Digital Elevation Model for 3D Cadastre Visualization in WebGIS Bhumi: Jakarta case study

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Keywords: 3D Cadastre, 3D Visualization, Digital Elevation Model, WebGIS, Cesium Terrain

SUMMARY

Elevation is an important aspect in cadastral 3D data visualization. The research at Pusdatin building of the Ministry of Agrarian Affairs (ATR) shows that the use of a digital elevation model from Lidar measurements presented in Cesium Terrain format can represent more accurate topographical conditions in the 3D data visualization of the building in WebGIS Bhumi. Accurate topographical conditions are important considering that the legal space for 3D data can be above or below ground level (Government Regulation No. 18/2021). Spatial information presented on WebGIS Bhumi will be consumed by the public so that the data presented should not cause public confusion, including in cadastral 3D data visualization.The legal space above the ground may have different legal treatment from the legal space below the ground. However, after other 3D data such as the MRT station in Blok M and the HI roundabout Jakarta is displayed in Bhumi's WebGIS, the data is not correctly match on the terrain surface. This could be due to the height difference between the terrain surface and the ground zero used in the 3D model. In addition, the terrain conditions presented by Cesium Terrain by default in the area around the HI roundabout are uneven even though the area should be flat considering the HI roundabout is in an urban area. This can be corrected by changing the default terrain provided by Cesium with a more accurate digital elevation model. An accurate digital elevation model can be obtained from the results of Lidar measurements, but the procurement of a Lidar DEM is expensive, so it may need to be done in stages. The most accurate digital elevation model currently available in Indonesia is DEMNAS. In this paper, DEMNAS data will be tried to be converted to the Cesium Terrain format which is then presented on WebGIS Bhumi. This project aims to provide more accurate topographical conditions in presenting cadastral 3D data on WebGIS Bhumi. This project will also produce a DEMNAS topographic surface service in Cesium Terrain format which can be used in 3D WebGIS development using Cesium.

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1. INTRODUCTION

Digital Elevation Model (DEM) is a digital image of elevation, topography, and/or bathymetry that describes the "elevation" of the ground surface, exclusively from man-made structures, vegetation, or whatever other objects on the ground. DEM used prominently in infrastructure planning and mapping, urban environmental planning, drainage and green landscaping, agriculture planting and irrigation strategies, ecological modeling, and geological applications (Croneborg et al., 2020). Since elevation is an important aspect in cadastral 3d data visualization, DEM is necessary to be used as a base terrain on 3D cadastre objects.

Spatial information presented on WebGIS Bhumi will be consumed by the public so that the data presented should not cause public confusion, including in cadastral 3D data visualization. The legal space above the ground may have different legal treatment from the legal space below the ground. However, after other 3D data such as the MRT station in Blok M and the HI roundabout Jakarta are displayed in Bhumi's WebGIS, the data is not correctly matched the terrain surface. This could be due to the height difference between the terrain surface and the ground zero used in the 3D model.

Since Bhumi used Cesium JS for 3D data visualization, the default base terrain used by Cesium in those areas of interest is SRTM DEM (Shuttle Radar Topography Mission). This can be noticeable by looking at the attribution given by cesium where in Indonesia coverage, commonly terrain was credited by USGS (U.S. Geological Survey) and CGIAR-CSI (Cesium JS, 2022). In addition, the terrain conditions presented by Cesium Terrain by default in the area around the HI roundabout are uneven even though the area should be flat considering the HI roundabout is in an urban area. This can be corrected by changing the default terrain provided by Cesium with a more accurate digital elevation model. An accurate digital elevation model can be obtained from the results of Lidar measurements as we can see on previous project related to 3D Cadastre data visualization on Web (Mulyadi et al., 2022). However, the procurement of a Lidar DEM to cover all Indonesia area will be very expensive so it may need to be done in stages. The most accurate digital elevation model currently available in Indonesia is DEMNAS.

In this paper, DEMNAS data will be tried to be converted to the Cesium Terrain format which is then presented on WebGIS Bhumi. The area of study will be focusing on two locations of MRT stations in Jakarta city (HI roundabout Station and Blok M Station). This project aims to provide more accurate topographical conditions in presenting cadastral 3D data on WebGIS Bhumi. This project will also produce a DEMNAS topographic surface service in Cesium Terrain format which can be used in 3D WebGIS development using Cesium. This terrain service can also be equipped with DEM data that is more thorough in stages such as DEM from Lidar measurements.

2. PREVIOUS WORKS AND RESEARCH

Stoter (2013) considered the interoperability of geo-services used for 3D cadastre visualization on the web by applying OGC standards, including WMS (Web Map Services), WFS (Web Feature Services), WCS (Web Coverage Services), and WTS (Web Terrain Services). WTS defines how to create views out of 3D data, like city models and digital elevation models. Stroter also states that the elevation terrain aspects should be treated with field-based models (raster) for spatial models rather than the object-based models (vector) approach due to terrain information is different to cadastral data characters such as parcels and property.

Kuliawak, et al. (2013) tried to disseminate the results of LiDAR surveys of some objects in the city of Gdansk to web. They used open-source technologies for web visualization (Cesium) and data distribution, such as 3D Tiles, LASer (LAS), and Object (OBJ). The object visualized in this paper is not a topographic surface that has continuous characteristics so the data format used in this paper will be different.

Koeva, et al. (2013) Investigate the opportunities for updating 3D cadastral objects in order to understand the possibility of the change detection of the cadastral object. The technology used is Lidar, Point Clouds derived from high-resolution imagery and maps to provide semantic information about the land cover and 2d information of cadastral objects. They also recommend the combinations with other point cloud data obtained from terrestrial laser scanning technology or Building Information Models (BIM), construction plans, CAD, and GIS data as additional information for automatic detection of changes.

Mulyadi, et al. (2022) develop a web-based 3D cadastre prototype on WebGIS Bhumi by integrating Building Information Modelling (BIM) of ATR/BPN's PUSDATIN building, DEM from Lidar measurements, orthophotos, and 2D land parcels. Cesium-ion cloud platform was used to generate Cesium Terrain from DEM Lidar.

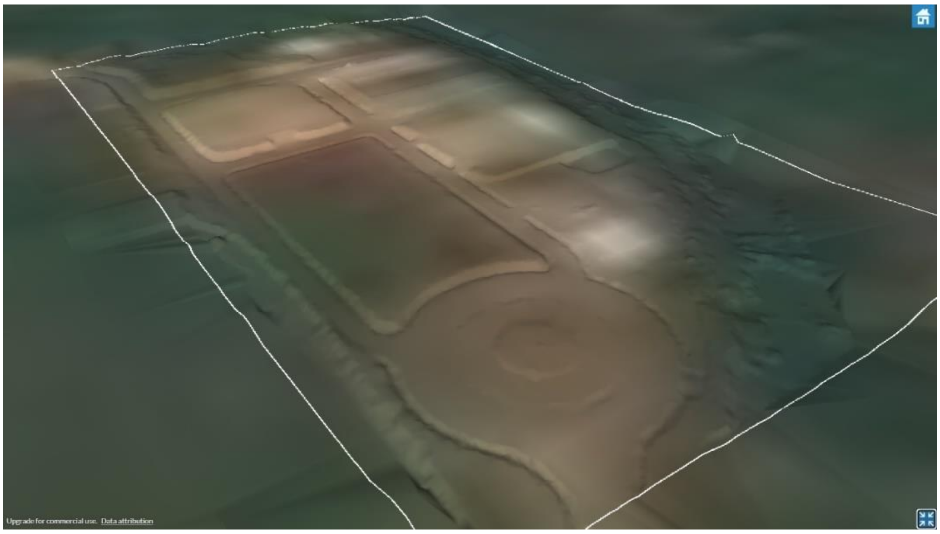

Figure 1. DEM Lidar as Cesium Terrain format in Cesium ION
(Mulyadi, et al., 2022)

Orthophotos in XYZ Tiles as a base map draped to DEM Lidar in Cesium terrain format produced more realistic 3D environment that represents real topographical conditions

The use of Cesium Terrain format recommended to publish more accurate DEM as 3D terrain. The DEM data can also be sourced from DEMNAS (DEM Nasional from BIG) as default if locally Lidar data is still not available. In this paper, we will proceed to create and testing Cesium Terrain services from DEMNAS.

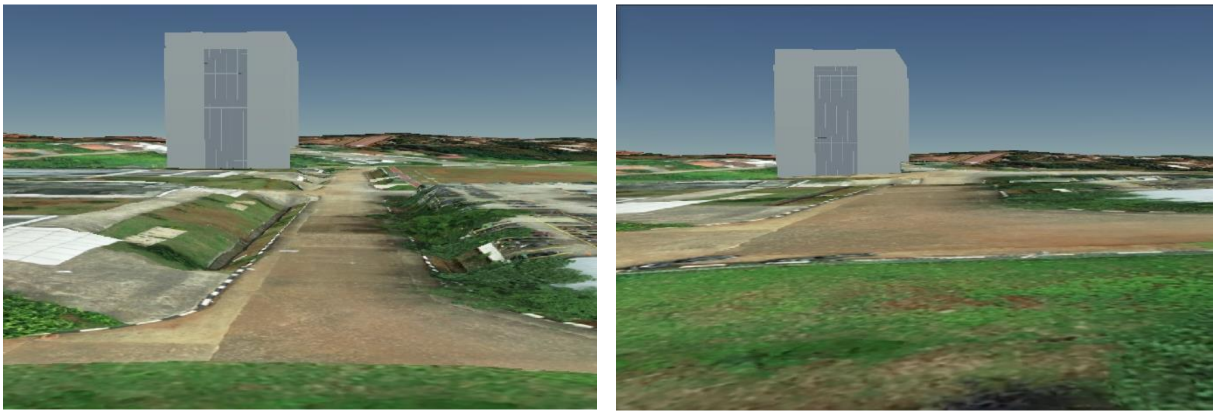

Figure 2. Cesium terrain from Lidar DEM (left) and default terrain (right) (Mulyadi, et al., 2022)

3. ISSUES AND PROPOSED SOLUTION

3.1. Default Terrain used in WebGIS Bhumi

Cesium World Terrain is a default terrain service in quantized-mesh format provided by Cesium so we can just use it as base terrain when we have no terrain data available to used. Cesium World Terrain fuses several data sources into a single quantized-mesh terrain tileset.

This terrain service has global coverage while the default terrain used in Indonesia coverage is SRTM (Shuttle Radar Topography Mission) with approximate spatial resolution in 30 meters (Cesium JS, 2022). Currently, Bhumi WebGIS use this default services to display base terrain in 3D visualization mode. However, after 3D data such as the MRT station in Blok M and the HI roundabout Jakarta was visualize, the data is not correctly matched the terrain surface as illustrated on **Figure 3**.

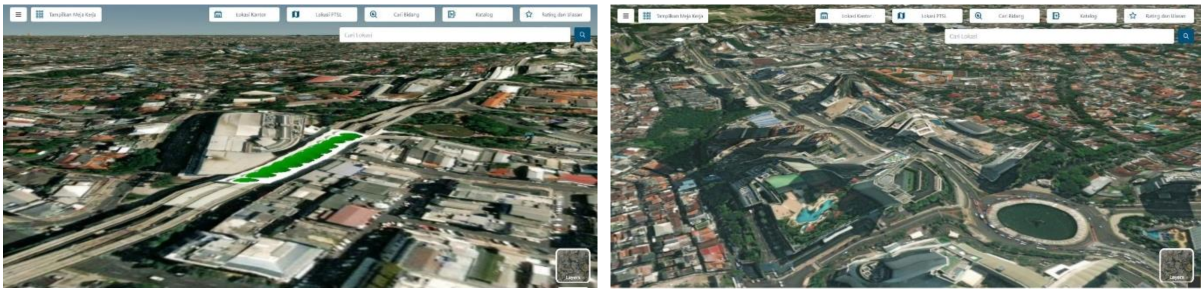

Figure 3. 3D model of Blok M (left) and HI Roundabout stasion (right) visualized on Bhumi

This could be due to the height difference between the terrain surface and the ground zero used in the 3D model. Cesium World Terrain services which is based on SRTM use EGM96 (Earth Gravitational Model 1996) as vertical datum (USGS, 2018). The MRT station 3D model were obtained by 3D BIM modeling captured from the Terrestrial Laser Scanner (TLS) surveying. The elevation of 3D model has been registered InaGeoid which is based on EGM2008 as global geoid model. In addition, the terrain conditions presented by Cesium Terrain by default in the area around the HI roundabout are uneven even though the area should be flat considering the HI roundabout is in an urban area.

3.2. Quantized-mesh Terrain format

Cesium Terrain is Quantized-Mesh format to fast render 3D objects on Cesium. A terrain tileset in quantized-mesh format is a simple multi-resolution quadtree pyramid of meshes (CesiumGS, 2022). The level of detail is controlled by zoom level and each terrain is splitting into a single tile with coverage.

zAll tiles have the extension *.terrain* and will be categorized based on zoom level for each directory. This format will be very effective when applied to wide terrain coverage, considering the possibility of creating more precise terrain base from DEM data for national coverage (Mulyadi et al., 2022).

At the time this paper was written, there are various ways to create Cesium-compatible terrain services. Platforms such as Maptiler Server and Cesium ION provide facilities to generate and publish terrain services with certain limitations.In this paper, the author is curious to make terrain tiles from DEM data with open source tools callsed CTB (Cesium Terrain Builder) that can be found in the github repository (https://github.com/geo-data/cesium-terrain-builder).

3.3. Custom Terrain services from DEMNAS

As explained in the previous chapter, the ability to create our own custom terrain and not depend on the default terrain can be a solution to the problem of incompatibility of 3D cadaster data with the base terrain on Bhumi WebGIS. Procurement of Lidar data can be a good solution to complement the base terrain. However, the cost for Lidar measurements is relatively expensive, it needs to be done in stages and utilize DEMNAS as the default terrain.

DEMNAS (National DEM) is Digital Elevation Model published by BIG (Geospatial Information Agency) for Indonesia coverage. This DEM was built from several data sources including IFSAR data (5m resolution), TERRASAR-X (5m resampling resolution from 5-10 m original resolution) and ALOS PALSAR (11.25 m resolution), by adding mass point data used in making Indonesian topographical maps (RBI).

The spatial resolution of DEMNAS is 0.27-arcsecond (approximately 8 meters), using the EGM 2008 vertical datum. The approximate of spatial resolution of DEMNAS is more precise than SRTM as default DEM used by Cesium World Terrain. DEMNAS data can be downloaded for free via the following url (https://tanahair.indonesia.go.id/demnas). Because the 3D data to be tested is the MRT Station in Jakarta, the DEM index to be used is inside coverage of Jakarta as shown in **Figure 4**.

Figure 4. DEMNAS index of DKI Jakarta area.
(https://tanahair.indonesia.go.id/demnas)

4. METHODS

4.1. Tools and Technology

In this paper, the author tries to choose an open-source solution with the consequences of its limitations. Using Cesium ION does make it easier to create a quantized-mesh terrain format from DEM data, but it is limited to certain storage for free. Cesium provides a number of different sources for terrain data. Cesium Terrain Builder (CTB) is an open-source library that can be used to create the tilesets that sit behind a terrain server used by CesiumTerrainProvider.

DEMNAS was converted to quantized-mesh Terrain format by using Cesium Terrain Builder (CTB). This tool was developed based on C++ and compatible to be rendered on Cesium Javascript library through *CesiumTerrainProvider* JavaScript class. The output of this process are batch of folders named based on zoom level. Each folder contains a folder that shows the position of the terrain on the Y-axis line. Inside that folder, there are files with the .terrain format named according to the position on the X-axis. This quantized-mesh terrain format is then published as terrain services using Nginx web server. **Figure 5** is an illustration of the tree structure of the quantized-mesh terrain dataset generated by CTB.

Figure 5. Tree structure of quantized-mesh format dataset for zoom level 17 and 18

4.2. Data Flows

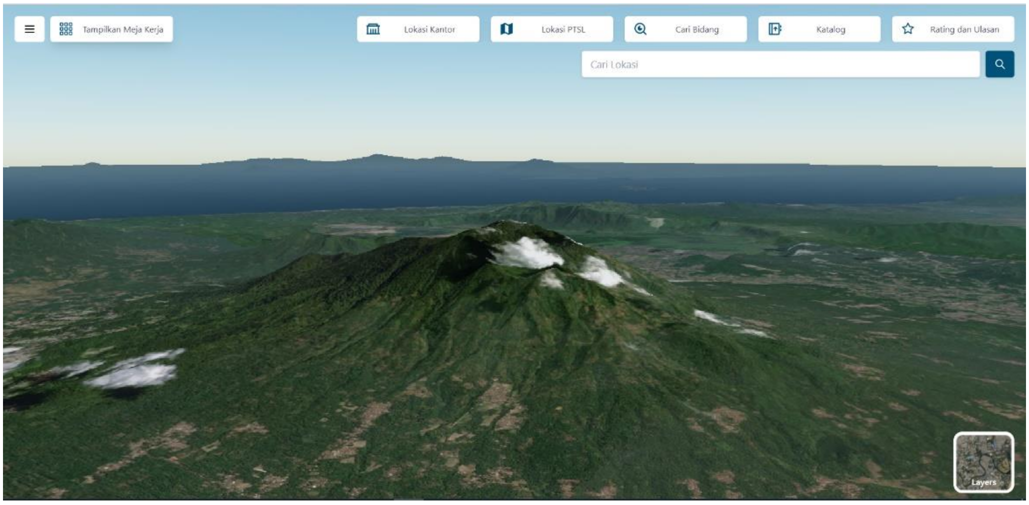

Figure 6. Terrain service visualized on Bhumi

Mulyadi et al., (2022) recommend that each of the Cesium 3D tiles, terrain, and XYZ tiles needs to be set up as services to support scalability of the web-based 3d cadastre system so that each system can be expanded and updated easily both in data storage or feature improvement. Raw data from BIM data, orthophotos, and DEM were converted to tiles format based on their functionality. Those data are then published in the form of services so that they are accessed not only on one platform but on more than one platform.

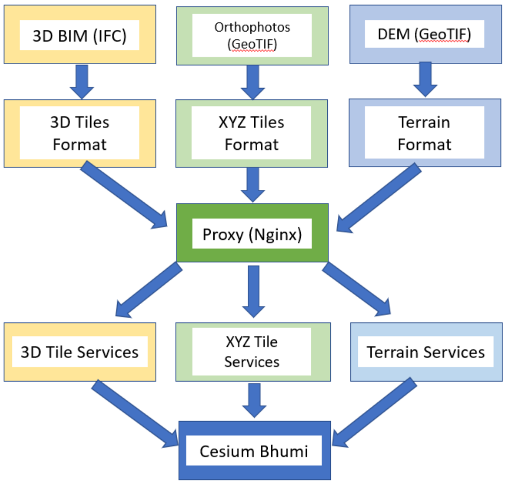

Figure 7. Data flows from raw data to services

Figure 6 illustrates how the terrain service is read and visualized in Bhumi's WebGIS. The data flow for 3D tiles from BIM and XYZ tiles from orthophotos format are also defined as services. **Figure 7** showing that these formats (Terrain, 3D Tiles, and XYZ Tile) are published using Nginx web server as a tile service that can be consumed by WebGIS Bhumi and another platform with supporting framework.

5. IMPLEMENTATION OF DEMNAS TERRAIN SERVICES

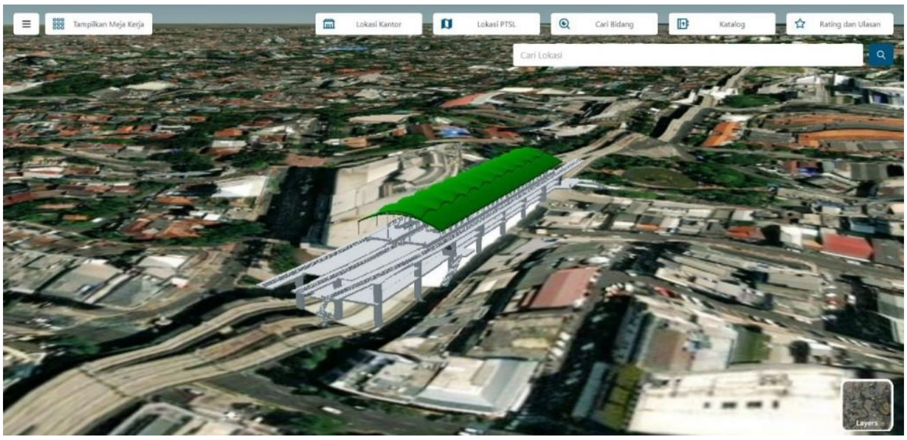

Figure 8. Model 3D of Blok M stasion with DEMNAS as base terrain

After the terrain custom service from DEMNAS was implemented in Bhumi WebGIS, the 3D model of the MRT station in Blok M was located relatively precisely on the topographical surface. However, there is still an uneven topographical surface around the 3D object as illustrated in **Figure 8**. The foundations of the block M stations are also still located under the suspected terrain due to an inaccurate DEM elevation definition due to the uncorrected surface of the flyover. If we look at the real conditions of the MRT train line at the Blok M MRT station, it is indeed a flyover.

The same result also occurs in the 3D model of the HI roundabout MRT station. The HI roundabout station which is located below ground level is more appropriate than using the default terrain as illustrated in **Figure 9**. Some parts of the station are still above ground level which is the access door to the bottom of the MRT station. The topography conditions around the station also still show uneven conditions. Both cases are suspected to be due to digital surface models obtained from DEMNAS which are still not perfectly corrected so that buildings and flyovers are still considered terrain. Another allegation is due to the incorrect rendering of the quantized-mesh terrain format on the Cesium web page.

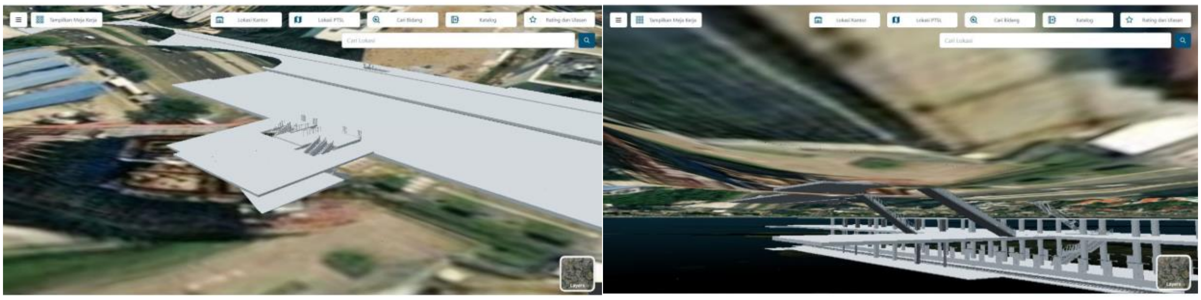
Figure 9. Model 3D of HI Roundabout stasion under ground (left)
and above ground (right) with DEMNAS as base terrain.

7. DISCUSSION AND CONCLUSION

The results of implementing DEMNAS as a base terrain in WebGIS Bhumi provide more actual topographical conditions instead of using default cesium world terrain services. The 3D model of the MRT stations at Blok M and HI roundabout are in a more suitable vertical position. However, the topography is still uneven even though it is better than the default terrain. This can be caused by 2 factors, (1) The rendering process is not correct on Cesium and (2) the DEM is still not completely clean from the canopy. Considering that the area is an urban area full of high buildings, it seems like the DSM (Digital Surface Model) to DEM conversion process is still not perfect and causing the wrong elevation.

Incorrect elevations that are only represented by pixel values may result in other errors when rendering to cesium terrain format. Based on our research regarding to implementing of DEM as base terrain on 3D cadastre, there are some aspects that need to be noticed such as:

1. The use of DEMNAS as a terrain base is still not fully optimal, so it is necessary to collectively provide DEM data with high resolution, such as using Lidar for 3D cadastral needs. Development of a platform to collect DEM data collectively and publish it as a terrain service is highly recommended. This platform can adopt a petadasar application (https://petadasar.atrbpn.go.id) where the platform provided to collect high-resolution aerial images for each regional office and publish them as tile service. Indrajit et al. (2020) also recommended local governments to provide an accurate Digital Terrain Model for the entire urban area using mapping technologies like Lidar.
2. The height reference system used for the 3D cadastre needs to be agreed upon. The height system used to define 3D cadastre data such as legal spaces must be the same as the system used to define height in Lidar data. The usage of orthometric height system was important considering that geoid model is an ideal height reference to define the elevation of cadastral objects because of its consistency and physical realization on the earth's surface (Heliani et al., 2013). The INAGEOID 2020 model as a national vertical geospatial reference system which is an orthometric height system can be used as a reference in defining a height system. Of course, there needs to be further study to agree on the height system used and the definition of ground zero.
3. The tools for creating quantized-mesh terrain formats for Cesium need to be further developed with respect to height systems as Cesium-ion gives us options for height systems (EGM 2008 or Ellipsoid). It is also necessary to pay attention to the sustainability of the tools used so the tools can refer to any update standards published by the OGC (Open Geospatial Consortium). These tools should also be open-source as used in this paper.

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