ITASCA™

Hydrogeology Services and Statement of Qualifications

II120-SOQ-HYD-01

GEOMECHANICS • HYDROGEOLOGY • MICROSEISMICS : CIVIL • MINING • ENERGY

"One company, providing the highest quality services in geochemistry, groundwater, geomechanics, and numerical modeling to the mining, civil, energy, environmental, and waste isolation industries worldwide."

ITASCA

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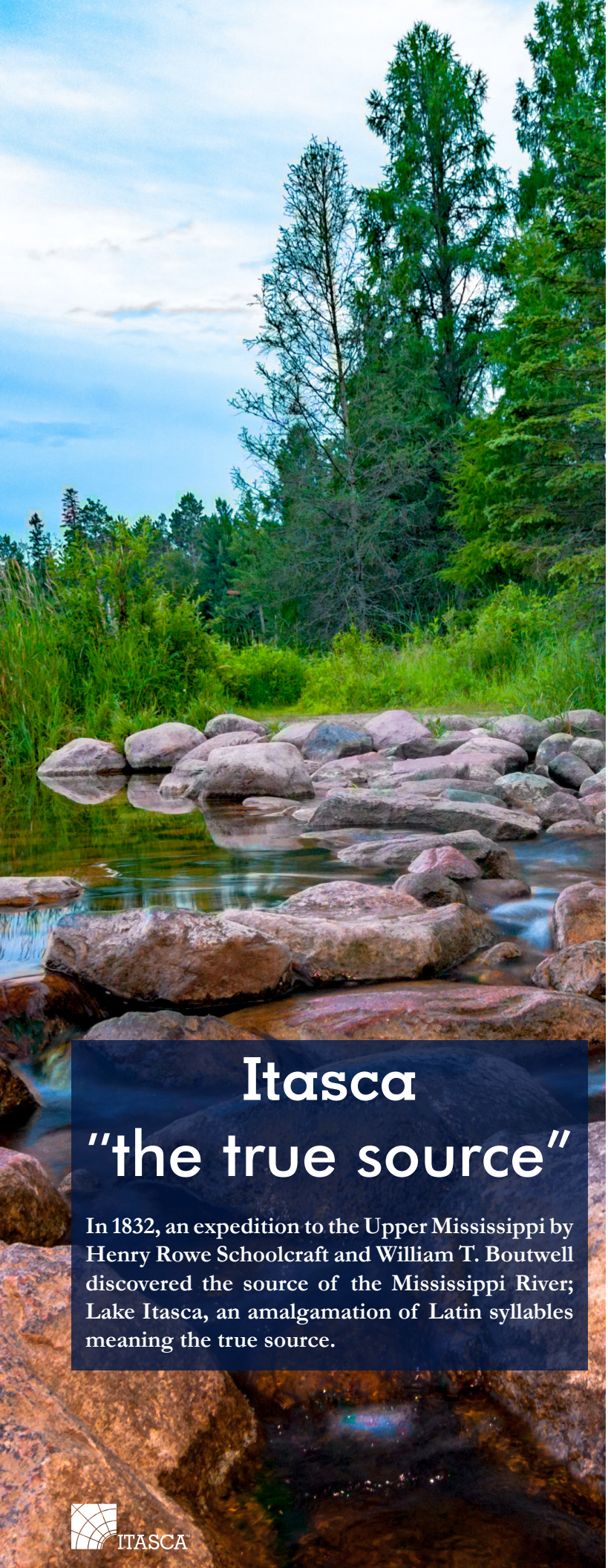


Itasca "the true source"

In 1832, an expedition to the Upper Mississippi by Henry Rowe Schoolcraft and William T. Boutwell discovered the source of the Mississippi River; Lake Itasca, an amalgamation of Latin syllables meaning the true source.

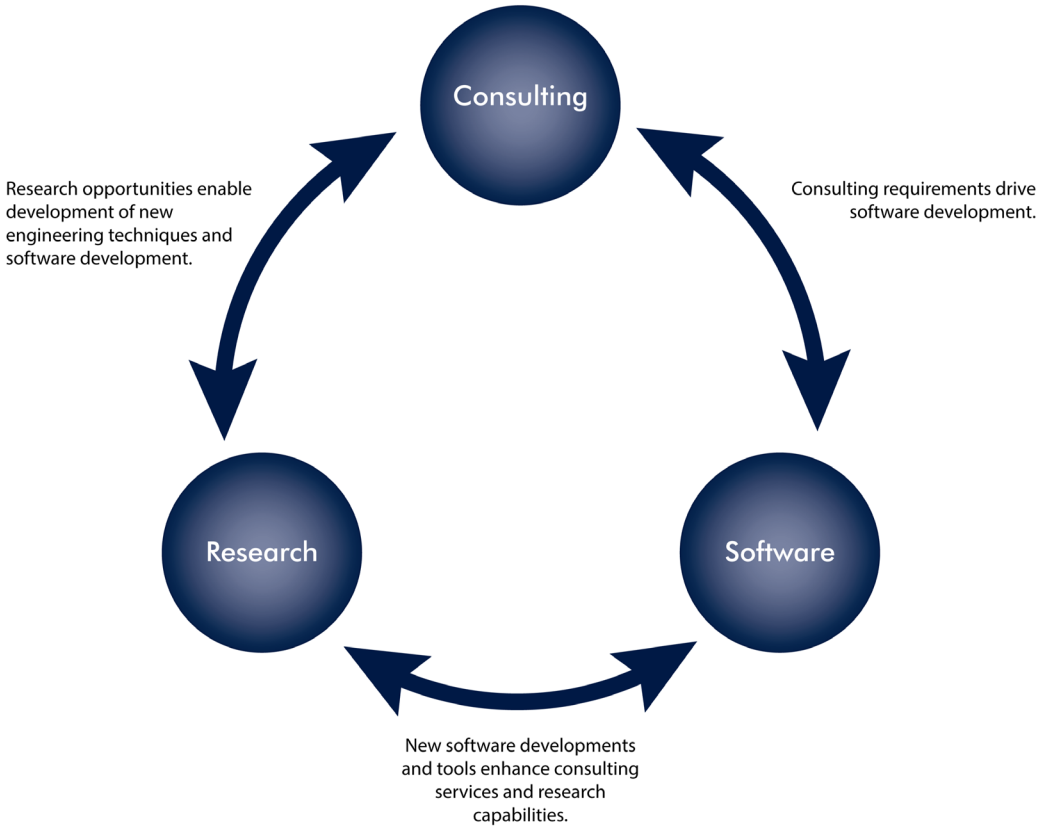
ITASCA INTERNATIONAL

Itasca International Inc. is an engineering consulting, research, and software development company founded in Minneapolis, Minnesota now with 14 offices worldwide. Itasca specializes in solving complex geomechanical, hydrogeological, and microseismic issues in civil, environment, manufacturing and material processing, mining, oil and gas, and power generation. Itasca works directly with industry, government, research and educational institutions, and as a specialist to other consulting firms.

Founded in 1981, Itasca has gained practical and technical knowledge of world-class engineering challenges and solutions. Itasca is staffed by leading engineers in the fields of site characterization, soil- and rock-mechanics, hydrology, hydrogeology, geochemistry, and software engineering. Our experienced staff work on projects ranging from practical field solutions to design issues to applications of Itasca modeling tools for solving difficult or unusual problems, including a wide range of civil works (from urban transportation infrastructure to large underground caverns) and materials (from soil and engineered materials to soft and hard rock).

Itasca understands the logistical constraints that often are encountered in solving engineering problems. Therefore, we believe in using the most appropriate levels and methods of engineering investigation that examine both technical and economic factors in order to provide practical solutions using the most suitable and best-available technology.

Use of numerical simulation software is an integral part of our consulting. Our numerical modeling software are among the most widely used and respected tools of their kind. Development and application of our advanced numerical simulation software sets Itasca apart from other engineering consulting firms. Itasca benefits from the dynamic interplay between consulting, software development, and contract research activities.



Itasca's consulting and research evolves our software, which in turn provides more advanced tools for us to use toward solving complex problems for our clients.

Our software is developed and proven with real-world problem solving driven by our consulting work. With a diverse client portfolio and multi-disciplinary team of engineers Itasca is one of the leaders in consulting services for subsurface environments.

With a large portion of our over 160 personnel possessing advanced degrees, our engineers and software developers have a proven track record of innovation, leading to new strategies and tools to better understand the complex environments in which we work.

Itasca also fosters education and university research worldwide through the Itasca Education Program (IEP) and Itasca Teaching Program (ITP), which offer our software free to qualified students and professors.

Sustainability

Itasca strives to deliver functional, actionable, and long-term sustainable solutions from an environmental and societal perspective. A good working procedure satisfies both technical aspects and the environmental demands of the client and all stakeholders with consideration to long-term sustainable social development. This means consideration of the surrounding environment during both execution and operation of a proposed solution, but also the influences on local society, working environment, and social interaction. Within projects, Itasca internally works for sustainable resource utilization through efficient travel, virtual meetings, and electronic document management. We always consider alternatives that minimize environmental impact in our work with clients. This includes both actions on our side (e.g., travel alternatives) and on the client side (different choice of methods and/or technologies that may reduce environmental impact). Itasca also follows "The Ten Principles of the UN Global Compact" concerning human rights, labor, environment, and anti-corruption.

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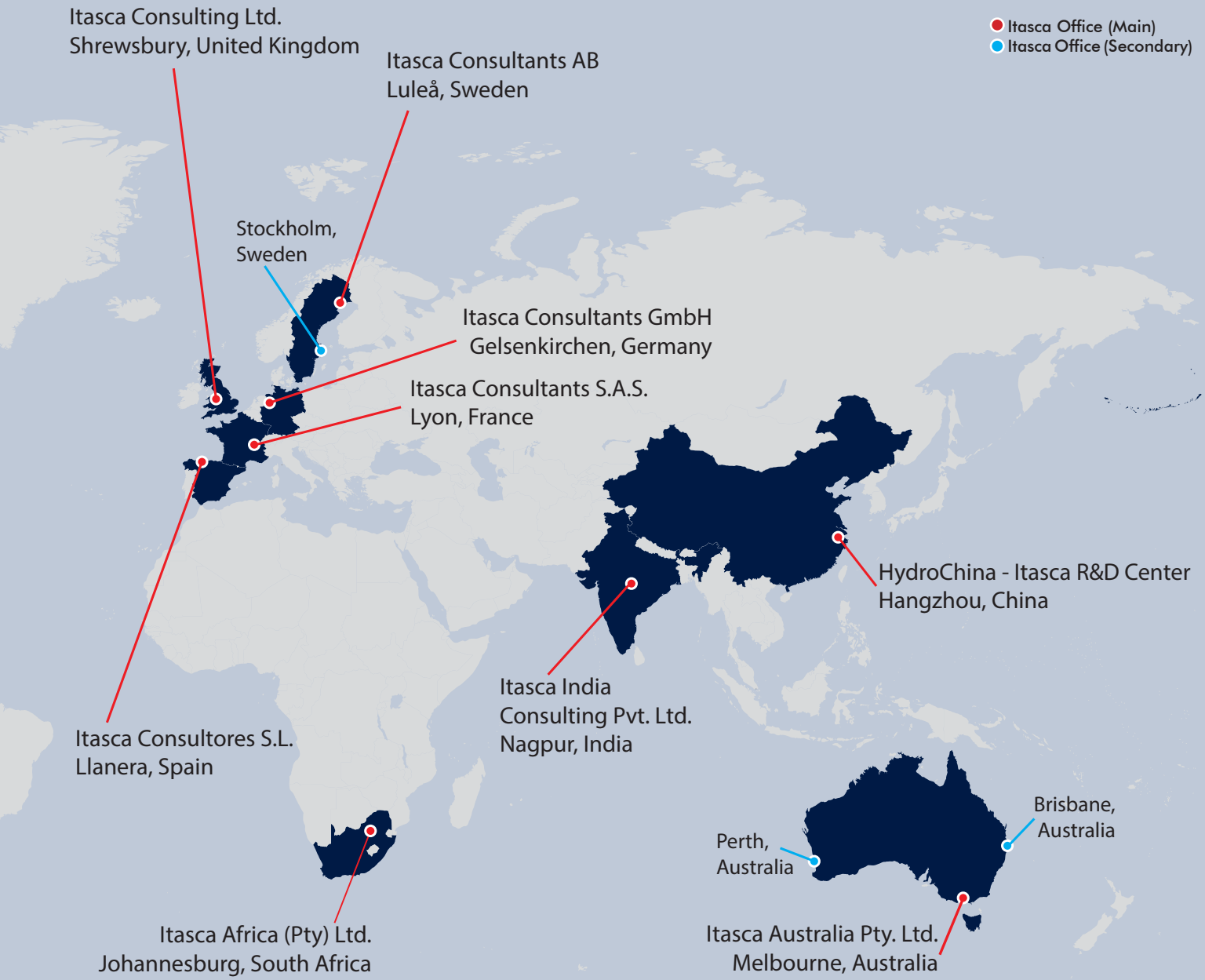


14 main consulting offices in 13 countries, and software agents based in another 11 countries, focused on servicing the global mining, civil, and energy industries.

HYDROGEOLOGY

Itasca provides consulting services in mining hydrogeology, contaminant hydrogeology, aqueous geochemistry, and seismology. Staff hydrogeologists, geochemists, engineers, geologists, and geophysicists specialize in solving hydrogeologic and seismic-related problems in the mining, petroleum, and environmental industries, with extensive experience working with regulatory agencies to achieve practical, cost-effective solutions to a broad range of environmental problems. The company is fully equipped to decipher complex hydrogeologic systems, such as those associated with ore bodies, highly-fractured bedrock, and complex depositional and/or tectonic environments. Itasca solves problems using effective methods and clearly communicates study results to clients and other stakeholders. Itasca offers a variety of services that build on its foundation of hydrogeologic expertise involving the practical and efficient application of fundamental principles to real-world problems:

- Baseline hydrogeologic and geochemical characterization
- Evaluation of groundwater supplies and identification of groundwater recharge/discharge relationships
- Exploration and development of groundwater supplies for mines, mills, and leaching operations, as well as technical support in obtaining groundwater rights and permits
- Development of conceptual hydrogeologic models
- Development of numerical groundwater flow models
- Prediction of mine dewatering rates and impacts, such as the extent of drawdown
- Prediction of pore pressures and phreatic surfaces in highwalls during mining (e.g., as inputs for slope stability analyses)
- Prediction of the rate-of-formation of mine pit lakes
- Prediction of dewatering-induced subsidence and the subsidence zone of influence surrounding open pit and underground mines
- Design and optimization of dewatering systems and evaluation of alternative dewatering systems
- Design and installation of test, observation (monitoring), and production wells (including technical specifications and bid packages), as well as analysis of step-drawdown tests and production logs
- Design and analysis of aquifer tests, especially in

more problematic fractured rock, low permeability materials, or cold regions
- Evaluation and optimization of gold heap-leach operations using a gold heap-leach simulator
- Hydrogeologic evaluation of covers using vadose-zone codes
- Expert witness, second opinion, and litigation support

Itasca works directly with industries, government agencies, law firms, and as specialists to other consulting firms in roles that address a wide range of water resource issues. Extensive experience with quantitative assessment of groundwater flow and water quality enables the company to efficiently provide clients with reliable information that is critical for attaining their operational and environmental goals as well as for navigating the complex technical, legal, and permitting aspects of water resources. Itasca's experience ranges from providing recommendations of approaches to remediate small diesel spills to conducting detailed investigations and hydrologic and geochemical modeling for Superfund sites.

GROUNDWATER FLOW

Itasca has extensive experience with quantitative assessment of surface and sub-surface groundwater flow. This enables Itasca to efficiently provide clients with reliable information that is critical for attaining their operational and environmental goals as well as for navigating the complex technical, legal, and permitting aspects of water resources. Examples of groundwater flow services provided include:

- Development of conceptual and numerical groundwater flow and transport models
- Evaluation of origins and/or flow paths using artificial and natural chemical and isotopic tracers
- Modeling of groundwater flow, multi-phase flow, and chemical transport
- Definition of equivalent hydraulic properties (permeability tensors) of fractured media
- Simulation of groundwater flow associated with block cave mining and solution mining operations

Mine Water Inflow

Project Description

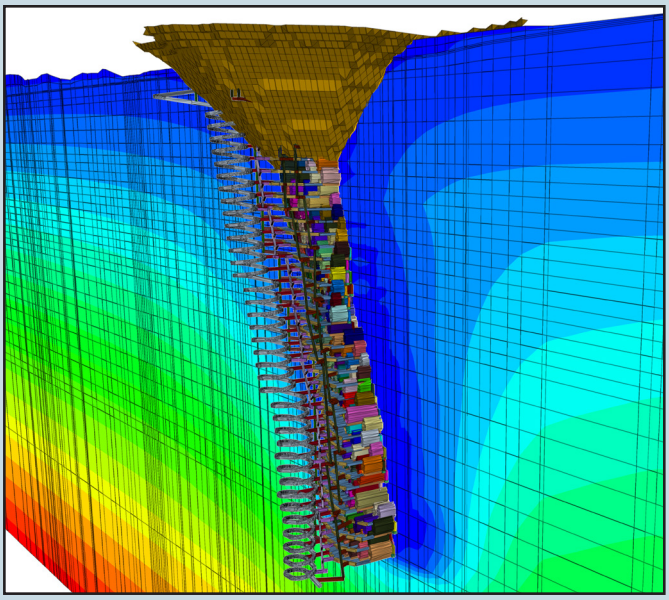
This project involved simulating the proposed open pits and underground mining of the Aurora Mine in Guyana, predicting potential inflow rates into the pits and underground workings, and estimating pore-pressure distributions.

Itasca's Contribution

A three-dimensional, finite-element groundwater flow model was developed based on available data from various site investigations. Five open pits and one underground mine were simulated for the feasibility study. Six shear zones, which will potentially intercept either open pits or the underground mine, were located within the model. The zone of relaxation (ZOR) related to the mining provided from the geomechanical model was also simulated in the groundwater model with approximately one order of magnitude higher hydraulic conductivity than the in-situ bedrock.

Outcomes

Predictions of expected inflows to open pits and different parts of the underground mine were made for various mine plans and designs. The simulated pore pressures from the groundwater model were exported as inputs to the geomechanical model. The model was utilized by both the mining company and financing agencies.



Cross-section of pore-pressure distribution of a *MINEDW* model with multiple open pits and underground mining.

DEWATERING AND DEPRESSURIZATION

Dewatering (lowering the water table) and depressurization (reducing pore pressure) can be critical for the safe and effective excavations below the ground water table. Typically the aim of dewatering include (Preene, 2015):

- Improved excavation stability and safety
- Improved working conditions
- Lower blasting costs
- Lower haulage costs
- Reduced environmental impacts

Dewatering techniques can be divided into two main groups: (1) pumping and disposal (in-excavation pumping, pumping from wells, sub-horizontal wells and drains, wellpoints and ejector wells, and drainage adits and tunnels; and (2) exclusion methods, where low permeability walls or barriers are used to reduce groundwater inflows into the excavation (bentonite slurry walls, grout curtains, and artificial ground freezing (Preene, 2015).

Itasca predicts dewatering and depressurization rates, through site characterization and by performing numerical modeling to estimate dewatering to design and optimize the dewatering and water-disposal systems, drain holes, and monitoring wells for tunnels, caverns, foundations, and construction sites.

Itasca complements hands-on field testing and instrumentation experience with these types of software tools to effectively provide comprehensive practical solutions to hydrologic and engineering problems that may arise from surface and underground mining. Itasca has developed a variety of software to facilitate its consulting services, the most notable of which is the advanced groundwater flow model code, *MINEDW*. This software was specifically designed to address water-related issues in complex hydrogeologic environments, such as those commonly associated with mining operations.

Preene, M. 2015. "Techniques and Developments in Quarry and Surface Mine Dewatering, " Proceedings of the 18th Extractive Industry Geology Conference 2014 and technical meeting 2015, pages 194-206.

Karowe Mine

Project Description

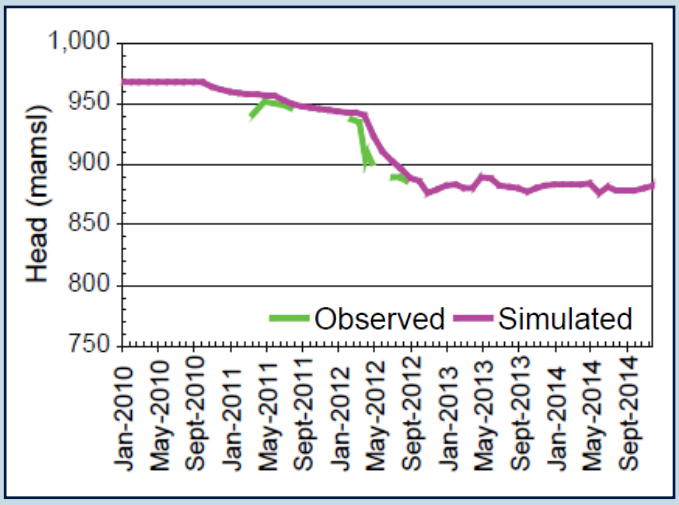
Karowe Mine, located approximately 16 kilometers (km) southwest of the town of Letlhakane, is a diamond mine where the second largest diamond (1,111 carats) ever found on record was discovered. This project involved simulating mine dewatering and excavation to evaluate future dewatering requirements, as well as providing guidance for future monitoring borehole and piezometer designs.

Itasca's Contribution

Based on available geologic, pumping, and water-level data, Itasca developed a conceptual hydrogeologic model of the Karowe Mine. This conceptual model was then used as the basis for the development of a *MINEDW* three-dimensional groundwater flow model for Karowe Mine. The groundwater flow model was calibrated to water-level and pumping data at the site. Subsequently, Itasca used the groundwater flow model to provide estimates of seepage, dewatering requirements, and water-levels to Karowe Mine to aid in the development of the Karowe pit. In addition, Itasca provided guidance for future monitoring borehole and piezometer designs in order to help Karowe Mine personnel monitor water levels and compare with target water levels.

Outcomes

The results were used by Karowe Mine to plan for dewatering requirements over the life of mine plan. In addition, strategic piezometers were recommended to help improve the confidence level of the predicted dewatering requirement.



McArthur River

Project Description

Pre-mining depressurizing of a deep ore body at the McArthur River mine, the largest single producer of uranium in the world, was considered to decrease the risk associated with mining and increase the ground stability and ore extraction. The challenge was to depressurize the high-grade ore bodies without propagating a significant amount of drawdown to the surface where impacts on surface-water resources and the associated aquatic habitat would be significant environmental issues. The objective was to evaluate the technical and economic feasibility of depressurizing the ore body.

Itasca's Contribution

Based on a limited amount of field data, a three-dimensional finite element groundwater flow model was developed using *MINEDW*. Both steady-state and transient calibrations of the groundwater flow model were conducted. Measured groundwater levels were replicated in the steady-state calibration. Subsequently, two transient calibrations were conducted, first to inflow from shafts and mine workings and then to the inflow rates and water levels following an unexpected, major inflow event. Lastly, predictive simulations were made with the calibrated model.

Outcomes

The prediction results were used to determine the amount of water that would have to be pumped from surface wells or extracted with underground drainholes to meet the depressuriziation goal, the associated magnitude and extent of drawdown that would propogate to the surface over the life of the operation, as well as its impact on surface-water resources. In addition, the results were used to design a prototype depressurizing well and a 30-day pumping test.

GEOCHEMISTRY

Itasca's hydrogeochemists have broad experience in evaluating the chemical characteristics of soil, tailings, waste rock, groundwater, and surface water at mining and environmental sites. Comprehensive evaluation of hydrogeology and geochemistry provides an integrated approach and can facilitate a more thorough understanding of complex groundwater and surface-water systems. Itasca offers a variety of geochemical services that integrate with its hydrogeologic services, including:

- Evaluation of source and extent of groundwater contamination
- Environmental characterization of materials, including ore, waste rock, and tailing
- Baseline characterization of water quality
- Assessment of potential water-quality impacts from mining, oil and gas activities, industrial, and agricultural
- Evaluation of groundwater source areas and flow paths using artificial and natural chemical and isotopic tracers
- Hydrogeochemical and hydrodynamic modeling (e.g., *PHREEQC*, *CE-QUAL*, and mass balance models)
- Chemical-transport and fate analyses in soil and groundwater
- Prediction of physicochemical characteristics of pit lakes
- Numerical modeling of solution mining
- Expert witness, second opinion, and litigation support

Ernest Henry Mine

Project Description

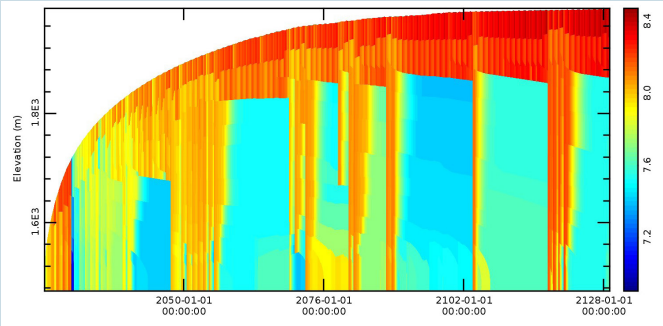
The Ernest Henry Mine is a large open pit copper mine in Australia. A Feasibility Study (FS) was conducted to evaluate transitioning to sub-level caving methods.

Itasca's Contribution

Itasca hydrogeologic and geochemical support for the FS involved field work, data analysis, and numerical modeling. Itasca performed packer permeability tests to characterize/quantify local hydraulic properties and identify structural zones of high groundwater inflows to the mine. Itasca calibrated *MINEDW* groundwater flow models, using site data and prior mine-dewatering records, and simulated 10 dewatering options. These simulations used *3DEC* geomechanical model results (caving extent, ground cracking, and relaxation around the excavations). Itasca also developed a coupled numerical hydrodynamic (*CAEDYM/DYRESM*) and geochemical-equilibrium (*PHREEQC*) water quality model to assess the potential stratification and water quality of the hydraulically-connected pit lake and flooded underground mine after closure.

Outcomes

Based on Itasca's field work and modeling analysis, a dewatering system utilizing 15 strategically-located deep dewatering wells was recommended to limit the residual passive inflow to the underground mine to a manageable rate. An underground drainage tunnel and associated drain holes were also recommended as an auxiliary method for underground mine pre-dewatering. Hydrodynamic and geochemical modeling of the ultimate pit lake predicted that periodic mixing would occur and that the mixing would maintain generally oxidizing conditions in the lake and resulting in low metal concentrations.



Modeled pit lake stage and dissolved oxygen profiles, showing stratification and episodic mixing.

Cove Pit Lake

Project Description

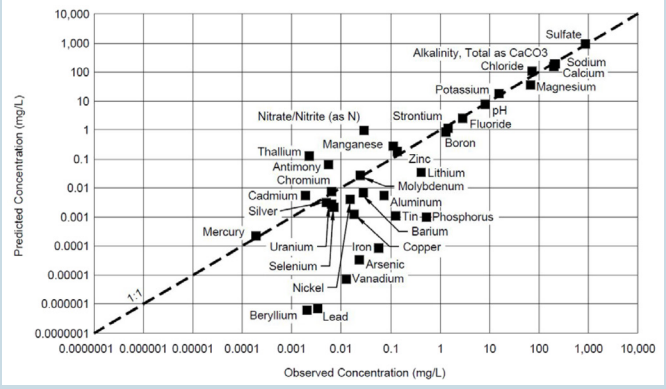
The McCoy-Cove mine is a closed gold mining complex along the Battle Mountain-Eureka Trend in central Nevada. The Cove pit has partially filled to form Cove pit lake. Regulatory requirements required predictive geochemical modeling of the pit lake to evaluate water-quality degradation potential and for use in ongoing permitting and closure activities.

Itasca's Contribution

An empirical geochemical model, based on the combination of solute loading, groundwater inflow, and aqueous geochemical processes to the pit lake, was developed to predict future water quality of the Cove pit lake. The terminal, groundwater-fed Cove pit lake began filling in 2001, and water-quality samples from the 15-year filling period were used to calibrate the pit-lake model and evaluate accuracy of the predictions.

Outcomes

Geochemical characterization data for the Cove ultimate pit surface allowed for the development of a predictive model. The predicted concentrations of most of the major and minor constituents are similar to the measured concentrations after approximately 15 years of infilling. Predicted concentrations of trace constituents were generally representative of the measured concentrations but were not as similar as for the major and minor constituents. Sensitivity evaluations generally represented the ranges of concentrations measured in the pit lake, and the model predictions were useful from a regulatory standpoint to assess the need (or, in this case, the lack thereof) for preventative actions in the pit lake.



Predicted and observed pit-lake chemistry.

ITASCA

SITE CHARACTERIZATION

In order to predict how an excavation or structure will behave, an understanding of the adjacent earth properties is required. To this end, Itasca reviews any existing data, in collaboration with our clients, to identify any knowledge gaps.

As required, Itasca works with third parties and across our offices using best-practices to facilitate or perform a wide range of laboratory and in-situ geomechanical, hydrogeological, and seismicity testing. This includes piezocone and dilatometer testing, lineament analysis, precise structural mapping, drill core logging, televiewer analysis, pressuremeters, stereophotos, and laboratory testing.

Itasca consultants can interpret and model earth and engineered-material behavior for any given range of anisotropies, scales, properties, and conditions, which gives Itasca an understanding of your project that is second to none.

Groundwater

Specific services provided include:

- Baseline conditions
- Sampling of water, rock, soil, waste, and ore chemistry
- Supervising drilling and hole abandonment
- Supervising and installing pumping wells, point piezometers, and monitoring systems
- Coordinating, supervising, and analysis of aquifer testing
- Investigation of subsurface contamination

Soils

Specific services provided include:

- Assessment of soil stratigraphy
- Identification of soil types
- Estimation of mechanical properties
- Estimation of permeability
- Estimation of water table and consolidation parameters
- Liquefaction potential
- Estimation of parameters for empirical assessment and calibrated numerical modeling for engineering design

Structural Geology and Rock Mass

Fractures have a significant impact on rock mass mechanical and hydraulic properties. Thus, a sound description of the fracturing characteristics is required. Obtaining accurate rock mass strengths requires an understanding of the intact rock and joint properties of each geotechnical unit and the in-situ stress state. In order to estimate rock mass strengths, Itasca uses the full gamut of engineering approaches, from analytical and empirical to numerical, and Itasca pioneers innovative techniques such as Synthetic Rock Mass (SRM).

Specific services provided include:

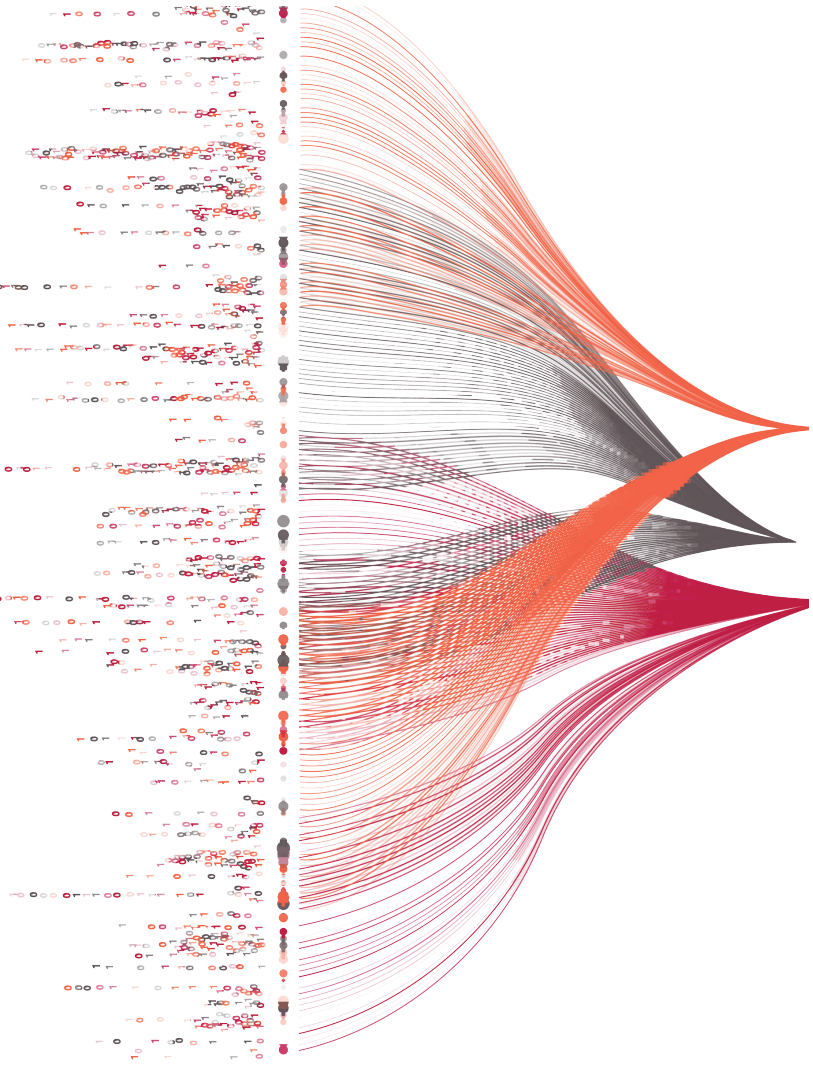
- Discrete Fracture Network (DFN) mapping and modeling
- Lineament analysis
- Precise structural mapping
- Drill core logging and televiewer analysis
- Photogrammetry and stereophotos
- Laboratory property assessment

In addition to DFN generation and calibration, Itasca has developed various tools to analyze and quantify flow from borehole logs. One of the main characteristics of fractured medium flow is its organization into channels, or preferential flow paths. Versatile indicators help define the number and the intensity of these main flow structures.

The advanced DFN models developed by Itasca, combined with data-derived hydraulic properties, are able to reproduce preferential flow paths. The software *DFN.Lab*, developed by the University of Rennes and Itasca, allow large flow simulations with various boundary and pumping conditions. In addition, we can compare simulated borehole flow logs with sampled data.

DATA MANAGEMENT AND PRESENTATION

Methodologies for the collection of hydrogeologic and geochemical data vary, as do the ways those data are managed and presented. Itasca offers consulting services to customize solutions that meet each client's needs related to the management and presentation of hydrogeologic and geochemical data.



IHOD

Itasca developed the customizable **Itasca Hydrologic Observation Dataviewer (IHOD)**, which is a QGIS (previously known as Quantum GIS) plug-in that merges high-level database input/output with tools in order to view hydrogeologic and geochemical data. It was developed to interact directly with underlying databases to retrieve data and provide users with intuitive access to those data in graphical and tabular formats that can be readily integrated into the user's work flow. QGIS is a free, open-source geographic information system (GIS) that provides a simple graphical platform to interact with a database management system. IHOD combines various tools that have been developed by Itasca and uses QGIS' extensive libraries to generate graphics, interact with database management systems, provide file input/output, and perform numerical and statistical analyses.

IHOD was developed specifically for groundwater data management with the following key features.

- It has the flexibility to populate a database from easy-to-use file formats. IHOD can be adapted to different data-file formats based on the individual client's needs.
- It is easy to retrieve data in an immediately useful format. IHOD can output data in a client-specified format.
- It adapts to the QGIS platform. IHOD uses the QGIS GUI platform and has a similar look and feel to QGIS.
- The database is easy to transfer. A complete database may be converted to a portable database format or exported into an ASCII document containing complete instructions for rebuilding it. These methods provide a simple, fast, and error-resistant

way to share data between networks, or to operate remotely.

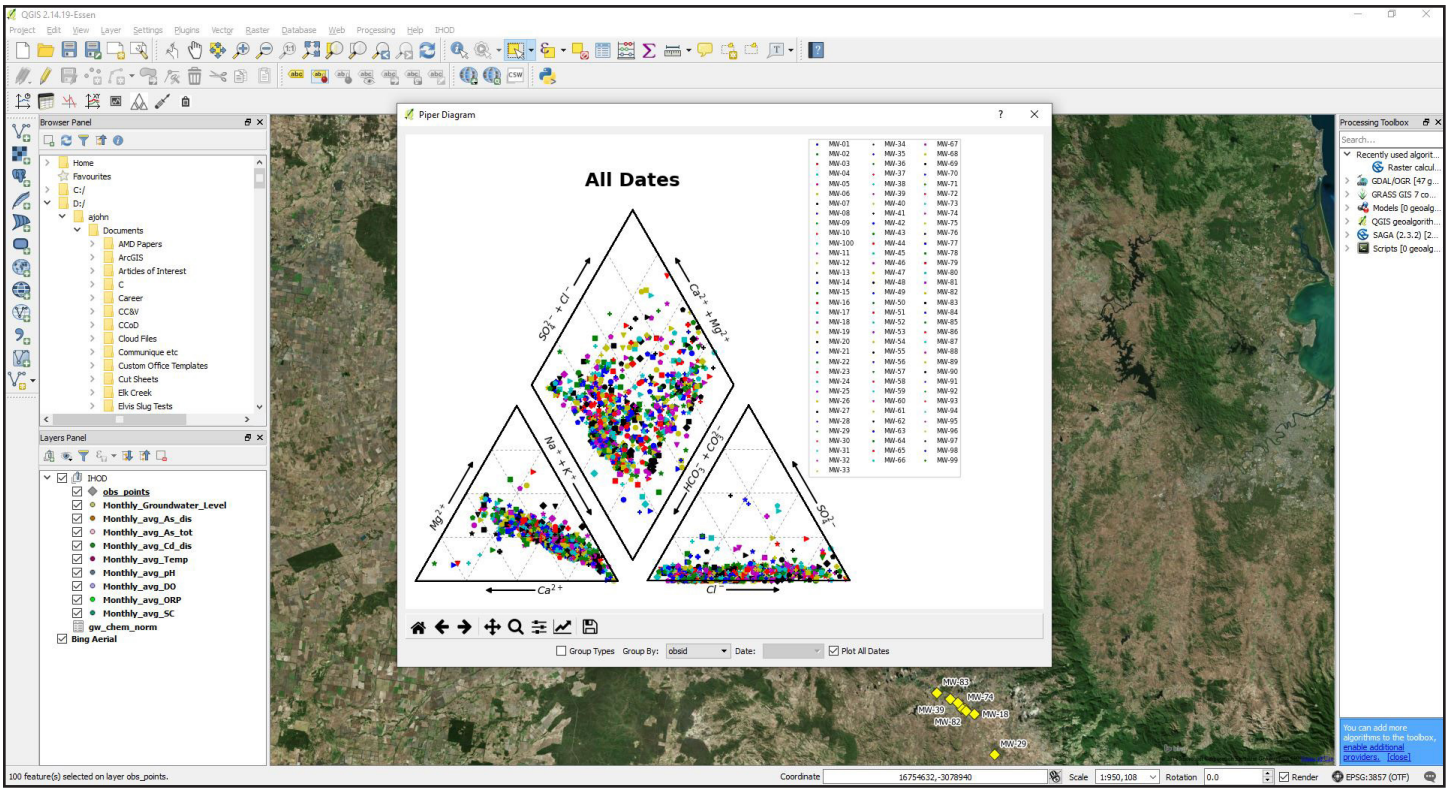
Itasca has the latest version of Ctech Development Corporation's EVS-PRO (now Earth Volumetric Studio), a powerful software application that is used for data analysis, visualization, and animation. This software incorporates three-dimensional gridding (including kriging), geostatistics, visualization and analysis of three-dimensional environmental data with EVS, geologic modeling, volumetric rendering and analysis, general GIS display capabilities, and more. It is well-suited to the presentation of data for site assessments, financial and remediation planning, litigation support, regulatory reporting, and public relations.

Itasca has successfully completed litigation projects using the EVS software to demonstrate geologic structures and extents of chemicals in soil and groundwater. Itasca uses the modular, customizable structure of EVS for the presentation of all types of geospatial (e.g., hydrologic, geochemical, geomechanical, and geophysical) data. The company has extensive experience using EVS for conveying data trends in time and space and for presenting comprehensive site models and complex datasets.

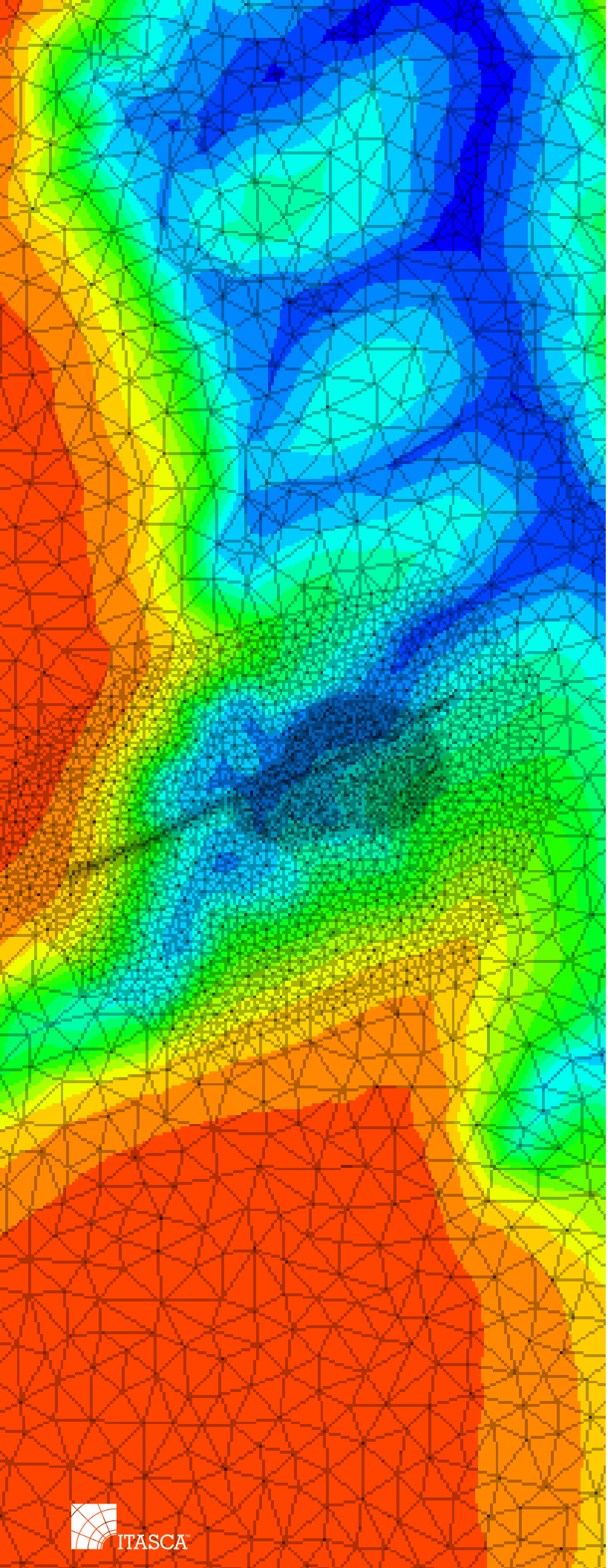
In addition to EVS, Itasca uses other software applications (e.g., Leapfrog, Surfer, and AutoCAD) to develop complex, three-dimensional, geologic models that can be used as inputs for groundwater flow models or as a platform for the illustration of contaminant concentrations and other environmental data. Itasca has also developed tools for presenting complex hydrogeologic data, such as pore-pressure distributions extracted from groundwater models. Itasca works with clients to find (or develop) the tools that are best suited for their data-presentation needs.

The following are the core services offered in data management and presentation:

- Consultation on database design, structure, and software options
- Construction of databases for hydrogeologic and geochemical data
- Development of customized tools for populating databases, extracting data, and visualizing data
- Development and visualization of complex, three-dimensional, geologic models
- Development of custom tools for manipulation and visualization of large, complex, three-dimensional datasets



The IHOD program displaying a piper diagram summarizing all water sample chemistry data for a site.



HYDROGEOLOGICAL MODELING

Itasca's geomechanical modeling software can incorporate effective stress (i.e., pore pressures) and fluid-flow. Additionally, Itasca engineers and scientists have developed specialized software *MINEDW* and *DFN.lab* for simulating mine dewatering and stationary and transient flow in 3D fracture networks, respectively. These programs are designed especially for large, robust, and complex hydrogeology analyses. Itasca offices also utilize third-party software as required, such as: *FEFLOW*, *SEEP/W*, Visual *MODFLOW Flex*, *PHREEQC*, *CE-QUAL*, Leapfrog, Surfer, and EVS-PRO for example.

Itasca consultants complement hands-on field testing and instrumentation experience with these types of software tools to effectively provide comprehensive practical solutions to hydrogeologic engineering issues.

MINEDW

Based on algorithms from the U.S. Geological Survey finite-element code *FEMFLOW3D*, *MINEDW* was customized to address water-related issues in complex hydrogeologic environments, such as those commonly associated with mining operations.

MINEDW mine dewatering applcaitions include:

- Prediction of requirements and schedule of dewatering wells and drainage galleries
- Drawdown predictions
- Assessment of impacts on surface water

Unique features that give *MINEDW* an advantage over other groundwater modeling codes for mine dewatering in complex settings include:

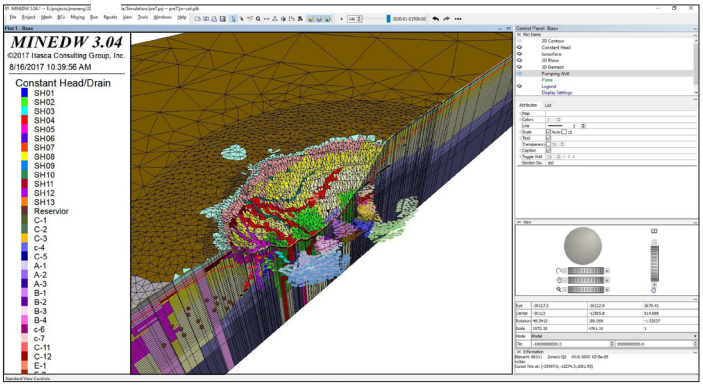
- Simulation of open pits, seepage faces, and pore pressure distributions
- Zone of mass rock deformation and relaxation
- Non-linear flow to underground workings through transmissive features
- Pit lake infilling simulations
- Dewatering wells
- Unbounded groundwater system

MINEDW can be applied to pore-pressure analysis to assess the effectiveness of various pore-pressure reduction plans and as an input to ground stability analysis (e.g., *FLAC3D* slope stability modeling).

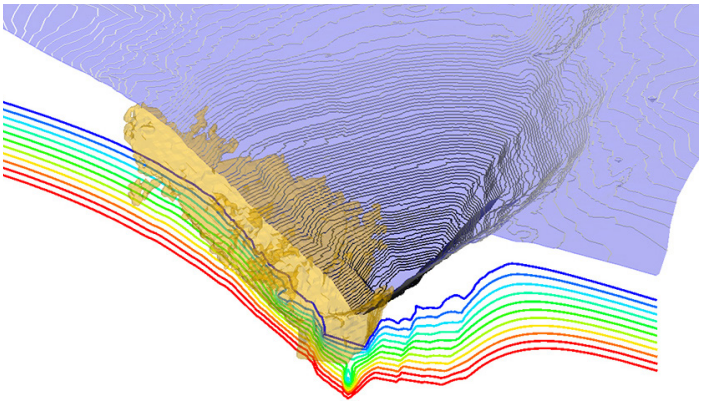
MINEDW is currently being used at many large-scale open-pit and underground mining operations around the world. It can also be used for civil applications, such as Tunneling and Hydro Engineering.

General features of *MINEDW* include:

- Triangular prism mesh for comples model geometries
- Progressive geometry according to mine schedules
- Staurated/unsaturated flow
- Flexible boundary conditions
- Very transmissive zones
- Groundwater/surface-water interaction
- Evaporation/evapotranspiration
- Pit lakes
- Time-variant conductivity
- Numerically stable where there is a high degree of hydraulic compartmentalization with steep hydraulic gradients
- Powerful 3D visualizations



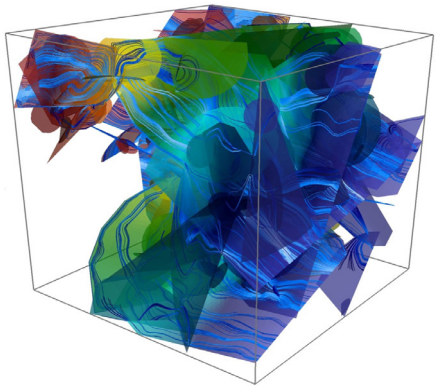
MINEDW user interface.



MINEDW model of an open pit mine.

DFN.lab

DFN.lab is an efficient and robust simulation tool for generating, analyzing, and simulating fluid flow and transport in 3D discrete fracture networks (DFNs) in rock. DFN.lab was developed by the Fractory, a joint laboratory between the French institute for scientific research (CNRS), the university of Rennes, and Itasca Consultants s.a.s. It's used to study the behavior of multi-scale fractured media for various engineering and research topics, including safety assessment for long-term nuclear waste storage, geothermal applications, and mining. *DFN.lab* computes stationary and transient flow with various boundary conditions in significantly large systems rapidly and can characterize both the DFN structure and its hydraulic properties based on novel statistical and innovative graph methods. *DFN.lab* can generate and compute flow and solute or heat transport on DFNs containing millions of fractures, with multi-scale heterogeneities at both the fracture and network scales ranging over more than three orders of magnitude. Simulations can contain boreholes, tunnels, and topographies; these structures are taken into account for flow and transport calculations and analyses.



DFN.lab flow simulation with particle traces.

ENVIRONMENTAL

Itasca specializes in site assessment, data analysis, the evaluation of impacts to water resources, the selection of remediation systems, the implementation of remedial actions that lead to the closure of sites where contaminated soil and groundwater are encountered, and seismology. Services are provided that range from the sampling of soil, sediment, and water to the construction of detailed models to be used in the assessment of the fate of chemicals in the environment. In addition, as a part of Environmental Assessments (EAs), Environmental Impact Statements (EISs), baseline investigations, and litigation, Itasca has completed many assessments of environmental impacts to the quantity and quality of water resources.

Core services include:

- Delineation of contaminant sources and evaluation of the extent of groundwater contamination
- Evaluation of remedial options and development of exit strategies for site closure
- Design, cost estimation, installation, and operation of groundwater, sediment, and soil remediation systems
- Prediction and analysis of environmental impacts on local and regional surface-water and groundwater systems
- Development of environmental-impact remediation strategies for permitting and closure
- Support for environmental permitting, permit renewals, and regulatory compliance
- Closure of mine facilities
- Design of monitoring systems
- High level review of project work by other parties
- Litigation support involving allocation, fate and transport analysis, and sources of contamination

PERMITTING

Itasca's staff is thoroughly versed in the environmental permitting process, having worked closely with different mining companies, with federal, state, and local government agencies, as well as with other consultants and subcontractors. Through these interactions, Itasca has earned a solid reputation for its ability to combine highly-defensible technical work with the appropriate level of discussion and regulatory interaction throughout the environmental permitting process. Itasca has first-hand knowledge of important hydrogeology and geochemistry issues, particularly those that arise in the western United States. The office is also highly experienced in the National Environmental Policy Act (NEPA) permitting process and in obtaining State and Federal discharge permits. Itasca has worked directly for mining companies as technical consultants, for Federal agencies as third-party contractors, and as disciplinary leads/reviewers for other consultants, engineering firms, and law firms.

Core services include:

- Preparation of technical studies in support of permitting (e.g., baseline hydrologic studies, environmental impact assessments, hydrogeologic and geochemical characterization, etc.)
- Subcontracting to other consultants as disciplinary leads for hydrogeology and geochemistry
- Independent review of existing studies, data adequacy, and/or potential permitting hurdles
- Development of groundwater flow and geochemical models in support of permitting
- Preparation of applications and supporting materials for state and federal permits (e.g., Water Pollution Control Permits, National Pollutant Discharge Elimination System [NPDES] permits, Permits to Mine, etc.)

THIRD PARTY REVIEWS

Itasca provides Third Party Reviews aimed at providing an independent and critical review of geomechanical and hydrogeological analyses performed by practitioners and other consultants. Itasca has extensive experience in providing independent due diligence review of projects for financial institutions and banks throughout the world. Itasca also works with operations to review and develop effective Quality Assurance (QA)/Quality Control (QC) programs and train operation personnel in order to minimize or avoid quality errors and develop corrective measures to ensure high quality work.

Third party reviews typically consist of three phases:

(1) Initial Information Review and Site Visit

Itasca reviews all existing and relevant technical documentation, which should include plans with excavation geometry, lithology of the surrounding rock mass and some information on geomechanical and hydrogeological properties, rock mass classification and fracturing (including natural and any blasting-induced fractures), and previous geomechanical and hydrogeological reports.

Itasca engineers next visit the site and discuss any questions resulting from the information review. A brief site report is issued following the site visit, focused on a "green/red flag" high level summary of the critical findings.

(2) Geomechanical and Hydrogeological Review

Itasca collects, organizes and reviews the existing data for the site, including previous assessments by staff and consultants. This task is for both rock mechanics and hydrogeological investigations, reports, and assessments. Included in this review, as needed, is an interview of mine staff, subcontractors, and consultants.

Critical information considered includes dewatering and depressurization plans, observed and anticipated modes of failure and the factors of safety for the various modes with the key hydrogeological factor considered being pore-pressure distributions. Because groundwater conditions may be affected by the regional

groundwater flow condition, Itasca will, as necessary, consider the regional geologic conditions based on the available data, such as precipitations, surface recharges, regional structures, and groundwater extraction.

(3) Independent Assessment

Based on the review results, Itasca may recommend conducting an independent assessment of the site hydrogeology and geomechanics.

The geomechanics assessment focuses on stability assessments based on the pore water pressures, rock mass characteristics, and small- and large-scale discontinuities. Geomechanical stability assessments will be via statics-based kinematics and deformation-based methods.

Under hydrogeology, Itasca assesses the site's pore-pressure distribution for future excavation plans. The phreatic surface around the excavation will be constructed based on a combination of observed groundwater levels, analytical solutions, groundwater flow models, and Itasca's experience.

LITIGATION SUPPORT

Itasca also provides expert support on litigation cases in mining, civil, energy, and environmental projects. Our professional engineers have assisted clients and government agencies in all stages of litigation to answer technical questions unbiasedly, prepare clear written technical reports, and testify as experts in state and federal courts. Itasca can also expertly use numerical modeling simulations, and other engineering methods, to validate our findings and demonstrate the scientific and engineering causes of damage or failure objectivity.

Well Systems Audit

Project Description

Due to reductions in the effectiveness of their dewatering efforts, the Debswana Diamond Company requested that Itasca complete an audit of the drainage and monitoring wells of their Jwaneng, Orapa, Letlhakane, and Damtshaa mines in Botswana.

Itasca's Contribution

Itasca's audit included reviewing the historical performance of the drainage well system, identification of problems in the drainage well system, the design and location of drainage wells, the location of piezometers and their design and ability to measure pore-pressure drops, and hydrogeological data management. Itasca visited the mines to gather site hydrogeological information, review the pumping systems, and review the associated dewatering organizational structure.

Outcomes

Itasca identified that the issues with the pumping systems were associated primarily with mechanical/electrical failures and failures associated with hydrochemistry in wells (i.e., corrosion and scale).

Itasca made recommendations to improve the management and analysis of hydrogeological and well operation information, to make proper diagnosis, and implement maintenance planning. This included well remediation, types of pumps to be used, and that the company update the pore-pressure model for the mines.

A corroded wellhead.

MINING SERVICES

Itasca has extensive knowledge of the options available to resolve a variety of mining related problems. Our staff of experienced hydrogeologists, geologists, and geochemists allows us to address all hydrogeologic aspects of mining operation issues including water quality, depressurization, supply and management, dewatering, mine-water disposal, and field investigations. With a long list of successful projects worldwide, Itasca possesses first-hand knowledge and experience of mining challenges inherent at different locales – whether mining in hard or soft-rock, and open pit or underground operations.

Itasca provides consulting services and partners with our clients to provide training, support, and/or oversight for hydrogeologic aspects of their projects ranging from field investigations to environmental permitting to operational design and optimization.

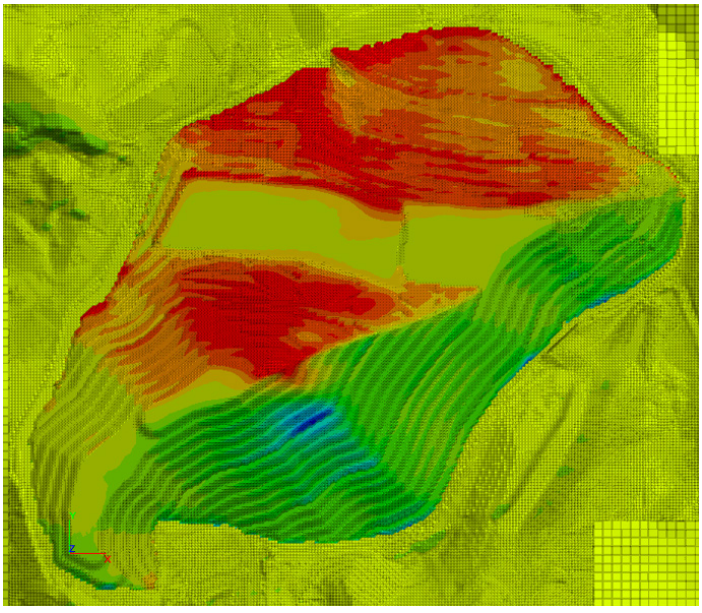
Tailings Dams

Tailings dams are among the largest and most critical artificial structures in the world. Their analysis requires careful evaluation of all components and loading conditions. Itasca has performed detailed design and stability analyses for major tailings dams. Each analysis has been reviewed by experts representing governing authorities. Although every tailings-dam analysis is unique, Itasca analyses typically include the following:

- Collection and review of site topographic and geotechnical data
- Specification and supervision of laboratory tests to determine static and dynamic properties of tailings, foundation, and other dam construction materials
- Selection of material models and calibration of material parameters to match laboratory test data
- Development of numerical models that simulate the continuous construction nature of tailings dams
- Analyses to represent the changes in pore pressure due to tailings consolidation and fluid flow over time
- Evaluation of static safety factors using the shear strength reduction technique
- Dynamic analysis of stability and liquefaction potential due to seismic loading
- Recommendations for monitoring to insure design assumptions are achieved

In addition to design analysis, Itasca has been involved in proposing standards for mining operations in seismically active areas, geotechnical investigations of tailings dam failures, and technical seminars to share experience and expertise. Selected examples of Itasca tailings dam projects can be seen in the following table.

Tailings Dam	Country
Pera Jusante y Gelado	Brazil
Assarel Medet	Bulgaria
Ellatzite	Bulgaria
El Mauro	Chile
El Morro	Chile
Laguna Seca	Chile
Lautaro	Chile
Mantos Blancos	Chile
Ovejería	Chile
Pampa Pabellón	Chile
Quillayes	Chile
Santo Domingo	Chile
Sierra Gorda	Chile
Torito	Chile
Tórtolas	Chile
Pampa Austral	Chile
Porvenir	Perú
Quebrada Honda	Perú
South Maybe Canyon	USA



FLAC3D model of a tailings dam (plan view) indicating horizontal displacements after a dynamic simulation.

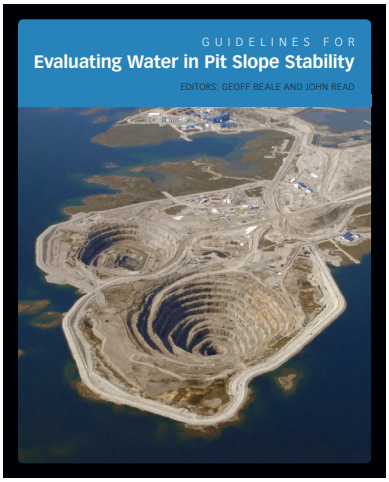
Heap-Leach Modeling

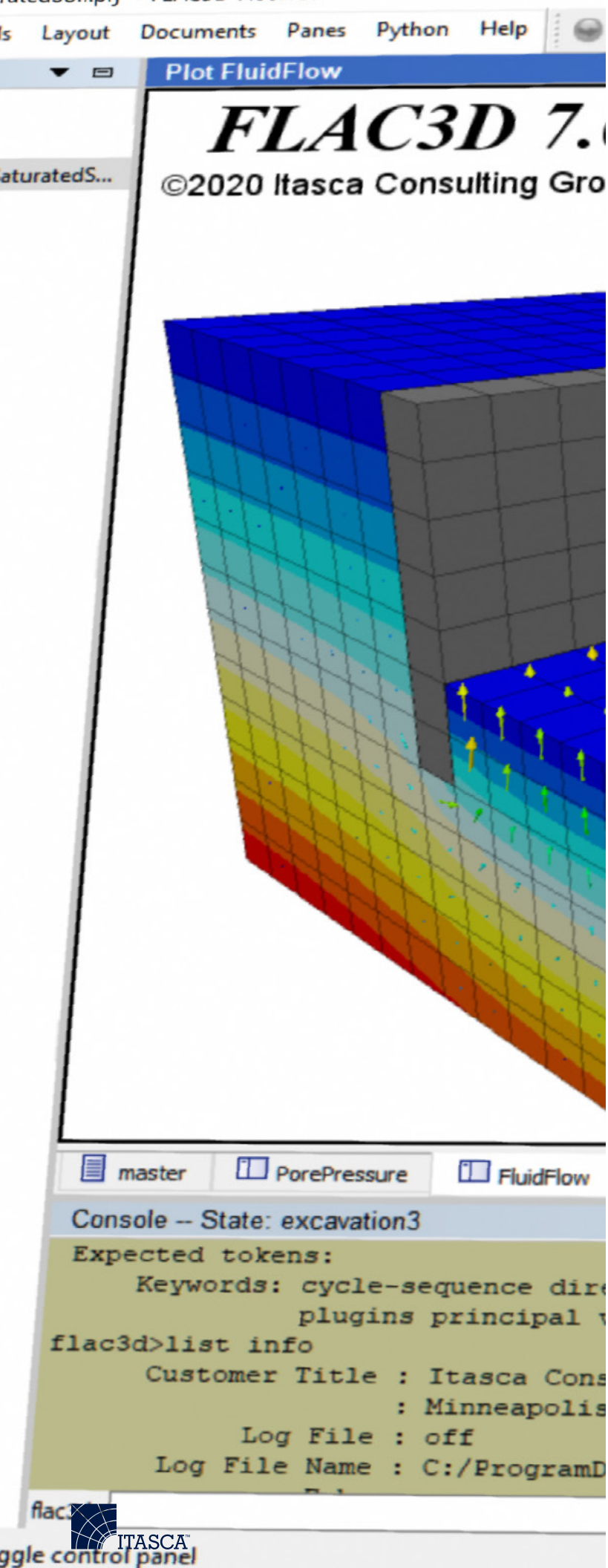
Itasca has developed a numerical model to estimate gold production from heap-leach operations. The objective was to simulate gold heap leaching using a model based on fluid flow and mass transport (hydrodynamic modeling) in a partially saturated pad, and quantitatively assess monthly production of gold-cyanide production.

Itasca has adapted *MOFAT*, a publically available 2D unsaturated chemical transport code, to simulate gold heap leach performance. The new program, called the Gold Heap Leach Simulator (*GHLS*), can assign the content of the gold in the ore and to calculate gold depletion; uses an enhanced solver and algorithm to maintain a mass balance between gold in the ore and the pregnant solution; and provides a user-friendly interface. *GHLS* can also assist in the design and optimization of heap-leach pads based on hydraulic properties of ore and moisture- and gold-contents. *GHLS* can be used to evaluate lift height, lixiviant application rates, timing of lixiviant applications, and rinsing and drain-down.

Large Open Pit Project

As part of the Large Open Pit (LOP) project, Itasca helped write the **Guidelines for Evaluating Water in Pit Slope Stability**, a comprehensive account of the hydrogeological procedures that should be followed when performing open pit slope-stability design analyses. (Click on the cover image below for more information.)





SOFTWARE SERVICES

Itasca first commercialized its software in 1985 when clients asked to have access to the software tools that our engineers used in their analyses. Itasca has pioneered and continues to innovate the application and development of numerical modeling software. Our software are among the most widely used and respected tools of their kind for analyzing and solving problems in geomechanics, hydrogeology, microseismic analysis, and other engineering fields. The result is a set of software that provides unparalleled speed, power, and proven capability for handling engineering problems ranging from traditional design work to understanding the most complex natural phenomena encountered in some of the most challenging environments.

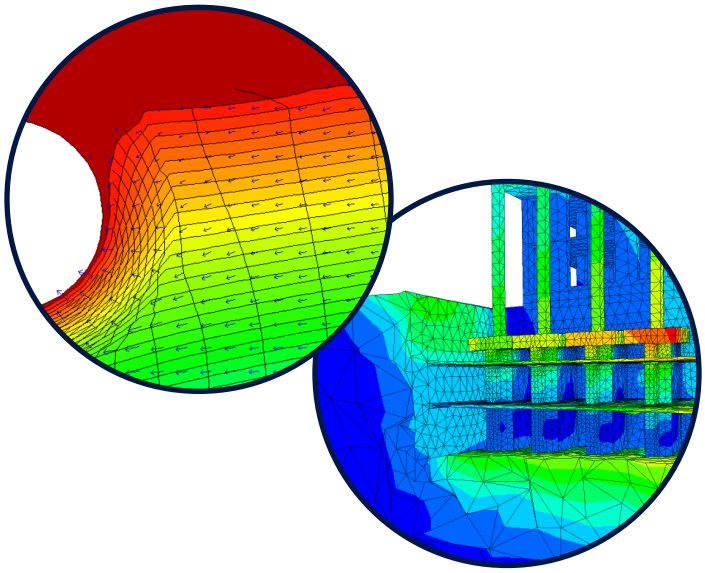
Itasca programs are used for design of major mining and civil construction projects, design of nuclear waste repositories, and oil reservoir treatment programs and have been used in a large portion of rock mechanics research projects worldwide. More than 4,000 mining and civil construction companies, consultants in rock and soil mechanics, and university and government researchers use these programs worldwide.

Itasca software programs include the two- and three-dimensional continuum programs *FLAC* (including *FLAC/Slope*) and *FLAC3D*, the two- and three-dimensional discontinuum programs *UDEC* and *3DEC*, the two- and three-dimensional particle-flow simulation programs *PFC2D* and *PFC3D*, the three-dimensional, finite-element groundwater flow code *MINEDW*, the integrated seismic data acquisition, processing, management and visualization software *InSite* for seismological studies, and the three-dimensional code *DFN.lab* for simulating 3D DFNs for engineering and research problems.

Itasca often performs custom modifications or development of these programs for specific project or client needs. Development of all software is governed by input from Itasca's consulting practice. Consequently, clients are assured that these software are practical, efficient analysis tools with a proven record of solutions to real-world problems.

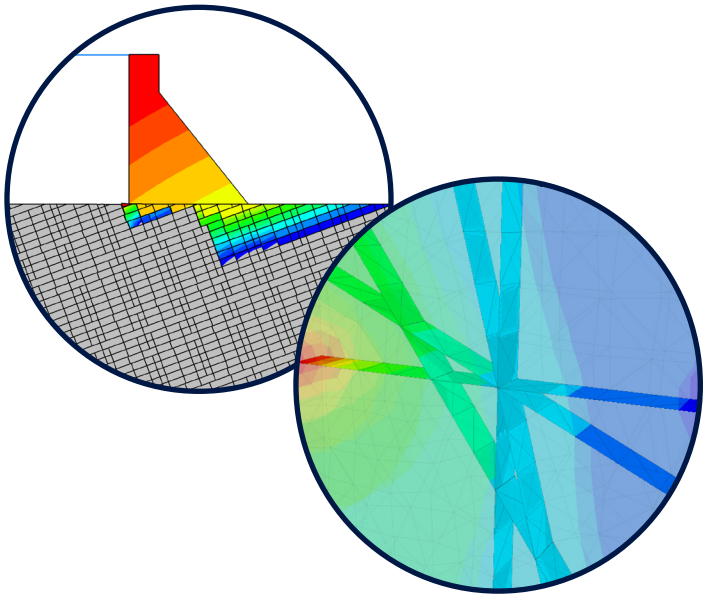
For more information or to download a free software demo, please visit: www.itascacg.com/software.

FLAC® – FLAC3D™



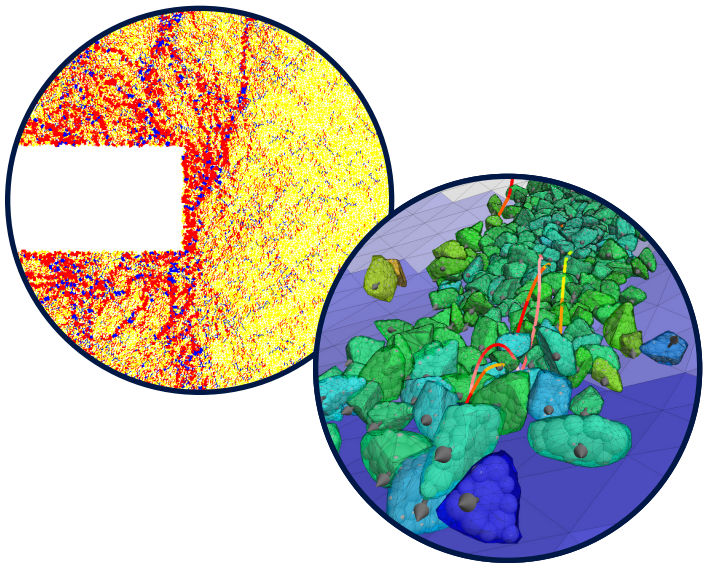
These are two- and three-dimensional explicit finite-difference programs for engineering mechanics simulations. These programs model the behavior of soil, rock, or other materials that are subject to plastic yielding. Materials are represented by a continuum of zones, which form a grid that is adjusted by the user to form the shape of the model to be simulated (e.g., tunnel, open pit, tailings dam, etc.). These programs are capable of simulating large strains (including unstable physical processes such as collapse), joints along which slip and/or separation can occur, groundwater flow, multiple excavation sequences (including backfilling), and dynamic processes and includes structural elements (e.g., liners, rock bolts, cables, beams, etc.).

UDEC™ – 3DEC™



Two- and three-dimensional distinct element codes for modeling discrete or jointed systems (e.g., rock mass, rock grains, hydro-electric dams on jointed rock foundations, masonry structures). Materials are represented by a network of blocks cut by discontinuities with surface (boundary) conditions. Blocks are able to rotate and slide along joints and joints can open or close. Blocks can be rigid or deformable (allowing yielding). The programs are capable of simulating large block displacements, groundwater flow along discontinuities, multiple excavation sequences, and dynamic processes and include structural elements (e.g., liners, rock bolts, cables, beams).

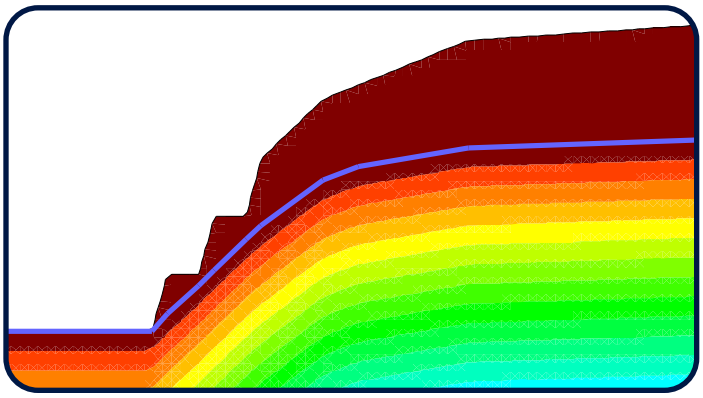
PFC Suite™



Two- and three-dimensional distinct element programs for modeling the movement and interaction of assemblies of arbitrarily-sized circular or spherical particles. *PFC Suite* includes both *PFC2D* and *PFC3D*. The codes create an ideal environment for study of the behavior of synthetic materials, modeling bulk flow and materials mixing, studies of micro- and macro-damage (cracks) in solid bodies, including damage accumulation leading to fracture, dynamic breakage, and seismic response. *PFC2D* is also sold separately.

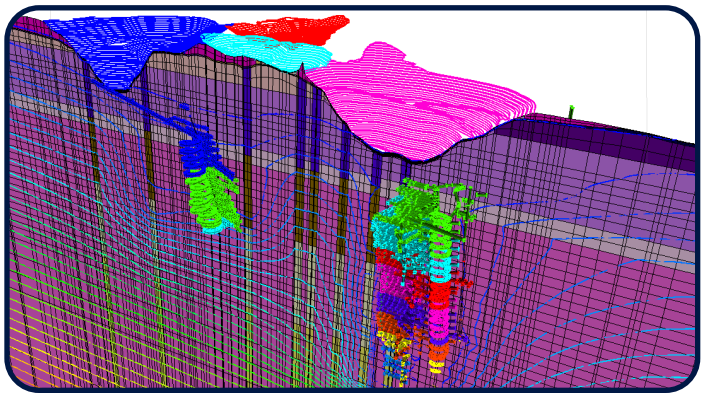
FLAC/Slope™

FLAC/Slope is a specialized version of *FLAC* designed specifically for slope stability factor-of-safety analysis. This code allows rapid generation of problem geometries and factor-of-safety calculation using the shear-strength reduction technique. One particular feature of this code is the ability to overlay DXF plots to speed model generation. Users can also specify water tables and pseudostatic earthquake loading.



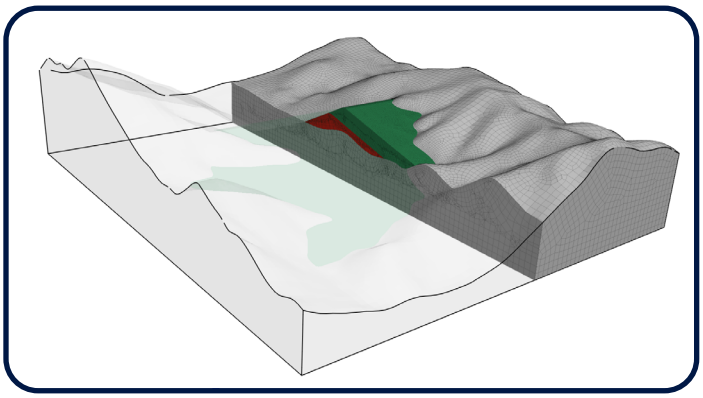
MINEDW™

Itasca's hydrogeological software has been specifically developed for simulating groundwater conditions. *MINEDW* (www.itascadenver.com/minedw) is very efficient in simulating complex geometry and spatial and temporal change of hydraulic conductivity of disturbed rock as the results of excavating. The simulated pore-pressure distribution from *MINEDW* model can be readily imported into Itasca's geomechanical models.



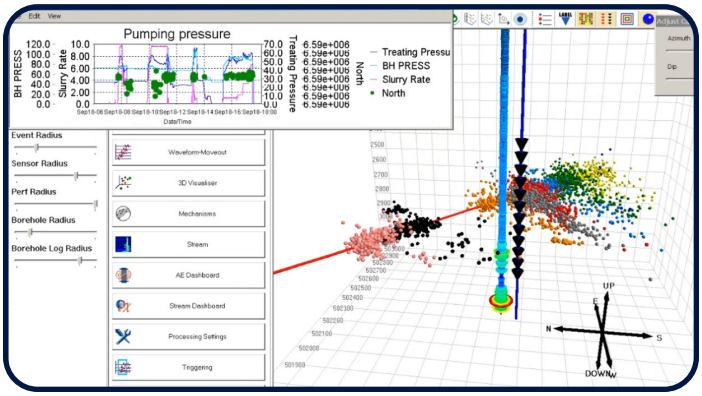
Griddle™

Griddle is a fully interactive, general-purpose mesh generation plug-in for the *Rhinoceros* 6.0 3D CAD software (www.rhino3d.com). *Griddle* can be used to remesh *Rhino* surface meshes to comply with precise size specifications and type (triangle or quad-dominant). Surface meshes can then be used as boundaries for *Griddle's* volume mesher, which produces high-quality tetrahedral or hex-dominant meshes. The volume meshes are ready for importing into most engineering analysis packages, including *FLAC3D* and *3DEC*.



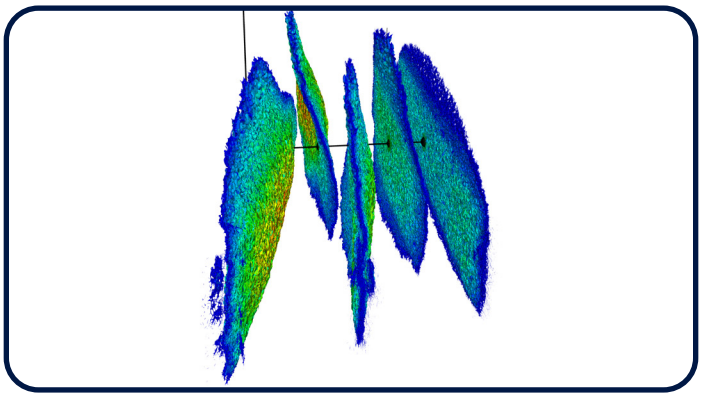
InSite™

Itasca's integrated seismic data acquisition, processing, management, and visualization software for seismological analysis, ranging in scale from acoustic emissions in the laboratory through microseismics around underground excavations up to regional-scale earthquakes. The software is independent of acquisition hardware and can be integrated with hardware packages to perform real-time data capture and processing. *InSite* software is used by many international companies and organizations for in-house processing and management of microseismic data. *InSite* is available as *InSite-Geo*, *InSite-HF*, and *InSite-Lab* for geomechanical, hydraulic fracturing, and laboratory applications. *InSite-Lite* is also provided as a free microseimicity viewer.



XSite™

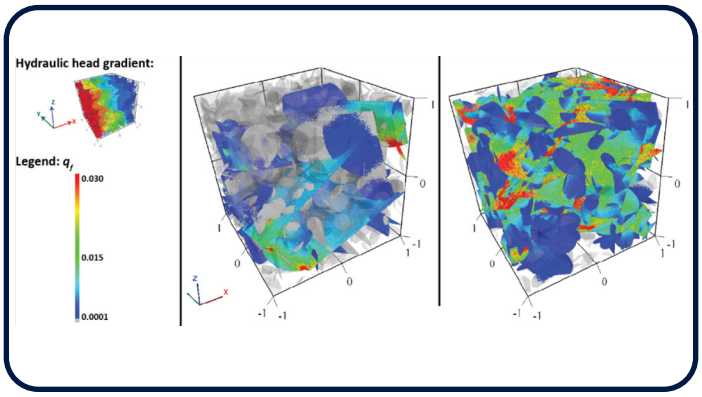
XSite is a powerful 3D hydraulic fracturing numerical simulation program based on the Synthetic Rock Mass (SRM) and Lattice methods. *XSite* is capable of modeling multiple wellbores with multiple stages and clusters, including open-hole completions and perforation tunnels. The models conduct fully coupled hydro-mechanical simulations. Fluid flow is simulated as fracture flow within the joint networks and as matrix flow within the intact rock. The borehole flow is coupled with the rest of the model to determine distribution of fluid between multiple clusters. Proppant transport and placement logic is included and synthetic microseismicity can be tracked and recorded.



DFN.lab™

DFN.lab is used for simulating fluid flow and trasport in 3D discrete fracture networks (DFNs) for engineering and research problems. *DFN.lab* is capable of:

- Generating genetic models containing millions of fractures based on the physics of fracturing
- Compute stationary and transient flow with various boundary conditions in significantly large systems
- Characterize the DFN structure and hydraulic properties using novel statistics and graph methods



Software Customization

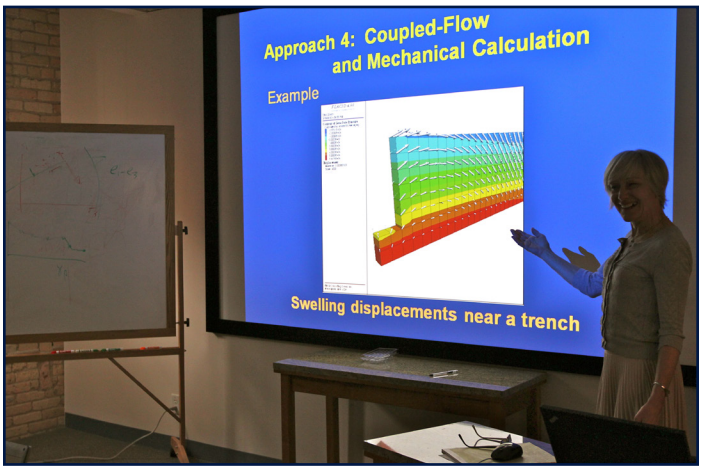
Itasca's software development is directed and refined by Itasca's consulting practice and client feedback. Itasca develops specialized material constitutive and contact models, *FISH* and Python functions, or even entirely novel simulation software in consultation with clients or as part of research collaborations. The software *REBOP* (cave mining), *Blo-Up* (blast design), *Slope Model* (slope stability), and *XSite* (hydraulic fracturing) were created in this manner and are used for both consulting and research.

For more information, please contact us at:

info@itascainternational.com

Training

Itasca offices worldwide routinely offer software training courses throughout the year.



You can find out which courses are currently available here:

www.itascainternational.com/training

Custom engineering or software training courses can also be arranged at one of our offices or at your organization. Online web forms can be found at the following addresses.

www.itascainternational.com/engineering-training
www.itascainternational.com/software-training

"More than 39 years of solving your hydrogeology challenges through engineering and computer simulation."

Thank you for your interest in Itasca's hydrology services. Please let us know how we can assist you with your work.

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