Ministry of Forests
Procedures and Guidelines for Operational Forest Resource Survey and Mapping Using Global Positioning System Technology

Prepared by
Ministry of Forests
GPS Steering Committee
for the
Resources Inventory Committee

February 2001

Version 3.0

Published by the
Resources Inventory Committee

National Library of Canada Cataloguing in Publication Data

Main entry under title:

The Ministry of Forests standards and guidelines for operational forest resource survey and mapping using Global Positioning System technology [computer file]

Previous ed. entitled: Operational field procedures for forest resource survey and mapping using Global Positioning System technology.
Available on the Internet.
Issued also in printed format on demand.

ISBN 0-7726-4472-1

1. Forest surveys - British Columbia – Methodology – Handbooks, manuals, etc. 2. Global Positioning System. I. British Columbia. Ministry of Forests. Resources Inventory Branch. II. Resources Inventory Committee (Canada) III. Title: Operational field procedures for forest resource survey and mapping using Global Positioning System technology.

SD387.S86M56 2001 333.75’11’0723 C2001-960035-6

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Preface

The Global Positioning System (GPS) is an important survey and mapping tool to supplement and, in many cases, replace conventional techniques because it is more accurate, efficient and cost effective. Ministry of Forests (MoF) has developed and implemented standards and procedures since early 1990's to ensure the quality of GPS survey work and the consistency and compatibility of GPS survey data in the forest inventory database. These standards and procedures were incorporated into a document named "*BC Standards, Specifications and Guidelines for Resources Surveys Using GPS Technology (Release 2)*" by the Public Sector GPS Users Committee (PSGUC), which was endorsed by the Resources Inventory Committee (RIC) as recommendations to all resource sectors in BC.

As the GPS technology evolves and forest application requirements change over the last several years, it was evident that there is an urgent need to revise and update the MoF document named "*Operational Field Procedures for Forest Resource Survey and Mapping Using GPS Technology, Version 2.0*" that was published in 1998. Resources Inventory Branch, under the recommendation of the MoF GPS Steering Committee, which has a mandate to oversee strategy and direction regarding use of GPS within the ministry, has completed a project to revise the document to improve its uses in forest operations.

There are several major changes included in this document (Version 3.0) which will supersede all its early versions previously published by MoF. For example, the format and structure of the document is changed so that it could be used as a stand-alone manual specifically designed to better serve and support the need of MoF operational programs. One major change is expansion of the quality assurance section to support MoF GPS contract administration and management. A new guideline to deal with the traversing and navigation for forest field sampling programs using uncorrected GPS and real-time DGPS is also included.

Any comments, suggestions, and/or recommendations are welcomed and can be sent to the MoF GPS Steering Committee (home page: http://www.for.gov.bc.ca/isb/gps).

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Acknowledgments

Funding of the Resources Inventory Committee work, including the preparation of this document, is provided by the Corporate Resource Inventory Initiative (CRII) and by Forest Renewal BC (FRBC). Preliminary work of the Resources Inventory Committee was funded by the Canada-British Columbia Partnership Agreement of Forest Resource Development FRDA II.

The Resources Inventory Committee consists of representatives from various ministries and agencies of the Canadian and the British Columbia governments as well as from First Nations peoples. RIC objectives are to develop a common set of standards and procedures for the provincial resources inventories, as recommended by the Forest Resources Commission in its report "The Future of our Forests".

For further information about the Resources Inventory Committee and its various Task Forces, please access the Resources Inventory Committee Website at: http://www.for.gov.bc.ca/ric.

It is acknowledged that this document is developed with a collective effort made by the project team with contributions from MoF branches, regions and districts, MoF licensees, and GPS consultants.

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List of Acronyms

ATV	all terrain vehicle
BC	British Columbia
BC ACS	British Columbia Active Control System
BCLS	British Columbia Land Surveyor
CAD	computer-aided design
CDMS	Cadastral Data Base Management System
CLS	Canada Land Surveyor
DGPS	differential GPS
DOP	dilution of precision
FRGIS	Forest Resource GIS, Resources Inventory Branch, Ministry of Forests
GIS	Geographic Information System
GPS	Global Positioning System
GDBC	Geographic Data BC, Ministry of Environment, Lands and Parks
GSRU	Geo-Spatial Reference Unit, Geographic Data BC, Ministry of Environment, Lands and Parks
IGDS	Interactive Graphic Design System
INCOSADA	Integrated Corporate Spatial and Attribute Database, Ministry of Forests
ITQ	Invitation To Quote
LIM	Land Information Manager
MoELP	Ministry of Environment, Lands and Parks
MoF	Ministry of Forests
NAD27	North American Datum of 1927
NAD83	North American Datum of 1983
PoC	point of commencement

PoT	point of termination
PSGUC	Public Sector GPS Users Committee
QC/QA	quality control/quality assurance
RFP	Request For Proposal
RIB	Resources Inventory Branch, Ministry of Forests
RIC	Resources Inventory Committee
RINEX	Receiver INdependent EXchange
RTEB	Resource Tenure and Engineering Branch, Ministry of Forests
SNR	signal to noise ratio
TRIM	Terrain Resource Integrated Mapping, Ministry of Environment, Lands and Parks
UTM	Universal Transverse Mercator
WGS84	World Geodetic System 1984

Table of Contents

CHAPTER 1 INTRODUCTION

This document is intended to provide standards and guidelines for the Ministry of Forests staff, their contractors and licensees involved in either contract or in-house GPS work, such as GPS project planning, contract preparation and administration, quality control and quality assurance, GPS data processing and management, and GPS data integration. It is a stand-alone and working document which shall supersede all its early versions previously published by MoF and shall be applied to all MoF GPS survey and mapping projects and contracts that require a mapping accuracy of 10 meters horizontal at the 95% confidence level.

This document has been developed based on the several documents previously published, such as:

- ***GPS Data Capture Schedule***, by the Ministry of Forests, 1992 and updated in 1995;
- ***MoF Standard Procedures for Georeferencing Field Sample Plots Using GPS Technology***, by the Ministry of Forests, December 29, 1995;
- ***Operational Field Procedures for Forest Resource Survey and Mapping Using Global Positioning System Technology (Version 2.0)***, by the Ministry of Forests, March 31, 1998; and
- ***BC Standards, Specifications and Guidelines for Resources Surveys Using GPS Technology (Release 2)***, by the Public Sector GPS Users Committee (endorsed by the Resources Inventory Committee), March 31, 1997, amended in 1999.

It is expected that the reader is familiar with the basic concepts and techniques of GPS. To accommodate various uses of GPS and needs of different programs, this document has been structured in such a way that readers can use it as a whole (e.g. for training purposes) or take individual chapters for particular projects. Below is a quick reference of individual chapters:

- Chapter 2 provides a collection of standards and procedures that could be taken as contract specifications (or with minimal modifications) applied to MoF GPS contracts and projects;
- Chapter 3 provides interpretations and further details about these standards and procedures specified in Chapter 2;
- Chapter 4 describes additional detail about GPS contract administration and as well guidelines for MoF in-house project management; and
- Chapter 5 gives detail quality assurance procedures and guidelines.

There is increasing interest in use of GPS for navigation in some forest resource operations such as Vegetation Resources Inventory field sampling, and Growth and Yield Permanent sampling. A document of procedures and guidelines for GPS navigation is also included in Appendix 1. Other background and technical information about GPS such as specific QA

procedures using Trimble and Microstation, reference documents, and registration on the MoF contractor eligibility list, can be found at the MoF GPS Steering Committee home page: http://www.for.gov.bc.ca/isb/gps.

CHAPTER 2 STANDARDS AND PROCEDURES

The following is a collection of standards and procedures that is normally attached, as a Schedule, to a standard Ministry of Forests GPS contract. Readers can reference Chapter 3 for detailed explanations and interpretation of these standards and procedures. Some of the terms in this chapter may be changed or modified according to specific contract requirements (see Chapter 4).

2.1 Interpretation

2.1.1 For interpreting the terms of references in this Schedule, the Contractor shall consult the following document: ***Ministry of Forests Procedures and Guidelines for Operational Forest Resource Survey and Mapping Using Global Positioning System, Version 3.0, February, 2001***.

2.1.2 This schedule shall be used in all forest resource survey and mapping operations using Global Positioning System (GPS) and mixed conventional/GPS methods undertaken by or for the British Columbia Ministry of Forests (the Ministry).

2.1.3 The Contractor is defined as a corporation, firm or individual who provides works or services to the Ministry under the terms and conditions specified in the contract. The Ministry Representative is defined as the Ministry of Forests' representative who has the authority for issuing and managing the contract and for receiving the items or services delivered by the Contractor.

2.1.4 The target accuracy for this Schedule is 10 metres in the horizontal dimension at a 95% confidence level.

2.2 Contractor and Equipment Qualification

2.2.1 The Contractor shall register on the MoF eligibility list of GPS contractors for the current field season prior to the contract awards.

2.2.2 The Contractor shall demonstrate or prove to the Ministry Representative's satisfaction that the Contractor has capacity, such as hardware/firmware and software, trained and experienced GPS personnel, and past project performance, capable of meeting the accuracy requirements of the contract.

2.3 Feature Interpretation and Mapping

2.3.1 The Ministry Representative shall conduct a pre-work conference with the Contractor to define what the significant features are and how the features are interpreted and mapped. The nature and quality of work expected in the contract and the quality assurance methods shall be clearly defined.

2.3.2 If Cadastral (legal) boundaries are required to be surveyed, the Contractor shall consult with the Ministry Representative for specific instructions. Legal boundaries and lot corners must be clearly identified before the survey.

Cadastral survey boundaries in British Columbia may only be definitively and legally located on the ground by a British Columbia Land Surveyor (BCLS) or, in specific cases, a Canada Lands Surveyor (CLS). Non-qualified persons may misinterpret boundary marks when occupying legal survey monuments. This could result in legal action being taken against the contractor or the Ministry if damages occur on adjacent lands.

2.3.3 All surveys shall include sufficient map ties as defined by the Ministry Representative to enable accurate geo-positioning and to provide reliability checks. These map ties shall be clearly marked on the ground. Examples of these map ties are: creek junctions, road intersections, or other significant land point features. Discrepancies between GPS field surveys and maps shall be identified and resolved using these map ties.

2.3.4 All significant deflections required to delineate line and polygon features at the required accuracy shall be mapped. This includes significant vertical breaks if elevations are required.

2.3.5 Semi-permanent reference markers shall be established at the survey stations according to the standards defined by the Ministry.

2.3.6 Other significant features, such as permanent sample plots (established by the Vegetation Resources Inventory, Inventory Audit, and Growth and Yield programs), Point of Commencement (PoC), and Point of Termination (PoT), shall also be marked to the standards specified by the Ministry Representative.

2.3.7 Static point features shall be collected at all semi-permanent reference markers.

2.3.8 Each semi-permanent reference marker at the survey station (including the significant features) shall show the date of installation, block number, type of the station (i.e. PoC, PoT, or survey stations, etc.), and a unique number. The locations of these reference markers shall be included on the map submitted by the Contractor.

2.4 Field GPS Data Collection

2.4.1 The field GPS receiver shall be set to position or record observations to a minimum of four satellites.

2.4.2 The minimum satellite elevation angle/mask for the field GPS receiver is 15 degrees above the horizon.

2.4.3 Dilution of Precision (DOP) values for both static (point) surveys and dynamic (line traversing) surveys shall not exceed the following values:

Horizontal DOP:	5	(preferred whenever possible)
Position DOP:	8	(only if HDOP is not available)
General DOP:	10	(only if neither HDOP or PDOP are available)
Vertical DOP:	5	(only when elevations are required)

2.4.4 For each standard static point feature, the minimum occupation time shall be 30 seconds and at least 15 individual position fixes shall be collected during that period. For each high significance point feature as defined by the Ministry Representative, the minimum occupation time shall be 150 seconds and at least 50 individual position fixes shall be collected during that period.

2.4.5 For line and polygon features surveyed in a dynamic mode, individual position fixes shall be collected no more than 25 metres apart, and the majority of fixes shall be no more than 5 meters apart.

2.4.6 For line and polygon features surveyed in a station to station mode, individual position fixes shall be collected no more than 50 metres apart, and the standard static point feature shall be used at each station.

2.4.7 For point offsets, the field operator shall record the following particulars in their field notes: slope distance; vertical angle; and magnetic or astronomic azimuth from the GPS antenna to the feature.

2.4.8 The maximum distances for point offsets shall be 25 metres, or 50 metres if offset observations are measured forward and backward. Offset bearings shall be accurate to at least 2 degrees, and offset distances to at least 1 metre. If the slope is over 10 percent and the offset distance is more than 10 meters, a slope correction with slope measurements accurate to 5 percent or 3 degrees shall be applied. Magnetic Declination shall be applied to all compass observations before computing offset coordinates.

2.4.9 For line offsets, the field operator shall note the horizontal distance and the direction (left or right) perpendicular to the direction of travel. The maximum line offset is 5 metres. Line offset distances shall be checked and adjusted periodically.

2.4.10 Supplementary traverses by conventional means shall follow rules:

- the supplemental traverse shall begin and end on standard GPS static points that shall be observed at each station;
- the supplemental traverse shall be accurate to 2 degrees in direction and 1 meter in distance; and
- if the slope is over 10 percent and the slope distance is more than 10 metres, a slope correction with slope measurements accurate to 5 percent or 3 degrees shall be applied.

2.5 GPS Data Processing and Mapping

2.5.1 All GPS positions shall be corrected by standard differential GPS methods. The same set of GPS satellites shall be used at the GPS Reference Station as at the field receiver for all corrected positions.

2.5.2 All GPS Reference Stations shall be validated by Geographic Data BC, Ministry of Environment, Land and Parks. If other reference stations are used, they shall be approved by the Ministry Representative before the field work starts.

2.5.3 The separation distance between the GPS reference station and field receivers shall be less than 500 kilometres.

2.5.4 Real-time corrections shall use a DGPS Service approved by the Ministry Representative.

2.5.5 All directions from compass observations shall be corrected for magnetic declination before offset or traverse computations.

2.5.6 Supplemental traverses shall have disclosures of no more than 1 percent (1:100) of the total traverse distance plus 5 meters. Supplemental traverses shall be adjusted (balanced) using a standard compass rule adjustment between the beginning and end points.

2.5.7 If any data (including hardcopy) is supplied on a datum other than NAD83, the methods used to transform the data shall be explicitly described in the project report and approved by the Ministry Representative. If NAD27 coordinates are required, the Canadian National Transformation (the latest version) shall be used for the conversion.

2.5.8 If elevations are required, ellipsoidal heights shall be converted to orthometric heights using the Canadian Geoid model (the latest version).

2.5.9 Any discrepancies between the GPS survey and existing mapping shall be resolved to the satisfaction of the Ministry Representative.

2.6 Deliverables and Data Management

2.6.1 The Contractor shall submit the final map products in a standard format and medium specified by the Ministry Representative.

2.6.2 If the final map product is required in the IGDS format, the Contractor shall ensure that it adheres to the Ministry IGDS standards.

2.6.3 Digital field data in specific format for full or portion of the project work shall be submitted. These data includes: GPS reference station data in proprietary or RINEX format; raw GPS field data in the receiver manufactory proprietary format; and corrected GPS data in the receiver manufactory proprietary format.

2.6.4 The Ministry Representative may require additional data in a specified format for quality assurance purposes.

2.6.5 Hardcopy maps at a specified scale shall conform to the Ministry of Forests Cartographic Standards and shall be submitted for each survey feature as defined by the Ministry Representative.

2.6.6 The Contractor shall submit a project report that includes the key information specified by the Ministry Representative.

2.6.7 All the data files created in the completion of the contract work under this schedule are the property of the Ministry and access to these files shall be made available to the Ministry.

2.6.8 The Ministry shall be responsible, or designate this responsibility to the Contractor, for archive, storage or destruction of the data files in accordance with government standards.

2.6.9 The Contractor shall store a back-up copy of all the materials and survey data in the formats outlined in 2.6.3 and 2.6.4 for at least two years, or as defined by the Ministry Representative, following the completion of the contract.

2.6.10 The Contractor shall inform the Ministry Representative before destruction of the materials and data created from the contract.

2.7 Quality Assurance and Audit

2.7.1 The Contractor shall be responsible for overall quality control of all components of a GPS survey. The Ministry Representative is responsible for quality assurance including audit of a GPS survey.

2.7.2 All submitted work shall be subject to Ministry of Forest's quality assurance and audit.

2.7.3 For GPS point features, at least 95 % of the individual position fixes shall be within 10 metres (horizontal linear measure) of the true location of the point. If statistical methods are used to reject outliers, 2 standard deviations shall be used for the minimum level of significance.

2.7.4 For GPS traverses done in the dynamic linear mode, at least 95 % of the individual GPS position fixes shall be within 10 metres (horizontal measurement perpendicular to the line) from the true position of the line.

2.7.5 The Contractor shall rectify at his or her own expenses all deficiencies identified by quality inspection/checks and audits.

2.8 Technological/Personnel Change

2.8.1 If there are any changes in the Contractor's GPS system components (i.e. hardware, firmware, software, methodology) or personnel during the period of the contract, the Contractor shall consult with the Ministry Representative who may choose continue discontinue, or modify the contract, whatever he/she deems appropriate.

2.8.2 The Contractor and the Ministry Representative shall ensure that the most current version of the MoF standards and procedures is used.

CHAPTER 3 GUIDELINES

This chapter provides detail guidelines, interpretation, or explanations of some important terms as defined in Chapter 2 (referred by the corresponding section numbers).

2.1.1 For interpreting the terms of references in this Schedule, the Contractor shall consult the following document: Ministry of Forests Procedures and Guidelines for Operational Forest Resource Survey and Mapping Using Global Positioning System, Version 3.0, February 2001.

This document supersedes all the documents previously published by the Ministry of Forests as listed in Chapter 1: Introduction.

2.1.2 This schedule shall be used in all forest resource surveys and mapping using Global Positioning System (GPS) and mixed conventional/GPS methods undertaken within the British Columbia Ministry of Forests (the Ministry).

Standards and procedures presented in Chapter 2 must be applied to all forest resource survey and mapping using Global Positioning System (GPS) technology done by, for, or requiring the approval of, the Ministry of Forests (hereinafter called the ministry) in the province of British Columbia. Examples of such operations are: pre-harvesting cut block traversing for Exhibit A mapping, silviculture treatment block layout survey and mapping, post-harvesting cut block mapping for inventory update, forest service road survey and mapping, and plot positioning for Vegetation Resources Inventory field sampling.

2.1.3 The Contractor is defined as a corporation, firm or individual who provides works or services to the Ministry under the terms and conditions specified in the contract. The Ministry Representative is defined as the Ministry of Forests' representative who has the authority for issuing and managing the contract and for receiving the items or services delivered by the Contractor.

In some cases, the Contractor could be a group of individuals, a firm, or any organizations performing GPS surveys within the scope outlined in 2.1.2. The Contractor could also be the ministry personnel for work done in-house. A single GPS contractor would be a self-contained unit which collects, processes and produces final data (coordinates or maps) using GPS, perhaps in conjunction with other surveying technologies. Examples of a GPS contractor are: a GPS contractor's firm/company, a licensee's field operation, a consortium of smaller firms, or a ministry district office. The Ministry Representative could be a contract administrator, contract officer, or contract manager.

2.1.4 The target accuracy for this Schedule is 10 metres in the horizontal dimension at a 95% confidence level.

GPS techniques can provide accuracy from a few millimetres to a hundred metres. For the purposes of this document, the target mapping accuracy is defined as 10

metres horizontal and 15 metres vertical, at the 95% confidence level. All standards and procedures in this document are designed to meet or, in most cases, exceed this target accuracy. This target accuracy will meet the requirements for most MoF survey and mapping operations such as vegetation resources inventory, silviculture, timber harvesting, range and recreation, and other related forest operations that involve mapping forest features. These features include points such as sample plots, reference markers, and map ties; lines such as roads, streams, and fences; and areas such as cut-blocks, burn or infested areas, and vegetation polygons.

2.2.1 The Contractor shall register on the MoF eligibility list of GPS contractors for the current field season prior to the contract awards.

2.2.2 The Contractor shall demonstrate or prove to the Ministry Representative's satisfaction that the Contractor has capacity, such as hardware/firmware and software, trained and experienced GPS personnel, and past project performance, capable of meeting the accuracy requirements of the contract.

All GPS contractors wishing to work under a MoF contract must register on the eligibility list of GPS contractors established and administrated by the Resources Inventory Branch, Ministry of Forests. The purpose of the eligibility list is to ensure that contractors are capable of conducting and delivering quality GPS data products/services, which are important for maintaining reliable and accurate inventory databases in support of many MoF operations and programs. This list allows MoF staff a quick access to eligible GPS firms capable of performing GPS surveys as defined in Section 2.1.2.

To register on the eligibility list of MoF GPS contractors, (1) contractors submit a response to the Request for Expressions of Interests issued (see Appendix 2) by MoF; (2) contractors submit all supporting materials required; and (3) the MoF evaluation team evaluate all the responses and establish a list of eligible contractors for the current field year. The evaluation is done based on the pre-established criteria for evaluating contractor's hardware/software, GPS personnel training and education, and past projects and experience. Detailed information about the registration can be found at http://www.for.gov.bc.ca/isb/gps/pre-qualification.

Adequately GPS trained and experienced GPS personnel is a key for ensuring good quality of GPS data products and services. It is required that GPS personnel in a GPS firm must demonstrate or prove their qualifications by having recognized GPS courses, education and experience.

2.3.1 The Ministry Representative shall conduct a pre-work conference with the Contractor to define what the significant features are and how the features are interpreted and mapped. The nature and quality of work expected in the contract and the quality assurance methods shall be clearly defined.

There are two sources of error in GPS data for forest surveys: errors generated from interpretation and mapping of the features, and errors inherent in the GPS positions. Under normal observing conditions, errors generated from interpretation and mapping are potentially the largest source of error. How well the features, especially the

boundary of the features, can be defined and identified on the ground is extremely important to the final quality of a survey.

GPS surveys are performed for many operational reasons. It is neither practical nor desirable to define all operational requirements in this document. It is, therefore, left to the ministry representatives in the branches, regions, or districts to define how features are interpreted and mapped. This section provides guidelines on how operational requirements can be met while minimizing the error caused by misinterpretation and mapping of the features.

The ministry representative will conduct a pre-work conference with the contractors. The Ministry Representative must define the features to be surveyed, boundaries of the features, guidelines for interpretation of special features (or under special circumstances), deliverables and services, quality requirements, payment schedule, and other relevant contract issues. There must be no doubt or confusion as to the nature and quantity of work expected. Methods of quality assurance and audit, and the project deliverables must also be clarified. Natural and man-made features such as cut-block boundaries or burnt areas are often difficult to define accurately on the ground. To minimize boundary determination errors, it is essential that the GPS contractor know exactly how features are to be interpreted. The ministry representative must explicitly define the boundary of the features according to the operational requirements. The following boundary definitions are recommended:

- **Pre-harvest boundary traversing:** pre-established ribbons or painted marks on tree trunks (e.g. one metre from the painted trees toward the inside of the polygon)
- **Post-harvest boundary traversing:** tree crown drip-line (line connecting perimeters of tree crowns that are projected to the ground), or line of disturbance if there are no standing trees
- **Silviculture treatment:** stump line (line connecting all identifiable tree stumps within the cut-blocks), or line of disturbance
- **Burnt, selective logging, and windfall areas:** crown drip-line (defined above) if affected trees are standing, and stump line if affected trees are fallen or removed
- **Forest service roads and recreation trials:** centre line (or a constant offset line for safety reasons)
- **Other boundary lines:** roadside lines, stream lines, man-made feature lines (.e.g. fences and power lines), edges of a lake, river, marshy area, swamps etc.

2.3.2 If Cadastral (legal) boundaries are required to be surveyed, the Contractor shall consult with the Ministry Representative for specific instructions. Legal boundaries and lot corners must be clearly identified before the survey.

For the purpose of this document, legal boundaries can be defined as cadastral boundaries or tenure boundaries.

(a) Cadastral Boundary

Cadastral boundaries include the boundaries of parcels of land, the boundaries of interests in land such as rights of way, easements and covenants and the boundaries of administrative areas.

Parcels of land include District Lots, Sections, Blocks, Parcels and Lots. A right of way is a defined corridor or parcel of land over which a party other than the owner has specified rights. Administrative areas include parks, ecological reserves and lands, such as Indian Reserves, over which the administration and control has been transferred to a government agency.

Cadastral boundaries are established by one of two methods. They are established by ground survey where the corners and boundaries are physically marked on the ground or they are established by a description such as a metes and bounds description or an Explanatory plan.

(b) Tenure Boundary

Examples of tenure boundaries are Forest Tenure boundaries. These include the boundaries of Tree Farm Licences, Woodlot Licences, Timber Sale Licences, and all Cutting Permits and Road Permits where they do not coincide with a cadastral boundary.

Determining Cadastral Boundaries

Only a British Columbia Land Surveyor (BCLS) may:

- Establish the location of a cadastral boundary on the ground.
- Demarcate on the ground cadastral boundaries established by metes and bounds descriptions
- Re-establish missing or damaged parcel corners that were originally established by ground survey.
- Provide a legal opinion on the location of a cadastral boundary.

The location of a cadastral boundary must be determined on the ground, where the limit of a forest tenure boundary lies within 150 metres of the cadastral boundary as depicted by Crown Land Registry Services spatial data.

The contractor and the ministry representative must consult a BCLS if all or part of a project is defined by cadastral boundaries where the condition of the survey evidence or the method in which the cadastral boundaries were defined is in doubt. The BCLS will advise if establishment or reestablishment of certain boundaries is recommended or required.

A survey technician may find and use survey evidence so long as the survey technician has adequate previous experience or training by a land surveyor in locating legal survey evidence. A survey technician may use such survey evidence to relate the location of features relative to a line intended by the technician to represent the cadastral boundary and to locate and mark a licensee's cut line to the limits described below. It should be noted that a line intended to represent a cadastral boundary that is determined by a technician is not necessarily the true cadastral boundary. Cadastral

survey boundaries may only be legally located on the ground by a British Columbia Land Surveyor. Misinterpretation of cadastral boundaries may result in (and has resulted in) legal action being taken against the contractor and/or the ministry where damage occurs on adjacent parcels.

Where the limits of a previously surveyed cadastral boundary must be determined and all original posts are found in place, the licensee may cut to a line located and marked by a technician and situated no closer than 20 metres from the intended cadastral boundary. The licensee may cut to the boundary where the cadastral boundary is certified by a British Columbia Land Surveyor.

Where the true limits of a previously surveyed cadastral boundary must be determined and all original posts are not found in place, the licensee may cut to a line calculated, located and marked by a technician and situated no closer than 30 metres from the intended cadastral boundary. The licensee may cut to the boundary where the cadastral boundary is defined by a British Columbia Land Surveyor.

Where a BCLS is engaged, he or she must submit a sketch plan showing the certified cadastral boundaries, primary evidence found, ancillary evidence found, posts replaced and horizontal distances along the boundary including distances to semi-permanent markers. The BCLS must submit a posting plan or post renewal form to the Office of the Surveyor General when cadastral monuments are upgraded or re-established.

Questions regarding requirements for surveys of cadastral boundaries should be directed toward the Office of the Surveyor General of the Crown Land Registry Services of the Ministry of Environment, Lands and Parks. Plans and notes of district lots, sections and blocks are available from the Office of the Surveyor General.

Determining Tenure Boundaries

Forest tenure boundaries established by a metes-and-bounds description that refers to watershed boundaries, which are not contiguous to a cadastral boundary, may be determined by a qualified technician.

If the forest tenure watershed boundary is indeterminate (lacking definition, i.e. marshy or hummocky ground) the contractor and ministry representative should consult a BCLS regarding the establishment of that boundary.

Where Forest Tenure boundaries follow watershed boundaries, which are not contiguous with cadastral boundaries, but are contiguous to another adjacent forest tenure, they may be established by a qualified technician along a series of tangents that are mutually agreed upon by all stakeholders.

Questions and further information regarding Forest Tenure boundaries should be directed toward the Resources Tenures and Engineering Branch (Special Projects and Boundaries Section), Ministry of Forests.

2.3.3 ***All surveys shall include sufficient map ties as defined by the Ministry Representative to enable accurate geo-positioning and to provide reliability checks.***

These map ties shall be clearly marked on the ground. Examples of these map ties are: creek junctions, road intersections, or other significant land point features. Discrepancies between GPS field surveys and maps shall be identified and resolved using these map ties.

Map ties are features that are identifiable on the map (e.g. forest cover or TRIM map sheet or other base maps such as orthophoto) and have GPS positions captured. They are used to help resolve discrepancies of the GPS surveys with the map base (often due to inaccurate or out-of-date mapping), and to provide permanent ground-based evidence for tenure purposes. Examples of map ties could be: creek junctions, road intersections, or existing survey monuments. For geo-referencing purposes, traversing a winding section of road can be valuable.

Sufficient map ties must be established and surveyed for each GPS operation whenever possible. The ministry representative must specify the number or tie points required, and should, if possible, specify where and what these tie points should be. Factors to consider in identifying tie points are: the reliability and compatibility (with GPS) of the local map base; the cost of establishing the ties, stability and distinctness of the ties, and other requirements such as for permanent ground ties.

If ties to geodetic or cadastral monuments are required, the ministry representative must ensure that there is no confusion about their location. If possible, they should be found, marked and shown to the contractor during the pre-work conference.

2.3.5 Semi-permanent reference markers shall be established at the survey stations according to the standards defined by the Ministry.

Semi-permanent reference markers are established to provide boundary evidence and tie points, and to create consistency in case of a re-survey or audit. These must be established according to existing ministry guidelines or requirements (e.g. the Forest Practices Code guidebooks for forest road engineering and boundary marking). The interval and type of markers must be stated in the contract. For example, the Resources Tenure and Engineering Branch specifically requires that the reference markers be established at least every 100 metres at the survey stations along the line being surveyed. Point of Commencement (PoC) shall be tied to survey station 1 of the line or polygon line to be surveyed. These standards were established standards for block layout traverses that are used for tenure definition (Exhibit “A”). These apply to conventional surveys as well as GPS surveys. They include:

(1) The semi-permanent reference markers must be established at least every 100 metres along the line being surveyed;

(2) PoC (Point of Commencement) must be taken from the nearest:

- surveyed corner of a Lot, Block, Sublot, Section, Legal Subdivision or Indian Reserve;
- existing geodetic control monument triangulation stations (horizontal ties); or

- confluence of named creeks and rivers (when a confluence is used right or left bank must be specified, e.g. PoC 100 m north and 20 m east of the confluence of Ken Creek on the left bank thereof and the Anita River on the right bank thereof).

If it is not possible to find suitable PoC in a reasonable distance from the feature being surveyed, a "tie point" must be established at the junction of the main and the access road. This point must be tied to station 1 of the polygon (i.e. the first measurement point along the survey block);

(3) PoC must be tied to station 1 on the block being surveyed; and

(4) The stations must be marked with unique sequential number, the first station starting with number one.

Semi-permanent reference markers must be established at high-significance-point features.

All reference markers must be captured as static point features, and offsets applied if necessary.

2.3.7 Static point features shall be collected at all semi-permanent reference markers.

All reference markers must be captured as static point features (i.e. minimum 30 seconds and 15 position fixes for the semi-reference markers, and minimum 150 seconds and 50 position fixes for the high-significance-point features). Offsets should be applied if necessary.

2.3.8 Each semi-permanent reference marker at the survey station (including the significant features) shall show the date of installation, block number, type of the station (i.e. PoC, PoT, or survey stations, etc.), and a unique number. The locations of these reference markers shall be included on the map submitted by the Contractor.

Required markings will vary according to operational requirements, but at a minimum, they must give the date of installation, survey identification (e.g. block number) and a unique identifier (e.g. a sequential number). Examples of marker types include metal tags, pin flags, survey hubs, etc. The location, type and identifier of these markers must be included on the digital files and hardcopy map submitted by the contractor.

2.4.1 The field GPS receiver shall be set to position or record observations to a minimum of four satellites.

A GPS receiver actually observes pseudoranges(distances) to four or more satellites and computes a position fix from those pseudoranges. All GIS-capable GPS receivers will also store attributes along with computed position fix. The basic GPS data from which a map is made is then a collection of positions, and attributes. All positions must be derived from simultaneous observations to at least four satellites above 15 degrees elevation (also known as "3D" mode).

Some receivers allow users to select a different mode (often called "2D") where only three satellites are used and the elevation is taken from some other source. GPS receivers alone can not provide elevations accurate enough to yield the 10 metre horizontal accuracy in these modes.

Some advanced integrated systems (e.g. tightly integrated inertial sensors) may provide the required accuracy, but these must be independently and rigorously tested before being approved. Such systems are beyond the scope of this document.

2.4.3 Dilution of Precision (DOP) values for both static (point) surveys and dynamic (line traversing) surveys shall not exceed the following values:

Horizontal DOP:	**5**	**(preferred whenever possible)**
Position DOP:	**8**	**(only if HDOP is not available)**
General DOP:	**10**	**(only if neither HDOP or PDOP are available)**
Vertical DOP:	**5**	**(only when elevations are required)**

The Dilution of Precision (DOP) is a simple multiplier relating the accuracy of the pseudorange measurements (2.4.1.) to the accuracy of the computed position. The lower the DOP, the more accurate the computed position. DOP can be stated in many ways: affecting the horizontal accuracy (HDOP), vertical accuracy (VDOP), three dimensional accuracy (PDOP), even the accuracy of the time plus position (GDOP). For most forest surveys, it is the horizontal accuracy (HDOP) which is important. Although a PDOP (3D) greater than 8 may be acceptable, an HDOP (horizontal) greater than 5 is never acceptable.

Most receivers automatically monitor PDOP or GDOP, and warn the operator when they exceed set limits. Sometimes when PDOP or GDOP exceeds the limits, the HDOP is acceptable (i.e. less than 5), since it is the vertical precision which is poor. An HDOP greater than 5 is never acceptable, but a PDOP greater than 8 or a GDOP greater than 10 is, as long as the HDOP is less than 5.

For rare instances where the elevation is important (e.g. road profiles), the VDOP must be less than 5.

The receiver should be set to log DOP values for audit and troubleshooting purposes. Where possible, HDOP thresholds should be used. If the receiver cannot set HDOP thresholds, PDOP or GDOP (in that order) should be used. If accurate GPS elevations are required, VDOP limits must be followed as well.

2.4.4 For each standard static point feature, the minimum occupation time shall be 30 seconds and at least 15 individual position fixes shall be collected during that period. For each high significance point feature as defined by the Ministry Representative, the minimum occupation time shall be 150 seconds and at least 50 individual position fixes shall be collected during that period.

Point features are usually surveyed as static point features where the GPS antenna is over the point for a period of time (at least 30 seconds). During that time, a number of individual GPS position fixes (at least 15) are collected and later averaged to give a

single location for the point. For a standard point feature, 30 seconds and 15 fixes are required.

Often under forest canopy, 30 seconds of occupation does not mean that there are 30 seconds of actual data (position fixes), due to signal blockage. Since the minimum time is set at 30 seconds, it is not reasonable to also insist that there must be 30 position fixes. However, in order that reliable averages and statistical information can be computed, at least 15 fixes are required. For example, a point feature with 42 seconds occupation and 17 position fixes over that time would be acceptable. Point features with less than either 30 seconds or 15 fixes (e.g. 30 seconds, 12 fixes) are not acceptable.

A high significance point feature might be called for one where high reliability is absolutely essential – for example a single point feature defining a plot centre, or points such as survey posts which may have some legal significance. Normally, points along a line feature (such as reference markers along a block boundary) should be considered "standard" point features, especially since the line data usually adds much information which will help competent data processors ensure that point features are correct.

2.4.5 For line and polygon features surveyed in a dynamic mode, individual position fixes shall be collected no more than 25 metres apart, and the majority of fixes shall be no more than 5 meters apart.

Line features are usually surveyed in a dynamic mode where the operator moves along the line and the receiver logs position fixes at set intervals. These fixes are later connected to form a single line – if areas are required, the line(s) bounding the area are connected to form a closed polygon.

The accuracy of a line feature depends on many things such as the nature of the forest cover and the quality of the receiver being used. All things being equal, however, the accuracy of the final line is mostly related to how many position fixes are available.

The maximum distance between individual fixes is 25 metres. However, the vast majority of the fixes should be much closer together – at least every five metres and preferably closer.

2.4.6 For line and polygon features surveyed in a station to station mode, individual position fixes shall be collected no more than 50 metres apart, and the standard static point feature shall be used at each station.

Sometimes it is not possible or desirable to use the dynamic mode described above – for example very steep lines where the operator cannot walk directly up or down the slope. In this case, the station to station mode may be used where the line is defined by a series of standard point features connected by straight lines. The maximum distance between the points is 50 metres.

The station-to-station mode is usually not as accurate as the dynamic mode because, under forest cover, static points are usually less accurate than dynamic lines. A single

station may have a significant error, which means that the line has an error in that area. For that reason, the dynamic mode is preferred for line features.

2.4.7 For point offsets, the field operator shall record the following particulars in their field notes: slope distance; vertical angle; and magnetic or astronomic azimuth from the GPS antenna to the feature.

2.4.8 The maximum distances for point offsets shall be 25 metres, or 50 metres if offset observations are measured forward and backward. Offset bearings shall be accurate to at least 2 degrees, and offset distances to at least 1 metre. If the slope is over 10 percent and the offset distance is more than 10 meters, a slope correction with slope measurements accurate to 5 percent or 3 degrees shall be applied. Magnetic Declination shall be applied to all compass observations before computing offset coordinates.

It is sometimes desirable to use offsets from the GPS antenna to the feature being located, for accuracy, safety and efficiency. For example, offsets can be made to a reference marker on a tree trunk while the GPS antenna is in the open. Similarly, the edge of a road can be picked up on an active logging road to avoid the centre line. However, offsets can be confusing and may lead to errors if they are not managed correctly. To avoid confusion, coordinates for both GPS and offset positions must be provided in the deliverables as described in the IGDS file specification. All offset details must be provided in the project report or submitted field notes.

With point offsets, the limiting factor on accuracy is usually the accuracy of the magnetic compass. Even though some digital compasses claim accuracy of better than one degree, the magnetic declination is only known to one or two degrees – local attraction can add many degrees of error.

For point offsets, the field operator must note the slope distance, vertical angle and the magnetic or astronomic (true) azimuth from the GPS antenna to the feature. The declination adopted for the survey and the methods of determining distance and direction should be noted in the project report. Declination must be applied to all compass observations before computing offset coordinates. The maximum distance for point offsets is 25 metres or 50 metres if the offset measurements are made forward and backward. All offsets must be accurate to 1 metre in distance and 2 degrees in bearing, or better.

Constant line offsets can be used in cases where it is easy to keep the antenna at a constant distance from the feature to be surveyed – for example a road centreline survey. The maximum distance is 5 metres, since the operator must constantly estimate the distance.

2.4.10 Supplementary traverses by conventional means shall follow rules:

- ***the supplemental traverse shall begin and end on standard GPS static points that shall be observed at each station;***
- ***the supplemental traverse shall be accurate to 2 degrees in direction and 1 meter in distance; and***

- ***if the slope is over 10 percent and the slope distance is more than 10 metres, a slope correction with slope measurements accurate to 5 percent or 3 degrees shall be applied.***

In cases where GPS techniques might not work well due to blockage or poor satellite coverage, conventional traverse methods may be used to supplement the GPS. Another instance where supplementary traverses might be common is in amendments to the field layout where it may not be economical to use GPS for a very short traverse.

The traverse should begin and end at a GPS point feature, which should be marked with ribbon or some other means. The same rules for measurement apply as for point offsets above

Methods and equipment used for the supplementary traverse must meet the Standards and accuracy specifications. The closure requirements between the GPS start and end points are 1:100, plus five metres. For example, a supplementary traverse of 300 metres must close to eight metres (3m + 5m). The misclosure is balanced according to standard ministry procedures (compass rule adjustment).

Conventional traverse observations may be kept on paper field notes or electronically, but must be submitted as part of the deliverables. The traversed portion should, if possible, be a different colour or line style on the map or digital file.

The start and end points of the conventional traverse must be surveyed as high-significance-point features and marked with special code (e.g. S1 PoC, ,meaning "Supplementary traverse 1 Point of Commencement"). Also, they could be marked as semi-permanent markers in some cases so that any discrepancies can be identified and resolved.

2.5.1 All GPS positions shall be corrected by standard differential GPS methods. The same set of GPS satellites shall be used at the GPS Reference Station as at the field receiver for all corrected positions.

To meet the specifications and target accuracy of this document, all GPS surveys must use some form of differential GPS corrections. Differential GPS uses data from a reference station fixed over a known point to correct data collected at a roving field receiver.

The accuracy of uncorrected GPS positions has increased greatly since Selective Availability (a deliberate error) was turned off. However, the error is still often more than 10 metres, especially in northern latitudes. Observing under forest canopy adds still more error to the positions. The only way to confidently achieve 10 metre accuracy is to perform differential correction.

Many manufacturers use filtering or smoothing methods, attempting to obtain better accuracy or reliability in corrected positions. It is important that these schemes be properly set-up and that any settings are noted in the project report so that the data can

be verified in case of an audit. This applies for all processing, interpretation and generalization of GPS data.

2.5.2 All GPS Reference Stations shall be validated by Geographic Data BC, Ministry of Environment, Land and Parks. If other reference stations are used, they shall be approved by the Ministry Representative before the field work starts.

Reference stations must be validated by the Geo-Spatial Reference Unit, (GSRU) of Geographic Data BC in MoELP (see the list at: http://www.elp.gov.bc.ca/gdbc/gsn/Validations/base_val.htm). The closest practical reference station should be used and the maximum distance to the reference station is 500 km.

There is an extensive network of suitable permanent reference stations in British Columbia and adjacent provinces and US. These are operated by agencies such as Geological Survey of Canada, Coast Guard (Canada and US), US Geodetic Survey, USDA Forest Service Base Stations, and others. Most of these reference stations are more than accurate enough for forestry surveys under these standards, and they often provide public and free access.

Temporary reference stations may also be established for a variety of reasons, such as improved relative accuracy, real time differential GPS and data accessibility in remote situations. The ministry representative must approve reference stations which are not on the GDBC's approved list before they are used.

2.5.5 All directions from compass observations shall be corrected for magnetic declination before offset or traverse computations.

Whether for point offsets or supplemental traverses, directions must be corrected for magnetic declination before any computations. Some compasses allow operators to apply the correction in the field, and some GPS receivers will accept magnetic bearings and apply the correction using an internal magnetic model.

If computations are done on the mapping plane (usually UTM), grid convergence must also be applied. Most GPS programs will automatically account for this, but few traverse programs or mapping packages will – they will assume grid bearings if they are using grid coordinates. The difference can be almost 3 degrees in BC, causing an error of 5% in the traverse.

Grid convergence can be obtained from topographic maps, or through the simple formula $\Delta\lambda \sin\phi$, where $\Delta\lambda$ is the difference (in degrees) between the user's longitude and the UTM central meridian and ϕ is the user's latitude.

2.5.6 Supplemental traverses shall have disclosures of no more than 1 percent (1:100) of the total traverse distance plus 5 meters. Supplemental traverses shall be adjusted (balanced) using a standard compass rule adjustment between the beginning and end points.

The closure requirement for supplemental traverses is 1/100 (1%) plus 5 metres. The

extra 5 metres is allowed because each of the GPS points could be out by a few metres, and even the most accurate traverse measurements might not close to the 1% error standard for conventional traverses. Note that for longer traverses (over 500m), this error becomes less than the 1% relative error.

Any disclosures should be balanced throughout the traverse, using the standard compass rule method.

2.5.9 Any discrepancies between the GPS survey and existing mapping shall be resolved to the satisfaction of the Ministry Representative.

Often there are discrepancies between a GPS survey and existing map base, largely attributed the errors historically existing in the old maps. How to deal with these discrepancies must be clearly defined to the satisfaction of the Ministry Representative prior to the GPS survey.

2.6.1 The Contractor shall submit the final map products in a standard format and medium specified by the Ministry Representative.

The following figure gives a "flowchart" representation of the typical processing and mapping steps in a GPS project (post-processed or real-time), and where during the process the deliverables are created.

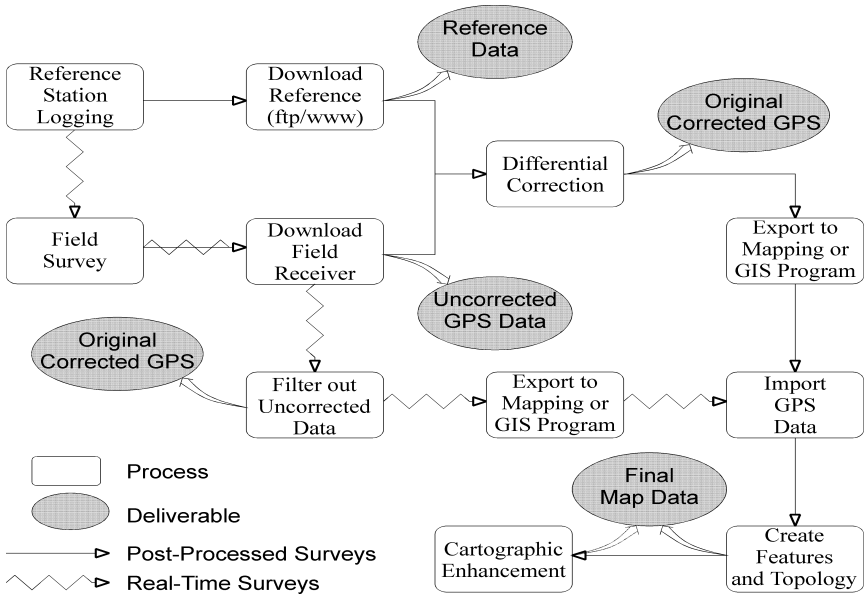

Figure 1. Typical GPS project flow and deliverables

Except the final map data, other data may not always be required for submission. In any case (either the Ministry or the contractor stores and archives all the GPS data), these data files should be able to be accessible if required for the QA purposes.

The final map data has the geographic features (points, lines, areas) derived from the corrected GPS data. The digital format of the final map file will vary depending on local requirements.

Usually, the final map consists of much more than the features (lines, points, polygons) derived from the GPS survey. There may be base map data, text and notes, map legend and surround information, title blocks, and so on. The map may follow certain cartographic conventions (e.g. symbology, level/file structure, etc.). Normally, the format and structure of the final maps are specified in the contract. For example, the following IGDS file format is recommended as a temporary working format which can easily be transferred to the FRGIS of INCOSADA database standards.

- Level 1: All original (unedited) corrected GPS data points
- Level 2: All edited, corrected GPS data points
- Level 3: All polygonal shapes collected as line strings as positional data only, including attribute data for each feature. This level must be vector and polygon clean
- Level 4: All linear features captured as line strings as positional data only, including attribute data for each feature
- Level 5: All point features as positional data only, including associated attribute data foe each feature
- Level 6: Legend and any representational information regarding the positional data provided
- Level 7: Data dictionary table, if required
- Level 9-63: As specified by the Ministry Representative.

2.6.2 If the final map product is required in the IGDS format, the Contractor shall ensure that it adheres to the Ministry IGDS standards.

All digital and hardcopy map products, if required in IGDS (Intergraph Version 8.0 or later, or Microstation Version 5 or later), must adhere to the existing Ministry of Forests FRGIS mapping standards as specified in:

- ***The Preparation and Creation of FRGIS Data Files***, published by the Resources Inventory Branch, September 1998 Revision, or

- ***The INCOSADA database standards*** (*http://www.for.gov.bc.ca/isb/incosada/technical_info/positional_spatial_data_standards/Posstd.htm*).

2.6.3 Digital field data in specific format for full or portion of the project work shall be submitted. The data includes: GPS reference station data in proprietary or RINEX format; raw GPS field data in the receiver manufactory proprietary format; and corrected GPS data in the receiver manufactory proprietary format.

The standard digital deliverables of GPS field data for full or portion (e.g. 10%) of the project work may be required to be submitted to the Ministry Representative for archiving and quality assurance purposes.

Reference Station Data. All the GPS reference station data that are originally downloaded from the receiver on the World Geodetic System 1984 (WGS84) datum must be in the manufacturer's original proprietary format or converted to the RINEX (Receiver INdependent EXchange, v2 or later) digital format.

Uncorrected GPS raw data. All GPS raw (uncorrected) field data that are originally downloaded from the receiver or datalogger on the WGS84 datum must be in the manufacture's original proprietary format. The data must be merged and compressed if possible. There must be no editing done to this file, as it is considered the equivalent of "field notes" for a conventional survey. If there is ever a dispute over some aspect of the survey, these are considered an unaltered record of the field work. Data from field receivers usually has some GIS attribute information and in most cases it is preferable to store field data in the manufacturer's proprietary format.

Original Corrected GPS Data. All original unedited GPS field data after differential correction must be in the manufacturer's proprietary format.

It is not practical nor necessary to request that all above mentioned data/files are submitted. Most MoF offices at the present time only require the final maps as only deliverable of the contract. It is recommended that MoF offices make arrangements (must specify in the contract) with the contractor to archive these files and for the Ministry, if they are not required to be submitted. This is to ensure that the Ministry can retrieve these files when required for resolving disputes or for quality assurance and audit purposes.

2.6.4 The Ministry Representative may require additional data in a specified format for quality assurance purposes.

See Chapter 5 for description of the extended deliverables for quality assurance.

2.6.6 The Contractor shall submit a project report that includes the key information specified by the Ministry Representative.

A project report is required to facilitate quality assurance and data archiving purposes. The following key information is suggested to be included in the project report:

- A brief description of the Contract, for example, the project name; names of Contractor; a Contract ID, the project scope (purpose, target accuracy, location, etc.), and key project/contract dates and milestones,
- A list of key personnel (Contractor and Subcontractors) involved in the project, and a list of hardware and software used on the project,
- A summary of the project including planning, field data collection methods and parameters, data processing methods and parameters, any project problems, anomalies, deviations, etc.
- An explanation of deliverables including formats, naming conventions, compress utilities, etc.).

- A list of any anomalies and solutions used with supporting materials such as field notes.

2.6.7 All the data files created in the completion of the contract work under this schedule are the property of the Ministry and access to these files shall be made available to the Ministry.

All data files and other items submitted are the property of the ministry and access to them by the ministry representative or designate must be made available. All documents submitted to the ministry will be subject to the disclosure provisions of *the Freedom of Information and Protection of Privacy Act*.

2.6.8 The Ministry shall be responsible, or designate this responsibility to the Contractor, for archive, storage or destruction of the data files in accordance with government standards.

Data from GPS projects is often used by different functions or programs within the ministry or among other government agencies. The original data may also be required for quality assurance and audit purposes. Therefore, it is required that all materials submitted must be archived by the ministry for at least five years, or longer if there are legal reasons to do so.

Each Ministry of Forests office must establish a system for managing and archiving GPS data because GPS projects can generate an enormous amount of data.

2.7.2 All submitted work shall be subject to Ministry of Forest's quality assurance and audit.

To facilitate the MoF QA process, the Contract must submit extended digital deliverables in addition to the standard deliverables, as defined in Chapter 5. There are also hardware/software tools and procedures required for the QA. For detail, refer Chapter 5.

It is important that the quality assurance procedures, and the amount and frequency of the checks are well defined and acknowledged by both parties. This should be part of a pre-work conference and attached to the contract.

Since the true position of a line or coordinates of a point cannot be exactly known, they can be approximated by the final map position of the line or the averaged position of the point feature respectively. If a re-survey is performed, then the two surveys are compared using statistical methods.

The ministry representative will overlay the final interpreted polygons, lines or points on the original uncorrected GPS position fixes using the current available mapping software. General data quality such as noise levels, obvious anomalies, bad data points or sections, and mapping errors can be assessed by visually inspecting the final map and the GPS position fixes on a computer screen. A standard deviation of the GPS position fixes from the interpreted features can thus be estimated.

2.7.5 The Contractor shall rectify at his or her own expenses all deficiencies identified by quality inspection/checks and audits.

If problems detected from the detail QA are substantial, the GPS survey could be subject to a detailed audit, determined by the Ministry Representative, and any deficiencies noted by the ministry must be rectified by the contractor at the contractor's expense..

It is up to the Ministry Representative to define what is "substantial", and what is acceptable or not, and what possible actions should be taken based on the value of the contract, importance and risk of the work, and other factors.

2.8.2 The Contractor and the Ministry Representative shall ensure that the most current version of the MoF standards and procedures is used.

For the most current version of this document, refer to the web site:
http://www.for.gov.bc.ca/isb/gps/standard

CHAPTER 4 GPS CONTRACT MANAGEMENT

Contract management includes the selection of contractors, the development and writing of contracts, the monitoring of progress, and acceptance and archiving of the contract deliverables.

4.1 Selection of Contractors

Skills and experience of GPS contractors and consultants vary greatly. In order to facilitate contracting practices and to ensure contractors (and ministry personnel) are competent to perform forestry GPS surveys, a process has been developed and administrated by the Resources Inventory Branch to pre-qualify all GPS contractors who are willing to work on MoF contracts.

Detailed information about procedures and requirements for registering on the MoF eligibility list can be found in the Request for Expressions of Interest shown in Appendix 1.

The MoF GPS Steering Committee web page (*http://www.for.gov.bc.ca/isb/gps/pre-qualification/index.htm*) also provides additional information such as Guidelines and Procedures for the contractor Pre-qualification, Frequently Asked Questions, and the current list of registered eligible GPS contractors.

All the MoF contract administrators and project managers should consult the list of eligible GPS contractors before sending out the RFP or ITQ.

4.2 Contract Terms of Reference

Because the technology is relatively new, contracts with significant GPS components must be consistent in the use of GPS-related terms of reference. It is very important to all parties (especially the GPS contracting industry) that consistent guidelines are in place in all forest districts, regions and branches. Having standard GPS terms of reference helps ensure that requirements on the contract are consistent with other contracts and bid packages, while best accommodating accuracy and data collection requirements of the specific project.

The standards and procedures as specified in Chapter 2 are established as a standard GPS contract terms of reference, applicable to most forest GPS surveys. Although, Chapter 2 was developed based mainly on pre-harvest block traversing operations for data collection for Exhibit A mapping purposes, it is also applicable to any other similar forest applications. For a specific survey contract, these terms of reference should be used with only minor modifications, if necessary, in order to meet specific operational requirements.

Readers should check the following sections of Chapter 2 for a specific forest operation and modify the terms, as they see the fit, to make them appropriate to their applications.

Section #	Comment
2.3.1	Give details about the feature definition, quality of work expected, amount of work to be checked or inspected, quality assurance methods to be used, etc.
2.3.3	Specify number and type of map ties and how these tie points should be established.
2.3.5	Specify the standards for reference marks.
2.3.6	Specify the significant point features.
2.6.1-2.6.5	Specify format and content of the final map data, the extended deliverables, scale and cartographic details and standards for the hardcopy maps.
2.6.9	Specify the length of time that the contractor must store the back-up data.

The price of a GPS contract is an important factor in contract competition. However, the lowest bid is not always the best. MoF staff must understand the implications to contract costs of any requirements for additional work. Such requirements might include the number of map tie points, an increase in target accuracy (say, five metres), the interval for semi-reference marks and special deliverables. The current industry convention used for calculating the contract price should be considered.

Generally, there are two methods of price estimating: (1) person day rate, or (2) total price for the entire contract. The first approach is relatively easy to calculate if the amount of work can be reasonably estimated. The standard industry day rate can range from $400 to $600.

The second approach is based on the type of work involved. This might include such tasks as pre-harvest, post-harvest and existing road surveys. Or it might involve the identification of culverts and bridges by driving conventional vehicles, by using an ATV or snowmobile, or by walking. The price could range from $100/km to $200/km for walking and $30/km to $100/km for survey by vehicle or helicopter. Other factors, such as terrain, travel distance, canopy conditions and any other additional work (painting boundaries, appraisal, etc.) will contribute to the price.

4.3 Accepting Contract Deliverables

The following is a checklist for accepting contract deliverables:

- Verify completeness of the deliverables (all files, reports, field notes, etc. are submitted)
- Verify qualification status of GPS contractor
- Create project directory on a computer workstation
- Upload digital files and verify file formats, naming conventions, etc.
- Review project report
  - Verify data capture parameters (elevation masks, DOP limits, etc.)
  - Note any anomalies for review
- Integrate submitted CAD/GIS files into mapping database
- Review CAD/GIS files
  - Verify position and general configuration of GPS survey
  - Verify that appropriate attribute information is integrated
- Review submitted hardcopy maps for completeness and presentation
- Archive digital files and hardcopy as appropriate

4.4 In-House GPS Project Management Procedures

Ministry staff sometimes do GPS survey work in-house, such as silviculture block surveys; assessment of insect, disease, fire, windbreak, and other damages; and field checking of the contractor ’s work. In these situations, the ministry staff will be responsible for all aspects of the GPS project, have all the qualifications in terms of training and experience, and follow the procedures as outlined in this document. Appendix 3 gives a check list of the procedures for the in-house GPS project management which are followed in a typical GPS survey project by the forest industry.. It should be pointed out that different types of surveys will have different requirements for accuracy, production, type of information required and so on, thus these procedures are very general.

CHAPTER 5 GPS QUALITY ASSURANCE PROCEDURES AND GUIDELINES

5.1 Overview

There are three general levels of QA procedures:

- GPS Data Inspection
- Standard GPS Quality Assurance
- Independent GPS Audit (office or field)

The GPS Data Inspection is a preliminary QA procedure intended to "catch" some very common errors, and does not require any special knowledge of GPS techniques. It is merely a critical look at the deliverables of a GPS project to ensure that there is enough information for further QA if required, and to ensure that the maps "look right". Many times there are large errors because of poor communication between people working on a project (e.g. missing areas or recent amendments not accounted for). The GPS Data Inspection is a very "high-level" procedure that should be done on all of the submitted data.

The Standard GPS Quality Assurance procedure involves visually checking the corrected GPS data used to create maps and other products, using in-house mapping or GIS packages. It does not require specific GPS tools and does not involve handling of the raw GPS data. Personnel performing Standard QA must have some understanding of GPS, especially the nature of the errors common under forest canopy, but detailed knowledge and field experience is not required. Standard QA would normally be carried out by mapping technicians, and only on a small proportion of submitted data. The main benefit of Standard QA is to provide a level of confidence in GPS surveys and to identify problems in the methods or equipment being used.

Independent GPS Audits are an in-depth examination of the GPS data, using GPS tools (processing software or even field equipment for re-surveying). Audits should be done by people with extensive knowledge of GPS, especially GPS under forest cover. Audits must be legally and technically defensible and should be carried out by individuals or organizations acceptable to all parties. Independent GPS Audits would seldom be performed and then only on a very small portion of submitted data. The procedures are expensive (especially if a re-survey is done) and under normal circumstances provide very little benefit over QA done in house. If Standard QA indicates major problems, audits could be performed. As well, if the data is extraordinarily sensitive, Independent GPS Audits may be required.

Because the GPS Data Inspection is a straightforward process and the Independent Audit is technically complicated, procedures for both processes are not discussed further. Below is detail description of the Standard QA procedures. These standard GPS QA procedures are designed so that they can be carried out "in-house" by mapping technicians and others with a basic understanding of what to look for. Much information on the nature of errors, how to recognize these errors, and the impact of these errors on the final product (e.g. areas, lines on a map, etc.) are contained within this chapter.

5.2 Required Resources

The QA procedures have been designed to be done in-house, using existing personnel and computer resources, supplemented by some specific training and tools under development by MoF. This section discusses the in-house resources required, and where to get any supplementary resources.

5.2.1 Personnel Requirements.

Personnel performing the standard GPS QA must have knowledge in forestry practices, mapping procedures, and GPS concepts. Usually, mapping technicians (e.g. LIM personnel in MoF District offices) will perform the QA. In some instances it may be a forestry technician (e.g. an area supervisor), if they can use some basic functions of the in-house mapping software. In either case, the essential skill is an understanding of mapping, and some knowledge of GPS data quality issues, especially pertaining to under canopy GPS.

Generally, personnel performing GPS QA should have the following qualifications:

- skilled at operating in-house mapping software
- familiar with the objectives and requirements of the particular project
- knowledgeable in basic GPS concepts
- understand the nature of errors in GPS positions under forest canopy
- familiar with common problems in GPS surveys.

The standard level of GPS QA is done using the mapping or GIS software (e.g. Microstation, ArcView) which is used for in-house mapping and data management. Personnel performing this QA must be able to use the software and any supplementary software tools which may exist specifically for QA. The QA does not require extensive knowledge and experience with GPS since it is a visual, "common-sense" approach to QA. It does not require any knowledge of the specific GPS software being used.

A two-day GPS QA training session (one day seminar, one day hands-on workshop) has been developed which will provide technicians who can use the mapping software with the requisite background in GPS quality issues and specific QA procedures. Some personnel may have attended more extensive training in GPS (e.g. a 5-day course), although such courses may not have sufficient training in specific QA and data quality issues. The MoF GPS Steering Committee (*www.for.gov.bc.ca/isb/gps/training*) should be consulted for details on training, including delivery of the standard QA training.

5.2.2 Time Requirements

The time required to perform standard QA on GPS projects will of course vary widely. It is very difficult to predict exactly how long QA should take. To provide a rough estimate, a 30 hectare Exhibit "A" sketch with 2-3 exclusions and acceptable data quality (no significant problems), should take approximately one hour. Much of the time required is for setting up, loading data, and so on - there will be efficiencies in doing more units at one time.

As a general "rule of thumb", users could expect to spend approximately 10 minutes per linear kilometre of GPS data for the actual analysis, plus time for data handling and administration.

Some of the factors affecting the time required are:

- complexity of the project
- quality of the data
- knowledge and experience of personnel performing QA
- availability of automated tools for certain tasks

Complex maps and projects can take much longer than simple ones. Often, especially when GPS is only a small component of a large, multi-phase project (such as preparing a cutting permit application), the data has been collected by different field crews, on different days, and in different segments. The final map may include many different lines, points, and polygons on it signifying such things as hand-falling zones, wildlife tree patches, roads and landings, established reference markers, and of course, base mapping data. The more complex the survey, the more care must be taken that all sections have been included, and that none have been mis-interpreted or mis-identified.

The data quality will have a bearing on the time required for the project. If all data, and the contractor's treatment of the data, is of high quality then it will take little time to verify. If, however, the data is marginal with much noise and missing sections, or the contractor has dealt with the errors poorly, then QA will take much longer. Each section will have to be examined carefully and notes taken on the problems. A consultation with the contractor will likely be required.

Organizations should plan for a "learning curve" in applying GPS QA, just as for any other new procedure. However, the procedures are mostly "common-sense" and very little extra training is required. The most important skills are operating the mapping software, which mapping technicians of course already have.

5.2.3 GPS and GIS/Mapping Hardware and Software Requirements

The standard GPS QA does not depend on any specific GPS hardware or software. The procedures are independent of the GPS manufacturer and local MoF offices performing QA do not need these tools for QA. The procedures will be done using whatever software is used in-house for mapping or GIS work.

Although the procedures themselves are very generic, one particular GPS receiver system (Trimble Pathfinder Office) is overwhelmingly (certainly over 90%) used in the province. As well, most MoF offices use Bentley MicroStation as the standard mapping software. For these reasons, software tools and procedures have been developed to most efficiently perform QA on Trimble data using MicroStation. The tools are modular and use intermediate files so that other systems can be adapted to take advantage of them.

These tools will be covered during the MoF-specific GPS QA training sessions. The most current versions and their application are available at the MoF GPS Steering Committee's web site (http://www.for.gov.bc.ca/isb/gps/qa).

5.3 Proportion of Projects Subject to QA

It would be prohibitively expensive and certainly not cost-effective if the standard GPS QA procedures are performed on all, or large portion of, GPS data submitted to the MoF. The

level of application (i.e. what portion of submitted data will be subject to QA) of any QA procedures will of course depend on local issues such as:

- available funds and personnel
- sensitivity and importance of the final product
- local confidence with GPS surveys and particular contractors
- accuracy requirements and equipment used
- intended or projected use of the data

Of the above factors, available funds are perhaps the most likely to affect the level of application of QA procedures. However, funding for QA should be "built-in" to a project as an administrative cost. That is, all projects using GPS methods to any degree should have some provision for the simple QA procedures described in 5.5. More comprehensive QA such as the Independent Audit is required only in special circumstances.

Personnel commitments are likewise something which should be planned for at the outset of a project. In most cases, personnel who perform most of the QA work require some additional knowledge of GPS in general and of the specific QA procedures. More information is available in 5.2.1. above.

The "sensitivity" of the project is a very important factor in considering the level of QA to be applied. Sensitivity is used to describe how "important" the GPS information is and the consequences (i.e. risk) of an error. For example, mapping forest roads for a 1:50,000 scale Forest District recreation map may be less "sensitive" than boundary layout for a cutting permit adjacent to a protected area. The consequences of a 10 metre error on the first are not noticeable whereas for the second can mean trespass charges and adversely affect operations.

The confidence which local MoF personnel have with GPS surveys is a big factor in the level of QA applied. If the office has long experience with GPS surveying without major problems, it is quite likely that there will be a high level of confidence in future GPS work. However, the mere fact that there have been "no problems with GPS" does not mean that there are no problems, only that they have not been noticed before – perhaps because QA has not been performed before. Until some QA is applied to GPS data, any confidence which has been gained locally may be misplaced.

However, some MoF offices and many contractors have been using GPS for five years or more. In some cases, in-house QA (such as re-surveying segments or comparing GPS to aerial photography) has been applied. These offices may choose to apply QA to a smaller proportion of the work than offices that are just beginning to use GPS. Likewise, the work of a contractor who's GPS work is well-known may be subjected to a lower level of QA than that of a contractor just beginning to use GPS.

Although most GPS receivers perform "as advertised" under ideal conditions, accuracy under forest canopy is not so predictable. Equipment which may meet the project accuracy specifications easily in the open may not perform well in real-world, forested conditions. Not all receivers are appropriate for the 10 metre accuracy class (95% confidence) in all conditions. Very few receivers can meet higher accuracy specifications such as 5 metres. Certainly if the accuracy requirement is higher than the standard MoF requirement (10 metres at 95%), QA should be applied at a much higher level.

If one type of equipment has consistently given good results in local forest conditions, that is not by any means a guarantee that other equipment will give comparable results. This is true even of receivers in the same general class and with identical specifications and cost. Surveys done with unfamiliar equipment, even with a known contractor, should be subject to higher levels of QA.

Another factor which must be considered is that data is often used for purposes other than its intended use. With current GIS databases, data often is stored in a "melting pot", where all data is treated the same - there is often little information (sometimes known as "metadata") about where the data came from, and its reliability and accuracy. Time and budget constraints mean that data often is re-used for purposes it was not intended (and may not be appropriate for). For example, data initially intended for a 1:50,000 for the recreation map above may end up being used to later define an administrative boundary – obviously the "sensitivity" of the data has changed, even though the quality of the data has not.

5.4 Data Requirements Specific to QA

For most GPS projects, there are two types of deliverables to be expected: standard deliverables, which would be required for the entire project, and, extended deliverables which would be required only for that portion of the project which will be subject to QA.

The standard deliverables include the raw GPS data files, the reference station files, and final map products as defined by the project. For GPS QA, there are two other deliverables which would be required (although one may be extracted from the standard deliverables):

- original corrected GPS data
- final map features

5.4.1 Original Corrected GPS

The original corrected GPS is considered as what is produced by the GPS software immediately after differential correction. If the survey was corrected in real-time, it is the file directly downloaded from the GPS receiver. No editing or modification should be done to this file as this is the file that most truly represents the overall quality of the GPS data.

The format of this file must be independent of the GPS software being used. Unfortunately, there is no standard format for location data and many GPS systems will only provide certain information in a mapping or GIS format. At a minimum, the original corrected data should be delivered in the mapping or GIS system (e.g. Microstation, Arc/Info) specified for the project. If at all possible, it should contain both the individual GPS position fixes and the derived features (points and lines) generated by the GPS software.

As mentioned in 5.2.3, the vast majority of users are using Trimble Pathfinder Office software. This software will produce a text version of the actual GPS data file, and the MoF has tools to read this file and automate much of the QA tasks outlined in section 5.5. Current instructions on how to create this file, and to use the software tools developed for QA, are available from the MoF GPS Steering Committee (*http://www.for.gov.bc.ca/isb/gps/qa*).

Similarly, the most common mapping software in MoF offices is Microstation, and a standard file structure (levels, colours, etc.) and cell library has been created. This is also available at the above web site.

5.4.2 Final Map Features

The other information essential for GPS QA is the final map features. After differential correction, the GPS positions will still have some residual error. In most instances under forest canopy, these remaining errors must be dealt with by the organisation performing the GPS mapping – this is known as the "interpretation" stage. The features (points, lines, polygons) on the final map are therefore considered to be interpreted from the original corrected GPS data.

The final map features are just these interpreted features, without the cartographic elements typical of a final map. Items such as map surround, base information, title blocks, notations, etc. should be eliminated from the final map features file. Depending on the project, this may be done by a GPS contractor for the portion of the project subject to QA, or perhaps by the in-house persons doing the QA work.

The file format for this would be the same as that for the mapping software being used for the QA. As above, if Microstation is used there is a standard file structure available from the MoF GPS Steering Committee at (*http://www.for.gov.bc.ca/isb/gps/qa*).

5.5 Standard GPS QA Procedures

The following is a generic, "high-level" discussion of the standard GPS Quality Assurance which will be performed on a portion of each project (as discussed in 5.3.). This discussion is independent of a GPS receivers and software, and independent of specific mapping software. For the most common receivers and mapping software used in BC forestry, some very specific procedures and supporting automated utilities have been developed. More information is available at *http://www for.gov.bc.ca/isb/gps/qa*, and through the specific GPS training (information available at the above website).

The basic premise of the standard GPS QA procedures is that the actual corrected GPS files are examined for:

- adherence to the MoF GPS standards
- overall data quality
- "interpretation" of residual GPS errors.

If there are problems noted in any of the above areas, these problems are considered as to their seriousness and how they affect the overall quality (accuracy, completeness, etc.) of the project. Some of these issues are discussed in section 5.6.

5.5.1 Adherence to the MoF GPS Standards

As much as possible, the data under QA is examined for adherence to MoF GPS Standards. Some receiver/software manufacturers include this information in the data files (or it can be gleaned from the files), with others it is difficult to find. If a project report or field notes are submitted, they may contain that information. If automated tools are available for the

particular receiver/software combination being used, the files will be subject to automatic scans.

Some of the parameters which will be examined (if possible given the data) are:

- minimum 4 satellites for all fixes
- minimum satellite elevation angle of 15 degrees
- maximum HDOP of 5 (or PDOP 8 or GDOP 10)
- point features have 30 seconds occupation time
- point features have at least 15 fixes
- all positions differentially corrected
- closures and computations of traverses and offsets

5.5.2 Overall Data Quality

This is a visual, "common-sense" examination of the original corrected GPS data, using in-house mapping or GIS software. "Original corrected" means that no editing has been done to the data after differential correction. The individual position fixes are displayed as well as the averaged points and derived lines. A trained technician will set a scale reference and pan throughout the file looking for problem areas.

The following potential problem areas will be looked for:

- noise or systematic errors in fixes comprising point features
- point features inexplicably offset from lines.
- large gaps (over 25m) in linear features
- fixes too far apart for linear features (majority should be less than 5m apart)
- excessive data noise (consistently at 10-metre level) in linear features.
- systematic errors in line features (rare with most receivers).

5.5.3 Interpretation of Residual GPS Errors

Almost invariably, the original corrected GPS data has some residual errors (usually due to forest cover and other obstructions. Although these errors are usually quite acceptable under these standards, they must be dealt with by the organization doing the GPS work. This is the process of "interpretation", where averaged point features are moved if necessary (due to common systematic errors), and the noise in linear features is "smoothed out", usually by digitizing a new line using the original GPS as a guide.

The interpreted GPS features (i.e. the points and lines) are extracted from the final map product and examined in context with the original corrected GPS and also considering the overall project requirements. During the examination, the following questions are typically asked:

- if there are problems with the data (e.g. points offset from lines, noisy line data), were they properly dealt with?
- was there any consistent mis-interpretation of noisy data?
- were any features mis-identifyied due to confusion in the field or office?

- is there GPS data supporting all of the features in the final map?
- are there obvious missing sections or amendments?

Obviously, this stage is more subjective than the other two stages where there are set standards to be met. However, during the initial production and during QA, this is usually the most important stage from a standpoint of overall data quality.

5.6 Results and Remediation

The GPS QA procedures described above will identify any problems with the submitted data. Even though assessing the interpretation (as discussed in 5.5.3) can be somewhat subjective, the results should be clear. However, the process following the QA is much more difficult to define. It is not possible, nor is it really desirable to establish a universal standard as to what will be considered "acceptable" or "unacceptable".

A report of any deficiencies identified by the QA should be prepared. This is especially important if the person doing the QA is not the person administering the contract as the actions to be taken are usually up to the contract administrator. This report should mention the deficiencies noted and more importantly discuss how they affect the overall data quality and impact the project objective. Such a report could be a formal written report, but more likely would be a summary report to be supplemented by discussion with the stakeholders.

If deficiencies are noted, they should be discussed with the contractor who performed the work – often deficiencies are due to mis-communication and can be resolved easily. Because many of the issues around data quality are subjective, arbitrarily applying sanctions before discussing it with all stakeholders is not appropriate.

Problems identified by QA must always be considered in the context of the overall project objectives. Often a few problems such as a point feature off of the expected line or a segment with a few gaps in the line will not affect the overall project. At the same time, problems which may seem minor, but are consistently noticed can seriously impact a project and affect future planning decisions.

It is up to the contract administrator to decide what are appropriate actions for remediation of perceived deficiencies (after discussion with stakeholders).

Such actions may include:

- further QA of a larger portion of the project
- initiate an independent audit procedure described in 5.1
- generate new interpreted features from the corrected GPS
- re-survey problem portions of a project
- re-survey an entire project
- accept the project with minor deficiencies.

These actions will depend entirely on local issues such as those discussed in section 5.3.

APPENDIX 1 GUIDELINES FOR GPS NAVIGATION

GPS can be used not only for forest mapping and surveying, but also for navigating to positions with known coordinates. GPS is generally less expensive, and more accurate and reliable than conventional methods for many forest navigation applications. Positioning accuracy, even with uncorrected GPS, may be sufficient for some forest applications such as inventory field sampling; reconnaissance surveys; and identification and positioning of forest recreation point features.

This section provides some general guidelines and procedures for Vegetation Resources Inventory field sampling program using GPS either differentially corrected in real-time, or uncorrected (with Selective Availability (SA) turned off).

In a typical navigation application, there are three types of ground points. These include **Field Point**: a point with known coordinates to be navigated to (e.g. a field sample plot centre, a destination point, a forest recreation site, a camp site, a wildlife habitat tree, etc.); **Tie Point**: a point identifiable from both maps and on the ground serving to relate ground measurements with maps; and **Navigation Point**: a point along a navigation route serving as a navigation check point.

1 Preparation Prior to Navigation

The coordinates of Field Points, Tie Points, and other points to be navigated to (often called "waypoints"), must be obtained either from maps or from a previous GPS survey. The source for these coordinates must be known as it affects later steps in these guidelines.

Waypoint coordinates should be referenced to the NAD83 survey datum, and should have a resolution of 1 metre or better if possible (if using geographic coordinates the equivalent resolution is: 1 decimal Seconds, or 3 decimal Minutes, or 5 decimal Degrees). If using UTM projected coordinates, make sure the correct UTM zone is used. If the waypoint coordinates provided are referenced to a survey datum other than NAD83, a choice must be made regarding how the datum transformation to NAD83 will be done before GPS navigation is possible. The internal transformation methodology built-in to GPS receivers is a generalized approximation, and will introduce errors of 10m or more. If this introduced error is acceptable, then the GPS receiver's datum can be changed to match the datum of the provided waypoints and these values can then be directly entered. If this transformation error is not acceptable, a more rigorous transformation to NAD83 will have to be done externally. For example, if NAD27 waypoint coordinates are provided, the "National Transformation" software (NTv2) should be used to transform to NAD83 to maintain <1m accuracy.

Forest cover maps at a scale of 1:5,000 (or 1:10,000 if forest polygons are too large) must be prepared with the Tie Points and Field Points intended, true north arrow, and UTM coordinate marks and annotations. If not available, the standard 1:20,000 forest inventory cover maps can be used.

Other information such as aerial photos, polygon attributes, important land marks, if available, should also be prepared prior to a field navigation

GPS receivers must be checked for battery and parameter configurations (e.g. survey datum/projection, file name conventions, offset conventions, True/Magnetic heading reference, etc.).

It is also important for field crews to be equipped with not only GPS receivers, but also conventional navigation tools such as compass, meter tape, string box, etc.

2 Field Checking Map Accuracy

If the waypoint coordinates are from a previous GPS survey, there is no need to adjust these coordinates and the reader can skip sections 2 and 3.

It is not unusual for forest inventory maps to be inaccurate due to problems with the quality of base maps, methods used to delineate forest polygons, age of maps, etc. Therefore, if waypoint coordinates are derived from these maps, the map quality should be checked to see if there is a need to adjust these coordinates before they are used for navigation. The suggested way to do this is to check a number of Tie Points that can be clearly identified on both the maps and on the ground. These Tie Points could be road intersections, creek junctions, man-made features such as bridges, dam corners, buildings, etc.

At least three Tie Points should be checked for the entire project area. Ideally, these Tie Points should be surveyed with differentially corrected GPS (DGPS). If this is not feasible, these points may be surveyed with uncorrected GPS, although this method will have lower accuracy and integrity (see below for procedures for surveying Final Navigation Points).

Tie points can be temporarily marked with colour ribbons, or permanently established by the same procedure described in the VRI Field Sampling Procedures Manual.

Effort should be made to ensure that the surveyed Tie Points are unrelated and are spread throughout the project area. The intention is to ensure that any coordinate adjustments are valid by requiring that the discrepancy vectors be internally consistent (size & direction) across at least 3 Tie Points. If the first 2 Tie Points agree within +/- 10m of the map coordinates, then this is a sufficient check, but if not, more Tie Points must be surveyed until at least 3 show good internal consistency.

3 Coordinate Adjustment

An adjustment of waypoint coordinates is necessary if there are substantial discrepancies between the GPS coordinates and map coordinates.

If the waypoint coordinates of the Field Points come from previous DGPS surveys (either post-mission or real-time differential corrections), no adjustment is required, and the reader can skip this section 3.

If the GPS coordinates of the Tie Points are within $\pm$10m of their map coordinates, no adjustment is required.

If the discrepancy between GPS coordinates and map coordinates at Tie Points is more than 10 meters (from checking at least three Tie Points), an adjustment to waypoint coordinates is required as follows:

$$N_{adj} = N_{map} + N_{shift}$$

$$E_{adj} = E_{map} + E_{shift}$$

Where:

N_{adj} , E_{adj} are the adjusted UTM North and East, for the Field Point.

N_{map}, E_{map} are the original map UTM North and East, for the Field Point.

N_{shift}, E_{shift} are the average coordinate shifts determined from at least 3 Tie Points. The coordinate shifts are formed as GPS coordinates minus the map coordinates at the Tie Points.

4 Navigation Procedures

Navigating to a Field Point could start at any point, however, it is preferable to choose some identifiable land marks that could be later recovered by its coordinates. If real-time DGPS or post mission DGPS is used, the minimum occupation time is 150 seconds and at least 50 individual fixes are collected during that period. The average of these 50 fixes collected at this point should be recorded as its true GPS position.

GPS navigation should be made at a number of Navigation Points along the navigation route. The distance between each adjacent Navigation Points must be less than 200m. Navigation bearing and distance should be calculated or adjusted at each Navigation Point.

When within 25m of the destination waypoint (Field Point):

1. select a location that allows strong GPS tracking (good signal strengths), and good DOPs;

2. survey this location with at least 200 GPS fixes if uncorrected, or with 50 fixes if real-time corrections are applied; and

3. compute the bearing and distance from this location (average of the fixes) to the Field Point. This can usually be computed directly by the GPS receiver. The bearing and distance should be recorded on the GPS navigation card.

When it is possible, the above 3 steps can be repeated at three different locations surrounding the Field Point, and an average taken to determine the accepted position of the Field Point.

At the survey location(s), once confirmed with GPS, a permanent marker should be established. The Field Point is determined and measured with a compass (accurate to one degree) and a measuring tape (accurate to one meter) using the computed bearing and distance from the survey location(s). Standard procedures (e.g. the VRI Field Sampling Procedures manual) for establishing permanent markers at the survey location and Field Points should be followed.

5 Data Processing and Reporting

All navigation information should be manually recorded on a pre-defined GPS navigation card. The card should indicate: project ID, crew names, GPS equipment details, files name(s), GPS methodology (real-time or uncorrected in the field), design coordinates for the Field Point, and the survey location details (physical marking, averaged coordinates, computed bearing and distance to the Field Point). All GPS data should be differentially corrected (either real-time in the field, or post-mission). The computed bearing and distance used in the field must be applied to the surveyed location to determine the final coordinates for the established Field Point.

The final coordinates, corrected (real-time or post-mission) or uncorrected, of these points should be stored for any future re-visitation and quality assurance purposes.

APPENDIX 2 REQUEST FOR EXPRESSIONS OF INTEREST

Ministry of Forests

Notice to Global Positioning System Contractors

Request for Expressions of Interest - REI #GPS0001

The Ministry of Forests is establishing an Eligibility List of qualified Global Positioning System (GPS) contractors who are willing to bid or submit proposals for upcoming fiscal year GPS related contracts. Only pre-qualified firms will be invited to submit tenders or proposals for the ministry's GPS contracts for the following ministry operations: (i) pre-harvest cut block traversing for Exhibit A production; (ii) post-harvest cut block mapping for inventory update; (iii) silviculture treatment unit layout surveys and mapping; and (iv) any other GPS data collection for 10 meter mapping accuracy as specified by the ministry contract administrators.

GPS contractors who are interested in being evaluated for inclusion on the Eligibility List are invited to submit Expressions of Interest to:

Ministry of Forests, Resources Inventory Branch
Box 9214, 722 Johnson Street
Victoria, BC V8W 9C2

Attention: Xiaoping Yuan, Inventory Technical Applications Officer
Phone: (250) 953-3626, Fax: (250) 387-5999
E-mail: Xiaoping.Yuan@gems9.gov.bc.ca

Expression of Interest may either be mailed, faxed, or sent on-line (http://www.for.gov.bc.ca/isb/gps/pre-qualification/index.htm) and should contain the following information:

1. Contact Information	Identify organisation name; address; telephone/fax/e-mail/web site; contact person name; and title
2. Corporate Profile	Identify business type; WCB #; size of workforce; type of services offered; areas of expertise, and number of years in business
3. GPS Personnel	Identify principals by positions/titles, key GPS personnel and their training and experience. Please attach any supporting documents.

4. GPS Equipment	List receivers and processing software (owned, leased, or rented, version number).
5. Mapping/GIS	List mapping/GIS software (name and version number).
6. Experience/Reference	Provide a list of past contracts/projects using GPS in the ministry business areas identified above. Also provide names addresses, and telephone numbers of at least two clients for whom GPS contracts were performed.

The Ministry of Forests intends to compile the eligibility list by February 25 of each year for the work to be conducted in the coming field season. To achieve this goal, Expression of Interest should be received by January 25. Submissions received after January 25 will be considered, however, there will be an evaluation period of up to 30 working days for the ministry to notify contractors of the evaluation results.

All materials submitted for the pre-qualification will become the property of the ministry and will not be returned.

The pre-qualification will be valid until further notice.

Submission of a pre-qualification application does not guarantee inclusion on a resulting eligibility list of pre-qualified contractors. The ministry reserves the right to limit the number of pre-qualified contractors invited to compete on subsequent contracts.

This solicitation is subject to Chapter 5 of the *Agreement on Internal Trade*.

APPENDIX 3 A CHECK LIST FOR IN-HOUSE GPS PROJECT MANAGEMENT

The following is a check list for managing and conducting an in-house GPS survey.

Project Planning

- Assess project requirements for accuracy, production and deliverables.
- Choose data capture methods, receivers, etc. necessary for the project.
- Assign personnel and train them if necessary.
- Assign GPS hardware and software (purchase, lease or rent as appropriate).
- Assign supplementary equipment (computers, vehicles, compasses, etc.).
- Acquire maps, permissions, etc. appropriate to the project.
- Derive or acquire navigation waypoints if necessary.
- Develop or adapt custom data capture model for receivers if necessary.
- Choose GPS reference station.
- Obtain GPS status information for predicted satellite outages, etc.
- Obtain current GPS almanac.
- Generate satellite visibility and DOP-time plots.
- Create observation schedule as necessary.

Project Management (remote projects)

- Verify operation and condition of GPS receivers, antennas, cables, batteries, etc.
- Verify software installation, drive space, software locks for all project computers.
- Obtain media for archive and transfer purposes.
- Verify necessary communications for remote projects.

Field Procedures (daily, pre-survey)

- Check operation of receiver, data logger, etc.
- Check battery status and data logger memory
- Check supplies of supplementary materials (flagging, paint, thread, etc.)

Field Procedures (surveying)

- Connect all cables, etc. and set up receiver for surveying.
- Pack spare cables, batteries, etc. if necessary.
- Re-check receiver operation, memory and battery status.
- Verify and set data logging parameters.
- Open data file, assign file name (descriptive if possible).

- Write start times, file names, crew, etc. in field book.
- Begin survey using appropriate methods from project plan.
  - Suspend data logging for detours, long breaks, etc.
  - Keep file sizes manageable during survey.
  - Monitor DOPs, signal strength, battery status, etc. periodically.
  - Note all anomalies, reference markers, boundary notes in field book.
- Close file on end of survey; note times in field book.
- Carefully store equipment for travel.

Field Procedures (daily, post-survey)

- Charge batteries for receiver, data logger, etc.
- Check cables and connections.
- Dry and clean equipment as necessary.

Post-Processing

- Download rover files from receivers.
- Examine field notes for rover anomalies, warnings, exceptions, etc.
- Obtain appropriate reference station files.
- Check GPS status notices for anomalies, satellite outages, etc.
- Import files into processing software.
- Merge reference files as necessary.
- Verify reference coordinates and datum.
- Set and note any processing parameters used.
- Differentially process data.
- Verify completed processing run.
- Analyze statistics -- change parameters and reprocess as necessary.
- Analyze corrected data visually -- change parameters and reprocess.
- Export data to GIS (or proceed to mapping within processing s/w).

Mapping and GIS Integration

- Interpret GPS position fixes with field notes and feature attributes.
- Compute and integrate offsets and supplementary traverses.
- Generate final interpreted points, lines and polygons.
- Perform appropriate quality control procedures.
- Transform GPS data from NAD 83 if necessary.
- Integrate GPS-derived data into existing mapping.
- Assess and resolve datum discrepancies if necessary.

- Derive coordinates, areas, etc. as required.
- Update GIS databases with point, line and polygon attributes.
- Edit map, add border, surround etc. for final hardcopy output.

Reporting and Archiving

- Compile project report.
- Generate appropriate files in required formats.
- Archive reference station and rover files as required.
- Copy and archive field notes as required.
- Copy and archive corrected GPS and mapping files.
- Transfer all appropriate files, reports, plots, notes, etc. to client.
- Delete temporary files and close project.

Quality Assurance and Audit

- Plan QA or audit process as defined before the project.
- Prepare sample data, products or work for QA.
- Check the sample data.
- Execute QA or audit process.
- Summarize and submit the QA or audit results.