FACILITATING DECISION MAKING USING 3D TECHNOLOGIES ON THE WEST EDMONTON SANITARY SEWER PROJECT

* Y. Zhang, and M. Al-Bataineh
S.M.A. Consulting Ltd.
230, 10123 99 ST
Edmonton, AB Canada T5J 3H1
*(*Corresponding author: ison@smaconsulting.ca)*

J. Zou, and S. Fernando
Drainage Design and Construction
14323 114 Ave NW
Edmonton, AB Canada T5M 3B8

S. AbouRizk
University of Alberta
9105 116 St NW
Edmonton, AB, Canada T6G 2W2

FACILITATING DECISION MAKING USING 3D TECHNOLOGIES ON THE WEST EDMONTON SANITARY SEWER PROJECT

ABSTRACT

The North Saskatchewan River flows southwest to northeast through a 22-km-long valley in the City of Edmonton, supplying the drinking water to dozens of downstream communities. During heavy rains, combined sewers occasionally overflow into the river, which has a significant negative impact on the water quality and the sensitive environment. The West Edmonton Sanitary Sewer (WESS) W12, a syphon connecting the Rat Creek Trunk to the Gold Bar Wastewater Treatment Plant across the river, was designed and constructed to take the overflow to the wastewater treatment plant. Due to the complexity of the project, various 3D technologies were applied to facilitate decision-making processes. 3D models were developed for design review and design conflict detection, while 4D models were established to help create a robust construction schedule. Construction sequencing animation was used to convey design intents and demonstrate construction stages to contractors and workers. The combined applications of 3D technologies helped the project team to identify critical issues, and assured effective communication among engineers, management, contractors, and other parties. Therefore, it provided more opportunities for the success of the project.

KEYWORDS

Drainage Construction, Construction Management, 3D Modeling, Animation, Design Review

INTRODUCTION

The North Saskatchewan River flows southwest to northeast through a 22-km-long valley in the City of Edmonton, supplying the drinking water to dozens of downstream communities. However, like most pre-1940 municipalities, the City of Edmonton is serviced in part by combined sewers. These sewers occasionally overflow into the North Saskatchewan River (NSR) during wet weather conditions. In this case, unprocessed pollutant is directly discharged to the NSR, resulting in deteriorated water quality, raising safety concerns in Edmonton and beyond. The Rat Creek outfall (see Figure 1) contributed 80% of the City of Edmonton's combined sewer overflow volume (about 2 million cubic meters per year) until 2011.

The Rat Creek outfall was targeted as part of the West Edmonton Sanitary Sewer project. WESS W12, a syphon connecting the Rat Creek combined trunk to the South Highlands Interceptor, was designed to take the overflow and convey it safely to the Gold Bar Wastewater Treatment Plant on the south side of the river. This was expected to reduce the CSO discharges into the North Saskatchewan River by over 70%, significantly improving water quality. Ultimately, the syphon would convey all flow from the 7 km of West Edmonton Sanitary Sewer project to the Gold Bar Wastewater Treatment Plant for treatment. Flow would be controlled by the Real Time Control (RTC) #3 structure located deep beneath the city streets. Associated Engineering was the designer for the project.

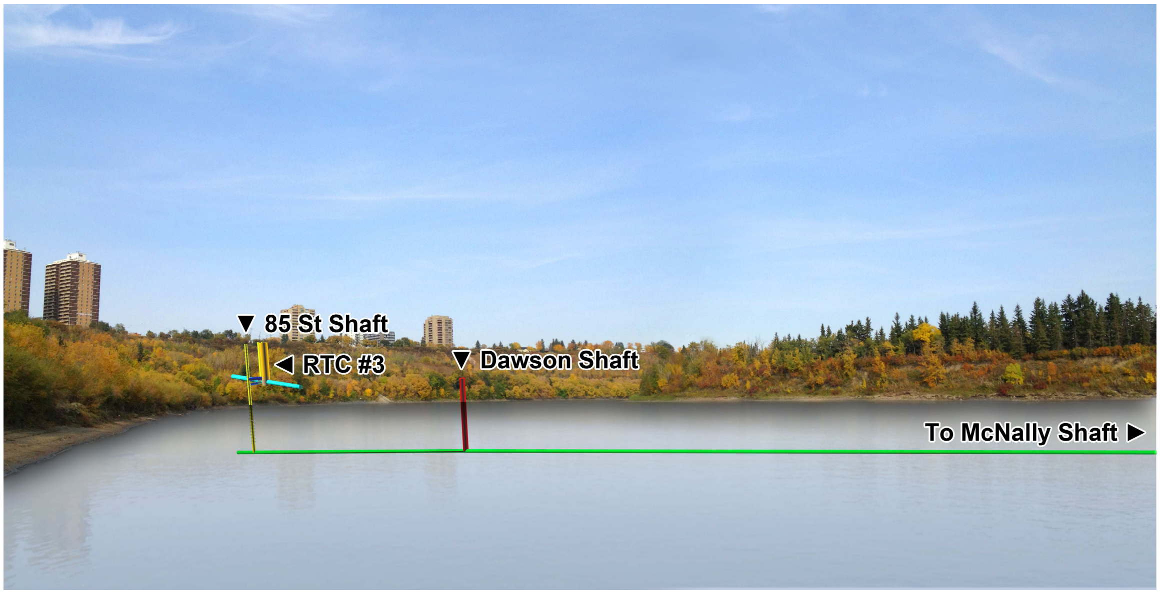


Figure 1 – Overview of the WESS W12 project

The construction of W12 proved to be extremely challenging. Its environmentally sensitive location in the river valley as well as its extreme depth—70 meters below downtown Edmonton—was understood. However, the geotechnical investigation revealed that almost the entire project was situated within the footprint of abandoned coal mines. Five deep shafts would have to be constructed in ground laden with coal seams, water pockets, and voids, with the detection of methane gas under pressure in several locations. The tunnel alignment would run between two coal seams. Access was also severely limited: the northern construction site was on Jasper Avenue; the main thoroughfare is through Edmonton's downtown; and most of the alignment was under the Riverdale Golf Course and the river itself.

Due to the uncertain ground conditions and other constraints, the City Drainage Design and Construction crews initially planned to work with a newly-acquired LOVAT Earth Pressure Balance tunnel boring machine, using bolted segmental liners—the best technology for the job, but not one the City of Edmonton crews are familiar with. The deep shafts meant delays in removing soil and supplying construction materials, and shaft placement was limited. Finally, construction of the RTC3 structure required tying in to a fragile, very old 3200 mm pipe, under live flow. This pipe was the current combined trunk, with flow of 3.7 m/s in dry weather, and the potential for even higher velocities if there was one of the sudden rainstorms common to the area—a major safety concern. Operation of the tunnel would also be challenging. The tunnel itself would have to meet zero-infiltration standards due to the sensitive location, and the complex RTC3 structure would need to function without flaw to avoid flooding basements upstream or pouring unnecessary CSO into the river.

Due to the complexity of the project, various 3D technologies were applied to facilitate decision-making processes. 3D models were developed for design review and design conflict detection, while 4D models were established to help create a robust construction schedule. Construction sequencing animation was used to convey design intents and demonstrate construction stages to contractors and workers. The combined applications of 3D technologies helped the project team to identify critical issues, and assured effective communication among engineers, management, contractors, and other parties. Therefore, it provided more opportunities for the success of the project. The construction of the project was completed in 2011 and the tunnel is now in operation, successfully conveying flow to Gold Bar Wastewater Treatment Plant. The initial budget and schedule underwent two revisions due to external events, construction challenges, and additional scope, and totalled $44 million. Zero exfiltration was confirmed by pressure tests.

The paper is organized in the following sections. First, it introduces the 3D design review processes and compares it to the traditional 2D review processes. Then, it depicts how to link 3D design models to construction schedule to develop a 4D construction model. The model helps produce a virtual validated construction schedule. Finally, the 3D animation approach is discussed, which is a more efficient and effective way to communicate design intents and construction stages.

DESIGN REVIEW AND CONFLICT DETECTION

It is said that drawing is the language of engineers. Drawings play an important role in conveying engineering information. However, with the emergence of easy-to-use 3D modeling/Building Information Modeling software tools, the disadvantages of 2D drawings have been fully exposed, especially when 2D graphics are used to represent 3D contents. The lack of the third dimension results in the need for multiple drawings to be produced in order to depict different perspectives of objects. 2D drawings can handle 3D contents with low level of complexity well. However, when designs become spatial complexities, 2D drawings are not sufficient to represent the design intents. This is where 3D models come into play.

The 3D modeling design approach has been adopted in various industries for years. It becomes valuable for construction projects under the following situations. 1) Designs with geometric complexity. With the development of high-strength material and new construction technologies, architects create a lot more innovative designs. The 2008 Beijing Olympics National Stadium is a good example; the top of its steel structure shapes along with a saddle surface with curves in two directions (Lu et al. 2009). It was designed in CATIA, which is a software tool mostly used for automobile and aircraft design. During construction, surveying coordinates were extracted from the 3D model, which would not be possible by using 2D drawings. 2) Sub-surface structures and utilities. Sub-surface structures and utilities, e.g. transportation tunnels, drainage tunnels, sewers, ductbanks, underground utilities such as power, gas, water, etc., cannot be seen by naked eyes. Design conflicts were identified by using 3D utility models on the North Light Rail Transit (LRT) extension project in Edmonton, Alberta, Canada. The early identification of design conflicts saved the project time and budget. 3) Structures with control operations. This kind of structure is designed to work with mechanical control components to fulfill special functionalities, thus becoming a dynamic structure instead of a static one, with several operation statuses. 3D models can help analyze the design of the structure in operation scenarios.

Considering the characteristics of the above mentioned situations, the 3D modeling approach was introduced to the WESS W12 project. 3D models of the RTC3 structure, diversion chamber, inlet shaft and connection tunnel structures were created along with the design processes based on issued 2D drawings. Typical 2D drawings are shown in Figure 2. It has been determined that inexperienced stakeholders find 2D drawings hard to read, and it even takes time for seasoned engineers to understand the details. In addition, while the invert elevations (the internal bottom elevation of a structure) of structures dictate the water flow, their relationships cannot be easily observed from 2D graphics.

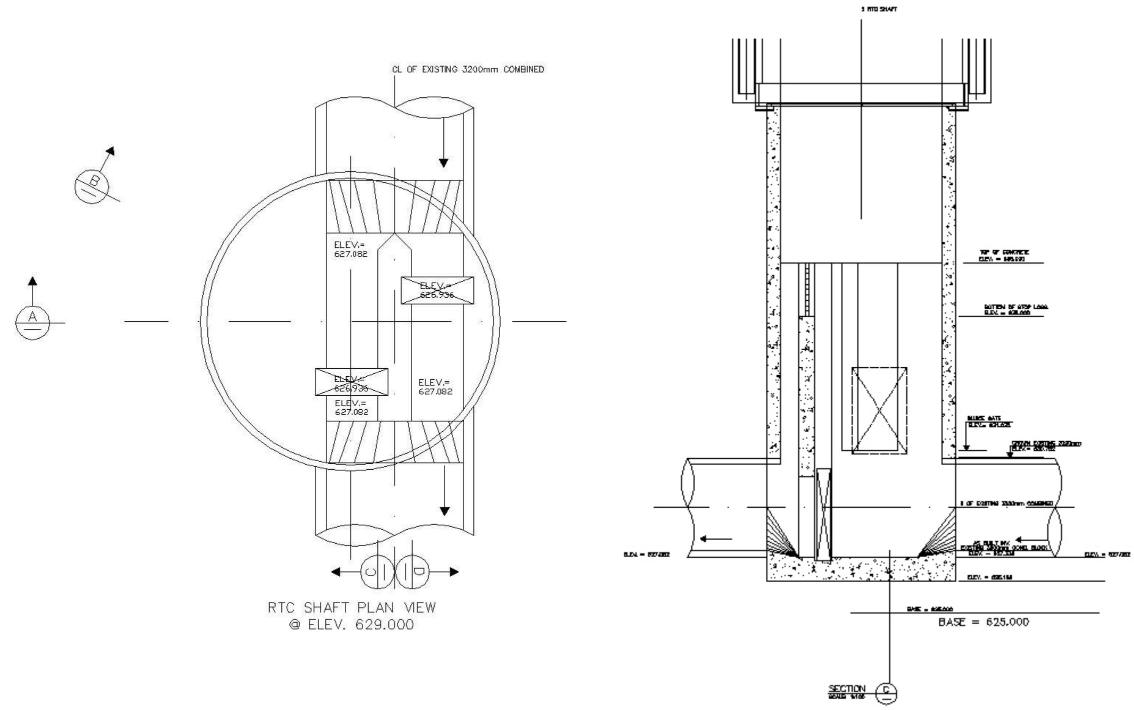


Figure 2 – Typical top view and cross section of RTC3 of WESS W12 (Drainage Design and Construction, City of Edmonton, AB, Canada)

The 3D model of the RTC3 structure is shown in Figure 3. It intuitively represents the internal structures and their elevations. The control gates, which are made of steel, are designed to control the water flow. They move along the grooves on the concrete wall. Water will be diverted to the inlet shaft through the gate at a higher elevation once the two bottom ones are closed. Several design changes were made after the 3D model was reviewed. Distances were directly measured on the 3D models to verify whether there was enough space for construction in different stages. As the design was updated several times, data consistency was hard to maintain. While the gate manufacturer worked on the old drawings, the designer increased the elevation of the concrete structure. Fortunately, the 3D model captured the difference between the designed elevation of the concrete structure and the total length of the gate system. This method successfully avoided what could have been a big surprise in the project, early on.

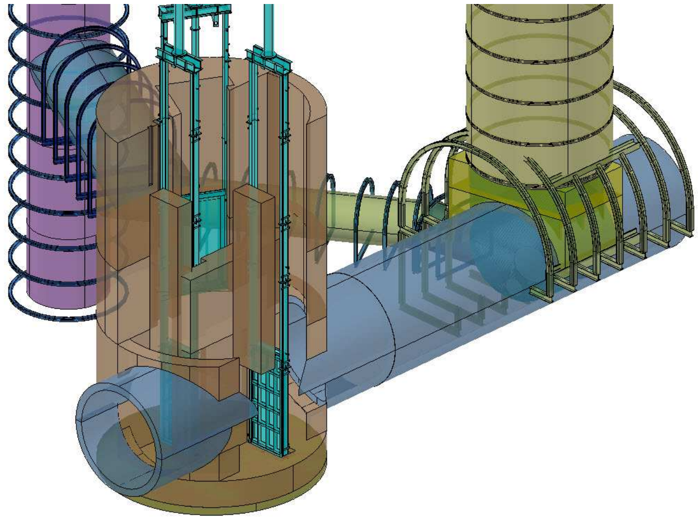


Figure 3 – The isometric view of the RTC3 structure, inlet shaft and diversion chamber

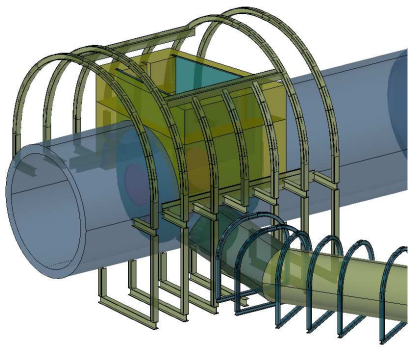
Creating a 3D model usually consumes more time than drafting 2D drawings. At this time, there is no specifically designed software package for modeling the shaft and drainage structures in an intelligent way. Generic modeling features were adopted in this project. It was found to be worthwhile to spend some time on the modeling as it prevented potential serious problems during the construction stage. 3D models provide virtual construction opportunities to the project team, which function as rehearsals for the actors before a real show.

FOUR-DIMENSIONAL CONSTRUCTION PLANNING

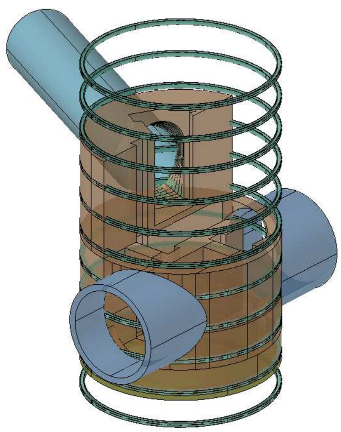
Four-dimensional modeling was introduced to the construction industry years ago (Koo and Fischer 2000). It is an approach that links 3D models with the construction schedule in order to get visualized construction sequencing. 4D construction planning has been adopted for a variety of projects and demonstrated its benefits.

Timing is important for the WESS W12 project. The design concepts behind it are discussed in this section. The RTC3 structure and inlet shaft are permanent structures which will be used to control the diversion of water. However, they need to be constructed on a live 3200 mm combined sewer pipe. And construction of the RTC3 structure must be in a dry condition to meet safety requirements. Thus, the engineers decided to build a temporary diversion chamber upstream of the RTC3 structure. The diversion chamber is built from the top of the existing 3200 mm pipe, and an opening is cut at the bottom of the pipe enabling a connection to the diversion tunnel to divert the flow to the inlet shaft. Before the diversion happens, the inlet shaft must be finished to accept the flow. In order to cut an opening at the bottom of the existing pipe, steel plates with temporary pipe assemblies are inserted into the diversion chamber to bypass the live flow. Once the opening is finished, the steel plates with temporary pipe assemblies are pulled out and replaced with double blocking plates. At this time, the RTC3 construction can begin. After the RTC3 structure is finished, the double blocking plates are pulled out and the opening is closed by a gate. The full system then begins to function.

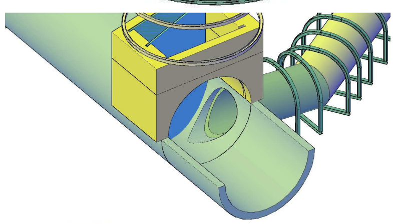
The construction schedule was created in Microsoft Project. However, the above-mentioned dependencies cannot be well presented by bar chart. The project team decided to link the schedule to the 3D model to better visualize the construction dependencies. The 4D model was developed using Autodesk Navisworks. It helped the project team to understand scheduling problems and optimize construction sequencing. Figure 4 shows key stages of construction.



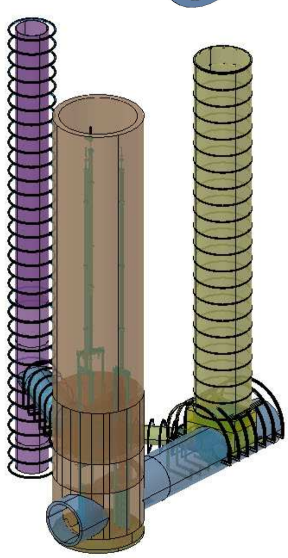
Build diversion chamber.



Build RTC3 structure.



Divert flow to the inlet shaft.



The finished structure.

Figure 4 – Key stages of construction

CONSTRUCTION SEQUENCING ANIMATION

While 4D models represent construction sequencing at a high level, construction sequencing animation represents it with more detail. Construction sequencing animations capture details of construction sequencing information and represent it in a more realistic way. These animations can be produced using commercial software such as 3ds Max, Maya, etc. Instead of a list of steps and working procedures, animations can help project stakeholders understand what activities are going to happen, where and at what time.

CONCLUSIONS

Several 3D technologies were applied to the WESS W12 project to facilitate decision-making processes. 3D models were developed for design review and design conflict detection, while 4D models were established to help create a robust construction schedule. Construction sequencing animation was used to convey design intents and demonstrate construction stages to contractors and workers. The combined applications of 3D technologies helped the project team to identify critical issues, and assured effective communication amongst engineers, management, contractors, and other parties. Therefore, it provided more opportunities for the success of the project.

REFERENCES

Lu, M., Zhang, Y., Zhang, J.P., Hu, Z.Z., and Li, J.L. (2009). *Integration of four-dimensional computer-aided design modeling and three-dimensional animation of operations simulation for visualizing construction of the main stadium for the Beijing 2008 Olympic games.* Can. J. Civ. Eng., 36: 473-479.

Koo, B., and Fischer, M. (2000). *Feasibility study of 4D CAD in commercial construction.* Journal of Construction Engineering and Management, 126(4): 251-260. Doi:10.1061/(ASCE)0733-9364(2000)126:4(251).