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Inuvik Super School VR Documentation: Mid-Project Status

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ABSTRACT: Over the last eight years the Construction Engineering and Management team at the University of New Brunswick have developed technologies to document the status of on-site progress. The evolving system, referred to as VR Doc, presents high-resolution, virtual reality panoramas of on-site operations in an interface that allows the user to explore the construction site throughout the project timeline. Since 2006 VR Doc has been used on six major projects, in particular on the Inuvik Super School for the Government of the Northwest Territories Department of Public Works and Services. This paper is a case study of VR Doc use. A variety of challenges have been overcome. These include temperature and lighting challenges during the photography step, processing challenges due to the low light level, and transfer challenges due to the file sizes. Continuing challenges include constraints on local personnel for on-site capture of the images as well as the integration of this new technology into traditional management processes. To date the greatest value from VR Doc has been as a communication medium for individuals within the Government of the Northwest Territories who are not involved in the project on a day-to-day basis but benefit from a fast visual record of the project. This case study is of interest to those who wish to understand cutting edge technologies for documenting construction progress. Possible roles of these technologies are: as a means of remotely monitoring project progress, as a pre-emptive means of resolving claims, as photographic as-builts for future reference, and as a training tool for personnel embarking on a similar project.

KEY WORDS: Arctic, construction project, progress documentation, virtual reality.

1 INTRODUCTION

The Government of the Northwest Territories' Department of Public Works and Services (GNWT PWS) contracted with the University of New Brunswick's Construction Engineering and Management team (UNB CEM) in August 2008.

The Northwest Territories is the third largest of the Canadian provinces/territories at over a million square km. Yellowknife is the largest center with approximately 45% of the population; Inuvik is the second largest center, having approximately 8% of the population. Project delivery for the GNWT PWS is managed by three regional project delivery offices each lead by a Regional Manager of Projects. The Regional Offices have a combined staff of 23 Project Officers who manage a combined portfolio of 195 projects. Six of the Project Officers are stationed in the Inuvik Office. Headquarters, in Yellowknife, provides programming and technical assistance. B. Rausch is GNWT PWS' Superintendent of Construction Project Management. T. Engram is the Inuvik Super School Senior Project Officer (i.e., the owner's on-site project manager) and also conducted the on-site photography.

In 2004 UNB CEM began work on the use of virtual reality to document construction progress. The first ongoing virtual reality documentation system (VR Doc) was developed in 2006 for the New Brunswick Department of Supply and Services who were building the Hartland School (Waugh et al. 2007). Since then a variety of projects have been completed or are underway, including, among others: the Point Lepreau Nuclear Generating Station Refurbishment for NB Power Corporation, the One Mile House Interchange for the New Brunswick Department of Transportation, the New Brunswick Law Courts jointly for Bird Construction Inc. and the New Brunswick Department of Supply and Services. L. Waugh is the principal investigator and F. Aziz is a key research assistant for UNB CEM's work on the Inuvik School project and a PhD candidate.

The contract between the parties included both initial and ongoing work by UNB CEM. The initial tasks were:

- to acquire, calibrate, and deliver the photographic equipment,
- to make presentations in Yellowknife and Inuvik to the potential users of the software interface and virtual reality panoramas, including GNWT PWS (the owner), the designer, and the contractor,
- to demonstrate and instruct on the use of this equipment while photographing the initial set of panoramas,
- to create the interface for navigating and viewing the virtual reality panoramas, and
- to process the initial set of panoramas.

These tasks occurred between September 8 and 13 of 2008 and established an excellent relationship between the parties – in particular, the previous photography expertise of the Senior Project Officer was particularly advantageous.

The ongoing tasks entailed on-site photography by GNWT PWS personnel and conversion of these into virtual reality panoramas by UNB CEM personnel, which is outlined in section 2 below. The ongoing deliverables are described in section 3.

2 BACKGROUND

2.1 Inuvik School

In 2008, the Inuvik Super School was the largest project to have been undertaken by GNWT PWS. The two-story steel building is located several meters from an existing high school and will house kindergarten to grade 12 in approximately 12,000 m^2 of floor area (UpHereBusiness 2010) supported by 465 steel piles (10" diameter x12m - 18m long) to elevate the school above permafrost. The total length of piles was 7,447m – almost 7.5 km. The project was expected to take five years (2008 to 2013) to complete but is scheduled for early completion in 2012. The general contractor is Dowland Contracting Ltd. and the prime designer is Pin/Taylor Architects.

The school is located at the mouth of the Mackenzie River in Inuvik which is at 68° north latitude, i.e., 2° north of the Arctic Circle. Inuvik is 1100 km northwest of Yellowknife by air or 3770 km by road. Yellowknife is the home base of GNWT PWS and Pin/Taylor Architects. Inuvik is the home base for Dowland Contracting Ltd.

2.2 Planned Photographic Record

Traditional forms of project documentation photography were planned on this project, including 100 to 200 photographs taken monthly as well as "as-required" photos by the Senior Project Officer. This photographic record has proceeded as planned. There is also a requirement of the general contractor to provide a photographic record of the construction phase of the project.

Although the parties intended to be flexible, the frequency of the VR Doc photos was planned as once per month with the number of panoramas per month ramping up from 10 for 2008-10, to 20 for 2010-11, and to 30 for 2011-13.

2.3 VR Doc Processes

In brief, the monthly VR Doc steps entail GNWT PWS personnel:

- photographing 12 individual images for each of the eventual panoramas,
- posting the individual images on a secure GNWT PWS server;

UNB CEM personnel:

- downloading the individual images,
- converting these images to virtual reality panoramas,
- integrating the virtual reality panoramas into the cumulative interface,
- posting the result on a secure server (FocalTrack 2012); and finally

GNWT PWS personnel:

- making the interface and virtual reality panoramas available to authorized parties.

UNB CEM's planned turnaround between receipt of individual images to posting of the interface and virtual reality panoramas was "within one week."

3 VR DOC DELIVERABLES

3.1 Screen Shots

The interface provides for navigation by date for each of three plan views: Site, Main, and 2nd Floor.

Figure 1 (a) and (b) show the interface screen for the Site and for the Main floor respectively on 2011 Oct 13, as indicated in red. The user may click on any date or plan view to navigate the interface.

The red cross-hair icons on these plan views indicate the locations from which photographs were taken and for which panoramas are available. The user may click on any such icon to open a virtual reality window displaying their selection.

Figure 2 (a) and (b) respectively show a zoomed out and zoomed in view of location 29 (Main floor) on 2011 Oct 13.

Within the virtual reality (QuickTime 2012) interface, the user may pan and zoom.

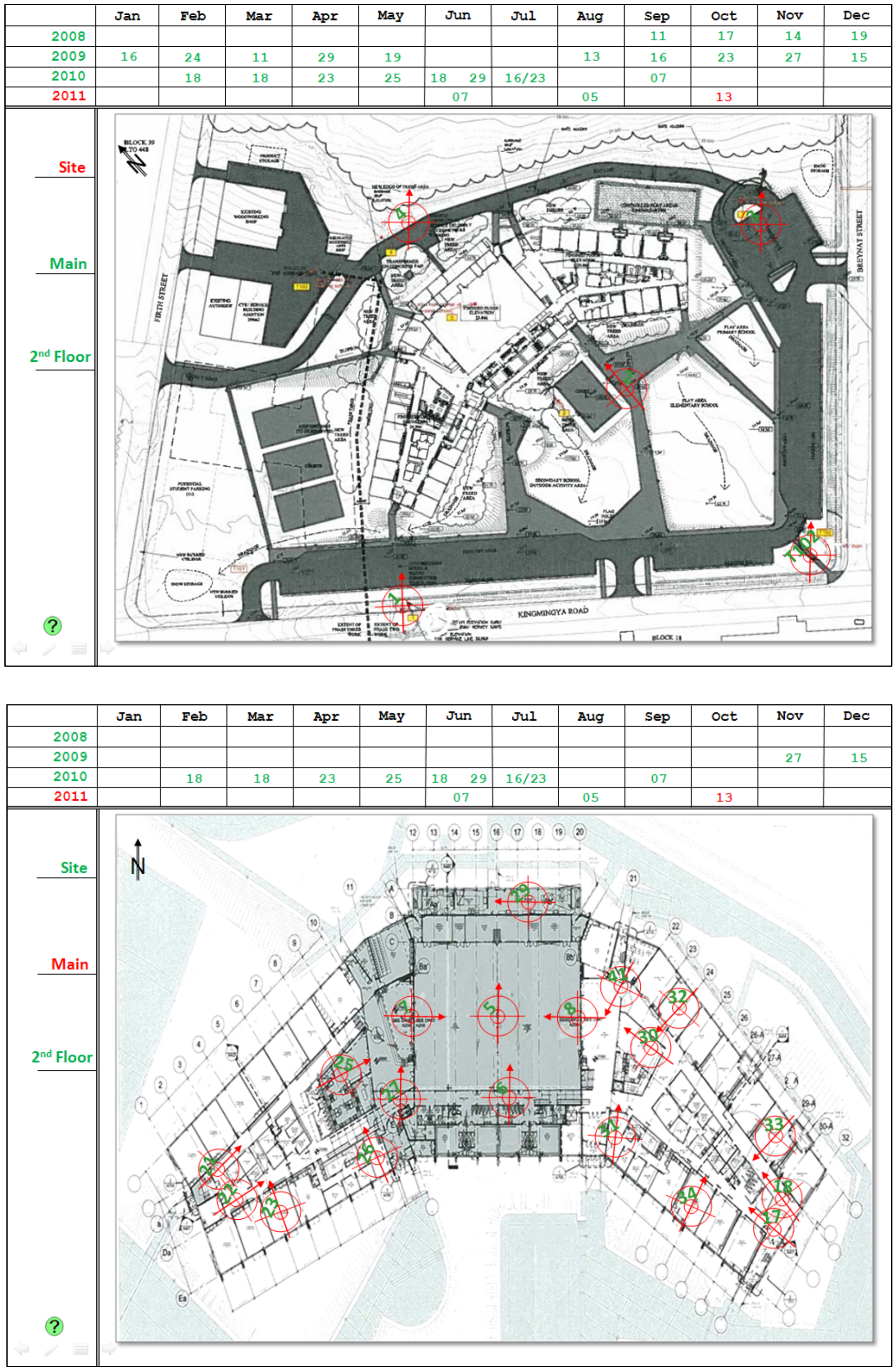

Figure 1: VR Doc Interface for the (a) Site plan and (b) Main floor

3.2 Summary

Figures 3 and 4 summarize the VR Doc photography completed between early September 2008 and the end of November 2011.

Figure 3 indicates the actual number of virtual reality panoramas photographed by season (Fall is designated as September to November to align with the contract years). The actual number of panoramas photo graphs increases significantly over the 13 seasons – for example there were 53 panoramas photographed during the first four seasons shown, whereas there were 114 panoramas photographed during last four seasons shown, despite two of the last four seasons not having any photography dates.

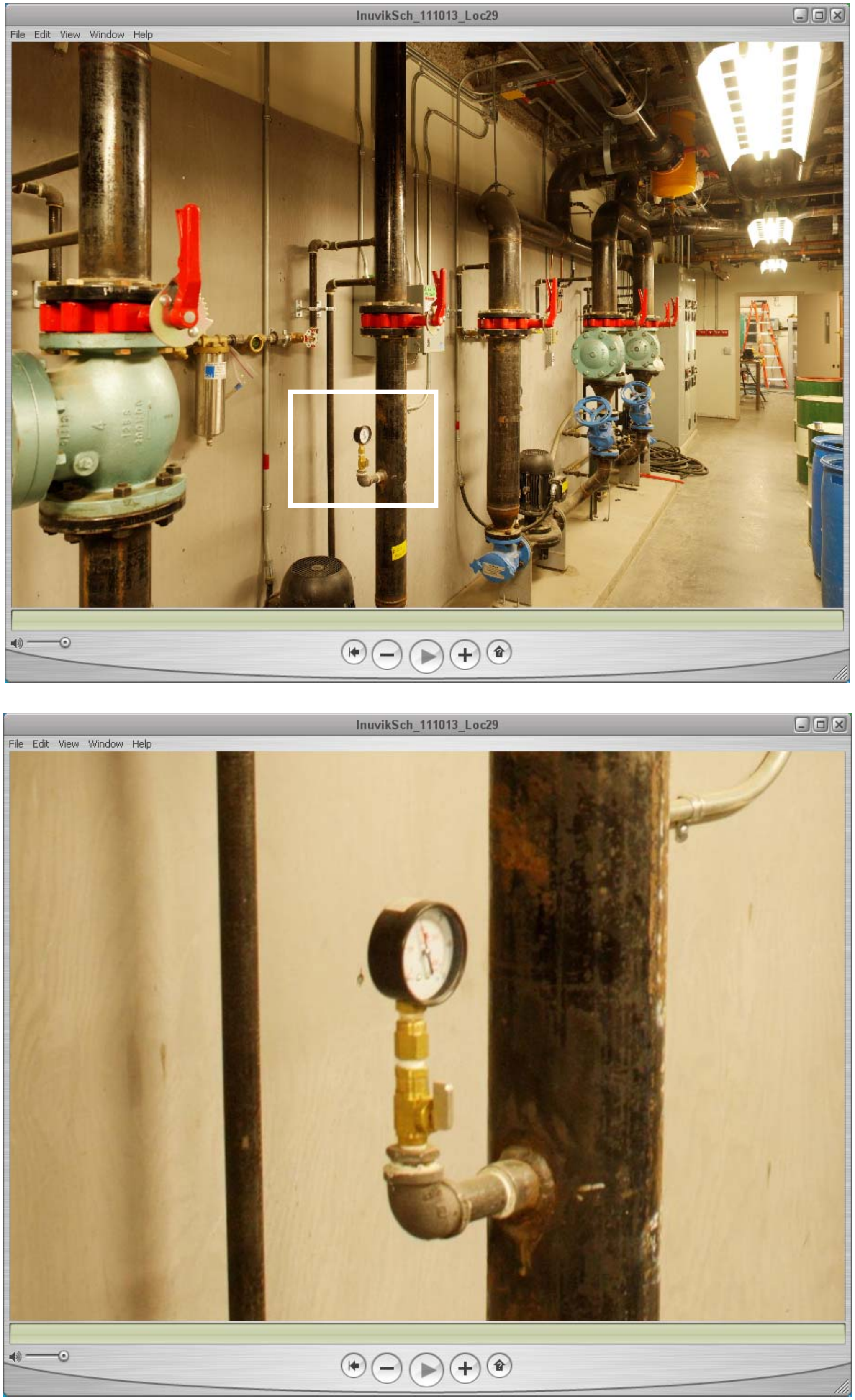

Figure 2: Virtual Reality Panoramas at Location 29 zoomed: (a) out (b) in

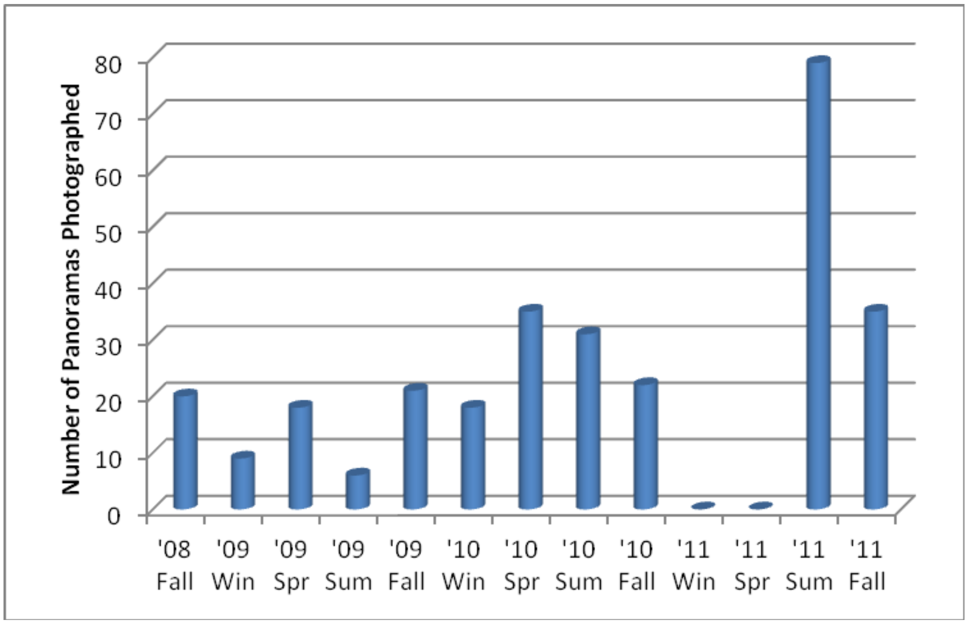

Figure 3: Actual number of panoramas photographed

Section 2.2 described the planned number of photography dates as well as the planned number of panoramas for each date. Figure 4 indicates (on a percentage basis) for each season, the planned vs. actual for each of these two targets. As noted above the actual number of panoramas photographed (and therefore the effort required) increased, but not as rapidly as planned. This was caused by the Senior Project Officer also managing another project in Inuvik that had a very aggressive schedule. The number of photography dates decreased since the Fall of 2010.

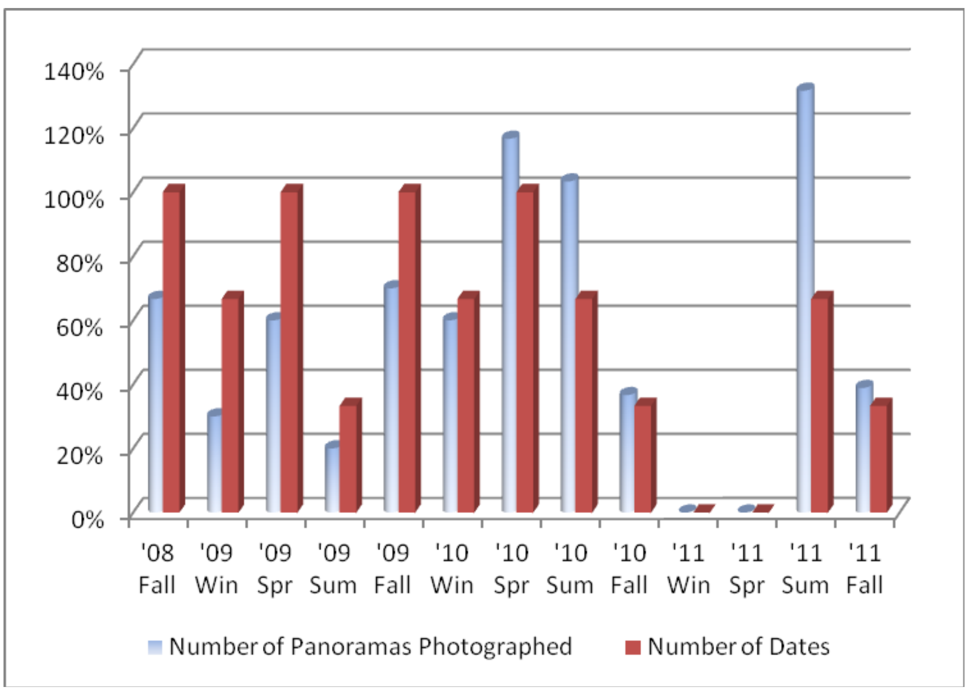

Figure 4: Planned vs. actual number of panoramas and dates

3.3 Intended VR Doc Audiences to Date

For project update purposes, the intended audiences for VR Doc within GNWT PWS were to be the Deputy Minister, the Assistant Deputy Minister, the GNWT PWS Superintendent of Construction Project Management, other GNWT PWS personnel in Yellowknife, as well as Pin/Taylor Architects who are also located in Yellowknife. Occasionally, there were also briefings of the Minister of PWS; Minister of Education Culture, and Employment; and Members of the Legislative Assembly. At this time, VR Doc is less valuable for project participants in Inuvik (i.e., the Project Officer, other GNWT PWS personnel and Dowland Contracting Ltd), since they have the alternative of visiting the site to view construction progress.

4 CHALLENGES

4.1 Capture Challenges

Due to its size and complexity, the project began with very limited time available for the Senior Project Officer to complete the on-site photography. As noted above, this was further exacerbated when the Senior Project Officer was also needed to manage another major GNWT PWS project in Inuvik, unavoidably delaying the capture of images and making it impossible to follow a preset schedule.

The other key challenges on-site were the temperature and lighting. The average monthly low temperature in Inuvik is below -30º C for December through March with extremes below -50sº C; this caused a serious challenge for outdoor photography. Fully charged batteries were kept warm inside a parka; however, in very cold weather they still only lasted approximately 20 minutes (approximately three panorama locations) due to the time required to level the panorama head, setup the camera, acquire 12 images at each location, and walk between locations.

In Inuvik, the sun does not set between late May and mid July. In late October and mid February the sun reaches a maximum height of 10º above the horizon; the sun does not rise at all for much of December. The angle of the sun is a challenge when seeking clear panorama photographs because it causes glare when facing the sun, because of the lack of light and shadows, and because of the blue tint of the daylight. As noted below, temporary site and interior lighting also caused site-photography difficulties due to the limited areas illuminated and the tint of the light.

4.2 Processing Challenges

Although a variety of processing challenges were overcome, including extension of the interface for use with Apple computers and pre-processing of the images prior to stitching to accommodate image alignment and focal length variations; however, white balance and low light conditions are most relevant to this case study. The 12 images assembled to create a single 360º panorama often contain varying light conditions. For example, many panoramas include both outside light entering though a window or unfinished exterior wall and incandescent lights strung as temporary lighting or florescent lights installed permanently. In comparison with florescent light, sunlight and incandescent light result in a blue and yellow tint respectively. The blue tint is especially pronounced at low angles of the sun in a snow-covered landscape. Without adversely affecting the ability to stitch the individual images into a panorama, we used the on-camera automatic white balance setting and we applied further chromatic improvements through the use of image processing software (DxO 2012) to mitigate the tint and low light level challenges.

4.3 Transfer Challenges

The raw photographs for ten panoramas (i.e., 120 still images) are approximately 1.0 Gigabytes in size. A problem arose transmitting these photographs to Fredericton over Internet connections slower than 0.1 Mbps. In 2008, and still today, most Internet service providers (ISPs) provide much faster download speeds than upload speeds since most users rarely need to upload files to a server. After a number of trials, it was determined that the most efficient method was to use two servers: one in Yellowknife from which image files were downloaded by UNB CEM personnel and one in New Brunswick from which the panorama files were downloaded by GNWT PWS personnel. In both cases the upload was over a short distance using a fast network connection.

4.4 Current Use Challenges

Like the technological challenges during transfer and processing, those faced by the user of the system are easily overcome. They fall under four headings: technology, time, training, and value. The interface software and the virtual reality software are inexpensive, are intuitive, run on standard hardware, and are readily available. However, the standard barriers to information technology adoption apply: getting the software installed, remembering how to open the software, and where to access the files. This is especially true if one has little spare time, has not had training, and does have a traditional means of accomplishing the task at hand without the adoption of a new information technology. For "project update" purposes, the value of VR Doc diminishes over time; if the virtual reality panoramas are very recent, they provide a virtual tour of the site. On the other hand, if they are several months old, it might be more enlightening to talk to a person on site by telephone.

5 USE OF VR DOC FOR THIS PROJECT

5.1 Use to Date

There is very little use of VR Doc by the GNWT PWS technical staff, the contractor, or the designer. The Deputy Minister is using VR Doc regularly to view the current status; this reduces the time spent on briefs by the Superintendent of Construction Project Management and provides insight that would be difficult with traditional briefings alone.

5.2 Post-Project Use

The uses during construction (to date) primarily relate to virtual visits by those who are a long distance from the project. However, after the project is complete there is potential that VR Doc will be used for three other purposes:

- as a pre-emptive means of resolving claims by helping the project participants to more accurately recall the project status at various stages of the work,
- as photographic as-builts for facility management purposes, and
- as an educational tool for those planning to work on similar projects.

6 CONCLUSIONS AND RECOMMENDATIONS

Having the Senior Project Officer personally responsible may have limited the time available for on-site photography. However, it is possible that no virtual reality photography at all would have been completed without him taking on this role. Furthermore, his choice of panorama locations was undoubtedly different than would have been chosen by non-project participants. It is typical for other VR Doc projects to stick to the same panorama locations throughout the majority of the project duration. A limitation of this approach is that priority should be given to efficient site operations; hence, material lay down areas will typically change as the project progresses making movement of panorama locations unavoidable. For a similar project in the future, we recommend an independent photographer who communicates with the Senior Project Officer on each photography date to determine which locations will capture the most representative and insightful record.

At the beginning of the project the project managers arranged that the general contractor and prime designer receive a full briefing of the use of VR Doc on this project. During this briefing they were informed that they would both have full and free access to the VR Doc interface and panoramas. This approach is a stark contrast to the adversarial relationships that are often found in the Canadian construction industry, where information is sometimes hoarded rather than shared in hopes of gaining an advantage if there are claims. Although intangible, this "information sharing" approach may have contributed to the project being on budget and a year ahead of schedule.

On a more recent VR Doc project, UNB CEM is pursing the use of secure, web-based delivery of the interface and panoramas. Permission to view the panoramas will be protected by a password to avoid unauthorized access. If this approach proves to be secure and fast, it will reduce (a) the effort required to post and distribute the interface and panoramas, and (b) the turnaround time between on-site photography and availability.

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