ARCADIS

Appendix C-2

Water Balance Technical Memorandum

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MEMO

~~To:~~
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~~From:~~
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~~Subject Date:~~
Water Balance at the HELSTF
~~8 July 2009~~

ARCADIS Project No.:
GP08WSMR.0REP.DP001

~~Subject:~~
~~Water Balance at the HELSTF~~

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1. Introduction

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This document summarizes the water balance analysis for the High Energy Laser Systems T (HELSTF) area at the White Sands Missile Range (WSMR), New Mexico. This analysis was completed to estimate the range of infiltration associated with known and potential sources of recharge in an effort to better understand the accumulation of vadose zone water above the regional water table.

~~Water-bearing zones have been identified in the vadose zone above the regional aquifer.~~ Because precipitation and natural infiltration in the area is very limited to nonexistent, the partial saturation of the vadose zone above the regional aquifer is believed to primarily be a result of leaks from water supply and sanitary systems and discharges from the operations at the HELSTF. The water balance at the HELSTF was evaluated to 1) estimate the potential flux of infiltrating water to the vadose zone, and 2) to estimate potential recharge and contaminant migration to the regional aquifer. Specifically, the flux of infiltrating water ~~flux~~ (Q_{inf}) was ~~calculated~~ estimated using the following equations~~by~~:

$$Q_{inf} = Q_{dis} + Q_{leak}$$

$$Q_{leak} = Q_{supply} - Q_{evap} - Q_{dis}$$

Where Q_{dis} is the recorded surface discharge flows, Q_{leak} is the flow of water leaking from water supply and sanitary systems, Q_{supply} is water supply flow, and Q_{evap} is the water flow loss due to evaporation.

The water balance analysis was based on available data and information primarily provided by WSMR. For example, the available data included metered annual water production data from 2004-2007 and daily metered and estimated water production and usage from a 290-day period in 1995-1996. Although the available data are relatively limited and there are resulting uncertainties in the water balance, the analysis provides a basis for estimating the potential flux of infiltrating water and ~~clearly~~ demonstrates that the vast majority of water in the vadose zone is likely attributable to HELSTF operations. ~~and that o~~Ongoing infiltration due to water supply and sanitary system leakage is likely on the order of several gallons per minute (gpm).

The following sections describe the specific water sources and losses in further detail and summarize the specific calculations associated with the water balance analysis.

2. Water Supply (Q_{supply})

Water ~~Supply~~ supply ~~Wells~~ wells MAR-1, MAR-2, and MAR-3 are the only known sources of water for the HELSTF area. Because the groundwater near the site is too saline for potable or industrial use without extensive treatment, water is extracted near the San Andreas Mountains range and is piped to the HELSTF area.

The average annual water production during the 2004-2007 period was approximately 12.1 million gallons per year, or 23.1 gpm. ~~Normalized~~ Average annual production during 1995-1996 was 16.8 million gallons per year, or 31.9 gpm. The difference in water production is likely related the site being more active in 1995-1996 than ~~since~~ during 2004.

3. Discharge/Infiltration Points (Q_{dis})

Known discharge points are discussed ~~separately~~ in detail below.

~~**Specific Infiltration Locations**~~

a) **Discharge from the LSTC**: From the 1960s to 2008, wastewater from the Laser Systems Test Center (LSTC) was discharged at the LSTC Wastewater Discharge Point (Solid Waste Management Unit [SWMU] 144). Wastewater from the reverse osmosis system was also discharged ~~t~~here. The only record of discharge to the LSTC discharge point was an observation of 40 to 50 gpm on July 24, 1990. No annual discharge has been recorded, and the potential infiltration from the LSTC discharge point is, therefore, not calculated explicitly but is included in the estimate of infiltration from leaking water and sewer lines. The vadose zone beneath the LSTC discharge point is partially saturated, suggesting that significant discharge has occurred; however,

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the infiltration rate cannot be estimated with currently available information. The discharge from this source will be considered part of Q_{leak}.

b) **Discharge of Wastewater from the Reverse Osmosis System**: The reverse osmosis system discharged to the LSTC Wastwater Discharge Point (SWMU 144) at an average normalized rate of 735,000 gallons per year, or 1.4 gpm, during the 290 days of records in 1995-1996. No record of discharge during 2004-2007 was found, and it was assumed that the discharge rate was constant between 1995 and 2007.

a)c) If this assumption is incorrect, the distribution of infiltration would change but the total estimated amount of infiltration would not change. **Discharge from Septic Systems**: Several septic systems are also present at the site. No discharge rates for these locations were recorded and, for the purposes of this analysis, it was assumed that the discharge from the septic systems was insignificant compared to other discharge points. Potential infiltration from septic systems is included in the estimate of infiltration from the water and sewer lines.

b) **Infiltration from the Dry Pond**: According to interviews conducted with personnel at WSMR, make-up water and water from boilers has also been discharged to the Dry Pond (SWMU 146). Although the discharges there were reported to have been of large volumes, the amount of water discharged is not known and it is not possible to estimate the discharge with currently available information. As a result, discharges that occurred there are accounted for in this analysis as "infiltration from leaking pipes and other unknown sources" or as part of Q_{leak}. Discharges were discontinued in 2008. Any discharge occurring at SWMU 146 is included in the amount of leakage from the water and sewer lines.

d)

c)e) **Infiltration from the Effluent Settling PondsSewage Lagoons**: The effluent settling pondsSewage Lagoons were constructed as unlined ponds lagoons in 1962 and two of the ponds lagoons were replaced with lined ponds lagoons in 1981 and the remaining two in 1984. There is visual evidence that the liners failed and that the lagoons leaked. New lagoons were constructed in 2007 and discharges to the leaking lagoons ceased in early 2008. The maximum infiltration rate from the ponds lagoons was estimated based on saturated conditions below the entire footprint of the ponds lagoons (hydraulic gradient of 1), horizontal hydraulic conductivity based on slug testing (0.1 foot per day [ft/day]), hydraulic anisotropy (k_v/k_h = 0.1), and estimated area of the four effluent settling ponds sewage lagoons (64,000 square feet [ft^2]). The maximum infiltration rate was

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estimated at 3.5 gpm to ~~place~~ place an upper bound of the infiltration rate. The infiltration is expected to be less than this maximum infiltration rate. Instead, the infiltration rate was calculated as the difference between the flow rate of wastewater to the lagoons and the calculated evaporation rate.

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Data from 1995-1996 indicates that 8.7 gpm of wastewater was discharged to the ~~Effluent Settling Ponds~~Sewage Lagoons. For the water balance calculations, it was assumed that the average evaporation and infiltration rates were constant between 1996 and 2007. Evaporation from the lagoons is discussed in more detail below and calculated to 7.2 gpm. The calculated infiltration rate from the ~~Effluent Settling Ponds~~sewage lagoons ~~is, therefore, 1.5 gpm,~~ the difference between 8.7 and 7.2 gpm, or 1.5 gpm. The infiltration rate likely decreased when the lagoons were taken out of commission in 2008 and will cease completely when the ~~Effluent Settling Ponds~~Sewage Lagoons become dry.

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4. Evaporation Losses (Q_{evap})

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a) **Sewage Lagoons (SWMUs 27, 28, 29, and 30)**: The amount of water that evaporated from the Sewage Lagoons was estimated based on pan evaporation rates from the climate station at Elephant Butte Dam, New Mexico. It was assumed that all four lagoons were constantly filled with wastewater effluent and an average evaporation rate was calculated. The average annual pan evaporation rate between 1917 and 2002 was estimated to be 113 inches per year. The pan evaporation rate was corrected by a factor of 0.80 for evaporation from an open surface (90 inches per year) (Western Regional Climate Center, undated). The average rate of evaporation from the 64,000 ft^2 sewage lagoons was calculated to be 7.2 gpm.

b) **Evaporation from the Cooling Tower**: Records from the 290-day period during 1995 and 1996 indicate that the normalized annual evaporation from the cooling tower was 5,733,200 gallons per year, or approximately 10.9 gpm. The amount of evaporation between 2004 and 2007 was not recorded, and it was assumed that the evaporation was the same as in 1995-1996.

It should be noted that some of the moisture infiltrating to the shallow subsurface would be expected to be wicked to the surface and lost to either evaporation or transpiration evaporate because the evapotranspiration extinction depth is approximately 15 feet in the area. As a conservative measure, this loss is not accounted for in the analysis; consequently, the Q_{inf} values presented are likely to be higher than the actual flow recharging the deep vadose zone and regional aquifer.

5. Infiltration from Leaking Pipes and Other Unknown Sources (Q_{leak})

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Infiltration from leaking pipes includes the sum of water loss from leaks in the water distribution system, wastewater pipelines, septic leaching systems, and any discharges to the Dry Pond~~,~~ (SWMU 146). The amount of water leaking from these sources cannot be determined directly but was inferred to be the

difference between water supply (Q_{supply}) and known water losses (Q_{evap} and Q_{dis}). The results of these calculations are summarized in the following section.

Evaporation Losses (Qevap)

Effluent Settling Ponds (SWMUs 27, 28, 29, and 30)

The amount of water that evaporated from the Effluent Settling Ponds was estimated based on pan evaporation rates from the climate station at Elephant Butte Dam, New Mexico. It was assumed that all four ponds were constantly filled with wastewater effluent and an average evaporation rate was calculated. The average annual pan evaporation rate between 1917 and 2002 was estimated to be 113 inches per year. The pan evaporation rate was corrected by a factor of 0.80 for evaporation from an open surface (90 inches per year). The average rate of evaporation from the 64,000 ft2 sewage ponds was calculated to be 7.2 gpm.

Evaporation from the Cooling Tower

Records from the 290-day period during 1995 and 1996 indicate that the normalized annual evaporation from the cooling tower was 5,733,200 gallons per year, or approximately 10.9 gpm. The amount of evaporation between 2004 and 2007 was not recorded, and it was assumed that the evaporation was the same as in 1995-1996.

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6. Summary of Water Balance

A summary of the water balance analysis is presented on Figure 1 and in Table 1. The calculations indicate that approximately 10.911 and 2.01 gpm infiltrated in 1995-1996 and 2.12 gpm infiltrated 2004-2007, respectively, from leaking water and sewer lines within the HELSTF area. In addition, approximately 1.5 gpm (on average) infiltrated from leaking Effluent Settling PondsSewage Lagoons and 1.4 gpm infiltrated from as a result of wastewater being discharged from the reverse osmosis system. Therefore, a total average flow of 13.8 gpm and 5 gpm is estimated to have infiltrated (Q_{inf}) to the vadose zone in 1995-1996; and similarly, the infiltration is estimated at 5 gpm between 2004 and 2007, respectively. The difference in calculated Q_{inf} values for the two time periods is because attributed to higher water use was greater in 1995-1996 than during 2004-2007. and tThe infiltration rate was likely to be greater prior to 2004 when the site was more active.

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Declining water levels at various many wells within the vadose zone provide evidence of reduced infiltration as a result of reduced activity at the site after 2004 (Figure 2). It should be noted that some of the moisture infiltrating to the shallow subsurface would also be expected to be wicked to the surface and lost to either evaporation or transpiration evaporate because the evapotranspiration extinction depth is approximately 15 feet in the area. As a conservative measure, this loss is not accounted for in the

analysis; consequently, the Q_{inf} values presented are likely to be higher than the actual flow recharging the deep vadose zone and regional aquifer.

Although the available data are relatively limited and there are resulting uncertainties in the water balance, the analysis above indicates that ~~historically~~ the vadose zone and regional aquifer have been recharged by leaks and discharges associated with HELSTF operations, and that ~~current~~ recharge rates are likely declining over time. It is also reasonable to expect that the current 2009/2010 leakage rates are continuing to decline, assuming site operations are continuing to be reduced. ~~are likely too low (estimated at about at 5 gpm site-wide) to support contamination of the regional aquifer at levels that are problematic.~~

References:

Western Regional Climate Center. Undated. Evaporation Stations. [webpage] Located at: http://www.wrcc.dri.edu/htmlfiles/westevap.final.html#NEW%20MEXICO. Accessed on 06/21/2010.

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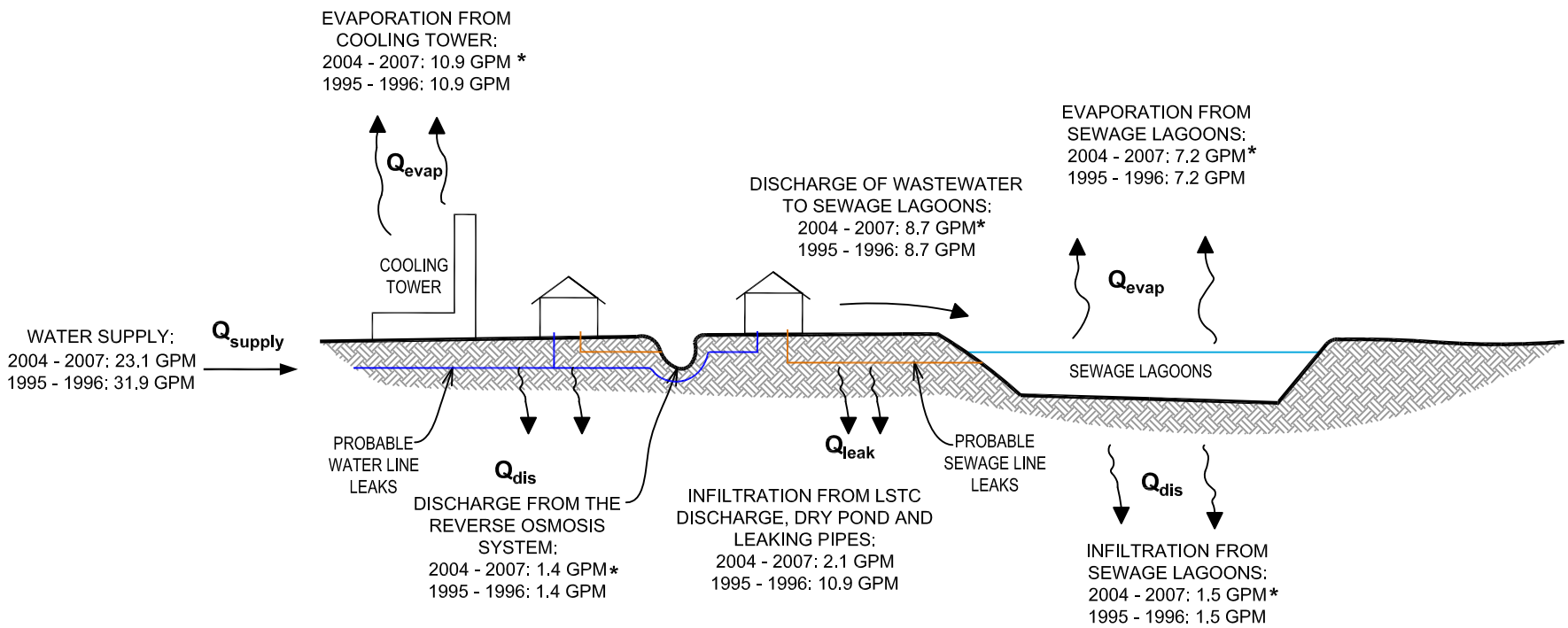
Table 1. Summary of Water Balance Calculations for the HELSTF.

Water Category	Contribution (gpm) 1995-1996	Contribution (gpm) 2004-2007	Comments
Source water production (input to HELSTF)	31.9	23.1	Metered water production
Recorded loss by evaporation from cooling tower	-10.9	-10.9	Evaporation assumed constant between 1996 and 2007
Estimated loss by evaporation from Sanitary Treatment System	-7.2	-7.2	Evaporation assumed constant between 1996 and 2007, and based upon published pan evaporation rates
Sum of evaporative losses	*-18.1*	*-18.1*	
Recorded discharge at the reverse osmosis system	-1.4	-1.4	Discharge assumed constant between 1996 and 2007
Estimated infiltration at the Sanitary Treatment System	-1.5	-1.5	Difference between influent to the ponds (1995-1996) and evaporation
Estimated leakage and infiltration from water and sewer lines and LSTC discharge	-10.9	-2.1	Difference between water production and other losses
Sum of leakage and infiltration	*-13.8*	*-5.0*	

Notes:
Information was available for 290 days in1995-1996 and from 2004-2007 only.
HELSTF - High Energy Laser Systems Test Facility.
LSTC - Laser Systems Test Center.



SUMMARY OF DISCHARGE/INFILTRATION (GPM)				
TIME RANGE	**REVERSE OSMOSIS SYSTEM**	**SEWAGE LAGOONS**	**LSTC DISCHARGE, DRY POND AND LEAKING PIPES**	**TOTAL INFILTRATION**
2004 - 2007	1.4	1.5	2.1	**5.0**
1995 - 1996	1.4	1.5	10.9	**13.8**

LEGEND:

WATER LINE
SEWAGE LINE

NOTE:

1. GPM = GALLONS PER MINUTE
2. * INDICATES THE ESTIMATE IS ASSUMED TO BE THE SAME AS THE 1995-1996 VALUE
3. $Q_{inf} = Q_{dis} + Q_{leak}$; $Q_{leak} = Q_{supply} - Q_{evap} - Q_{dis}$
4. NOT TO SCALE, ILLUSTRATION ONLY

WHITE SANDS MISSILE RANGE
NEW MEXICO
REVISED PHASE III RCRA FACILITY INVESTIGATION (RFI) REPORT – HELSTF SITE – SECOND REVISION (AUGUST, 2010)

WATER BALANCE

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FIGURE
1

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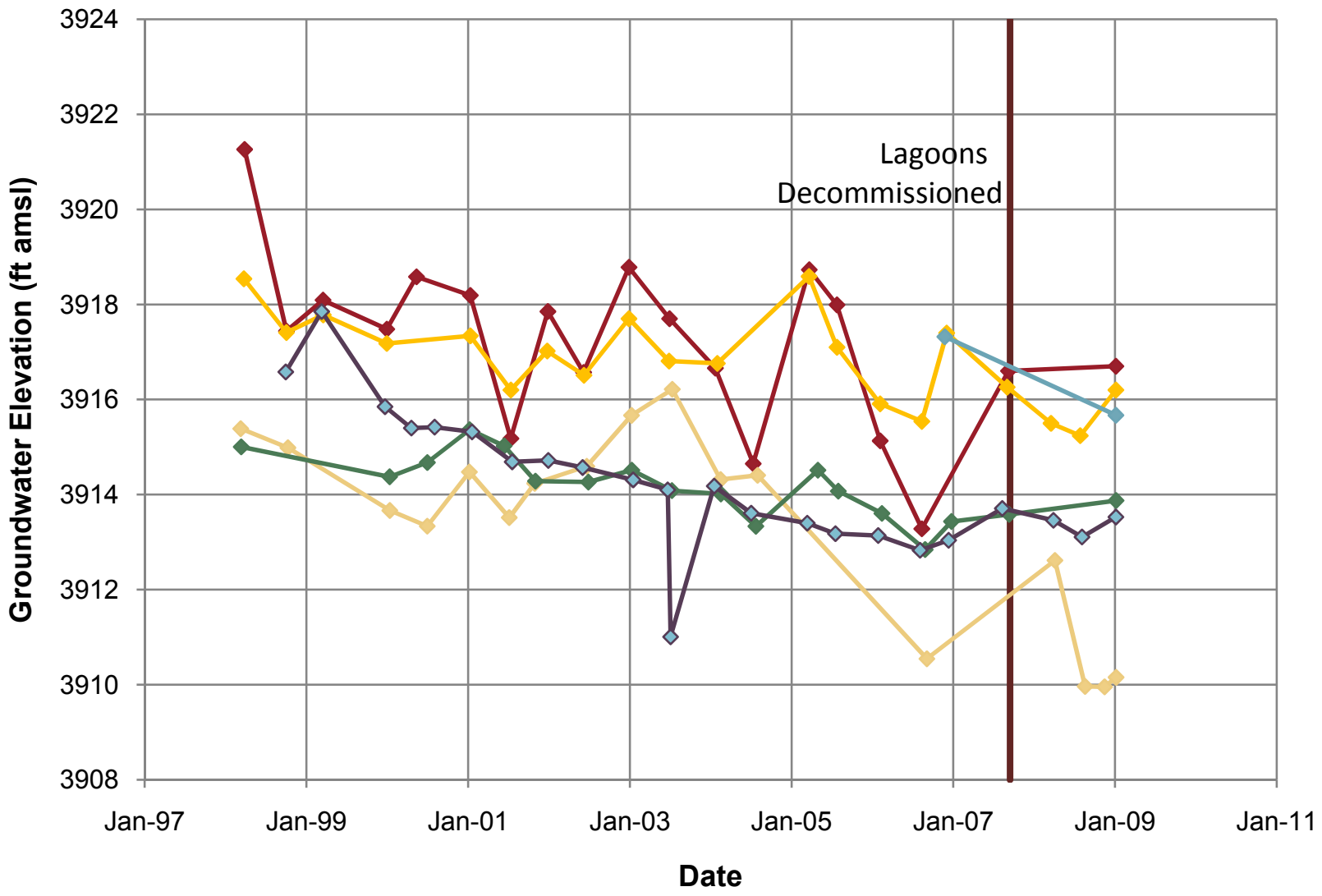

HMW-13 HMW-43 DRW-02

HMW-23 DRW-05 HMW-33

WHITE SANDS MISSILE RANGE
NEW MEXICO
REVISED PHASE III RCRA FACILITY INVESTIGATION (RFI) REPORT – HELSTF SITE – SECOND REVISION (AUGUST, 2010)

DECLINING VADOSE ZONE WATER LEVELS

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FIGURE
2

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