COLLECTION FOR RE-INJECTION MASS BALANCE/REMOVAL ANALYSIS

PREPARED FOR:
HOMESTAKE MINING COMPANY

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CAP	Corrective Action Program
CO	Confirmatory Order
COC	constituent(s) of concern
DP-200	Discharge Plan-200
gpm	gallon(s) per minute
GRP	Grants Reclamation Project
GWPS	Ground Water Protection Standard(s)
HMC	Homestake Mining Company
kg	kilogram
lb	pound
LTP	Large Tailings Pile
NMED	New Mexico Environmental Department
NRC	United States Nuclear Regulatory Commission
RAIs	Requests for Additional Information
RO	Reverse Osmosis
STP	Small Tailings Pile

1. INTRODUCTION, RESTORATION PROGRESS AND SUMMARY

This report is submitted as part of the Confirmatory Order (CO) issued on March 28, 2017 by the United States Nuclear Regulatory Commission (NRC) regarding Homestake Mining Company (HMC) of California's Grants Reclamation Project (GRP). Confirmatory Order Condition 8 requires the use of the mass balance methodology described in the revised 2012 groundwater Corrective Action Program (CAP) submittal to evaluate the impact of the collection for re-injection on the completion of the restoration. In consultation with the NRC, it was agreed that a surface analysis approach to estimating contaminant mass and water volumes could be used to evaluate the impact of the collection for re-injection program within the hydraulic control area. This surface analysis approach, while producing mass and volume estimates similar to those generated by the methodology used in the CAP, can utilize more of the available water level and water quality data for the area of interest. A separate analysis using the methodology described in the CAP was performed specifically to evaluate the mass removal/balance of the L area plume, which is outside of the hydraulic control area, and the resulting impact of re-injection of ground water inside the hydraulic control area. In this separate analysis for the L area collection, the issues raised by the NRC in requests for additional information (RAIs) were considered in applying the methodology. The separate analysis for the L area was undertaken to avoid obscuring the mass changes within the L area by the inclusion of the much larger mass within the hydraulic control area.

1.1 Introduction

The collection for re-injection program was originally approved in 1995 by the New Mexico Environmental Department (NMED) in its Discharge Plan-200 (DP-200). The primary objective of this approved plan was to capture slightly impacted ground water that does not meet site clean-up standards for one or more constituents of concern (COC) and re-inject that water within the hydraulic control area in locations where it could enhance restoration of more severely impacted ground water. The hydraulic control area is located in the area of the Large Tailings Pile (LTP) with the western and southern edges formed by the hydraulic boundary shown on Figure 1-1. Although the collection component of the collection for re-injection program occurred both within and outside of the hydraulic control area during the early years of the program, the greatest benefit accrued from collecting slightly impacted water from the L area outside of the control area and injecting the water within the control area.

The hydraulic control area results from a combination of collection of impacted ground water in the area of the LTP and injection of treated and fresh water in a roughly semicircular area on the south and west sides of the LTP and associated facilities. This combination of collection at and near the source of the contaminants (i.e., the LTP), and injection in what is naturally the downgradient direction in the alluvial aquifer causes a local gradient reversal and containment of impacted water within the hydraulic barrier along the injection wells and infiltration lines.

The collection and treatment of ground water from within the control area is the highest priority activity at the GRP because it is necessary to maintain the gradient reversal from the hydraulic barrier towards the LTP area. Although the injection of treated and/or fresh water strengthens the gradient reversal and containment, without collection of alluvial ground water the containment will be lost. Therefore, virtually all of the available reverse osmosis (RO) treatment and evaporation[1] capacity has been utilized for the ground or tailings water collected from within the hydraulic control area over the life of the project.

The preceding discussion on the necessity of maintaining the highest possible collection rates within the hydraulic control is included to emphasize that diverting even a part of the RO treatment or evaporation capacity to other collected waters would significantly detract from the most critical component of the ground water restoration program. Along with being necessary to maintain the containment in the control area, the preferential treatment of collection waters from inside the control area had the benefit of a higher rate of mass removal of COCs from the ground water. The most severely impacted ground water is located in the alluvium beneath and around the LTP. By collecting the more severely impacted ground water for RO treatment, the rate of mass COC removal is maximized. In contrast, substituting slightly impacted ground water for a portion of the severely impacted ground water in the RO feed would reduce the rate of mass COC removal from the ground water, and ultimately extend the restoration program.

1.2 Restoration Progress

The restoration progress during the period when collection for re-injection was utilized is documented in numerous annual reports for the GRP submitted to the NRC and NMED. The restoration progress in the hydraulic control area can be assessed by examining total mass removed by the collection program and the reduction in average or typical COC concentrations. As discussed in Section 3 of this report, the average uranium concentration in the alluvial aquifer within an area representing the typical hydraulic control area was reduced from approximately 20.8 mg/l in 1995 to approximately 8.1 mg/l in 2015. Over this same period of time, approximately 343,710 lbs of uranium were removed by ground-water collection. This restoration progress was a result of the ground-water collection for treatment or evaporation and was not significantly affected by the collection for re-injection program.

The collection of lightly to moderately contaminated water from the L area for re-injection in the hydraulic control area would have produced at worst a trivial increase in the volume of contaminated water in the control area, but resulted in a dramatic reduction in COC concentrations in the L area collection wells, and controlled the expansion of the L area plume. Given current treatment capacity, any increase in the volume of water within the hydraulic area requiring treatment would have required only a small increase in the time to restoration. Figure 1-2 presents the measured

[1] Prior to completion of the RO plant in 1999, all collected ground water was evaporated.

uranium concentration in L area collection wells L5 and L10 during the period when the program was utilized. The uranium concentrations have been reduced from several mg/l to slightly over the current Ground Water Protection Standard (GWPS) of 0.16 mg/l. The concentrations of other COCs have been similarly reduced. Thus, the collection for re-injection both greatly reduced the level of contamination in the L area plume, and controlled the volume of contaminated ground water that would ultimately require remediation.

As described in Section 3 of this report, the re-injection of ground water within the hydraulic control area did not measurably delay restoration progress. Both the collected contaminant mass and water volume collected for re-injection were small in comparison to the resident and ongoing mass/water exchanges within the hydraulic control area, so the overall impacts to restoration progress are generally negligible. Figure 1-3 presents a schematic illustrating the general hydraulic impacts of the re-injection within the hydraulic control area and also the potential benefit of the collection from within the hydraulic control area that occurred during the early years of the collection for re-injection program. As shown on Figure 1-3, additional collection (for re-injection) in the area of ongoing ground-water collection for treatment can have the minor benefit of strengthening the local gradient reversal. Simultaneously, the re-injection of water collected from within the hydraulic barrier can slightly increase the gradient driving impacted ground water to collection wells. This secondary benefit also occurs with the limited re-injection of ground water collected from outside of the hydraulic control area.

1.3 Summary

The evaluation of mass and/or water balance was performed for the general hydraulic control area and for the L area by two differing methodologies. The uranium mass and water volumes were estimated for the hydraulic control area using commercial surface analysis software, while the mass balance/removal analysis for the L area was performed with a Spatial Moments analysis similar to that used in the CAP.

1.3.1 Hydraulic Control Area

The resident COC mass and water volume within the hydraulic control area were evaluated using commercial surface analysis software (QUICKSURF), which can utilize mapping data to determine areas, volumes, masses and other quantities. QUICKSURF allows arithmetic operations to be performed on surfaces, in this instance allowing it to calculate quantities such as water volumes or COC mass using surfaces including the potentiometric surface, the elevation of the base of the alluvium, and the COC concentration. The mapping of alluvial aquifer water-level elevation and uranium concentration data included in annual reports served as the basis for this analysis, with surface data extracted from both individual well data points and interpreted contours. The evaluation used available data to calculate uranium mass and resident water volume in the alluvial aquifer within the hydraulic control area in five year intervals.

The volume and mass analysis for the hydraulic control area indicated a reduction of nearly 68,000 lbs in uranium mass in the alluvial aquifer between 1995 and 2015. During this same interval, the water volume in the alluvial aquifer increased significantly. While the reduction in resident mass in the alluvial aquifer is significant, the mass exchanges occurring over the same period were greater than the change in resident mass in the hydraulic control area. The major uranium mass removal of 343,710 lbs by the collection system is contrasted with an estimated uranium mass input of 198,990 lbs with seepage from the LTP and an estimated mass of 181,200 lbs within the vadose zone. These mass exchanges are dramatically larger than the mass transfer by L area collection (4,282 lbs) described in the following section.

1.3.2 L Area

The mass balance/removal analysis described in Section 4 of this report was used to estimate the quantity of uranium captured by the L area collection wells and transferred to within the hydraulic control area. The analysis confirmed that, when compared to the very large contaminant mass within and extracted from the control area and LTP, the contaminant mass transferred from the L area is trivially small. The capture of the slightly to moderately impacted ground water in the L area prevented the uncontrolled migration of a plume that was outside of the hydraulic control area. The major findings developed during this analysis follow.

- The collection from the L area prevented the continued migration of the contaminant plume which would have resulted in a greatly expanded volume of ground water requiring collection and treatment.
- The available RO treatment and evaporation capacity were fully utilized for processing ground water collected from within the control area while the collection for re-injection program was operating. This maximized the rate of contaminant removal from the ground water by treating more severely impacted water.
- The contaminant mass transferred from collection wells in the L area to re-injection wells near the LTP is a tiny fraction of the contaminant mass that has and continues to be extracted from within the hydraulic control area.
- Given the absence of sufficient treatment capacity to address both the hydraulic control area and the L area plume simultaneously, there were two alternatives in addition to the collection for re-injection program for addressing the ground-water contamination. Their benefits and impacts are:
    1. No collection for re-injection
        - The contaminant plume in the L area would continue to expand and it is estimated that more than three times the present ground water volume in the plume area would be impacted and require treatment
    2. Treating or evaporating the L area collection water
        - The rate of contaminant mass removal from the ground water would be reduced because the average COC concentrations in the RO treatment

feed stream or discharge to evaporation ponds would be reduced. This would ultimately delay ground-water restoration.

- Although this would avoid the direct transfer of contaminant mass from the L area into the control area, the quantity transferred is so small in comparison to the mass removed from or remaining in the control area that the transfer had at worst trivial effect on restoration progress.

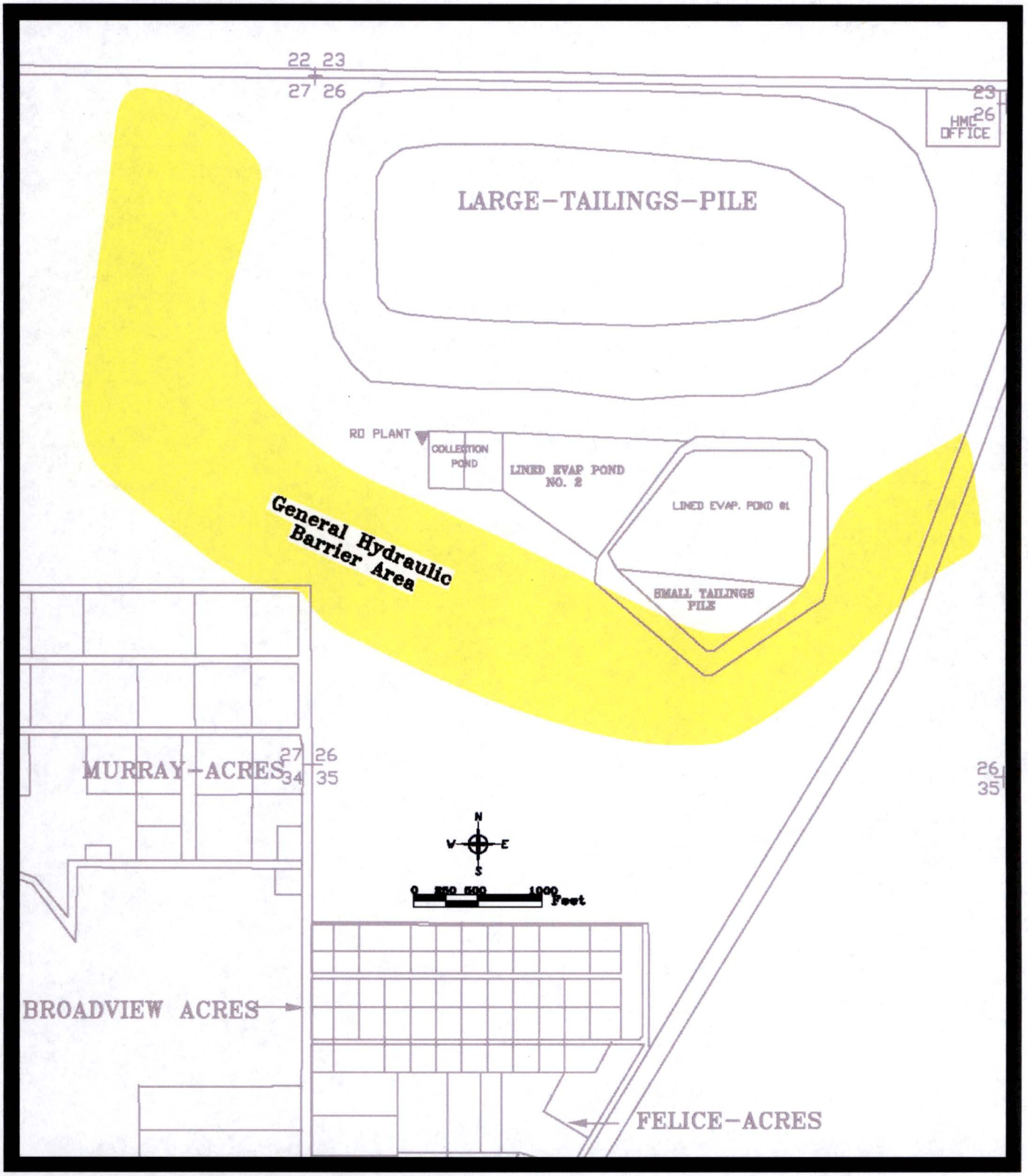

Figure 1-1. General Hydraulic Barrier Area

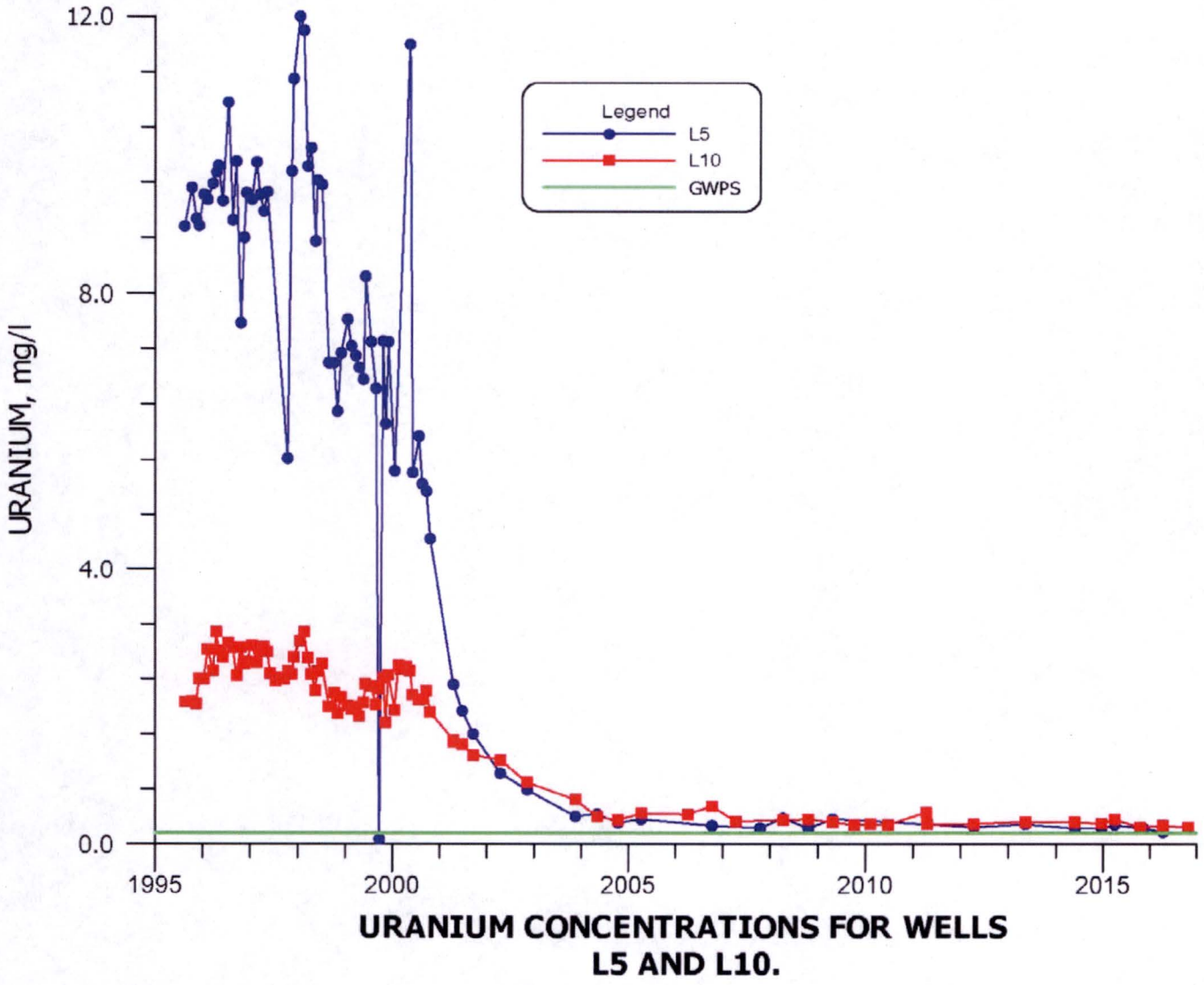

Figure 1-2. L Area Restoration Progress

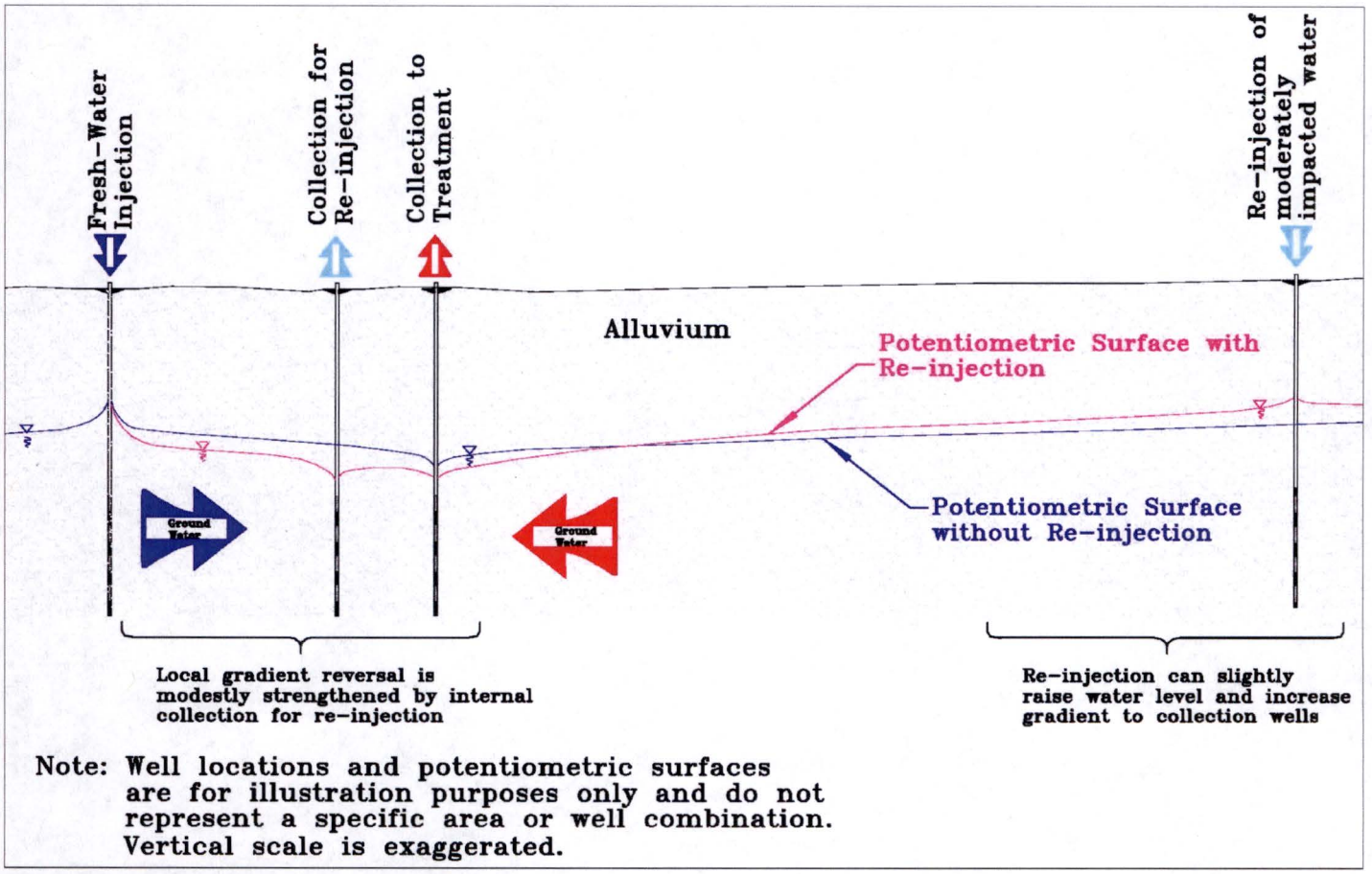

Figure 1-3. Collection for Re-injection Schematic

2. HISTORY AND COLLECTION AREAS

The collection for re-injection program began in 1995 and continued through July of 2016. The general collection areas are shown on Figure 2-1. During the first years of operation, collection occurred from the L area wells and wells located generally within the hydraulic control area. Of the groupings of wells shown on Figure 2-1, the S area, C area, K Line, and J area collection wells are located generally within the hydraulic control area, while the L Line and expanded L area collection wells are outside of the hydraulic control area.

The primary re-injection area was near the southern toe of the LTP as shown on Figure 2-1. During the early years of operation, re-injection occurred within the area shown on Figure 2-1 as well as some of the X-series of wells located on the eastern edge of the small tailings pile (STP) and in the general area of the HMC office. From 2002 through the end of the program, the only X-series wells used for re-injection were X11 and X12, which are near the southern toe of the LTP.

The collection from within the present hydraulic control area was used to increase local gradients and to drive more severely impacted ground water to collection wells that were discharged to the RO treatment system or the evaporation ponds. While this collection for re-injection from inside the hydraulic control area did not change the contaminant mass or water volume within the control area, it had the secondary benefit of slightly altering local gradients to make the other collection efforts more effective in removal of contaminant mass from the ground water. Because the collection for re-injection from inside the hydraulic control area did not introduce additional contaminant mass to the control area, it would not alter the restoration progress or scheduling, and is discussed primarily from a historical perspective in this report.

The collection from the L area wells was done to capture a contaminant plume that was located outside of the hydraulic control area (see Figure 2-1) and was largely successful as illustrated in Figure 1-2. The re-injection of L area collection water in selected LTP area wells did result in a very slight increase in the contaminant mass within the control area, but produced dramatic results in terms of reduced contamination within and control of the volume of the L area plume. Given current treatment capacity, the slight addition of contaminated collection water from L area wells would have required minimal additional time in terms of restoration of water quality within the hydraulic control area.

2.1 Collection Scheduling

The collection for re-injection began in 1995 at limited rates. Based on available annual reports, collection in L area wells has occurred since late 1995 and the collection for re-injection continued through July 2016. The collection from the C area wells continued through 1998 with collection from S area and K area wells continuing through 1999 and 2001, respectively. While the duration of the pumping for the C, K, and/or S wells was much shorter than that of the L area wells, a significant

part of the mass extraction from ground water by the collection for re-injection program occurred while one or more of the interior well groups were operating.

Only the collection from L area wells is considered in the mass removal analysis described in Section 4 of this report. Because much of the uranium mass capture by the collection for re-injection program occurred while C, K, and/or S collection wells were operating, only a portion of the total mass captured was transferred into the hydraulic control area from the L area wells

2.2 Collection Rates and Constituent Concentrations

Table 2-1 presents the yearly average collection rates for the wells supplying the re-injection program. The water quality data listed in Table 2-1 include uranium concentration which is used as the key indicator of water quality and restoration progress. With the largest collection rates from 1996 through 1999 coinciding with the largest uranium concentrations, the majority of the uranium mass extraction by the program occurred during a four year period. As will be described later in this report, much of the extracted mass was also transferred within the hydraulic barrier. The transfer of contaminant mass and ground water within the hydraulic control does not affect the general mass or water balance within the control area.

For the purposes of estimating water volume transferred to the hydraulic control area by collection from the L area, the L area collection rates from 1996 through 1999 were assumed to be 40 gpm and the rates in 2000 and 2001 were assumed to be 30 gpm. From 2002 through 2015, the L area collection rates are as listed in Table 2-1.

Table 2-1. Yearly Average Collection Rates and Water Quality Data for Re-injection Supply Wells Through 2015

Year	COLLECTION RATE (GPM)	Cl (mg/l)	SO4 (mg/l)	TDS (mg/l)	U (mg/l)	Mo (mg/l)	NO3 (mg/l)	Se (mg/l)
1995	27	164	789	2152	0.84	0.25	1.5	0.13
1996	60	323	1607	3580	5.16	8.55	4.4	1.13
1997	108	323	1654	3508	5.41	8.05	3.9	1.05
1998	95	283	1535	3351	5.92	7.78	4.2	0.90
1999	88	269	1416	3144	5.32	7.84	3.3	0.85
2000	40	219	887	2209	3.31	6.95	2.9	0.91
2001	41	177	670	1845	1.80	3.51	2.2	0.60
2002	40	215	654	1638	1.25	2.41	1.7	0.29
2003	40	143	522	1325	0.89	1.90	1.7	0.18
2004	39	114	420	1160	0.71	1.87	1.3	0.17
2005	34	203	499	1341	0.60	2.14	1.7	0.22
2006	53	118	444	1136	0.54	1.45	1.3	0.14
2007	42	145	403	1090	0.29	1.22	1.5	0.17
2008	43	91	368	955	0.38	1.00	1.1	0.10
2009	45	129	437	1142	0.35	1.16	1.4	0.14
2010	33	119	430	1108	0.43	1.14	1.1	0.11
2011	25	147	433	1129	0.30	0.74	1.2	0.11
2012	28	191	447	1198	0.41	1.68	1.1	0.18
2013	39	--	392	1114	0.33	1.40	1.1	0.11
2014	37	126	404	1155	0.33	0.63	1.2	0.09
2015	25	132	411	1113	0.27	0.38	1.6	0.07

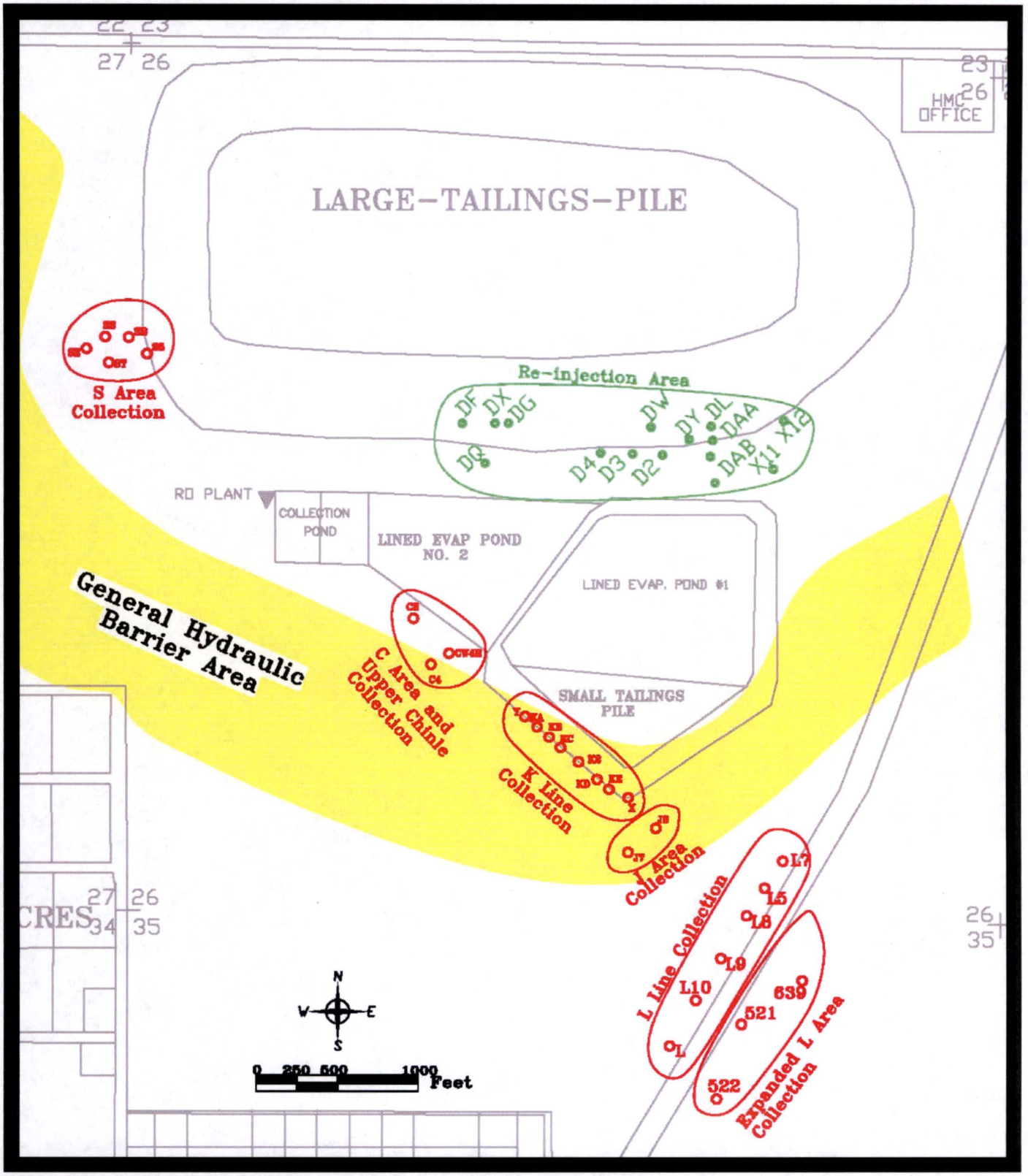

Figure 2-1. Collection for Re-Injection Program Areas

3. CONTROL AREA MASS BALANCE/EXCHANGE ANALYSIS

The evaluation of the resident mass within the hydraulic control area was performed using the QUICKSURF surface analysis software as described in Section 1.3.1. The surface analysis approach is similar to the Spatial Moments method used in the CAP in that it can be used to produce an estimate of uranium mass or water volume in a selected area at a specific time. The surface analysis approach is more versatile in that it can use more of the available water level or COC concentration data at the selected analysis time.

The surface analysis approach was used to evaluate the resident uranium mass and water volume within the hydraulic control area shown in Figure 3-1. This evaluation was performed for years 1995, 2000, 2005, 2010 and 2015 using data and mapping presented in annual reports corresponding to the respective years. Over the same interval (1995 through 2015), estimates were made of the exchanges of water volume and COC mass within the alluvial aquifer in the hydraulic control area.

The major uranium mass input to the alluvial aquifer in the hydraulic control area is from past and ongoing seepage from the LTP. The rate of seepage from the LTP and the COC concentration in the seepage is not affected by collection or injection activities within the alluvial aquifer. The seepage must also travel vertically through the partially saturated zone beneath the LTP to reach the alluvial aquifer and thus there is a delay in the arrival of seepage water and COC mass to the alluvial aquifer. Because the seepage from the LTP has occurred over several decades, there was also a large COC mass within the partially saturated zone that resulted from LTP seepage prior to 1995. Both the COC mass from the 1995 through 2015 LTP seepage and the COC mass moving through the partially saturated zone of the same time period represent major inputs to the alluvial aquifer. The LTP seepage rates and uranium concentrations were estimated using available data prior to 2000, and the Reformulated Mixing Model results from 2000 through 2015. A memorandum with an overview of the Reformulated Mixing Model is attached to this report.

An estimate of the uranium mass and drainable water volume in the partially saturated zone beneath the LTP was made using measured COC concentrations within the tailings and other historical operational information. Uranium concentrations approaching and exceeding 100 mg/l have been measured in tailings wells, toe drain discharge and alluvial aquifer wells near the LTP. These relatively large uranium concentrations are considered representative of those in past LTP seepage prior to the tailings flushing program and other activities that reduced LTP uranium concentrations. During operations, a relatively high water level would be maintained in the tailings and there would be a correspondingly high seepage rate and volume of drainable water within the partially saturated zone. The seepage rate would decline with a lowering of the water level within the tailings, but there would be some lag in the drainage of water from the partially saturated zone. These factors were considered in estimating the drainable water volume (10 % of total volume) and uranium concentration (70 mg/l) in the partially saturated zone in 1995.

3.1 Mass Balance/Exchange Analysis

The procedure described in the following listing was used in evaluating the mass balance and exchange occurring within the hydraulic control area designated in Figure 3-1. The water and uranium sources contributing to the hydraulic control area were then evaluated to compare with the contributions of the collection for re-injection program.

- The area of interest for the evaluation was defined as the hydraulic control area as presented in Figure 3-1.
- Potentiometric surfaces were developed for 1995 through 2015 in five year increments using annual reports and available data. The water-level elevation contour mapping for selected years of 1995, 2005 and 2015 is presented in Figures 3-2, 3-4 and 3-6, respectively. The contour mapping for only three of the five evaluation periods is presented in the figures in the interest of brevity and does not affect the conclusions.
- The saturated thickness for each of the five evaluation periods (1995, 2000, 2005, 2010, and 2015) was calculated by subtracting the base of alluvium elevation from the water-level elevation using QUICKSURF.
- The saturated volume in the area of interest was calculated as the sum of the saturated thickness over the hydraulic control area using QUICKSURF. This volume is tabulated as the bulk saturated volume in Table 3-1 along with an estimated alluvial water volume in gallons using an effective porosity of 0.20.
- Uranium concentration surfaces were developed for 1995 through 2015 in five year increments using annual reports and available data. The uranium concentration contour mapping for selected years of 1995, 2005 and 2015 is presented in Figures 3-3, 3-5 and 3-7, respectively.
- The uranium mass surface (in units of mg/l $*ft^3$) was calculated as the product of the saturated thickness surface and the uranium concentration surface for each of the five evaluation periods (1995, 2000, 2005, 2010, and 2015) using QUICKSURF.
- The uranium mass in the area of interest was calculated as the sum of the uranium mass surface over the hydraulic control area using QUICKSURF. This volume is tabulated as the bulk uranium mass in Table 3-1 along with a conversion to estimated mass in kg and lb.
- Additional calculations were performed using the QUICKSURF generated volumes and masses and those calculations are described as follows.
    - The water volume change between each of the successive evaluation intervals was calculated (see Table 3-1). This was also converted to an equivalent rate, which ranged from 28 to 65 gpm of increase in water volume over the 20 year evaluation period.
    - The uranium mass change between each of the successive evaluation intervals was calculated (see Table 3-1). With the exception of the 2010 through 2015 interval, the uranium mass in the hydraulic control area decreased significantly. The increase in uranium mass between 2010 and 2015 likely occurred as a result of increased seepage rates from the LTP and/or the arrival of uranium mass that was moving through the partially saturated zone above the alluvial aquifer.
    - An average uranium concentration for the hydraulic control area was calculated for each of the five evaluation intervals. The average uranium concentration consistently declines from 1995 through 2015

- The contribution of both water and uranium mass by the tailings was estimated using estimated seepage rates and uranium concentrations in the seepage from the tailings. For the period from 2000 through 2015, these estimated rates and concentrations were taken from the Reformulated Mixing model. These rates, along with measured uranium concentrations in the tailings after 2006, are presented in Table 3-2.
- The exchange rates for water in the alluvial aquifer were estimated using data from the annual reports and the preceding analyses. These exchange rates are presented graphically in Figure 3-8. A brief description of the various water exchange rates presented in Figure 3-8 follows.
    - The largest water input rate to the alluvial aquifer is the fresh-water injection rate (red line and symbols). A portion of this injection rate is captured within the hydraulic control area while the remainder flows outward from the hydraulic control area to the south and west.
    - The RO product injection is the second largest water input to the alluvial aquifer.
    - The estimated seepage rate from the tailings is a significant contribution of both water and uranium mass to the alluvial aquifer.
    - The natural alluvial aquifer flow rate through the area is estimated as 60 gpm (orange symbols and line).
    - The alluvial collection rate is the largest water extraction rate from the alluvial aquifer. This ground water is treated (or evaporated prior to 1999) and the product is injected.
    - Between 1995 and 2015, the saturated volume within the hydraulic control area increased, but as shown in Figure 3-8, the rate of increase was very small in contrast to the inputs from fresh and RO product injection as well as the seepage from the LTP.
    - The collection for re-injection from the L area is at a rate that is very small in comparison to other water inputs to the alluvial aquifer. The collection for re-injection from within the hydraulic control area would not affect the internal water balance and is not reflected in Figure 3-8.
- The estimated uranium mass in the vadose zone directly beneath the LTP footprint in 1995 was roughly estimated using the volume between the base of the tailings and the alluvial aquifer water-level elevation, a drainable water fraction of 0.10, and a uranium concentration of 70 mg/l. This calculation resulted in an estimated uranium mass of slightly over 180,000 lbs in the vadose zone beneath the LTP. The majority of this mass had likely reported to the alluvial aquifer by 2015.
- A comparison of resident and mass exchanges is presented in Table 3-3. This tabulation indicates that the mass transferred into the hydraulic control area by L area collection is very small in contrast to the mass exchanges occurring from 1995 through 2015.

Table 3-1. Hydraulic Control Area Mass/Volume Summary

Year	Bulk Saturated Volume	Estimated Alluvial Water Volume	Water Volume Change	Water Volume Change Rate	Bulk Uranium Mass	Average Uranium Concentration	Estimated Uranium Mass	Estimated Uranium Mass	Uranium Mass Change
	(ft^3)	(gallon)	(gallon)	(gpm)	(mg/l * ft^3)	(mg/l)	(kg)	(lb)	(lb)
1995	640,511,163	958,204,700			1.33E+10	20.76	75,312	166,033	
			74,238,825	28					-4,557
2000	690,136,046	1,032,443,525			1.29E+10	18.75	73,245	161,476	
			170,960,286	65					-50,318
2005	804,414,312	1,203,403,811			9.01E+09	11.21	50,421	111,158	
			93,413,732	36					-21,651
2010	866,856,646	1,296,817,542			7.17E+09	8.27	40,600	89,507	
			154,204,354	59					8,982
2015	969,934,423	1,451,021,897			7.89E+09	8.13	44,674	98,488	

Table 3-2. Estimated Volume and Mass Transfer in LTP Seepage

Year	Estimated LTP Seepage Rate	Est. Uranium Concentration	Measured LTP Uranium Conc.	Uranium Mass in Seepage	Uranium Mass in Seepage
	(gpm)	(mg/L)	(mg/L)	(kg)	(lb)
1995	60	70		8362	18435
1996	55	65		7118	15692
1997	50	60		5973	13168
1998	42	55		4599	10139
1999	38	50		3783	8340
2000	54.9	39.38		4304	9488
2001	40.4	38.14		3066	6760
2002	62.5	30.46		3789	8353
2003	151.1	21.93		6598	14545
2004	201.0	20.62		8252	18193
2005	186.6	19.44		7222	15921
2006	141.8	17.79	12.28	5021	11069
2007	141.8	14.71	11.70	4152	9153
2008	138.1	12.70	9.41	3492	7698
2009	183.9	9.98	8.45	3653	8053
2010	178.2	8.45	8.07	2997	6606
2011	149.6	7.82	7.09	2330	5136
2012	136.5	6.52	6.54	1772	3907
2013	127.9	5.42	5.92	1381	3045
2014	129.7	4.60	5.69	1189	2620
2015	170.1	3.57	5.34	1211	2669

Blue seepage rates estimated using toe drain rates.

Red seepage rates and uranium concentrations estimated by Reformulated Mixing Model.

Table 3-3. Uranium Mass and Exchange Comparison

Uranium Source or Exchange 1995 through 2015	Estimated Uranium Mass
	(lb)
Uranium mass in hydraulic control area	89,507 to 166,033
Uranium in seepage from LTP	198,990
Uranium in ground-water collection	343,710
Uranium in vadose zone below LTP (est. for 1995)	181,200
Uranium extracted by L area collection	4,282

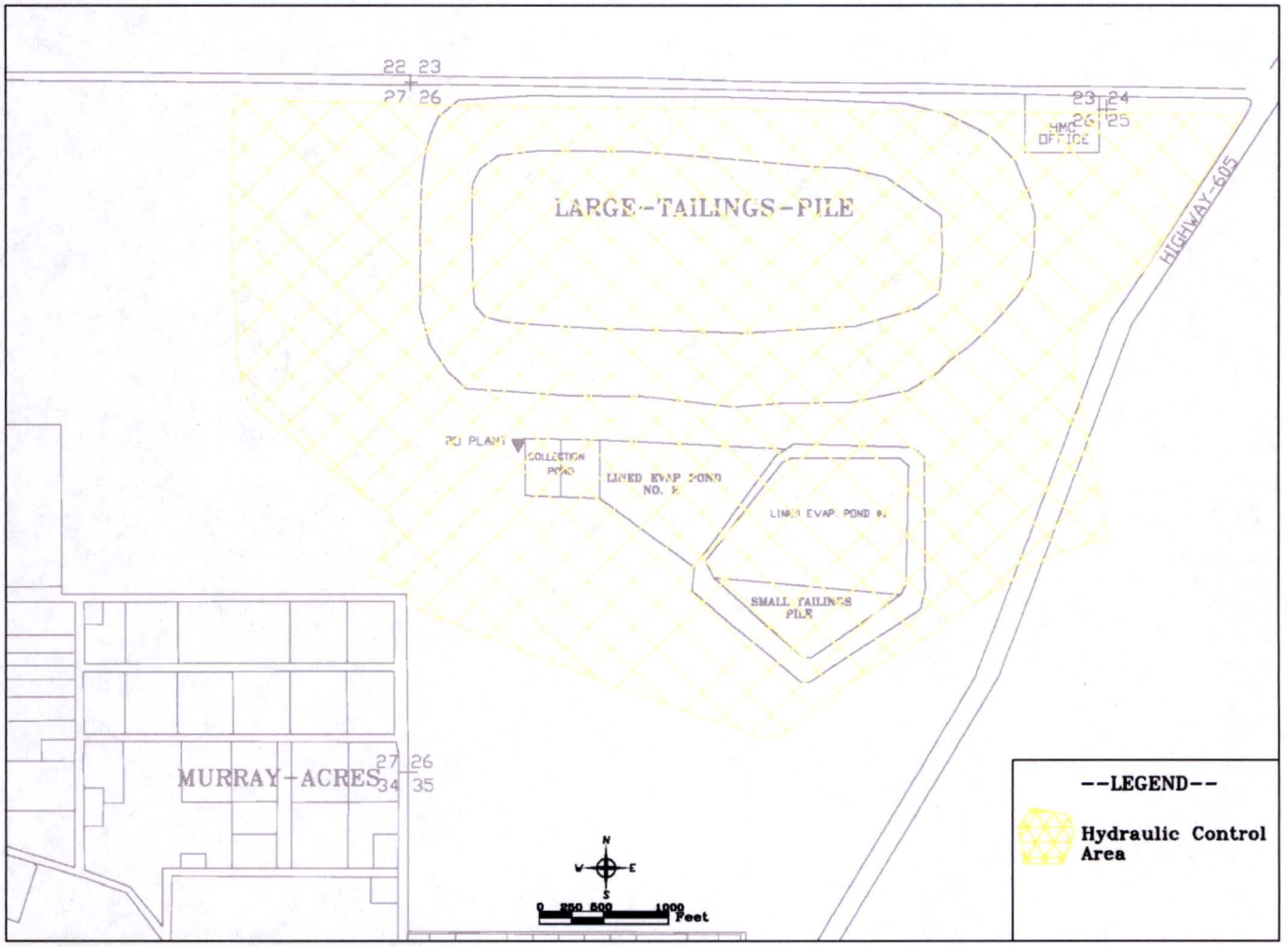

Figure 3-1. Hydraulic Control Area

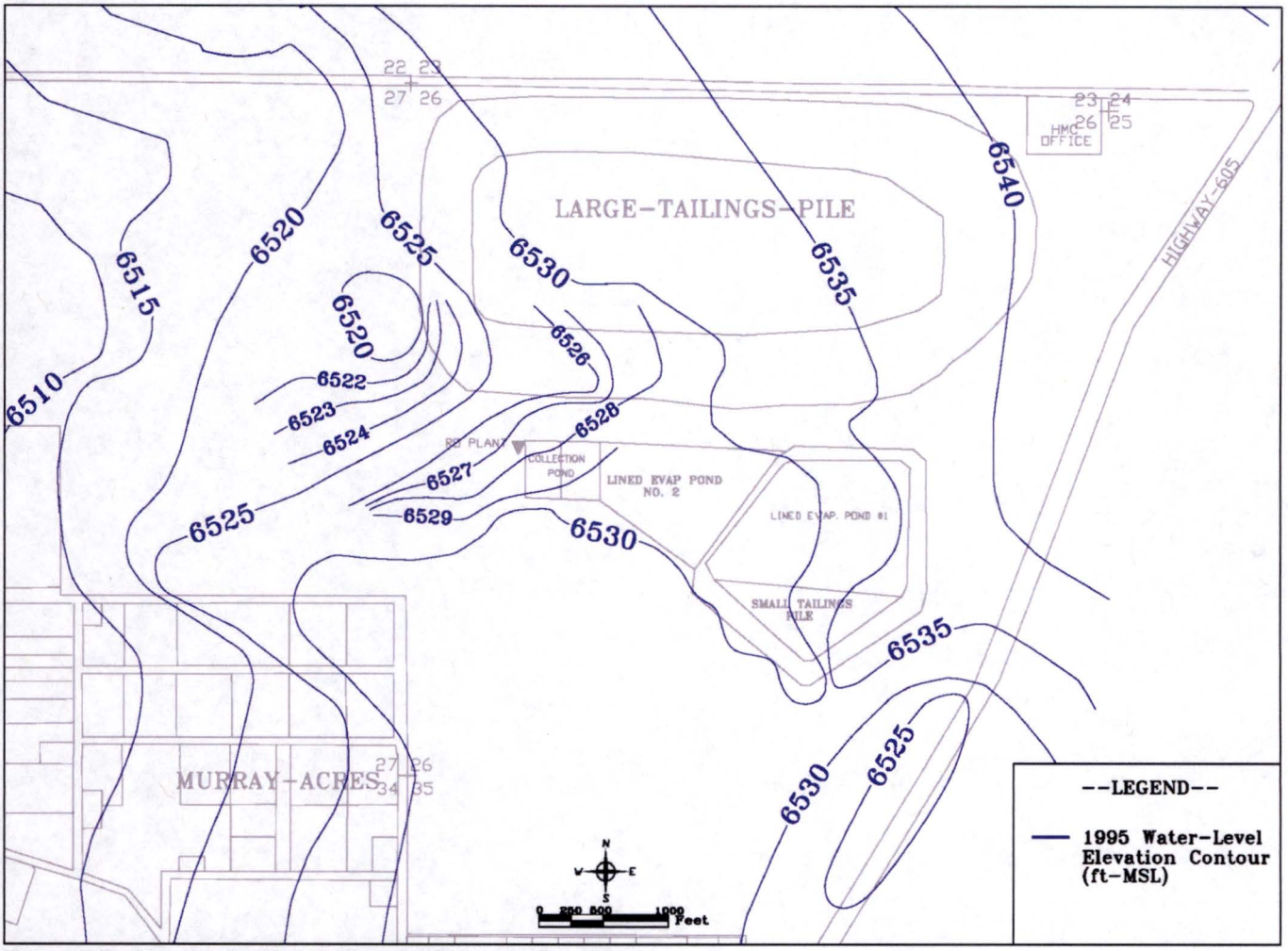

Figure 3-2. Alluvial Aquifer Water-Level Elevation in 1995

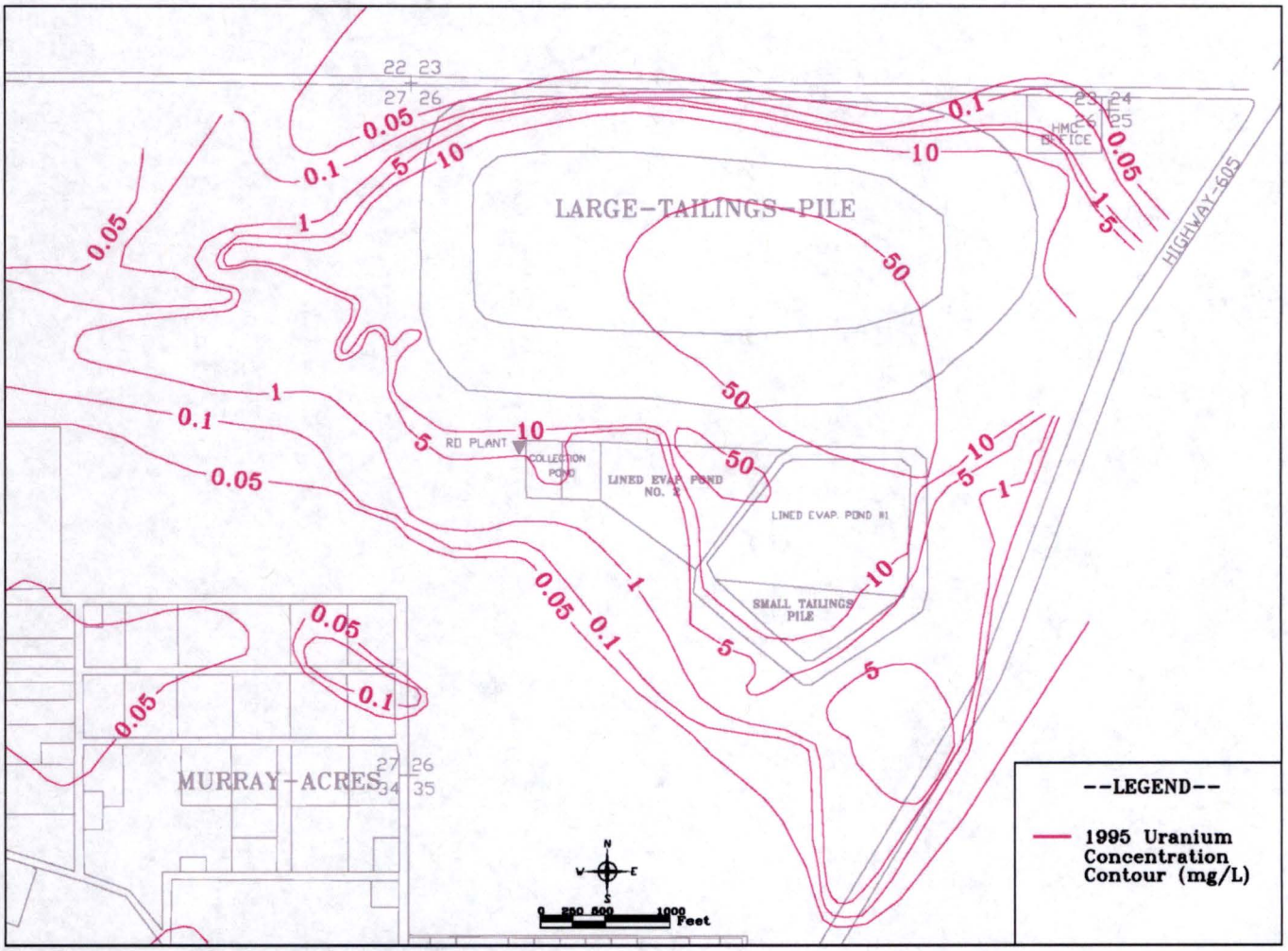

Figure 3-3. Alluvial Aquifer Uranium Concentration in 1995

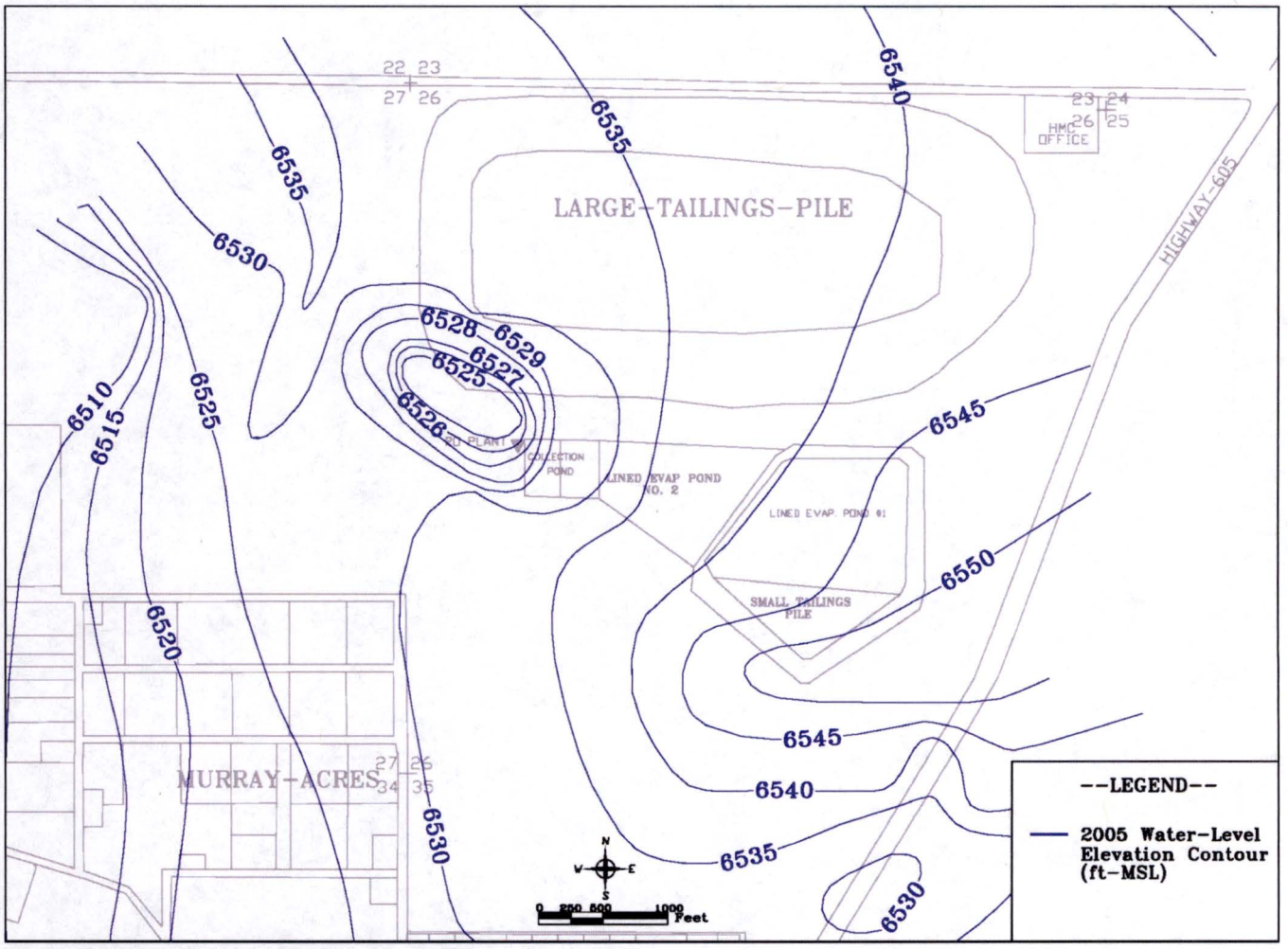

Figure 3-4. Alluvial Aquifer Water-Level Elevation in 2005

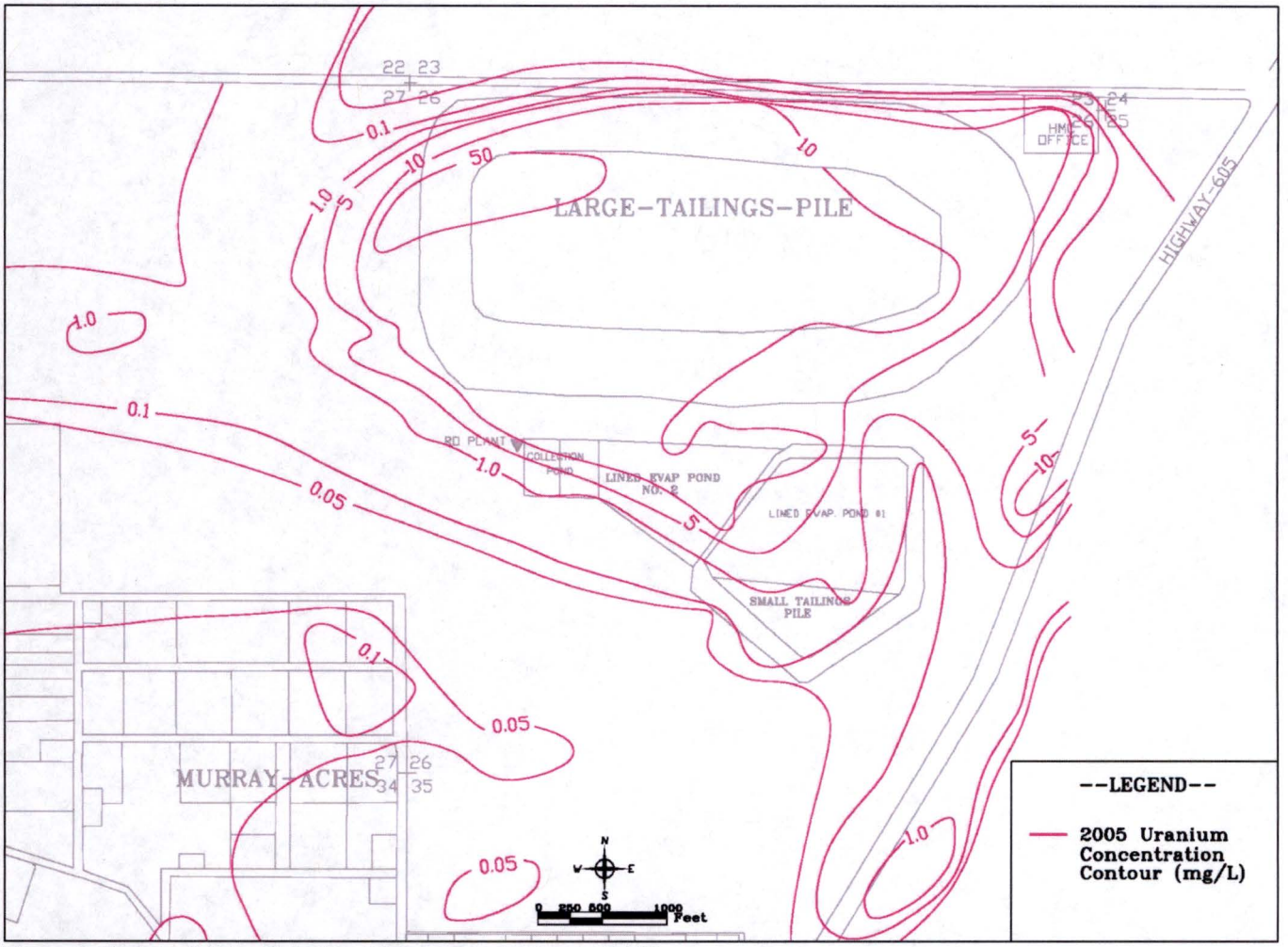

Figure 3-5. Alluvial Aquifer Uranium Concentration in 2005

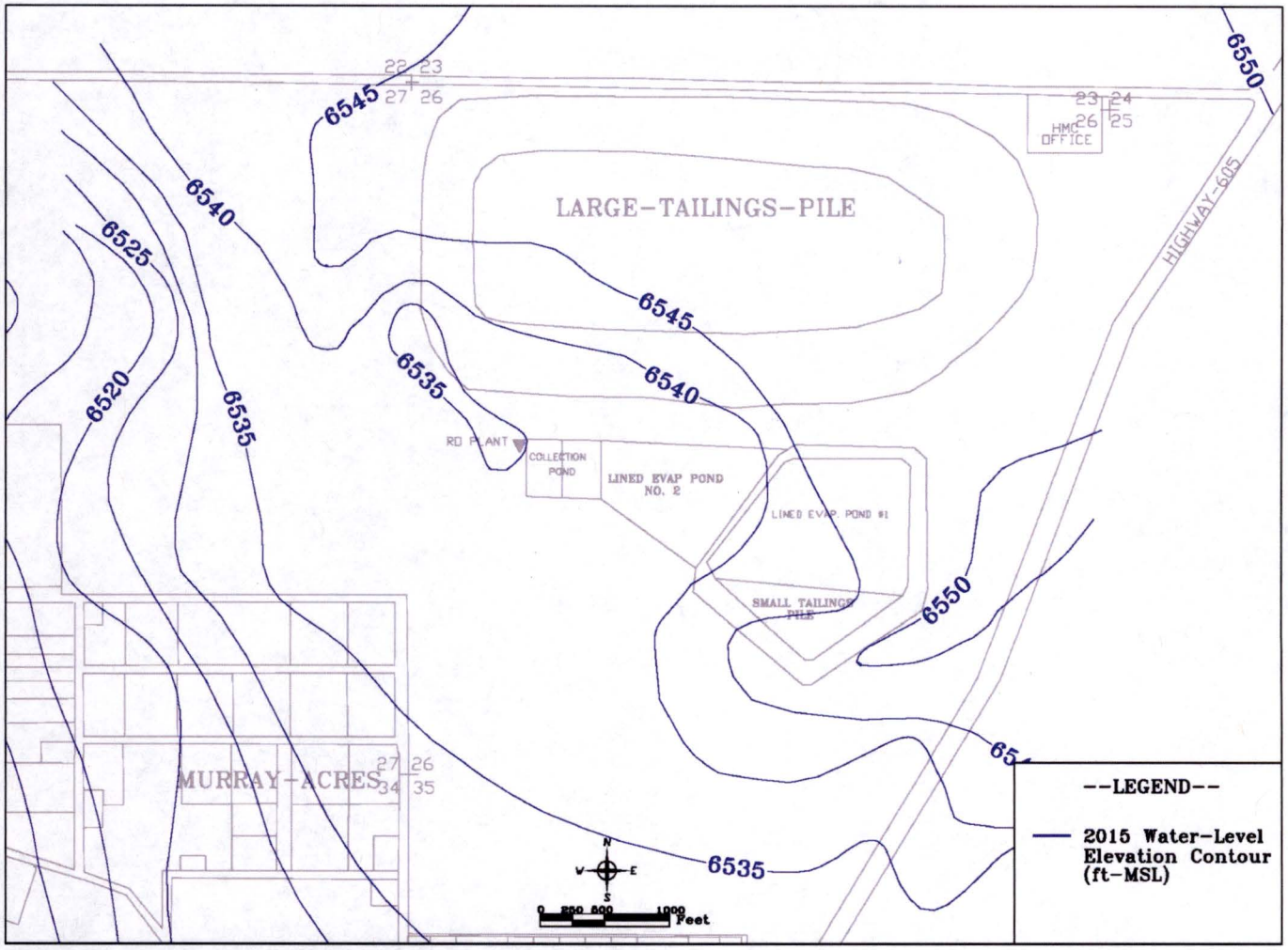

Figure 3-6. Alluvial Aquifer Water-Level Elevation in 2015

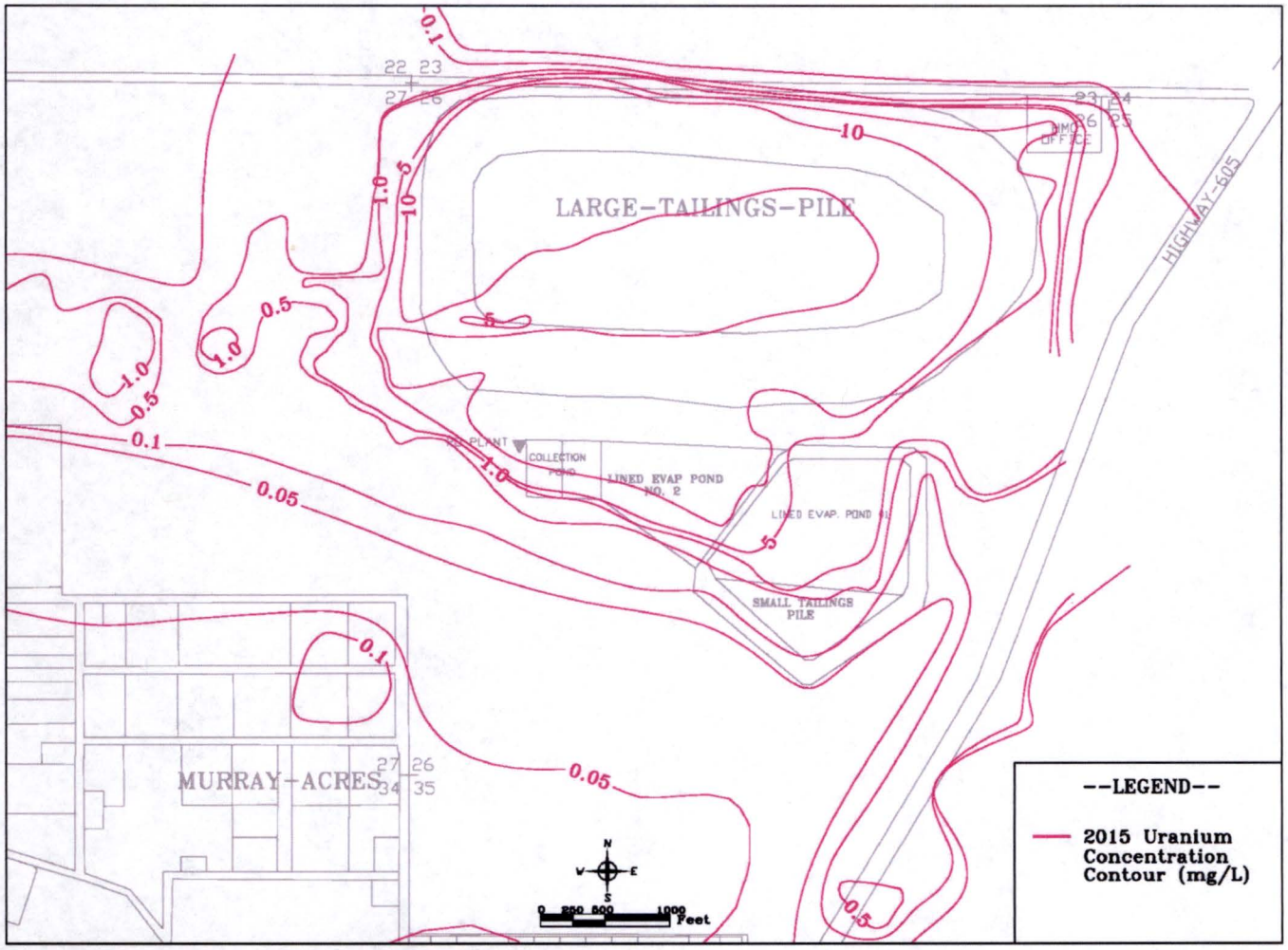

Figure 3-7. Alluvial Aquifer Uranium Concentration in 2015

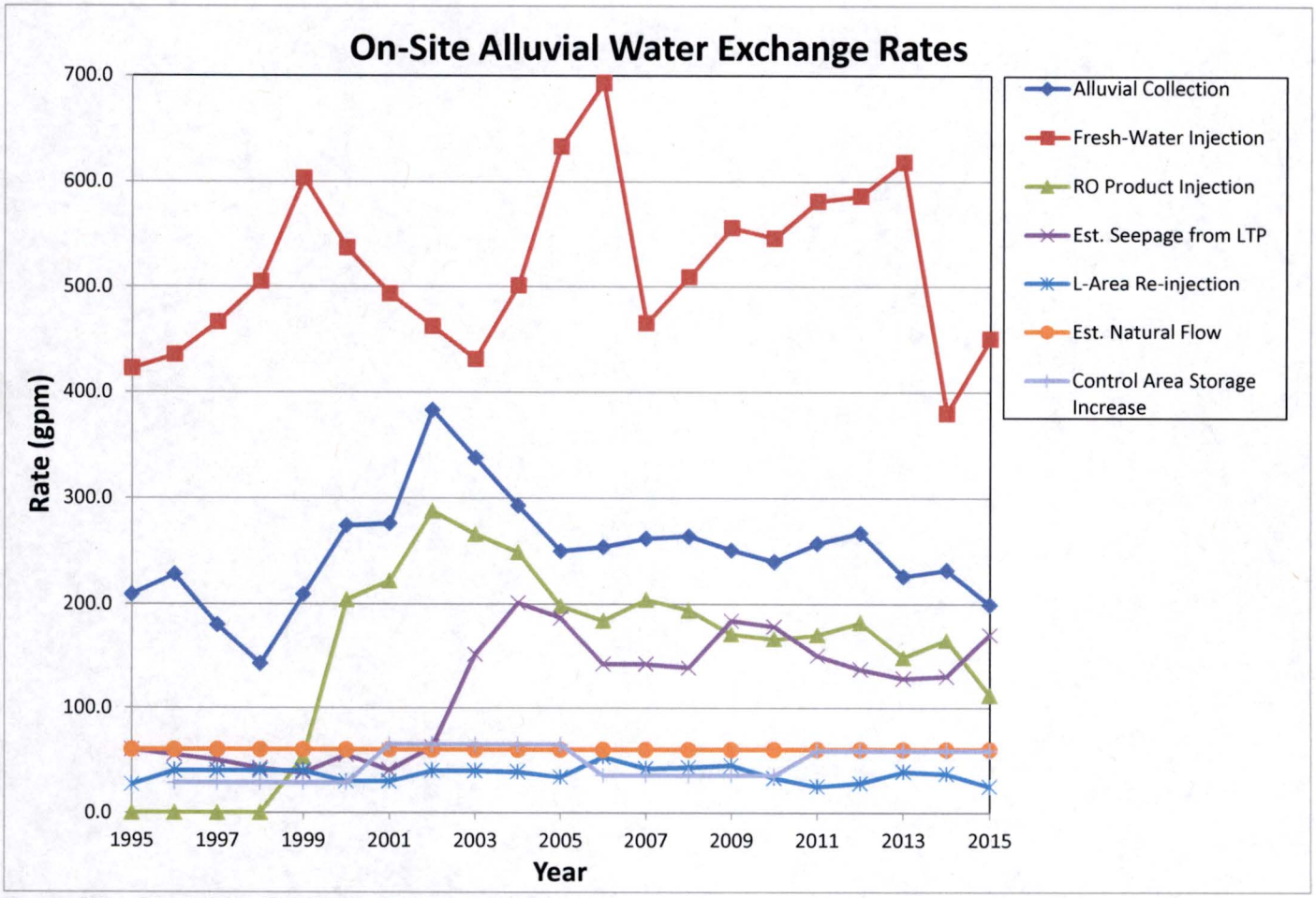

Figure 3-8. Alluvial Aquifer Water Exchange Rates

4. L AREA MASS BALANCE/REMOVAL ANALYSIS

The mass balance/removal analysis for the L area was conducted using the methodology described in the 2012 CAP submittal. This method is essentially a Spatial Moments analysis using a record of water quality data from selected wells to perform a mass balance accounting over a defined interval. Thiessen polygons were used to define the region of influence for each of the selected well locations.

The utility of the method is subject to the number and location of wells used in the analysis and the completeness of the water quality record for the wells. In this mass removal analysis, uranium is used as the key indicator constituent to evaluate the collection for re-injection program.

4.1 Methodology

As described in the 2012 CAP submittal, the zeroth spatial moment (M_o) represents the total solute mass in the dissolved-phased plume, and is calculated by:

$$M_o = \sum_{i=1}^{N} b_i \, A_i C_i \Phi_i(x, y)$$

where b_i is the aquifer thickness, A_i is the area associated with each well, C_i is the measured concentration at each well and Φ_i is the effective porosity at each well or sampling location. A constant value of 0.20 was used for Φ in the analysis.

4.2 Selection of Wells

The twelve wells selected for the mass removal analysis in the L area are L, L5, L6, L7, L8, L9, L10, 521, 522, 639, 1M and 1K. The wells were selected based upon distribution over the area of interest (see Figure 4-1) and the available water quality record. Each of the twelve wells falls within the area where impacted alluvial ground water was present during collection for re-injection. Wells 1K, 1M and L6 cover an area where the ground water impacted by seepage from the LTP would move to the south and would largely be captured by the L area collection.

4.3 Polygon and Grid System Analysis

A boundary was drawn around the general plume area surrounding the L area collection system and is shown as the outer boundary around the twelve wells shown with magenta symbols and text in Figure 4-1. A grid-based adaptation of the Thiessen polygon method was then used to further subdivide the area according to the well representing the individual polygons.

As shown in Figure 4-2, a 50 foot by 50 foot grid was overlaid in the area of interest. Each cell in the grid was then assigned to the closest well, and the cells representing a particular well were

assembled to form the polygon representing that well. Figure 4-3 presents the polygon and grid system in the area of the operating collection wells.

A saturated thickness was then determined for each cell using a recent mapping of saturated thickness with an AUTOCAD® based surface and a surface/volume analysis program (QUICKSURF) described previously. The alluvial potentiometric surface in the area included in the analysis is generally stabilized by continuing injection and collection operations and the changes in saturated thickness are relatively small. Therefore, the use of a constant saturated thickness for each cell over the period of analysis is appropriate and does not significantly affect the analysis. The fixed area of each cell (2500 square feet) was then multiplied by the saturated thickness and the cells within each polygon were then composited to define a saturated volume for each well.

4.4 Uranium Concentration in L Area

The period of analysis from 1996 through 2015 was selected to span as much of the collection for re-injection program as possible. The available water quality data were reviewed and assembled as yearly average measured concentration. When multiple samples were taken in a single year, a simple average of the sample results was used. As noted previously, the available record of water quality can be somewhat limiting in using the Spatial Moments approach. The sampling record for some of the wells does not span the period of interest and it was necessary to interpolate missing annual sample concentrations as well as extrapolate concentrations from the first or last available sample data.

The measured uranium concentrations in each of the selected wells are presented in Table 4-1. The red text in Table 4-1 indicates the values were interpolated or extrapolated from the nearest available measured concentration(s) in the table for each well. The blue text in Table 4-1 indicates the values were taken from a nearby well. The number of cells within the polygon representing each well and the composite saturated volume for each polygon are also included in Table 4-1.

4.5 Mass Balance/Removal

The yearly average concentrations presented in Table 4-1 were multiplied by the composite saturated volume in each polygon and the effective porosity of 0.2 to calculate the estimated mass of uranium in kilogram (kg) within the polygon representing each well. This value of porosity was used in the 2012 CAP analysis and the ground-water modeling. A sum of the mass for all of the polygons in each year is listed at the bottom of Table 4-2 in units of both pounds and kg. As expected, the total estimated uranium mass in the area is greatest before year 2000 with a gradual decline in mass through 2015. The uranium mass estimates in 1996 and 1997 are significantly lower than that of 1998, which illustrates the limitations of performing a mass balance calculation with a small number of wells and incomplete data for the entire period of interest.

Table 4-1. Uranium Concentrations and Polygon Characteristics for Selected Wells

Well Name	No. of Polygon Cells	Composite Saturated Volume (ft^3)	Uranium Concentration in Year (mg/l)																			
			1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
L	82	3,675,987	2.42	2.14	1.98	1.75	1.53	1.73	1.55	1.18	0.73	0.69	0.66	0.43	0.77	0.51	0.69	0.59	0.40	0.51	0.46	0.50	0.38
L5	63	1,944,308	8.62	9.22	8.84	6.55	6.18	1.95	0.91	0.40	0.37	0.36	0.27	0.23	0.30	0.36	0.32	0.28	0.24	0.28	0.23	0.25	0.17
L6	174	4,052,879	2.99	2.70	3.05	3.36	3.44	1.20	0.47	0.38	0.31	0.22	0.14	0.17	0.17	0.19	0.19	0.18	0.18	0.26	0.27	0.24	0.23
L7	122	3,331,662	7.08	3.67	3.73	3.79	3.85	2.19	0.94	0.49	0.41	0.27	0.30	0.22	0.21	0.22	0.18	0.17	0.16	0.21	0.25	0.28	0.26
L8	71	2,396,332	5.73	5.52	5.80	5.28	3.71	1.40	0.70	0.39	0.28	0.22	0.10	0.21	0.20	0.18	0.19	0.21	0.17	0.19	0.17	0.20	0.31
L9	88	3,295,154	3.78	4.07	3.78	3.08	3.06	1.44	0.74	0.40	0.30	0.24	0.21	0.23	0.25	0.20	0.15	0.23	0.35	0.29	0.26	0.24	0.21
L10	78	3,259,729	2.53	2.62	2.40	2.12	2.27	1.43	1.06	0.64	0.37	0.45	0.49	0.32	0.35	0.30	0.28	0.37	0.29	0.32	0.31	0.30	0.25
521	71	2,395,300	1.06	1.06	1.06	1.06	1.06	1.06	2.47	1.33	1.23	1.02	1.02	0.71	0.62	0.54	0.58	0.64	0.70	0.70	0.70	0.70	0.70
522	37	1,465,842	0.52	0.52	0.52	0.52	0.52	0.52	0.52	1.21	1.39	0.67	1.01	1.10	1.19	0.43	0.87	0.31	0.57	0.51	0.79	0.79	0.79
639	83	2,127,240	1.09	1.09	1.09	1.09	1.09	1.09	2.54	1.92	1.70	1.30	0.78	0.03	0.29	0.54	0.41	0.15	0.66	0.66	0.66	0.66	0.66
1K	143	3,061,968	5.78	10.1	43.5	22.7	12.6	2.58	2.12	3.61	2.39	1.47	1.62	1.85	7.65	6.16	4.66	3.17	1.67	1.46	1.24	1.03	0.81
1M	131	2,755,939	0.05	0.28	0.4	0.54	0.43	0.43	0.11	0.11	0.12	0.14	0.16	0.18	0.01	0.05	0.08	0.11	0.13	0.14	0.15	0.17	0.18

Red concentration values are interpolated or extrapolated from available data.
Blue concentration values are estimated from data for a nearby well.

Table 4-2. Estimated Uranium Mass for Each Year in Polygons for Selected Wells

Well Name	No. of Polygon Cells	Composite Saturated Volume (ft^3)	Uranium Mass in Year (kg)																			
			1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
L	82	3,675,987	50	45	41	36	32	36	32	25	15	14	14	9	16	11	14	12	8	11	10	10	8
L5	63	1,944,308	95	102	97	72	68	21	10	4	4	4	3	3	3	4	4	3	3	3	2	3	2
L6	174	4,052,879	69	62	70	77	79	28	11	9	7	5	3	4	4	4	4	4	4	6	6	5	5
L7	122	3,331,662	134	69	70	71	73	41	18	9	8	5	6	4	4	4	3	3	3	4	5	5	5
L8	71	2,396,332	78	75	79	72	50	19	9	5	4	3	1	3	3	2	3	3	2	3	2	3	4
L9	88	3,295,154	70	76	71	57	57	27	14	7	6	4	4	4	5	4	3	4	7	5	5	4	4
L10	78	3,259,729	47	48	44	39	42	26	20	12	7	8	9	6	7	5	5	7	5	6	6	6	5
521	71	2,395,300	14	14	14	14	14	14	34	18	17	14	14	10	8	7	8	9	9	9	9	9	9
522	37	1,465,842	4	4	4	4	4	4	4	10	12	6	8	9	10	4	7	3	5	4	7	7	7
639	83	2,127,240	13	13	13	13	13	13	31	23	20	16	9	0	3	7	5	2	8	8	8	8	8
1K	143	3,061,968	100	175	754	394	218	45	37	63	41	25	28	32	133	107	81	55	29	25	22	18	14
1M	131	2,755,939	1	4	6	8	7	7	2	2	2	2	3	3	0	1	1	2	2	2	2	3	3
		Sum (kg)	675	688	1265	859	658	282	220	187	142	107	102	87	196	160	138	107	85	87	84	81	73
		Sum (lb)	1485	1513	2782	1890	1447	620	485	412	313	235	224	191	431	351	304	235	188	191	184	178	162

The summations in Table 4-2 show a consistent reduction in uranium mass in the L area from 1998 through 2007. During this period, the mass balance approach is producing reasonably reliable estimates of uranium mass in the L area. In 2008, there was an abrupt increase in uranium concentration in well 1K to 7.35 mg/l (see Table 4-1) with the next sample taken in 2012 having a uranium concentration of 1.67 mg/l. The large concentration sample result is considered anomalous, but it was not rejected because it was within the range of historic measured concentrations for well 1K. The single 2008 sample concentration in well 1K, when used in interpolating estimated uranium concentrations for 2009, 2010 and 2011, caused an increase in total uranium mass between 2007 and 2008 with a gradual reduction through 2012. This again illustrates the limitations of performing this analysis with a relatively small number of wells and corresponding sample results when a single unusual or anomalous sample result can exert undue influence on the results of the evaluation. After 2013, there was a consistent reduction in estimates of total uranium mass in the L area.

Despite the irregularities in the mass balance introduced by the 2008 sample in well 1K and the likely unrepresentative results for 1996 and 1997, the overall reduction of uranium mass in the L area is consistent with expectations. Using the difference between the estimated uranium mass of 2,782 lb in 1998 and 178 lb in 2015, the mass removed from the L area through 2015 is 2,604 lbs. Because the L area collection wells were operated in 1996 and 1997, the actual mass removed is very likely greater than the estimated 2,604 lbs.

The mass removed from the L area during 1996 and 1997 can be roughly estimated using an assumed collection rate of approximately 40 gpm with uniform collection rates from collection wells L, L5, L7, L8, L9 and L10. The average uranium concentration in these six wells was 5.02 mg/l in 1996 and 4.54 mg/l in 1997. Using these assumptions, the estimate of uranium extraction by L area collection during 1996 and 1997 is 881 lbs and 797 lbs, respectively. Combined with the 2,604 lbs estimated by the mass removal analysis, the total estimated mass removed through 2015 would be 4,282 lbs.

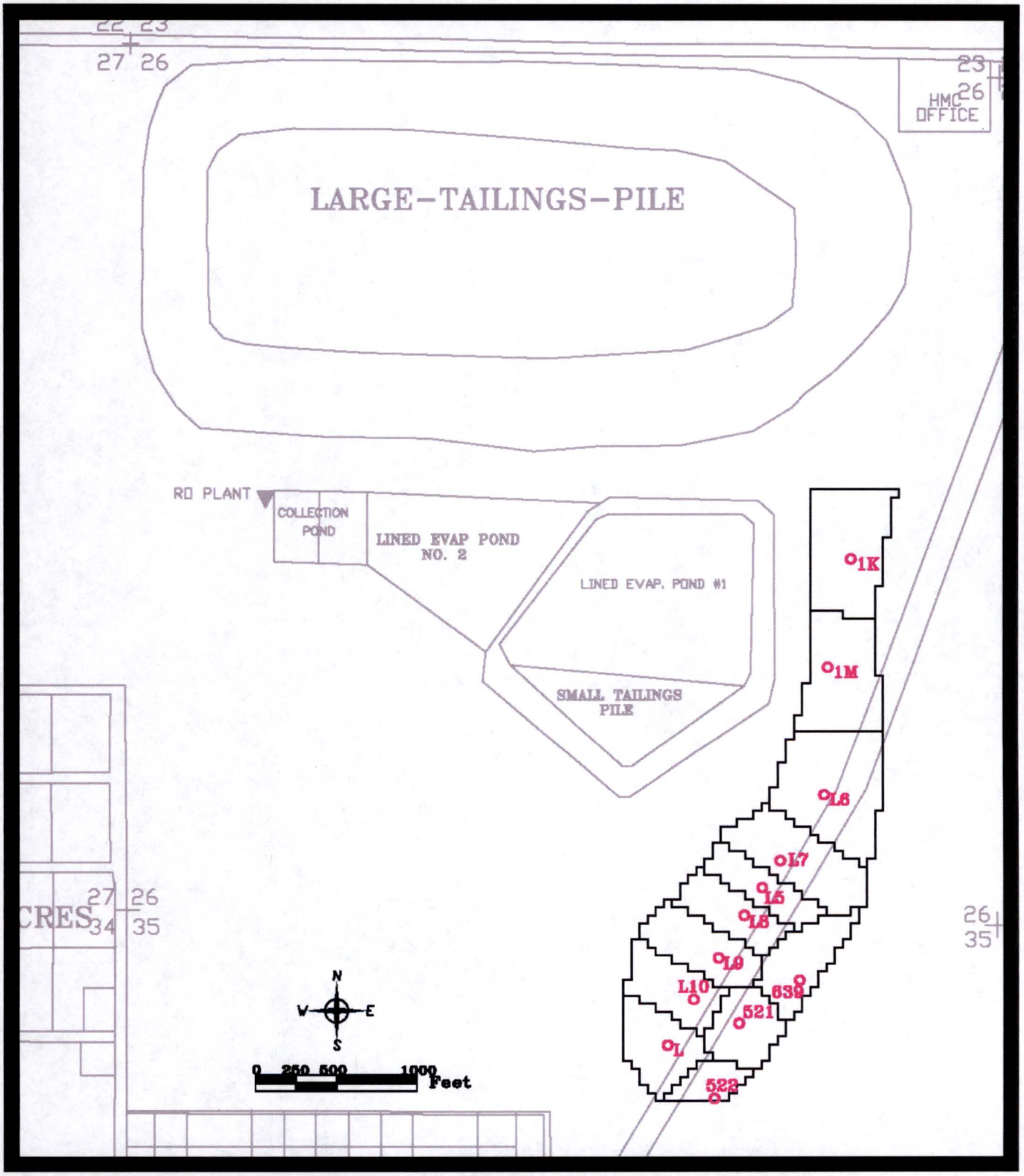

Figure 4-1. Selected L Area Analysis Wells and Polygon Boundaries

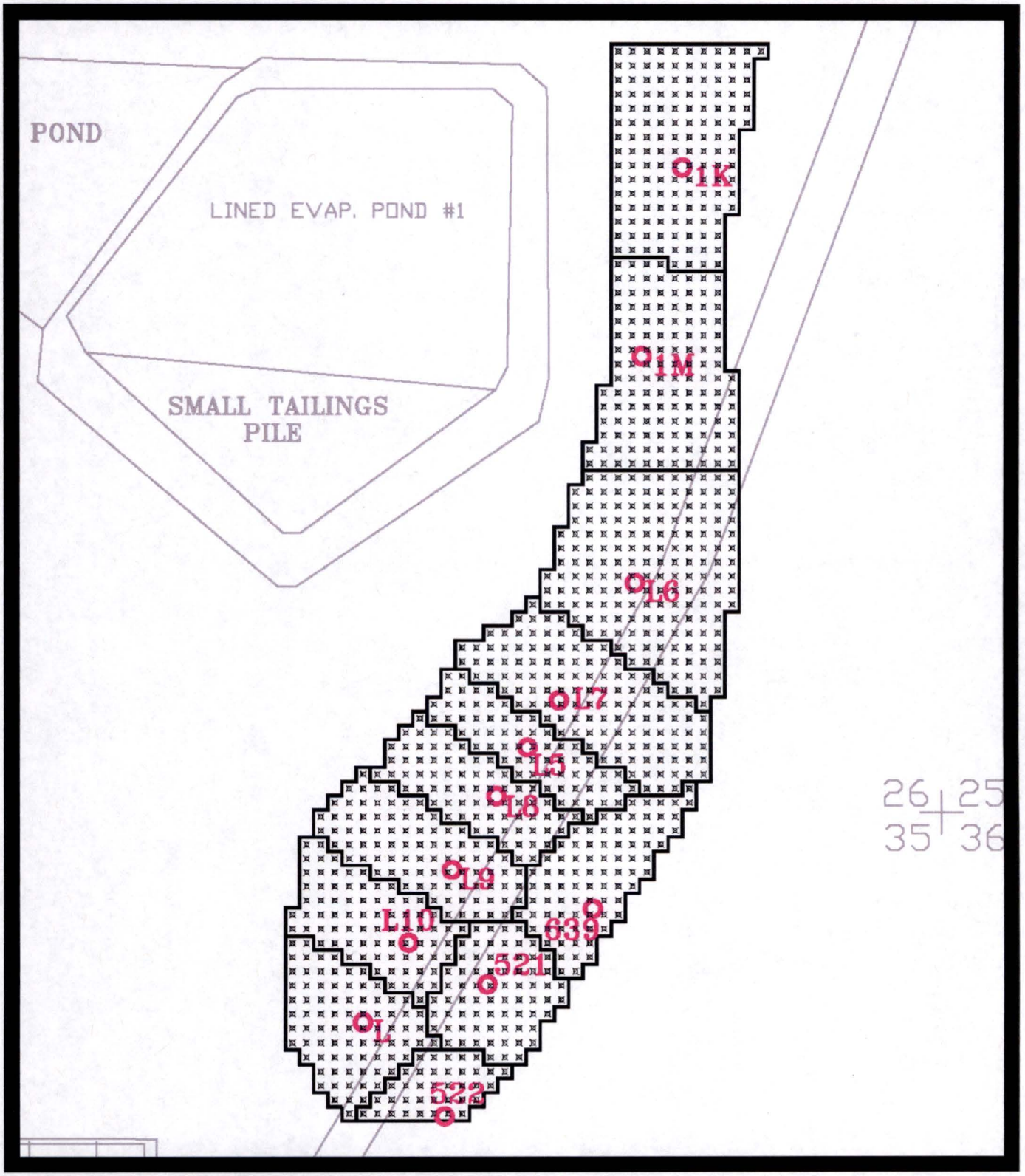

Figure 4-2. Grid-Based Polygon Definition for the L Area

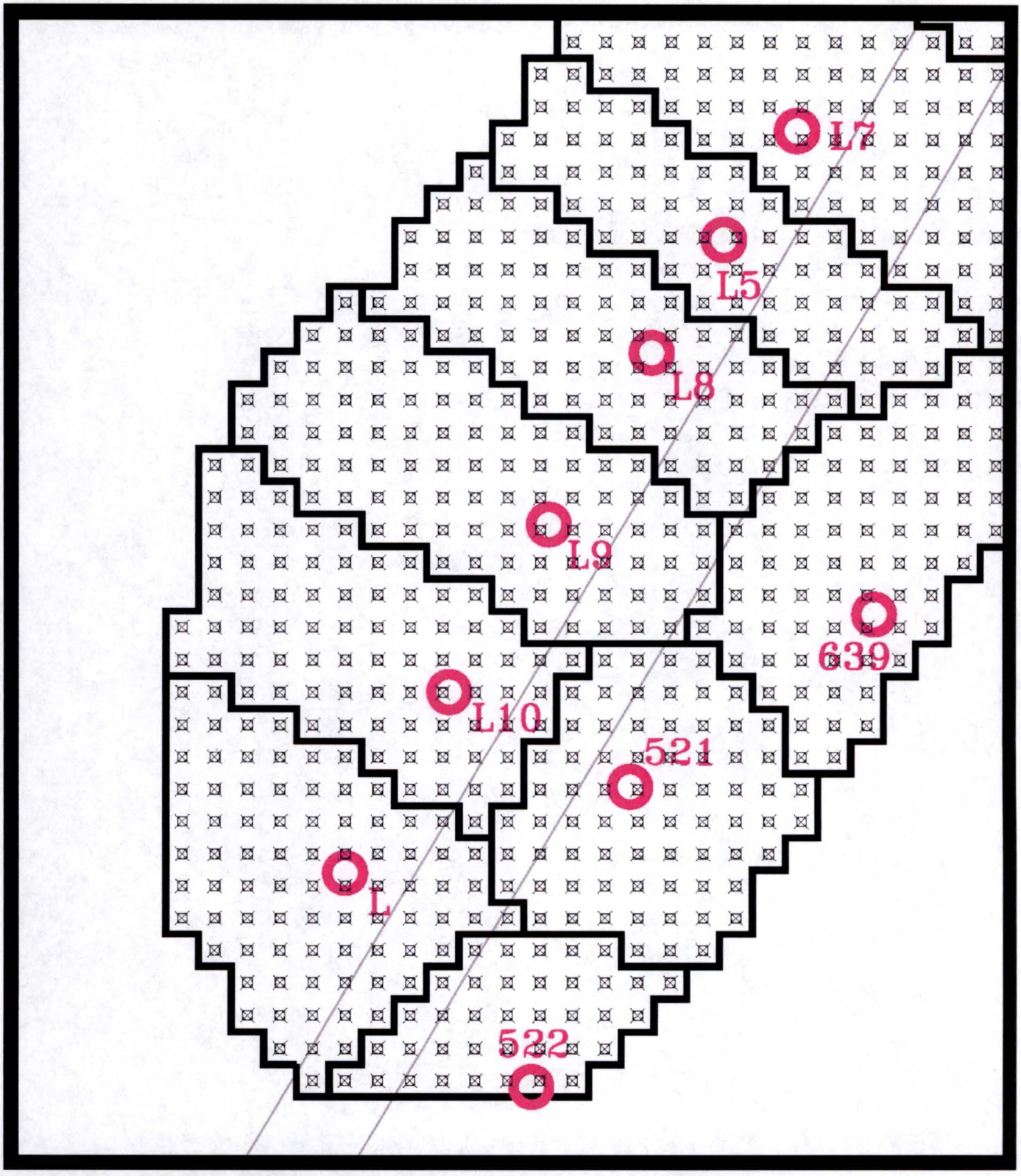

Figure 4-3. Polygon Definition for the L Area Collection Wells

5. MASS COMPARISONS AND IMPACTS TO RESTORATION PROGRESS

The uranium mass extracted by collection wells in the L area was transferred to the hydraulic control area, but represents a very small mass in comparison to the mass that has been extracted from the ground water and LTP. The removal and transfer of the estimated 4,282 lbs of uranium described in the preceding section would not measurably delay restoration progress as discussed below.

5.1 Mass Exchange Comparison

During the period of interest from 1995 through 2015, the uranium removal by RO treatment and evaporation is estimated at over 340,000 lbs, with the majority extracted from within the hydraulic control area. There is also continuing seepage from the LTP, albeit at a diminishing rate, which adds uranium mass to the alluvial ground water within the hydraulic control area. In addition, a large uranium mass within the partially saturated zone has reported to the alluvial aquifer. Table 3-3 includes estimates of the uranium mass in seepage and within the vadose zone that has reported to the alluvial aquifer. These exchanging masses are much greater than that transferred by the L area collection operations.

The total mass extraction by collection for re-injection through 2015 from both within and outside of the hydraulic control area is shown in Figure 5-1. The estimated 4,282 lbs of uranium extracted from the L area and transferred into the control area represents approximately 40% of the total extraction in Figure 5-1, with the remaining mass simply transferred within the hydraulic control area.

Figure 5-2 presents a calculation and comparison of mass extraction or removal for each year based on the data presented in Figure 5-1 and the mass balance analysis presented in Section 4.5. The calculation using the mass balance is made using the difference in uranium mass in the area for subsequent years. The yearly mass removal analysis compares favorably with the total mass extraction by collection for re-injection, particularly after year 2001 when all collection was from the L area. The very similar mass removal indicated by the two methods of calculation applied for the 1998 through 2014 data indicates that, with relatively consistent and complete water quality data, the mass balance calculation is very supportive of past estimates of uranium transfer.

5.2 Impact on Restoration Progress and Timing

The transfer of an estimated 4,282 lbs of uranium from the L area over a twenty year period is not expected to have a measurable impact on the restoration progress or timing **within** the hydraulic control area. The quantity transferred is slightly over 1% of the total uranium removed from ground water by treatment or evaporation over the same interval.

For the L area contaminant plume located outside of the hydraulic control area, the capture of the uranium mass by collection wells had a dramatic impact on restoration progress and timing. As illustrated in Figure 1-2, the typical uranium concentrations in the L area have been reduced by an order of magnitude and the migration and substantial expansion of the plume has been prevented, greatly reducing the volume of water that would ultimately require treatment.

5.3 Impacts of Alternatives

In order to further evaluate the impacts of collection for re-injection on the restoration timing, two alternatives to the collection for re-injection program are described below.

5.3.1 No Collection for Re-injection

The following listing presents expected advantages, disadvantages and time frame impacts of an alternative where no collection from the L area with re-injection to wells within the hydraulic control area occurred, given the constraints that then existed on the treatment system capacity.

- Benefits/Advantages
  - No additional uranium mass (estimated 4,282 lbs) is transferred from the L area to within the hydraulic control area.
  - No water treatment or evaporation capacity is diverted from the more severely impacted and higher priority ground-water collection within the hydraulic control area.
- Detriments/Disadvantages
  - The size of the impacted plume area near the L area wells would continue to increase until collection was initiated.
  - The plume area would potentially reach non-HMC property where it affects other landowners.
  - If the plume area reached non-HMC property, access for restoration activities would likely be limited.
  - The volume of ground water requiring restoration would likely be increased by a factor of three or more due to uncontrolled plume expansion in the L area.
  - With the same uranium mass distributed through a much larger volume of ground water, the efficiency of the uranium removal by water treatment will be dramatically reduced.
- Time Frame Impacts
  - The time frame for restoration of the expanded plume in the L area would be significantly increased because a much larger volume of ground water would require collection and treatment.
  - The uranium mass transferred from the L area into the hydraulic control area is a very small fraction of the mass removed by collection from the control area. Therefore, the

time frame for restoration within the hydraulic control would not be measurably reduced had the collection for re-injection not occurred.

5.3.2 Treatment or Evaporation of Collection for Re-injection Waters

The following listing presents expected advantages, disadvantages and time frame impacts of an alternative where the ground water collected from the L area was treated or evaporated rather than re-injected to wells within the hydraulic control area.

- Benefits/Advantages
  - No additional uranium mass (estimated at 4,282 lbs) transferred directly from L area to within the hydraulic control area.
- Detriments/Disadvantages
  - With a fixed water treatment and/or evaporation capacity, a significant portion of the higher priority collection well operation inside the hydraulic control area would have to be suspended to allow treatment of L area collection waters.
  - The mass of uranium removed by RO treatment or evaporation would be reduced because the uranium concentration in the treatment feed stream would be reduced.
  - The benefits of using re-injection to drive higher concentration ground water to collection wells would not be realized.
- Time Frame Impacts
  - Because the uranium concentration in the L area wells was typically a factor of 5 to 10 times smaller than that in collection wells within the hydraulic control area, devoting part of the finite treatment/evaporation capacity to the L area collection water would significantly reduce the mass of uranium removed by treatment or evaporation. Thus, this alternative would increase the time required for restoration.
  - The time frame for restoration of the plume in the L area would be largely unchanged.

5.4 L Area Plume Restoration and Control

The primary benefit of the collection for re-injection program was the control and restoration of the L area plume. The existing treatment capacity did not allow for treatment of both the hydraulic area water and the L area water, and the focus of the treatment system was on the more heavily contaminated water within the control area. Without collection, the plume area in the L area would have continued to expand with an expected expansion area contrasted with the current area of the plume as shown in Figure 5-3. The area of the expansion in Figure 5-3 is approximately 3.6 times larger than the current plume area. Based on the comparison in Figure 5-3, the volume of ground water in the L area requiring treatment would likely have been increased by a factor of three or more without collection from the L area.

The volume of water collected from the L area from 1996 through 2015 was estimated at slightly less than 390,800,000 gallons using rates discussed in Section 2.2 and presented in Table 2-1. From 1995 through 2015, an estimated 2,770,000,000 gallons of ground water collected primarily from within the control area was treated or evaporated. Figure 3-8 illustrates graphically that the rate of water transfer from the L area was very small in comparison to the ongoing exchanges within the hydraulic control area. The estimated volume of water collected from the L area and transferred to the hydraulic control area is approximately 14% of the water treated or evaporated over a twenty year period. While this is a significant transfer of slightly impacted ground water, the re-injection of this L area water had the secondary benefit in changing gradients to more effectively drive more severely impacted ground water to collection wells. Contrasting this with the alternative of **not** collecting ground water from the L area until the treatment capacity was dramatically increased, the volume of water requiring eventual treatment would increase to an estimated 1,172,400,000 gallons for removal of a uranium mass similar to the 4,282 lbs estimated to be removed by collection from the L area. In any event, the volume of slightly contaminated water transferred to the control area, given current treatment capacity, would not require substantial additional time for treatment.

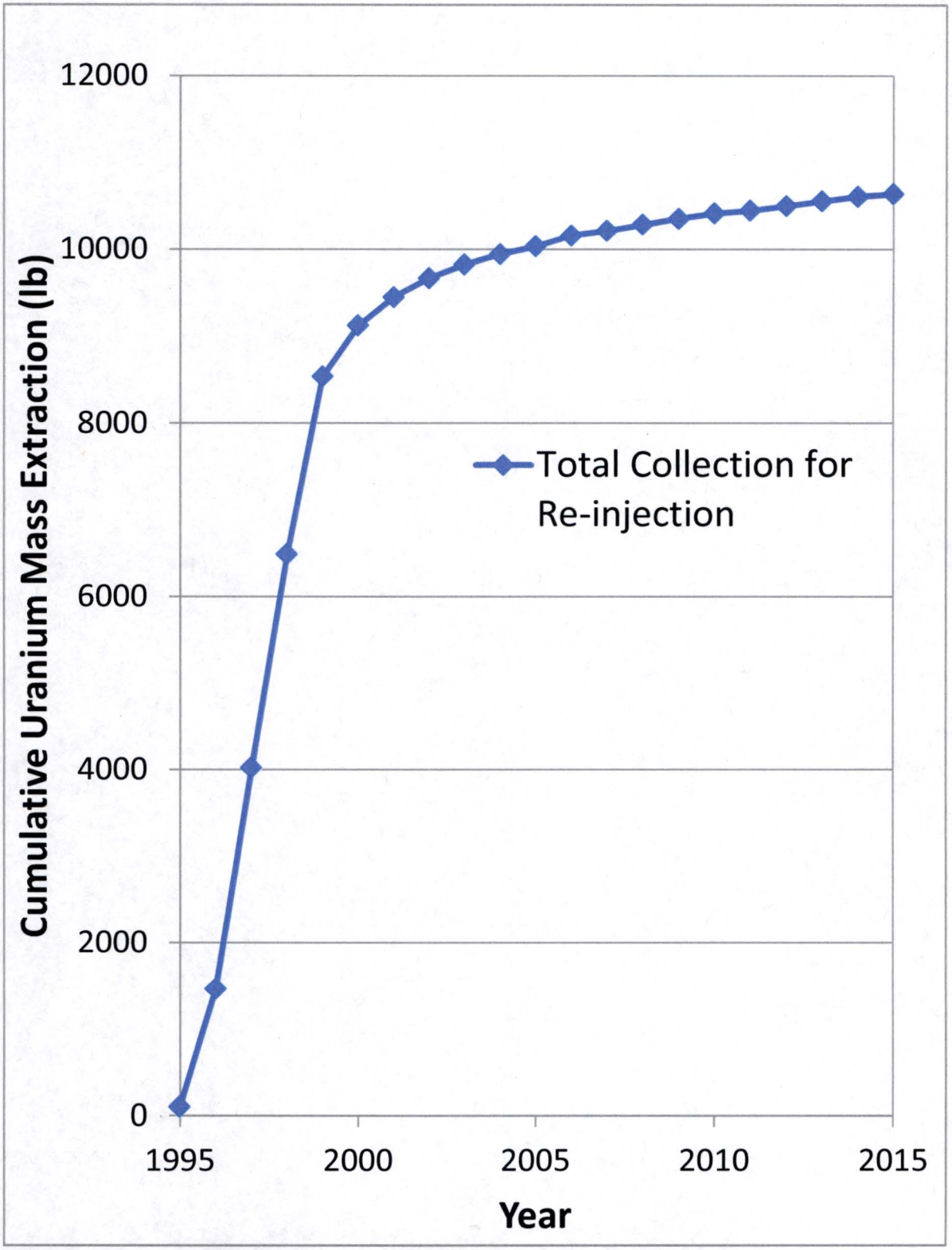

Figure 5-1. Cumulative Uranium Mass in Re-injection Water

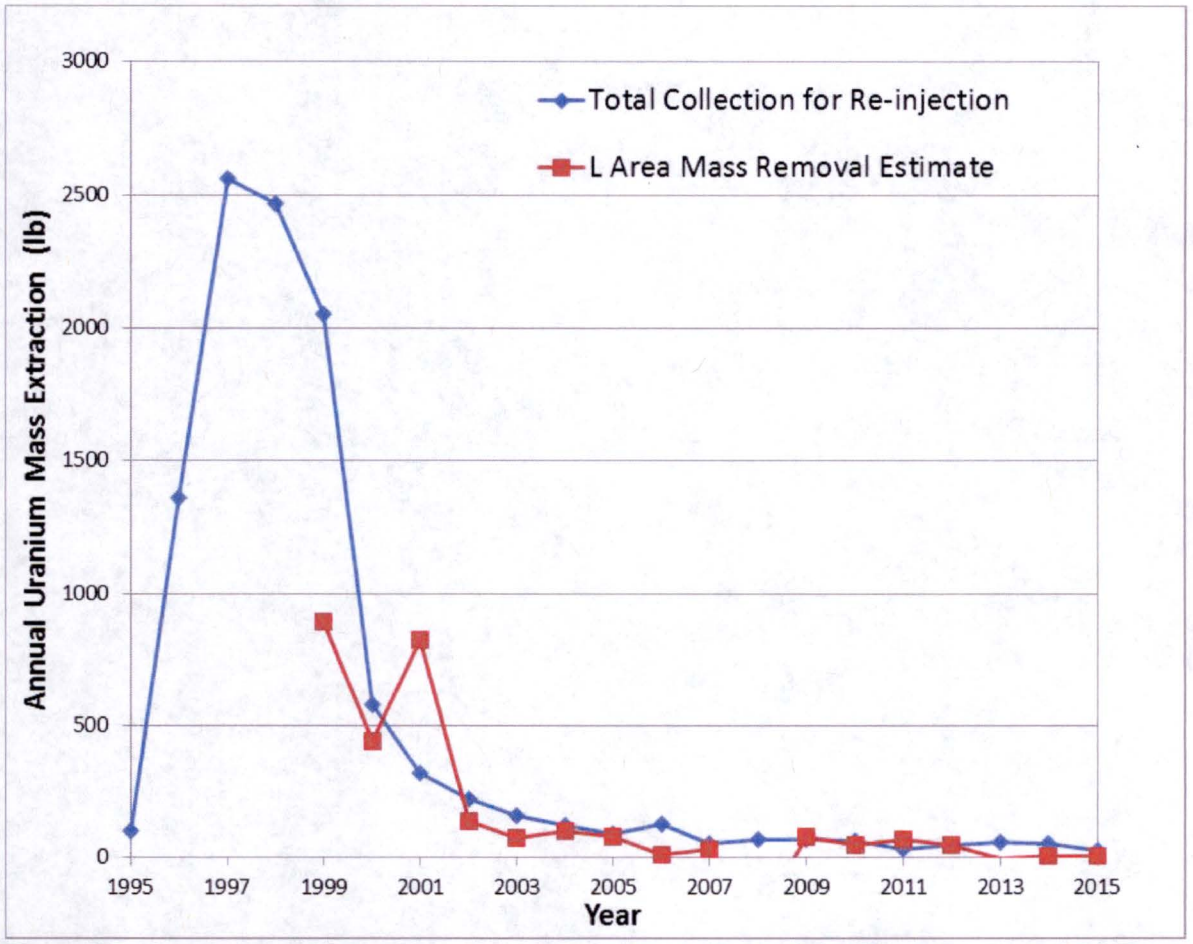

Figure 5-2. Comparison of Total Collection for Re-injection Mass Extraction and L Area Mass Removal

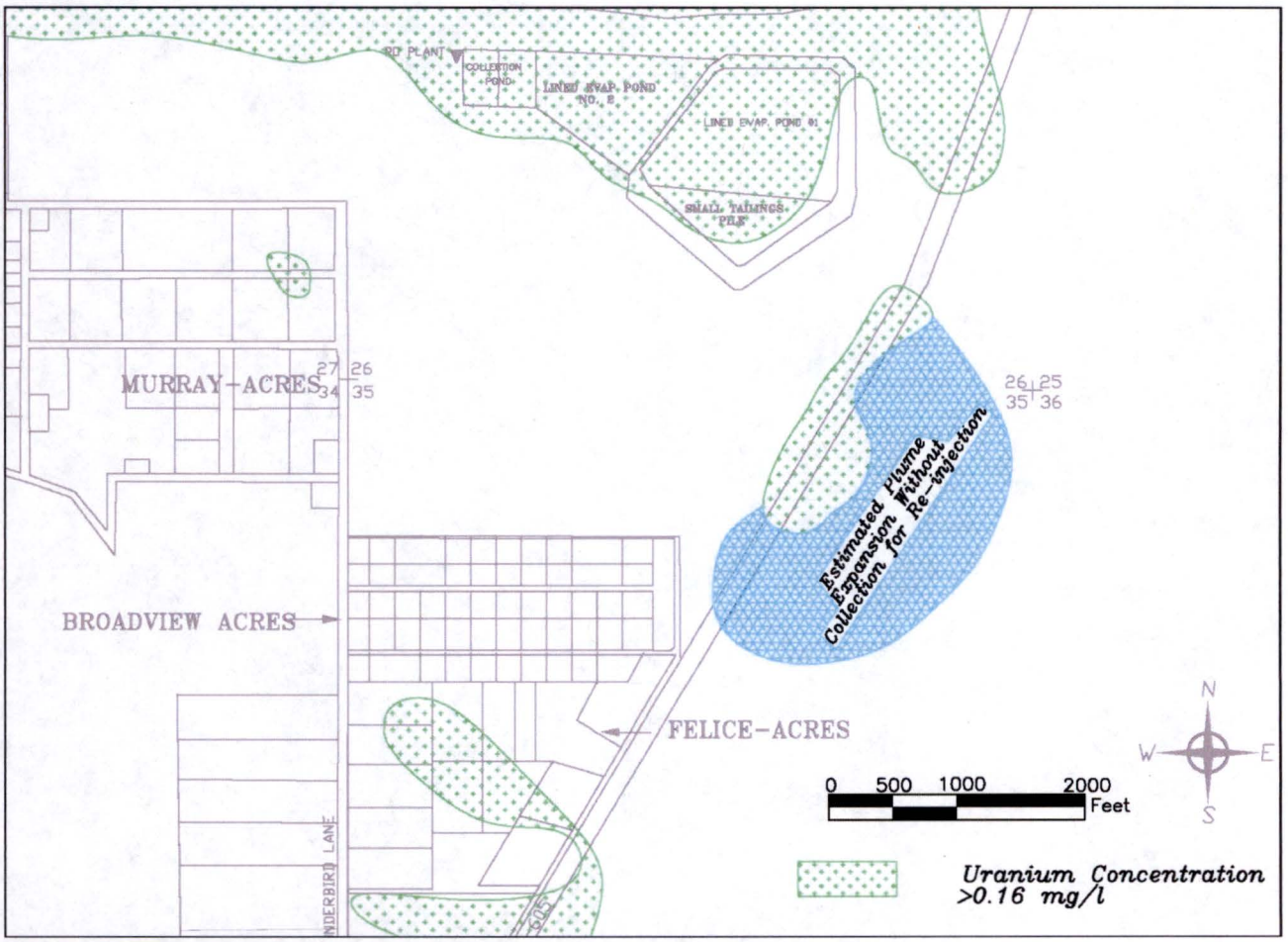

Figure 5-3. Estimated Plume Expansion Without Collection for Re-Injection

6. SUMMARY AND IMPLICATIONS FOR CAP

The CAP submitted to the NRC in 2012 included forecasts of restoration progress and completion based on an expansion of RO treatment plant that was in the planning phase, and use of alternate treatment systems such as zeolite that were in the testing phase at the time of the submittal. The inability to meet the predicted timetable for completion of remediation is the result of the fact that, to date, the water treatment rates that are central to the restoration progress have not met those anticipated at the time of the 2012 submittal.

The impacts of the collection for re-injection program to the forecasts of restoration progress in the 2012 CAP are very minor. The operation of the L area collection wells with re-injection to wells in the LTP area was incorporated in the modeling done for the 2012 CAP and in updated modeling efforts reported to the NRC in October of 2014. While the transfer of both ground water and contaminant mass with collection for re-injection are included in the past modeling, the restoration progress prediction is driven almost entirely by the dramatically larger collection rates occurring from the severely impacted ground water beneath and near the LTP. The mass balance/removal analysis indicated that the uranium mass removed from the L area was slightly more than 1% of the mass removed from the ground water by RO treatment or evaporation from 1995 through 2015. This represents a trivially small increase in the mass within the hydraulic control area resulting from re-injection of L area collection water. The collection for re-injection program did not delay or diminish the restoration progress in the hydraulic control area, and in fact, prevented a dramatic expansion of the L area plume.

It is expected that the restoration schedule will need to be extended from that presented in the 2012 CAP submittal. The recent completion of the RO plant expansion and the construction of the larger zeolite treatment system, along with operational experience with the expanded treatment systems, will allow a more reliable forecast of future water treatment capacity. The revised CAP to be submitted by the end of 2018 will include restoration progress forecasts and scheduling based upon these forecasts of future available treatment capacity.

CAP RAI 5

Memorandum on the Reformulated Mixing Model

Reformulated Mixing Model: Concept, Development, Implementation and Updates

The Reformulated Mixing Model (RMM) was developed as a revision and enhancement of an earlier version of the spreadsheet-based model to predict uranium and water exchanges and balances within the Large Tailings Pile (LTP) at the Grants Reclamation Project (GRP) site. The earlier version of the model was designated as the Original Mixing Model (OMM) and has been superseded by the RMM. Since it was first developed, the RMM has been updated and several features have been added to refine the predictions of water and uranium balances.

Model Concept

The OMM was developed as an empirical means of predicting future uranium concentrations in the LTP with the flushing program along with estimates of seepage from the tailings to the underlying alluvial aquifer. The concept in developing the OMM and the subsequent RMM was an analogy to a mixed reactor in which flushing water is injected into the LTP while water is removed from the tailings by seepage and dewatering. The "clean" flushing water displaces or mixes with the resident solution in the LTP and results in a gradual reduction in the quantity of uranium and the average uranium concentration in the LTP. However, the analogy to a mixed reactor is imperfect and a more empirical means of predicting water and uranium exchanges was employed in the RMM. In its simplest form, the RMM sums the uranium and water inputs to and outputs from the LTP on an annual basis to maintain a tabulation of predicted water and uranium balance from the LTP. With ongoing revision, the RMM has expanded to incorporate separate balances for and exchanges between the slime and sand portions of the tailings in the LTP. This expansion was facilitated by the available monitoring record and the fact that sand dikes around the perimeter of the interior slime areas represent relatively distinct portions of the tailings that function somewhat independently.

Development

The RMM was developed within an EXCEL worksheet and the calculations are performed by Visual Basic routines activated as a macro. The EXCEL worksheet provides a convenient format to tabulate water and uranium quantities and rates annually. The spreadsheet also conveniently provides graphical presentation of the results that are updated with the tabulation. The following description includes the general water and uranium exchanges in the RMM.

Inputs

The primary inputs to the tailings are flushing water and natural recharge through the surface of the tailings. Flushing injection added large quantities of water and relatively small quantities of uranium to the LTP up until flushing was discontinued in 2015. The natural recharge through the tailings cover is a relatively small quantity of water in contrast to the flushing, and the quantity was adjusted in 2007 after additional cover was placed on the tailings. The quantity of uranium added to the LTP by the natural recharge is insignificant. The input section of the RMM is shown in Figure 1 and includes the tabulation of actual flushing and dewatering

rates through 2015, and projected dewatering rates for 2016. In the current RMM spreadsheet, both inputs and outputs are separated into slime and sand exchanges.

An additional input of both water and uranium was included as the recapture calculation. The recapture calculation is an empirical estimate of water and uranium quantities that are added to the resident quantities when the water level in the LTP rises due to flushing injection. The reasoning behind the recapture calculation was that, prior to flushing, the residual water in the partially saturated zone of the tailings would likely have large uranium concentrations. When the water level increases due to flushing injection, both the residual water and uranium in the partially saturated zone are "recaptured" to the resident volumes or masses in the RMM. The significant recapture of uranium was limited to a single cycle of water level rise.

The uranium inputs to the LTP consisted of the relatively small contribution by the flushing water and the assumed recapture uranium mass. The assumed concentration of uranium in the recapture water is listed in the input parameters in Figure 1 as the Assumed Recapture U Concentration.

Outputs

The primary outputs from the tailings are dewatering collection, seepage and toe drain collection. The toe drain collection actually represents a portion of the seepage that is intercepted on the perimeter of the tailings, but the rates are separated from the seepage discharge in the RMM.

The rates of seepage and toe drain discharge from the tailings were originally estimated using the VADOSE/W modeling described in the CAP. Since the original implementation of the RMM, the sequence and rates of flushing and dewatering have changed significantly and it was necessary to modify the estimates of seepage and toe drain rates to accommodate these changes. To that end, the VADOSE/W predictions of toe drain and seepage rates were plotted against the estimated resident water volume in the tailings from the RMM with the result shown in Figure 2. The following factors were considered in extending the available VADOSE/W predictions to a modified sequence of flushing and eventual LTP drain down.

- The seepage and toe drain rates generally increase as the water volume in the LTP increases due to increasing head and an expansion of the saturated footprint of the tailings.
- The seepage and toe drain rates generally decrease as the water volume in the LTP decreases due to decreasing head and shrinkage of the saturated footprint of the tailings.
- The measured water levels and water balance predicted by the RMM showed that seepage and toe drain rates will equilibrate with the difference between the inputs (flushing plus natural recharge) and the dewatering extraction. There are changes in water level and water storage in the LTP when there is a change in flushing or dewatering rates, but eventually the water levels stabilize and at that point the seepage and toe drain rates are equivalent to the difference between other inputs and outputs from the LTP.
- With the flushing program operated through 2015, there was an extended period wherein observed water levels and measured injection and dewatering rates reveal the relative stability of the estimated resident water volume in the LTP when net injection rate was relatively steady.
- When dewatering is terminated, the seepage and toe drain rates are predicted to gradually decline as the water levels decline and the saturated footprint of the LTP shrinks.

Equations for predicting seepage and toe drain rates were developed by fitting two line segments to both the seepage and toe drain rates as shown in Figure 2. A two segment linear fit was used to generally represent the active flushing and long-term drainage phases independently. Like the flushing inputs to the tailings, the

seepage rates were proportioned between the slime and sand portion of the tailings according to seepage fractions listed in the input table shown in Figure 1. The combination of seepage or toe drain rates and resident water volumes used to calculate the predicted output rates are also shown with blue shading in Figure 1.

The estimated quantity of uranium removed from the LTP in seepage from the slime and sand is calculated for each year and is proportional to the estimated average concentration in the corresponding portion of the tailings, and to the corresponding seepage and toe drain rates. During flushing, the uranium concentration in the seepage is assumed to be a fraction of the average LTP sand or slime concentration to incorporate a variety of factors in expected uranium exchange during flushing. The factors include the following.

- Portions of the flushing injection at the base of the tailings will effectively bypass the tailings by contributing to seepage without significant mixing with the resident water in the LTP.
- Portions of the tailings that have been successfully flushed will continue to contribute seepage to the alluvium at relatively low uranium concentrations.
- Heterogeneities in the tailings hydraulic properties may allow some short circuiting of the mixing process.

The fraction of the average uranium concentration estimated to be present in the seepage from the sand or slime tailings is listed as 0.4 in the input table shown in Figure 1. This factor is applied to calculate uranium removal from the tailings through the date listed as the End of Injection in Figure 1. After flushing, the uranium concentration in the seepage is assumed to be the corresponding average concentration in the LTP. The dewatering extraction is assumed to be at the average uranium concentration in the corresponding portion of the tailings.

LTP Internal Exchanges

Because the sand and slime portions of the LTP have dramatically different hydraulic properties and can be treated as somewhat independent, the RMM calculates and tabulates water and uranium balances separately for the sand and slime. The flushing injection was primarily in the slime tailings through 2013, but with the increased head within the slime tailings, much of the water from the slime will flow outward to the perimeter sand dike. In the RMM, this transfer was represented as a slime to sand transfer of both uranium and water. The portion of the resident water volume that is assumed to reside in the slime tailings is included in the input table in Figure 1 as 60 percent of the total volume. The RMM spreadsheet makes an iterative calculation as indicated in Figure 3 to maintain this approximate 60 vs. 40 percent resident water distribution between slime and sand tailings by transferring water from the slime to sand tailings. Because much of the water transferred from the slime to sand tailings is flushing injection water, only a small fraction of the average slime tailings uranium concentration is assumed to be transferred with the water (see Figure 1).

Updates

The RMM has been updated to include the most recent available operational flushing and dewatering rates. The predicted model results are compared with the measured uranium concentrations within the LTP as presented in Figures 4 and 5. Figure 6 presents the tabulation of model results for the most recent update. There is relatively good correspondence between measured and predicted uranium concentrations in the sand, slime and overall LTP (see Figure 5). The operational configuration of the flushing program and the physical exchange processes within the tailings have resulted in the significantly different uranium concentrations in the slime and sand tailings. The dramatically lower hydraulic conductivity of the slime tailings results in much slower vertical and horizontal water movement and limited practical dewatering rates. In contrast, the sand tailings on the perimeter of the LTP have much greater hydraulic conductivity and faster corresponding

rates of water movement. The flushing injection was primarily in the slime tailings through 2013. However, a significant portion of the flushing injection in the slime tailings moves laterally into the sand tailings resulting in the significant reduction in measured sand uranium concentration as shown in Figure 6. In effect, the flushing of slime tailings indirectly flushes the sand tailings, and this exchange process is expected to continue after flushing is completed. With this exchange process, the difference between predicted uranium concentration in the sand and slime tailings gradually becomes smaller.

The estimated long-term seepage and toe drain rates from the LTP are predicted to vary within a modest range during the operation of the flushing injection, with a fairly rapid decline after flushing is terminated (see Figure 4). Given that the combination of seepage and toe drain discharge from the LTP effectively balances the net inputs to the LTP (flushing injection plus natural recharge minus dewatering) over the duration of the flushing program, the extension of the VADOSE/W model results to a longer flushing program provides a reasonable estimate of discharge from the tailings. After flushing and dewatering are completed, the rate of seepage and toe drain discharge from the LTP declines fairly quickly and will gradually approach the very small estimated rate of recharge to the LTP through the cover system.

Summary

The RMM has been refined and updated to provide a more comprehensive method of estimating the quantity and uranium concentration in seepage from the tailings. The record of water levels and measured uranium concentration in the LTP through 2015 has allowed comparison of measured and predicted uranium concentrations. The long-term predicted uranium concentration in seepage from the LTP with the current update of the RMM is slightly greater than three (3) mg/l. As noted, the RMM is an empirical model, but numerous inputs can be adjusted to develop a good representation of available measured LTP uranium concentrations and further refine model predictions.

Figure 1. RMM Input Section

Assumed Tails Partition Fraction	1.00
Assumed Starting U Concentration	39.38
Assumed Long-Term Flushing U Concentration	0.15
Assumed Scaling Slimes Volume (gallon)	6.05E+07
Slimes Specific Yield Scaling Factor	3.20
Assumed Scaling Sand Volume (gallon)	6.34E+07
Sand Specific Yield Scaling Factor	2.13
Initial Fraction U Conc. In Seepage & Toe Drain Water	0.4
Final Fraction U Conc. In Seepage & Toe Drain Water	1
Other Water Uranium Conc.	0.1
Residual Partially Saturated Water Recapture Fraction	0.3
Assumed Recapture U Concentration	55
Slime to Sand U Transfer Fraction	0.15
Assumed Slime Portion (%)	60
Calculated Sand Fraction (%)	40

Seepage Lower Threshold	0.45	*At Volume*	2.2E+08
Seepage Break Threshold	6	*At Volume*	2.7E+08
Seepage Upper Threshold	160	*At Volume*	4.55E+08
Toe Drain Lower Threshold	0.3	*At Volume*	2.2E+08
Toe Drain Break Threshold	2	*At Volume*	2.7E+08
Toe Drain Upper Threshold	50	*At Volume*	4.55E+08

Year	Slime Dewater Rate (gpm)	Sand Dewater Rate (gpm)	Total Dewater Rate (gpm)	Total Injection Rate (gpm)	Slime Injection Rate (gpm)	Effective Slime Injection (fraction)	Sand Injection Rate (gpm)	Effective Sand Injection (fraction)	Injection Uranium Conc. (mg/l)
2000	23.6	0	23.6	61	61	1	0	0	0.40
2001	60	0	60	162	162	1	0	0	0.40
2002	34	0	34	302	302	1	0	0	0.44
2003	17	0	17	267	267	1	0	0	0.57
2004	84.9	0	84.9	280	280	1	0	0	0.91
2005	87.2	0	87.2	228	228	1	0	0	0.92
2006	84.5	0	84.5	269	269	1	0	0	0.72
2007	46.7	0	46.7	224	224	1	0	0	0.21
2008	14.68	0	14.68	300	300	1	0	0	0.21
2009	56.1	0	56.1	284	284	1	0	0	0.15
2010	25	0	25	193	193	1	0	0	0.15
2011	104	0	104	270	270	1	0	0	0.15
2012	105	0	105	264	264	1	0	1	0.15
2013	60.4	0	60.4	232	232	1	0	1	0.15
2014	46	0	46	308	200	1	108	1	0.15
2015	5	11.8	16.8	79	30	1	49	1	0.15
2016	10	10	20	0	0	0	0	0	0.15

Assumed Slime Seepage Fraction (%)	40
Calculated Sand Seepage Fraction (%)	60
End of Injection	2,015

Figure 2. Seepage Rate Correlation

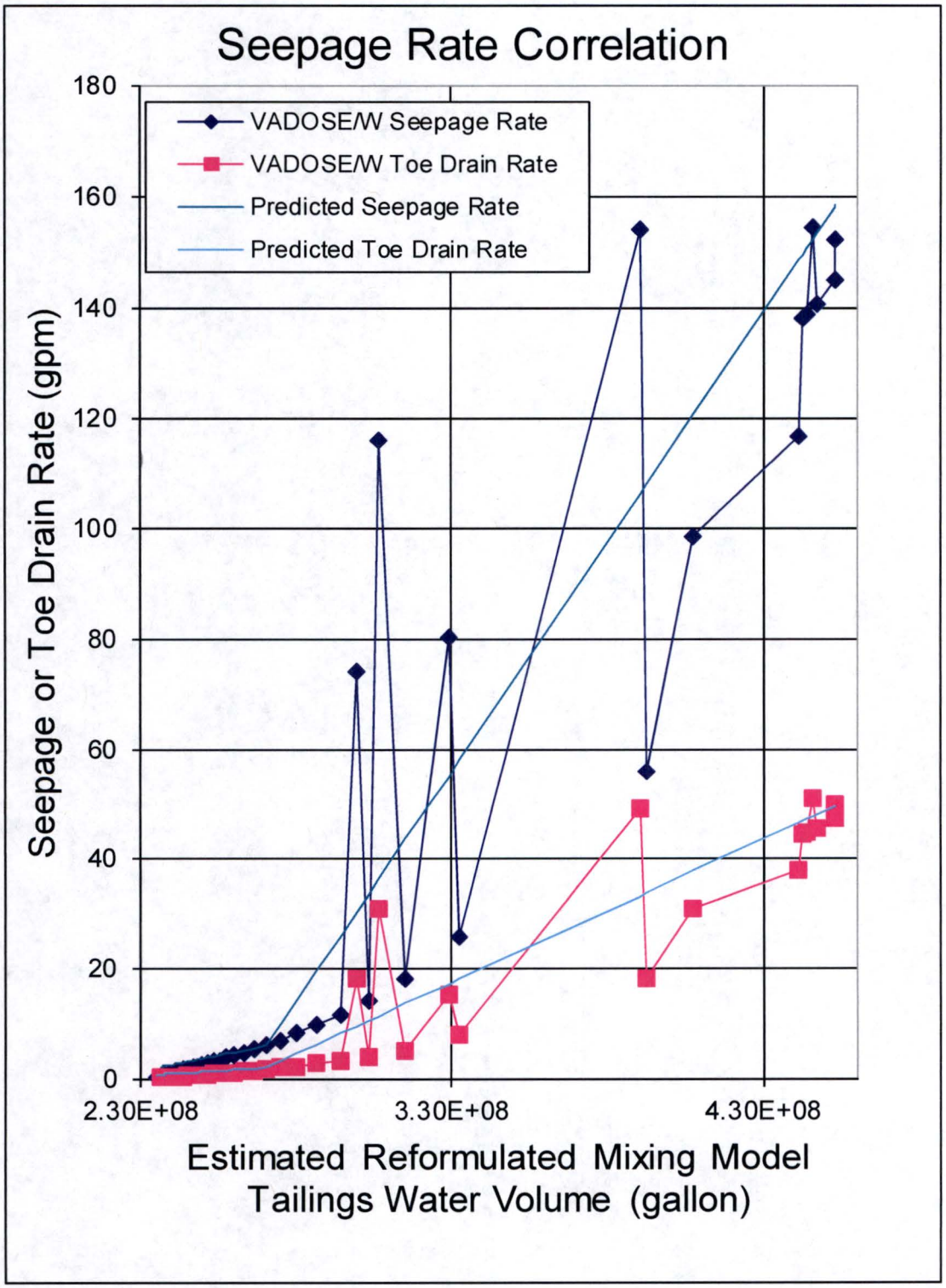

Figure 3. RMM Simplified Flow Chart

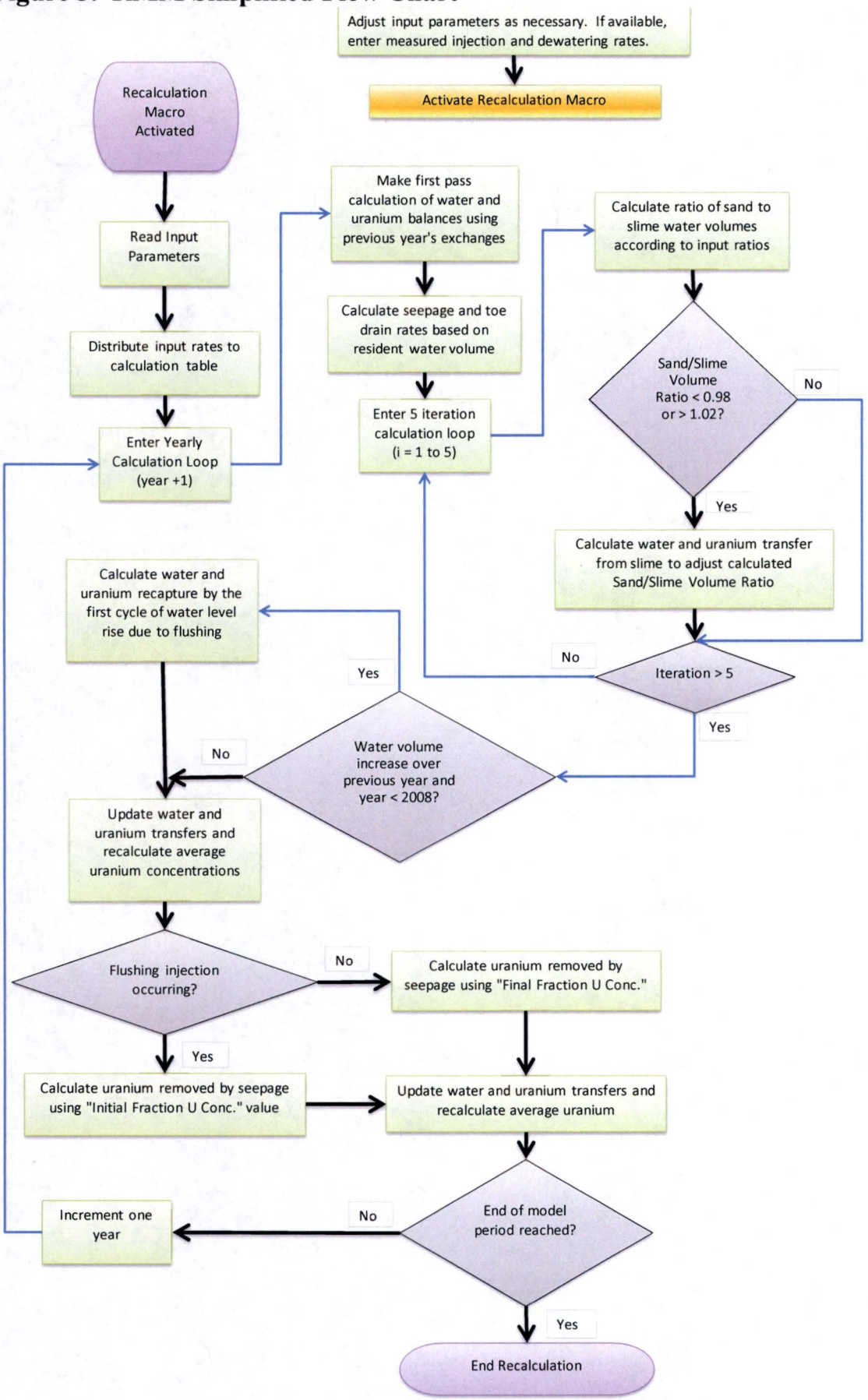

Figure 4. RMM Predicted Seepage Rates and Average Uranium Concentration

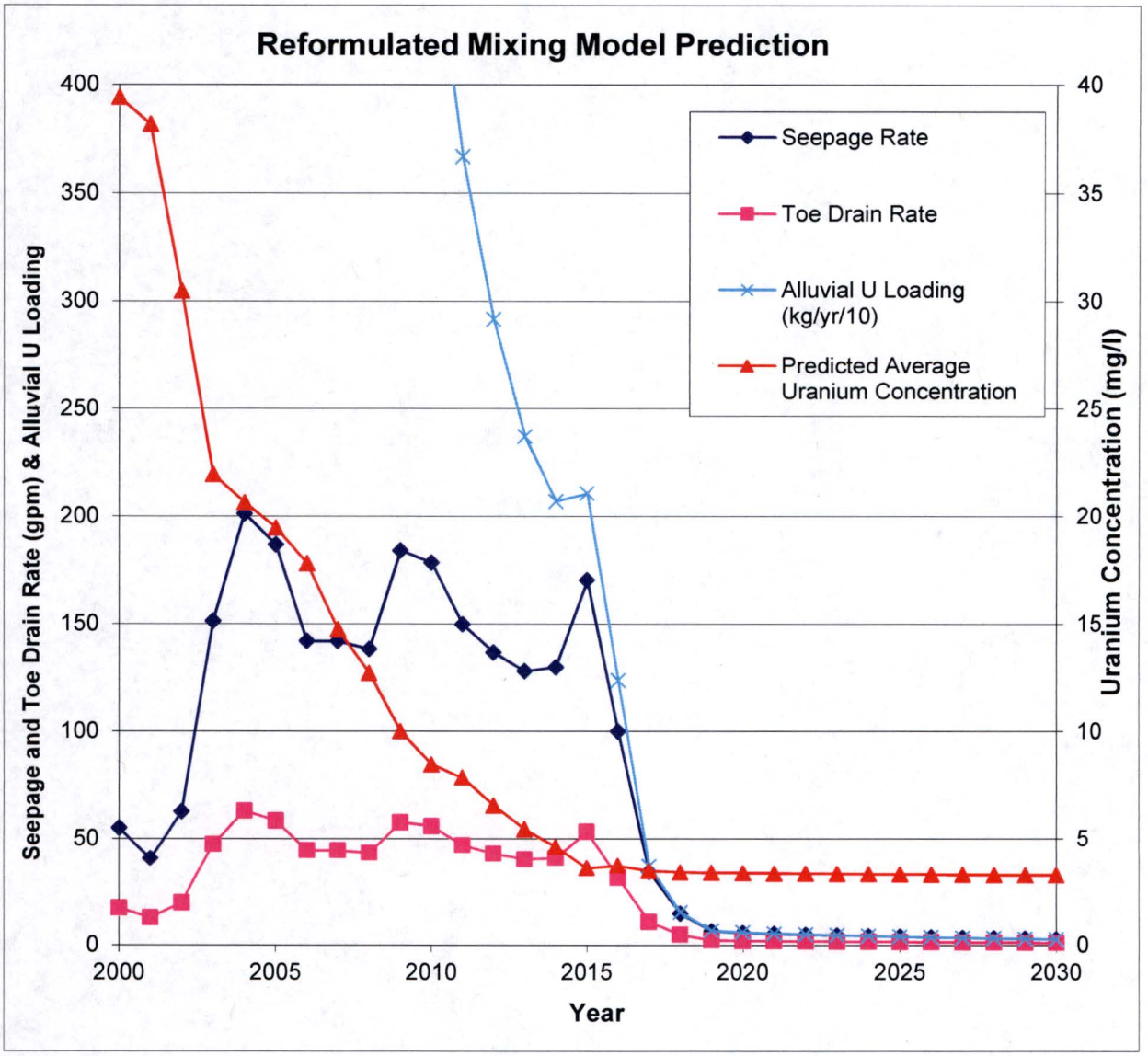

Figure 5. RMM Predicted and Measured Uranium Concentrations

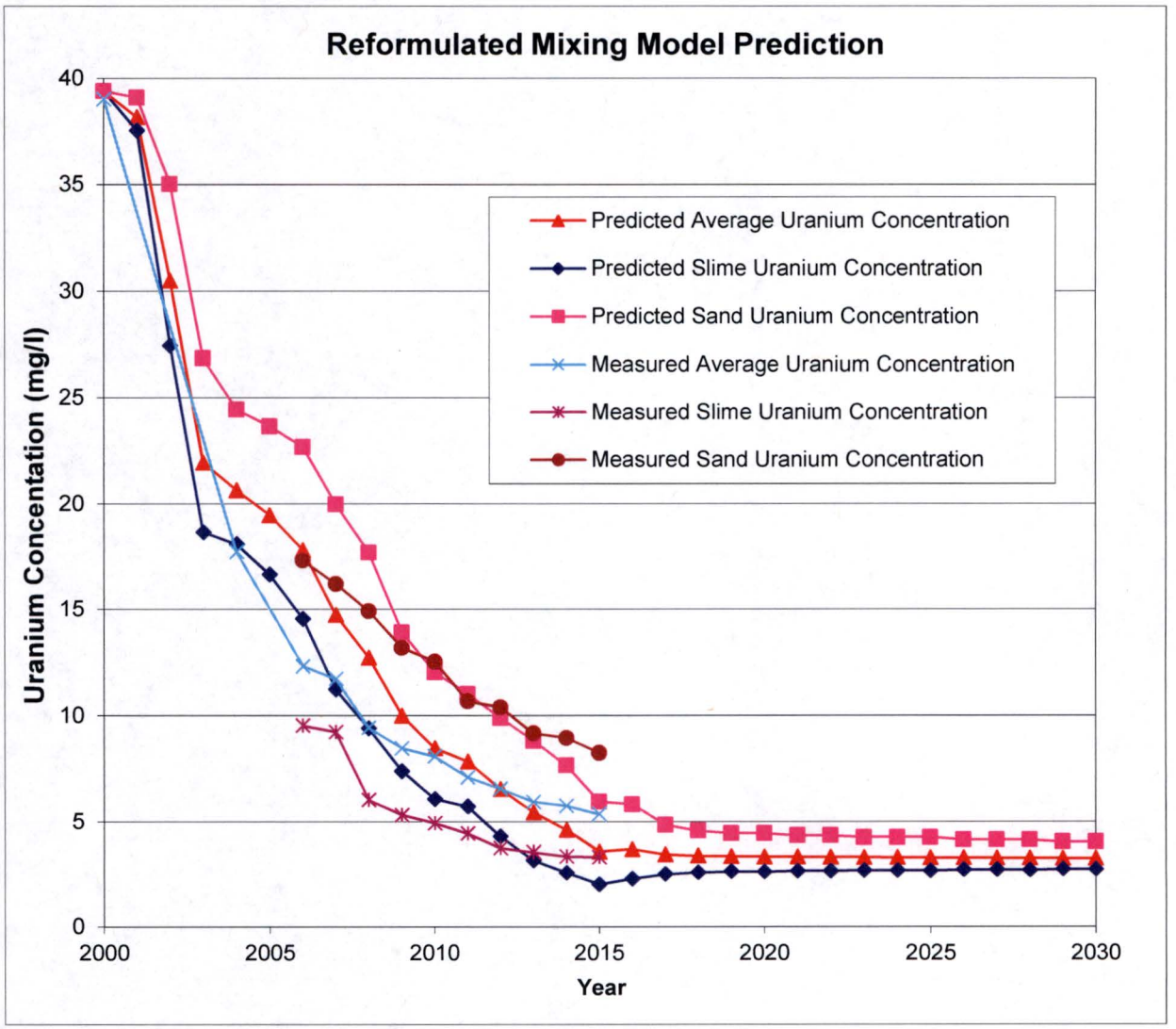

Figure 6. RMM Estimated Uranium Concentration and Water Balance

Estimated Flushing Water Mixing and Tailings Uranium Concentration (Starting in Year 2000)

Year	Resident Water Volume (gallon)	Slime Water Volume (gallon)	Sand Water Volume (gallon)	Slime Solution Uranium Mass (lb)	Sand Solution Uranium Mass (lb)	Resident Solution Uranium Mass (lb)	Slime Average Uranium Conc. (mg/l)	Sand Average Uranium Conc. (mg/l)	Average Uranium Conc. (mg/l)	Total Alluvial U Loading (kg/yr/10)	Slime Residual Water Recapture Volume (gallon)	Slime Residual Water Uranium Added (lb/year)	Sand Residual Water Recapture Volume (gallon)	Sand Residual Water Uranium Added (lb/year)	Slime Effective Flushing Rate (gpm)	Slime Flushing Uranium Added (lb/year)	Sand Effective Flushing Rate (gpm)	Sand Flushing Uranium Added (lb/year)	Slime Dew. Rate (gpm)	Slime Dewatering Uranium Removed (lb/year)	Sand Dew. Rate (gpm)	Sand Dewatering Uranium Removed (lb/year)	Slime Seepage &Tor D Rate (gpm)	Slime Seepage Uranium Removed (lb/year)	Sand Seepage &Tor D Rate (gpm)	Sand Seepage Uranium Removed (lb/year)	Slime Water to Sand (gal/year)	Slime Uranium to Sand (lb/year)	Other Water Added (gal/year)	Total Seepage Rate (gpm)	Total Tor Drain Rate (gpm)
Initial	328,731,600	197,238,960	131,492,640	64,763	43,175	107,938	39.38	39.38	39.38		0																					
2000	328,731,600	197,238,960	131,492,640	64,763	43,175	107,938	39.38	39.38	39.38	563.5					61.0	107	0	0	23.6	4,076	0	0	22.0	1517	50.2	3466	19,401,746	956	831,000	54.9	17.2
2001	311,309,270	186,453,162	124,856,108	58,322	40,665	98,986	37.51	39.06	38.14	408.0					162.0	284	0	0	60.0	9,871	0	0	16.2	1063	37.0	2532	29,700,754	1384	831000	40.4	52.7
2002	337,839,347	202,371,208	135,468,139	46,278	39,526	85,805	27.43	34.99	30.46	534.2	4,775,414	2,190	3,183,609	1460	302.0	576	0	0	34.0	4,089	0	0	25.0	1202	57.1	3504	69,092,890	2370	831,000	62.5	19.6
2003	444,352,479	266,279,087	178,073,392	41,383	39,852	81,235	18.64	26.84	21.93	961.4	19,172,364	8,792	12,781,576	5861	267.0	667	0	0	17.0	1,390	0	0	60.5	1977	137.9	6494	83,344,272	1943	831,000	151.1	47.2
2004	504,272,014	302,230,808	202,041,205	43,533	41,163	84,696	18.07	24.43	20.42	1181.5	10,785,516	4,946	7,190,344	3297	280.0	1116	0	0	84.9	6,727	0	0	80.4	2549	183.4	7861	81,948,177	1852	831,000	201.0	62.8
2005	486,970,305	291,849,783	195,120,522	40,467	38,451	78,919	16.63	23.63	19.44	1048.3					228.0	919	0	0	87.2	6,359	0	0	74.6	2178	170.3	7059	67,602,474	1406	831,000	186.6	58.3
2006	433,082,079	259,516,847	173,565,232	31,443	32,799	64,242	14.53	22.66	17.79	747.8					269.0	849	0	0	84.5	5,385	0	0	56.7	1445	129.4	5143	67,665,153	1230	831,000	141.8	44.3
2007	433,088,938	259,520,963	173,567,975	24,253	28,883	53,118	11.20	19.96	14.71	640.5					224.0	206	0	0	66.7	2,294	0	0	56.7	1114	129.4	4530	65,925,386	923	263,000	141.8	44.3
2008	428,739,541	257,138,525	171,601,016	20,108	25,279	45,387	9.38	17.67	12.70	566.6					300.0	276	0	0	14.7	604	0	0	55.3	909	126.1	3907	88,126,234	1034	263,000	138.1	43.2
2009	483,661,568	290,091,741	193,569,827	17,838	22,406	40,243	7.37	13.88	9.98	571.6					284.0	187	0	0	56.1	1,814	0	0	73.5	951	167.8	4085	85,354,114	787	263,000	183.9	57.4
2010	476,883,981	286,025,188	190,858,792	14,472	19,108	33,579	6.07	12.01	8.45	474.9					193.0	127	0	0	25.0	663	0	0	71.3	759	162.6	3425	71,613,100	543	263,000	178.2	55.7
2011	442,512,600	265,402,360	177,110,240	12,631	16,226	28,857	5.71	10.99	7.82	366.7					270.0	178	0	0	104.0	2,603	0	0	59.8	599	136.5	2631	65,372,568	467	263,000	149.6	46.8
2012	426,815,698	255,984,219	170,831,479	9,140	14,062	23,201	4.28	9.87	6.52	291.5					264.0	174	0	0	105.0	1,972	0	0	54.6	410	124.6	2158	61,242,956	328	263,000	136.5	42.7
2013	416,448,023	249,763,614	166,684,409	6,603	12,232	18,835	3.17	8.80	5.42	236.9					232.0	153	0	0	60.4	840	0	0	51.2	285	116.7	1802	62,136,438	246	263,000	127.9	40.0
2014	418,652,900	251,086,540	167,566,360	5,385	10,676	16,061	2.57	7.64	4.60	206.7					200.0	132	108	71	46.0	519	0	0	51.9	234	118.4	1587	24,750,683	80	263,000	129.7	40.6
2015	467,106,642	280,158,785	186,947,857	4,684	9,229	13,923	2.01	5.93	3.57	210.3					30.0	20	49	32	5.0	44	12	307	68.0	239	155.2	1614	28,161,807	71	263,000	170.1	53.1
2016	382,737,980	229,537,588	153,200,392	4,350	7,422	11,771	2.27	5.81	3.69	123.5					0.0	0	0	0	10.0	100	10	255	39.9	398	91.2	2323	21,402,385	61	263,000	99.8	31.3
2017	303,584,036	182,045,222	121,538,814	3,791	4,905	8,696	2.50	4.84	3.44	36.7					0.0	0	0	0	0.0	0	0	0	13.6	149	31.1	660	6,948,172	22	263,000	34.0	10.7
2018	280,368,412	168,115,847	112,252,565	3,621	4,267	7,888	2.58	4.56	3.37	15.2					0.0	0	0	0	0.0	0	0	0	5.9	66	13.5	269	3,017,107	10	263,000	14.6	4.7
2019	270,476,197	162,180,518	108,295,679	3,545	4,007	7,552	2.62	4.44	3.35	6.6					0.0	0	0	0	0.0	0	0	0	2.6	29	6.0	116			263,000	6.4	2.1
2020	266,261,108	161,098,739	105,162,370	3,515	3,891	7,407	2.62	4.44	3.34	5.8					0.0	0	0	0	0.0	0	0	0	2.2	26	5.2	102	2,624,998	9	263,000	5.6	1.9
2021	262,604,257	157,457,354	105,146,903	3,481	3,798	7,279	2.65	4.33	3.32	5.3					0.0	0	0	0	0.0	0	0	0	2.1	24	4.9	92			263,000	5.2	1.7
2022	259,226,101	156,631,506	102,594,595	3,457	3,706	7,163	2.65	4.33	3.31	4.9					0.0	0	0	0	0.0	0	0	0	1.9	22	4.5	86	2,221,252	7	263,000	4.8	1.6
2023	256,105,402	153,558,041	102,547,361	3,427	3,628	7,055	2.68	4.24	3.30	4.5					0.0	0	0	0	0.0	0	0	0	1.8	21	4.2	78			263,000	4.5	1.5
2024	253,222,537	152,883,854	100,338,683	3,406	3,549	6,956	2.67	4.24	3.29	4.2					0.0	0	0	0	0.0	0	0	0	1.7	19	3.9	73			263,000	4.1	1.4
2025	250,559,381	152,276,944	98,282,437	3,387	3,477	6,863	2.67	4.24	3.29	3.9					0.0	0	0	0	0.0	0	0	0	1.5	18	3.6	68	2,872,669	10	263,000	3.8	1.3
2026	248,099,189	148,736,314	99,362,876	3,359	3,418	6,778	2.71	4.13	3.28	3.6					0.0	0	0	0	0.0	0	0	0	1.4	17	3.4	61			263,000	3.6	1.3
2027	245,826,494	148,266,965	97,559,529	3,342	3,357	6,699	2.70	4.13	3.27	3.3					0.0	0	0	0	0.0	0	0	0	1.3	16	3.2	57			263,000	3.3	1.2
2028	243,727,005	147,832,653	95,894,352	3,327	3,300	6,626	2.70	4.13	3.26	3.1					0.0	0	0	0	0.0	0	0	0	1.2	15	3.0	54	2,374,823	8	263,000	3.1	1.1
2029	241,787,523	144,947,314	96,820,209	3,304	3,254	6,558	2.73	4.03	3.25	2.8					0.0	0	0	0	0.0	0	0	0	1.1	14	2.8	49			263,000	2.9	1.0
2030	239,995,852	144,627,288	95,368,594	3,290	3,205	6,496	2.73	4.03	3.25	2.7					0.0	0	0	0	0.0	0	0	0	1.1	13	2.6	46			263,000	2.7	1.0
2031	238,340,728	144,329,014	94,011,714	3,278	3,160	6,437	2.72	4.03	3.24	2.5					0.0	0	0	0	0.0	0	0	0	1.0	12	2.4	43	1,982,348	7	263,000	2.5	0.9
2032	236,811,744	141,981,847	94,829,898	3,259	3,124	6,383	2.75	3.95	3.23	2.3					0.0	0	0	0	0.0	0	0	0	0.9	11	2.3	39			263,000	2.3	0.9
2033	235,399,288	141,757,909	93,641,379	3,248	3,086	6,332	2.75	3.95	3.23	2.1					0.0	0	0	0	0.0	0	0	0	0.9	10	2.1	37			263,000	2.2	0.8
2034	234,094,477	141,566,933	92,527,544	3,237	3,048	6,285	2.74	3.95	3.22	2.0					0.0	0	0	0	0.0	0	0	0	0.8	10	2.0	34			263,000	2.0	0.8
2035	232,889,109	141,406,408	91,482,701	3,228	3,013	6,241	2.74	3.95	3.21	1.9					0.0	0	0	0	0.0	0	0	0	0.8	9	1.9	32	2,208,649	8	263,000	1.9	0.7
2036	231,775,604	138,960,163	92,815,442	3,211	2,989	6,200	2.77	3.86	3.21	1.7					0.0	0	0	0	0.0	0	0	0	0.7	9	1.8	30			263,000	1.8	0.7
2037	230,746,962	138,853,751	91,893,210	3,202	2,959	6,161	2.77	3.86	3.20	1.6					0.0	0	0	0	0.0	0	0	0	0.7	8	1.7	28			263,000	1.6	0.7
2038	229,796,714	138,771,346	91,025,369	3,194	2,931	6,125	2.76	3.86	3.20	1.5					0.0	0	0	0	0.0	0	0	0	0.6	7	1.6	26			263,000	1.5	0.6
2039	228,918,887	138,711,115	90,207,772	3,187	2,905	6,092	2.76	3.86	3.19	1.4					0.0	0	0	0	0.0	0	0	0	0.6	7	1.5	25			263,000	1.4	0.6
2040	228,107,961	138,671,370	89,436,591	3,180	2,880	6,060	2.75	3.86	3.19	1.4					0.0	0	0	0	0.0	0	0	0	0.5	7	1.4	23	2,235,247	8	263,000	1.3	0.6
2041	227,358,837	136,310,102	91,048,735	3,166	2,864	6,030	2.79	3.77	3.18	1.3					0.0	0	0	0	0.0	0	0	0	0.5	6	1.3	22			263,000	1.3	0.6
2042	226,666,805	136,306,764	90,360,042	3,160	2,842	6,002	2.78	3.77	3.18	1.2					0.0	0	0	0	0.0	0	0	0	0.5	6	1.2	21			263,000	1.2	0.5
2043	226,027,515	136,319,575	89,707,940	3,154	2,822	5,976	2.77	3.77	3.17	1.1					0.0	0	0	0	0.0	0	0	0	0.4	5	1.2	19			263,000	1.1	0.5
2044	225,436,946	136,347,305	89,089,641	3,148	2,802	5,951	2.77	3.77	3.17	1.1					0.0	0	0	0	0.0	0	0	0	0.4	5	1.1	18			263,000	1.1	0.5
2045	224,891,385	136,388,817	88,502,568	3,143	2,784	5,927	2.76	3.77	3.16	1.0					0.0	0	0	0	0.0	0	0	0	0.4	5	1.1	18	1,810,619	6	263,000	1.0	0.5
2046	224,387,403	136,527,242	89,860,161	3,132	2,772	5,905	2.79	3.70	3.16	1.0					0.0	0	0	0	0.0	0	0	0	0.4	5	1.0	16			263,000	0.9	0.4
2047	223,921,830	134,593,247	89,328,584	3,128	2,756	5,884	2.79	3.70	3.15	0.9					0.0	0	0	0	0.0	0	0	0	0.4	4	1.0	16			263,000	0.9	0.4
2048	223,491,740	134,670,116	88,821,624	3,123	2,740	5,864	2.78	3.70	3.15	0.9					0.0	0	0	0	0.0	0	0	0	0.3	4	0.9	15			263,000	0.8	0.4
2049	223,094,427	134,757,023	88,337,405	3,119	2,725	5,845	2.78	3.70	3.14	0.8					0.0	0	0	0	0.0	0	0	0	0.3	4	0.9	14			263,000	0.8	0.4
2050	222,727,395	134,853,201	87,874,194	3,115	2,711	5,827	2.77	3.70	3.14	0.79					0.0	0	0	0	0.0	0	0	0	0.3	4	0.8	14			263,000	0.8	0.4
2051	222,382,335	134,957,943	87,430,390	3,112	2,697	5,809	2.77	3.70	3.13	0.8					0.0	0	0	0	0.0	0	0	0	0.3	3	0.8	13	1,825,532	6	263,000	0.7	0.4
2052	222,075,115	133,139,869	88,935,246	3,102	2,691	5,793	2.79	3.63	3.13	0.7					0.0	0	0	0	0.0	0	0	0	0.3	3	0.8	12			263,000	0.7	0.4
2053	221,785,766	133,259,835	88,525,931	3,099	2,678	5,777	2.79	3.63	3.12	0.7					0.0	0	0	0	0.0	0	0	0	0.3	3	0.7	12			263,000	0.6	0.4
2054	221,518,669	133,386,553	88,131,916	3,095	2,666	5,762	2.78	3.63	3.12	0.7					0.0	0	0	0	0.0	0	0	0	0.2	3	0.7	12			263,000	0.6	0.4
2055	221,271,544	133,519,509	87,752,035	3,092	2,655	5,747	2.78	3.63	3.12	0.6					0.0	0	0	0	0.0	0	0	0	0.2	3	0.7	11			263,000	0.6	0.3
2056	221,043,437	133,658,227	87,385,210	3,090	2,644	5,733	2.77	3.63	3.11	0.6					0.0	0	0	0	0.0	0	0	0	0.2	3	0.7	11			263,000	0.6	0.3
2057	220,832,714	133,802,265	87,030,445	3,087	2,633	5,720	2.77	3.63	3.11	0.6					0.0	0	0	0	0.0	0	0	0	0.2	3	0.7	10			263,000	0.5	0.3
2058	220,638,052	133,951,228	86,686,823	3,084	2,623	5,707	2.76	3.63	3.10	0.6					0.0	0	0	0	0.0	0	0	0	0.2	3	0.6	10	1,829,796	6	263,000	0.5	0.3
2059	220,458,224	132,169,735	88,288,490	3,075	2,619	5,694	2.79	3.56	3.10	0.5					0.0	0	0	0	0.0	0	0	0	0.2	2	0.6	10			263,000	0.5	0.3
2060	220,292,102	132,327,453	87,964,649	3,073	2,609	5,682	2.79	3.56	3.09	0.5					0.0	0	0	0	0.0	0	0	0	0.2	2	0.6	9			263,000	0.5	0.3
2061	220,138,641	132,489,009	87,649,632	3,070	2,600	5,670	2.78	3.56	3.09	0.5					0.0	0	0	0	0.0	0	0	0	0.2	2	0.6	9			263,000	0.4	0.3
2062	219,996,874	132,654,165	87,342,709	3,068	2,591	5,659	2.77	3.56	3.09	0.5					0.0	0	0	0	0.0	0	0	0	0.2	2	0.6	9			263,000	0.4	0.3
2063	219,865,913	132,822,630	87,043,283	3,066	2,582	5,648	2.77	3.56	3.08	0.5					0.0	0	0	0	0.0	0	0	0	0.2	2	0.6	9			263,000	0.4	0.3
2064	219,744,932	132,994,151	86,750,780	3,064	2,573	5,637	2.76	3.56	3.08	0.5					0.0	0	0	0	0.0	0	0	0	0.2	2	0.5	8			263,000	0.4	0.3
2065	219,633,171	133,168,496	86,464,675	3,062	2,565	5,627	2.76	3.56	3.07	0.5					0.0	0	0	0	0.0	0	0	0	0.2	2	0.5	8			263,000	0.4	0.3
2066	219,529,928	133,345,448	86,184,480	3,060	2,556	5,616	2.75	3.56	3.07	0.5					0.0	0	0	0	0.0	0	0	0	0.2	2	0.5	8	1,864,078	6	263,000	0.4	0.3
2067	219,434,553	133,555,532	87,879,021	3,052	2,555	5,606	2.78	3.49	3.06	0.4					0.0	0	0	0	0.0	0	0	0	0.2	2	0.5	8			263,000	0.4	0.3
2068	219,346,447	131,737,119	87,609,327	3,050	2,547	5,596	2.78	3.49	3.06	0.4					0.0	0	0	0	0.0	0	0	0	0.2	2	0.5	8			263,000	0.4	0.3
2069	219,265,055	131,920,763	87,344,292	3,048	2,539	5,587	2.77	3.49	3.06	0.4					0.0	0	0	0	0.0	0	0	0	0.1	2	0.5	8			263,000	0.4	0.3
2070	219,189,867	132,106,306	87,083,561	3,046	2,531	5,577	2.77	3.49	3.05	0.4					0.0	0	0	0	0.0	0	0	0	0.1	2	0.5	7			263,000	0.4	0.3
2071	219,120,409	132,293,604	86,826,805	3,044	2,524	5,568	2.76	3.49	3.05	0.4					0.0	0	0	0	0.0	0	0	0	0.1	2	0.5	7			263,000	0.4	0.3
2072	219,056,244	132,482,523	86,573,721	3,043	2,517	5,559	2.75	3.49	3.04	0.4					0.0	0	0	0	0.0	0	0	0	0.1	2	0.5	7			263,000	0.3	0.3
2073	218,996,970	132,672,939	86,324,031	3,041	2,509	5,550	2.75	3.49	3.04	0.4					0.0	0	0	0	0.0	0	0	0	0.1	2	0.5	7			263,000	0.3	0.3
2074	218,942,213	132,864,738	86,077,474	3,039	2,502	5,541	2.74	3.49	3.04	0.4					0.0	0	0	0	0.0	0	0	0	0.1	2	0.5	7			263,000	0.3	0.3
2075	218,891,629	133,057,815	85,833,813	3,038	2,495	5,533	2.74	3.49	3.03	0.4					0.0	0	0	0	0.0	0	0	0	0.1	2	0.5	7	1,945,133	7	263,000	0.3	0.3
2076	218,844,900	133,201,740	85,643,160	3,029	2,495	5,524	2.77	3.41	3.03	0.4					0.0	0	0	0	0.0	0	0	0	0.1	2	0.5	7			263,000	0.3	0.3
2077	218,801,732	131,397,088	87,404,644	3,028	2,488	5,516	2.76	3.41	3.02	0.4					0.0	0	0	0	0.0	0	0	0	0.1	2	0.4	7			263,000	0.3	0.3
2078	218,761,855	131,593,444	87,168,411	3,026	2,481	5,508	2.76	3.41	3.02	0.4					0.0	0	0	0	0.0	0	0	0	0.1	2	0.4	7			263,000	0.3	0.3
2079	218,725,016	131,790,730	86,934,287	3,025	2,475	5,499	2.75	3.41	3.02	0.4					0.0	0	0	0	0.0	0	0	0	0.1	1	0.4	7			263,000	0.3	0.3
2080	218,690,985	131,988,876	86,702,110	3,023	2,468	5,491	2.75	3.41	3.01	0.4					0.0	0	0	0	0.0	0	0	0	0.1	1	0.4	7			263,000	0.3	0.3