MEMORANDUM

To: Olen Zirkle, Ducks Unlimited
From: Neil Schild, P.E.
Prepared by: Laura Jean Wilcox, Hydrogeologist
Reviewed by: Chris Petersen, P.G., C. HG.
Date: April 6, 2006
Subject: Task 7.1d - Refine Well Yield - Groundwater vs. River
Attachment: A – Email correspondence with Matt Reed, Reynolds Inc.

Purpose

This memorandum summarizes estimates of collector well yield at the M&T Ranch / Llano Seco Ranch site with respect to river meander. Drawdown in the collector well caisson was predicted for a series of scenarios using a spreadsheet based tool to solve a series of groundwater flow equations (**Attachment A**). Drawdown was evaluated for two sets of conditions: the first assumed that no well interference occurred; the second assumed there was interference from three additional collector well caissons pumping at 24.25 million gallons per day (MGD) that were spaced 1,500 to 2,000 feet apart from each other. Drawdown at the collector well caisson was evaluated for the two sets of conditions assuming that the constant head boundary was located 750, 1,000, 2,000, and 4,000 feet horizontally from the center of the caisson.

For the purposes of this study, the east bank of the Sacramento River is assumed to be the constant head boundary. It is also assumed that the Sacramento River and ground surface at the well caisson are equivalent in elevation.

Interpretation

Simulations representing a worst-case-scenario predict that if the Sacramento River migrated westward 4,000 feet, collector wells would maintain their predicted production rate of 24.25 MGD with an additional 21.8 feet of drawdown (**Table 1**). Laterals would be located at 95 feet

TABLE 1: Predicted Drawdown at Various Distance from Constant Head Boundary With and Without Well Interference

Horizontal Distance from Collector well Caisson to Constant Head Boundary (feet)	Drawdown Assuming No Well Interference (feet bgs)	Drawdown Assuming Well Interference (feet bgs)
750	51.0	51.0
1,000	53.4	53.4
2,000	59.1	63.1
4,000	64.8	72.8

below ground surface, allowing sufficient head in the well for pumping at that rate. More realistic simulations of river migration predict 2.3 feet of additional drawdown for the 4-collector well system if the constant head boundary moved from 750 to 1,000 feet away from the center of the well caisson.

Figure 1 shows that as distance between the collector well and the constant head boundary increases, the influence on increased drawdown is exponentially less.
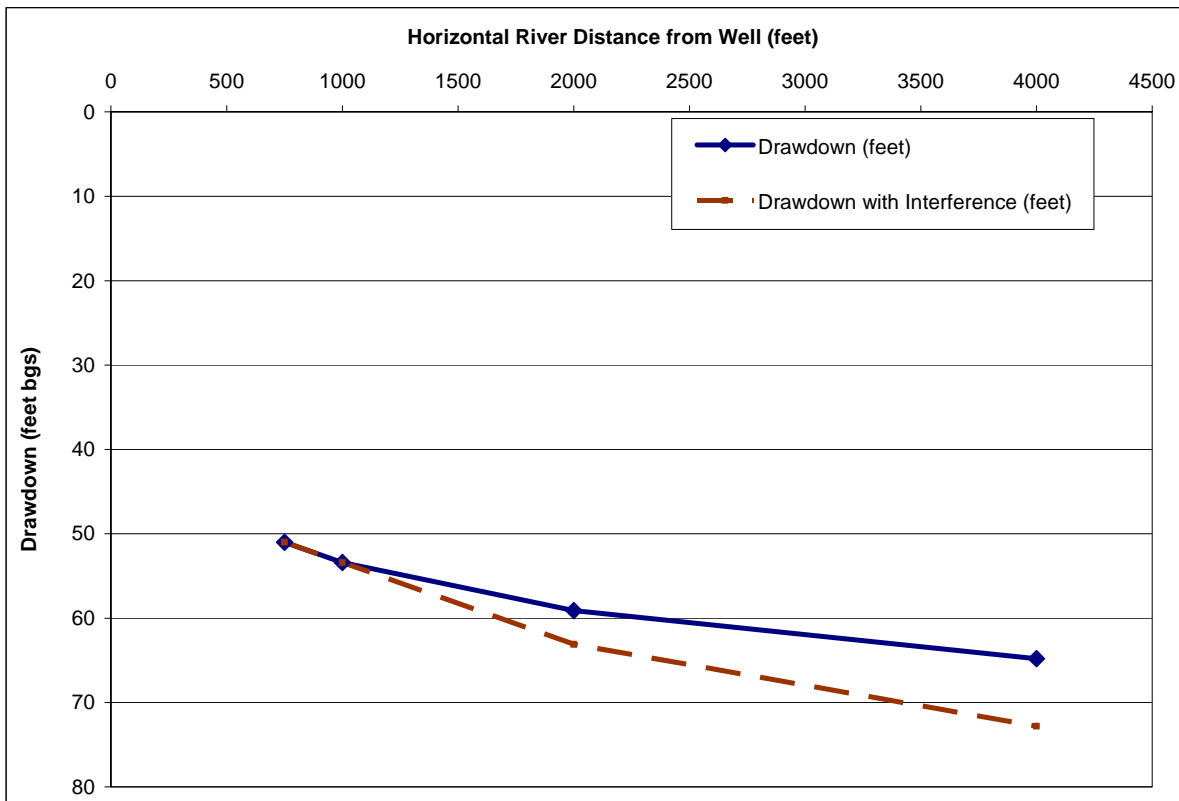

FIGURE 1. Anticipated Drawdown at the Well Caisson Assuming Various Magnitudes of River Meander

Figure 2 shows the relationship between drawdown, horizontal distance to the Sacramento River, and groundwater table slope. This relationship illustrates a fundamental equation of groundwater flow, Darcy's Law:

$$Q = K * A * dh/dl$$

Where Q is well production or yield (constant in these simulations at 24.25 MGD), K is hydraulic conductivity (a constant characteristic of encountered subsurface geologic conditions), A is the cross sectional area of the aquifer, and dh/dl is gradient of the water table. If Q and K are held constant and dh/dl is decreasing with increasing distance to the river, then A must increase with increasing distance.

Conclusion

Based on the evaluated simulations, it is not expected that river migration will substantially affect yield capacity and operation of one to four collector wells operating at 24.25 MGD each, spaced 1,500 to 2,000 feet between well caissons, and with 200 foot long laterals placed at 95 feet bgs.

Water Table Slope Assuming No Well Interference

West

Distance from Well to Constant Head Boundary (feet)

East

4000   3500   3000   2500   2000   1500   1000   500   0

dh/dl =
0.016

dh/dl =
0.030

dh/dl =
0.053

dh/dl =
0.068

Depth to Water when Pumping at 24.25 MGD
(feet below ground surface)

Water Table Slope Assuming Well Interference

West

Distance from Well to Constant Head Boundary (feet)

East

4000   3500   3000   2500   2000   1500   1000   500   0

dh/dl =
0.018

dh/dl =
0.032

dh/dl =
0.053

dh/dl =
0.068

Depth to Water when Pumping at 24.25 MGD
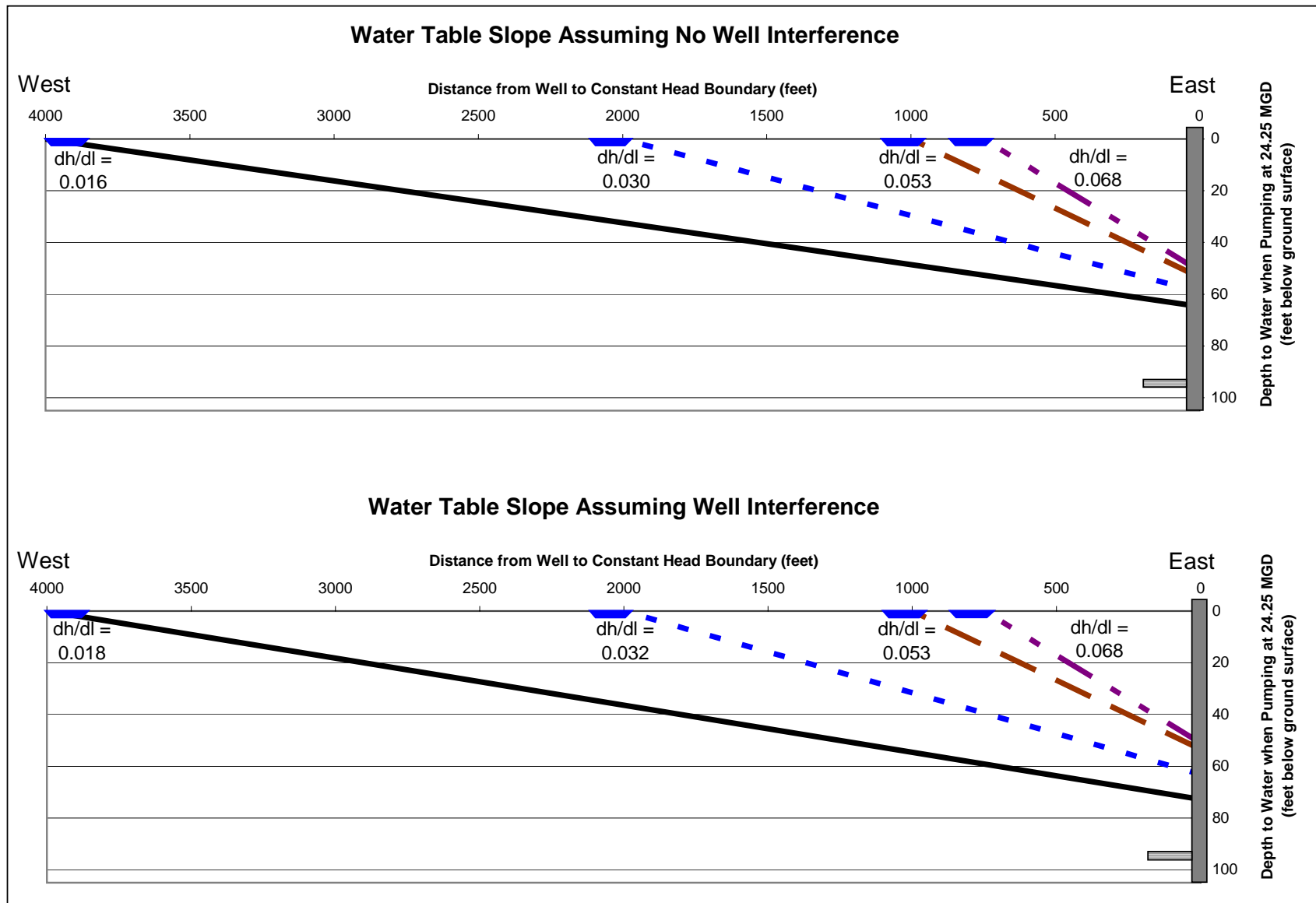(feet below ground surface)

**FIGURE 2: Projected Slope of Water Table With and Without Well Interference Assuming
Constant Pumping Rate of 24.25 MGD and Well Spacing of 1,500 to 2,000 Feet**

ATTACHMENT A

"Matthew Reed"
<mreed@ReynoldsInc.com>

03/29/2006 11:44 AM

To "Laura J Wilcox" <Laura.J.Wilcox@us.mwhglobal.com>

cc "Chris E Petersen" <Chris.E.Petersen@us.mwhglobal.com>

bcc

Subject M&T Drawdown

History:	🖼 This message has been replied to.

Laura Jean:

I've come up the with following for drawdowns at various distances to the hydraulic boundary.

Distance (ft)	s (ft)	depth (bgs)	depth w/ interference
750	31	51	51
1000	33.4	53.4	53.4
2000	39.1	59.1	63.1
4000	44.8	64.8	72.8
8000	50.5	70.5	83.5

These calculations assume 4 collectors, each with a yield of 16,840 gpm (24.25 mgd) and spaced 1500 to 2000 feet apart. Laterals are at 95 feet bgs.

Matt