PROVINCE OF BRITISH COLUMBIA

BC Ortho-image Specification

Base Mapping and Cadastre, GeoBC

March 2011

Revision #	Revised by	Description	Approved by	Date
2	T. Han	a) Void pixels in an ortho-image need to be specified as [0, 0, 0] in RGB channels (p.15). b) Organization name change	T. Han	31/03/11
1	T. Han P. Quackenbush	Rewrite based on the previous orthophoto specifications	P. Quackenbush	31/03/09

Table of contents

1. Introduction

Ortho-images, which combine the merits of a map and imagery, form the foundation layer of the provincial geospatial information infrastructure of British Columbia (B.C.). In the past decade, ortho-image generation had experienced significant technological advances due primarily to the extended applications of digital camera, Light Detection and Ranging (LiDAR), Global Positioning System (GPS), and computing technology. The analogue camera-based ortho-image generation using the conventional photogrammetric procedure is gradually being replaced by the digital workflow built on the digital inputs of image, topography, orientation, and location collected respectively by digital mapping camera, LiDAR, Inertial Measurement Unit (IMU), and GPS. Compared to the conventional procedure, this new dataflow does not require film scanning, alleviates the effort to conduct Aerial Triangulation (AT), and requires less ground control points (GCP). This has been proven to be more efficient, both in time and cost, for ortho-image production.

As the custodian of the ortho-images produced for the Province of B.C., the Base Mapping and Cadastre Section of GeoBC, under Ministry of Forests, Lands, and Natural Resource Operations, takes full responsibility to define, maintain, and update the standard and specification regarding ortho-image production across B.C. to ensure that the best mapping practice and the up-to-date mapping technology are adopted. This specification covers the production of digital ortho-images with the intention to define the minimum requirements to satisfy different prospective users from government, industry, academia, and general public. This specification is developed based on the previous orthophoto specifications and updates of B.C. [1] and those from other sources, including U.S. Geological Survey (USGS) [2], U.S. Federal Geographic Data Committee [3-4], European Commission [5], and American Society on Photogrammetry and Remote Sensing (ASPRS) [6].

The widespread industrial adoption of digital mapping technologies makes it possible to produce sub-meter ortho-images using not only the traditional scanned aerial photos but also airborne and even space-borne acquired digital images. It is GeoBC's intention to expand this specification to cover ortho-image production based on different imaging sources. To reflect this extension, the term of ortho-image, instead of orthophoto, is used throughout this specification.

It should be noted that wherever brand or trade names are mentioned in this specification, these are meant for example only and are not to be considered as an endorsement or being exclusive of other instruments or procedures that provide similar levels of quality. It should also be noted that the requirements specified in this specification are the minimum ones to be met in ortho-image production, which are defined in line with the current mapping technology, targeted areas of ortho-image applications, quality and availability of the upstream products that are used as inputs for ortho-image production. These requirements are expected to be updated regularly to reflect the advance of mapping technology and user demands.

2. Dataflow of orthorectification

As the final product of normal aerial mapping projects, ortho-images are generated based on different inputs by using some standard procedures of data processing flow to rectify image distortions associated with the perspective image acquisition and terrain. The exact procedure and the required inputs depend on the methodology employed to produce the ortho-images. For the conventional method based on analogue airborne cameras, the dataflow includes a few steps, as summarized in Figure 1, which starts with the analogue photo acquisition. This dataflow is not full digital, as films need to be digitized a priori. Alternately a more automatic method based on digital mapping cameras and IMU/GPS, referred to as direct

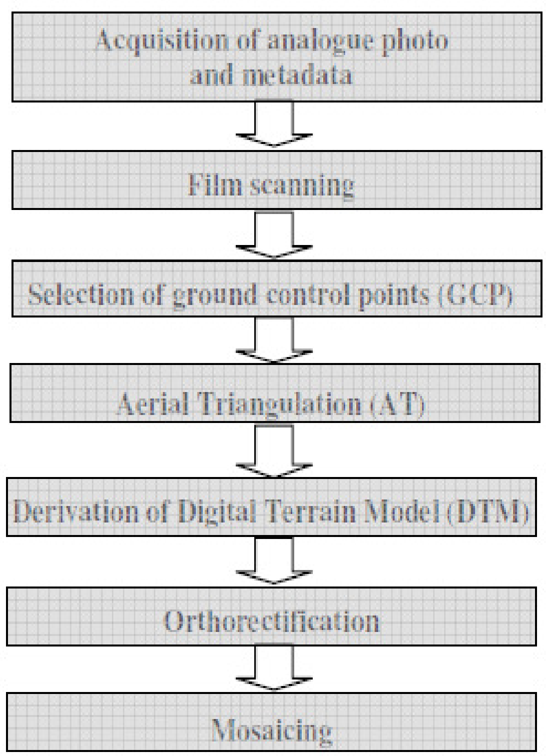


Figure 1. Conventional dataflow of orthorectification

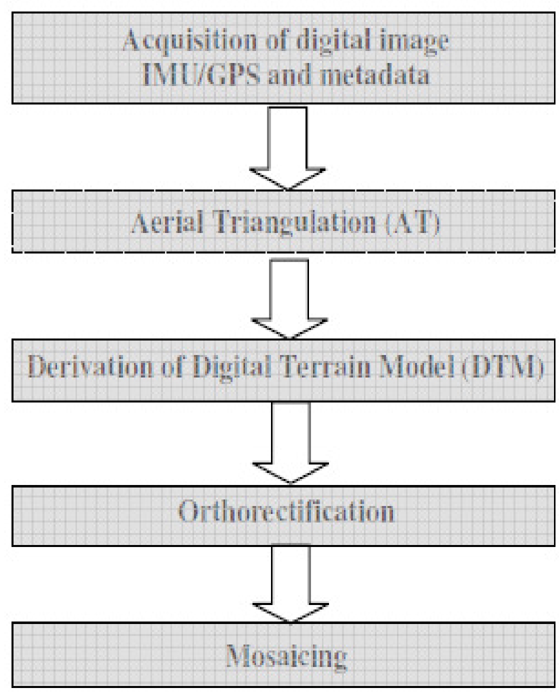


Figure 2. Automatic dataflow of orthorectification, where the AT step is optional

geo-referencing, has been gaining publicity, for it is capable of generating ortho-images in a complete digital dataflow with fewer steps as illustrated in Figure 2. It should be noted that in practice the use of GCPs (for checking and calibration purposes) is still required for the direct geo-referencing based on IMU/GPS. But the number of GCPs required can be greatly reduced. Currently the GCP free ortho-image operations are only accepted for some special applications, such as rapid response for disaster mapping and evaluation.

Production of ortho-images needs certain inputs regardless of which method of the above two is employed. The inputs must include the digital images to be rectified (either film scanned or originally acquired digitally), orientation and position (either via pre-determined GCPs and AT or IMU and GPS), DTM (either from stereo compilation or LiDAR measurements), and camera/sensor calibration parameters, including focal length and coordinates of principal points and fiducial marks (if frame cameras are used). Once all the inputs are in place, a rectification algorithm can then be executed to generate the ortho-image. Compared to other rectification algorithms, the generalized sensor model represented by Rational Function Model (RFM) [7] has become increasingly popular (especially for space-borne imaging). RFM has the following two advantages: 1) alleviation of the requirement to obtain physical sensor models that are often difficult to acquire (space-borne sensors particularly); 2) relaxation of sole dependence on GCPs for interior and exterior camera/sensor orientation. Because of these advantages, the RFM based algorithms have been implemented for various high-resolution sensors (IKONOS and QuickBird) and incorporated in many commercial off-the-shelf software packages, including Erdas-Imagine, PCI-Geomatics, ITT-ENVI, and ZI-Imagine.

3. Quality requirements

In this specification, ortho-image quality is decomposed into the following aspects of quality considerations, including spectral bands and coverage, radiometric integrity, spatial resolution and coverage, geometric integrity, colour balancing and enhancement, positional accuracy, graphic perfection, correctness of format and file naming, and completeness of metadata. The contents of these quality considerations are detailed as follows.

a) Spectral bands and coverage

A spectral band is a well-defined, continuous wavelength range in the spectrum of solar electromagnetic energy that is collected by a camera or sensor. The spectral coverage is the total wavelength range covered by all the spectral bands. The following are the requirements of these attributes. Ortho-images may be produced in the future by using more spectral bands with a wider spectral coverage.

- **Spectral bands: 3 (RGB) or otherwise specified**
- **Spectral coverage: visible or otherwise specified**

b) Radiometric integrity

The radiometric integrity of an ortho-image is evaluated in terms of the following three radiometric metrics on individual image bands: resolution, range, and distribution. Radiometric resolution determines how finely an ortho-image can represent or distinguish differences of grey levels. It is usually expressed as a number of bits. Radiometric range defines how many grey levels are utilized by an ortho-image. The nominal radiometric range is defined as (0, 2b – 1), where b is the radiometric resolution in number of bits. In reality, however, the radiometric range of an ortho-image is often narrower than the nominal one. The wider the range, the richer colours an ortho-image represents. Radiometric distribution, often expressed by the histogram of an ortho-image, reveals the occurrence of the utilized grey levels across the entire radiometric range, which in a sense indicates the continuity of grey levels. As the histogram is related to the resampling algorithm used in image rectification, the adopted resampling algorithm is also specified as follows.

- **Radiometric resolution: 8 bits or otherwise specified**

- **Radiometric range: 85% of (0, 28-1) or equivalently (0, 255)**
- **Radiometric distribution: generalized Gaussian curves**
- **Resampling algorithm: cubic convolution**

Ortho-images of higher radiometric resolution and hence wider radiometric range are gaining publicity as digital mapping cameras and sensors are capable of producing 12 or even 16-bit digital images, which boost the radiometric ranges up to (0, 4095) and (0, 65535) correspondingly. Though ortho-images have traditionally been used for visualization purposes, the high radiometric resolutions provide opportunities of using ortho-images for the full-fledged analysis-based applications, such as segmentation, classification, and change detection.

c) Spatial resolution and coverage

Spatial resolution, measured as Ground Sampling Distance (GSD), refers to the minimum distance between two adjacent features or the minimum size of features that can be discerned on an ortho-image. The spatial resolution of an ortho-image is closely related to the pixel size of digital images to be rectified, the spatial resolution of the DTM used for the rectification, and the desired mapping scale. The pixel size of the digital images to be rectified, in turn, is determined by either the film scanning resolution or the cell size of the Charge-Coupled Device (CCD) in digital cameras/sensors that are used to capture the digital images. The spatial coverage of an ortho-image is defined by the corresponding mapping project boundaries, which are usually specified in terms of British Columbia Geographic System (BCGS) mapsheets. To facilitate image mosaicing and colour balancing, an ortho-image should be generated with a 100-pixel over edge in additional to the specified mapping area. The required spatial resolution and coverage are given as follows.

- **Spatial resolution in GSD: 0.5 m or otherwise specified**
- **Spatial coverage: the specified mapping area plus a 100-pixel over edge**

The following formula, Spixel = 0.8 × 106 × SGSD × Cscale, is empirically developed to specify the interrelationship among the pixel size (in microns) of the digital image to be rectified (Spixel), the spatial resolution (in meters) of the generated ortho-image (SGSD), and the project mapping scale (Cscale). The coefficient, 0.8, in the above formula is set in order to ensure that the ortho-image images are created at a coarser resolution than that the original images or scanned films theoretically support. For instance, to generate an ortho-image of 0.5 m spatial resolution, one needs to use digital images with the pixel size no bigger than 20 microns, given the project mapping scale is 1:20,000. It is not recommended, however, to improve an ortho-image's GSD by scanning films using an over fine scanning resolution. To decide a proper scanning resolution, please refer to "Specifications for Digital Aerial Photographic Images" at

http://ilmbwww.gov.bc.ca/bmgs/airphoto/specs/DIGITAL_AERIAL_PHOTOGRAPHIC_IMAGES_SPECS_05022008.pdf

d) Geometric integrity

Ortho-images may be generated with some geometric flaws, such as broken or deformed linear features (roads and streams), leaning trees and buildings, smearing, blurs, and double imagery. These geometric flaws are often due to, among others, acquiring image under low sun angles, using a DTM of inadequate spatial resolution and accuracy, applying an inappropriate rectification algorithm, mosaicing spatially misaligned images, or rectifying digital images with the inconsistent spatial accuracies. These geometric flaws should be avoided as much as possible and should not be visible at a specified viewing scale as follows.

- **Geometric flaws are not visible on ortho-images at the viewing scale of 1:4000**

To avoid the DTM related geometric flaws, breaklines or other DTM densification approaches are required wherever apparent elevation changes happen due to complicated terrains or manmade structures. Digital Surface Model (DSM) may be required to generate ortho-images that cover urban areas with tall buildings.

e) Colour balancing and enhancement

Illumination variations may cause colour unbalanced within an ortho-image or across multiple ortho-images. Examples of these issues include visible mosaic seam lines, hot spot, and Newton Rings. Radiometric normalization should be considered to reduce these colour imperfections so that they are not visibly recognizable at the viewing scale that interpreters often choose for ortho-image interpretation. In addition, an ortho-image needs to be enhanced in such a way that the primary land covers of interest are rendered as close as possible to their natural colours.

- **Colour unbalancing is not visible on ortho-images at the viewing scale of 1:4000.**
- **Ortho-images are enhanced so that the primary land covers of interest appear in their natural colours.**

f) Positional accuracy

The positional accuracy of an ortho-image, as suggested in [4], is evaluated in terms of root-mean-square error (RMSE), calculated as the average of a set of squared differences between dataset coordinate values and the coordinate values from an independent source of higher accuracy for the identical points. Accuracy is reported in ground distances at the 95% confidence level, which means that 95% of the positions selected in an ortho-image will have an error with respect to true ground positions that is equal to or smaller than the required accuracy value. To facilitate the accuracy evaluation, a minimum of 20 check points need to be burned in each ortho-image during the AT process. These check points should be visible and spatially well distributed. The RMSE is calculated based on the true location coordinates and the corresponding coordinate readout of these points from the same ortho-image.

- **Positional accuracy (RMSE): 10m at the 95% confidence level based on the minimum of 20 check points.**

This indicates that the following two conditions need to be satisfied: 1) The RMSE is smaller or equal to 10 meters calculated using the coordinates of the 20 check points. 2) Among the 20 check points, only one of them at maximum is allowed to deviate more than 10 meters in Euclidean distance from the corresponding reference point. The above 10m-positional-accuracy is set only for the orthoimages with 0.5 or 1 meter GSD, which represent most of the orthoimages produced provincial wide. This accuracy requirement may change if smaller GSDs are used in the future.

g) Graphic perfection

Artefacts can be introduced into ortho-images due to poor weather condition, careless film scanning (if applicable), and missing data acquisition. These artefacts as listed below should be avoided as much as possible.

- **Scratch, image gap, dust, fibre, cloud cast shadow, and other graphic imperfections are not visible at the viewing scale of 1:4000.**

.

- **It is not allowed to fill image gaps using images acquired from different years.**

h) Image format and geo-referencing

GeoTIFF in compliance with the GeoTIFF Specification and Revision 1.0 [8] is the only format accepted by CRGB for orthoimage production. The header of each orthoimage in GeoTIFF format should include the proper tags and keys representing the required geo-referencing and geo-coding information as listed in Appendix A. This header can be created by a freeware called "listgeo" [8]. The generated orthoimages have to be un-tiled, uncompressed, and without any overview included. For geo-referencing, the accepted projections are the Universal Transverse Mercator (UTM) and BC Albers Equal Area Conic, both of them use North American Datum of 1983 (NAD83) based on the Geodetic Reference System 1980 (GRS80).

- **Format: GeoTIFF with the specified geo-keys and tags included**
- **Geo-referencing: UTM or BC Albers using NAD83 based on GRS80**

i) File naming

The following information needs to be embedded in each ortho-image file name, including province acronym, mapsheet block identifier, spatial resolution, projection, and year of photo acquisition. This is to facilitate users and image administrators to get as much background as possible without opening the image files. Each piece of information is separated by an underscore character. All characters must be in lowercase. As ortho-images can be delivered in three scales of mapsheet grid, including 1:20k, 1:10k, and 1:5k, file naming varies slightly in mapsheet block identifier, which is exemplified as follows.

- **File naming convention by example(20k grid): bc_094m008_xc500mm_utm10_2004.tif**
- **File naming convention by example(10k grid): bc_094h008_2_xb1000mm_albrs_1998.tif**
- **File naming convention by example(5k grid): bc_103h010_3_4_xc500mm_utm08_2004.tif**

Note that the lowercase "x" appeared in all three examples above is needed only by the CRGB image administrators for file name parsing purposes. The first example denotes an ortho-image delivered in 20k grid, which covers the mapsheet of 094m008; is in color; has a spatial resolution of 500 mm; is projected into UTM zone 10; and is generated using the photos acquired in 2004. Similarly the second example refers to an ortho-image delivered in 10k grid, covering the 2nd quadrant of 094h008, being in black and white, having a spatial resolution of

1000 mm, is projected using BC Albers, and being generated using the photos acquired in 1998. The last example is self explanatory, which is an orthoimage delivered in 5k grid. Compared to the 20k case, this one requires two more numbers to specify the mapsheet block identifier. Please refer to Appendix D for the details regarding the 10k and 5k grid block ordering.

j) Completeness of metadata

The metadata associated with each ortho-image is stored in the following two places: the GeoTIFF header and a separate ASCII metadata file. This information provides a complete background regarding the ortho-image history and production that are essential for quality control purposes and are interest of ortho-image users. The included items are summarized as follows. Details are given in Appendix A and B.

- **Metadata embedded in the GeoTIFF header: horizontal spacing (pixel size), tie point, datum, projection method and parameters, linear unit, and coordinates of scene center and four corners.**
- **Metadata embedded in the ASCII file: producer name, production date, software, image pixel size, DTM source and spatial resolution, and project mapping scale.**

4. Quality check

Upon receiving the ortho-images a series of checks on the ortho-image quality should be carried out. These checks, as shown in Figure 3, are stipulated based on the quality requirements specified in the previous sections. The details of each check step are described below.

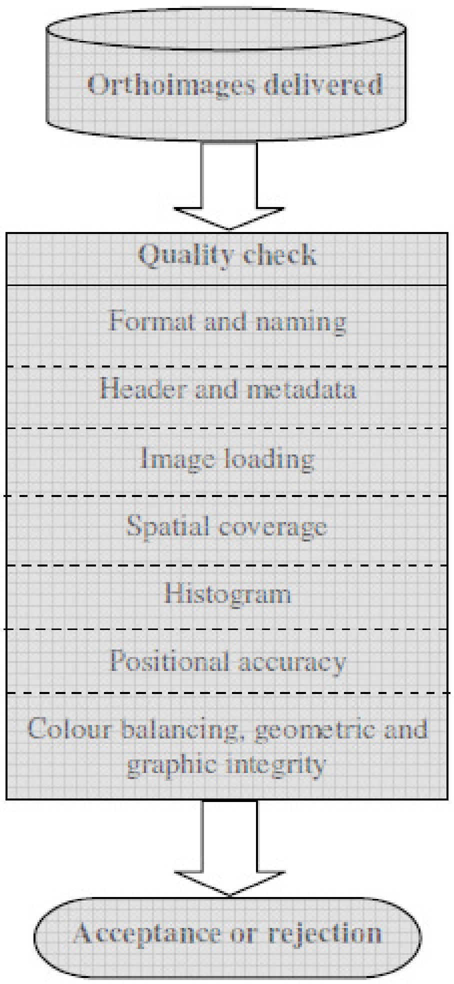


Figure 3. Scheme of orthoimage quality check

a) Format and file naming

This step of check is designed to ensure that each delivered ortho-image has 3 bands and 8-bit pixel depth. It is saved in the required GeoTIFF format and named properly in compliance with the specified file naming convention.

b) Header and metadata

This step is dedicated to examining the correctness and completeness of the meta data associated each ortho-image, which are stored in both the GeoTIFF header and the ASCII metadata file.

c) Image loading

As ortho-images are often used for GIS applications, loading ortho-images using a GIS package is always a priori. This step is conducted by loading each of the delivered ortho-images with ESRI ArcMap, the most widely used GIS software package among ortho-image users, to ensure that the images can be opened properly without issues of incompatibility.

d) Spatial coverage

Spatial coverage check is to make sure that each ortho-image appearing in the correct location and covering enough areas. This can be conducted by overlaying a boundary vector file on top of the corresponding ortho-image.

e) Histogram

Histogram is employed to examine the radiometric properties of each ortho-image, specifically the range and distribution. Irregularly-shaped histograms that significantly deviate from a general Gaussian distribution may lead to a rejection. Examples of these unusual histograms are those

- too skinny, indicating that radiometric range is too narrow, which leads to low image contrast;
- significantly distorted towards 0, indicating that too many pixels assume low grey levels, which causes an image look dark and possible information loss for targets of low illumination;
- significantly distorted towards 255, indicating that too many pixels assume high grey levels, which causes an image look over bright and possible information loss for targets of intense illumination.

Appendix F provides a few examples of histogram that are considered unacceptable. They are either overly skinny, flat, or skewed too much.

f) Positional accuracy

For each ortho-image, its positional accuracy is evaluated based on the delivered positional accuracy report and the agreement between some spatial features extracted from a digitized map and those extracted from the ortho-images delivered. TRIM vector data, such as road network or streams, can be used as the digitized maps for the evaluation.

g) Colour balancing and geometric and graphic integrity

This check is designed to identify ortho-image imperfections related to colour balancing, feature geometric shape, and graphic appearance. Compared to other check steps in this section, which have potential to be automatically conducted, this step is often time consuming since it has to be done manually at a relatively large viewing scale (1:4000).

h) Void pixel specification

Void pixels in ortho-images, due to missing data or cloud obstruction, should be specified using [0, 0, 0] RGB digital numbers.

5. Deliverables

For each ortho-image delivered, the following files are expected:

- an image file in GeoTIFF format with the proper geo-keys and tags included (See Appendix A for details);
- an ASCII metadata file (See Appendix B for details);
- an ESRI shapefile (and the associated files) containing mosaic seam lines;
- an ASCII file containing the positional accuracy report (See Appendix C for details).

These files have the same basic name as the GeoTIFF image file specified in file naming convention but different extensions. For instance, if the basic name is "bc_094m008_xc500mm_utm10_2004", then the above files are named as follows, respectively,

Orthoimage file: bc_094m008_xc500mm_utm10 _2004.tif

Metadata file: bc_094m008_xc500mm_utm10 _2004.met

Shapefile: bc_094m008_xc500mm_utm10 _2004.shp

bc_094m008_xc500mm_utm10_2004.dbf

bc_094m008_xc500mm_utm10_2004.prj

Accuracy report: bc_094m008_xc500mm_utm10_2004.rep

For delivery purposes, these files can be put on any form of portable massive storage media. Currently the CRGB preferred media are USB interfaced hard drives.

Acknowledgements

CRGB would like to thank the following individuals representing Canadian academia, B.C. aerial mapping industry, and B.C. Ministry of Forests and Range for their active involvement and contribution to the development of this specification, who are Babak Ameri, Geosys Technology Solutions, Vancouver, B.C.; Jean-Marc Fortier, Global Geomatics Ltd., Qualicum Beach, B.C.; Ian Grady, Integrated Mapping Technologies Inc., Vancouver, B.C.; Ayman Habib, Department of Geomatics Engineering, University of Calgary, Calgary; Richard Marty, Integrated Mapping Technologies Inc., Vancouver, B.C.; Ann Morrison, Ministry of Forests and Range, Victoria, B.C.; Dick Mynen, TDB Consultants Inc., Prince George, B.C.; and Dan Tresa, McElhanney Engineering Services Ltd., Vancouver, B.C. This specification would not have been put together without their support.

Appendix A – An example of GeoTIFF header

```
Geotiff_Information:
    Version: 1
    Key_Revision: 1.0
    Tagged_Information:
        ModelTiepointTag (2, 3):
            0           0           0
            434441      5995120.5   0
        ModelPixelScaleTag (1, 3):
            0.5         0.5         0
    End_Of_Tags.
    Keyed_Information:
        GTModelTypeGeoKey (Short, 1): ModelTypeProjected
        GTRasterTypeGeoKey (Short, 1): RasterPixelIsArea
        GeogLinearUnitsGeoKey (Short, 1): Linear_Meter
        GeogAngularUnitsGeoKey (Short, 1): Angular_Degree
        ProjectedCSTypeGeoKey (Short, 1): PCS_NAD83_UTM_zone_10N
    End_Of_Keys
End_Of_Geotiff

PCS = 26910 (name unknown)
Projection = 16010 ()
Projection Method: CT_TransverseMercator
ProjNatOriginLatGeoKey: 0.000000 ( 0d 0' 0.00"N)
ProjNatOriginLongGeoKey: -123.000000 (123d 0' 0.00"W)
ProjScaleAtNatOriginGeoKey: 0.999600
ProjFalseEastingGeoKey: 500000.000000 m
ProjFalseNorthingGeoKey: 0.000000 m
GCS: 4269/NAD83
Datum: 6269/North American Datum 1983
Ellipsoid: 7019/GRS 1980 (6378137.00,6356752.31)
Prime Meridian: 8901/Greenwich (0.000000/ 0d 0' 0.00"E)

Corner Coordinates:
Upper Left    ( 434441.000, 5995120.500)
Lower Left    ( 434441.000, 5983807.500)
Upper Right   ( 447697.000, 5995120.500)
Lower Right   ( 447697.000, 5983807.500)
Center        ( 441069.000, 5989464.000)
```

Appendix B – An example of ASCII metadata file

Producer name: TDB Consultants Inc., Prince George, B.C.

Production date: Dec. 12, 2008

Software: ZI-Imagine

Image pixel size: 16 microns

DTM source and spatial resolution: TRIM and 25 m

Project mapping scale: 1:20,000

Appendix C – An example of positional accuracy report

	Reference Coordinates		Coordinates being checked		
Check point	**Easting**	**Northing**	**Easting**	**Northing**	**Squared Difference**
1	566422.64	5994481.53	566430.41	5994479.31	65.30
2	569307.75	5994625.79	569314.41	5994622.46	55.44
3	572016.54	5994545.64	572023.20	5994548.97	55.44
4	574549.03	5994273.16	574550.14	5994276.49	12.32
5	577241.79	5994160.96	577241.79	5994158.74	4.93
6	567031.72	5991965.08	567039.49	5991969.52	80.09
7	569564.20	5991836.85	569559.76	5991831.30	50.52
8	572337.11	5991772.74	572332.67	5991780.51	80.09
9	574949.74	5991644.51	574949.74	5991636.74	60.37
10	577674.56	5991452.17	577675.67	5991446.62	32.03
11	566679.10	5990041.67	566673.55	5990049.44	91.18
12	569019.24	5990057.70	569023.68	5990056.59	20.95
13	571679.95	5989993.59	571678.84	5989994.70	2.46
14	574565.06	5989913.45	574557.29	5989919.00	91.18
15	577161.65	5989785.22	577164.98	5989783.00	16.02
16	573026.33	5987044.37	573029.66	5987046.59	16.02
17	570093.14	5987140.54	570086.48	5987139.43	45.59
18	574484.91	5986948.20	574479.36	5986952.64	50.52
19	576937.25	5986531.46	576943.91	5986529.24	49.28
20	578139.38	5984543.94	578131.61	5984547.27	71.46
RMSE					**6.90**

Appendix D – Mapsheet block ordering

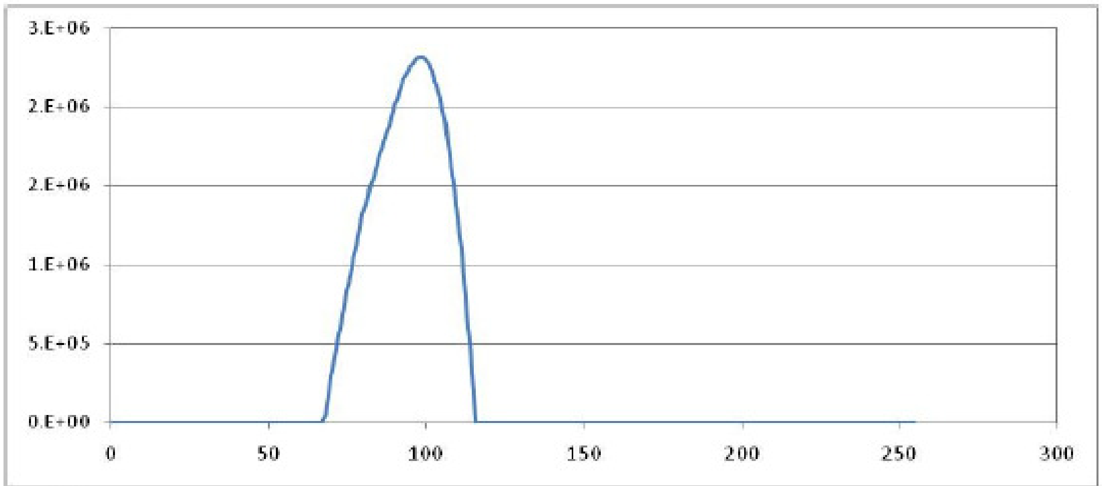
Scale 1:10,000

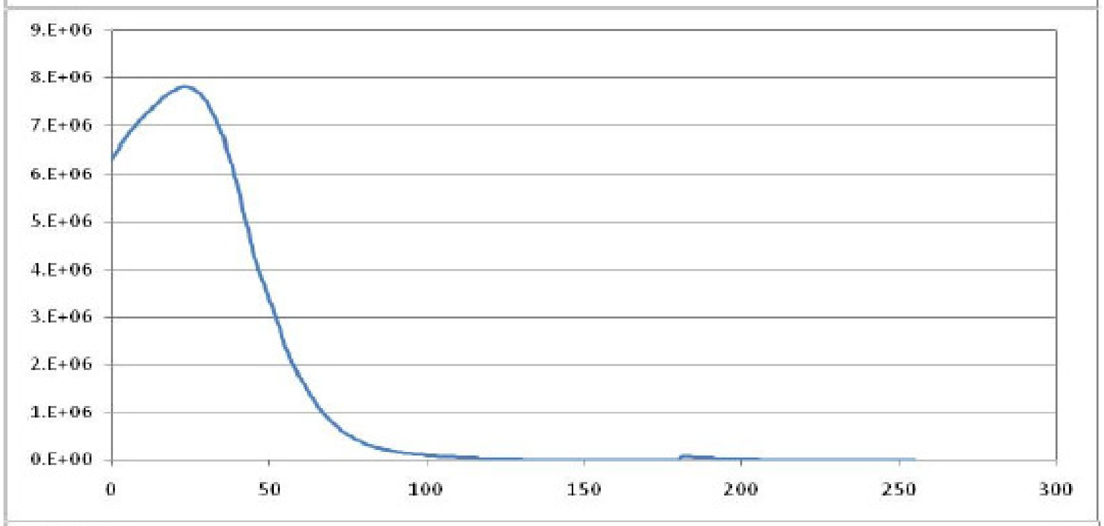
3	4
1	2

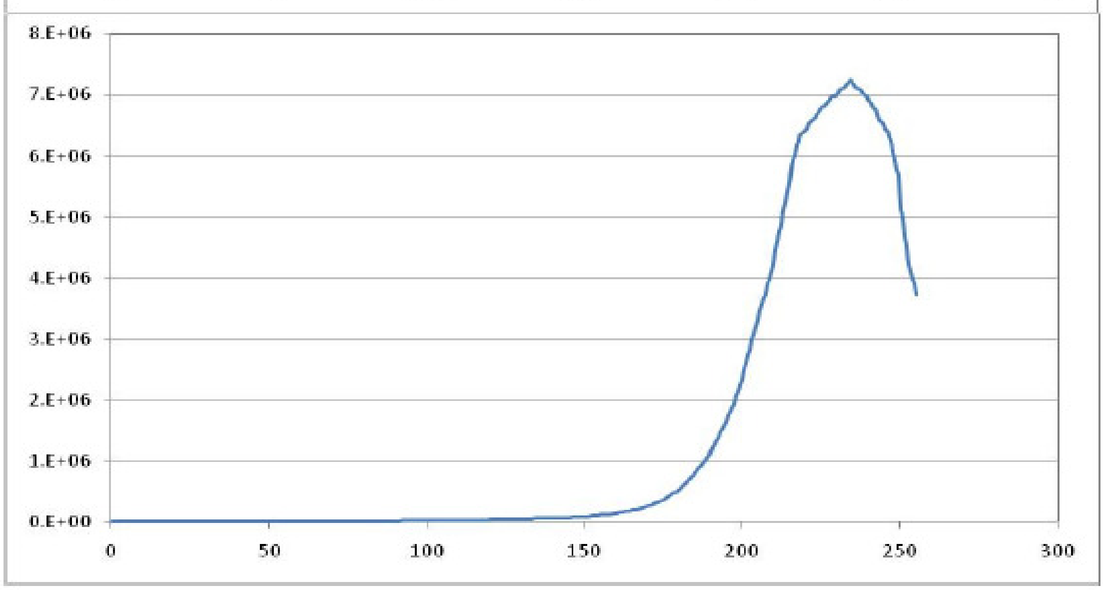
Scale 1:5,000

3-3	3-4	4-3	4-4
3-1	3-2	4-1	4-2
1-3	1-4	2-3	2-4
1-1	1-2	2-1	2-2

Appendix E -Examples of unacceptable histogram







Appendix F – Quick check list prior to delivery

- ✓ 3 bands (RGB) and 8-bit pixel depth per band or otherwise specified
- ✓ Void pixels specified using [0, 0, 0] RGB digital numbers
- ✓ 0.5 m spatial resolution (GSD) or otherwise specified
- ✓ A Gaussian-like histogram with grey levels spreading at least 85% of (0, 255)
- ✓ A minimum of 100-pixel over edge
- ✓ No visible geometric flaws at viewing scale of 1:4000
- ✓ No visible colour unbalancing at viewing scale of 1:4000
- ✓ Primary land covers of interest appear in their natural colours
- ✓ A minimum of 20 check points burned into each ortho-image and visible
- ✓ 10m positional accuracy at the 95% confidence level based on a minimum of 20 check points
- ✓ No visible graphic imperfections at viewing scale of 1:4000
- ✓ Ortho-image format: GeoTIFF with the specified geo-keys and tags included
- ✓ File naming example: bc_094m008_xc500mm_utm10 _2004
- ✓ Metadata embedded in the GeoTIFF header: horizontal spacing (pixel size), tie point, datum, projection method and parameters, linear unit, and coordinates of scene center and four corners
- ✓ Metadata embedded in the ASCII file: producer name, production date, software, image pixel size, DTM source and spatial resolution
- ✓ Completeness of auxiliary files: ASCII metadata file, mosaic seam line shape file, and positional accuracy report

References

[1] Base Mapping and Geomatic Services, “B.C. Digital Orthophoto Specifications,” 1997, http://ilmbwww.gov.bc.ca/bmgs/pba/trim/specs/orthospec.pdf

[2] U.S. Geological Survey (USGS), “Specifications – Standards for Digital Orthophotos,”1996, http://rockyweb.cr.usgs.gov/nmpstds/doqstds.html

[3] U.S. Federal Geographic Data Committee, “Content Standards for Digital Orthoimagery,” 1999, http://www.fgdc.gov/standards/projects/FGDC-standardsprojects/orthoimagery/orth_299.pdf

[4] U.S. Federal Geographic Data Committee, “Geographic Information Framework Data Content Standard -Part 2: Digital Orthoimagery,” 2008, http://www.fgdc.gov/standards/projects/FGDC-standards-projects/framework-datastandard/GI_FrameworkDataStandard_Part2_DigitalOrthoimagery.pdf

[5] European Commission, “Guidelines for Best Practice and Quality Checking of Ortho Imagery,” 2003, http://mars.jrc.ec.europa.eu/mars/Bulletins-Publications/Guidelines-forBest-Practice-and-Quality-Checking

[6] ASPRS, “Report to the U.S. Geological Survey on Digital Orthoimagery,” 2005, http://nationalmap.gov/report/ASPRS_Report_on_Digital_Orthoimagery.pdf

[7] A. Croitoru, Y. Hu, V. Tao, Z. Xu, F. Wang, and P. Lenson, "The Rational Function Model: A Unified 2d And 3d Spatial Data Generation Scheme, " 2004, Proceedings of ASPRS Annual Conference, Denver, Colorado, USA.

[8] GeoTIFF Working Group, “GeoTIFF Format Specification and Revision 1.0,” 2000, http://www.remotesensing.org/geotiff/spec/geotiffhome.html