Continued Evaluation of the Deep Aquifer Alaska Department of Fish & Game Elmendorf Fish Hatchery

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This memorandum presents CH2M HILL's continued evaluation of the deep aquifer that lies beneath the Alaska Department of Fish & Game's (ADF&G) Elmendorf Fish Hatchery located at 941 North Reeve Boulevard, in Anchorage, Alaska. The continued evaluation of the aquifer is based on the ongoing operation of ADF&G Well #6 and installation and testing of ADF&G Well #7 (Exhibit 1).

Conclusions

- Based on the two week (335-hour) pumping test of ADF&G Well #7 and response data observed in ADF&G Well #6, Test Well "A", Elmendorf Well BW-2 and Anchorage Water and Wastewater Utilities (AWWU) Well #4, we conclude our previous conclusions from the testing of ADF&G Well #6 are still valid and that there should be adequate water available from the deep confined aquifer for pumping of both wells at a combined flow rate of 3,000 gallons per minute (gpm).
- Although the pumping test data do not show direct recharge to the confined aquifer within the timeframe of the pumping test, we believe that aquifer recharge occurs on a seasonal basis.
- The aquifer in which AWWU Well #3 is completed is not directly connected to the aquifer tested at the hatchery. There were no water level changes in Well #3 caused by the pumping of Well #7 as expected nor were tidal influences observed in Well #3 similar to the other monitored wells.
- The current construction and condition of AWWU Well #4 is not compatible with long-term pumping at 3,000 gpm from the new hatchery wells. This situation should be resolvable, with cooperation by AWWU, by completing three actions:
  - Rehabilitate AWWU Well #4 to reduce the amount of pumping headloss.
  - Lower the pump intake 50 feet deeper into the well to create more available drawdown.
  - After completion of the Well #4 modifications, scope and conduct an additional long-term pumping test program to satisfy concerns AWWU may have about the usability of their well after the new hatchery is constructed and in operation.

Recommendations

- Conclude negotiations with AWWU regarding long-term pumping from the confined aquifer to support the proposed hatchery and needed improvements to Well #4.
- Rehabilitate Well #4, lower the pump intake at least 50 feet, and then scope and conduct a long-term pumping test to demonstrate to both ADF&G and AWWU that the deep confined aquifer can sustain pumping from ADF&G Wells #6 and #7 and AWWU Well #4.
- Finalize hatchery water rights with ADNR.

Corrections to Previous Well Identifications

The first 12-inch production well installed by M-W Drilling at the Elmendorf Hatchery in November 2006 was incorrectly identified in our memorandum dated December 21, 2006, as ADF&G Well #7. In order to correctly match the water rights application filed by ADF&G to the Alaska Department of Natural Resources (DNR), the previous 12-inch production well is now referred to as Well #6 (formerly Well #7) and the onsite 6-inch observation well used in the pumping and recovery tests is designated Test Well "A" (formerly Well #6). We have revised our previous memorandum dated December 21, 2006, to reflect the changes in well identifications and provided a copy of the revised memorandum entitled *Revised Evaluation of Pumping and Recovery Test of Elmendorf Fish Hatchery Well #6*, dated April 24, 2007, as Attachment 1 of this report.

Previous Aquifer Testing at the Elmendorf Hatchery

A 12-inch diameter production well (Well #6) previously installed by M-W Drilling at the Elmendorf Hatchery in November 2006 (Exhibit 1), was tested from December 4 to December 10, 2006 (see Attachment 1 for well construction and testing results). Well #6 was pumped at a constant flow rate of 1,400 gpm for 72 hours followed by a recovery period of 72 hours. Maximum observed drawdown in the pumping well was 50 feet. The onsite observation well (Well "A) had a reported drawdown of 14 feet while AWWU's Well #4 had a maximum reported drawdown of 10 feet.

ADF&G Well #6 Operations

ADF&G installed a submersible pump in Well #6 on February 1, 2007, and since February 2, has been utilizing water from this well for Hatchery use. A data logging transducer was installed in Well #6, and has been recording water levels since pumping of the well began. The data obtained from Well #6 is being treated as a long-term pumping test. The flow rate from Well #6 has remained relatively unchanged (with the exception of Well #7 testing) at approximately 1,450 to 1,480 gpm since startup.

ADF&G Well #7 Installation

M-W Drilling drilled and installed a second 12-inch diameter well, designated ADF&G Well #7 (Well #7), approximately 20 feet north of ADF&G's settling basin and 50 feet south of ADF&G's existing Well #5 (Exhibit 1) in February 2007. During well drilling the same prolific groundwater aquifer as identified in Well #6 was penetrated at a depth of approximately 240 feet below ground surface (bgs). Based on observation of drill cuttings, the aquifer consists of poorly-graded coarse gravel with sand. The gravel appeared to

increase in diameter with depth. Drilling of the well terminated at a depth of 345 feet bgs when finer gravels, sands, and trace silts were encountered. Water flow from the bottom of the aquifer (within the finer materials) was reduced as compared to flow from the remainder of the aquifer. Well #7 was completed with 60 feet of 150-slot well screen placed between 288 and 348 feet from the top of casing. A static water level (with Well #6 pumping) was recorded in Well #6 at approximately 24 feet below the top of the casing upon completion of the well. A copy of the well log will be provided by M-W Drilling under separate cover.

Well #7 was developed on February 26 and 27 by use of air injection. Less than 2 cubic feet of fine-grained material was removed during the development process.

Well #7 Step-Rate Pumping Test

M-W Drilling installed a 75-horsepower submersible test pump in Well #7 on March 8, 2007. The submersible pump's intake was installed at approximately 150 feet below the top of casing (approximately 130 feet below the water table). The pump's discharge was routed through an orifice plate to measure flow rates (Photograph 1 and 2) prior to discharging into the settling pond south of the well (Exhibit 1).

The approximate yield of Well #7 was evaluated on the afternoon of March 8 by pumping the well at several flow rates with each flow rate held steady at least 30 minutes while drawdown within Well #7 was monitored and recorded manually and by a data logging water level transducer. The results of the step-rate pumping test (Exhibit 2) show that Well #7 could produce approximately 1,500 gpm for the long-term constant rate test (combined flow from Wells #6 and #7 at 2,900 to 3,000 gpm).

Well #7 Constant-Rate Pumping Test

The constant-rate pumping test of Well #7 began March 9 at 10:15AM and concluded on March 23 at 10:15AM for a test period of 335 hours (1 hour loss due to daylight savings time). The well was pumped at an average rate of approximately 1,470 gpm. Pumping of ADF&G Well #6 continued throughout the pumping test of Well #7. The flow rates from Well #6 decreased slightly from 1,470 gpm at the beginning of the pumping test to approximately 1,410 gpm at the conclusion of the pumping test.

In addition to monitoring groundwater levels in Well #7, water levels were also monitored in ADF&G Test Well "A", ADF&G Well #6, Elmendorf Well BW-2 (former power plant) and Anchorage Water and Wastewater Utility's (AWWU) Wells #3 and #4 (see Exhibit 1 for locations). Test Well "A" is located within the Hatchery compound approximately 340 feet to the east of Well #7. Well #6 is located approximately 900 feet northeast of Well #7. Elmendorf Well BW-2 near the former powerhouse is located approximately 1,550 feet west of Well #7. AWWU Well #4 is located just south of William Tyson Elementary School north of Commercial Drive, approximately 1,980 feet south of Well #7. AWWU Well #3 is located near the intersection of Orca Street and 3rd Avenue approximately 5,380 feet southwest of Well #7. Data logging transducers were used to monitor the groundwater levels within all six wells prior to, and during the pumping test. AWWU has an automatic water level monitoring device installed in Well #4.

At the beginning of the pumping test, Well #7 (the pumping well) experienced very rapid drawdown. The rate of the drawdown in Well #7 declined over the length of the test, but did not stabilize. Upon conclusion of the test, Well #7 had drawn down approximately 99.5 feet (Exhibit 3). Drawdown in Test Well "A" (the nearest observation well) did not stabilize during the duration of the test. Test Well "A" experienced a maximum drawdown of 25.5 feet at the conclusion of the pumping test (Exhibit 3). ADF&G Well #6 and Elmendorf Well BW-2 experienced similar responses to the pumping of Well #7 (Exhibit 3). Both Well #6 and BW-2 reached a maximum drawdown of about 13.5 feet at the conclusion of the pumping test. Exhibit 3 also shows the AWWU Well #4 drawdown data provided to CH2M HILL by AWWU upon conclusion of the testing. The drawdown in Well #4 did not stabilize prior to conclusion of the pumping test. AWWU Well #4 experienced a maximum drawdown of 12.5 feet at the conclusion of the pumping test. AWWU Well #3 did not experience water level changes associated with the pumping test nor tidal influences as observed in the other monitored wells (Exhibit 4).

Well #7 Recovery Test

Upon conclusion of the two week pumping test (March 23), water level recoveries were measured and recorded in ADF&G Wells #6, #7, and "A", Elmendorf Well BW-2, and AWWU Wells #3 and #4 for an additional two weeks. Pumping of ADF&G Well #6 continued throughout the recovery test. The flow rate from ADF&G Well #6 increased from 1,410 gpm to 1,460 gpm by March 26.

Exhibits 4 and 5 shows the change in water levels observed within the wells during the recovery test. Similar to the constant-rate pumping test, the pumping well (Well #7) recovery was very rapid initially and diminished over time. Well #7 had not fully recovered by the end of the recovery monitoring period.

The water levels recorded within ADF&G Well #6 and "A", Elmendorf Well BW-2, and AWWU #4 (Exhibit 5) showed recovery similar to the pumping drawdown. Water levels remained below static water levels in all the wells at the conclusion of the monitoring period. Water levels remained relatively unchanged in AWWU Well #3 (Exhibit 4).

Aquifer Properties

Using the water level data recorded in ADF&G Test Well "A", #6, and #7, Elmendorf Well BW-2, and AWWU Well #4 during the constant-rate pumping test and the recovery test, estimates of the aquifer hydraulic characteristics were made (Attachment 2). Table 1 summarizes the transmissivity and storage coefficients calculated using the pumping data and Table 2 summarizes the transmissivity calculated using the recovery data. The aquifer properties were estimated using analytical solutions derived by both Theis and Cooper-Jacob for pumping from a well in a confined aquifer, by Popodopolus-Cooper using a solution for pumping from a well in a confined aquifer with well bore storage, and by Theis for recovery of a well in a confined aquifer.

TABLE 1
Calculated Aquifer Properties – Pumping Test Data
Elmendorf Hatchery Aquifer Test #2, March 9–23, 2007

	Theis Solution		Cooper-Jacob Solution		Papadopulos-Cooper Solution	
Well	Transmissivity (ft^2/day)	Storage (unitless)	Transmissivity (ft^2/day)	Storage (unitless)	Transmissivity (ft^2/day)	Storage (unitless)
ADF&G Well #6 Pump Startup						
ADF&G #6	1.338E+04	1.118E-04	1.374E+04	1.721E-06	1.387E+04	1.037E-02
ADF&G Well #7 Pumping Test						
ADF&G #6	1.508E+04	9.927E-05	1.474E+04	1.064E-04	1.621E+04	8.398E-05
ADF&G #A	1.224E+04	3.897E-06	1.197E+04	5.020E-06	1.007E+04	2.045E-05
AWWU #4	1.031E+04	1.888E-04	1.068E+04	1.625E-04	9.595E+03	2.178E-04
ADF&G #7 (Manual)	2.143E+04	N/A	2.464E+04	N/A	2.398E+04	N/A
ADF&G #7	2.676E+04	N/A	2.456E+04	N/A	2.405E+04	N/A
Elmendorf BW-2	1.394E+04	8.719E-05	1.226E+04	1.262E-04	1.394E+04	8.719E-05
Average	**1.663E+04**	**9.479E-05**	**1.648E+04**	**1.000E-04**	**1.631E+04**	**1.024E-04**

N/A = not applicable

TABLE 2
Calculated Aquifer Properties – Recovery Test Data
Elmendorf Hatchery Aquifer Test #2, March 23-April 6, 2007

	Theis Recovery Solution
Well	Transmissivity (ft^2/day)
ADF&G Well #7 Recovery Test	
ADF&G #6	1.510E+04
ADF&G #A	1.198E+04
AWWU #4	1.093E+04
ADF&G #7 (Manual)	1.207E+04
ADF&G #7	1.204E+04
Elmendorf BW-2	1.226E+04
Average	**1.240E+04**

Analysis of the pumping test data estimated transmissivity for the aquifer ranges from a low of 9,595 feet squared per day (ft^2/day) as estimated in AWWU Well #4 to a high of 26,760 ft^2/day as estimated in Well #7. The transmissivity of the analyzed recovery test data ranged from a low of 10,930 ft^2/day in ADF&G Well A to 15,100 ft^2/day in Well #6. Based on the range and variability of the results, an average transmissivity of about 14,400 ft^2/day is estimated for the aquifer.

Based on the data collected during the pumping and recovery test, the aquifer behaved like a confined aquifer, as expected by the observed geology. The influence of the pumping test was easily observed within ½ mile of the pumping well and would most likely be observable at a distance of at least 2 miles. Moreover, the lack of water level stabilization in all the monitored wells suggests that the Well #7 cone of depression still had not encounter a constant head boundary (such as a lake or stream) at the end of the test, nor was there leakage from above or below the aquifer equal to the total Well #6 and #7 pumping rate.

Aquifer Usage & Impacts

ADF&G wants to pump groundwater from Well #6 and Well #7 to supply water necessary for current and future hatchery needs. ADF&G now predicts that the peak hatchery demand from these two wells is about 3,000 gpm of combined flow.

To ascertain the potential impacts to the aquifer caused by the continuous pumping of both wells at peak discharge (both conservative assumptions); CH2M HILL performed two simple groundwater modeling simulations. The first model simulation (summarized in Table 3) was run to predict water level declines in AWWU Well #4 over time using the transmissivity value (approximately 10,000 ft^2/day) calculated for AWWU Well #4, continuous flow of 1,500 gpm from both pumping wells (Well #6 & #7), and and a storage coefficient of 0.0001. The second model simulation (summarized in Table 4) was run in an attempt to match actual observed conditions within the hatchery pumping wells and predict impacts to neighboring pumping wells using a transmissivity of 14,400 ft^2/day (the average transmissivity), continuous peak flow at 1,500 gpm from both pumping wells, and a storage coefficient of 0.0001. Recharge was not accounted for in either simulation (a conservative assumption) because recharge was not observed during the extensive testing period and information about seasonal recharge to the aquifer is unavailable. Modeling outputs are presented in Attachment 3.

TABLE 3
Groundwater Modeling Results: Flow = 1,500 gpm in Well #6 & #7; T = 10,000 ft^2/day
Elmendorf Hatchery Aquifer Test #2

Well	Predicted Drop in Groundwater Levels (feet)			
	3 Days	1 year	2 years	10 years
AWWU Well #4	24	50	54	62

TABLE 4
Groundwater Modeling Results: Flow = 1,500 gpm in Well #6 & #7; T = 14,400 ft²/day
Elmendorf Hatchery Aquifer Test #2

Well	Predicted Drop in Groundwater Levels (feet)			
	3 Days	1 year	2 years	10 years
ADF&G Well #6	62	80	83	89
ADF&G Well #7	112	142	146	156
ADF&G Test Well "A"	26	41	43	48
Elmendorf Well BW-2	18	33	36	41

As presented in Table 3, groundwater levels after 10 years of continuous pumping (assuming no recharge) are predicted to drop by 62 feet in AWWU's Well #4. Modelling with the higher (reported average) transmissivity value (Table 4) shows groundwater levels are predicted to drop by 41 feet in Elmendorf's Well BW-2, 48 feet in Test Well A, 89 feet in Well #6, and 156 feet in Well #7 after 10 years. Given Well #6 has about 255 feet of available drawdown (usable water column) the model results show that there still will be approximately 165 feet of water column after 10 years of pumping. Similar to Well #6, the model results show that Well #7 will still have approximately 115 feet of water column after 10 years. Therefore, the deep aquifer beneath the Elmendorf Hatchery should be able to continue to sustain continuous combined pumping of 3,000 gpm for ten or more years.

Modifications to AWWU Well #4

Based on information provided by AWWU, Well #4 was drilled to a total depth of 328 feet bgs with a 0.080-inch well screen installed from approximately 270 feet bgs to 320 feet bgs. The well pump intake was installed at a depth of approximately 220 bgs. Current static water levels are reported by AWWU to be 140 feet above the pump intake in the well with a water level reported at 42 feet above the pump intake while pumping. Therefore, the pumping level in Well #4 would be at or below the pump intake in less than one year with ADF&G pumping at an annualized flow rate of 1,500 gpm in both wells unless modifications to Well #4 are made. We again recommend the following modifications to Well #4 to ensure adequate availability of water:

1. Redevelop the Well #4 screen to reduce headloss within the well while pumping. The well screen at Well #4 has been redeveloped in the past because of mineral deposits building up, restricting flow and thereby increasing headloss (lowering efficiency) within the well.
2. The well pump should also be lowered within Well #4 an additional 50 feet. Calculations should be made to ensure that the pump can lift the water the maximum predicted extra 60 feet (based on continious pumping of 3,000 gpm from the hatchery wells).
3. Upon completion of well redevelopment and the pump lowering, an additional long-term pumping testing program could be developed to satisfy potential concerns AWWU may have about the continued usability of their well.