MEMORANDUM

To: Susan Gordon, Multicultural Alliance for a Safe Environment (MASE) and Candace Head-Dylla, Bluewater Valley Downstream Alliance (BVDA)
From: Ann Maest, PhD, Buka Environmental
Date: 24 November 2019
Re: Evaluation of background selenium concentrations in the alluvial, mixed Chinle, Upper Chinle non-mixed, Middle Chinle non-mixed, and Lower Chinle non-mixed aquifers at the Grants Reclamation Project, New Mexico

Summary

The current groundwater protection standards (GWPS) for the Grants Reclamation Project Site do not accurately reflect pre-mining/milling-influenced, background conditions because the standards are based on many sample results that reflect mining influence. This memorandum presents an alternative approach to calculating GWPS values for the alluvial aquifer, the Chinle Mixing Zone (as a whole and separately for each section of the Chinle aquifer), and for each Chinle Non-Mixing Zone. A comparison of the results from the current and proposed GWPS values is shown in Table S-1.

Table S-1. Comparison of current and proposed GWPS dissolved selenium values (mg/L) for the Grants Reclamation Project Site.

Aquifer	Alluvial	Chinle Mixing Zone: Combined	Chinle Mixing: Upper	Chinle Mixing: Middle	Chinle Mixing: Lower	Upper Chinle Non-Mixing Zone	Middle Chinle Non-Mixing Zone	Lower Chinle Non-Mixing Zone
Current GWPS	0.32	0.14	Not determined			0.06	0.07	0.32
Proposed GWPS	0.063	0.079	0.011	0.078	0.082	0.024	0.027	0.022

Introduction

Groundwater protection standards (GWPS) for the Homestake Mining Company's Grants Reclamation Project were proposed by Homestake Mining Company and accepted by the New Mexico Environment Department (NMED), the US Environmental Protection Agency (EPA), and the Nuclear Regulatory Commission (NRC) in 2006 (NRC 2006; Arcadis 2018 and 2019*). The GWPS were published in the Federal Register in 2006 with a proviso that they could be re-evaluated if new information came to light*. The primary contaminants of concern around the former Homestake mill site are uranium and selenium. The GWPS also include values for molybdenum, sulfate, chloride, total dissolved solids (TDS), nitrate, vanadium, thorium-230, and radium 226 and 228 (Ra-226, Ra-228). The primary aquifers at the site are the alluvial aquifer and the underlying Chinle bedrock aquifer, which is divided into upper, middle, and lower sections. Each section of the Chinle aquifer has an upper mixing zone that has been influenced by mixing with groundwater from the alluvial aquifer.

This memorandum evaluates and recommends new selenium background values for the alluvial, mixed Chinle, Upper Chinle non-mixed, Middle Chinle non-mixed, and Lower Chinle non-mixed aquifers. The

memorandum discusses the approach, assumptions, and methods used. Plots, interpretations, and summaries of the results are included, as well as a discussion of the rationale for including and excluding certain data points or groundwater wells. A comparison of the new values to the current GWPS for selenium is presented in the summary sections at the beginning and end of the memorandum.

Data Sources, Assumptions, and Approach

Water Quality Data Used

The water quality data used for the background evaluation from Homestake/Holland and Hart was received through EPA on October 15, 2019 as an Access database called *GRANTS.mdb*. The data from this file is referred to as "Homestake database" in this evaluation. The main tables with water quality data are called GMB Data File and GMB Data File Archive. The first file includes more recent data (1997 to 2019), and the second file contains older water quality data from 1945 to 1996. The parameter list table is called GMC Parameter Codes, and tables called GMB System Codes, GMB Location Codes, and GMB Sample Points were also used. The GMB Sample Points table contains locational information (northings and eastings) for each well, total depth, locations (from GMB Location Codes, including, e.g., Felice Acres, Murray, Broadview), and sample point descriptions for some wells. All tables were exported to Excel as separate files. The wells used for this background evaluation in each of the five aquifers were identified using Arcadis (2019), Table 3. This allowed wells used for background evaluations to be sorted in Excel. Background water quality data for the more recent and archived files were selected and combined in one Excel worksheet to facilitate graphing. Far upgradient wells not used in the background evaluation were also identified in two original ~~the~~ water quality data files.

Assumptions and Approach

The following assumptions and approaches were used in the selenium background evaluation:

- The data in the Homestake database are an accurate representation of original data from the laboratories, the database was checked for quality control, and any transcription errors were corrected.
- The aquifer designations of wells in Arcadis (2019) and NRC (2006) are correct.
- The designations of wells in the three Chinle mixing and non-mixing zones (NRC, 2006, Table 3) are correct.
- None of the water quality data in the Homestake database are lab-rejected data, which are usually designated with an "R" qualifier (a column in the archived database called Lab Code has "R" entries, but the codes are not defined in the Access database). Rejected data should not be used in the background water quality evaluation.
- Background water quality is representative of natural conditions absent effects from uranium mining. Water quality data showing a consistent increase or decrease in concentration over time and across seasons or years for the identified contaminants of concern is an indication of mine-influenced water and should not be used for the background evaluation.
- Water quality samples from wells in identified contaminant plumes in the alluvial aquifer for a given time period have been affected by mine discharge and should not be used for the background evaluation.
- Results from wells before selenium concentrations began to increase can be used for background water quality.
- Results from wells showing increasing concentrations of uranium but not showing increasing concentrations of selenium can be used for selenium background water quality. The sources and relative mobility of the two elements control when the contaminant shows up at a given well. For example, the selenium plume may have reached a location before the uranium plume because uranium may be more reactive in the alluvial aquifer (Arcadis, 2018, p. 23).

- The alluvium under the LTP would have received alluvial groundwater from areas east of the East Fault and between the East and the West Faults. Therefore, a mix of groundwater from east and west of the East Fault should be considered in establishing background groundwater quality for selenium and other contaminants of concern (COCs), as long as they are not affected by mining activity.
- There are very few alluvial samples that are not affected by selenium from mining activity. In most cases, sulfate, calcium and other major elements are elevated but U and Se are not always elevated in these samples due to their different attenuation characteristics in the aquifer.

Results and Discussion

The selenium background water quality evaluation is presented for each of the aquifers and mixing zones within the Chinle aquifer in the following sections. The water quality data from the Homestake database were plotted versus time and compared to GWPS for the aquifer or mixing zone. The selenium GWPS for each aquifer and the Chinle Mixing Zone are presented in Table 1. All selenium GWPS are based on a site-specific statistically based value (Arcadis, 2019), but in many cases mining-influenced results were incorrectly included in the dataset used to determine background values.

Homestake (2015, p. 1-2) states that uranium concentrations used in the background analysis completed in 2004 have not been affected by upgradient mining and are representative of local natural conditions. The same approach would presumably apply to selenium and other COCs with established GWPS values.

Table 1. Groundwater Protection Standards for selenium (mg/L) in the alluvial and Chinle aquifers and the Chinle mixing zone.

Alluvial	Chinle Mixing Zone	Upper Chinle Non-Mixing Zone	Middle Chinle Non-Mixing Zone	Lower Chinle Non-Mixing Zone
0.32	0.14	0.06	0.07	0.32

Source: Arcadis, 2019, Table 1.

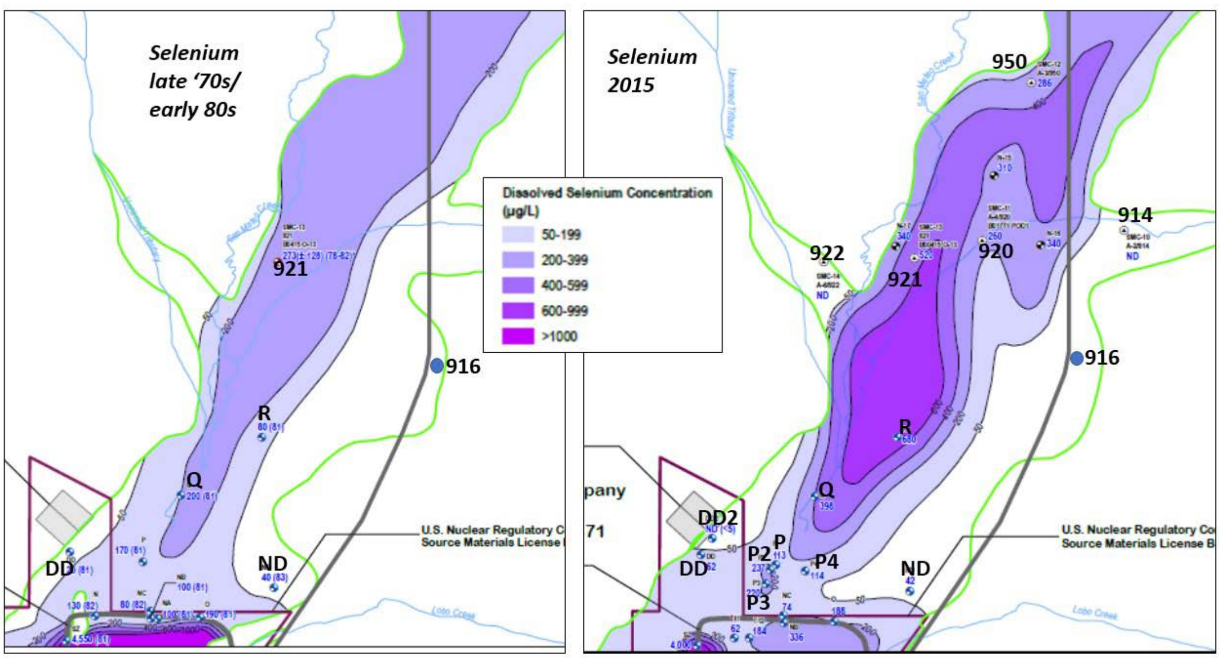
Alluvial Aquifer

Flow Paths

Uranium concentrations in the alluvial aquifer are believed to travel along different flow paths, as shown in Figure 1, reflecting higher uranium source materials to the west and lower uranium sources to the east. Selenium concentrations in the alluvial aquifer are generally higher on the western side of the aquifer, as shown in the plume maps in Figure 2. Concentrations in the center of the selenium plume have increased markedly between the late 1970s/early 1980 to the present. As shown in Figure 3, uranium concentrations are high in well DD, which is used in the alluvial background evaluation, but have been decreasing recently. In contrast, selenium concentrations in DD have remained low until recently. The increasing concentrations of sulfate and nitrate in well DD since approximately 2010 (Figure 3) suggest that the plume of mine contamination from the north has reached this area recently, and is increasing selenium concentrations and decreasing uranium concentrations. These results are an indication that uranium at this location is either natural or caused from another mining source, but that selenium is likely related to upgradient sources.

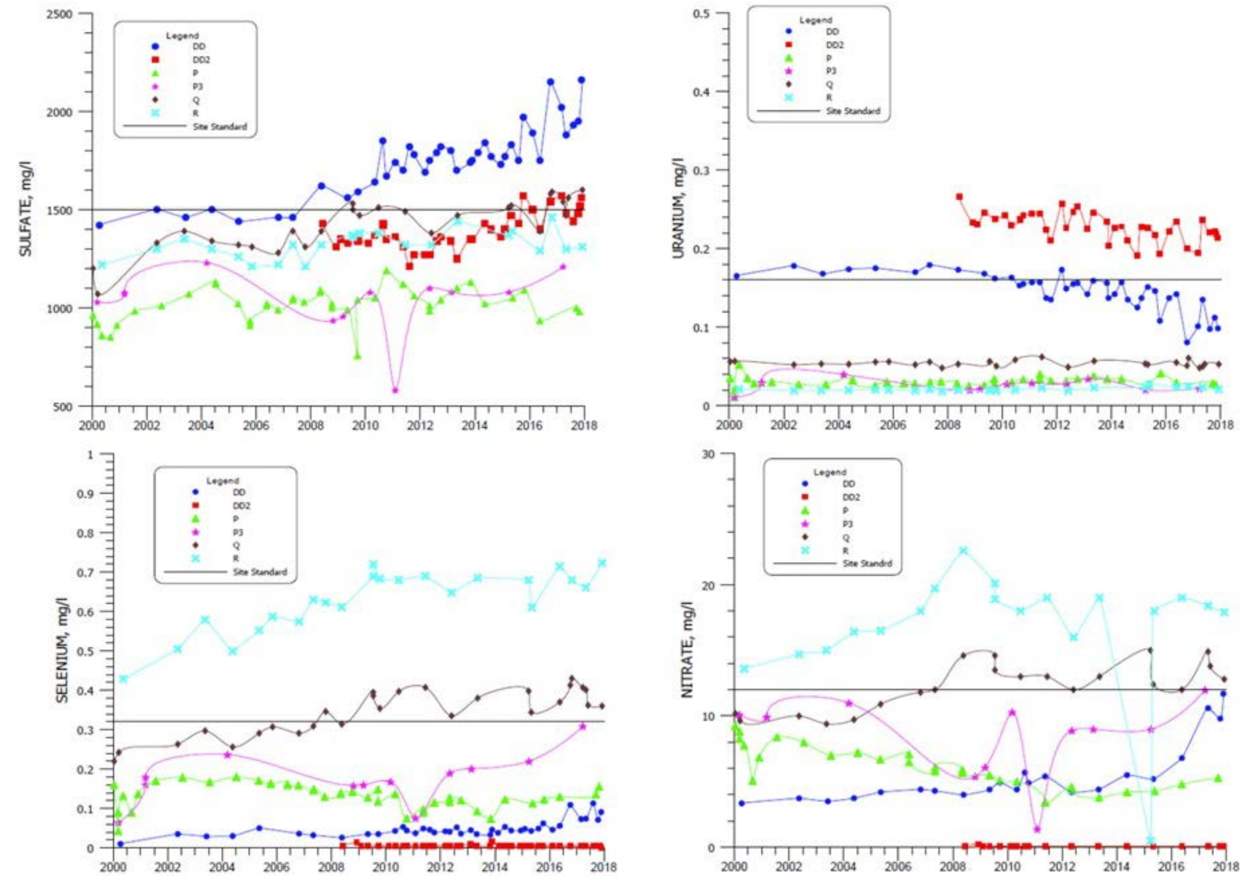
Source: Purcell (2019).

Figure 1. Separate groundwater flow paths for high and low uranium groundwater in the alluvial aquifer. Note that the high-uranium water does not flow through the immediate LTP area.



Source: Modified from Weston Solutions, 2018, Figures A4-17 & A4-18 (approximate location of well 916 taken from Fig. A4-28)

Figure 2. Selenium plume maps for late 1970s/early 1980s and 2015, alluvial aquifer.



Source: Homestake and Hydro-Engineering, 2018. Figures 4.3-3, 4.3-54, 4.3-71, 4.3-105.

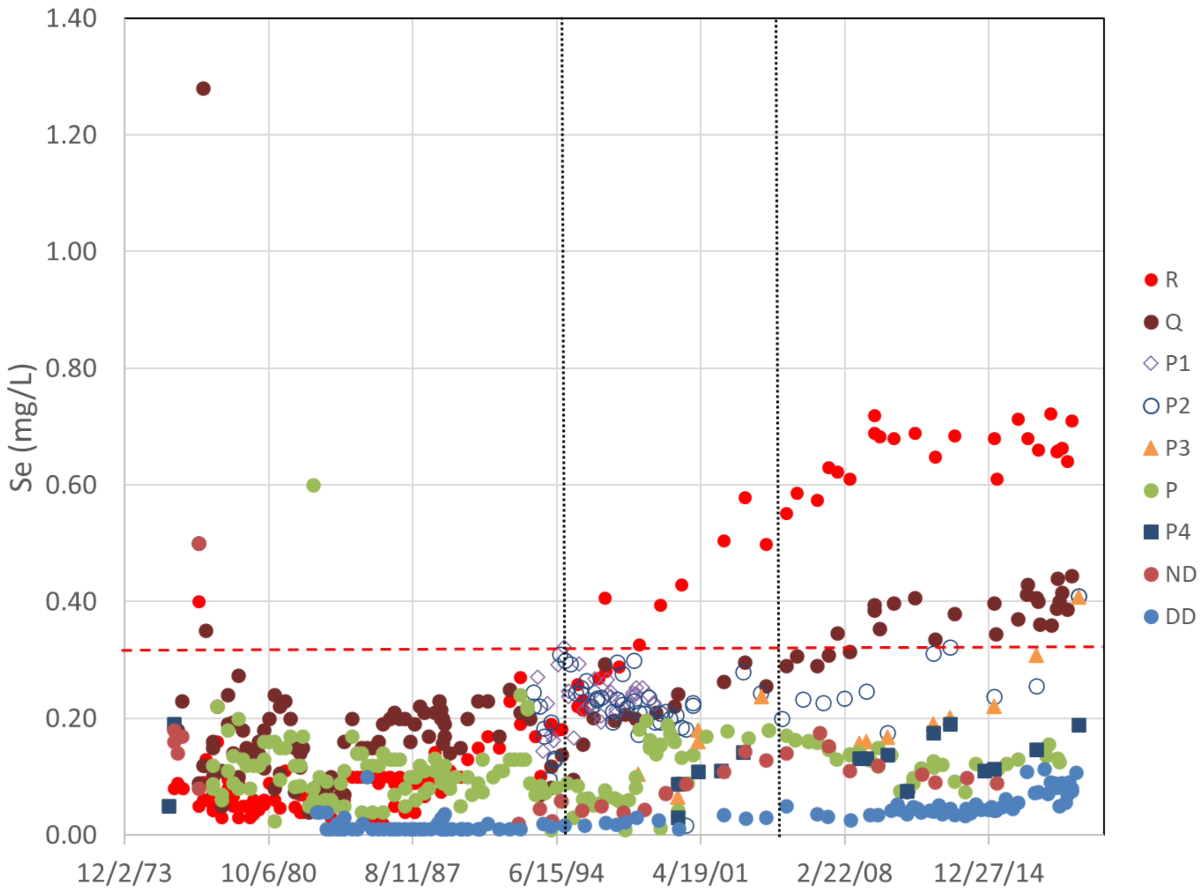
Figure 3. Concentrations of sulfate, uranium, selenium, and nitrate in near-upgradient wells from 2000 to 2017.

Wells and Time Periods Used

The current GWPS for the alluvial aquifer are based on values from 1995 to 2004 for the near-upgradient wells and include wells DD, ND, P, P1, P2, P3, P4, Q, and R (NRC, 2016; Arcadis, 2019). Figure 4 shows the nine wells selected for the background determination by NRC (2006) from the mid-1970 through 2018. The time period selected for the current background analysis (1995 through 2004) is shown by the vertical black lines in Figure 4.

However, very few wells in the center of the alluvial aquifer are unaffected by mine-influenced water in the period 1995 to 2004, as shown in Figure 5. All alluvial wells except DD, P1, and P2 used in the current GWPS evaluation had increasing concentrations of selenium during this time period, indicating mine-related influence, likely from upgradient mines in the San Mateo Creek basin. Because the selenium plume appears to be moving more rapidly from upgradient mining sources than the uranium plume, earlier sampling results are less likely to be impacted.

As noted in Homestake (2015, p. 1-3), selenium and nitrate concentrations in wells Q and R showed impacts from upgradient mining beginning in the mid-1990s. Therefore, these two wells should not be used for background determination, especially in the period 1995-2004.



Data source: Homestake Access groundwater chemistry database.

Figure 4. Dissolved selenium concentrations in near upgradient, selected background alluvial wells. The red dashed line indicates the GWPS of 0.32 mg/L Se, and the vertical black lines indicate the selected time period of 1995 to 2004.

The proposed GWPS exclude wells Q and R and use wells P (1995-1997), DD (1981-2014), ND (1983-1998), and 916 (1994-2005). Selenium concentrations in wells P1 and P2 have consistent concentrations over the narrow period of sampling (see Figure 5), but concentrations are similar to those in R and Q, which are known to be affected by mining-related sources. While wells R and Q had lower concentrations before the early 1990s, wells P1 and P2 were not sampled during this timeframe. P3 concentrations increased from the first sampling, so this well was excluded from consideration as background. Well P concentrations jumped in 1998, and concentrations from 1998 forward are not used.

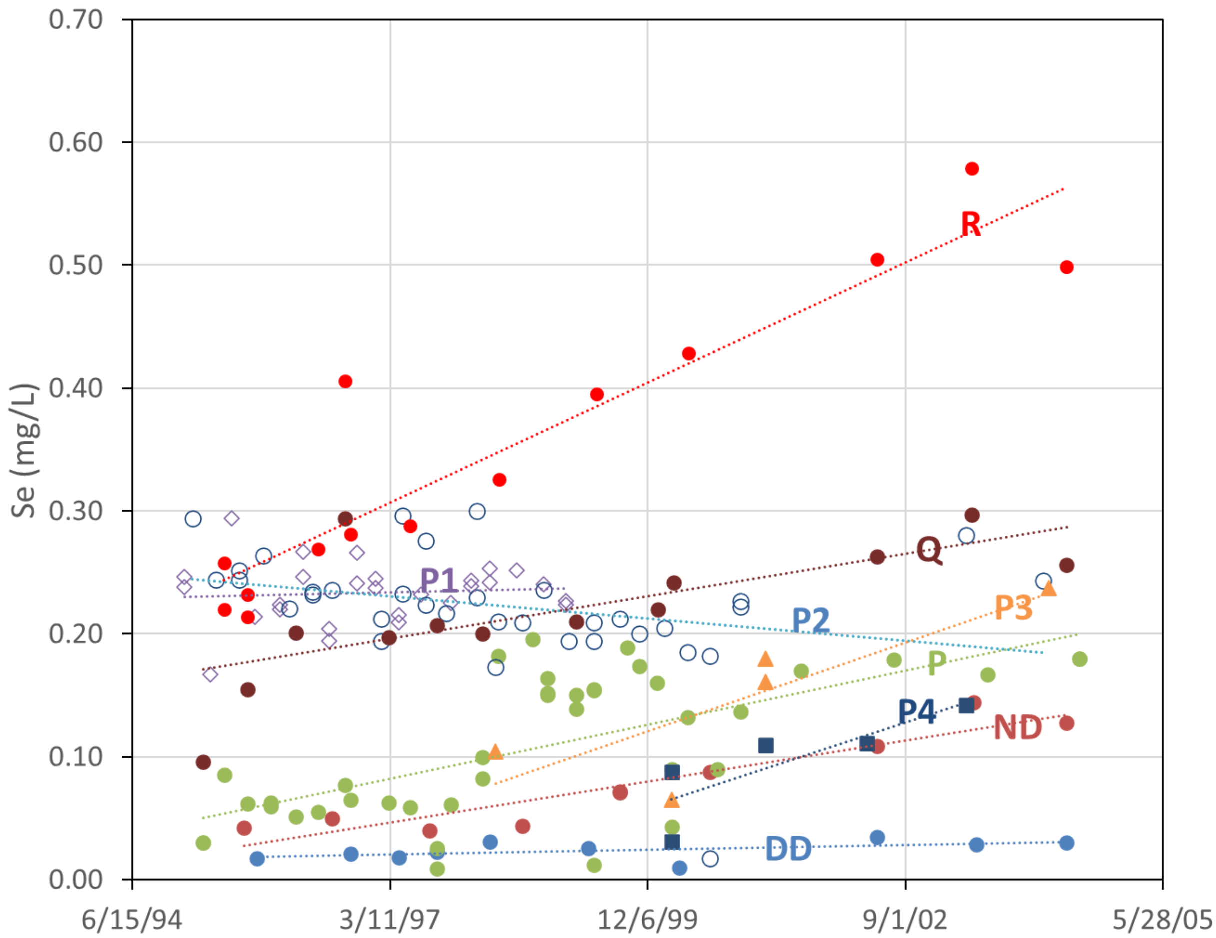
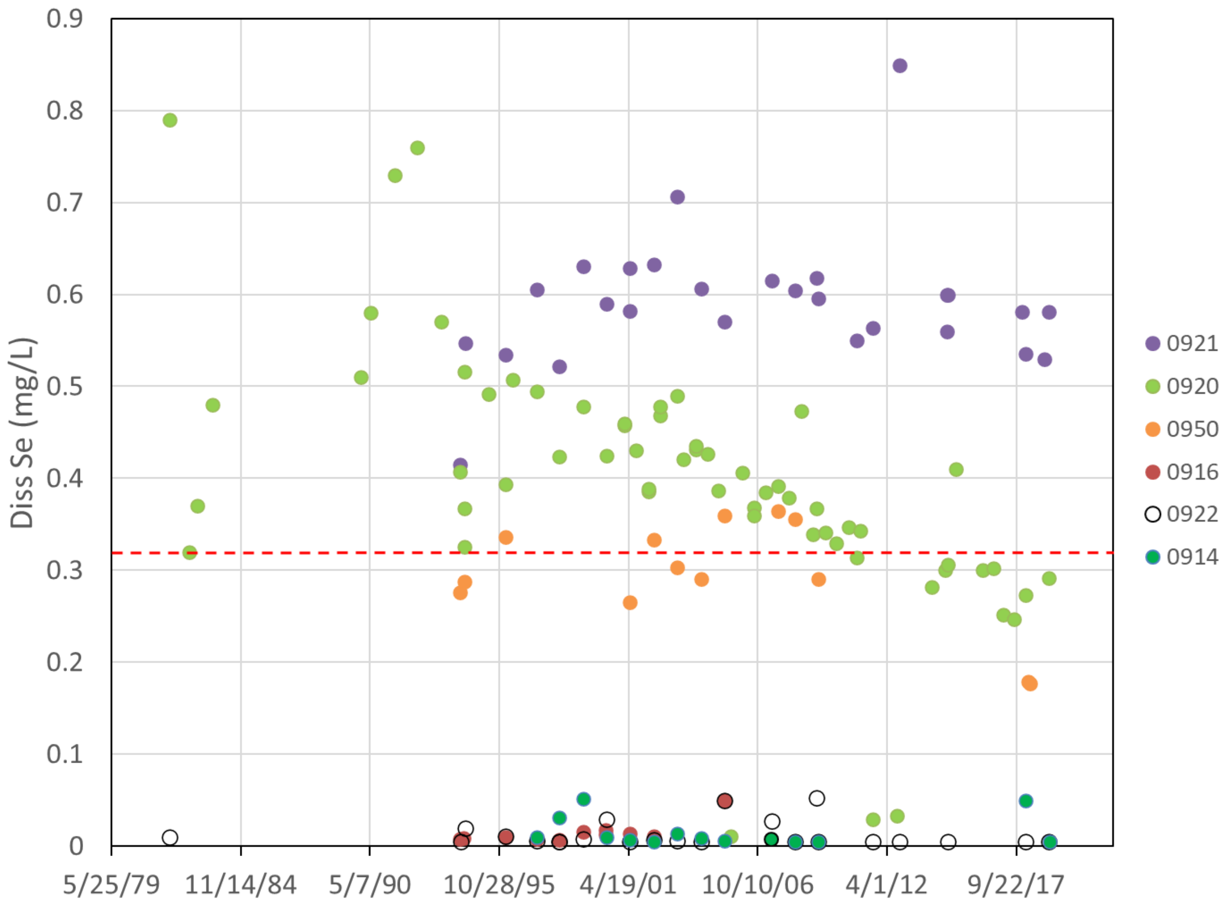


Figure 5. Selenium concentrations from 1995 through 2004 in the near upgradient wells used for background water quality.

The selenium concentrations in the “far upgradient” wells are shown in Figure 6; these wells were not used for background determination based on comments from the New Mexico Environment Department (NMED) (NRC, 2006, p. 7). The locations of the far upgradient wells are shown in Figure 2 (right side). Although not stated explicitly by Homestake (2015), some of the reasons for excluding the far upgradient wells are: 1) some wells appear to be impacted by uranium from farther upgradient mining sources (well 920), and uranium concentrations have begun to increase in wells 921 and 950 (Homestake, 2015, p. 2-8); and 2) the water chemistry is different between the far upgradient wells known to be impacted from upgradient mining (Homestake, 2015, p. 2-11 – 2-12). However, the major element chemistry was shown to be similar in far upgradient well 920 and the near upgradient wells (Arcadis, 2018, p. 21). Another reason for excluding the far upgradient wells is that they are domestic wells without adequate well completion information. Well 916 is the only far upgradient well with information on total depth and the screened interval (Homestake, 2018 Tables 4.1-1 and 4.1-4.). Far upgradient well 916 was therefore used for the proposed GWPS evaluation. Well 916 is also called B-0013R and SMC-08 (see Phase 2 report, Fig. A4-28 for TDS and Fig. A4-22 for SO4). Results for well 916 were reported for the entire monitoring period.



Data source: Homestake Access groundwater chemistry database.

Figure 6. Dissolved selenium concentrations in far upgradient alluvial wells. The red dashed line indicates the GWPS of 0.32 mg/L Se. Only wells 914, 916, and 922 have stable Se concentrations over time and are outside the selenium plume in the alluvial aquifer (see Fig. 1).

The rank percentile values for the wells ~~and~~ time periods used for the proposed alluvial aquifer GWPS are shown in Figure 7. The total number of values was 131. Because only 9.2% of the values were below detection, they were replaced by ½ the detection limit. However, because the 95th percentile is used to calculate the GWPS, differences in the low concentration range do not affect the high percentile values. The most common detection limit was 0.01 mg/L; 27 of the 131 values were at the detection limit (but not marked as below detection) and therefore have the same percentile (hence the gap in the curve). The resulting 95th percentile value was 0.0625 mg/L selenium.

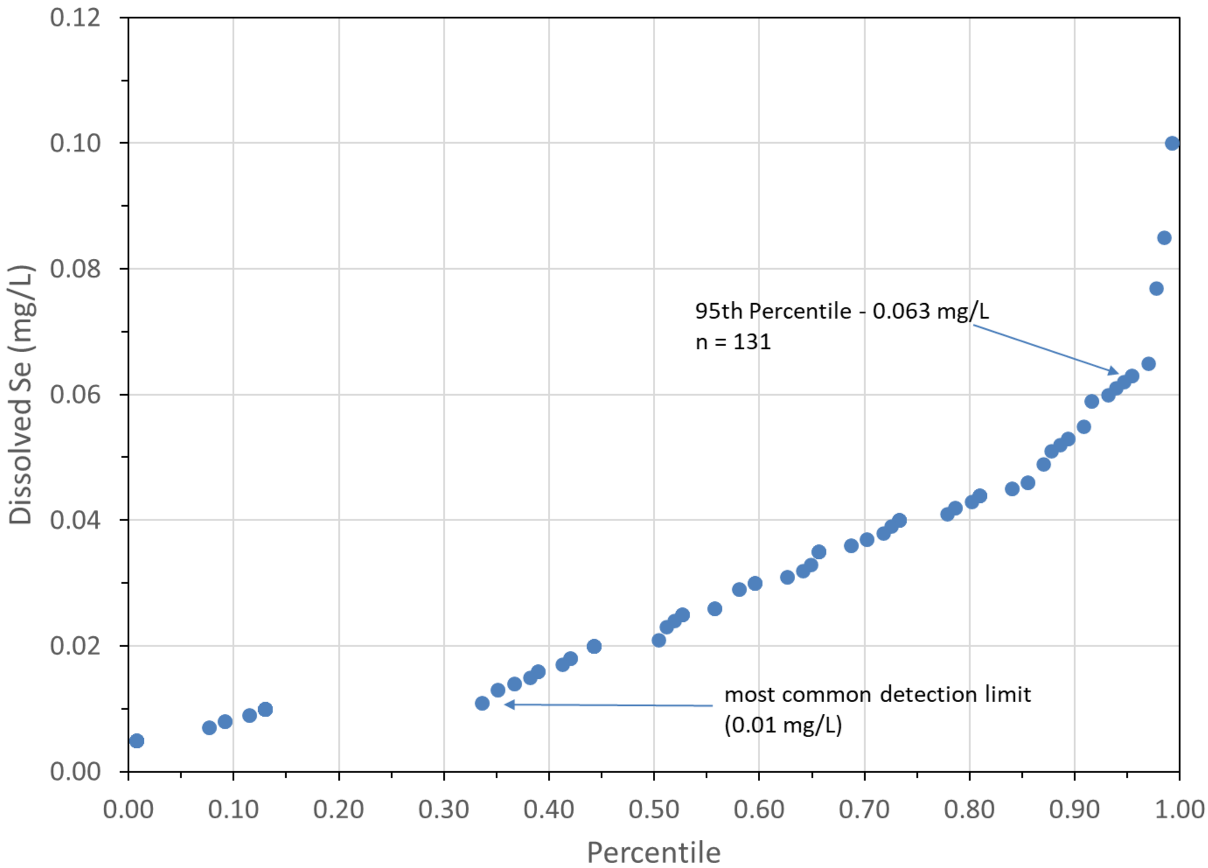
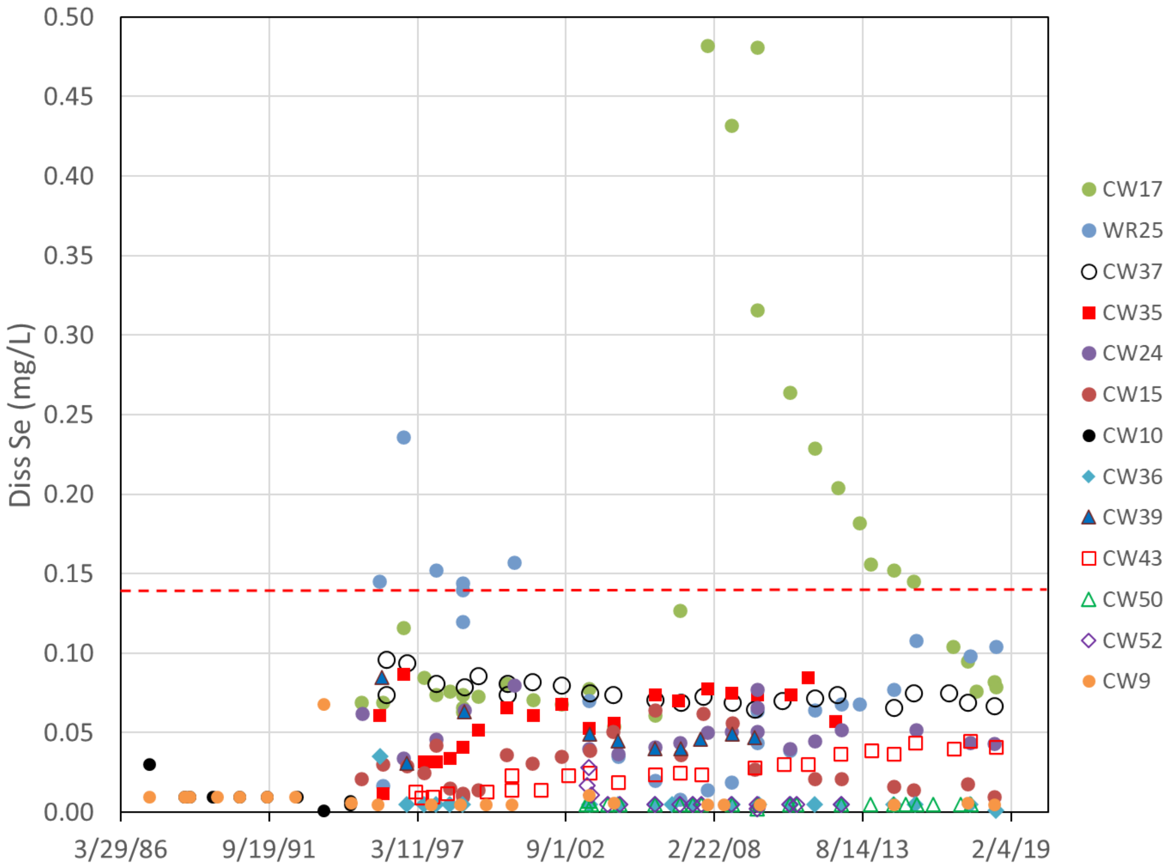


Figure 7. Rank percentile for selenium background values in the alluvial aquifer.

Chinle Mixing Zones

The selenium concentrations for all wells used in the background evaluation are shown in Figure 8. Wells CW17 and WR25 are clearly influenced by mining activity – WR25 in the mid/late 1990s and CW17 starting in 2006. Without these mining-influenced points, Chinle Mixing Zone Se background would be substantially lower than the current GWPS of 0.32 mg/L. The Chinle Mixing Zone was divided into its three aquifer components – Upper, Middle, and Lower – and each Chinle Mixing Zone is discussed in the following sections.



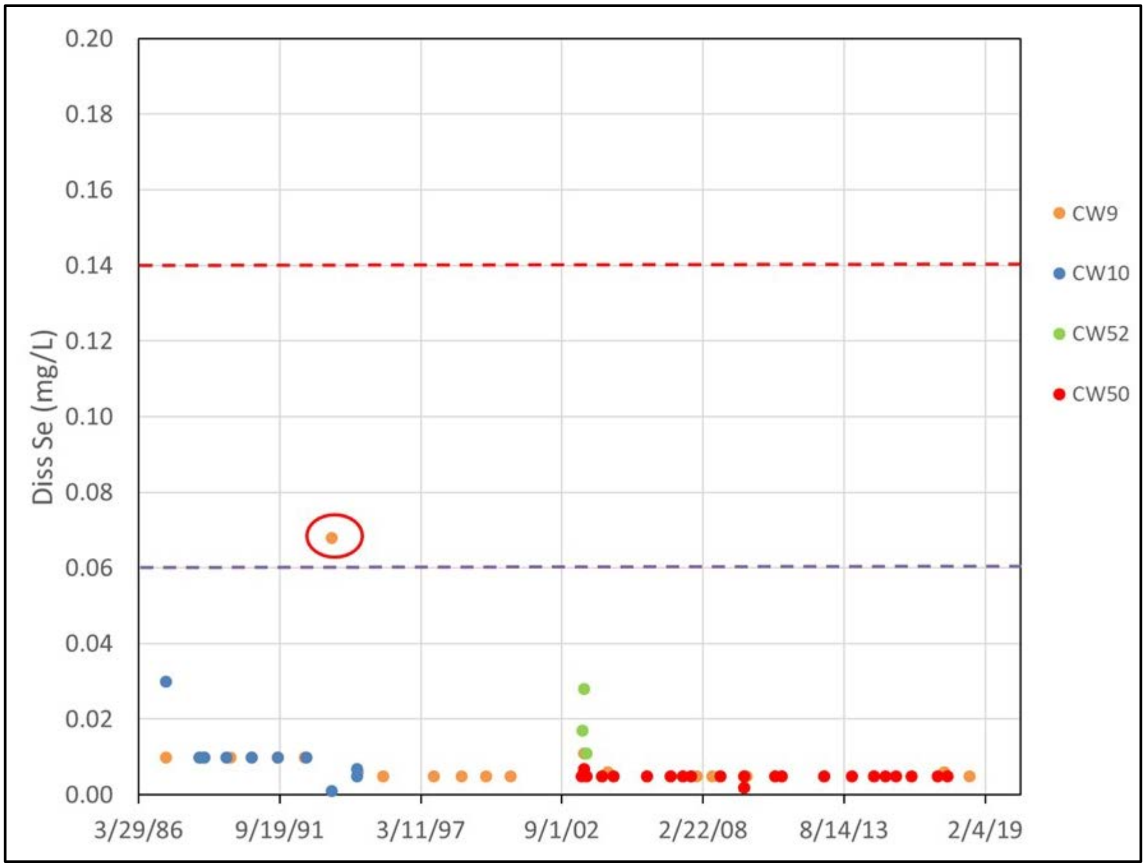
Data source: Homestake Access groundwater chemistry database.

Figure 8. Dissolved selenium concentrations in all Chinle Mixing Zone wells used for background. The red dashed line indicates the GWPS of 0.32 mg/L Se.

Upper Chinle Mixing Zone

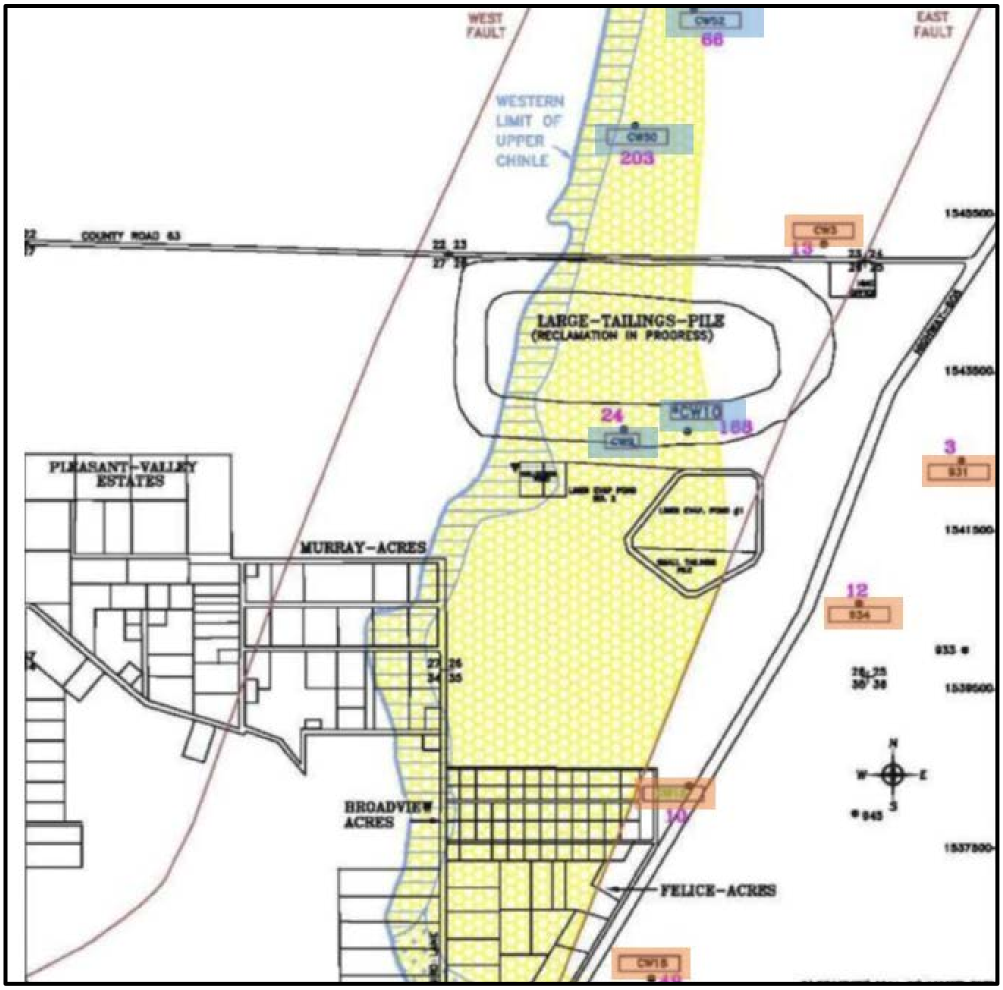
The selenium concentrations in the Upper Chinle Mixing Zone are shown in Figure 8a for all results in the Homestake database. The circled point for well CW9 shown in Figure 8a was eliminated as an extreme outlier because it was more than six times higher than the other CW9 values, and 11 of the 22 CW9 values were below detection at 0.006 or 0.005 mg/L.

The location of the Upper Chinle aquifer is shown in Figure 8a.1, with the subcrop below areas of saturated alluvium depicted in blue horizontal lines. Wells CW9 and CW10 are located at depth under the LTP, and wells CW50 and CW52 are located at depth north of the LTP. The wells do not appear to be affected by milling activity. The 95th percentile was calculated using all data shown in Figure 8a except the high circled point for CW9. The 95^{th} percentile for the Upper Chinle Mixing Zone data is 0.011 mg/L using 68 data points with 67.7% below detection at 0.005 or 0.006 mg/L.



Data source: Homestake Access groundwater chemistry database.

Figure 8a. Dissolved selenium concentrations in the Upper Chinle Mixing Zone wells used for background (1987 – 2017). The red dashed line indicates the GWPS for the Chinle Mixing Zone of 0.14 mg/L Se, and the purple dashed line indicates the GWPS for the Upper Chinle Non-Mixing Zone of 0.06 mg/L.



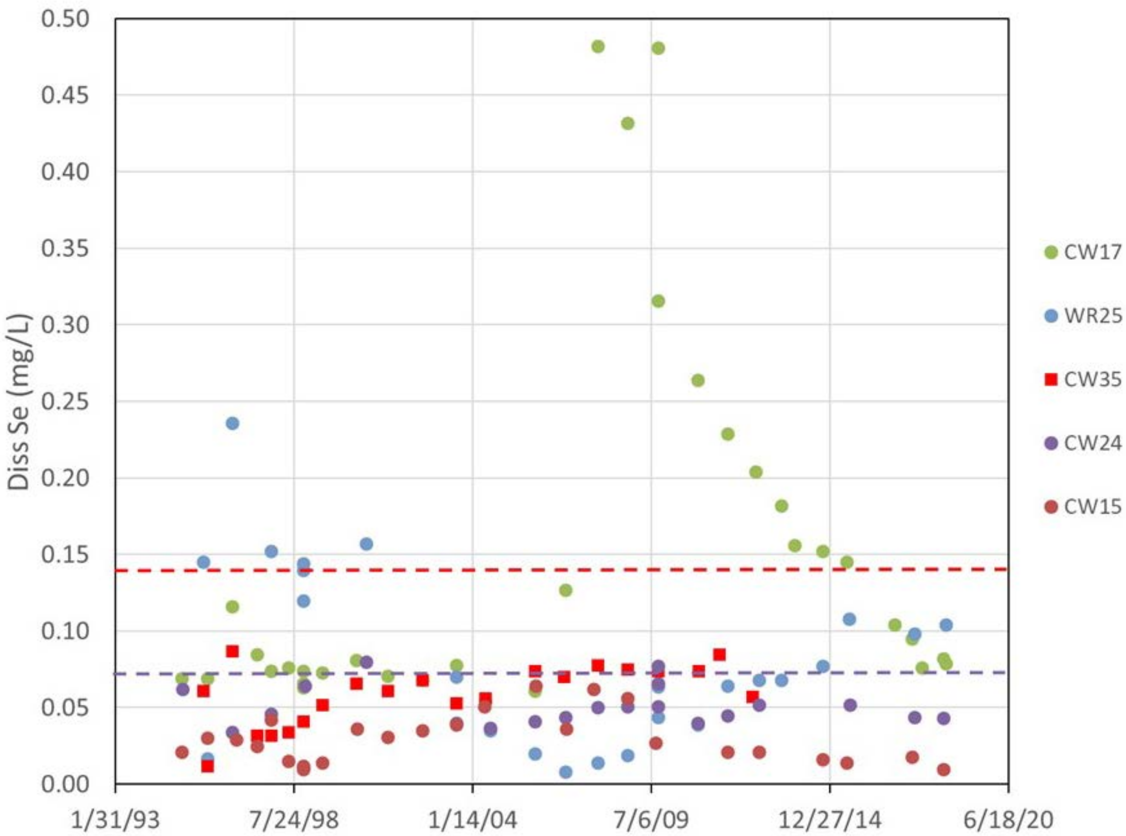
Source: Modified from Homestake, 2015, Figure 6-1.

Figure 8a.1. Location of wells used for background water quality in the Upper Chinle Mixing (blue highlight) and Non-Mixing (orange highlight) zones. Blue horizontal lines denote Upper Chinle subcrop areas below saturated alluvium, while blue plus signs denote subcrop areas below unsaturated alluvium (Homestake, 2015).

Middle Chinle Mixing Zone

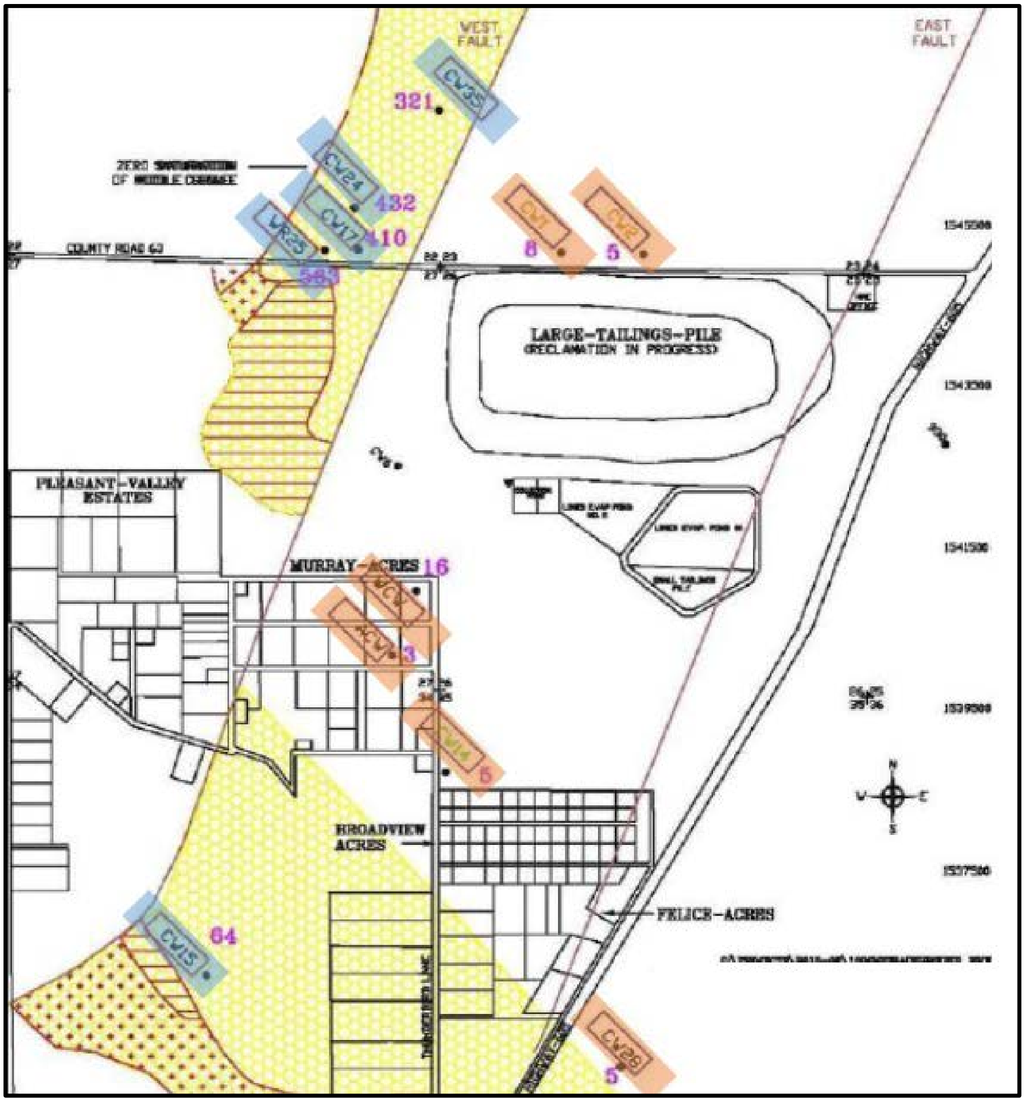
Higher selenium concentrations are present in the Middle Chinle than the Upper Chinle Mixing Zone wells. Results from this zone (and the Lower Chinle Mixing zone, as discussed in the following section) will control remediation values for the combined Chinle Mixing Zone if they do not have separate remediation targets.

Selenium concentrations in the Middle Chinle Mixing Zone from 1995 to 2018 are shown in Figure 8b. The locations of all Middle Chinle wells (mixing zone and non-mixing zone) are shown in Figure 8b.1. Results from well CW17 (see Figure 8b) were eliminated from consideration because early values contained notable unexplained spikes; values increased sharply in November 2006 followed by a steady decrease in concentrations, indicating mining influence. All values for well WR25 were eliminated from consideration. Early results for well WR25 contained spikes from October 1995 to October 2000, and values from November 2007 to July 2015 consistently increasing, indicating mining influence. Using all the remaining 68 values in Figure 8b, the 95th percentile is 0.078 mg/L Se; no values were below detection.



Data source: Homestake Access groundwater chemistry database.

Figure 8b. Dissolved selenium concentrations in the Middle Chinle Mixing Zone wells used for background (1995 – 2018). The red dashed line indicates the GWPS for the Chinle Mixing Zone of 0.14 mg/L Se, and the purple dashed line indicates the GWPS for the Middle Chinle Non-Mixing Zone of 0.07 mg/L.

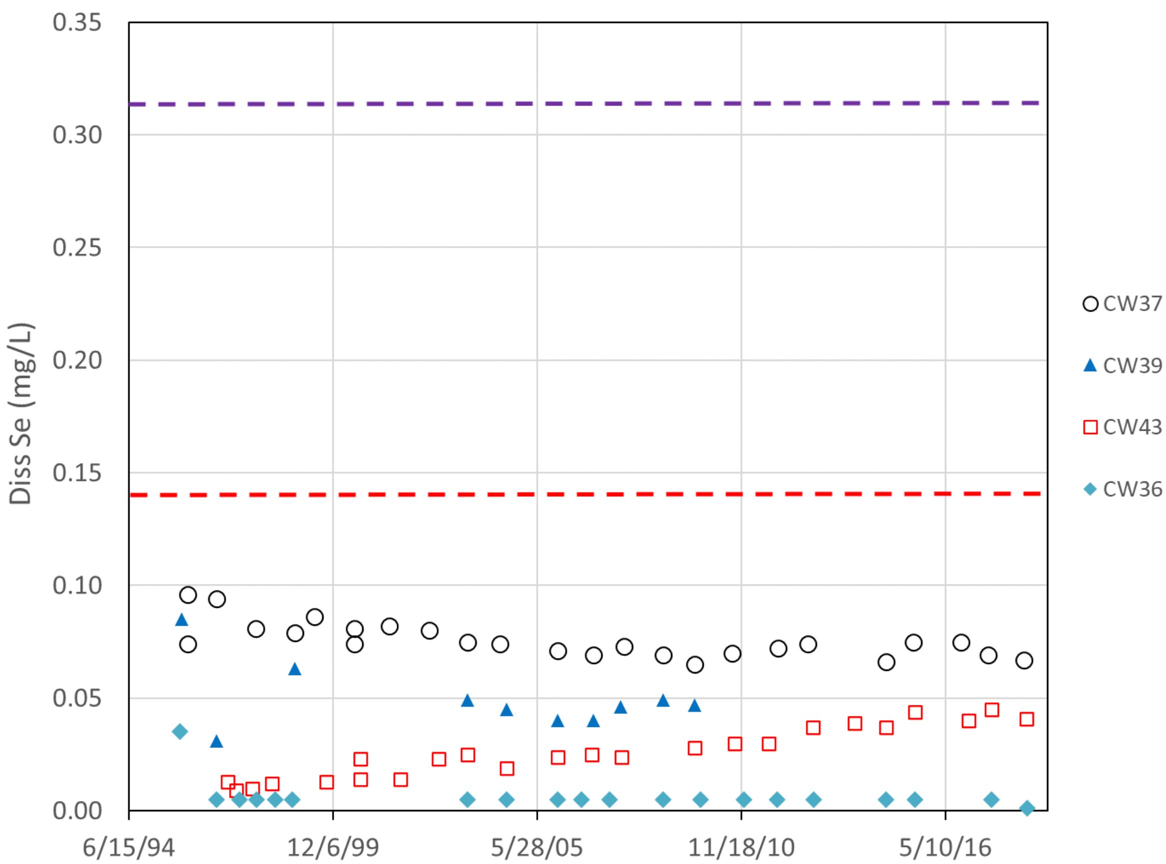


Source: Modified from Homestake, 2015, Figure 6-2.

Figure 8b.1. Location of wells used for background water quality in the Middle Chinle Mixing (blue highlight) and Non-Mixing (orange highlight) zones. ~~Areas with~~ Brown horizontal lines denote Middle Chinle subcrop areas below saturated alluvium, while ~~areas with~~ brown plus signs denote subcrop areas below unsaturated alluvium (Homestake, 2015). Non-Mixing Zone well CW14 southeast of Murray Acres is a water injection well, and wells CW1 and CW2 north of the LTP are remediation collection wells.

Lower Chinle Mixing Zone

Groundwater was pumped from all three Chinle aquifers during site remediation for elevated uranium concentrations (Homestake, 2019, p. 1.1-5). Pumping of the Lower Chinle aquifer began around 1999, and uranium concentrations were subsequently reduced. Selenium concentrations from 1995 through 2017 are shown in Figure 8c with the current GWPS values for the Chinle Mixing Zone as a whole (red line, 0.14 mg/L Se) and the current GWPS for the Lower Chinle Non-Mixing Zone (purple line, 0.32 mg/L Se). Both standards are substantially higher than selenium concentrations in the Lower Chinle Mixing Zone, suggesting that selenium concentrations in the Lower Chinle Non-Mixing Zone are higher than in the Lower Chinle Mixing Zone. Therefore, the current GWPS (0.14 mg/L Se) for the mixing zone as a whole should not be used as background for the Lower Chinle Mixing Zone.



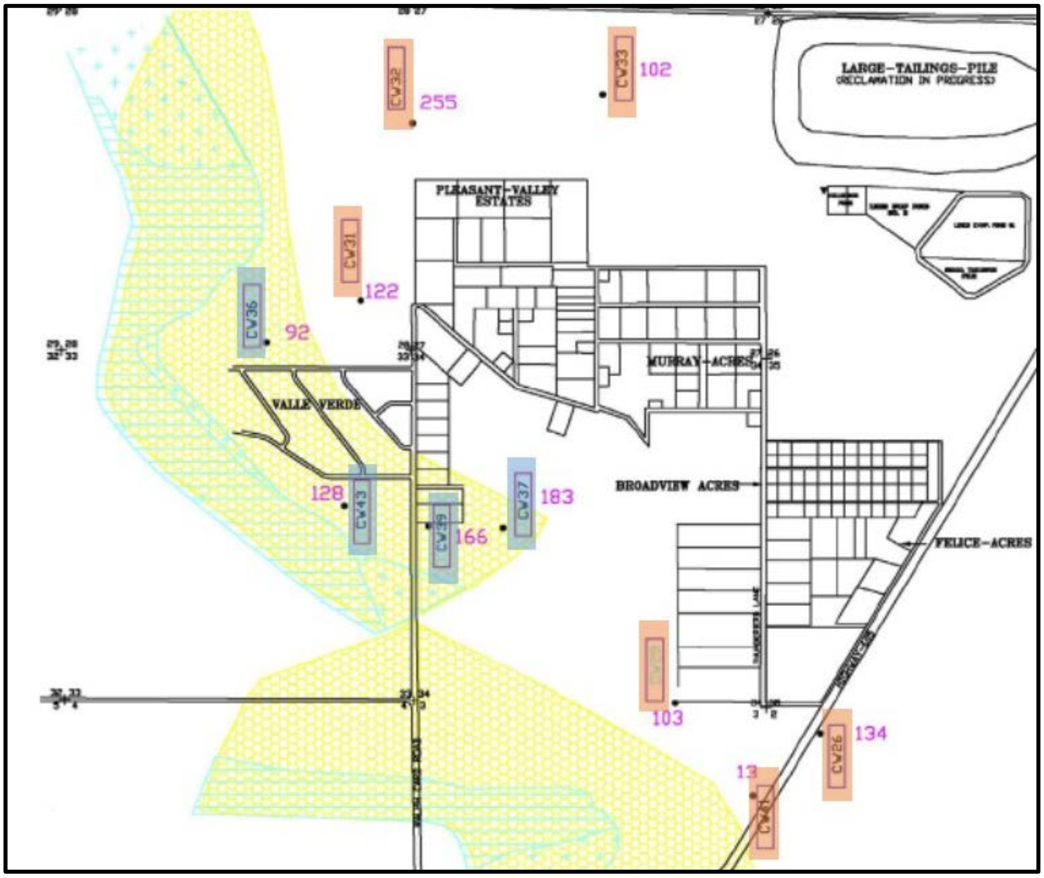
Data source: Homestake Access groundwater chemistry database.

Figure 8c. Dissolved selenium concentrations in the Lower Chinle Mixing Zone wells used for background (1995 – 2018). The red dashed line indicates the current GWPS for the Chinle Mixing Zone as a whole of 0.14 mg/L Se, and the purple dashed line indicates the GWPS for the Lower Chinle Non-Mixing Zone of 0.32 mg/L.

The wells used for background in the Lower Chinle Mixing Zone are shown in Figure 8c.1 and include well CW36, just north of Valle Verde; well CS43, just south of Valle Verde, and wells CW39 and CS37, south of Pleasant Valley Estates and southeast of well CW43. All wells are west of the West Fault.

Concentrations in well CW37 and possibly CW39 show a slight decrease over time, and values in well CW43 are increasing over time (see Figure 8c). Ongoing remediation efforts make it difficult to estimate a representative background concentration for selenium (or any other constituent) in wells affected by

remedial measures. However, no data were excluded for evaluation of the proposed GWPS for the Lower Chinle Mixing Zone. Using all 79 data points shown in Figure 8c, the 95th percentile value for selenium is 0.082 mg/L, with 24% of the values below detection at 0.005 mg/L Se (one value was below detection at 0.001 mg/L).



Source: Modified from Homestake, 2015, Figure 6-3.

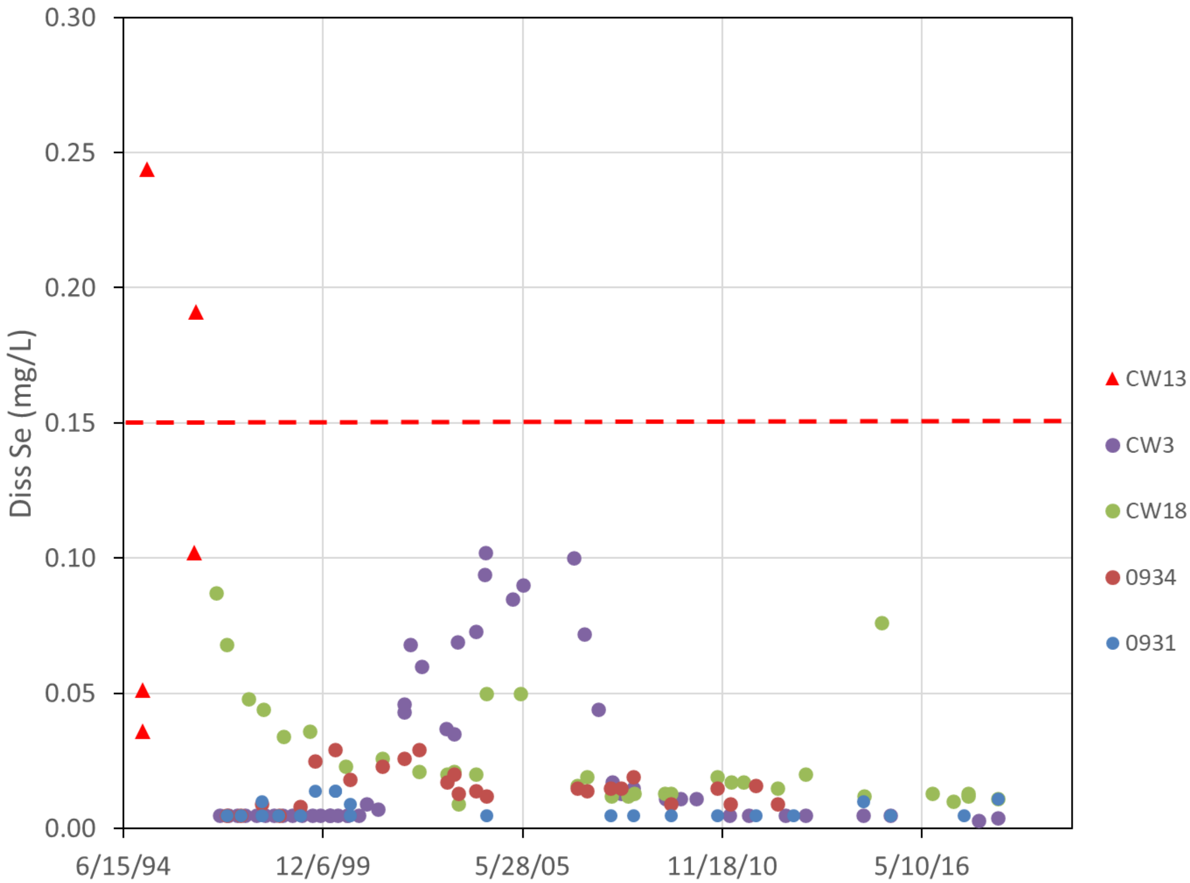
Figure 8c.1. Lower Chinle aquifer showing wells near the communities south of the LTP. ~~Areas with~~ Blue horizontal lines denote Lower Chinle subcrop areas below saturated alluvium, while ~~areas with~~ blue plus signs denote subcrop areas below unsaturated alluvium (Homestake, 2015).

Chinle Mixing Zone Combined

Combining all 215 selenium results used in the analyses above, the 95th percentile for the Chinle Mixing Zone is 0.079 mg/L; 30.2% of the values were below detection. The current GWPS for the Chinle Mixing Zone is 0.14 mg/L Se. The values in the Middle and Lower Mixing Zones control both the proposed and current GWPS. Given the large variability in concentrations among the three mixing zones, different remediation targets should be set for each of the three mixing zones, or at least for the Upper Mixing Zone. More work should be done to better distinguish impacted and true background values in the Middle Chinle Mixing Zone.

Upper Chinle Non-Mixing Zone

The locations of wells used for background water quality in the Upper Chinle Non-Mixing Zone are shown in Figure 8a.1 in orange highlight. Wells 931 and 934 are east of the East Fault; CW3 is between the West and East Faults; and CW13 (in green type) is east of the East Fault and is a freshwater injection well used for remediation. Well CW18 is located southeast of Felice Acres and is east of the East Fault.



Data source: Homestake Access groundwater chemistry database.

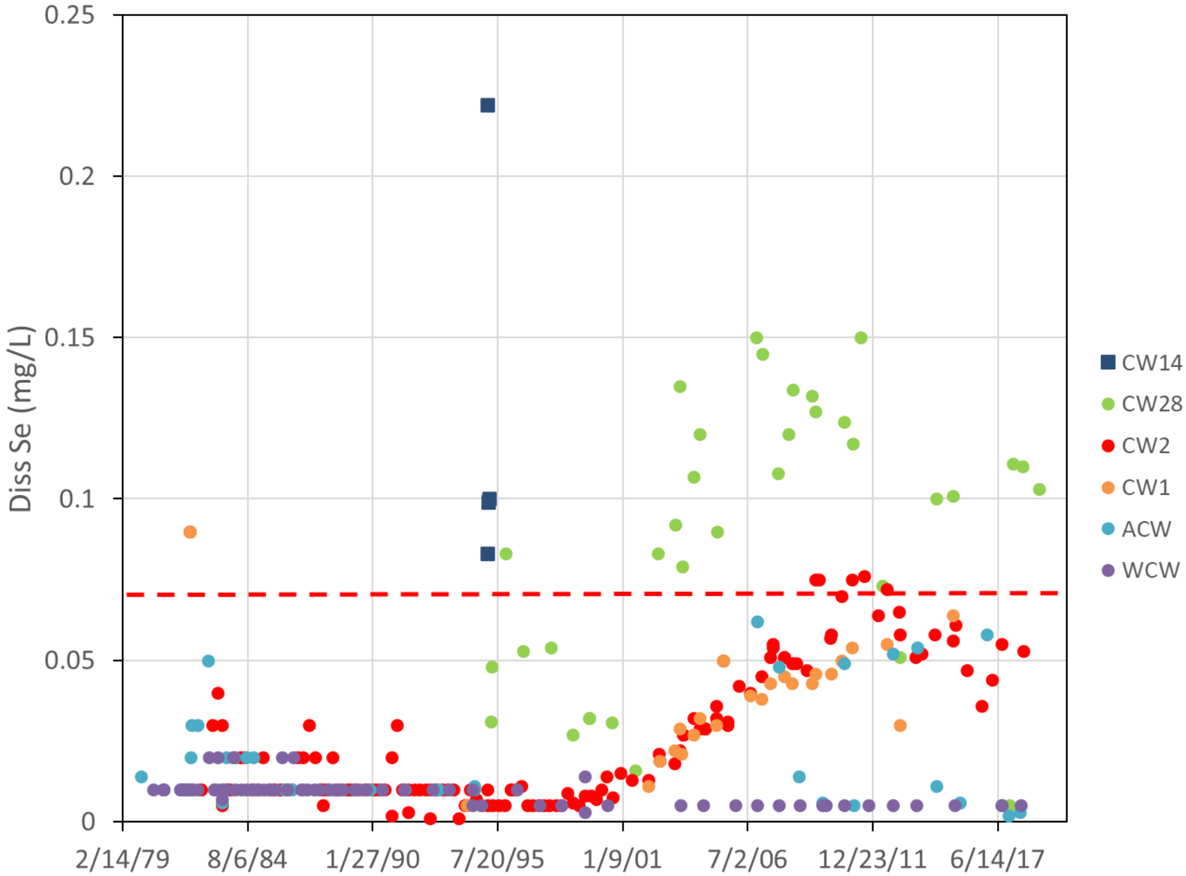
Figure 9a. Dissolved selenium concentrations in the Upper Chinle Non-Mixing Zone wells used for background. The red dashed line indicates the current GWPS for the Upper Chinle Non-Mixing Zone of 0.06 mg/L Se.

Selenium concentrations for the NRC-selected Upper Chinle Non-Mixing Zone wells are shown in Figure 9a. Well CW13 concentrations are high and erratic - it is used as a remediation freshwater injection well, and none of the results should be used for background. Results from February 2002 onward in well CW3 should be excluded because they reflect increasing concentrations from mining-influenced sources (concentrations increased more than eight times; all previous concentrations were below detection). All Well CW18 data should be excluded ~~completely~~ because concentrations were high initially (first sample was collected in January 1997) and more recent concentrations may not yet reflect lower pre-mining background levels.

Of the 48 remaining selenium results, 70.8% were below detection at 0.005 mg/L, and the 95th percentile value is 0.024 mg/L Se.

Middle Chinle Non-Mixing Zone

The location of wells used by NRC (2006) for background water quality in the Middle Chinle Non-Mixing Zone are shown in Figure 8b.1 (orange highlighted locations). Non-Mixing Zone well CW14, located southeast of Murray Acres, is a water injection well, and wells CW1 and CW2, located north of the LTP, are remediation collection wells.



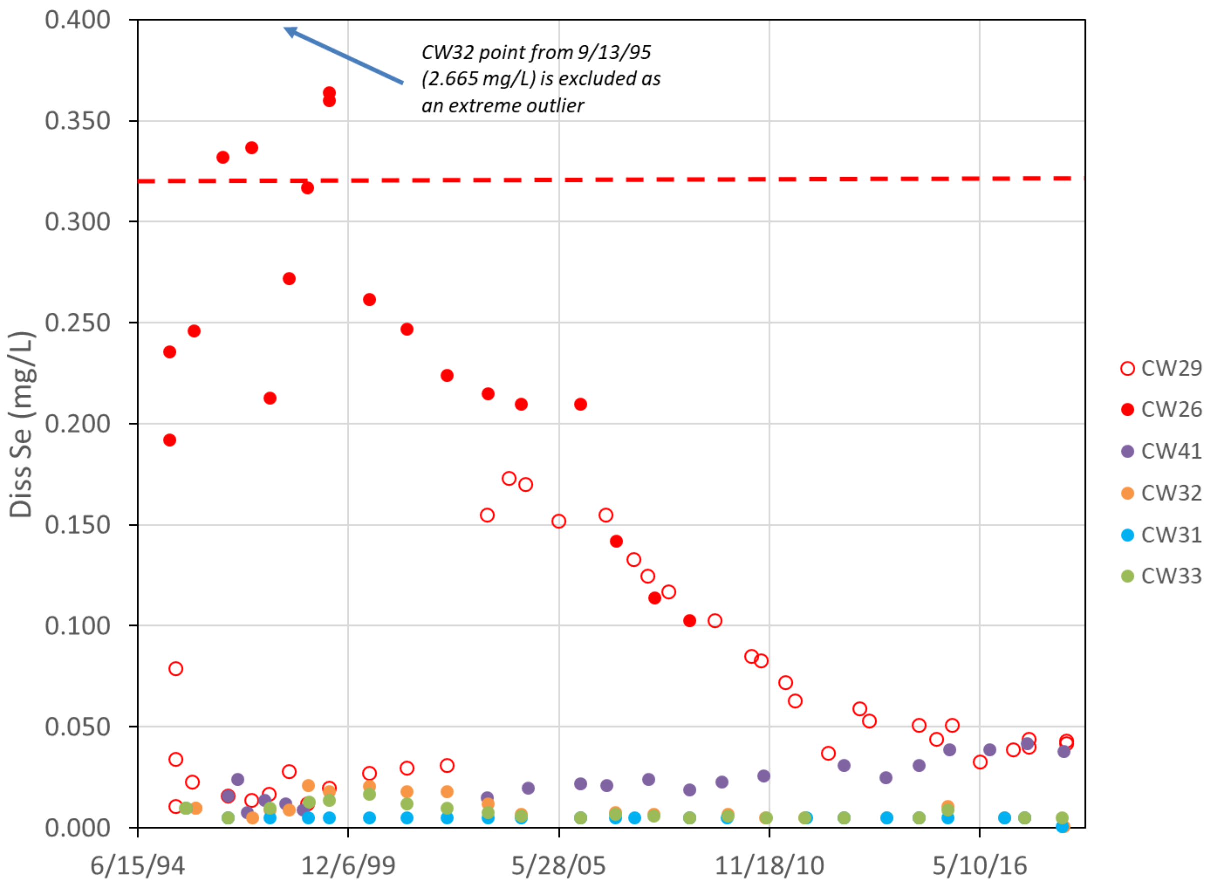
Data source: Homestake Access groundwater chemistry database.

Figure 9. Dissolved selenium concentrations in the Middle Chinle Non-Mixing Zone wells used for background. The red dashed line indicates the current GWPS for the Middle Chinle Non-Mixing Zone of 0.07 mg/L Se.

Selenium concentrations in the Middle Chinle Non-Mixing Zone are shown in Figure 9. Concentrations in well CW14 are substantially higher than any of the others. The fact that CW14 is a water injection well for remediation implies that this area had elevated concentrations of COCs and needed to be remediated. Values for CW14 are excluded from consideration in assessing background water quality for selenium. Selenium concentrations in well CW28 began to rise after the first sampling in the mid-1990s and must be excluded as not representative of background. CW1 and CW2 are pumped for remediation (collection wells), also indicating that this area just north of the LTP was affected by mine-influenced water. Concentrations in CW1 and CW2 began to rise in the late 1990s and may not have returned to possible background values. Therefore, concentrations since 2000 should not be used for background. Early spikes are also unexplained and were excluded. Concentrations in well WCW were at or slightly above the detection limit of 0.01 mg/L, which decreased to lower detection limits of 0.005 or 0.003 mg/L in the mid-1990s. Concentrations in ACW spiked in the early years and have been more consistently elevated since 2000. Early spikes in Se concentrations in wells CW1, CW2, and ACW (see Figure 9) have not been explained but possibly reflect intermittent releases from the LTP. Excluding the spikes and samples with increasing concentrations leaves a sample size of 108 data points, with 79% below detection. The 95th percentile of the data is 0.027 mg/L Se.

Lower Chinle Non-Mixing Zone

The location of the five wells used by NRC (2006) for background water quality in the Lower Chinle Non-Mixing Zone are shown in Figure 8c.1 (orange highlighted locations). Wells CW31, CW32, and CW33 are located west of the West Fault, and CW29 is an off-site collection well used for remediation (see Homestake, 2015, Figure 5-4). Wells CW41 and CW26 are located south of Felice Acres.



Data source: Homestake Access groundwater chemistry database.

Figure 10. Dissolved selenium concentrations in the Lower Chinle Non-Mixing Zone wells used for background. The red dashed line indicates the GWPS for the Lower Chinle Non-Mixing Zone of 0.32 mg/L Se.

Concentrations in wells CW26 and CW29 should be excluded from background because concentrations in CW26 were high initially and have decreased, but they have not decreased to values similar to other wells (CW32, CW31, CW33), indicating mining influence. Se concentrations in well CW29 increased markedly in July 2003 and remain elevated relative to most of the other values shown in Figure 10. It is unclear ~~if even~~ whether the earlier values from the mid to late 1990s were also affected by mining. The extreme outlier for CW32 (2.665 mg/L) is excluded from consideration for background. Se concentrations in well CW41 began to rise by at least 2010, indicating mining influence, and will be excluded from 2010 onward. Using the remaining 87 data points, 52.9% are below detection, and the 95th percentile is 0.022 mg/L selenium.

Summary: Comparison of Current and Proposed Groundwater Protection Standards

A comparison of current and proposed GWPS values for selenium in all the site aquifers is presented in Table 3. The table also included the wells and time period used and excluded, the sample size, and the percent of the values used that were below detection. The current GWPS values were not determined for the individual mixing zones (Upper, Middle, Lower Chinle), but this evaluation covers all Chinle mixing zones separately as well as a combined mixing zone for all Chinle aquifers. The wells and time period used in the analysis, the wells or samples excluded, and the sample size and percent below detection for the proposed, selected background data are also presented in Table 3.

The proposed selenium GWPS values range from 0.011 for the Upper Chinle Mixing Zone to 0.082 for the Lower Chinle Mixing Zone. All proposed GWPS values are lower than the current GWPS values because the samples that reflect mining influence have been excluded.

Table 3. Comparison of Current and Proposed background dissolved selenium values (mg/L) and statistical values for the aquifers.

Aquifer	Current GWPS[1] (mg/L)	Proposed GWPS (mg/L)	Wells Included (time periods)	Wells excluded (see text for explanation)	Sample size	% Below Detection for Selected Data
Alluvial	0.32	0.063	P (1995-97), DD (1981-2014), ND (1983-98), 916 (1994-2005)	Q, R, P1, P2	131	9.2
Chinle Mixing Zone: Combined	0.14	0.079	See below	See below	215	30.2
Chinle Mixing: Upper	NA	0.011	CW9 (1987-2018), CW10 (1987-94), CW50 (2003-2017), CW52 (2003-2012)	CW9 (1 outlier)	68	68
Chinle Mixing: Middle	NA	0.078	CW15 (1995-2018), CW24 (1995-2018), CW35 (1995-2012)	CW17, WR25	68	0
Chinle Mixing: Lower	NA	0.082	CW36 (1995-2018), CW37 (1996-2018), CW39 (1995-2005), CW43 (1997-2018)	None	79	24
Upper Chinle Non-Mixing Zone	0.06	0.024	931 (1997-2018), 934 (1997-2012), CW3 (1997-2001)	CW3 (2002 onward), CW13, CW18	68	35

Aquifer	Current GWPS[1] (mg/L)	Proposed GWPS (mg/L)	Wells Included (time periods)	Wells excluded (see text for explanation)	Sample size	% Below Detection for Selected Data
Middle Chinle Non-Mixing Zone	0.07	0.027	CW1, CW2, and ACW (excluding spikes and increases); WCW	CW1, CW2, and ACW (spikes and increases); CW14, CW28	108	79
Lower Chinle Non-Mixing Zone	0.32	0.022	CW31 (1995-2018), CW32 (1995-2018), CW33 (1995-2018), CW41 (1996-2010)	CW16, CW29, CW32 (1 outlier), CW41 (2010 onward)	87	53
1 Arcadis (2019); NA not analyzed						

Recommendations

The primary recommendations for selenium GWPS values are:

- Re-evaluate the background water quality results for selenium and all other COCs, excluding data that reflects mining influence.
- The Upper Chinle Mixing Zone should be remediated to a lower (more protective) selenium concentration than the other two Chinle mixing zones.
- More work should be done to understand the relative transport rates of selenium and other COCs to help predict the future extent of contaminant plumes. Understanding transport rates will help to focus remediation efforts ~~to~~ on preventing the spread of existing and future contamination. Analysis of groundwater samples for selenium and uranium speciation will help to predict transport rates.

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