**GOLDSIM USER CONFERENCE**

**POSTER ABSTRACTS**

# **1. A simple method for modelling floods events in a water balance using GoldSim**

Authors: Philippe Benoit, WSP Canada

Vlad Rojanschi, WSP Canada

Water management plans for industrial and mine sites usually involve two types of surface water quantity modelling: short-term storm design modelling used to conservatively estimate runoff reporting to water management infrastructure during flood events, and medium and long-term water balance modelling that seeks to identify and quantify each key water inflow and outflow for the site against long term climate conditions and seasonal hydrology. The GoldSim platform is often used for the later as it allows the user to easily implement a large range of climatic inputs scenarios and test multiple site configurations for daily or longer simulation timesteps, while the former generally uses other specialized surface hydraulic software designed with shorter simulation timesteps. For the study presented in this poster, the option to dynamically control the timestep in GoldSim is used to successfully implement short-term, design event floods in a water balance model. This implementation allows the user to efficiently quantify overflow risks at any period during the site’s lifecycle. A further discussion is presented on how combining these results with typical water balance projections can enhance the GoldSim model’s value to clients.

# **2. Comparison of OneLake and Sharepoint for GoldSim File Storage**

Author: Heath Orcutt, SRK Consulting

GoldSim has proven itself to be a highly effective tool for integrated teams of modelers to display, model, and simulate complex, multi-disciplinary systems. Often, GoldSim modeling requires development and input from remote users looking to access the same GoldSim files and/or linked Excel files that import data such as historical records, lookup tables, and input parameters. To support this, many companies have shifted from storing files on local or networked drives to a cloud-based system that syncs the local and cloud storage seamlessly.

When working with specifically tailored software, such as Microsoft Office components, this is a great tool for multi-user projects; however, for other software, sharing violations prevent multiple users from accessing the same GoldSim model and/or linked Excel file. As a result, GoldSim will create “zombie” Excel instances – halting workflows and resulting in lost work. SRK Consulting would like to present our takeaways from comparing two potential solutions from Microsoft: 1) integration of OneLake, a data file focused sharing system and 2) a “Check In/Check Out” workflow within SharePoint, a collaboration focused tool.

# **3. GoldSim Applied to Contaminant Transport Modeling in a Sodium Fast Reactor**

Author: Phillip I. Johnson, TerraPower

In the last calendar year, we developed a mass and radiological transport model of the Natrium Demonstration Reactor to be built by TerraPower, LLC. The model makes special use of reference fluid cloning and hierarchical indexing to produce a GoldSim simulation that takes state functions assigned to the process level and translates them to a suite of thermodynamic and mass transport properties with a meticulous referencing methodology. The model emphasizes an assessment of high priority radiological contaminants such as tritium and cesium. Specially engineered adsorptive systems, designed to maintain process fluid activity levels below designated thresholds, are simulated using empirically derived isothermal adsorption models. These isotherms are applied to GoldSim aquifer pathways via custom modification of the set of temporary cell pathways it creates. This effectively allows for an advection-dispersion solution via finite difference approximation whilst employing non-linear partitioning between fluid constituents and the solid adsorbent. Tritium and other hydrogen isotopes play a special role in their ability to migrate through metallic containment barriers. This behavior is uniquely modeled as a spatially continuous diffusive transport process across a series of cell pathways which are used to represent discretized regions of solid containment barriers. Partition coefficients for most species at the gas-liquid interface are defined primarily by the gamma-phi modification to Raoult’s law. However, given the disassociation of gaseous homonuclear diatomics within solid and liquid metals, empirically derived Sievert’s law relations are employed to define non-linear partitioning between respective interfaces. Empirical relations are used to generate densities, diffusivities, solubilities, viscosities, and vapor pressures to support other GoldSim specific and transport related functions. In the absence of empirical relations, theoretical models are employed for predicting the diffusion coefficient of various species such as the Stokes-Einstein and Chapman-Enskog equations for the gas and liquid phases, respectively. In sum, the fully integrated plant model produces reasonable approximations for the distributions of choice contaminants across relevant reactor processes; aiding to inform design opportunities and limitations.

# **4. Clones, Arrays and Indexing for Large Multi-node Models; Solubility calculations and other uses**

Author: Alex Fitzpatrick, Klohn Crippen Berger

Large, multi-node models, which are often required for complex water quality models, create large sets of inputs that can rapidly lead to complex and confusing function chains. The complexity can be mitigated by maximizing the use of using clones, arrays (vectors and matrices) and indexing to create centralized elements that contain the relevant input values for all nodes. This paper aims to show how this approach can lead to a more organized and externally-transparent model. A particular example to be to illustrate this lies in the calculation and application of dynamic mineral solubility controls on predicted water quality using thermodynamic data for multiple minerals across multiple nodes from source, mixing zones, and receivers. The approaches shown provide a means to maintain model structure and organization but that is expandible as additional requirements develop during the modelling process.

# **5. Input Data for Safety Study on Radioactive Waste Disposal Facility in Korea**

Authors: Hyojoo Kim, Pohang University of Science and Technology

Jueun Kim, Pohang University of Science and Technology

Wooyong Um, Pohang University of Science and Technology

Radioactive iodine, a major fission product, is highly mobile due to low adsorption affinity to geological mediums. The present study investigated the transport characteristics of iodine under a radioactive waste repository in Korea. Based on experimental results, we developed a dataset to be used as an input parameter for the safety assessment of radioactive waste disposal facilities in Korea for GoldSim simulation codes. Solid samples (rock and sea soil) and solution samples (groundwater, seawater) were collected from the Gyeongju repository to simulate the far-field natural barrier, and potential engineering barrier materials (WRK bentonite, concrete) were also obtained. Using the solid and solution samples, batch sorption tests, through diffusion tests, and dynamic column tests were conducted. In the near-field engineering barriers, the main mechanism for iodine transport was diffusion. In the fractured zones of the natural barrier far from the disposal site, the main transport mechanism of iodine was advection and dispersion. Therefore, retardations by chemical reaction with rock were hardly expected. The database constructed in the present study provides a complete understanding of the site-specific hydrogeological parameters influencing the fate and transport of the iodine and can be utilized as the input parameters in a safety assessment of the disposal facility.

**Acknowledgements**

This work was supported by the Institute for Korea Spent Nuclear Fuel (iKSNF) and National Research Foundation of Korea (NRF) grant funded by the Korea government (Ministry of Science and ICT, MSIT) (No. 2021M2E1A1085203 & No. 2016R1D1A1B02013310).

This work was also supported by the human resources development project for high level waste management hosted by Korea Radioactive waste agency (KORAD) and South Korean Ministry of Trade, Industry and Energy (MOTIE)

# **6. Building better water balance models for tailings and mine rock stockpiles**

Authors: Tony Zheng, University of Alberta/OKane Consultants

Rebecca Hurtubise, AECOM

Nicholas Beier, University of Alberta

In mining operations, seepage from tailings and mine rock stockpiles typically contribute a small percentage of the overall site wide water balance yet their effect on water quality is often disproportionate due to leaching of oxidized products as acid rock drainage. Most site-wide water balance models built for the permitting stage of a mining project make simplified, empirical assumptions on the hydrology of these structures. This work will show-case some examples of physics-based models built in GoldSim. At the same time, it is critical to know why and when it makes sense to build physics-based models in GoldSim (and when not to).

# **7. Nested Modeling Approach to Simulating Contaminant Release for use in Hanford Site Performance Assessment**

Authors: Ryan Nell, Intera

Wei Zhou, Intera

Benoit Paris, Intera

Sunil Mehta, Intera

Performance assessment (PA) studies are underway to evaluate the long-term impacts from disposal of radioactive wastes in the waste disposal facility at the Hanford Site. Waste release models were development to calculate radionuclide release rates for different waste form types and storage configurations. A unique waste form emplaced in one of the facility trenches is comprised of uranium fuel rods with technetium-99 impurity which were encased in grout as a single monolithic structure. Referred to as the uranium billet monolith, this unique waste form required more sophisticated reactive transport modeling to evaluate the waste release characteristics. A stand alone reactive transport model was developed by coupling GoldSim with PhreeqcRM via a dynamic-link library interface to perform a variety of ambient temperature aqueous geochemical calculations. This approach allows for flexibility in evaluating the uranium billet monolith system through Monte-Carlo uncertainty analysis to assess potential secondary uranium mineral precipitate formation and porewater chemistry evolution over the course of the 10,000 year simulation period. Release rate results from the uranium billet monolith uncertainty analysis, performed using 300 realizations, were incorporated into the larger system level GoldSim model for the PA. Integration of the two models, reactive transport model for simulating contaminant release from the uranium billet monolith and system model for the total disposal system, allowed for evaluation of overall compliance for the all-pathway doses and groundwater protection for the waste disposal facility in the Hanford Site.

# **8. Near-Field Groundwater Flow Model Abstraction from HYDRUS 3D into GoldSim**

Authors: Kate Catlett, Neptune and Company

Aaron Bandler, Neptune and Company

Micah Gilbreath, Neptune and Company

Sean McCandless, Neptune and Company

Bonnie Jones, Neptune and Company

Dylan Boyle, Neptune and Company

The West Valley Site includes four underground high-level radioactive waste storage tanks that have been mostly emptied of waste. Neptune has been contracted by the State of New York and the US Department of Energy to evaluate close-in-place options for the tanks, such as filling each tank with cementitious grout. A steady state model of the grouted tank and surrounding cement vault was developed using HYDRUS 3D software. Output from this complex process-level groundwater flow model was abstracted into the site-wide probabilistic performance assessment model, built in GoldSim. Challenges related to building this model in GoldSim will be discussed, along with model structure in HYDRUS 3D and GoldSim.

# **9. GoldSim Dashboard Tips 'n' Tricks**

Author: John Tauxe, PhD, PE, Tauxian Solutions

This presentation covers a variety of uses of the GoldSim Dashboard Authoring Module.

Some examples show creative uses of standard Dashboard tools, examining the GoldSim programming behind them. Other examples address some workarounds for limitations inherent in the Dashboard tools, again with the background programming that makes them work. Examples are taken from existing models of radioactive waste disposal sites in different states of operation.

# **10. An evaluation of scenarios for a radioactive repository using GoldSim**

Authors: Hyun Jin Yu, Chosun University

Ki Tae Yang, Chosun University

Jong Soon Song, Chosun University

Concrete is crucial in domestic high-level radioactive waste disposal environments, serving as a key engineering barrier within the multi-barrier concept for radioactive waste containment. Over time, concrete can deteriorate due to factors such as waste dissolution, groundwater flow, subsidence, and seismic activity, potentially leading to the release of waste into the environment. A common deterioration mechanism is sulfate attack, especially when concrete structures interact with groundwater.

Ensuring a high-level radioactive waste disposal facility's safety post-closure requires analyzing potential phenomena within the facility and its surroundings. While direct prediction of these phenomena is challenging, simulation programs can evaluate predictable scenarios. Among various safety assessment programs, GoldSim stands out. It was instrumental in licensing the Yucca Mountain repository in the US and excels in simulating mass and volume transfer in complex disposal systems, including nuclide migration and groundwater flow. GoldSim has also been extensively used to study concrete deterioration.

Before creating scenarios in GoldSim, a preliminary study examined concrete deterioration due to sulfate infiltration using KURT groundwater. An experimental tank was constructed, and 20-year-old waste concrete was prepared, cut into 36 specimens of Ø50 x 50H sizes, and classified into grades A to D. The specimens were immersed in a water tank for 365 days to accelerate deterioration. Every 30 days, specimens were removed for analysis using SEM and EDS to observe deterioration phenomena. The experimental data were then applied to GoldSim to model the impact on the ecosystem runoff process.

This study outlines a basic evaluation model using GoldSim, incorporating data from preliminary experiments. A scenario was modeled where radioactive waste leaks into the ecosystem through a series of barriers: disposal container, silo, concrete barrier, and natural barrier. The results highlight the influence of concrete deterioration on the release of radioactive waste into the natural ecosystem.

**Acknowledgements** This paper is a result of The Human Resources Development Project for HLW Management hosted by KORAD.

# **12. Case Study: GoldSim as a Predictive Tool for Oil Sands Operations**

Author: Candace Whitten, WSP

Matthew Ryans, WSP

Oil Sands mining operations generate multiple tailings types requiring various treatment methods, storage components and time for maturation. For this project GoldSim was used to simulate an oil sands mining operation to estimate cumulative tailings production (by type) over the life of mine. Planned mining operations and tailings generation were modeled to assess if the proposed storage facilities have capacity to store the tailings waste on-site and assess whether the available treatment options would be sufficient for waste treatment.

# **14. It's about time: reflecting temporal changes in the geochemistry of a waste rock storage facility and ore stockpile in GoldSim**

Authors: Ryan Shaw, WSP

Kristina Skeries, WSP

Aria Druker, WSP

Water quality modelling of mine sites generally apply a conservative approach to the development and application of geochemical source terms. Despite the evolving geochemical state that many exposed geological materials (in particular, those that are potentially acid generating) experience, such approaches often use a single condition (for example, the steady-state conditions of a kinetic test that has begun producing acidity) to represent geochemical characteristics in perpetuity.

In this case study, we present an approach that was applied in a mine site water quality model which allowed for the representation of a waste rock storage facility becoming gradually acid generating over time. A module was developed in GoldSim to track the tonnage of all recently exposed waste rock as it was deposited in a storage facility. It incorporated a discretization within the tonnages by geochemical domains and further sub-classifications based on acid generation potential, namely short-term, long-term and non-potential. A defined lag-time for each sub-classification of each domain was then applied, which allowed for the tracking of the tonnage of aged material. Combined with loading rates developed specifically for recently exposed and aged material, the result was a gradual shift of loading rates reflective of recently exposed conditions, to those of aged material conditions over time. Further, this approach was successfully modified for the ore stockpile to account for both the addition and removal of ore, often simultaneously, while still tracking this gradual shift between recently exposed and aged material. Other potential applications of this straightforward module will also be discussed.

# **15. Practical Applications of Glacial Recession Modeling to GoldSim Mine Water Balance and Water Quality Models**

Authors: Steve Byers, WSP

Paul Haby, WSP

Glacial area and volume decreases have been documented across the globe since the mid-twentieth century, with the decreases accelerating in the early twenty-first century in many regions. As a result, established baseline streamflow conditions in glaciated watersheds may not be representative of future conditions where the seasonal glacial contribution to the hydrologic regime may be significantly reduced. The resulting decrease in hydrologic contribution from seasonal glacial melt has potential water supply and water quality implications for both current and planned mining operations in glaciated settings such as Alaska, the Golden Triangle of British Columbia, and the Andes.

To characterize potential hydrologic and water quality impacts resulting from continued glacial recession trends, a generalized approach was developed in GoldSim for the simulation of changes in glacial area, glacial volume, and glacial melt. This approach can be implemented using publicly available data sources and published regional trends, but can be further refined through the use of site-specific monitoring data when available. An added benefit of this approach is that the driving inputs are precipitation and air temperature, making this approach responsive to projected changes in these variables under climate change scenarios. This novel approach has the potential to refine water balance and water quality models used for long-term water supply and water quality assessments of glaciated watersheds.

# **16. WRRM1 and WRRM2: GoldSim Implementations of IWA Benchmark Models (BSM1 and BSM2) for Biological Nutrient Removal**

Author: Lloyd R Townley, Nanjing Smart Technology Development Co. Ltd (China) and GW-SW Pty Ltd (Australia)

New simulation software has been developed using GoldSim for use in training, and to facilitate the use of simulation software for improving the performance of water resource recovery facilities (WRRFs). Computer simulation of WRRFs (formerly known as wastewater treatment plants or WTTPs) is useful for:

• design of new WRRFS,

• design of modifications to existing WRRFs,

• diagnostic analysis to understand the behavior of existing WRRFs,

• design of new control strategies to improve the performance of WRRFs, and

• training of operators, professionals and students.

Initially the main reason for developing new software was the desire to have a standalone executable that can be launched by calls from an external control program. This would allow development and testing of new optimal control algorithms based on many simulations being run in parallel. Another advantage of GoldSim is the ability to visualize dynamic processes interactively.

**17. LWBC: A Lake Water Balance Calculator for estimating exchange fluxes between surface water bodies and groundwater**

Author: Lloyd R Townley, Nanjing Smart Technology Development Co. Ltd (China) and GW-SW Pty Ltd (Australia)

New simulation software has been developed using GoldSim to help researchers and managers of lakes and wetlands to estimate the flux of groundwater into a surface water body and the flux of surface water into groundwater, i.e. two components of the exchange flux rather than a single net flux that can be calculated by normal water balance methods. A flow-through surface water body is assumed to gain groundwater inflow I, to lose water as groundwater outflow O, to gain precipitation P and to lose water by evaporation E. LWBC allows a user to compute the dynamics of storage, solute concentration (e.g. chloride or TSS), stable water isotope concentrations (oxygen-18 and deuterium) and radon, initially with the assumption that I, O, P and E are constant in time over a period of weeks or months. A consistent set of analytical solutions has been developed, including the relatively novel use of 1 + δ as an approximation to isotope "concentration", and new solutions for radon in terms of an upper incomplete exponential integral. Balances are calculated using GoldSim, and the analytical solutions have been used to verify the GoldSim implementation. A GoldSim dashboard allows a user to fit observed measurements to as many balances as possible, by trial and error. LWBC is intended to support design and interpretation of field experiments and will soon be extended to allow a user to supply measurements of P and E that relax the assumption of constant climatic forcing

**18. Comparison of the Applicability of GoldSim and RESRAD Software for Radiological Performance Assessment**

Author: Ralph Perona, Neptune and Company

Katie Catlett, Neptune and Company

The GoldSim modeling software has great flexibility for modeling the performance of radiological disposal systems. Neptune has applied GoldSim for Performance Assessments for sites at Los Alamos National Laboratory, Nevada National Security Site, EnergySolutions in UT, Waste Disposal Specialists in TX, West Valley Demonstration Project in NY, and more. Although the GoldSim Contaminant Transport Module facilitates dynamic modeling of natural and engineered systems, the user must create the model “from scratch” and provide the documentation and Quality Assurance to support the model and associated output. By contrast, the RESRAD-ONSITE and -OFFSITE computer codes are pre-built and come with code verification and benchmarking work completed. The poster will identify how the Conceptual Site Model and project modeling and decision-making objectives can be applied to determine whether RESRAD or GoldSim is likely to be suitable for a radiological Performance Assessment.

**19. Water Balance Model for an Underground Mine in the Great Lake Region**

Authors: David Hoekstra, SRK Consulting

Christina James, SRK Consulting

Brent Thiele, SRK Consulting

This poster will present the key components of a comprehensive water balance model developed to support a Pre-feasibility study of an underground metal mine in the Great Lake Region. The model includes the underground mine component, process areas, and a remote tailings facility, as well as the surrounding watersheds, drainages, and lakes to evaluate the impact of the mine on the surrounding environment. SRK developed several modules to support the water balance, including stochastic rainfall and temperature generation, snow pack and snow melt behavior, lake ice up and ice out volumes, stream routing, and dynamic tailings stage storage curves. The model is being used to evaluate many aspects of the mine plan, including backfilling campaigns, inter-basin transfers, and excess or surplus water conditions.

**20. Using GoldSim to Evaluate the Impacts of Aqueous Infiltration Rates on Simulated Radiological Doses: A Probabilistic Modeling Study of Los Alamos National Laboratory’s Area G**

Authors: Amy Rice, Neptune and Company

Daniel Levitt, Neptune and Company

Emmie Boettcher, Neptune and Company

Mike Vogler, Neptune and Company

Kay Birdsell, Neptune and Company

Kelly Crowell, Neptune and Company

Kate Catlett, Neptune and Company

Potential transport of radionuclides from waste repositories is of interest to the gamut of stakeholders, from grassroots community members to high-level government officials. Material Disposal Area G (Area G) is a radioactive waste disposal facility located at Los Alamos National Laboratory, New Mexico. It consists of pits and shafts containing waste. Because Area G is an active low level waste disposal facility, it is the focus of analyses required by the U.S. Department of Energy Order 435.1, Radioactive Waste Management. These analyses include numerical modeling for performance assessment (PA) and composite analysis (CA). The current Area G PA/CA model utilizes the GoldSim Contaminant Transport Module to predict radiological doses to hypothetical future receptors. In FY2024, Neptune and Company, the Area G PA/CA model custodians, updated the modeling of steady-state aqueous infiltration at the ground surface. This was a multistage task that included (i) gathering infiltration data, (ii) weighting the data for site-specific conditions, (iii) generating infiltration rate distributions, (iv) modeling infiltration probabilistically, and (v) simulating radionuclide transport. In this poster, the workflow and models used are discussed, with techniques and lessons-learned that may apply to other multistage modeling projects using GoldSim. Also, insight is provided on the relationship between aqueous infiltration and simulated radiological doses at Area G. Specifically, we describe how the use of a wider infiltration distribution and site-specific weighting may lead to additional radionuclide leaching. Increased leaching is linked to a decrease in the dose associated with biotic transport (i.e., movement of buried contaminants upwards to the ground surface by plants and burrowing animals) and a negligible increase in groundwater dose. We find that use of a more realistic (in this case, wider) infiltration distribution does not increase doses above Order 435.1 performance objectives.

**21. Using Mine Water Balances to Predict Impact of Rehabilitation Activities on Mine Water Management**

Author: Nirvishee Juggath, WSP Group Africa

WSP Group Africa (Pty) Ltd. has been assisting a mining client within Southern Africa with their water balance for the past 7 years. The mine consists of various current open cast operations and historically mined out open cast and underground workings. The current and future mining operations include greenfields open cast operations as well as both open cast and underground mining operations aimed at mining the pillars left behind during the historical underground mining operations. Water management at this site over the years therefore has been complex and multi-dimensional.

The key objectives of the project was to identify adequate measures to manage the water on site. Water emanates from normal recharge, runoff and rainfall on the current workings areas, recharge and runoff from previously mined out areas, recharge and seepage from backfilled mined out areas and water that has accumulated over the years in historically mined out underground areas that are recharging and potentially decanting. The management of water has been multifaceted and evolved over the years to cater for key drivers including environmental, legislative and budgetary.

GoldSim has been pivotal in assisting WSP to model the system in its various forms and allow for creating various modules associated with the various activities and mining states. Successful modelling is underpinned by the treatment of critical input information including mining land states and rehabilitation plans. The poster will focus on highlighting what these critical inputs are and how these were prepared and analyzed. The current state of land and projected changes over the years are inputs which will be highlighted in the poster. The poster will show transitioning that has historically occurred and planned to occur regarding the land states. Water management concerns of the different areas will be indicated on the poster showing the integral way in each step that GoldSim was used to identify water inflows and excess water and water management measures. The change in water volumes over the years will be indicated showing the improvement and/or lack of with regards to water management