# BC Ortho-image Specification

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**4/12/2019**

# Table of Revisions

| Revision # | Revised by | Description | Approved by | Date |
|---|---|---|---|---|
| 4 | R.Prins<br>A.Christian<br>J.Godau | a) New information regarding clipping of ortho deliverables (p.15)<br><br>b) Removed Ascii Metadata file as a deliverable (p. 17-18)<br><br>c) Added MrSID format as an accepted deliverable (p.22) | H.Steiner | 12/04/19 |
| 3 | R.Prins<br>A.Christian | a) Radiometric Integrity (p.8)<br><br>b) Image format and geo-referencing and File naming (p.12)<br><br>c) Representation of data and no-data areas (p.15-16) | H.Steiner | 31/03/16 |
| 2 | T. Han | a) Representation of no-data areas (p.15).<br><br>b) New items added to Appendix F – Quick check list prior to delivery (p.23)<br><br>c) Organization name change | T. Han | 31/03/11 |
| 1 | T. Han<br>P. Quackenbush | Rewrite based on the previous orthophoto specifications | P. Quackenbush | 31/03/09 |

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# 1.0 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, Natural Resource Operations and Rural Development (FLNRORD), 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.

## 2.0 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

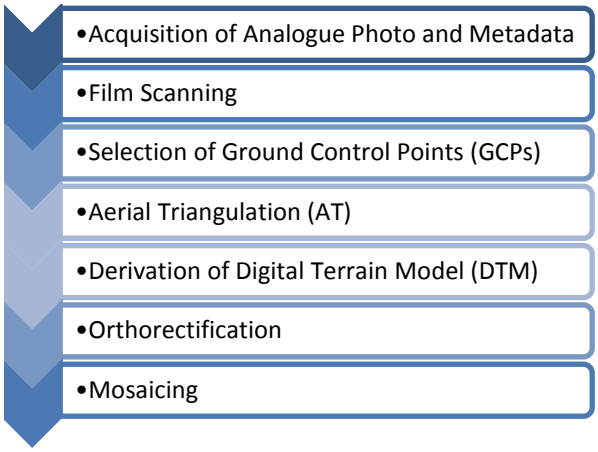



Figure 1: Conventional Dataflow of Orthorectification

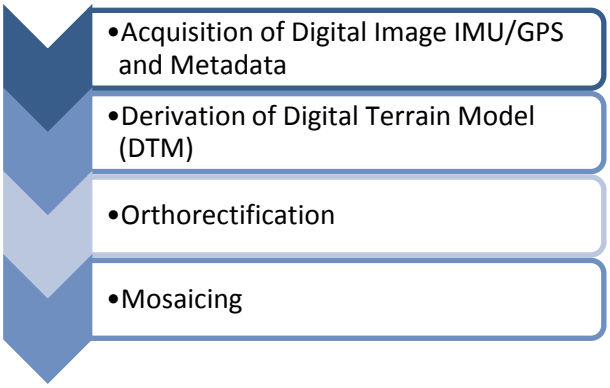



Figure 2: Automatic Dataflow of Orthorectification

geo-referencing, has been gaining popularity, 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 indirect geo-referencing based on AT. 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), digital terrain model (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.

## 3.0 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.

### 3.1 Spectral Bands and Coverage

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

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.

### 3.2 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 a bit depth. In reality, however, the radiometric range of an ortho-image is often narrower than the nominal one. The wider the range, the richer set of 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. Ortho-images of higher radiometric resolution and hence wider radiometric range are gaining popularity 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.

## 3.3 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 the light-sensitive sensor in digital cameras 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: 10cm, 30cm, or 50cm, or as otherwise specified**
- **Spatial coverage: the specified mapping area plus a 100-pixel over edge**

## 3.4 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.

To avoid the DTM related geometric flaws, breaklines or other DTM densification approaches are required. GeoBC suggests a grid density of ortho-imgae pixel resolution * 4. Digital Surface Model (DSM) may be required to generate ortho-images that cover urban areas with tall buildings.

## 3.5 Colour Balancing and Enhancement

Illumination variations may cause colour unbalancing within an ortho-image or across multiple ortho-images. Examples of these issues include visible mosaic seam lines, hot spots, 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.

## 3.6 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 accuracy evaluation, a minimum of 5 GCPs are required (unless otherwise stated). GCPs 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 5 GCPs.**

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 5 GCPs, only one of them at maximum is allowed to deviate more than 10 meters in Euclidean distance from the corresponding reference point.

## 3.7 Graphic Artifacts

Artifacts can be introduced into ortho-images due to poor weather condition, poor rectification algorithms, careless geo-referencing, careless film scanning (if applicable), and missing data. These artifacts as listed below should be avoided as much as possible:

- **Image gap, image flare, blooming, missing pixels, vertical smearing, cloud cast shadow and other graphic imperfections are not visible.**
- **It is not allowed to fill image gaps using images acquired from different years.**
- **Each ortho-image must include any available imagery from neighbouring map tiles necessary to ensure seamless tiling.**
- **Ortho-images tiles must fill the bounding box of the associated BCGS grid tile specific to the projection used rather than the grid tile itself.**

## 3.8 Image Format and Georeferencing

GeoTIFF in compliance with the GeoTIFF Specification and Revision 1.0 [8] and MrSID (.sid) are the only formats accepted by GeoBC for ortho-image production. The header of each ortho-image in GeoTIFF format should include the proper tags and keys representing the required geo-referencing and geo-coding information as listed in Appendix A.. GeoTiff ortho-images have to be uncompressed and without any overview included. MrSID image must have a compression ratio no higher than 15:1. 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 CSRS). **Format: GeoTIFF with the specified geo-keys and tags included**

- **Geo-referencing: UTM or BC Albers using NAD83 (CSRS)**

## 3.9 File Naming

The following information needs to be embedded in each ortho-image file name, including province acronym (bc), 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 various scales of mapsheet grid, including 1:20k, 1:10k, and 1:5k, or 12500, 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_xb1m_bcalb_1998.tif**
- **File naming convention by example(5k grid): bc_103h010_3_4_xc500mm_utm08_2004.tif**
- **File naming convention by example(2500 grid): bc_082g010_3_4_1_xc500mm_utm08_2004.tif**

Note that the lowercase "x" appeared in all three examples above is required by the GeoBC 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 of1 metre, is projected using BC Albers, and being generated using the photos acquired in 1998. The last example is self explanatory, which is an ortho-image 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.

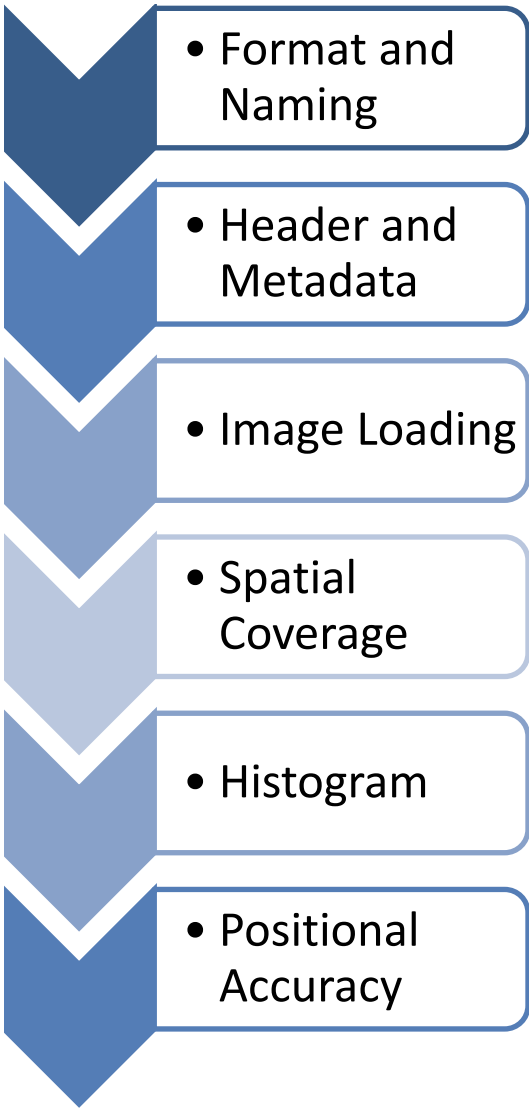
## 3.10 Completeness of Metadata

The metadata associated with each ortho-image is stored in the following two places: the GeoTIFF header. This information provides a complete background regarding the ortho-image history and production that are essential for quality control purposes and are of interest to ortho-imagery 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.**

## 4.0 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.




### 4.1 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.

### 4.2 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 the GeoTIFF header.

### 4.3 Image Loading

As ortho-images are often used for GIS applications, ortho-images should be loaded and viewed using a GIS package as a first step in quality checking.

### 4.4 Spatial Coverage

Spatial coverage check is made to ensure that each ortho-image appears in the correct location, covers enough area, and does not exhibit any void areas at along the edges due to improper projection or re-projection. This can be conducted by overlaying a vector file representing the bounding box of the corresponding BCGS grid tile on top of the corresponding ortho-image.

## 4.5 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.

## 4.6 Positional Accuracy

For each ortho-image, its positional accuracy is evaluated based on the delivered positional accuracy report.

## 4.7 Colour Balancing

This check is designed to identify ortho-image imperfections related to colour balancing. There should be no significant colour discrepancies between tiles or across seamlines.

## 4.8 Representation of Data and No-data Areas

No-data areas may occur in an ortho-image due to lack of photo caused by cloud, smoke, haze, or other factors. These no-data areas must be filled with void pixels whose RGB digital numbers are [0, 0, 0].

Data areas within the overall image extents must not include pixels with RGB digital numbers [0,0,0,]. In the case of 8-bit images, minimum and maximum pixel values should be limited to RGB values of [10,10,10] and [245,245,245], respectively.

## 5.0 Deliverables

For each ortho-image project:

- an ASCII file containing the positional accuracy report (See Appendix C for details).

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

- an image file in GeoTIFF and in MrSID format with the proper geo-keys and tags included (See Appendix A for details);
- an ESRI shapefile (and the associated files) containing mosaic seam lines;

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
**MrSID file:** bc_094m008_xc500mm_utm10 _2004.sid
**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

Currently the GeoBC-approved delivery media are USB3.0 interfaced hard drives formatted as NTFS.

## Acknowledgements

GeoBC 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 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

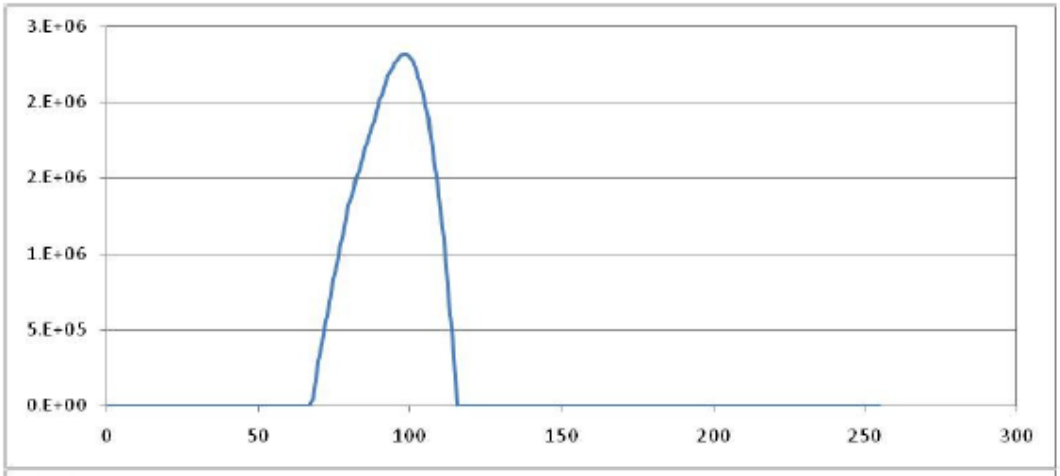
**Scale 1:10,000**

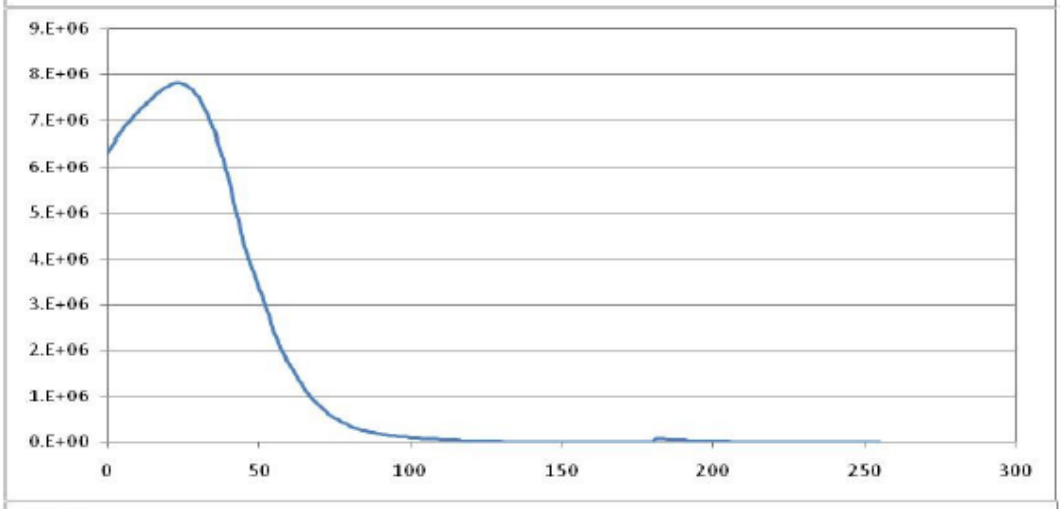
| | |
|---|---|
| 3 | 4 |
| 1 | 2 |

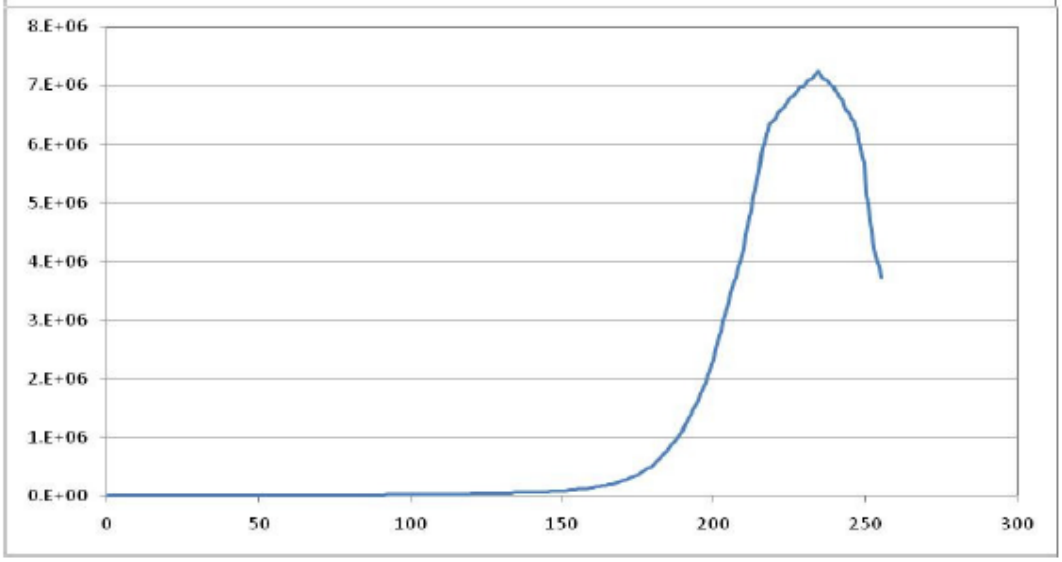
**Scale 1:5,000**

| | | | |
|---|---|---|---|
| 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 Checklist Prior to Delivery

- ✓ 3 bands (RGB) and 8-bit pixel depth per band or otherwise specified
- ✓ No-data areas of each ortho-image being filled with void pixels whose RGB digital numbers are [0, 0, 0]
- ✓ 0.5 m spatial resolution (GSD) or otherwise specified
- ✓ A Gaussian-like histogram with digital numbers spreading at least 85% of (0, 255)
- ✓ A minimum of 100-pixel over edge of each mapsheet neatline
- ✓ Seamless and complete coverage of the entire area of mapping if all ortho-images are geo-spatially placed together
- ✓ No visible geometric flaws at viewing scale of 1:4000
- ✓ No visible colour unbalancing within each individual ortho-image and across the entire area of mapping 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
- ✓ Completeness of auxiliary files: 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

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