HERITAGE DOCUMENTATION AND DIGITAL PRESERVATION: THE USE OF CLOUD-BASED SERVICES FOR HERITAGE CONSERVATION (THE CASE OF ST. ALBERT RIVER LOTS)

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ABSTRACT:

Climate change has become, among countless pressures, a dominant threat to heritage places. It is critical to identify, analyse, assess, and mitigate immediate risks, and manage unforeseeable, unavoidable, and adverse impacts of climate on heritage values. There is an urgency in the heritage field to identify practical, efficient, and repeatable ways to document and monitor the condition of diverse heritage resources and develop climate adaptation strategies. Digital technologies, cloud computing, and digital preservation of heritage places can play a vital role in support of condition assessment, conservation planning, and sustainable management of heritage resources. This paper discusses a pilot project that experiments with the application of this idea on a selected case study, St. Albert River Lots in Alberta, Canada, and examines the challenges and opportunities of employing Amazon Web Services (AWS) and other Cloud-based applications. The project aimed to prepare a 3D model, as a foundation for recording current conditions and a tool for monitoring the impacts of climate change on heritage aspects and values in order to assist with the preparation of a detailed conservation management plan for the place in a digital format and contribute to the interpretive programming activities and raising public awareness.

1. INTRODUCTION

This paper outlines the processes and preliminary results of an ongoing pilot research project that focuses on the application of cloud computing services to facilitate heritage documentation and digital preservation of heritage resources. The project involves St. Albert River Lots in Alberta, Canada, and will contribute to a larger research idea on the Climate Vulnerability Index (CVI) and its potential application in heritage conservation practice in Canada which is currently under development. Heritage resources are at risk because of climate change. There is an urgency in the heritage field to identify practical ways to document and monitor the condition of diverse heritage resources and develop climate adaptation strategies. To this end, the Elastic Compute Cloud (EC2) from Amazon Web Services (AWS) is utilised to access on-demand computing system resources, in particular data storage and computing power, without direct active management by the research team. This pilot project could serve as a model for rapid documentation of heritage places as faster processing at reduced costs could be achieved. The project digitally documented River Lots 23 and 24 to construct a virtual model representing the sites in their current condition. This baseline model can be used to monitor the impacts of climate change in the near and far future. The existing archival and background information inform the project and complement the virtual model with additional information. The development of an informative virtual model can provide site stewards a valuable tool for decision-making, planning, and managing interventions (professional conservation projects) and interpretation and presentation initiatives (engaging communities and raising public awareness).

2. CONTEXT AND HISTORICAL BACKGROUND

The two historic river lots located in the City of St. Albert; the oldest, non-fortified community in Alberta in western Canada. River Lots 23 and 24 are designated Municipal Historic Resources protected under Alberta Historical Resources Act (Revised Statutes of Alberta, 2000, Chapter H-9) and are managed by St. Albert Arts and Heritage Foundation. The river lots are significant heritage resources and valuable examples of a form of land division that were transferred to western Canada from Québec; "the long-lot survey introduced to Canada in 1630s came from eastern Normandy." (Haris, 1984, xix) The River Lot System can be viewed as cultural patterns across the landscape, as evidence of the interaction between people and the land and the manifestation of the applied knowledge of various cultural groups and their understanding of the surrounding environment. The river lots followed the organic form of the river as the focal point. The narrow and long lots varied in size and shape, and due to geographic constraints, they were often irregular. The type of settlement buildings found on the river lots are also unique and representative of different era construction style built from local resources, in this case logs from spruce trees from the adjacent spruce forest now recognised as a Municipal Historic Resource. The location of buildings and structures on the lots is another distinctive characteristic of the river lots; access to water for food, farming, and transportation was as important as building family houses near houses in the neighbouring lots. River lots are not a common feature in Alberta and were a unique type of living cultural landscape. The surviving river lots represent the transition from a historically rural/agricultural landscape to the present-day urban landscape. St. Albert developed from a Mission Settlement (established in 1861) and Métis Settlement

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into an agriculture community with river lot farms and now a thriving city.

Today, River Lot 23 and 24, and historic houses and agricultural buildings within them, are historic sites that are open to the public and tell the story of the early settlement. These sites are “a window into Métis[1] life in the twentieth century; life at home, at work, and in the community as a whole.” (Buckingham, 2000, 1) The two buildings on River Lot 23 were moved to this location in 2000s; however, the other two houses on River Lot 24 “are considered ‘in situ’ which means they remain in their original location on the landscape.” (St. Albert Arts and Heritage Foundation, 2023; 2015). These two houses are Cunningham House (c 1912), a one and one-half storey frame structure built on an almost square plan and Hogan/Belcourt House (c 1900), a storey and one half-storey gable-roofed structure located on the east side of River Lot 24 (Larmour, 2017).

These historic houses and buildings cannot be conserved in isolation and should be considered within the larger context including their natural and historical contexts and intangible values as they relate to the community. As cultural landscapes, they require an inclusive and holistic conservation and management approach that protects the sense of place and identity and strengthens its distinctiveness and uniqueness. The City of St. Albert’s Heritage Management Plan prioritizes heritage conservation strategies for the next ten years. “Heritage Education and Awareness” is part of “Strategy 2: A Broader Recognition of Heritage” of this plan that lists action item “2.2.4 Preserve and interpret River Lots 23 & 24 part of the implementation of the Heritage Sites Functional Plan.” (2013, p. 12) 3D models can be utilized to document and safeguard both tangible and intangible values of the site and tell the stories and layers of history of the river lots. Virtual visitors can learn about Métis Culture and “how Métis people made their imprint on Alberta as a province.” (Morin in Lamb & Bremness, 2020). For this purpose, the land covering River Lots 23 and 24, including structures, vegetation, and the Sturgeon River, were digitally documented.

3. DIGITAL DOCUMENTATION

3.1 Data Acquisition Workflow

A Remotely Piloted Aircraft System (RPAS or drone) is “a set of configurable elements consisting of a remotely piloted aircraft, its associated remote pilot station(s), the required command and control links and any other system elements as may be required, at any point during flight operation (ICAO 2011).” The instrument primarily used for this project, the DJI Mavic 2 Enterprise Dual, is a foldable, portable, long-range flying camera and accessory system that enables surveying and monitoring of difficult to access resources. The unit features a three-axis gimbal stabilized camera housing a side-by-side 4K sensor for capturing visible light and a FLIR micro-camera for capturing thermal data. The drone was flown over River Lots 23 and 24 in 3 separate missions to capture a series of 1,700 oblique and nadir overlapping aerial images using the drone’s optical sensors (data size ~8GB) (Figure 1).

Additionally, a FARO Focus M70 laser scanner was used. A laser scanner is a tripod-mounted, active imaging system that collects a dense set of three-dimensional points in a large angular field of view by deflecting a laser beam in two orthogonal dimensions (Dawson 2018). The scanner utilises a phase-shift method of range measurement. It is capable of measuring up to 500,000 points per second with a ranging error of ±3mm.Multiple point clouds were captured from 14 stations carefully selected around a structure of interest on River Lot 24 (Cunningham House). The scans were colorized using HDR images captured by the instrument’s onboard camera (Data size ~4.7GB) (Figure 2).

Figure 1. Instruments used for Data Acquisition: DJI Mavic 2 Enterprise Dual RPAS unit.

Figure 2. ARO Focus M70 laser scanner. Additionally, a Nikon D7000 DSLR camera equipped with a NIKKOR 18-200mm DX VR II Lens was used to record extant conditions of the exterior of the Cunningham House and its surrounding.

The data set was further complemented by a photographic record of site resources and conditions captured on a Nikon D7000 DSLR camera equipped with a NIKKOR 18-200mm DX VR II Lens. 347 images recording extant conditions of the exterior of the Cunningham House and its surrounding on River Lot 24 were captured (Data size ~2.9GB).

3.2 Data Processing Workflow

The dataset was processed on two different setups:

The Desktop configuration consisted of a Lenovo workstation with an intel Xeon Bronze 3204 1.9 GHz and 32GB RAM equipped with a NVIDIA Quadro P400 GPU with 2GB RAM. The workstation was already available to the authors; however,

[1] First Nations, Inuit, and Métis are Indigenous Peoples in Canada.

the cost of a similar infrastructure is estimated to be around $4,000 CDN. It is also worth noting that the workstation is rather heavy (~10 Kg) and is not easily portable.

The Cloud configuration is illustrated in Figure 3. Phase 1 of the project was focused on creating working instances of Elastic Compute Cloud (EC2) on Amazon Web Services (AWS) platform and establishing the environment for processing the collected datasets.

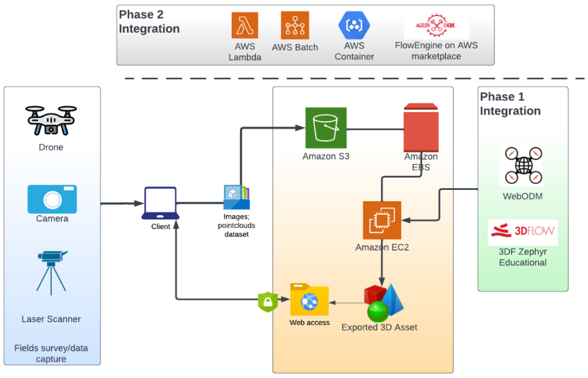

Figure 3. Project Cloud Configuration

AWS is a comprehensive cloud computing platform provided by Amazon that includes a mixture of infrastructure-as-a-service (IaaS), platform-as-a-service (PaaS) and packaged-software-as-a-service (SaaS) offerings. It offers a platform to access computing resources, data storage, and content management services (Amazon 2023a). EC2 is a web service that provides secure, reliable, and scalable computing infrastructure on demand (Amazon 2023b).

A number of services from AWS were identified for this pilot project; however, setup and access to these services were often cumbersome and required extensive technical and IT knowhow. RONIN is a web application that provides a user-friendly solution to self-service cloud computing via an intuitive interface, hence making the enormous power of AWS accessible to the research group (RONIN 2022). The authors were fully supported by RONIN Development Team, AWS Enterprise Support Team, and Athabasca University’s IDEA Lab IT Team during the initial setup and on other milestones of the project.

The RONIN for Athabasca University (AU) is constructed under AU’s Virtual Private Network (VPN). The secured connection provided a safe and reliable environment for the authors to create a sandbox and implement ideas and experiments. Different EC2 configurations on AWS were explored to find the optimal cost-performance machine to complete the tasks effectively. Results were then stored on Amazon Elastic Block Store (EBS) instances and can be accessed and reused readily (Amazon 2023c).

WebODM application was used to produce an orthomosaic map from imagery obtained by the drone survey (Figure 4). WebODM is an open-source, user-friendly, extendable application and API for drone image processing. It generates georeferenced maps, point clouds and textured 3D models from aerial images (Toffanin, 2019) (Figure 5).

Processing on both configurations produced similar results. The processing on the desktop configurations was time consuming (77.5 continuous hours) and at times used all system resources. In comparison, processing the same dataset on the cloud configuration was completed only after 18 minutes. The cost of running the process was short of $3 CDN per hour, not including the initial investment for learning the infrastructure setup and/or installation of appropriate software. The platform is also accessible on any laptop with a network connection. The results were promising, as this would offer exciting solutions to accessibility and resource democratization specially for remote areas or regions where costs of IT infrastructure are prohibitive.

Figure 4. River Lot 23 and 24 located north of the Sturgeon River in St. Albert, Alberta, Canada.

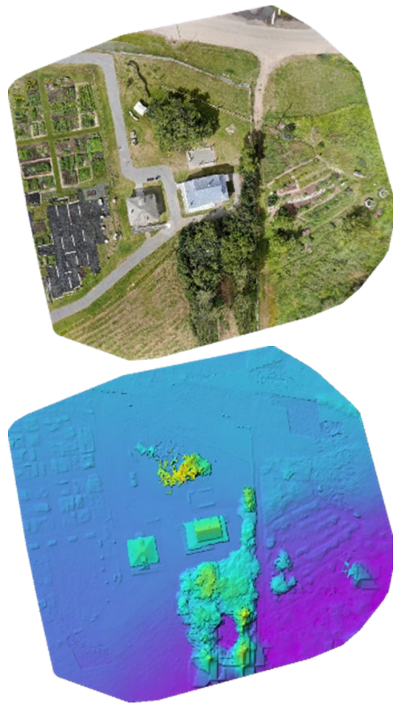

Figure 5. Cunningham House and Hogan/Belcourt House on River Lot 24. Stitched orthomosaic aerial photo (Top) Digital Surface Model (DSM) Heatmap highlighting elevation differences (Bottom.)

Phase 2 of the project is focused on finding suitable solutions for processing the dataset from the laser scan surveys on the cloud and integrating the 3 datasets (Drone survey, laser scanning, and terrestrial photogrammetric record) into one cohesive and complete 3D model. To this end, experiments using various applications and tools (e.g., CloudCompare, Meshroom, and 3DFlow by FlowEngine) are underway (Figure 6).

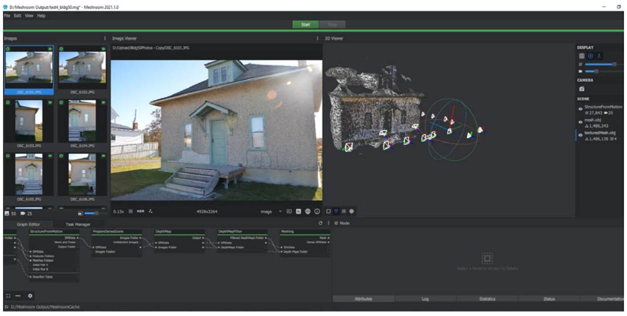

Figure 6. Screenshot showing progress made on Meshroom.

These applications and similar tools require great processing capacity and heavily rely on a dedicated graphics card, which usually translates to a more expensive desktop machine. These solutions are incapable of delivering adequate results on the EC2 mainly due to the fact that the processes require numerous graphic inputs from the user that is more efficient on a desktop machine (due to latency and throughput). A few other applications available on AWS platform may present some opportunities (e.g., Pixyz) that seem to be capable of processing datasets from laser scan surveys to generate a unified dense point cloud (Figure 7).

Figure 7. Screenshot showing progress made on the 3DFlow API instance on the EC2. This is a work in progress and additional efforts are being made to optimise the process to achieve desirable outcomes.

3.3 LESSONS LEARNED

Preliminary results from this pilot project are promising and offer exciting opportunities to address accessibility issues and resource democratisation specially for remote areas or regions where costs of IT infrastructure are prohibitive. There are, however, some observations and challenges to consider:

Cost Evaluation: The authors have explored multiple combinations on AWS instances to find optimal configurations to complete the tasks within a reasonable cost. Since all instances of AWS including computing units and storages are priced in different ways, there is a need to monitor the created instances and schedule the up/down time with flexibly. For instance, the service provider offers a variety of options in a user-friendly interface to suit different users’ needs. However, researchers must evaluate the cost of each applied selection of instances to avoid burning out of the budget. In addition, any high-performance instances should not remain idle but active on the cloud.

Initial investment (financial and time) to enable researchers access to the cloud-based computing service is generally high; however, these requirements are short in nature and minimal input will be required once the platform is set up. In contrast, the flexibility by which additional IT resources (CPU, GPUI, memory, storage) could be added to the project on-demand, enables processing of rather large dataset on the cloud to be extremely fast and low cost. This provides opportunities for technology democratisation and access in areas that technical knowhow is not readily available.

Security, privacy, and rights infringement: the research group accessed the cloud platform through an API constructed under Athabasca University’s Virtual Private Network. The secured connection provided a safe and reliable environment for the authors. In addition, access levels could be controlled to allow different user groups access based on their role or project needs. The processing time for large datasets on the cloud proved to be extremely short; therefore, the raw data and the outcome files could potentially live on the cloud platform for a rather short period of time, hence reducing the risks. This research did not rely on the proposed cloud setup for long-term data storage, as there are many well-established data repositories that are better suited for this purpose.

Despite these challenges applying new workflows under the advanced cloud-based architecture, the cloud-based computing still provides opportunities to manage multiple formats of dataset, offer a variety of processing tools, reduce the time required for processing, share the results on cloud easily, and store/re-use the dataset in the future. The team members’ prior knowledge of technologies and past experiences with IT are essential assets to reduce the time required for problem-solving. During the development phase of research, a few other cloud-based services were identified in the marketplace. These cloud-based services can be deployed in the next phase of the project to achieve the outcomes in a more efficient way.

4. DOCUMENTING CLIMATE-RELATED IMPACTS

The premise of this research project is to explore the use of digital tools, applications, and cloud computing for effective documentation of heritage resources and recording and presentation of their significance in order to facilitate development of climate adaptation approaches to protect them for the future generations. It aims to gather baseline data for monitoring purposes, supporting decision making, informing strategies and possible future studies, and planning and managing interventions. The outcomes of the research not only can be used to tell the story of the site and community, it can also be employed as a virtual support in the ongoing work with local communities, raise awareness about climate change and communicate the relevance of heritage conservation to climate action/adaptation because heritage conservation is climate action.

Cultural and natural heritage places all over the world are under increasing threat from environmental decay, climate change, neglect, and conflict. Climate change impacts natural and cultural values and tangible and intangible aspects of heritage. As the Intergovernmental Panel on Climate Change Working Group II notes, "Risk of climate-related impacts results from the interaction of climate-related hazards (including hazardous events and trends) with the vulnerability and exposure of human and natural systems. Changes in both the climate system … and socioeconomic processes including adaptation and mitigation … are drivers of hazards, exposure, and vulnerability." (IPCC WG II, 2014, 2)

Among the vulnerability assessment tools, Climate Vulnerability Index (CVI) is of relevance to this project as it considers both the climate-related vulnerability of values of the heritage resource and the community vulnerability. CVI is "a systematic and rapid assessment tool that is values-based, science-driven and community-focused." (CVI, 2023). It is "scientifically robust, transparent, and repeatable" (Day, et al., 2020, 144) and engages the associated community and stakeholder groups to assess their adaptive capacity. This tool has been applied in selected World Heritage Sites but never applied in Canada or on a non-World Heritage Site as of yet. There are valuable lessons that could be learned from this tool and its adopted methodology to assist with the protection of St. Albert's river lots and other historic resources by working with Indigenous Knowledge keepers, non-Indigenous scientists, and local community members.

The impact of climate change on the river lots and its character defining elements might not be devastating at this time; however, this can change suddenly. For example, the water levels along the Sturgeon River rose above its banks during 2019 and 2020 floodings. These floodings are not uncommon but are a good reminder that sudden changes in the natural elements can happen any time and little time to prepare for actin.

Such changes can irreversibly impact the site's vegetation, condition of existing materials, building foundations, and overall physical integrity of the site. Through this project, data was proactively gathered and processed. The local site stewards can use this foundational information to start the condition and risk assessments and planning process. (Figure 8).

Figure 8. Flood inundation maps show areas at risk for different sized floods. Flood height that has a long-term likelihood of occurring once in every 100 years (Top) compared with a flood that has a 2-year recurrence interval (Bottom) (Government of Alberta, 2020)

5. CONCLUSION

Climate change has become one of the most significant threats to heritage resources. The use of cloud-based computing services could expedite and facilitate more efficient heritage documentation. This pilot project explored the use of cloud computing to improve the documentation and condition assessment of historic resources. Creating an extant record of resource conditions is a vital step towards proper and sustainable resource management and heritage conservation planning. Resources produced during the project will remain as a record for future research on the River Lots 23 and 24 in St. Albert. Although this project is still in its early stages, lessons learned so far could assist other researchers evaluate the suitability of similar services. The preliminary outcomes can support St. Albert Arts and Heritage Foundation, the stewards of heritage sites, in their continued collaboration with the community and stakeholders and in future assessment and planning efforts through regular monitoring of the character defining elements of the river lot, recording of the changes on the digital model and photographs, and updating of the digital data. After one or two rounds of monitoring cycle is complete, this process can be re-examined in a few years' time and improved based on the observations and input from the stakeholders. The recording, assessing, and monitoring of the impacts of climate change should be a priority in the management planning of heritage resources and proactive documentation and regular communication are key to the protection of heritage resources for the future generations.

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