COPY TO J. HOLONICH

40-8968

HRI, Inc.

2929 Coors Road, NW - Suite 101 Albuquerque, NM 87120-2929
505-833-1777 Voice 505-833-0777 Fax

November 18, 1996

William Ford
Hydrologist

Overnight mailing address:
U.S. Nuclear Regulatory Commission
One White Flint North
11555 Rockville Pike
North Bethesda, MD 20852-2738

RE: Comments on Groundwater Velocity Calculations (12/15/95) at Crownpoint.

Dear Bill:

Bill, you asked that I comment on your groundwater velocity calculations (12/15/95) for the Crownpoint area (see Attachment 1) and I am happy to do so. I have attached portions (as Attachment 2) of the Geraghty & Miller report (10/7/93) which you referenced in your groundwater velocity calculation and I have attempted to clarify the materials that have been submitted at various times which address the concerns about contamination of the drinking water wells at the Town of Crownpoint.

(1) Your calculations showed the transmissivity as being MULTIPLIED by the aquifer thickness, rather than DIVIDED: (5,772 gpd/ft * 0.1337 gal/ft3 * 335 ft). But checking your results, it appears you divided, as required.

(2) I am interested in the basis for the hydraulic gradient of **70** feet of head in 700 feet of horizontal distance. I have attached a copy of Figure 8 from the Geraghty & Miller report (10/7/93), which I believe you used. According to that report, the hydraulic head should be 7 feet (or less) per 700 feet. This would result in groundwater velocities LOWERED BY AN ORDER OF MAGNITUDE.

This lower velocity is also supported by the summer and winter gradients of 5.6 feet/year and 10.6 feet/year (respectively) as noted on page 5 and on Figures 3 and 4 of the Geraghty & Miller report (that portion is attached here under Attachment 2). In addition, HRI's response to Q1/54 (text only is attached here as Attachment 3) showed a groundwater velocity in the Crownpoint area of 8 to 11 feet/year. I do not believe it is appropriate to use the ultimate drawdown at the Town water wells themselves, since they do NOT represent the average drawdown or velocities across the area which the water has to move.

NL05/1

As you are well aware, pressure differential directly determines groundwater velocities, as shown by the 'dh/dL' in velocity equations. The higher the pressure gradient, the greater the velocity, for the same permeabilities. Potentiometric maps, such as Figure 8 from Geraghty & Miller (see Attachment 2), provide a way to GRAPHICALLY ESTIMATE (as you did) the pressure gradient and, thus, to GENERALLY estimate water velocity in areas of CONSTANT gradient. Yet, as you know, the key issue in contaminant hydrogeology is the **pathway, speed** and **ultimate destination** of contaminants. Pathlines **directly** represent that fluid movement.

Pathline or particle tracking computer programs use the SAME velocity equations as used in graphical procedures noted above, but are not constrained by the need for constant gradient over a fairly large area. Thus, these programs can estimate travel time through the summation of THOUSANDS of velocities along the pathline, rather than just one of two points. I have attached the pathline plot from Q1/50 (Attachment 50-2) here as Attachment 4. The same transmissivity, storage coefficient, and flowrates for Town water wells, used in calculating the potentiometric surface of Figure 3 discussed by Geraghty & Miller (in Attachment 2 here), were also used in the pathline calculations of Attachment 4. This is as you suggested in Q1/54 "*It is suggested that for the Crownpoint site, in areas without wells, ground-water flow modeling which includes the effect of all five community supply wells could provide a adequate description of ground-water flow directions.*". Thus, if you were to painstakingly estimate and sum multiple velocities from the potentiometric surface maps by using the graphical procedure discussed above, the limit, as the increment or step size decreased, would be the time values shown in Attachment 4. Attachment 4 used ALL of the velocities found along the pathline, including the much faster velocities near the wellbore. The result was 90.4 years for the first contaminated fluid from the eastern boundary of the proposed Crownpoint ISL project to reach the nearest Town water well and 1,657 years from the eastern side of the Unit 1 project to reach that same well. These are **worst** case (fewest years) and extremely conservative values in that they do **not** include any ISL bleed or overproduction to recover this theoretical excursion.

The pathline or particle tracking can also be done for the flow system depicted in Figure 8 by Geraghty & Miller [and this was done: Q1/50 (Attachment 50-2), here as Attachment 4 described above]. However, it is NOT valid to calculate the travel times from the "Ground Water Divide" of that Figure to the Town water wells for two reasons.

a) Since we are involved in a radial flow system, the monitor wells WILL detect any lixiviant excursion. It is not reasonable to consider that the ISL wellfields would be operated in the same fashion for YEARS after an excursion is detected, until the lixiviant is at, and then beyond, the "Ground Water Divide". The NRC license itself will require termination of lixiviant injection within 60 days (Section 8.7.2, Consolidated Operating Plan, Crownpoint Uranium Project) if an excursion is not corrected or recovered. This 60 days or 0.17 years is compared to the 90.4 years (Crownpoint) and 1,657 years (Unit 1) for the fluid movement to the nearest Town water well, as described above.

b) The "Ground Water Divide" in Figure 8 (Attachment 2) is 400-1000 feet BEYOND the monitor wells. Since water canNOT travel parallel to the pressure gradient, water on the monitor well side will not cross that divide. As we **increase** the wellfield bleed rate, the ground water divide moves out even FARTHER beyond the monitor well ring and toward the Town water wells. Much HIGHER ISL bleed rates can be used which will cause the ground water divide to move even closer to the Town water wells, say within 5-10 feet of one of the Town wells. In this case at these **higher** bleed rates, if we were to capriciously assume the scenario wherein an excursion will **somehow** move beyond the ground water divide, then the contaminated groundwater would move to the Town water wells almost instantaneously. This would lead us to the **erroneous** conclusion that the HIGHER wellfield bleed rates provide the LEAST protection for the Town water wells, while **lower** ISL bleed rates would provide the **greatest** protection. The best protection would then be at a bleed rate of zero, or even with overinjection, since that would move the ground water divide even further away from the Town water wells. This is NOT reasonable, and shows that the arbitrary assumption of groundwater contamination at the ground water divide is not justified.

The ISL bleed rates used in the groundwater model to develop Figure 8 were chosen to show that reasonable and easily attainable bleed rates would protect the Town water wells by causing the ground water divide to be **beyond** the monitor wells separating the proposed ISL wellfields and the Town wells. Obviously, even smaller bleed rates would accomplish this same objective.

(3) I'm perplexed by your use of 0.05% porosity. HRI's porosity estimate of ~25% was garnered from permeability/porosity reports on the core holes in the area, and there is nothing to indicate that porosity might be as low as 5% in the Crownpoint area, ESPECIALLY with permeabilities of 500-600 md. Surely, HRI and NRC should NOT use the generalized range of 5-30% from Cherry's Table 2.4 in lieu of actual porosity measurements on cores. With this, and the discussion below, I don't believe that a SINGLE velocity value of 1,679 feet/year is reasonable, and it would be especially inappropriate and misleading to use this to actually characterize the whole of the velocity vector field in the area of the Town water wells. Using a hydraulic gradient of 7 feet head per 700 feet distance and 25% porosity (both discussed above), and the higher 5,772 gpd/ft transmissivity (as you did in your calculations), the groundwater velocity is 33.6 feet/year. Certainly this low fluid velocity would be easily controllable by ISL wellfield operations, and loss of contaminated water to the Town water wells would NOT result.

The continued question of groundwater velocities causes concern that additional portions of Q1/54 might still be open. "*The NRC staff believes that this discussion concerning pre-mining velocities and the rate of excursion is flawed, because should an excursion occur it would move at a rate faster than the pre-mining velocities. The combination of injection pressures in the well field and potential pumping influences from nearby supply wells will allow an excursion to travel at a faster rate than pre-mining velocity field.*" . The issue of greatest concern is whether excursions will be "lost" to the Town water wells, which subsequently leads us into a discussion of groundwater velocities. As detailed in its numerous submittals and discussed here, HRI

believes that it has shown conclusively that the high-velocity field (as characterized by the NRC above) near our monitor wells does NOT occur. We have tried to show the reasoning behind the various assumptions used in our groundwater models and to discuss the applicability of the results to our proposed ISL operations. We certainly understand NRC investigating such a scenario out of abundant caution, but without some technical justification, HRI cannot see that this can be treated as a credible concern. However, HRI would welcome the opportunity to review and discuss **any** credible hydrologic study or data indicating otherwise, or to model a particular hypothetical scenario which might particularly concern you, so that proper safeguards can be determined and implemented.

In addition, the extensive and successful operating history of URI/HRI in ISL (as well as the experience in issues of groundwater and contaminant hydrogeology of our consultant, Geraghty & Miller) should not be whimsically discounted. Our operating personnel also have extensive experience in groundwater modeling and have run THOUSANDS of design and excursion scenario simulations for both wellfield design and actual ISL operations.

One of the most useful and instructive aspects of hydrologic models in ISL is to develop scenarios which will FORCE or cause an excursion. We do this commonly at HRI to provide insight into possible operational problems, need for adjustment of wellfield design, need for additional operational safeguards or monitor wells, etc. However, when this is done for the proposed Crownpoint ISL project, we do NOT see the uncontrollable circumstance in protecting the Town water wells which is alluded to above. Again, HRI would welcome the opportunity to review and discuss **any** credible hydrologic study or data indicating otherwise.

With respect to this, a portion of HRI's response to Q4/74 is applicable and is reproduced here --

HRI takes strong exception to the implication that excursions are likely because of the uncontrollable affects of the Town water wells: "[moving the Town water wells] *would greatly reduce the influence of the town wells on the Crownpoint site well field and, therefore, reduce the potential for excursions to occur. It would also have the effect of increasing the distance between the town wells and the well field which would allow more time for excursion definition and correction.*" This characterization makes it appear that the Town water wells will affect groundwater velocities in the vicinity of the ISL wellfields and surrounding monitor wells on the order of hundreds of feet per year, and therefore, if an excursion were to occur, the contamination of the Town water wells would be imminent. This is not so. The impact on groundwater velocities at the ISL wellfields and on the surrounding monitor wells by the Town wells is VERY SMALL. HRI believes that it has shown this through its hydrologic modeling and explanatory submittals, and that credible engineering studies or data have not been provided indicating otherwise, which would allow alternate operational plans and safeguards to be developed if necessary.

The general effect of flowrates from the Town water wells on groundwater velocities in the vicinity of the Crownpoint project monitor wells can be also demonstrated through the use of professionally accepted and generally available groundwater models. Whether using particle tracking, pathlines, or graphical procedures with potentiometric surface maps, pressures changes and groundwater velocities at various distances from producing water wells can be determined. This was done below, incorporating the various reservoir characteristics in the Crownpoint area:

2,550	gpd/ft	transmissivity
8.6e-5		storage coefficient
0.251		porosity
201	feet	thickness.

A single well was used to gauge the affect of widely varying flowrates. Figure 8 (attached as part of Attachment 2) of Geraghty & Miller's "Analysis of Hydrodynamic Control, HRI, Inc., Crownpoint and Churchrock New Mexico Uranium Mines" (10/7/93) shows that NTUA #1 is the nearest Town water well to the proposed ISL operations to the west at about 1,700 feet. Geraghty & Miller found that the well had a flowrate of 27.7 gpm during the summer period of higher water usage. More distant wells would have even less affect, but could easily be included. Distances of 1700, 1600 and 1500 feet from the producing well were used in the model. This is equivalent to an excursion at the monitor well (1700 feet) shown in Figure 8, and 100 feet beyond the monitor well toward the Town water well (1600 feet), and 200 feet beyond the monitor well (1500 feet). Two flowrates were used, 25 gpm and 100 gpm, at different times but from the same producing well, to show the affects of a **huge** increase/decrease in flowrate. Drawdowns were calculated using unsteady state flow, while velocities were determined at steady state to **maximize** their values. Table 1 shows the results for a well at 25 gpm and Table 2 for a well at 100 gpm.

Table 1

Groundwater Velocities and Drawdowns
Caused by Producing Well at 25 gpm

Distance from Producing Well (feet)	Distance from MONITOR Well (feet)	Velocity (ft/day) Toward Producing Well [Steady State]	Velocity (ft/year) Toward Producing Well [Steady State]	Drawdown (feet) After ONE Day [Unsteady State]	Drawdown (feet) After FIVE Days [Unsteady State]	Drawdown (feet) After TEN Days [Unsteady State]
1,700	At Mon. Well	8.93e-3	3.26	1.5	3.1	3.9
1,600	100' beyond	9.488e-3	3.46	1.6	3.2	4.0
1,500	200' beyond	1.012e-2	3.7	1.7	3.4	4.1

Table 2

Groundwater Velocities and Drawdowns
Caused by Producing Well at 100 gpm

Distance from Producing Well (feet)	Distance from MONITOR Well (feet)	Velocity (ft/day) Toward Producing Well [Steady State]	Velocity (ft/year) Toward Producing Well [Steady State]	Drawdown (feet) After ONE Day [Unsteady State]	Drawdown (feet) After FIVE Days [Unsteady State]	Drawdown (feet) After TEN Days [Unsteady State]
1,700	At Mon. Well	3.572e-2	13.0	5.8	12.4	15.5
1,600	100' beyond	3.795e-2	13.9	6.3	13.0	16.0
1,500	200' beyond	4.048e-2	14.8	6.8	13.5	16.6

Comparison of the Tables shows a 10-15 feet change in water levels, yet an insignificant change in fluid velocity. Insignificant in that, if an excursion were to occur, it could be readily controlled withOUT imminent contamination of the Town water wells. This demonstrates that estimated groundwater travel times from the Crownpoint project to the Town water wells of 90.4 YEARS (~33,000 days) shown on the pathline plot from Q1/50 (Attachment 50-2, and here attached as Attachment 4) is reasonable, and well beyond the time (60 days) in which corrective action will be required by the NRC for an excursion. The up and down changes in water level at a specific point does NOT equate to a change in velocity, which is caused by the pressure

differential BETWEEN points. Thus, flowrate changes in Town water wells will NOT cause severe groundwater flow problems at the proposed ISL site.

The impact of the Town water wells on groundwater velocities in the area of the proposed Crownpoint ISL operations was also addressed in HRI's response to Q2/76, which is included here as Attachment 5. The monitor wells in Figure 2 of Attachment A of Q2/76 show as extending to the vicinity of the Town water well, NTUA #1, and indicate that NTUA #1 would be plugged and abandoned (P & A). Since September, 1992 (the date of the letter referenced in Q2/76) the proposed license boundary of the Crownpoint ISL project has been moved approximately 1,700 feet to the west of NTUA #1. However, the results of the modeling shown in Q1/76 are still instructive, in that the velocity of the groundwater in the area of the monitor wells, caused by a **different** water production **scenario** from the Town water wells than shown in Attachment 4 here, ranges from 12.3 to 20.3 feet/year. Again, these are very low water velocities which are easily controllable by ISL wellfield operations if an excursion were to occur, and would NOT cause imminent contamination of the Town water wells.

This does NOT mean that HRI does not take excursions very seriously. We design and operate wellfields with this constantly in mind, as our operating history shows. Therefore, we disagree with the apparent discounting of the hydrodynamic models and results, which were run by HRI and its consultants, to verify the initial wellfield designs and operations at the Churchrock and Crownpoint sites: "*Due to the lack of data and model design, the model was not able to take into account variations in aquifer properties, variations in water levels over time, and actual well field design and operation.*" This is not at all the case. Over five thousand geophysical and lithologic logs at Churchrock, Unit 1 and Crownpoint and surrounding areas were interpreted and correlated, and the breadth and extent of multiple ore fronts identified. Preliminary wellfields were then designed for these ore fronts, **well by well**: about 860 wells for Churchrock, 640 wells for Unit 1 and 770 wells for Crownpoint. These wellfields were balanced for flowrates **well by well** (including flowrate bleed) just as done in normal HRI/URI operations, modeled, analyzed for areas of possible excursions, the design and bleed rates were revised, and models re-run. Multiple schedules of production and restoration were developed and revised for each project (an example, originally part of Q2/78, is attached as part of Q4/74, Attachment Q4/74-3). The wellfield schedule, along with start and stop times for production **and** restoration for **each** of the wells, and the flowrates, which **varied** well to well and again from production to restoration, were then used in the hydrodynamic models by Geraghty & Miller. In addition, pre-existing pressure gradients **were** included in the models, and the Town water wells were included in the Crownpoint model at the higher summer flowrates as determined by Geraghty & Miller. The wellfields were NOT generalized by a few injection/extraction wells and flowrates for of the wells. **Each** of the flowrates for each well for production **and** restoration were included. The effort was intense and provides a realistic view of the wellfield production and restoration operations at Churchrock and Crownpoint. Thus, the wellfield design and variable flowrates and operation WERE included in the model. Since the change in flowrates causes the variations in water levels, water level fluctuations **were** incorporated into the model.

Of course, for each scenario developed and modeled, many more can be envisioned and the smallest of variations made. **However, this should not mean that a single groundwater velocity generalized over the whole of the area, from HRI's proposed Crownpoint ISL project site to the Town water wells, provides a valid or reasonable representation of fluid velocities, as compared to detailed and in depth hydrodynamic studies.** HRI believes that the iterative models used in characterizing the potential for contamination in the public water supply wells proves conclusively that the potential for contamination is not only unlikely, but of minuscule probability. However, HRI would welcome the opportunity to review and discuss **any** credible hydrologic study or data indicating otherwise, so that proper safeguards can be determined and implemented prior to any ISL operation.

I would be happy to discuss these issues further if you would like.

Sincerely yours,

Craig S Bartels

Craig S. Bartels
VP - Technology
HRI, Inc.

Attachments

cc: J. Holonich - NRC
D. Gillen - NRC
R. Carlson - NRC
R. Clement - HRI
Mark Pelizza, HRI

Attachment 1

FAX TO: Mark S. Pelizza
Environmental Manager
Uranium Resources, Inc.
12750 Merit Drive
Suite 1210, LB 12
Dallas, Texas 75251
(214) 387-7779

FROM: W. Ford W. Ford
Hydrogeolgist
U.S. Nuclear Regulatory Commission

SUBJECT: CALCULATIONS OF GROUND WATER MOVEMENT, RELEVANT TO CROWNPOINT COMMENT 54

Please find attached the calculation sheets that documented the calculations done by the NRC staff in comment 54.

NRC FORM 383 (11-88)

U.S. NUCLEAR REGULATORY COMMISSION

CALCULATION WORKSHEET

SHEET ___ OF ___

PROJECT	CALCULATED BY	DATE
Crownpoint Property	W. Ford	12/15/95

DOCKET NUMBER	SUBJECT	CHECKED BY	DATE
	Groundwater velocity from wellfield to NTUA-1		

	Porosity - (~~From~~ Freeze & Cherry Groundwater, 1979, Page 37)	5-30%
	Thickness of Aquifer (from cross section C'-C" Crownpoint Application)	335 ft.
Geraghty + Miller 10-7-93 Report	Head - (figure 8, Crownpoint model)	70 ft
	Distance - (figure 8, Crownpoint model	700 ft
	Major transmissivity (Crownpoint Application Page 54)	5,772 gpd/ft
	minor transmissivity (Crownpoint Application page 54)	1,526 gpd/ft
	[illegible]	
	Calculations	
~~Major Hydraulic~~	Major Hydraulic Conductivity	
	(5772 gpd/ft * 0.1337 ft³/gal) ~~*~~ 335 ft.	2.3 ft/day
	minor Hydraulic Conductivity* CSB MARKINGS	
	(1526 gpd/ft * 0.1337 ft³/gal) ~~*~~ 335 ft.	0.609 ft/day
	First Velocity Calculation	
	$V = -\frac{K\,dh/dl}{\cancel{\theta}}$ (from USGS Prof Paper 708, p.10)	
	$V = \frac{2.3\ \text{ft/day}\left(\frac{70\ \text{ft}}{700\ \text{ft}}\right)}{0.05}$	4.6 ft/day or 1679 ft/year

NRC FORM 383

U.S. NUCLEAR REGULATORY COMMISSION

CALCULATION WORKSHEET

SHEET ____ OF ____

PROJECT		CALCULATED BY	DATE
DOCKET NUMBER	SUBJECT	CHECKED BY	DATE

2nd velocity

$$\frac{(2.3\ \text{ft/day})\left(\frac{70\ \text{ft}}{700\ \text{ft}}\right)}{0.30}$$

0.7666 ft/day

280 ft/year

3rd velocity

$$\frac{0.609\ \text{ft/day}\left(\frac{70\ \text{ft}}{700\ \text{ft}}\right)}{0.05}$$

1.218 ft/day

444.57 ft/year

4th velocity

$$\frac{0.609\ \text{ft/day}\left(\frac{70\ \text{ft}}{700\ \text{ft}}\right)}{0.30}$$

0.203 ft/day

74.1 ft/year

W.H. FORD

Ground-Water Hydraulics

By S. W. LOHMAN

GEOLOGICAL SURVEY PROFESSIONAL PAPER 708

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1972

TABLE 3.—*Land subsidence in California oil and water fields*

Well field	Subsidence (ft)	Through year
Wilmington oil field (see Gilluly and Grant, 1949)	[1] 29	1966
Water fields:		
Santa Clara Valley (San Jose)	13	1967
San Joaquin Valley:		
Los Banos-Kettleman Hills area	26	1966
Tulare-Wasco area	12	1962
Arvin-Maricopa area	8	1965

[1] Stabilized at this amount by repressuring. This figure includes some recovery due to repressuring.

more porous than associated sands or gravels; hence, they contain more fluid per unit volume at a given fluid pressure. When the pressure is gradually reduced, as by discharge of fluids from wells, such beds slowly release fluids and undergo nonelastic (plastic), generally irreversible, compaction. (See Athy, 1930; Hedberg, 1936; and Poland and Evenson, 1966.) Compaction of this type is much greater than purely elastic compression, and it has caused appreciable subsidence of the land surface in both oil and water fields in California, Texas, and elsewhere. Latest available data for several California oil and water fields (J. F. Poland, U.S. Geol. Survey, written commun., Oct. 27, 1967) are given in table 3.

MOVEMENT OF GROUND WATER— STEADY-STATE FLOW

In steady-state flow, hereinafter referred to simply as steady flow, as of ground water through permeable material, there is no change in head with time. Mathematically, this statement is symbolized by $dh/dt=0$, which says that the change in head, dh, with respect to the change in time, dt, equals zero. Steady flow generally does not occur in nature, but it is a very useful concept in that steady flow can be closely approached in nature and in aquifer tests, and this condition may be symbolized by $dh/dt \rightarrow 0$.

Figure 9 shows a hypothetical example of true steady radial flow. Here steady radial flow will be reached and maintained when all the recoverable ground water in the cone of depression has been drained by gravity into the well discharging at constant rate Q.

DARCY'S LAW

Although Hagen (1839) and Poiseuille (1846) found that the rate of flow through capillary tubes is proportional to the hydraulic gradient, Darcy (1856) seemingly was the first to experiment with the flow of water through sand, and he found that the rate of laminar (viscous) flow of water through sand also is proportional to the hydraulic gradient. This is known as *Darcy's law* and it is generally

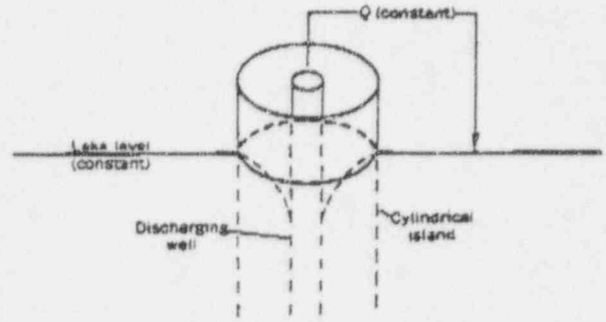

FIGURE 9.—Hypothetical example of steady flow (well discharging at constant rate Q from a cylindrical island in a lake of constant level).

expressed, by rewriting equation 13,

$$q=\frac{Q}{A}=-\frac{Kdh}{dl} \quad [LT^{-1}]. \tag{26}$$

It will be noted that K, the constant of proportionality in Darcy's law, is the hydraulic conductivity.

To illustrate the use of equation 26 (Darcy's law), assume that we wish to compute the total rate of ground-water movement in a valley where A, the cross-sectional area, is 100 ft deep times 1 mile wide, where $K=500$ ft day^{-1}, and $dh/dl=5$ ft per mile. Then

$$Q=-(100\text{ ft})(5{,}280\text{ ft})(500\text{ ft day}^{-1})\left(\frac{-5\text{ ft}}{5{,}280\text{ ft}}\right)$$

$$=250{,}000\text{ ft}^3\text{ day}^{-1}. \tag{27}$$

VELOCITY

Because the hydraulic conductivity, K, has the dimensions of velocity, LT^{-1}, some might mistake this for the particle velocity of the water, whereas, as may be seen from equations 13 and 14, K is actually a measure of the volume rate of flow through unit cross-sectional area. For the average particle velocity, $\bar{v}$, we must also know the porosity of the material. Thus

$$Q=\bar{v}A\theta=-KA\frac{dh}{dl},$$

where

$\bar{v}$ = average velocity, in feet per day, and
θ = porosity, as a decimal fraction.

Other terms are defined for equation 13. Rewriting the above equation,

$$\bar{v}=-\frac{Kdh/dl}{\theta} \quad [LT^{-1}]. \tag{28}$$

For example, using the values of K and dh/dl given in

equation 27, and assuming $\theta = 0.2$,

$$\bar{v} = -\frac{(500 \text{ ft day}^{-1})(-5 \text{ ft}/5{,}280 \text{ ft})}{0.2}$$

$$\approx 2.4 \text{ ft day}^{-1} \text{ (rounded)}. \qquad (29)$$

It should be stressed that the solution of equation 29 is the *average velocity* and does not necessarily equal the actual velocity between any two points in the aquifer, which may range from less than to more than this value, depending upon the flow path followed. Thus, equation 28 should not be used for predicting the velocity and distance of movement of, say, a contaminant introduced into the ground.

AQUIFER TESTS BY WELL METHODS—POINT SINK OR POINT SOURCE

STEADY RADIAL FLOW WITHOUT VERTICAL MOVEMENT

The first mathematical analysis of steady flow, using a discharging well, was made by Dupuit (1848), who made the important assumption that within the cone of depression of a discharging well the head is constant throughout any vertical line through the water body and therefore is represented by the elevation of the water table. Actually, this is true only in confined aquifers having uniform hydraulic conductivity and having a fully penetrating discharging well, or in confined aquifers remote from the discharging well. Nevertheless, methods based upon this assumption can be applied satisfactorily when certain precautions are taken.

Much of the mathematical analysis of Dupuit was repeated by Adolph Thiem (1887), but it remained for his son Günther Thiem (1906) to develop a readily usable solution, by determining that the Dupuit-Thiem methods could be applied to any two intermediate points on the cone of depression of a discharging well to determine the hydraulic conductivity of the aquifer. As will be shown later, it is now known that many more points may be used.

In order to derive the Thiem equation and show its relation to Darcy's law, let figure 10 represent half the cross section of the cone of depression in an unconfined aquifer around well A that has been pumped at constant rate Q long enough that steady flow is being closely approached, and the quantity of water still draining from storage is negligible compared with the quantity of water moving toward well A. Although figure 10 depicts an unconfined aquifer, the method is applicable also to confined aquifers. If the material is reasonably homogenous, and if the base of the aquifer and the undisturbed water table are assumed to be parallel and horizontal; then, by the law of continuity, and provided that changes in storage are negligible compared to Q, virtually equal quantities of

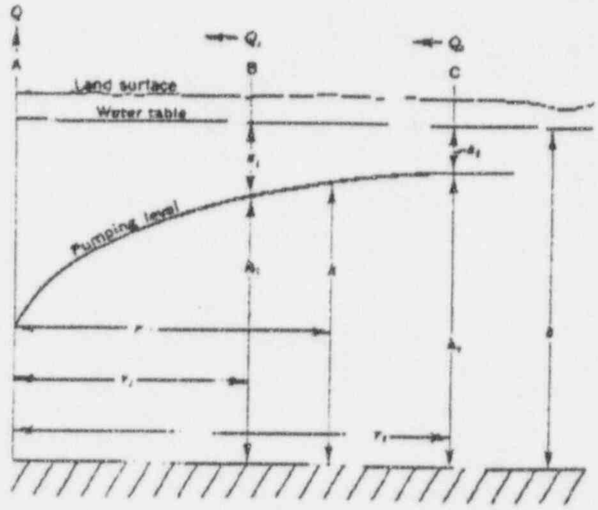

FIGURE 10.—Half the cross section of the cone of depression around a discharging well (A) in an unconfined aquifer.

water are discharged from well A (Q) and flow radially toward well A through any two concentric cylinders within the cone of depression, as at observation well B (Q_1) at radius r_1 or at observation well C (Q_2) at radius r_2. Thus $Q \approx Q_1 \approx Q_2$. Under these assumed conditions Darcy's law may be expressed as a first-order ordinary differential equation in cylindrical coordinates

$$Q = -K 2\pi r h \frac{dh}{dr} \qquad [L^3T^{-1}]. \qquad (30)$$

Separating variables,

$$\frac{dr}{r} = -\frac{2\pi K}{Q} h\,dh.$$

Integrating between r_1 and r_2, h_1 and h_2,

$$\int_{r_1}^{r_2} \frac{dr}{r} = -\frac{2\pi K}{Q} \int_{h_1}^{h_2} h\,dh,$$

hence

$$\log_e \frac{r_2}{r_1} = -\frac{2\pi K}{Q} \left[\frac{h_2^2 - h_1^2}{2}\right].$$

Converting to common logarithms and solving for K,

$$K = -\frac{2.30Q \log_{10} r_2/r_1}{\pi(h_2^2 - h_1^2)} \qquad [LT^{-1}]. \qquad (31)$$

In confined aquifers (where there is no unwatering) or in thick unconfined aquifers (where s is negligible compared to b), $h_2 + h_1$ may be assumed equal to $2b$. Then, as $h_2^2 - h_1^2 = (h_2 + h_1)(h_2 - h_1)$, $h_2 - h_1 = s_1 - s_2$, and $T = \bar{K}b$,

18.

R. Allan Freeze

Department of Geological Sciences
University of British Columbia
Vancouver, British Columbia

John A. Cherry

Department of Earth Sciences
University of Waterloo
Waterloo, Ontario

GROUNDWATER

Prentice-Hall, Inc.
Englewood Cliffs, New Jersey 07632

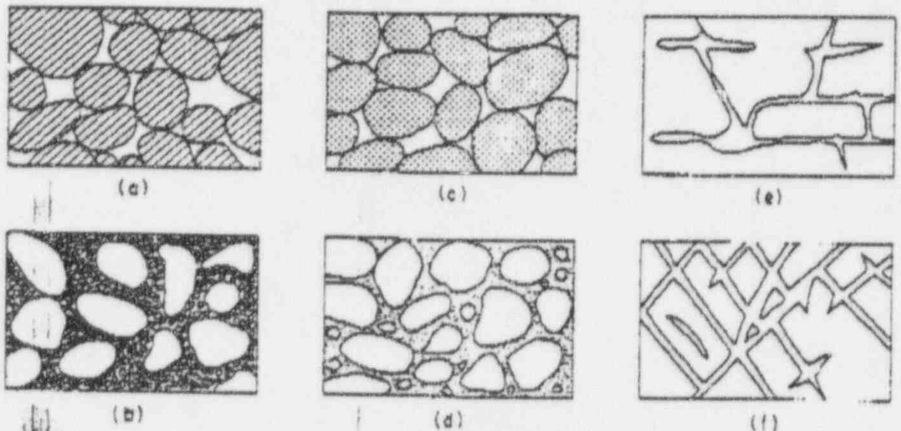

Figure 2.11 Relation between texture and porosity. (a) Well-sorted sedimentary deposit having high porosity; (b) poorly sorted sedimentary deposit having low porosity; (c) well-sorted sedimentary deposit consisting of pebbles that are themselves porous, so that the deposit as a whole has a very high porosity; (d) well-sorted sedimentary deposit whose porosity has been diminished by the deposition of mineral matter in the interstices; (e) rock rendered porous by solution; (f) rock rendered porous by fracturing (after Meinzer, 1923).

soil or rock matrix [Figure 2.11(a), (b), (c), and (d)], and *secondary porosity*, which may be due to such phenomena as secondary solution [Figure 2.11(e)] or structurally controlled regional fracturing [Figure 2.11(f)].

Table 2.4, based in part on data summarized by Davis (1969), lists representative porosity ranges for various geologic materials. In general, rocks have lower porosities than soils; gravels, sands, and silts, which are made up of angular and

Table 2.4 Range of Values of Porosity

	n(%)
Unconsolidated deposits	
Gravel	25–40
Sand	25–50
Silt	35–50
Clay	40–70
Rocks	
Fractured basalt	5–50
Karst limestone	5–50
Sandstone	5–30
Limestone, dolomite	0–20
Shale	0–10
Fractured crystalline rock	0–10
Dense crystalline rock	0–5

Attachment 2

ANALYSIS OF HYDRODYNAMIC CONTROL, HRI, INC. CROWNPOINT AND CHURCHROCK NEW MEXICO URANIUM MINES

October 7, 1993

Prepared for

HRI, Inc.
12750 Merit, Suite 1210
Dallas, TX 75251

Prepared by

Geraghty & Miller, Inc.
American Bank Plaza
711 North Carancahua, Suite 1700
Corpus Christi, TX 78475-1801
(512) 883-1353

The first part of the modeling operation involves inputting or calculating a pre-mining hydraulic gradient. The second portion of the model involves inputting extraction and injection wells for both mining and restoration phases to determine the predicted aquifer response.

HRI has measured water levels at the Crownpoint Mine for the last several years, allowing Geraghty & Miller to create a hydraulic gradient map. The hydraulic gradient is directly affected by pumpage of nearby municipal wells. These wells, which are east of the mine area, create a steeper hydraulic gradient in the summer during peak production, and a less-steep, winter-time gradient. These gradients, simulated in AQUISIM and calibrated to actual data (including pumping rates of all the nearby municipal wells) are presented in Figures 3 and 4. Groundwater velocities calculated for the winter and summer gradients are 5.6 feet/year and 10.6 feet/year, respectively.

Once the hydraulic gradients were established, the mining schedule supplied by HRI was input to the model. Geraghty & Miller utilized the summer hydraulic gradient in the model because it represents the steeper of the two gradients.

Initial well field configurations supplied by HRI provided virtual hydraulic containment as predicted by the model, but small areas within the mine were predicted to have potential excursions sometime during the mining or restoration phases. Minor adjustments to the original proposed well schedule were made by HRI, and the final model simulations were prepared. These simulations are shown in Figures 5 through 10.

Computer simulated output maps were generated to show the piezometric surface at the end of each mining phase, as well as the end of the restoration of the final mining area. These points in time were used because they represent the points of maximum hydraulic stress on the aquifer during the mining and restoration phases.

Attachment 3

ADDITIONAL INFORMATION REQUEST
HYDRO RESOURCES, INC. IN-SITU LEACH URANIUM MINE
CROWNPOINT, NEW MEXICO

ISSUE: Water Resource Protection

Comments Applicable to
Crownpoint, UNIT 1, and Churchrock

54. Potentiometric Surface Map and Ground-Water Flow Velocities For The Westwater Aquifer

Discussion - In the application it is stated that ground-water flow velocity calculated for the Churchrock site is 8.7 ft/yr. (Reference 3, page 7). However, the text does not provide enough information to confirm how these ground water gradients were calculated and how they vary over the site area. With the information provided, ground-water flow velocities cannot be confirmed.

The NRC staff is unable to find a potentiometric surface map for the entire UNIT 1 Site. The only map we have found covers a small part of the northeast corner of the site (Figure 2.7-3, Reference 11, page 2-64). With out this information it is not possible to confirm the direction of ground-water flow.

In the application, it is stated that "*HRI, INC. has calculated the maximum rate of natural ground water movement at a proposed monitor well location east of UNIT 1 and closer to the town of Crownpoint extraction, as 20.3 feet in one year*" (Reference 10, Section O. Plans for Well Failures). However, the text does not provide enough information to confirm how these ground water gradients were calculated and how they vary over the site area.

The NRC staff is unable to find a Westwater potentiometric surface map for the entire Crownpoint Site. In Reference 1 (page 3-12) it is stated that pumping from the town of Crownpoint water supply wells in the Westwater causes ground-water under the Crownpoint mine units to flow towards the water supply wells in Crownpoint (Reference 1, page 3-12). This conclusion indicates that ground water under the entire area to be licensed is moving towards the town of Crownpoint wells. In other words, water is moving towards the town wells from the north, east, south, and west. A potentiometric surface map was generated using water levels generated by a ground-water flow model. According to Reference 3 (page 5) the model included the pumpage of nearby municipal wells and was calibrated to water levels collected at the proposed Crownpoint mine. From this model, both a summer and a winter potentiometric surface map were prepared, with the summer gradient being the steeper of the two. However, the potentiometric map only covers the east one half of the property.

With the information provided, ground-water flow velocities cannot be confirmed for the Crownpoint site. In the application it is stated that ground-water flow velocities calculated for the winter and summer gradients are 5.6 ft/yr. and 10.6 ft/yr., respectively (Reference 3, page 5). However, the text does not provide enough information to confirm how these ground water gradients were calculated and how they vary over the site area.

Changes in the rate of pumping by the Crownpoint public water supply wells change the ground-water velocities under the Crownpoint property. These changes could effect the ability to control well field solutions or the rate that solutions could move from the well field should an excursion occur or after restoration of a well field. While the application does provide some insight into the rate of change by providing a summer and a winter estimate, it does not provide a range of velocities over the entire Crownpoint property.

The Crownpoint potentiometric surface maps were developed using the ground water flow model to simulate the potentiometric surface for the summer and winter conditions. The model was calibrated using the average transmissivity (2,550 gpd/ft.) and storativity (0.000086) determined from pumping tests and assuming a uniform hydraulic gradient to the north-northeast. For the summer map, average summer pumping rates (372 gpm total) for the six Crownpoint water wells in the summer of 1992 were assumed to have been active for five years. The starting head for the uniform gradient was then varied until the simulated ground water elevations at the Crownpoint monitor wells matched actual values measured in August 1992 by HRI. This map was considered to be the baseline condition. The model simulations of the various stages of the mining were then run by maintaining the baseline conditions and adding the projected operating mine wells. These model grid data were then output to Surfer for contouring the potentiometric surface. Except for the sensitivity runs, the summer gradient was utilized in the mine simulations. In order to show the mining detail, the output maps were projected for the Crownpoint area and east to the nearest Crownpoint water well (NTUA-1). Attachment 54-1 is a version of the baseline potentiometric surface map showing the area from Unit 1 to the town of Crownpoint. This map was developed as described above, but expanded to show a larger area and the pumping effects at the Crownpoint water wells.

Average ground water velocities for the Crownpoint and Churchrock mine areas were calculated using the following formula:

$$V = K * I/n$$

where: K = average hydraulic conductivity
I = hydraulic gradient
n = effective porosity

At both areas, the average transmissivity (T) value for the Westwater Canyon sand was used to determine the average hydraulic conductivity (K). Based on aquifer testing, the average transmissivity value for the Westwater sand in the Churchrock area was 1,154 gallons per day per foot (gpd/ft), and in the Crownpoint area was 2,550 gpd/ft. The average K was determined by dividing the T by an effective sand thickness of 200 feet for each area. The effective porosity of the sand was estimated to be 0.25. The hydraulic gradient across each mine area was determined from measurements on the potentiometric surface maps discussed above. The average velocities were then calculated using the above formula.

The ground water velocity across the Churchrock mine area were calculated to be approximately 0.0237 feet per day (ft/d) or 8.7 feet per year (ft/y). The hydraulic gradient is generally uniform across the site as shown on the static potentiometric surface map. The static potentiometric surface at the Crownpoint mine area was mapped for the conditions in the summer when levels are low and the Crownpoint water wells were pumping at higher rates, and the winter when water levels are high and ground water pumping rates are low. Average ground water velocities at the Crownpoint area range from about 0.031 ft/d (11 ft/y) at the east side near Crownpoint well NTUA-1, to about 0.0227 ft/d (8 ft/y) at the west side of the mine area. The average velocity at the Unit 1 area as measured on Attachment 54-1 is approximately 0.0146 ft/d (5 ft/yr.).

Based on a comparison of the above velocities between the Crownpoint mining simulations and well NTUA-1, ground water movement from the mine area toward NTUA-1 will be much slower during mining than pre-mining. Although injection wells will create high pressure points within the active wellfields, the net effect on the bleed from the overall field will actually reduce the velocity of ground water from the mine zone toward the city wells.

During the November 27 to 29, 1995, site visit, HRI, Inc. stated that the pre-mining ground-water velocities of 5.6 ft and 10.6 ft/yr. are the velocities that contaminants would move if they escaped from the well field. Using a distance of 700 feet from the ground-water divide between the modeled well field and well NTUA-1 shown in Reference 3, Figure 8, this produces average travel times of 125 years and 66 years. However, as shown in the model, the ground-water gradient between the ground-water divide and well NTUA-1 will be steeper than pre-mining gradients. Using the model generated head gradients in Reference 3, Figure 8 and information contained in the application, the NRC staff has independently calculated average travel times that range from 9.5 years to 0.45 years.

The NRC staff believes that this discussion concerning pre-mining velocities and the rate of excursion is flawed, because should an excursion occur it would move at a rate faster than the pre-mining velocities. The combination of injection pressures in the well field and potential pumping influences from nearby supply wells will allow an excursion to travel at a faster rate than the pre-mining velocity field.

<u>Action Needed</u>: Provide a potentiometric surface map for the UNIT 1 and Churchrock properties that shows the data points including well locations, water level elevations, and when the water level data were collected. Describe how the ground water gradients were calculated and how they vary over the sites. Provide a potentiometric surface map of the Westwater aquifer for the entire Crownpoint Site in sufficient detail to determine the general direction of water movement. It is suggested that for the Crownpoint site; in areas without wells, ground-water flow modeling which includes the effect of all five community supply wells could provide a adequate description of ground-water flow directions. Quantitatively describe how the ground water velocity changes over the Crownpoint property as a function of distance and with variations in the cumulative pumping effects of the Crownpoint public water supply wells.

<u>Response</u>

Ground water flow velocities in the Crownpoint mine area were calculated based on the available existing water level data. Because there was not sufficient ground water level data from the Unit 1 area for the same time periods and the emphasis was on the Crownpoint area because of the municipal water wells, the Unit 1 area was not included in the modeling. Additionally, as noted in the discussion for Comment No. 50, ground water flow from the Unit 1 area, if it does have an easterly component, will be through the Crownpoint area. Any mining activity that occurs in the Unit 1 area will have the net effect of decreasing the velocity relative to natural ground water velocities. Because the Unit 1 area is much further away from the Crownpoint water wells, and ground water from this area would have to move into and through the Crownpoint mine area before reaching the Crownpoint water wells, it was not necessary to include this area on the static potentiometric surface map or in the model maps. The ground water flow model was developed primarily as a verification of the ground water conditions anticipated in the mining area adjacent to the Crownpoint water wells. The model merely verified that mine fluids could be successfully controlled and be protective of the Crownpoint water supply wells.

The potentiometric surface maps of the Crownpoint and Churchrock mine areas were provided in the hydrodynamic model report (Reference 3) as simulated hydraulic gradient maps. The Crownpoint mine area is represented by a map showing winter conditions and a map showing summer conditions. Because of the lack of significant ground water use in the vicinity of the Churchrock facility, one map was developed.

While the titles indicate the maps are simulations, they, in fact, are representations of the actual conditions. The map for the Churchrock area was made by mapping the potentiometric surface with existing monitor well data from March 1993. An X-Y-Z data file with the well coordinates and ground water elevations were input to a contouring program (Surfer) resulting in a gridded representation of the potentiometric surface over the designated area. This resulted in a very close representation of the actual potentiometric surface with a regular spaced grid file of the same area to be modeled. This potentiometric surface map was not output from the ground water flow model, but was developed as a baseline condition depiction so the model drawdown values on the same grid could be subtracted from the static surface values to yield the model potentiometric surface maps.

Attachment 4

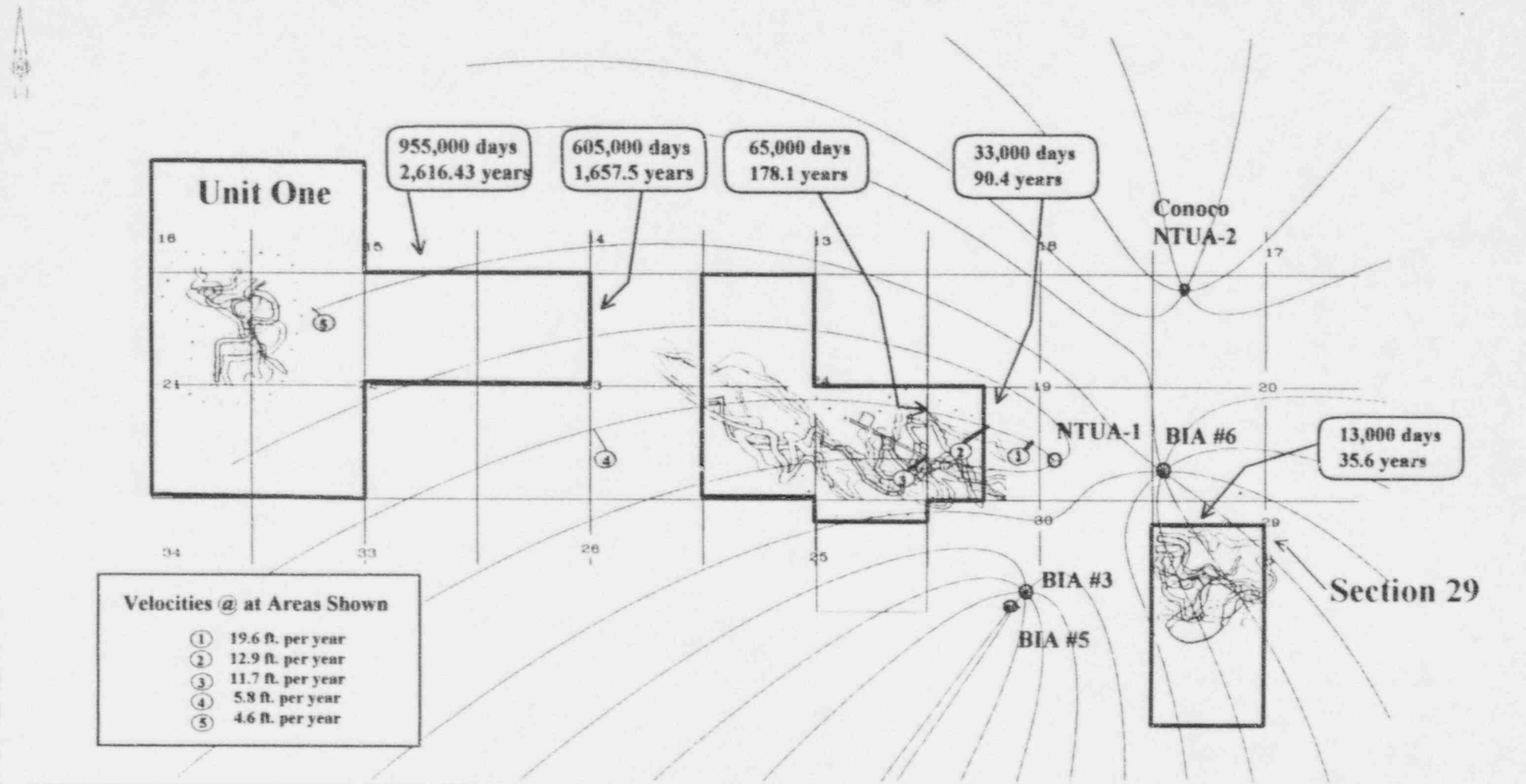

Figure 50-2

Crownpoint New Mexico

Flow Pathways for Crownpoint Water Wells

Pathways Indicate Withdrawal Area for Well Vs. Time

Each Line Represents 10 GPM

Color Changes every 5,000 days

File: Long_1.sam | HRI, Inc. | Date 3-25-96

Withdrawals by Crownpoint Water Wells:

1. NTUA-1	27.7 gpm
2. NTUA Conoco	58.7 gpm
3. BIA #3	79.4 gpm
4. BIA #5	6.2 gpm
5. BIA #6	100.0 gpm
6. Little Water	100.3 gpm

All Flowrates Average Summer Values 1993.

Assumptions:

1. All Withdrawals from Westwater.
2. Formation Net Thickness 201 ft.
3. Porosity 0.251
4. Regional Groundwater Gradient 2.5 ft./Yr @ 70 degrees.

Attachment 5

CLARIFICATION AND ADDITIONAL INFORMATION REQUEST
HYDRO RESOURCES, INC. IN-SITU LEACH URANIUM MINE
CROWNPOINT, NEW MEXICO

Q2/76. **Discussion:** This comment requested that for the Crownpoint property, the applicant should describe why continuous pumping in the well fields does or does not need to be maintained until they have been declared fully restored. The applicant states in the April 1, 1996 response to NRC comments that a bleed will be continued at the Crownpoint property until the well fields have been declared fully restored to the required permit/regulatory limits. The NRC staff considers that if the NRC issues a license for this property, the bleed be continued until the applicant has received approval from the NRC that the well field has been restored and until the period of stabilization monitoring has ended. The NRC staff would also like to know if emergency generators will be required to assure that a continuous bleed is maintained.

Action Needed: The applicant should revise the application documents to clarify its intent to continue the bleed in restored wellfields at the Crownpoint property until HRI receives written approval from the NRC to discontinue the bleed, after restoration is verified through a stability monitoring period. The applicant should also provide a discussion of how it will assure the bleed is continuously maintained in the event of a electrical power outage.

Response:

HRI commits to continue the bleed in restored wellfields at the Crownpoint property until HRI receives written approval from the NRC to discontinue the bleed, after restoration is verified through a stability monitoring period.

HRI also commits to maintain emergency generator capacity, capable of maintaining a 50 gpm bleed from the mine zone throughout the mining and restoration life of the mine. A copy of a correspondence to the State of New Mexico Environment Department is within Attachment Q2/76-1.

Attachment

Q2/76-1

DUPLICATE

HRI, INC.

(A Subsidiary of Uranium Resources, Inc.)

5656 South Staples
Suite 250. LB 8
Corpus Christi, TX 78411
Telephone (512) 993-7731
Telecopy (512) 993-5744

12377 Merit Drive
Suite 750. LB 14
Dallas, Texas 75251
Telephone (214) 934-7777
Telecopy (214) 934-7779
TWX 910-867-4701

Post Office Box 777
Crown Point, New Mexico 87313
Telephone (505) 786-5845

September 21, 1992

Mr. Richard Ohrbom
Water Resources Specialist
Ground Water Section
New Mexico Environmental Department
P.O. Box 26110
Santa Fe, New Mexico 87502

CR
URI → ED

RE: DP-870

Dear Mr. Ohrbom:

The following is in response to your letter dated July 17, 1992, where you requested further information pertaining to the subject discharge plan. I have formatted this response by first restating your question and then responding accordingly.

1. **A contingency plan which will prevent migration of dissolved mineral ions and metals out of the injection/extraction zone in the event the in-situ circulation system fails or is shut down. Please list in detail the preventative measures to be taken. This is especially critical for aquifer protection down gradient from the in-situ zone and along the east parameter of your proposed in-situ zone which is juxtaposed to the Crownpoint water supply wells.**

Response:

The primary contingency for the protection of water wells, including the Crownpoint wells, outside of the monitor well ring is the routine monitoring of water quality within the monitor wells. We plan to do so two times per week. As shown in Attachment A, the maximum rate of natural groundwater movement at a proposed monitor well location is 20.3 feet in one year. Therefore, If circulation failed and the bleed were to temporarily terminate, and If a indicator parameter were to show the presence of leach solution, and If no corrective action was taken, then in a one year period, the affected water would only move 20.3 feet. A system failure for one full year is farfetched under any circumstances. A one-week failure, although given the safeguards that will be discussed below, is virtually impossible, is more realistic to consider. Given the maximum rate of groundwater movement at MW-24 shown in Attachment A, groundwater would travel 4.7 inches in a one-week period.

To assure a cone of depression at the Crownpoint leach facility, HRI proposes to maintain a bleed of approximately 50 gpm, by over extracting approximately 1% of the mining solution. During restoration, the bleed volume will increase. Two conceivable events could interfere with the bleed volume; power failure and mechanical plant failure.

In the event of power failure at the facility, HRI will maintain in service diesel electrical generating capacity, to power the pumps necessary to extract 50 gpm from the mine zone.

If the plant is shut down for maintenance or any unforeseen reason, adequate submersible pumps will be available to pump the wellfield 50 gpm, independent of the plant.

2. **How will the monitor wells be sampled; bailers, submergible pumps, dedicated pumps/bladders, etc.? Also, what protocol will be followed during sampling and transportation of samples to the laboratory doing the analyses?**

Response:

Samples will be obtained with submersible pumps mounted on either a coil tubing unit which can be moved from well to well or with permanent in place pumps in each well. An individual well will be pumped for at least 15 minutes until three consecutive samples taken at five minute intervals have consistent conductivity measurements. Thereafter, a sample will be obtained and preserved.

Routine monitor well samples which are analyzed at the HRI site laboratory will be placed on ice in the field and delivered to the lab, as quickly as possible for analysis, at least two times per shift.

Samples which are shipped to an outside lab will be filtered in the field, acidified with HCL, H_2SO_4 or HNO_3 to pH <2, as appropriate for the required analysis, iced down, and shipped.

3. **What type of flow meter(s) will be employed to measure the volume of the injectate, extraction and bleed off?**

HRI will measure injection extraction at the individual well heads, and at master manifolds going to and from the wellfield. Bleed amounts will be measured at the master manifolds going to and from the wellfields and also by the volume of liquid going to waste disposal.

Meters on individual well heads consist of corrosion-resistant mechanical meters such as these manufactured by Hershey. Larger inline meters, on main injection or extraction laterals, employed by HRI are mechanical with digital readouts.

Please feel free to contact me if you have questions pertaining to this matter.

Yours very truly,

Mark S. Pelizza
Environmental Manager

MSP/dlg

ATTACHMENT A

GROUNDWATER VELOCITY CALCULATIONS

GROUNDWATER VELOCITY CALCULATIONS

FOR MONITOR WELLS

AT

HRI'S CROWNPOINT PROJECT

Crownpoint Town Water Wells	Flowrate (gpm)	
NTUA #1	0	(Assumed P+A)
BIA #6	134.2	
BIA #3	85.5	
BIA #5	105.6	
NTUA Conoco	145.3	
NTUA Littlewater	155.1	
Total Flowrate	625.7	

Proposed HRI Monitor Well	Velocity (Ft//Yr)
M1_24	19.0
M2_24	20.3
M3_24	19.7
M4_24	18.8
M5_24	17.8
M6_24	16.8
M7_24	15.8
M8_24	15.0
M9_24	14.3
M10_24	13.9
M11_24	13.7
M12_24	13.4
M13_24	13.1
M14_24	12.9
M15_24	13.4
M16_24	13.7
M17_24	14.0
M18_24	14.1
M19_24	14.2
M20_24	14.4
M21_24	14.8

Proposed HRI Monitor Well	Velocity (Ft//Yr)
M22_19	15.2
M23_19	15.6
M24_19	15.7
M25_19	16.0
M26_19	16.0
M27_19	16.1
M28_19	16.1
M29_19	15.8
M30_19	15.3
M31_19	14.1
M32_19	12.3
M33_19	13.4
M34_19	16.0
M35_19	18.0
M36_19	19.2
M37_19	19.9
M38_19	19.9
M39_19	19.4

Figure 2

HRI's Crownpoint Project

Locations of Town Water Wells
and Proposed Monitor Wells