A deep, non-potable water supply for the Ochoa Sulphate of Potash (SOP) Mine Project, Lea County, New Mexico, U.S.A.

Peter Castiglia[1], Terre Lane[2], Randy Foote[2], William Linderfelt[1], Cheng Cheng[1], David Jordan[1], Daniel Wilson[1], Annelia Tinklenberg[1]

[1]*INTERA Incorporated, 6000 Uptown Blvd. NE, Suite 220, Albuquerque, New Mexico 87110, U.S.A., pcastiglia@intera.com*

[2]*Intercontinental Potash Corp. (USA), 30 Johnson Road, Suite 300, Golden, CO 80401, U.S.A., tlane@icpotash.com*

Abstract Competing with communities, agriculture, and industry for potable-water resources can pose great challenges for mining companies seeking public and regulatory support for proposed projects. In semi-arid and arid regions of the world where fresh-water resources are limited, using potable resources as a water supply for mining operations often faces opposition from existing water users or is subject to lengthy regulatory reviews. This paper describes how Intercontinental Potash Corp. (USA; "ICP") developed a deep, non-potable water supply for its Ochoa SOP Mine Project (Ochoa Project) in southeastern New Mexico, United States of America, that safeguards the limited fresh-water resources.

Keywords Water supply, desalination, brackish water, saline water, potash.

Introduction

Fundamental to the successful development and operation of most mines is securing a sufficient, long-term supply of process water required for routine functioning. In locations where water supplies are short, clashes between mining companies and competing water users can cause delays in development schedules and, in turn, losses in revenue. Those companies that compete for limited fresh-water resources risk losing public and regulatory agency support for their projects. In contrast, those companies that consider non-potable options can avoid pitting their interests against other water users, thereby increasing the probability that they will secure critical support required to advance development and operational goals. This paper presents the water supply strategy used by ICP to develop the Ochoa Project in southeastern New Mexico, a region that contains the largest potash reserve in the United States of America (Barker and Austin 1993), but is relatively water-short.

ICP's fully owned Ochoa Project is located 100 km east of Carlsbad, New Mexico, and less than 35 km from the New Mexico/Texas state line (Fig. 1). ICP aims to become a global industry leader in the production and distribution of high-quality, low-cost specialty fertilizer. The operations will include a conventional underground polyhalite mine and processing facility that will produce SOP and sulphate of potash magnesia (SOPM). The processing of polyhalite, mining, and administrative needs on site require a total water consumption of about 190 liters per second (L/s).

As part of the Pre-Feasibility Study published by ICP (Gustavson Associates 2011), a variety of water-supply options were considered for the Ochoa Project. These supply options included purchasing or leasing potable water from nearby municipalities, purchasing or leasing existing water rights, purchasing an out-of-state source of water, applying to the State of New Mexico for a new appropriation of water, or developing a deep, non-potable resource. Developing a non-potable resource

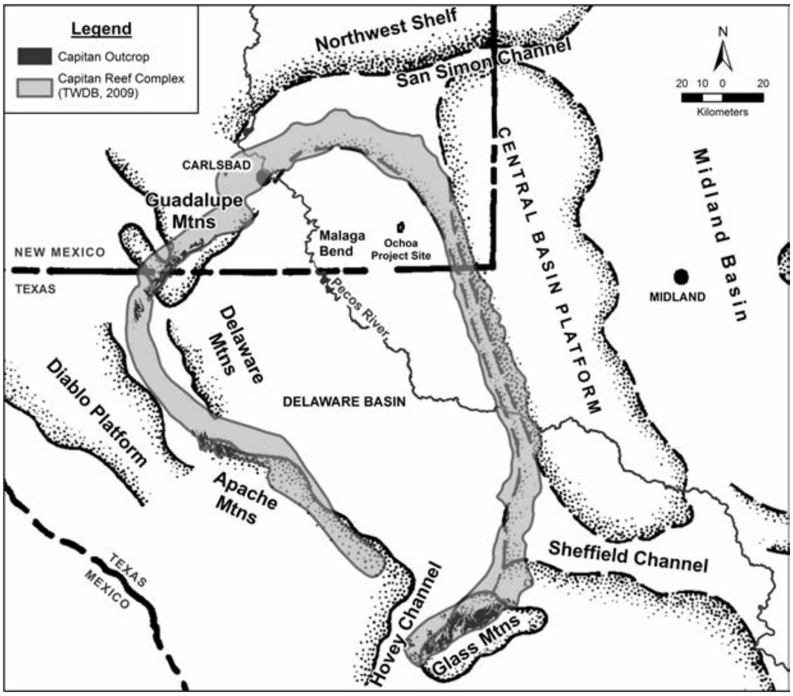

***Fig. 1** Location of Ochoa Project site near Texas/New Mexico state line, Capitan Reef complex (grey), and the Pecos River in addition to large-scale features delineated from subsurface studies from Ward et al. (1970).*

from the Capitan aquifer was selected as the water–supply option for the Ochoa Project because:

- The Capitan aquifer is recognized by the U.S. Geological Survey (Hood and Kister 1962) and state agencies (*e.g.* Texas Water Development Board 2010) as a significant brackish water resource with a proven history of industrial use for oil and gas development during the 1960s and 1970s;
- The New Mexico Office of the State Engineer (NMOSE), the state agency responsible for regulating the use water throughout the state, and the U.S. Bureau of Land Management (BLM), the federal agency regulating the construction and operation of the mine, are both supportive of the use of the Capitan aquifer for mining and industrial purposes;
- No permit is required to pump the deep, non-potable water for mining purposes because the aquifer meets several basic criteria that permits development without requiring a lengthy permitting process;
- Developing the aquifer would not compete with other water users in the area who live in the community of which ICP will be a part.

In the Ochoa Project area, domestic, municipal, and agricultural water supplies are produced from shallow, fresh-water aquifers that are thousands of meters above the Capitan aquifer and hydraulically separated from the deeper water. As a result, ICP will be able to secure essential processing-water resources without competing with the surrounding communities' use of fresh water.

Within Lea County, New Mexico, the Capitan aquifer ranges from 240 to 670 m thickness, and is approximately 20 km wide near the Eddy County and Lea County, New Mexico, boundary, and 10 km wide directly east of the Ochoa Project (Leedshill-Herkenhoff Inc. *et al.* 2000). The aquifer is associated with the Permian-age Capitan Reef Complex (Texas Water Development Board 2010), which crops out in the Guadalupe Mountains in New Mexico and Texas and in the Glass Mountains and Apache Mountains in Texas. The Capitan Reef Complex dips below the ground surface to the east and north from the areas of outcrop in the Guadalupe and Glass mountains, and in some areas, the bottom of the aquifer is more than 1,525 m below ground surface (Hiss 1975). Submarine canyons that were incised into the limestone reef and then filled in with sandstone, siltstone, and clay, are present along the northern and northeastern portions of the Capitan Reef complex (Hiss 1975). The most prominent of the submarine canyons occur near the Eddy County/Lea County boundary in New Mexico and create a groundwater divide (Hiss 1975) between the eastern portion of the aquifer in the Ochoa Project area and the western portion of the aquifer near the City of Carlsbad and the Pecos River.

Methods

ICP drilled two exploratory wells spaced 457 m from one another that fully penetrated the Capitan Reef to provide sufficient data for modeling and water-treatment testing. The wells, each drilled to approximately 1,615 m below ground surface using conventional oilfield drilling technology, were completed in June 2012. Step-drawdown tests were completed to characterize the specific capacity of the wells in support of engineering and design of the well field.

Following well construction and testing, an aquifer test was completed to characterize bulk aquifer properties in support of developing a numerical groundwater flow model for the permitting process. The pumping well was pumped at a constant rate of 31 L/s for 7 days, followed by a recovery period of 23 days. Water levels were monitored in the pumping and observation wells before commencing the test, during the pumping phase, and during the recovery phase. The data were analyzed to define transmissivity, hydraulic conductivity, and storativity.

In support of the permitting effort for the Ochoa Project, conceptual and numerical groundwater models were developed in cooperation with the NMOSE and BLM. The conceptual groundwater model provided the basis for development of a numerical groundwater flow model of the Capitan aquifer. The numerical groundwater flow model provided quantification of potential impacts of pumping deep,

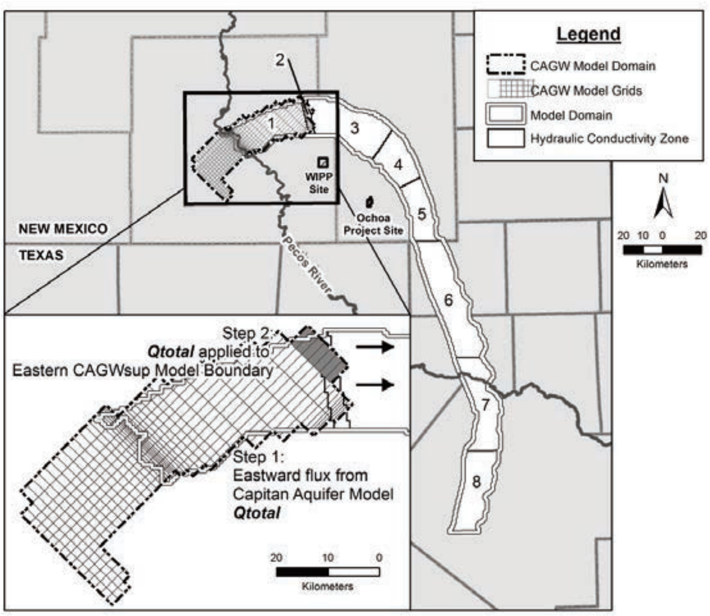

Fig. 2 *Model domain with zones of hydraulic conductivity and method of linking CAGWsup model and Capitan aquifer model*

saline groundwater from the ICP wells on existing wells and springs producing from, and surface water bodies in contact with, the aquifer in New Mexico and Texas. The aquifer was modeled using the USGS’s three-dimensional, finite-difference groundwater flow code, MODFLOW-2000 (Harbaugh *et al.* 2000), which is an updated version of the well-known groundwater flow code MODFLOW (McDonald and Harbaugh 1988).

The portion of the aquifer included in the model domain extends east and south from near Carlsbad, New Mexico, to the Glass Mountains in Texas (Fig. 2). Fortunately, the large number of oil and gas wells in the region provided many well logs with data at the needed depths. A review of available oil and gas well logs, as well as other data sources, and the subsequent development of a database of the formation tops, were key components for delineating the hydrostratigraphic units to be included in the numerical groundwater flow model. In addition to the use of pre-existing data, aquifer test data from the two ICP water wells provided site-specific information on the Capitan aquifer.

Four models were developed: a no-action model, a calibration model, and two predictive models representing the ICP water supply pumping and recovery scenarios. Predictive models were run for 50-year scenarios to cover the period included in the Ochoa Mine Plan of Operations submitted to the BLM using a proposed pumping rate of 252 L/s. Lateral flow exchanges between the Capitan aquifer and adjacent back-reef aquifer or Delaware Mountain Group (the aquifer on the Delaware Basin side of the Capitan aquifer, or basin aquifer) were determined using one-dimensional MODFLOW models linked to different sections of the Capitan aquifer boundary. Initial conditions for the one-dimensional models were a uniform, static water level. The thickness of all one-dimensional models was estimated at 304 m based on information from Hiss (1975) on the basin and back-reef aquifers. A standard model domain of 153 km was used for all one-dimensional models

Potential impacts to groundwater in the vicinity of the Pecos River near Carlsbad, New Mexico, were based on reduced groundwater discharge to the Pecos River. An extensive and detailed evaluation of the groundwater flow system was conducted by the NMOSE (Barroll *et al.* 2004). As a result of that work, the numerical model of the flow system in that area, the Carlsbad Area Groundwater (CAGW) model, was developed to assess potential impacts. A superposition model of the CAGW model (CAGWsup) was further developed as a tool for evaluating impacts on river flows due to additional withdrawals from the aquifer in that area (Papadopulos 2008). The CAGWsup model was used to evaluate impacts due to pumping of ICP wells (Fig. 2). The impact evaluated was induced leakage from the Pecos River. This leakage was compared to the overall groundwater discharge to the river estimated using the CAGW model, which averaged 1,625 L/s for the period from 1965 through 2001.

Results

Pump testing indicated that the supply wells can sustain pumping rates of 31 L/s or greater for extended periods of time. The specific capacity of the well is summarized in Table 1. Rapid rebound was observed upon cessation of pumping in the pumping well during the step test, where the water level returned to

Step No.	Flow Rate (L/s)	Water Level Drawdown (m)	Specific Capacity (L/s/m)
1	20	56.1	0.36
2	28	90.5	0.31
3	37	140.8	0.26

Table 1 *Results of specific capacity testing at three pumping rates (steps) used for well testing.*

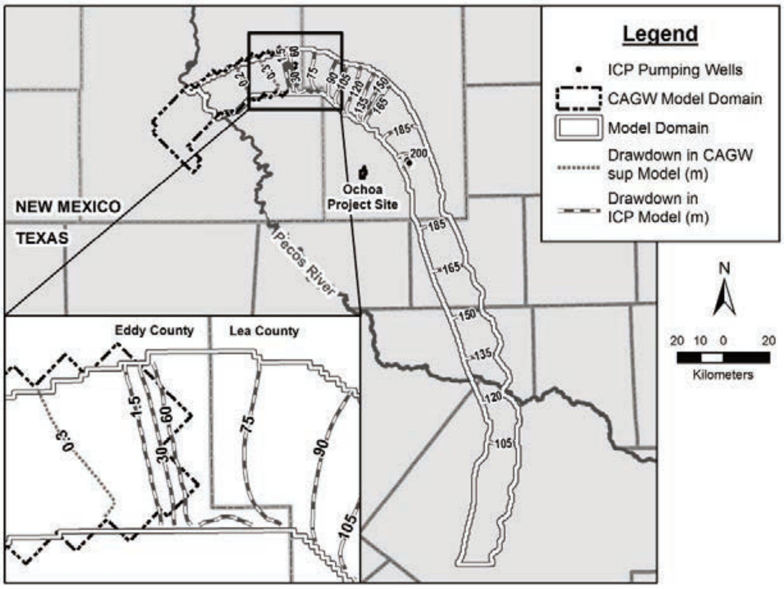

Fig. 3 *Drawdown in the Capitan aquifer after 50 years of pumping 252 L/s. Area enlarged shows Eddy-Lea County line in vicinity of submarine canyons that restrict flow.*

100 % of the pre-test level within one hour. As expected, the specific capacity decreases with an increase in flow rate.

The estimated storativity value from the 7-day pumping test is 5.0×10^{-5}. Transmissivity of the Capitan aquifer was estimated to be 650 m^2/d, yielding an estimated horizontal hydraulic conductivity of 2.1 m/d, applying a 304 m thickness for the open-hole producing zone.

Results of the numerical groundwater flow model indicate that drawdown will be greater east of the groundwater divide that is created by the submarine canyons (Fig. 3), far from the Pecos River, springs, and other water users. There will be a limited impact to groundwater discharging to the Pecos River near Carlsbad, New Mexico, after 50 years of pumping. Reduction in groundwater discharging to the Pecos River due to pumping of ICP wells was estimated at 0.07 %. A sensitivity analysis conducted on the Capitan aquifer model established that the parameter estimates used in the model were reasonable and that the model was representative of the groundwater flow system. Impacts on the back-reef aquifer were estimated to be up to 0.007 % of the total amount of water in the back-reef aquifer, and impacts on the basin aquifer were estimated to be up to 0.002 % of the total amount of water in the basin aquifer.

Conclusions

The exploratory drilling, testing, and modeling work completed by ICP in support of the permitting process significantly reduced the risk to the water supply for the Ochoa Project and provided valuable data for final design and engineering. Well testing confirmed the desired capacity of the deep wells. Aquifer testing confirmed the aquifer is suitable to provide the Ochoa Project with a long-term supply of deep, non-potable water that will not compete with the surrounding community for use of fresh water. Evaluating the effects of pumping with the numerical groundwater flow model shows insignificant impacts to other water uses and surface water connected to the aquifer.

By supplying the mine with deep, non-potable water from the Capitan aquifer, ICP has avoided a relatively complicated process for developing freshwater, and has instead safeguarded its use for other purposes that are essential to the surrounding community. Though developing deep, non-potable water requires deeper wells and desalination treatment, making the commitment to safeguard limited freshwater resources can add value to a project through public and regulatory support received when proposals do not include a new and competing use of fresh water. As freshwater resources become more limited, those companies that choose to adopt conventional drilling and treatment technologies to develop non-potable resources may also realize value in the support received for such proposals.

Acknowledgements
We thank the shareholders of IC Potash Corp. (TSX:ICP, OTCQX:ICPTF) for their support in developing the Ochoa Project and the men and women who participated in the drilling, construction and testing of the deep groundwater wells. In addition, we are grateful for the support for the proposed Ochoa Project that ICP has received from the communities of Lea County and Eddy County, New Mexico, and for the constructive criticism we have received through this process from the NMOSE and U.S. Department of Interior BLM Carlsbad Field Office.

References
Barker JM, Austin GS (1993) Economic geology of the Carlsbad Potash District, New Mexico. New Mexico Geological Society Guidebook, 44th Field Conference, Carlsbad Region, New Mexico and West Texas, p 283–291

Barroll P, Jordan D, Ruskauff G (2004) The Carlsbad Area Groundwater Flow Model. Consultant's Report prepared by INTERA Incorporated and submitted to the New Mexico Interstate Stream Commission

Gustavson Associates (2011) National Instrument 43-101 Technical Report, Prefeasibility Study for the Ochoa Project: Lea County, New Mexico, December 30, 2011

Harbaugh AW, Banta ER, Hill MC, Mcdonald MG (2000) MODFLOW-2000, The U.S. Geological Survey Modular Ground-Water Model – User Guide to Modularization Concepts and the Ground-Water Flow Process. U.S. Geological Survey Open-File Report 00-92, 130 p

Hiss WL (1975) Stratigraphy and Groundwater Hydrology of the Capitan Aquifer, Southeastern New Mexico and Western Texas. Unpublished Ph.D. dissertation, University of Colorado, Boulder, 396 p

Hood JW, Kister LR (1962) Saline-water resources of New Mexico, U.S. Geological Survey Water-Supply Paper 1601, 76 p

Leedshill-Herkenhoff, Inc., John Shomaker & Associates, Inc., Montgomery & Andrews, P.A. (2000) Final Report, Lea County Regional Water Plan. Prepared for Lea County Water Users Association. December 7, 2000, 128 p

McDonald MG, Harbaugh AW (1988) A Modular Three-Dimensional Finite-Difference Ground-Water Flow Model. In Techniques of Water-Resources Investigations, Book 6. Washington, DC: U.S. Geological Survey/U.S. Government Printing Office

S.S. Papadopulos and Associates, Inc. (Papadopulos) (2008) Carlsbad Area Groundwater Model, Superposition Version GUI. Prepared for the State of New Mexico/Interstate Stream Commission. June 5

Texas Water Development Board (2010) Aquifers of West Texas. In: Mace RE, Mullican WF, Angle ES, (Eds), Texas Water Development Board Report No. 356, 281 p

Ward RF, Kendall CG, Harris PM (1970) Upper Permian (Guadalupian) Facies and Their Associations with Hydrocarbons – Permian Basin, West Texas and New Mexico, The American Association of Petroleum Geologists Bulletin 70(3): 239-262