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Black Hawk, Colorado, Construction Dewatering Evaluation

Thomas S. Norman, P.E. and Phillip E. Brown, P.G.,

Stewart Environmental Consultants, Inc.
214 North Howes Street, Fort Collins, Colorado 80521

INTRODUCTION

In Black Hawk, Colorado, several casinos have been constructed within a stream valley that is deeply incised with nearly vertical bedrock walls. Because of lack of space, these casinos are being built in a valley where tailings from former mining operations were deposited. The excavations for the casino foundations normally are 4 to 10 meters below ground surface in saturated alluvium/tailings underlain by Precambrian granite gneiss. The main area of construction lies west of a fault that follows the trace of North Clear Creek and separates the gneiss from the Idaho Springs schist. The sites are usually within three meters of North Clear Creek. During construction, the creek is enclosed using precast concrete culverts.

The tailings are often the main aquifer under the casino sites and are granular in nature. These tailings have been tested to have hydraulic conductivity on the order of 2×10^{-3} cm/sec. The ground water at the sites has been contaminated by leachate from both tailings (high concentrations of heavy metals) and residue from leaking underground petroleum storage tanks that were removed during the casino construction.

For the construction of the casinos, contractors generally excavated into tailings to the bedrock and placed foundation slabs approximately 4 to 9 meters below grade. Foundation dewatering systems are required since the water table lies approximately 3.5 meters below grade. The dewatering systems are usually designed using slotted pipe at the bottom of a trench backfilled with gravel. Water is routed to a sump and pumped to a treatment plant.

Stewart Environmental Consultants, Inc. of Fort Collins, Colorado, has been directly responsible for evaluation of the environmental and dewatering considerations for three sites in Black Hawk. To perform these tasks, the following work was completed:

- An analytical ground water model was developed for the site to predict inflow to the construction excavations,
- The pumping rate to dewater the foundations was calculated and treatment system requirements defined and
- Predictions of what may happen to the ground water regime were made for various flood events for North Clear Creek.

MODEL DESCRIPTIONS

The ground water of the Black Hawk site is dynamic and fluctuates seasonally in direct response to rainfall, as well as to the various stages of North Clear Creek. To properly analyze the site hydrogeology, a transient model would have to be developed. However, for foundation dewatering evaluation, it was believed that a steady-state analytical computer model would be adequate.

The analytical model used is based on the steady state solution of the problem of a discharging finite length sink in a homogeneous aquifer of infinite extent. The program extends the algorithm to transient problems using the method of successive steady states. The method of successive steady states assumes the potentiometric surface has a steady state curvature at all points in time. The radius of influence is estimated using a semi-empirical equation. The successive steady state algorithm is an excellent approximation in all both the shortest times.

Recharge wells are represented by a finite length, constant source. The rise in water level from these sources may be calculated at any point in time. Withdrawal wells are represented by finite line constant flow sinks. Drawdowns away from the wells may also be calculated. If a recharge source is turned off or the flow is reduced, a constant flow sink is superimposed on top of the line source to simulate recovery. The same holds true in reverse for the pumping wells.

The analytical model assumes a uniform, homogeneous aquifer of infinite areal extent (the assumptions of the Theis equation for nonsteady well discharge). To simulate an aquifer with boundaries, either constant head or impermeable, the theory of superposition may be used. Superposition may be used because drawdown is directly proportional to discharge. Boundaries for finite line sinks may be simulated using the same methods that are used with well simulation models. An impermeable boundary is simulated placing an image line sink on the other side of the assumed boundary and equidistant from it. A constant head boundary is simulated by placing an image line source on the other side of the assumed boundary and equidistant from it. Multiple boundaries are simulated using a series of image sinks or sources.

SITE EVALUATION

At one site located within two meters of North Clear Creek, the ground water influx into the excavation was simulated using the analytical method outlined above. The following assumptions were made:

- Water table conditions
- Hydraulic conductivity of 2×10^{-3} cm/sec
- Average aquifer thickness of 5 meters
- Specific yield of 0.1
- Static water table elevation 2452 meters (amsl)
- Excavation dimensions of 18.3 x 21.3 x 3.7 meters
- Bedrock at 5 meters

Three scenarios were simulated and are described as follows:

Scenario 1—No Creek Influence

For this simulation, two line sinks were used for the excavation—one 18.3 meters in length trending north-south and the other 21.3 meters in length trending east-west. Two image line sinks were placed west of the excavation boundary.

Scenario 2—With Creek Influence

In this scenario, the same line sinks and image sinks were used to simulate the excavation as described for Scenario 1. In addition, four image sources were used to simulate the influence of North Clear Creek. These image sources were placed on the west side of the creek at an equal distance as the excavation from the source.

Scenario 3—Flood Conditions

This scenario uses the same line sinks and image sinks as described for Scenario 2. However, the saturated thickness of the tailings aquifer has increased to the same elevation of the creek at various flood stages.

In each case, flow rates were determined to lower the phreatic surface to 1.3 meters below the slab. The bedrock on the east side of the creek, which is considered to be a no-flow boundary, was not simulated. These assumptions make the results of the modeling effort considered to be conservative.

RESULTS

The results for Scenarios 1, 2 and 3 are presented in Tables 1, 2 and 3, respectively. Estimated inflows into the excavation and drawdown in the center of the excavation with time for Scenarios 1 and 2 are given in the first two tables. Excavation drawdowns for Scenarios 1 and 2 are based on a pumping rate of 76 liters/minute. Estimated inflows for one and two days for various flood stages are presented in Table 3 for Scenario 3.

CONCLUSIONS

Under normal circumstances, inflows into the excavation will be influenced by North Clear Creek as demonstrated by Scenario 2. Initial inflows will be high (approximately 254 liters/minute) and taper down to 40 liters/minute with time. Using the model, it was also determined that during the first day of dewatering, a pump rate of 76 liters/minute from the sump could be used to dewater the excavation and lower the water level to an elevation of 2450.6 meters (amsl), which is 1.4 meters below the elevation of the foundation slab.

During flood events, some pumping will be required to lower the water level to two feet above the slab (safety elevation). Maximum rates of pumping required would be on the order of 76 liters/minute. However, pumping at a rate of 76 liters/minute throughout the flood would lower the water level to a safety elevation in a short period of time.

TABLE 1--Scenario 1 No Influence of Creek	
EXCAVATION INFLOW:	
TIME (Hours)	FLOW (Liters/Min)
1	250
6	91
12	65
24	44
48	30
72	25
120	19
168	17
336	13
504	11
CENTER EXCAVATION DRAWDOWN:	
TIME (Days)	DEPTH (cm)
1	17.4
6	79.2
10	103
14	118.6
21	137.2

TABLE 2--Scenario 2 Creek Influence	
EXCAVATION INFLOW:	
TIME (Hours)	FLOW (Liters/Min)
1	250
6	91
12	65
24	49
48	40
72	40
120	40
168	40
336	40
504	40
CENTER EXCAVATION DRAWDOWN:	
TIME (Days)	DEPTH (cm)
1	46.9
6	137.2
10	137.2
14	137.2
21	137.2

TABLE 3--Scenario 3 Flood Conditions				
		EXCAVATION INFLOWS (Liters/Minute)		
EVENT	STAGE (Meters)	Day 0.5	Day 1	Day 2
10-Year	2.35	90	68	57
50-Year	2.96	102	80	68
100-Year	3.06	106	80	68