoming urban areas. Values could be up-graded as required. This assumes much administration to keep track of the differing standards for all the "integrated" points as well as the redundancy of having to go back, retrace the point and re-integrate to the higher standard. If integrated surveys are to be the interim step towards the use of coordinates in place of monuments, then higher standard is necessary.
- Monuments in an integrated survey area should be coordinated to an accuracy of 2cm. relative to the control framework. The preferred accuracy indicator would be the 95% confidence ellipses from a statistically valid least square adjustment.
- Expand the accuracy standards to include the use of error ellipses, primarily for GPS surveys and eventually eliminate the closure concept. Extend the distance to two km to increase the number of integrated surveys. Eventually integrate all surveys regardless of distance from survey control markers.
- Under CLS requirements, surveyors must use dual frequency GPS receivers, which under normal conditions yield satisfactory results. Prevent the use of hand held receivers.
- Require mandatory geo-referencing of all surveys on Canada Lands to NAD 83 CSRS. To facilitate integration with existing surveys, all surveys should also be

connected to closest existing cadastral fabric. The existing one km requirement should be extended.

.

Who should develop standards?

- Standards and regulations for integration of British Columbia provincial cadastral surveys should be developed by the Surveyor General in consultation with interested parties.
- The surveying profession has to take the lead in deriving the standards and in convincing all of the stakeholders as to the long term benefits of integration to those standards.
- Regulatory agencies (e.g. provincial legal survey, geodetic survey, and mapping branches), surveying profession, municipalities and planning authorities.
- Depends on the model of integration adopted. If integration is at the level of precision required by land surveyors, they should obviously be involved. In such a case, land surveyors and government can partner in developing the standards. Those levels of accuracy will suffice for all other users. If a different level of precision is to be adopted (i.e., mapping) then others need to be involved.
- For Alberta, the Alberta Land Surveyors' Association, the Director of Surveys Branch, and the cities of Edmonton and Calgary should be involved..
- All stakeholders should be involved, i.e regulatory agencies including land administrators and the survey industry and profession. Landowners should not be much involved because integration is sought principally for land management issues.
- Standards should be set by individuals in the surveying profession who have Understand the benefits and limitations of CSRS.
- Prior to making integration mandatory a thorough consultative process with the ACLS and industry is needed. The technology is changing so rapidly that perhaps the industry is ready to have mandatory integration for all surveys, however it is important to get their buy-in.