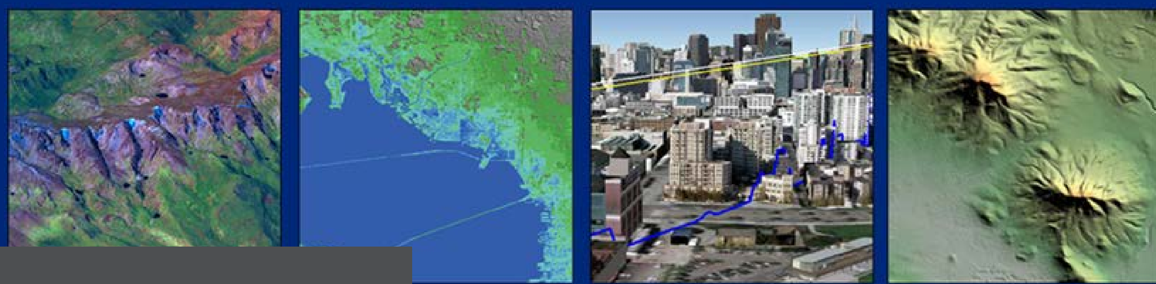

ASSESSMENT

Vertical Accuracy Assessment of NEXTMap DTM for Big Hole River, Montana

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1 Background

Intermap Technologies, a worldwide 3D digital mapping and geospatial solutions company, is pleased to announce that its NEXTMap USA IFSAR-generated digital elevation dataset, which provides coverage for the contiguous United States and Hawaii, now meets the recently released FEMA guidelines (Procedure Memorandum No. 61, dated September 27, 2010) for accuracy and density for low and medium decile watersheds. NEXTMap USA data is available immediately and is less expensive than many higher-accuracy datasets on the market.

The NEXTMap USA dataset is compatible with,, Lidar-derived data, planners now have more options than ever before to broaden their elevation data coverage for updating risk maps. For areas where Lidar data is limited, we offer a proprietary data fusion process that merges existing Lidar data with our NEXTMap data; thus, creating a seamless transition between the two datasets.

NEXTMap USA's high-resolution digital terrain model (DTM) is hydro-enforced, with elevation points removed from the tops of bridges, culverts, and other selected drainage structures – perfectly suited for a majority of the Risk MAP updates across the country. Additionally, the metadata within the NEXTMap USA DTM is fully compliant with Federal Geographic Data Committee (FGDC) standards and is easily incorporated into FEMA's Mapping Information Platform (MIP) via a simple documented process provided by Intermap. Furthermore, the Company's production, quality assurance, and quality control processes are certified according to International Organization for Standardization (ISO) 9001:2008 standards.

This report provides a statistical evaluation of the vertical accuracy of Intermap's NEXTMap DTM elevation data compared to a variety of reference sources, including elevation surfaces from the National Elevation Dataset (NED) and from reference data consisting of LiDAR and survey control points. It also identifies where the NEXTMap data covers the low and medium decile watersheds.

2 Project Site

2.1 Area of Interest

The region of interest for this report is Big Hole River, Montana. This area of interest covers 416 kilometers square and is depicted in Figure 1.

Figure 1. Study site location

2.2 Data Sets

NEXTMap Digital Terrain Model (DTM)

Intermap Technologies commercially operates several single-pass across-track 3 cm wavelength (X-HH) interferometric synthetic aperture radar (IFSAR) sensors mounted in airborne platforms (e.g., King Air, Learjet 36) which collect nationwide elevation data and imagery (Intermap, 2009). Data from these IFSAR platforms are called NEXTMap®. The NEXTMap® data are interferometrically processed by Intermap using a mature, proprietary IFPROC processor which has been used to generate over 15 million square kilometers of high quality data around the world over the past 15 years.

Intermap's X-band IFSAR system collects a first-surface model of the area being flown. This first-surface model, known as a Digital Surface Model or DSM, contains all cultural features such as buildings, bridges, and trees, etc. The DSM is derived from the return signals received by two radar antennas mounted on Intermap's aircraft. As these signals bounce off the first surface they strike, be it the ground or vegetation canopy, they result in an elevation estimate of this first surface. The DTM is derived from the DSM by experienced editors using Intermap's semi-automated proprietary stereo editing software using a set of edit rules described in the Intermap Product Handbook (Intermap, 2009). During the edit process spikes and wells in the DSM and DTM are detected and removed, voids in the data are populated with tie line and/ or overlapping flight-line data or filled in with ancillary data using a sophisticated algorithm to ensure continuity and water bodies are identified and hydrologically enforced. Hyro-enforcement ensures:

- the ocean elevation is set to 0 meters
- lakes of 400 meter diameter or more are flattened and set to a constant height
- double-line streams (> 20 meters wide) are classified and are stepped to maintain monotonicity
- single-line streams visible in the ORI and greater than 20 meters in length are delineated by vectors and are monotonically stepped

The NEXTMap DSM and DTM data are processed in 32-bit floating point format on a 5m ground sampling distance (GSD) grid using the NAD83 horizontal datum with geographic coordinates. The vertical datum is NAVD88. The data have a 1 m vertical and 2 m horizontal RMSE accuracy in regions that are unobstructed with flat to moderately sloped terrain (Intermap, 2009).

National Elevation Data (NED)

The United States National Elevation Data (NED) is a DTM (representing bare ground elevations) in geographic co-ordinates for the contigious U.S. The NED data have a horizontal datum of NAD83, a vertical datum of NAVD88, a resolution of 10 m and 30 m, and a specified accuracy of 2.4 m to 7.3 m RMSE (U.S. Geological Survey, 2004; Gesch et al., 2002; Carabajal and Harding, 2005; 2006). The NED database is the result of the maturation of the USGS effort to provide 1:24,000-scale DTM data for the conterminous U.S.

NED is a dynamic dataset that is updated bimonthly to incorporate the best available digital elevation data (e.g. aerial photo, contour maps, LiDAR, etc.), which were reorganized and combined into a seamless dataset designed to cover all United States territory. As more 1/3 arc second (10 m) data coverage is obtained it is integrated into the dataset. Comparing NED data with NGS geodetic control points, the overall absolute vertical accuracy was found to be 2.44 m RMSE (NED, 2011); i.e., much better than the expected accuracy given above.

The NED data across the United States ranged in age, with a mean age of 25 years. The variation in age differences between the NED and the NEXTMap data may contribute to the differences in the vertical accuracy assessments presented in this report. Nonetheless, the NED dataset is widely used and thus worthwhile to compare against the NEXTMap DTM data.

ICESAT DATA

The Ice, Cloud, and Land Elevation Satellite (ICESat) was an experimental scientific satellite launched by the National Aeronautics and Space Administration (NASA) in January 2003 with the Geoscience Laser Altimeter System (GLAS), which comprises three lasers (Laser 1, Laser 2 and Laser 3) as the primary instruments on board. The primary purpose of the GLAS instrument was to detect ice-elevation changes in Antarctica and Greenland (Bae and Schutz 2002, Zwally *et al.* 2002). However, the application of these data reached far more aspects than the initial purpose. These data have been used widely in other fields, including deriving sea-ice freeboard, forest canopy height, cloud heights, aerosol-height distribution and land-terrain changes, and ground control (Zwally 2010).

ICESat completed 19 successful campaigns for Earth observation missions following its launch in 2003. The Geoscience Laser Altimeter System (GLAS) on board ICESat provided data of high quality and accuracy over the globe. The three laser sensors of GLAS acquired a large volume of data between 2003 and 2010. As an active remote sensor, GLAS transmits laser pulses at a frequency of 40 Hz and illuminates the earth's surface with 60m footprints and 170 m spot spacing (Zwally et al., 2002). Over flat areas, the lowest distinct peak usually corresponds to the ground elevation if there is enough laser energy reflected from the ground. However, over mountainous areas with high relief, the peaks from ground and surface objects can be broadened and mixed, which makes the extraction of ground elevation very difficult (Harding and Carabajal).

This system provided a consistently referenced elevation data set excellent accuracy and quantified measurement errors that can be used to generate GCPs with sub-decimeter vertical accuracy. Intermap employs a unique system to filter the selection of ICESat data to remove cloud and vegetation elevations. Using this technique, a set of survey-grade reference points was obtained to represent the bare-ground elevations in unobstructed low-slope regions with a typical accuracy of 25 cm RMSE or better.

National Geodetic Survey (NGS) Control Points

The National Geodetic Survey (NGS) provides the public with survey-grade control information such as latitude, longitude, height, and quality of the survey reference point across the United States with a vertical accuracy of 30 cm (NOAA, 2011). These geodetic data include the final results of geodetic surveys, software programs to format, compute, verify, and adjust original survey observations or to convert values from one geodetic datum to another, and publications that describe how to obtain and use Geodetic Data products and services.

The NGS provides a base of reference for latitude, longitude and height throughout the United States. Vertical control stations (those with precise Orthometric Heights) were established in accordance with FGDC publications "Standards and Specifications for Geodetic Accuracy Standards" The final Orthometric Height of these stations were in most cases determined by a least squares adjustment of the vertical observations but in some cases may have been keyed from old survey documents.

Vertical control stations have Orthometric Heights displayed to 2 or 3 decimal places and are identified by attribute ELEV_SRCE of ADJUSTED, ADJ UNCH, POSTED, READJUST, N HEIGHT, RESET, COMPUTED. Geodetic Data are continuously being processed; their standards and specifications are being reviewed for next publication release. [1]

Control Distribution

The distribution of the 109 available combined National Geodetic Survey (NGS) and ICESat LiDAR reference control points in this area of interest is depicted in Figure 2.

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[1] Standards and Specifications for Geodetic Control Networks", 1984 and "Geometric Geodetic Accuracy Standards and Specifications for Using GPS Relative Positioning Techniques," FGCS (formally FGCC) publication version 5.0 1989, are most current published documents

Figure 2. Reference Control Point (red dots) Distribution over the area of interest

3 Absolute Vertical Accuracy Assessment Method

3.1 Accuracy Reporting

Absolute Vertical Accuracy

Statistical analysis was implemented with the use of the National Geodetic Survey (NGS) geodetic data points and ICESat-derived control as a combined reference source. The reference source was used to assess the absolute vertical accuracy of the NEXTMap DTM and the NED DEM data expressed as Linear Error 95%. This control data set provided a base of reference for latitude, longitude and height throughout the area of interest.

NEXTMap Data Characterization

Every post in a gridded NEXTMap DTM dataset has been characterized based on land cover type and slope class. Every post was thus assigned a class from 1 to 12 (Table 2). Each post was assessed manually for suitability and categorized based upon slope and terrain as categorized in Table 1.

Table 1.Characterization Classification

<table>
<tr><th colspan="8">Characterization Class Number</th></tr>
<tr><th>Slope (deg)</th><th>Open/Bare</th><th>Agriculture</th><th>Vegetation or Sparse Urban</th><th>Dense Urban</th><th>Dense Vegetation</th><th>Water</th><th>Void-Interpolated</th></tr>
<tr><td>0-10</td><td>1</td><td>2</td><td>3</td><td rowspan="2">7</td><td rowspan="2">8</td><td rowspan="3">10</td><td rowspan="3">11</td></tr>
<tr><td>11-29</td><td>4</td><td>5</td><td>6</td></tr>
<tr><td>> 30</td><td colspan="5">12</td></tr>
</table>

The NEXTMap DTM gridded data has a class number (i.e. 1 through 12) assigned to every post to yield what is called the data characterization mask, as illustrated for the area of interest in Figure 3.

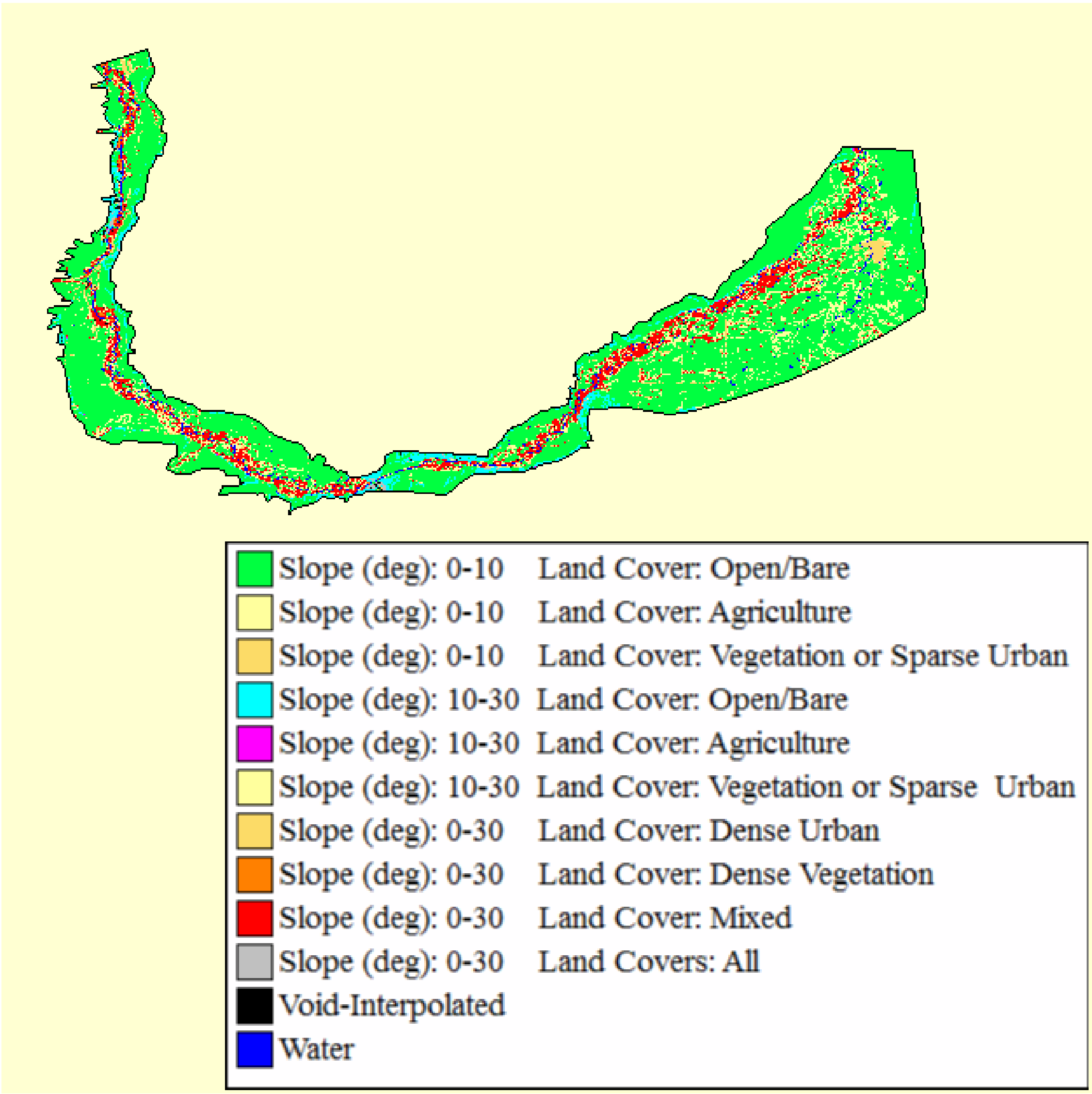

Figure 3. Data Characterization Map Example

FEMA Deciles Suitability

The map (Figure 4) was taken out of FEMA's "Procedure Memorandum No. 61 - Standards for Lidar and Other High Quality Digital Topography". FEMA uses their data assign a risk value and a risk rank to each area. The areas are grouped into 10 classes called "Risk Deciles" with 1 being the highest risk and 10 being the lowest risk. This map shows the deciles for each watershed in the US. Since the font is really small at the bottom, I have written out the 10 data that were used.

1.Total Population Density
2. Historical Population Growth,
3. Predicted Population Growth,

4. Housing Units,
5. Flood Policies,
6. Single Claims,
7. Repetitive Losses,
8. Repetitive Loss Properties,
9. Number of Streams & Coastal Miles,
10. and Declared Disasters.

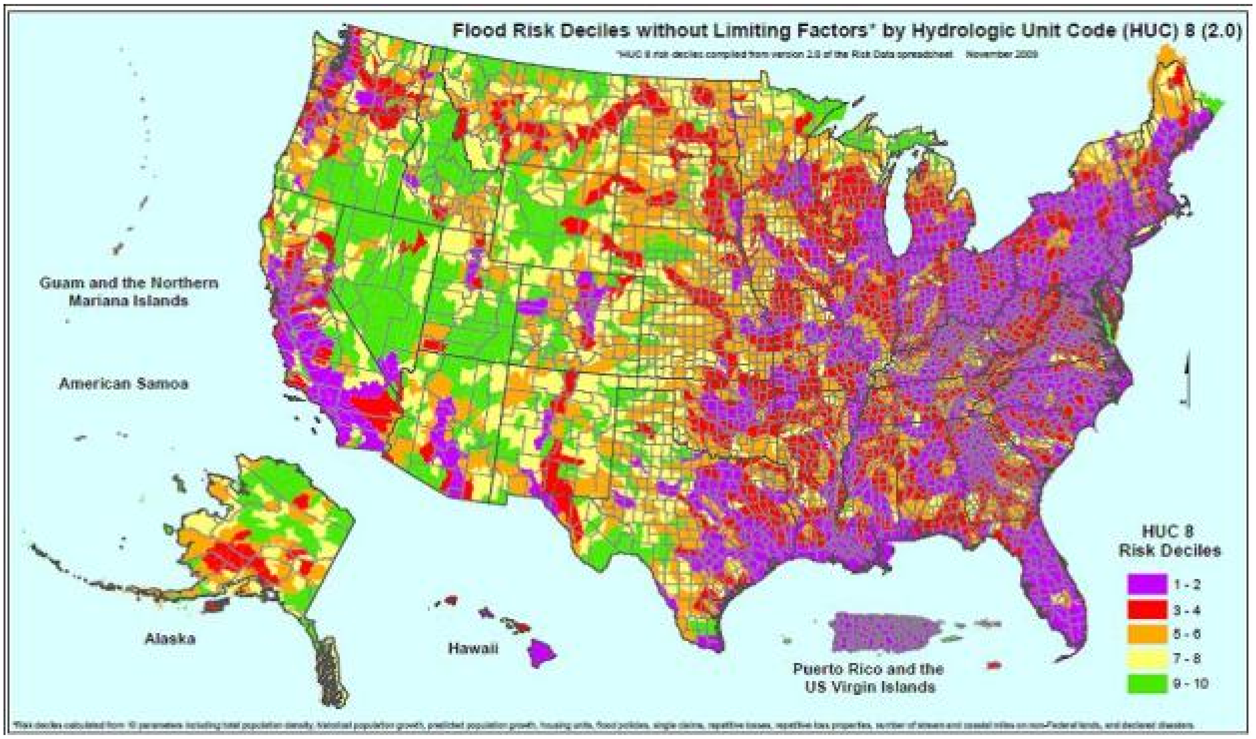

Figure 4. FEMA Deciles

The Flood Hazard Mapping Program, in the Department of Homeland Security Emergency Preparedness and Response Directorate (FEMA), has created a new flood hazard information product. The Standard DFIRM Database is a digital version of the FEMA flood insurance rate map that is designed for use with digital mapping and analysis software. DFIRM Databases have been completed for a number of communities and counties. These deciles are used as guidelines to determine what elevation data may be use to update DFIRMs.

When it comes to using Digital Elevation Models in flood modeling for DFIRM production, many users refer to Appendix A in FEMAs Guidelines and Specs. In the 2003 version, it states that this appendix is for “guidance for ground surveys of control points, cross sections, and hydraulic structures, and for topographic mapping using photogrammetry, Light Detection and Ranging

(LIDAR), or other airborne remote-sensing technologies consistent with FEMA and industry standards." However, this appendix can be somewhat confusing because it really only focuses on the specs for LiDAR and photogrammetry; the specs for "other" DEMs is somewhat vague. This document was intended to touch on elevation data requirements for the more detailed studies, where centimeter vertical accuracy is needed.

In section A.4, Data Requirements, the second paragraph states that, "New flood hazard data may be generated through detailed or approximate analyses. Updated flood hazard data may be developed through detailed or approximate analyses or re-delineation of floodplain boundaries from the effective FIRM using more up-to-date and/or more accurate topographic data than were used to prepare the effective FIRM." And the last sentence in section A.4 reads, "The requirements summarized in this Appendix are based on the assumption that suitable data do not exist from alternative sources and that new ground/aerial surveys will be required." Thus, reaffirming that the rest of the document is not intended to give the specifications for SRTM, ASTER, IFSAR, NED, etc., however, this is only a very small part of this rather large document and is easily passed over, especially when people are just looking for the specs that are required for their project.

Intermap has made it easy for end users to understand where the NEXTMap data may be used for DFIRM updates, by creating a FEMA suitability map for use with NEXTMap data. This was created using the NEXTMap data characterization mask, the NEXTMap DTM data, and the FEMA deciles specifications. Figure 5 is the FEMA DFIRM suitability map for use with NEXTMap data with explanations for deciles given in Table 2. This type of map was generated for the study site and is presented in the results in Section 4.

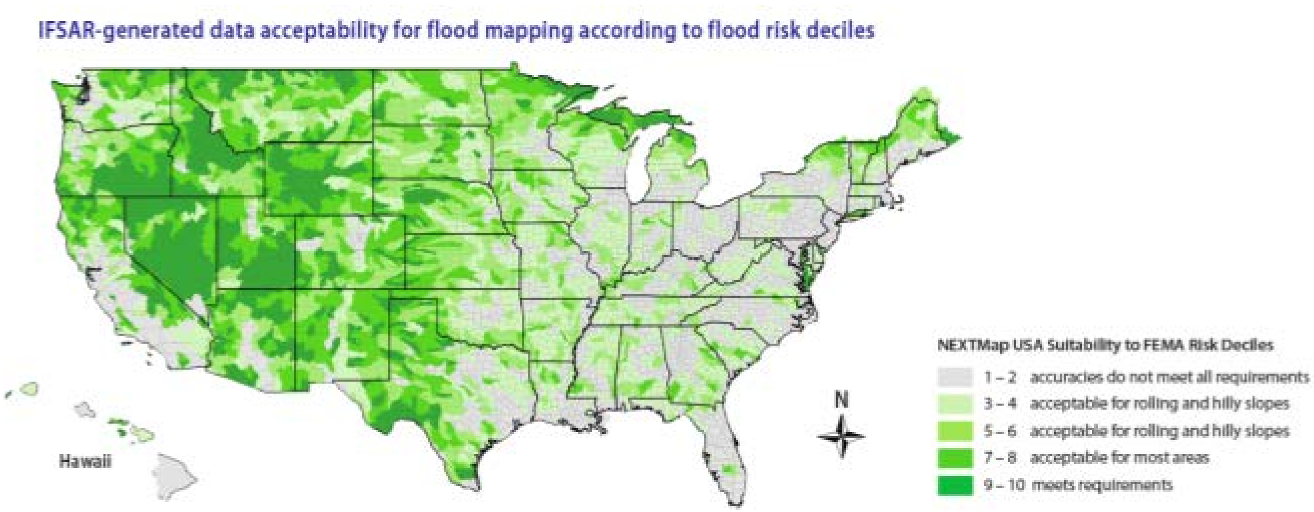

Figure 5. Data suitable for FEMA applications

The last column in Table 2 provides a comment about the suitability of the NEXTMap data per a given decile. For example the NEXTMap data meets the requirements for the low and medium deciles. The NEXTMap decile maps for the region of interest, provided in the results Section 4, may be used as a guideline to illustrate where every elevation posting of the NEXTMap DTM data falls within the FEMA decile accuracy specification.

Table 2. Data suitable for FEMA applications

Level of flood risk	Typical slopes	Specification level	Vertical accuracy 95% confidence level (FVA / CVA)	Equivalent contour accuracy	RMSE	NEXTMap USA accuracies meet minimum requirement
High (deciles 1, 2, 3)	Flattest	Highest	24.5 cm / 36.3 cm	2 ft	0.61 ft (18.5 cm)	POSSIBLE
High (deciles 1, 2, 3)	Rolling or Hilly	High	49.0 cm / 72.6 cm	4 ft	1.22 ft (37.1 cm)	POSSIBLE
High (deciles 2, 3, 4, 5)	Hilly	Medium	98.0 cm / 145 cm	8 ft	2.43 ft (73.9 cm)	YES (at discretion)
Medium (deciles 3, 4, 5, 6, 7)	Flattest	High	49.0 cm / 72.6 cm	4 ft	1.22 ft (37.1 cm)	POSSIBLE
Medium (deciles 3, 4, 5, 6, 7)	Rolling	Medium	98.0 cm / 145 cm	8 ft	2.43 ft (73.9 cm)	YES (at discretion)
Medium (deciles 4, 5, 6, 7)	Hilly	Low	147 cm / 218 cm	12 ft	3.65 ft (1.11m)	YES
Low (deciles 7, 8, 9, 10)	All	Low	147 cm / 218 cm	12 ft	3.65 ft (1.11m)	YES

Derived from table 2.2 and 2.3 of "Standards for Lidar and Other High Quality Digital Topography."

NEXTMap – NED Differencing

The NEXTMap DTM data are approximately 3-5 years old, where as the mean age of the NED data is 25 years. A difference of the NEXTMap DTM minus the NED DEM was created to illustrate the difference in elevation values between the two surfaces. The difference provides a look at the change in elevation over time.

4 Absolute Vertical Accuracy Assessment Results

Absolute Vertical Accuracy

The absolute vertical accuracy assessment analysis of the NEXTMap DTM data has shown that approximately 95% of the NEXTMap DTM data will have a vertical accuracy better than 1.89 meters or 189 cm for this site (Table 3). This would indicate that the NEXTMap DTM data for this site is suitable for Medium and Low deciles as described in the last three row of Table 2.

Table 3. NGS and ICESat LiDAR Reference Statistics [*] *for the area of interest*

Big Hole River, MT	# of Control Points	NEXTMap DTM Vertical Accuracy Compared against Control	NED DTM Vertical Accuracy Compared against Control
LE95%	92	1.89m	6.59m

The cumulative error distribution plot is shown in Figure 6 to help visualize what percentage of data can be expected to meet each level of accuracy.

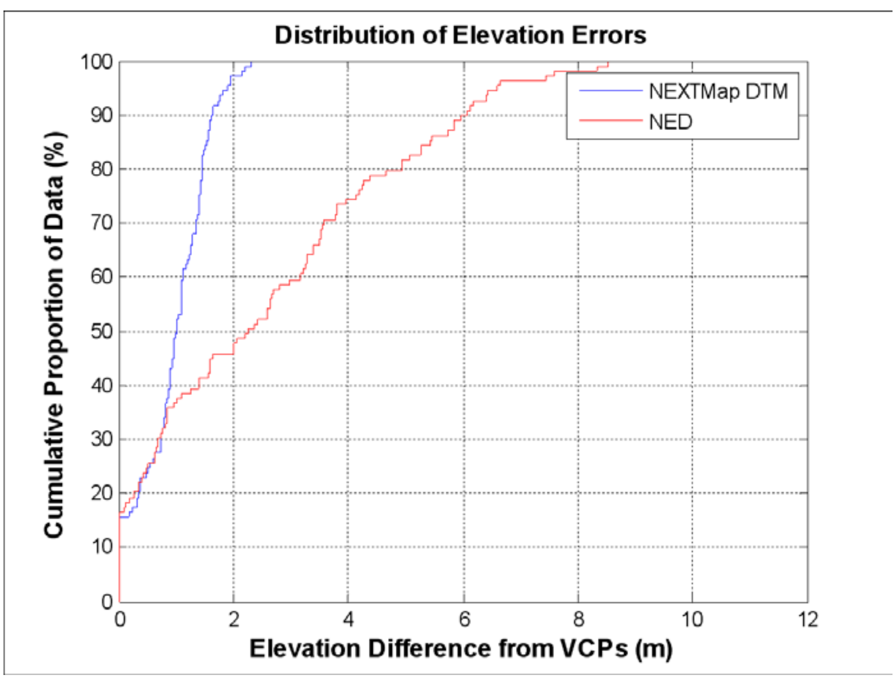

Figure 6. Cumulative Distribution of Errors for NEXTMap DTM and NED

[*] LE95% The LE95 is derived directly from the cumulative distribution. See Appendix A for detailed information about how statistics were computed.

NEXTMap Data Characterization

The NEXTMap data Characterization map depicts each elevation posting as a class number 1 through to 12, as outline in Table 1. The bulk of the study suite is dominated by the land cover open/bare in regions of terrain slope less than 10 degrees (Figure 7). This class represents the highest accuracy class for the NEXTMap data.

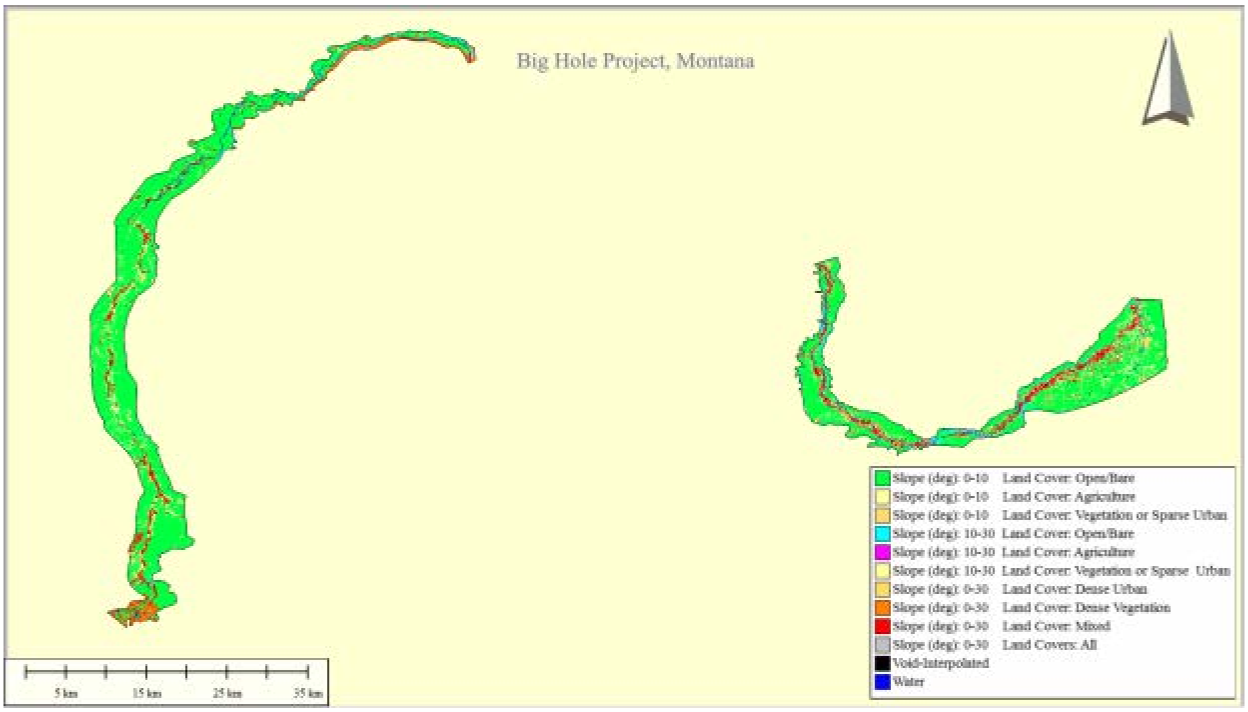

Figure 7. Data Characterization Map of Big Hole River, CO Project Area

FEMA Decile Suitability

The NEXTMap data suitable for FEMA Deciles in Big Hole River, MT is presented in Figure 7. The vertical accuracy assessment indicates a 119 cm LE95 for this site, indicating that the NEXTMap data is suitable for deciles 7-10.

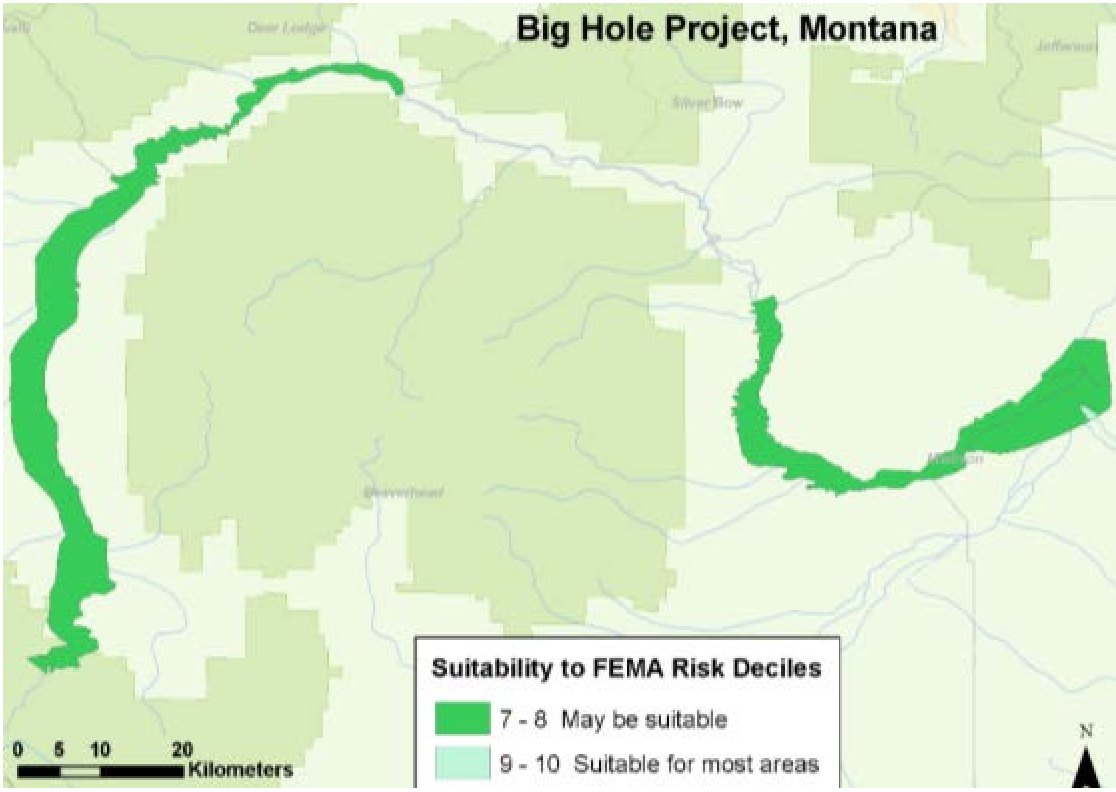

Figure 7. NEXTMap suitability for FEMA Risk Deciles

NEXTMap – NED Differencing

A map depicting the DTM – NED difference for Big Hole River, CO is presented in Figure 8 to illustrate the change in elevation between the two datasets due to the difference in their age.

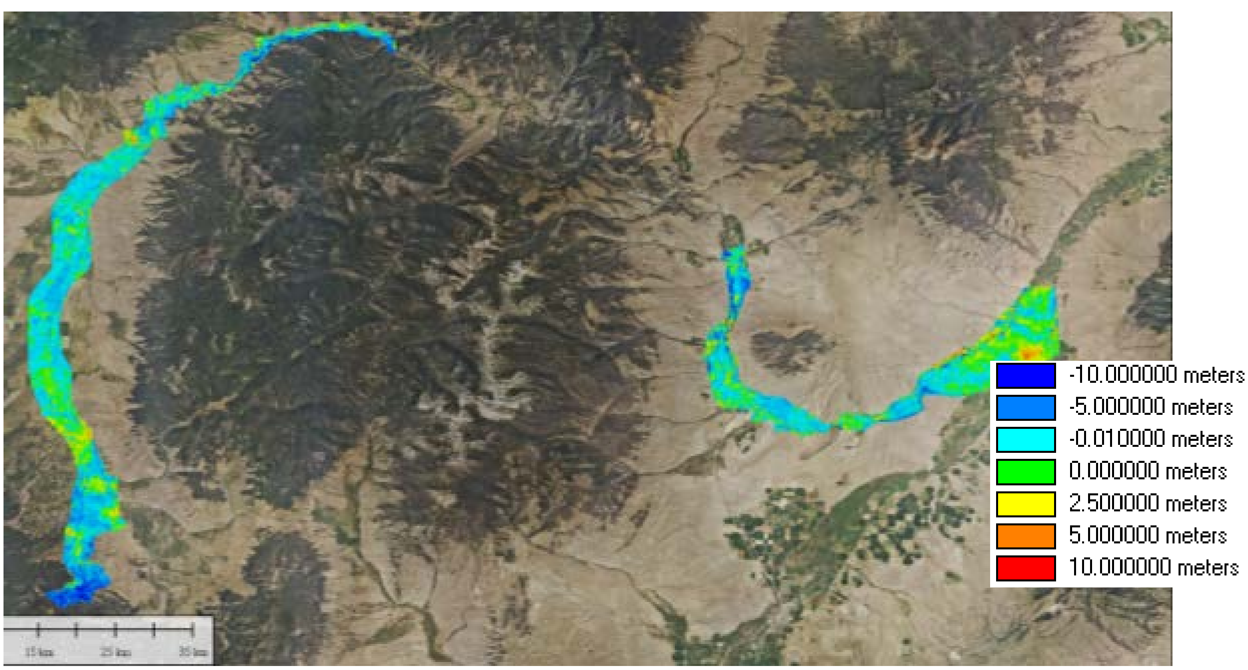

Figure 8. NEXTMap DTM minus NED Difference Surface Overlaid on the NAIP Imagery

5 Quality Management

Intermap maintains a Quality Management System that is compliant with ISO 9001:2008 standards and has been certified by Underwriter Laboratories DQS, Inc. since 1999. All process documents and work instructions are available to all staff, at all locations, and online through a central repository that is controlled by strict configuration management practices.

At Intermap, our certification encompasses the Quality Assurance organization, quality resources, and quality product criteria in a multi-faceted approach to assure the production hardware, software, and personnel produce products of exemplary quality. The Quality Assurance organization shares quality assurance responsibility with product management, the production teams, and, ultimately, the customer. Quality resources include the personnel, training, equipment, and software necessary to produce quality products and services.

As previously mentioned, Intermap and its worldwide offices are audited annually by Underwriter Laboratories. The processes in the following offices are Certified under our ISO 9001:2008 Quality program: Denver, Calgary, Jakarta, and Prague.

The certified internal Quality Assurance team conducts periodic audits of all sites and maintains the open lines of communication between Intermap and its customers.

6 Corporate Overview

Intermap is a worldwide leader in providing three dimensional geospatial solutions that allow customers to make better terrain-based decisions. By providing the best-of-breed 3D terrain information, Intermap enables commercial enterprises and government agencies to build a wide variety of innovative geospatial applications and efficiently perform analyses. Intermap is committed to helping geospatial professionals leverage the Company's products and services so they can increase productivity and decrease costs. Industries such as energy, engineering, government, risk management, telecommunications, water resource management, and automotive can benefit from the Company's high-quality 3D terrain products and advanced geospatial services.

Intermap has proactively remapped entire countries and built uniform national databases, called NEXTMap, consisting of affordably priced elevation data and geometric images of unprecedented accuracy. NEXTMap Europe, consisting of 3D digital elevation data for all of Western Europe, was made commercially available in May 2009; NEXTMap USA, comprising the contiguous United States and Hawaii, has been commercially available since the second quarter of 2010.

Intermap meets the challenge of its mission through the use of its proprietary interferometric synthetic aperture radar (IFSAR) technology. IFSAR provides a cost-effective method of data collection that results in highly accurate regional and national mapping products. Since the commercialization of this technology in 1996, Intermap has continued to invest significantly in research and development. Improvements in sensor technology, processing tools, and workflows have helped Intermap to make significant leaps in the quality and accuracy of the data, and have helped to keep prices competitive.

Intermap has undertaken some of the world's largest mapping projects and has performed custom and licensed mapping in more than 85 countries. The Company's data covers more than 15 million km^2 on six continents.

A Appendix A

Geospatial data are generated using devices (e.g. radar sensors) that are subject to various kinds of perturbations and noise. The common model to characterize the associated errors is that of a combined systematic and random error composite. While the random part can be conveniently analyzed on the basis of normally distributed data it is more difficult to include the systematic contribution as it generally does not adhere to a mathematical model. The following accuracy measures will therefore be mainly restricted to the random error while it is assumed that the systematic component can be eliminated through additional knowledge (e.g. ground truth, proper calibration, etc.).

In general, the data set under investigation has to be tested against a reference source. For elevation data this is typically a model from an independent observation, sometimes acquired with a different technique (e.g. LiDAR). It is essential that the reference information is of superior accuracy so that the accuracy estimation yields a meaningful result. As a rule of thumb the reference data set should be better by at least one order of magnitude (or a factor of 10). Comparing against a reference source of similar or inferior accuracy may still prove useful in the identification of blunders, but careful consideration and investigation is required in order to properly interpret the results.

LE95

LE95 stands for "Linear Error 95". This accuracy descriptor specifies the so-called 95% confidence interval, which is the (one-dimensional) range within which 95% of the data values lie. In other words, if the LE95 is specified as 1 m then 95% of the samples have an error less than or equal to 1 m and 5% of them are allowed to have a larger error.

In general, the LE95 can be determined for data with or without systematic error components, however only in the case of negligible mean (i.e. normally distributed data with zero mean) can it conveniently be described in a mathematical sense. Then, the LE95 covers the area under the Gaussian curve with a radius of 1.96σ around zero. Since 1.96 is very close to 2, the LE95 is often synonymously used with the term *2σ error*. Figure 6 illustrates the area under the Gaussian distribution curve covered by the LE95 interval. Since geospatial data rarely meet the criteria of zero mean and normal distribution, the LE95 value cannot be derived mathematically. For the purposes of this report, the LE95 (and LE90) values are not computed mathematically, but are derived directly from the cumulative error distributions. This ensures the values are exact and not statistical approximations.

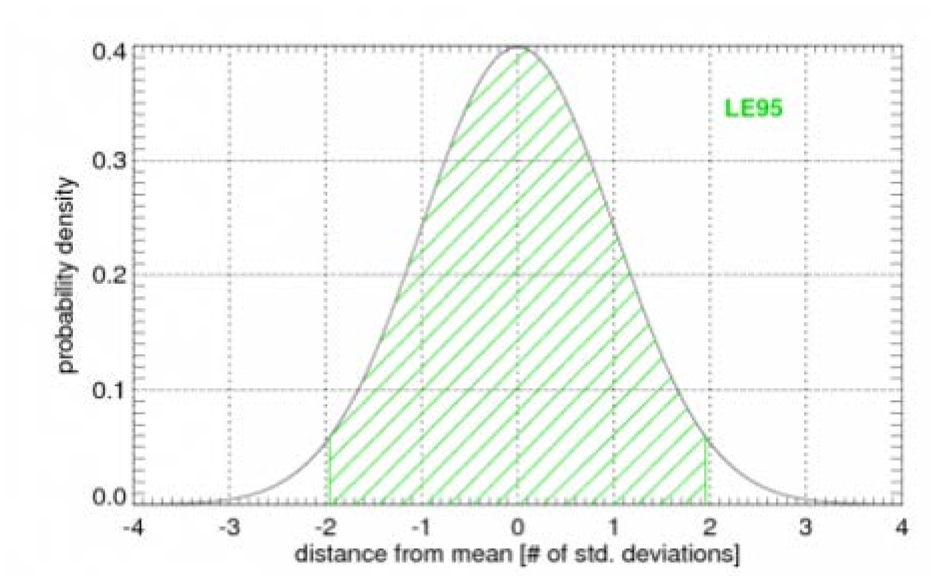

Figure 10. Normally distributed error, with the shaded area corresponding to LE95 or 95% confidence interval covering 95% of the area under the Gaussian Curve

The LE95 is a quasi-standard in the US mapping community for vertical accuracies, used for instance by FGDC (*Federal Geographic Data Committee*) as their *National Standard for Spatial Data Accuracy* (NSSDA).

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