TECHNICAL MEMORANDUM

December 19, 2018

Prepared for: Blue Valley Downstream Alliance and Multicultural Alliance for a Safe Environment.

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Re: Review of Phase 2 Ground-Water Investigation Report for the San Mateo Creek Basin Legacy Uranium Mines Site

The Environmental Protection Agency (EPA) has released its Phase 2 Ground-Water Investigation Report for the San Mateo Creek Basin Legacy Uranium Mines Site, for Cibola and McKinley Counties, New Mexico. Weston Solutions of Houston prepared the report on behalf of the EPA, but it is treated herein as an EPA report. The report is of the second phase of an Expanded Site Inspection groundwater water investigation of the San Mateo Creek Basin legacy Uranium Mine Sites. The focus is a 321 square mile drainage which contains 85 legacy uranium mines and four former milling facilities. The Homestake Mill is near the downgradient and downstream end of this watershed. The mines and milling operations discharged substantial quantities of solid waste, effluent, and seepage into the San Mateo Creek Basin and caused widespread contamination of soils and groundwater.

The study was part of a five-year plan to assess the potential impacts of the legacy mining and milling on water resources. A previous Phase 1 study had been completed in 2016, although EPA repeats much of the data from that study herein.

The report had three main parts. Part 1 is a hydrological, water quality and geochemical analysis focus on the artificial recharge by mining effluent discharges. Part 2 is a comparison of the groundwater chemistry data with drinking water standards. Part 3 is a review of the operational and regulatory history of the site.

A major interest of the Blue Valley Downstream Alliance and Multicultural Alliance for a Safe Environment is the background water quality in the aquifer near the Large Tailings Pile (LTP) at the Homestake Site. Although this report covers the entire basin and four millsites, the focus of this review is on evidence and analysis affecting background at the LTP. Thus, there are two purposes for this review. The first is to assess the study results as to whether they provide evidence regarding background levels of Uranium (U) at and south of the LTP of the Homestake Millsite at Milan. The second is to provide a critique of the methods and conclusions reached by the EPA.

The review primarily references EPA (2018) and refers to figures and page numbers from that report. Some figures have been snapshotted into this review and have figure numbers starting at 1. Other more complex references to figure number and page numbers are to EPA (2018), which has not been noted for brevity. Throughout this review, “report” means EPA (2018).

Part A: Hydrological, Water Quality and Geochemical Analysis

A hypothesis is that the mine discharge water (MDW) in the upper basin controls various water quality constituents in the alluvium through-out the basin. MDW generally is water that mining companies pumped to keep the mines dry (dewatering water) but that included water drained from the mine stopes and other mined areas. It included water used for leaching U from the stope walls. The mines discharged dewatering water and process water into the arroyos in the Upper Basin, specifically the Arroyo del Puerto. This water created an aquifer in the alluvium under the Arroyo and of course caused the groundwater chemistry observed in that aquifer. It also temporarily affected the water table through the lower San Mateo basin. Mining exposed the ore bodies to air allowing oxidation and subsequent contamination across the geologic formations. Some dewatering water was used to leach in-situ formations underground which increased its U content. In some areas, tailings were used as backfill resulting in water from at least one source having U concentrations that exceeded 100 mg/l (p A3-6). The following description of mine discharge water is accurate:

> Geochemical data and information presented above demonstrates the MDW most likely consists of a mixture of ground water sourced from three major hydrogeologic units, and the solution is evolved chemically as mining operations commenced, advanced, and ended. After the MDW was released to unnamed drainages, Arroyo del Puerto, and/or San Mateo Creek channel as surface flow, it eventually became a source of recharge to the alluvium and/or bedrock hydrostratigraphic units and more chemical changes occurred, including mineral precipitation and dissolution reactions, mixing, and evaporation. (p A3-9, -10).

In other words, the chemistry of the water discharged to the arroyos changed with time as the proportion of water sourced from different formations changed and as the mining processes changed. The one constant was that as the chemistry changed the U concentrations were likely high and would have been reflected in water that recharged the alluvium and underlying bedrock (Figure 1).

Part A of the report explores this hypothesis in several ways. First, it uses historic data to show how the mine dewatering water expanded through the alluvium throughout the basin, vastly increasing the saturated volume and area. It also uses chemistry and water quality data collected since the 1970s to show how plumes of various constituents expanded through the alluvium. The report provides both plume maps and time series plots. Finally, the report compares data collected in 2015 and 2016 as parts of Phase I and Phase II of this study to associate water chemistry with geologic formations and location. The data considered includes various isotopes and radioactive parameters that have different attenuations rates so that a better determination of the source of water can be estimated. The report considers bedrock, but unless the Upper Basin bedrock aquifer has been mined or is near a vertical pathway such as a fault, there is no impact from MDW. In the Lower Basin, the underlying bedrock has been affected by seepage from the overlying alluvium. The focus of this review is on the alluvium.

Hydrogeology

The hydrogeologic cross-section along the San Mateo Wash indicates the primary pathway for water from the Ambrosia Lake area to mix with groundwater near the Homestake Mill, including in the Chinle and alluvial formations, is through surface water or through the alluvium (Figure 1). The downward dip of the formations north of the Chinle would not be conducive for bedrock flow anywhere other than into the alluvium if there is enough head in the bedrock. The fault between the Chinle and other bedrock formations might inhibit downgradient flow from the Upper Basin, even if the fault enhances vertical flow at the fault contact. The San Mateo fault generally parallels and coincides with the section in Figure 1. The cross-section also shows water levels in 1975 much higher than in 1960 or at present. The report directly acknowledges that seepage from the Homestake mill recharged and contaminated the underlying Chinle water-bearing sandstone units where they subcrop to the alluvium (p A4-2).

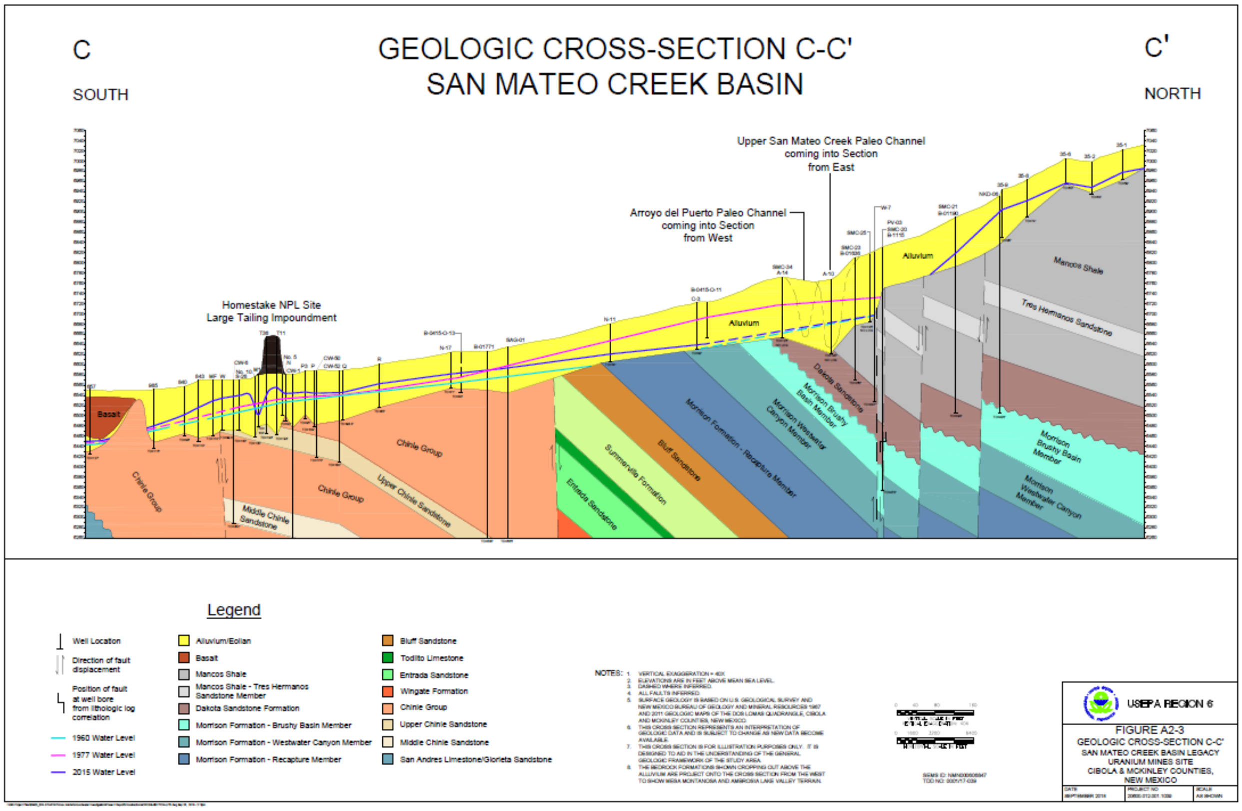


Figure 1: North-south hydrogeologic cross-section along the San Mateo Wash. The cross-section show the Homestake Mill on the left (southern portion of the cross-section) and the confluence of the Arroyo del Puerto and upper San Mateo Creek on the north. Source: Figure A2-3 from EPA (2018)

Expansion of Saturated Alluvium

The hypothesis describing groundwater flow throughout the alluvium in the basin before and during mining is as follows. The San Mateo Creek alluvium had groundwater flow from the northeast portion of the basin near the town of San Mateo through the confluence with alluvium from the Arroyo del Puerto from the northwest (Figure 2). Alluvium beneath the Arroyo del Puerto was probably dry. Beyond the confluence, the alluvium was saturated to the point it joined with Rio San Jose water southwest of the site. Mine discharge water in the northwest portion of the basin, Ambrosia Lake area, caused the saturated area to become thicker and expand to cover a larger area.

The report documents the evolution of the level of saturation in the alluvium from 1960 (Figure 2) to 1975-77 (Figure 3) to 2015 (Figure 4). In 1960, the San Mateo Creek alluvium was saturated from about the town of San Mateo through the confluence with Arroyo del Puerto and Sand Curve to south of the Homestake Mill, but there was no saturated alluvium in the Ambrosia Basin (Figure 2). In 1960, the saturated thickness near and south of the Homestake Mill was very thin, less than 5 feet, although there were few wells for measurement because there were few domestic wells. In 1960 there was very little alluvial water in the area of the Homestake Mill, further indicating that most alluvial water in succeeding decades resulted from seepage from the millsite.

In the mid-1970s, saturation was extensive, with the most impressive increase in area being in the Ambrosia Basin which of course is where the mines were discharging water. The saturated area near the confluence, Sand Curve and Homestake Mill Site is constrained by the width of the paleo channel. One section between the confluence and Sand Curve expanded in the mid-1970s. The saturated thickness has increased substantially, from about 11 feet at Sand Curve in 1960 to 56 feet in the mid-1970s. Between the confluence and Sand Curve, the thickness in the mid-1970s ranges from the 50s to 60s feet.

At present, there is substantial residual saturation in the Ambrosia Basin. The residual saturation in Ambrosia Basin probably reflects the underlying bedrock having a low conductivity and a bit of damming in the alluvium that prevents flow to the confluence. The very narrow saturated zone in the mid-1970s reflects this (Figure 3). Saturation has contracted substantially in the lower San Mateo basin to closely resemble the saturation in 1960 (Figure 2). It is notable that the saturated thickness is maximum at present at the Homestake Mill where the thicknesses range from the teens to over 40 feet, substantially more than during the mid-1970s. This is due to the ongoing injection/extraction activities at the millsite.

The figures also indicate the saturated alluvium south of the LTP grew since 1960. The blue saturated area covered a smaller area southwest of the LTP in 1960 (Figure 2), than in the 1970s (Figure 3). The saturated thickness would also have increased commensurately. In this area, the millsite seepage was most responsible for increasing the saturation in the alluvium.

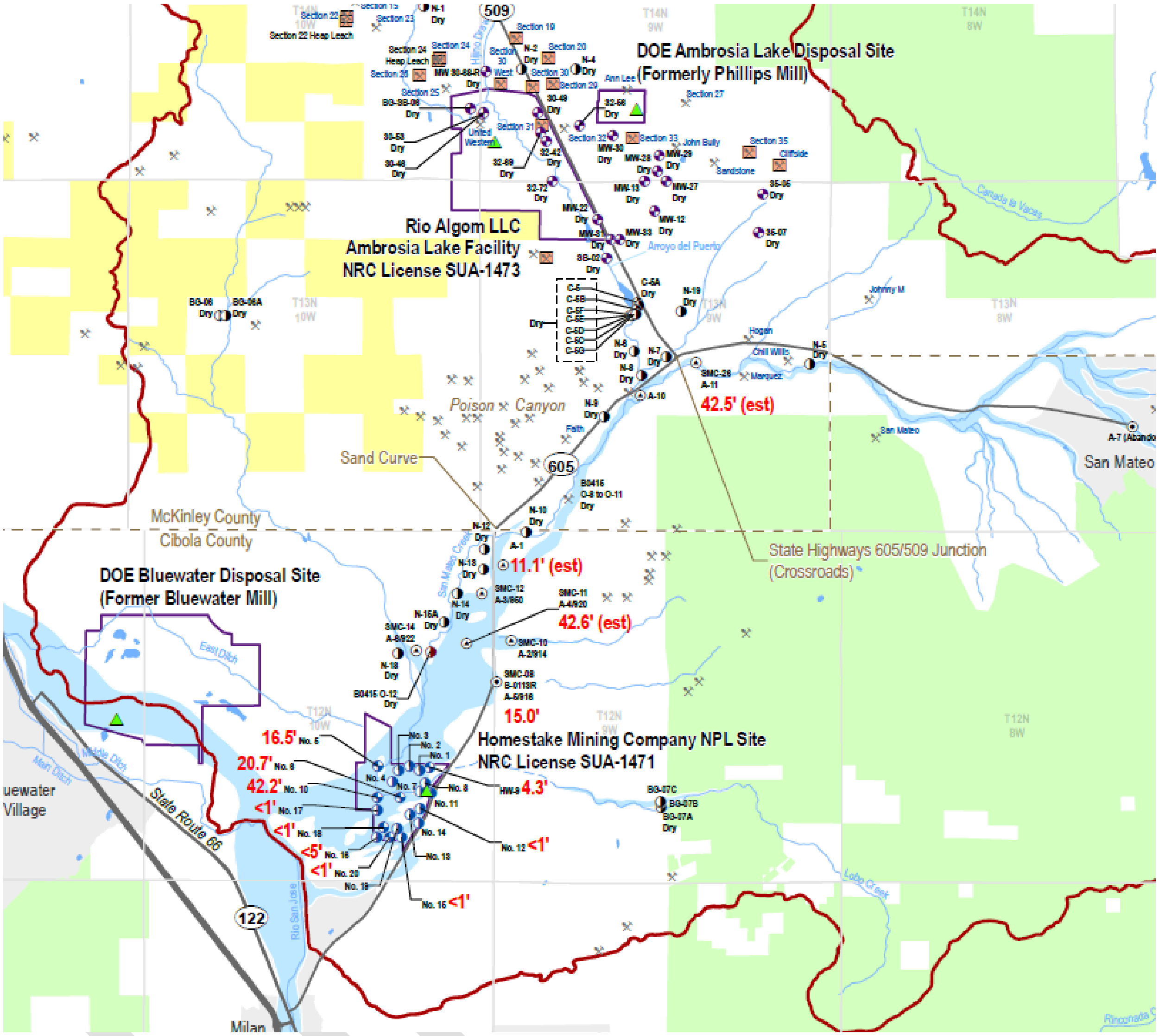


Figure 2: Alluvial saturation shown in blue for 1960. Source EPA (2018) Figure A4-2

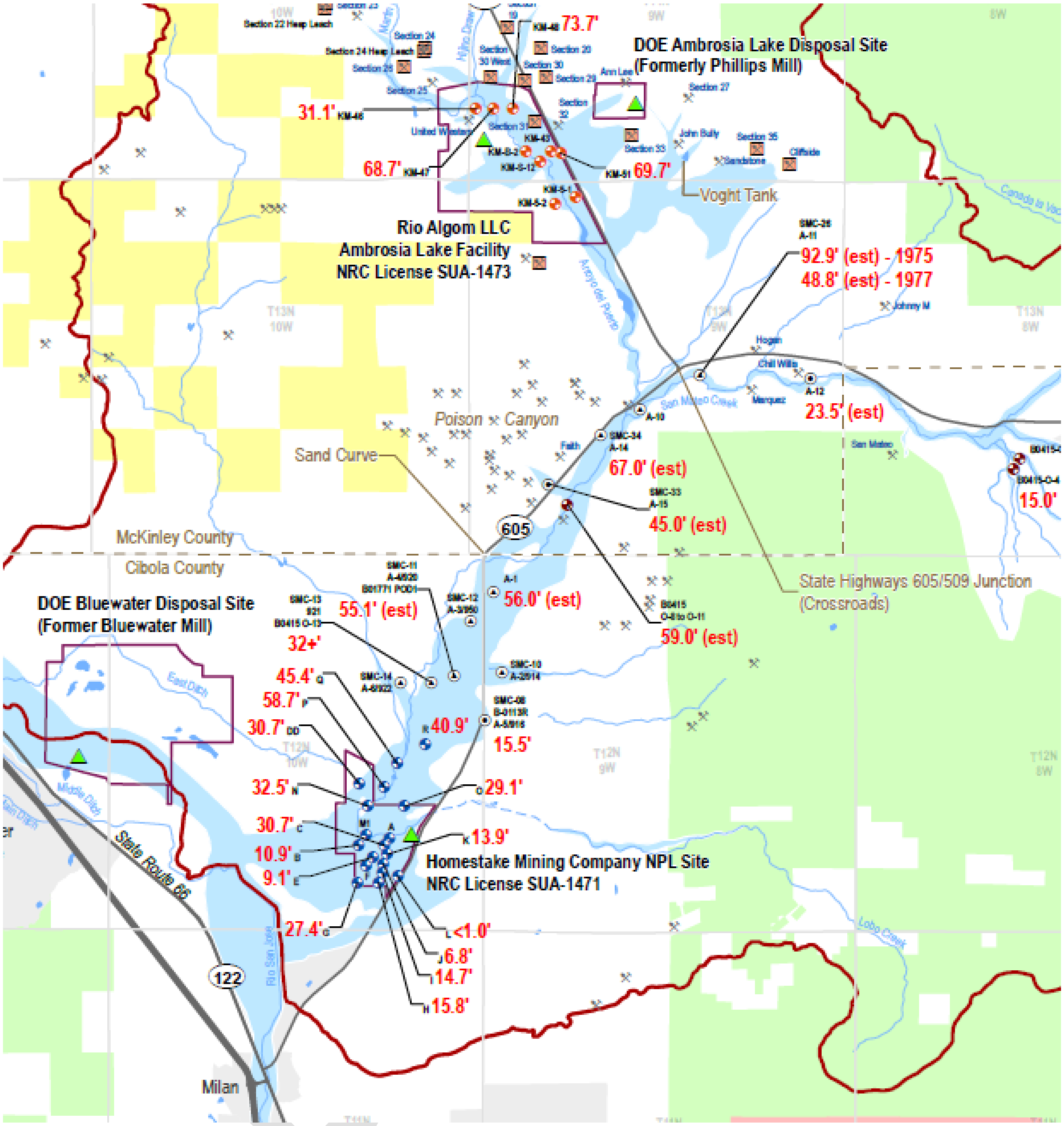


Figure 3: Alluvial saturation shown in blue for the 1975 to 1977 period. Source EPA (2018) Figure A4-2

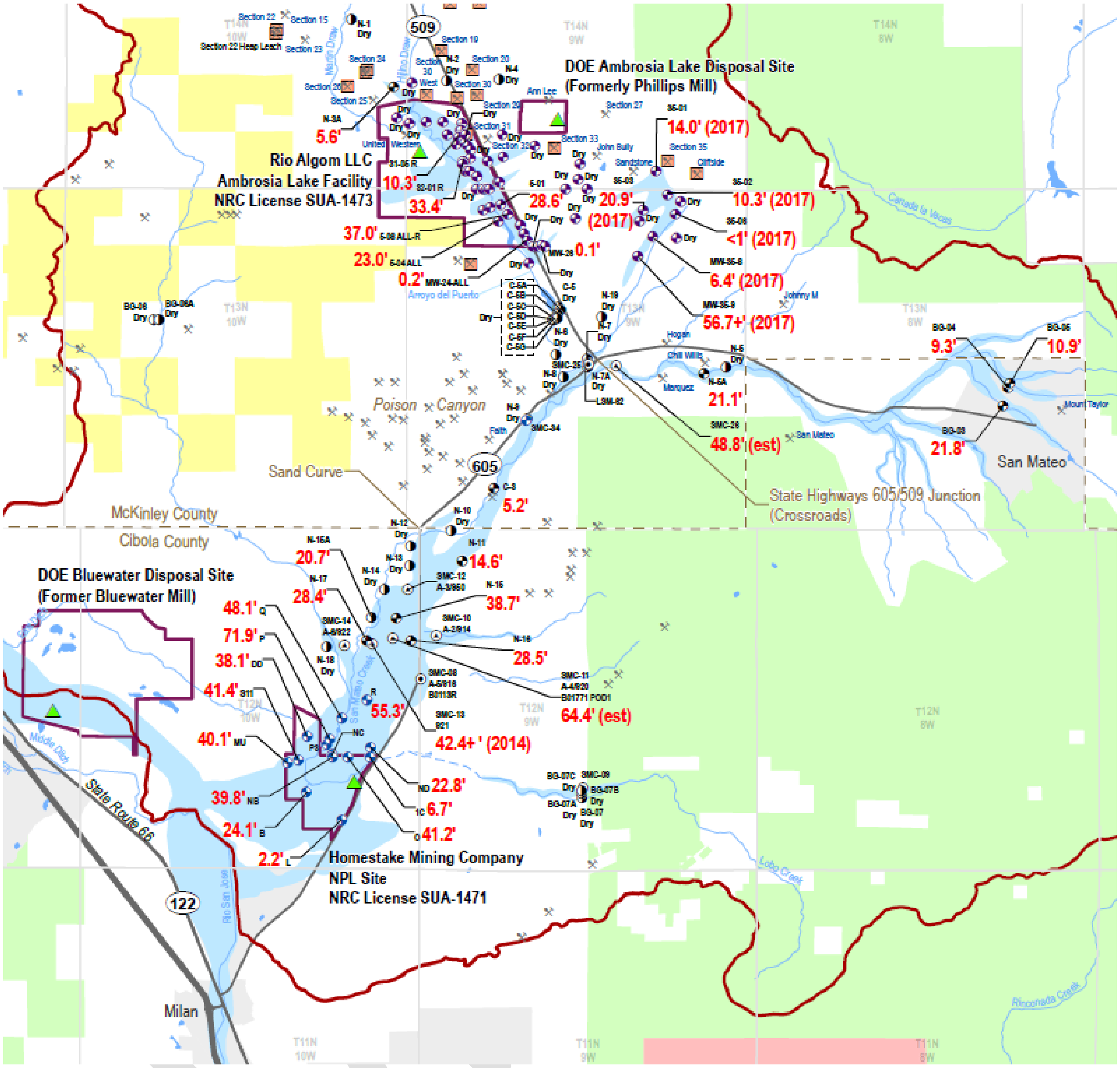


Figure 4: Alluvial saturation shown in blue for the 2015 to 2016 period. Source EPA (2018) Figure A4-3

The groundwater level in the lower San Mateo Basin increased from 1960 to 1975 and the aquifer increased in width (Figure 5). Compared with Figure A4-8, groundwater levels increased from over 50 feet near the confluence to a couple feet between Sand Curve and the Homestake Millsite (the numbers in green boxes in Figure 5 show the change between 1960 and 1975). One reason the increase in groundwater table and saturated thickness is so much more upstream near the confluence could be the narrowness of the alluvial channel which causes the groundwater to pond in that area. It could also be that a wave in the groundwater was passing through the confluence and was only beginning to reach the channel near and south of Sand Curve. The report would have to include a series of maps through the 1980s to determine whether this explanation is possible.

Groundwater levels near the LTP have increased more than they increased further upstream even though there is no obvious difference in the alluvial channel area that would cause ponding at that point. This increase near the LTP visible in 1975 could be the beginning of a mound forming beneath the LTP, as hypothesized by Myers (2015) as a means of a short-distance gradient reversal to cause U to move from the LTP seepage northeast against the general flow through the alluvium. The development of a mound would be easier to assess with a series of maps through the 1980s.

Groundwater elevations and the changes between 1975 and 2016 show the movement of a groundwater slug from the confluence through Sand Curve toward the LTP (Figure 6). Groundwater levels decreased over 50 feet at the point furthest north, in the confined bedrock channel (well C-3). Further south overall changes were much less although some wells show that a higher groundwater elevation was attained in the 1990s after which either a substantial decrease occurred (well SMC-12) or, further south, most increase occurred before the 1990s and since the decrease has been slight (wells SMC-11, SMC-10). Further south near the LTP, the increase has simply continued (where there were readings in the 1990s, more groundwater level increase has occurred since then). This effectively describes a slug moving through the alluvium in the bedrock channel, with the mounding under the LTP damming the groundwater flow. Although the alluvium has effectively desaturated from the Sand Curve to the north since the 1970s, the saturated thickness has increased since then south of Sand Curve.

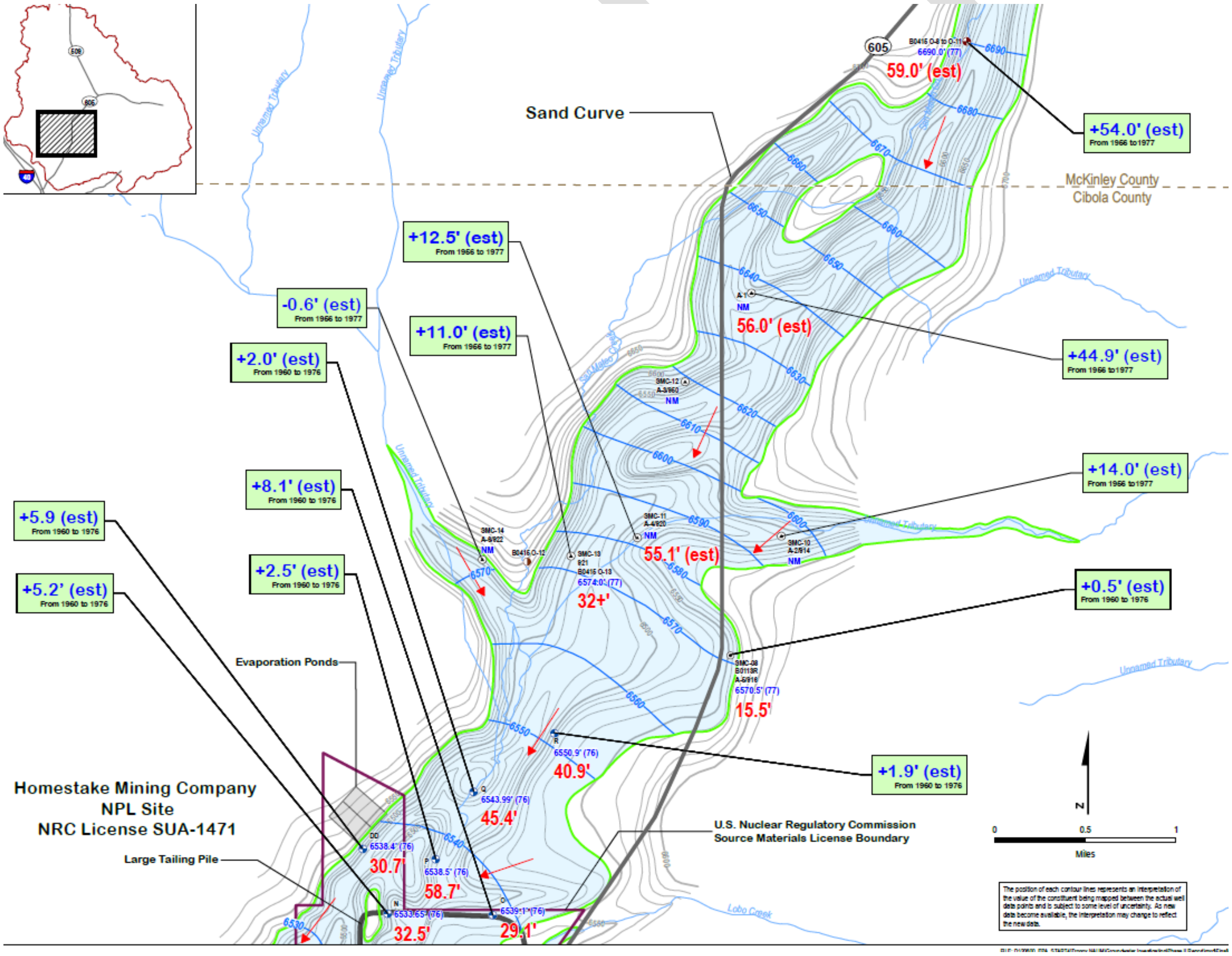
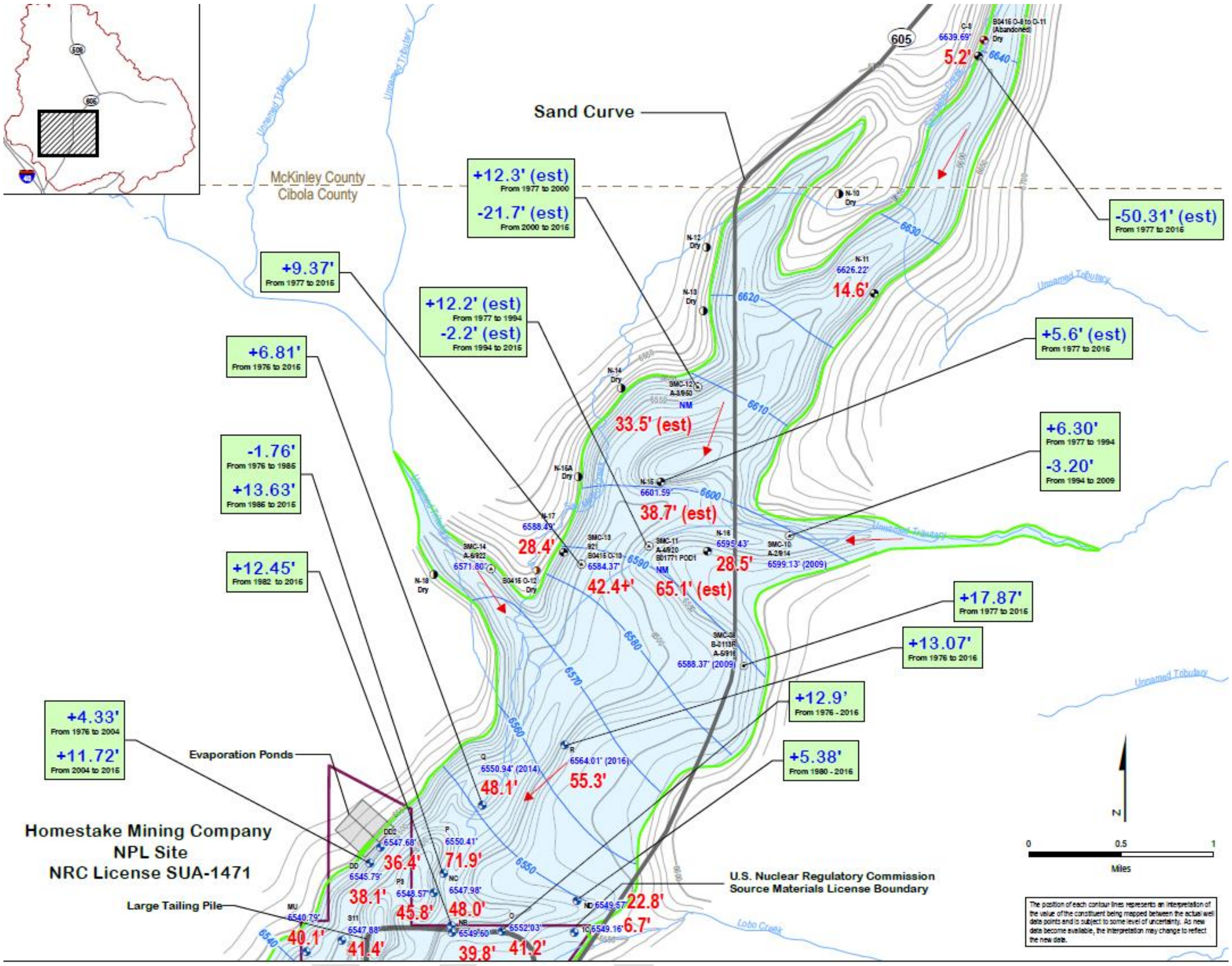


Figure 5: Alluvial groundwater elevation and spot changes between 1960 and 1975 in the lower San Mateo Basin. Source: EPA (2018) Figure A4-9



The position of each contour lines represents an interpretation of the value of the constituent being mapped between the actual well data points and is subject to some level of uncertainty. As new data become available, the interpretation may change to reflect the new data.

Figure 6: Alluvial groundwater elevation and spot changes between 1975 and 2016 in the lower San Mateo Basin. Source: EPA (2018) Figure A4-11

Temporal Evolution of Groundwater Quality

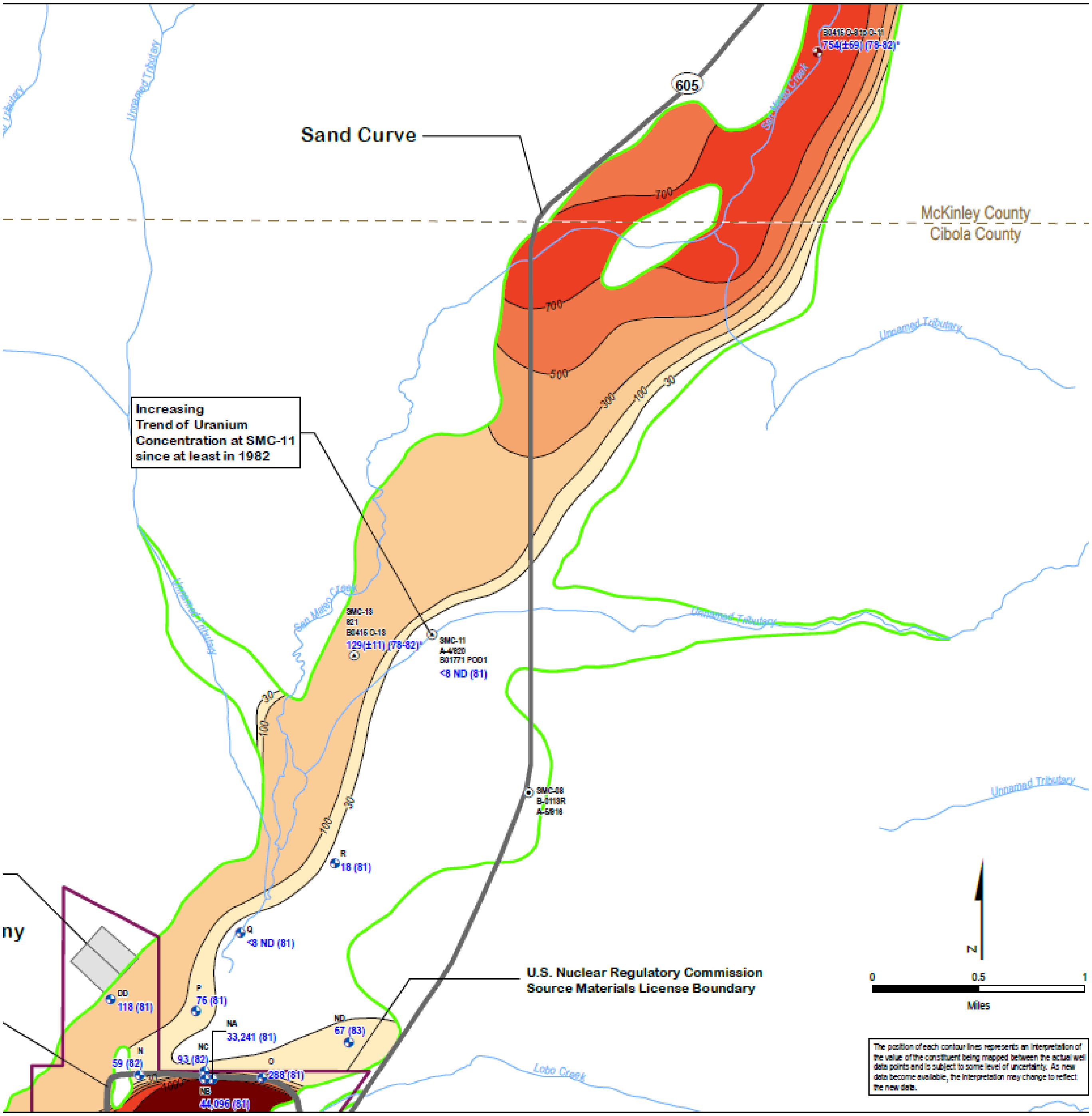
EPA's initial analysis of groundwater chemistry for the lower San Mateo Basin provides comparative plume maps for the 1970s and 2015 (present) along with time series plots at specific wells for U, Se, SO4, and TDS.

First, the time series plots have a significant error in their presentation. The plots show a straight-line linear regression suggesting trends along the time series. It is inappropriate to use this kind of analysis because it assumes a linear trend from 1976 through 2014 without regard to cycles in the data or other anomalies, such as occasional very high values which have an inordinate effect on the regression. For example, the analysis of U for well P in Figure A4-14 demonstrates why the linear regression should not be used. The linear regression line shows a substantial downward slope from about 0.075 mg/l in 1976 to less than 0.025 mg/l in 2015. However, almost every data point from 1993 to 2015 is above the line. From 1983 to 1990, most points are below the line and the points show a distinct increasing trend from 0.025 to 0.05 mg/l. Several high outliers occur in this portion of the line. The reason the line shows a substantial downward trend is the presence of about four very high outliers, including a 0.7 and 0.35 mg/l, in the 1970s.

The report also notes the time series plots could be used to track the movement of plumes downgradient (p A4-16). This is correct, but only by considering the annual fluctuations without assuming a trend from the 1970s to the present (see the previous paragraph).

U plume maps for the 1970s and the mid-2010s show the movement of U downstream along the San Mateo Wash, showing the movement of a plume from the Crossroads area to near Sand Curve (Figures 7 and 8). However, the 1970s plot is based on too little data. There is only a cluster of observations averaging 0.754 mg/l; however, the 0.7 mg/l contour extends south along the channel particularly in the deeper paleochannel on the west side (Figure 7). The report notes the "elongated and narrow plume of higher uranium concentrations extending from the northern boundary of the map to the southern boundary of the map along the western margin of the SMC paleo-channel" (p A4-17). Because SMC-13 has U at 0.129 mg/l, there must be a gradation between the points, but the report cites no data to support drawing the 700 ug/l plume so far southwest along the paleo channel. However, the DD well in the paleochannel near northwest of the LTP has U at 118 ug/l while the concentrations nearer the LTP are much lower. This observation supports the concept of a plume moving southwest in the paleochannel.

The 2015 U plume map shows the plume has spread southwestward along the paleochannel, but also that it has spread so the highest concentrations are lower than in the 1970s (Figure 8). This is reasonable, but again the data does not support the plot. There is a large area over a mile long that exceeds 300 ug/l just south of Sand Curve but only one well, M-16, with a U concentration equal to 300 ug/l (Figure 8). The extent of the 200 to 399 ug/l contour further south to well DD2 has more support with three wells exceeding 200 ug/l. The plume maps show that U from upstream moved along the San Mateo paleochannel to the LTP region through time. However, in 2015, wells just north of the LTP, P3 and P4, had very low concentrations, just 20 and 15 ug/l (Figure 8). If the 1970s observations in this area had been affected by mounding under the LTP, as suggested by Myers (2015), the 2015 data presented here suggests that more recent groundwater flows have helped to restore the groundwater to pre-millsite conditions. The report suggests there is a small inflow from the Lobo Creek drainage that is not affected by mining; this could be returning part of the groundwater to background conditions, and be representative of background in the area (p A1-40 and A5-19).



Increasing Trend of Uranium Concentration at SMC-11 since at least in 1982

U.S. Nuclear Regulatory Commission Source Materials License Boundary

The position of each contour lines represents an Interpretation of the value of the constituent being mapped between the actual well data points and is subject to some level of uncertainty. As new data become available, the Interpretation may change to reflect the new data.

Figure 7: Uranium concentrations in the alluvium of the Lower Basin. Source: EPA (2018), Figure A4-12.

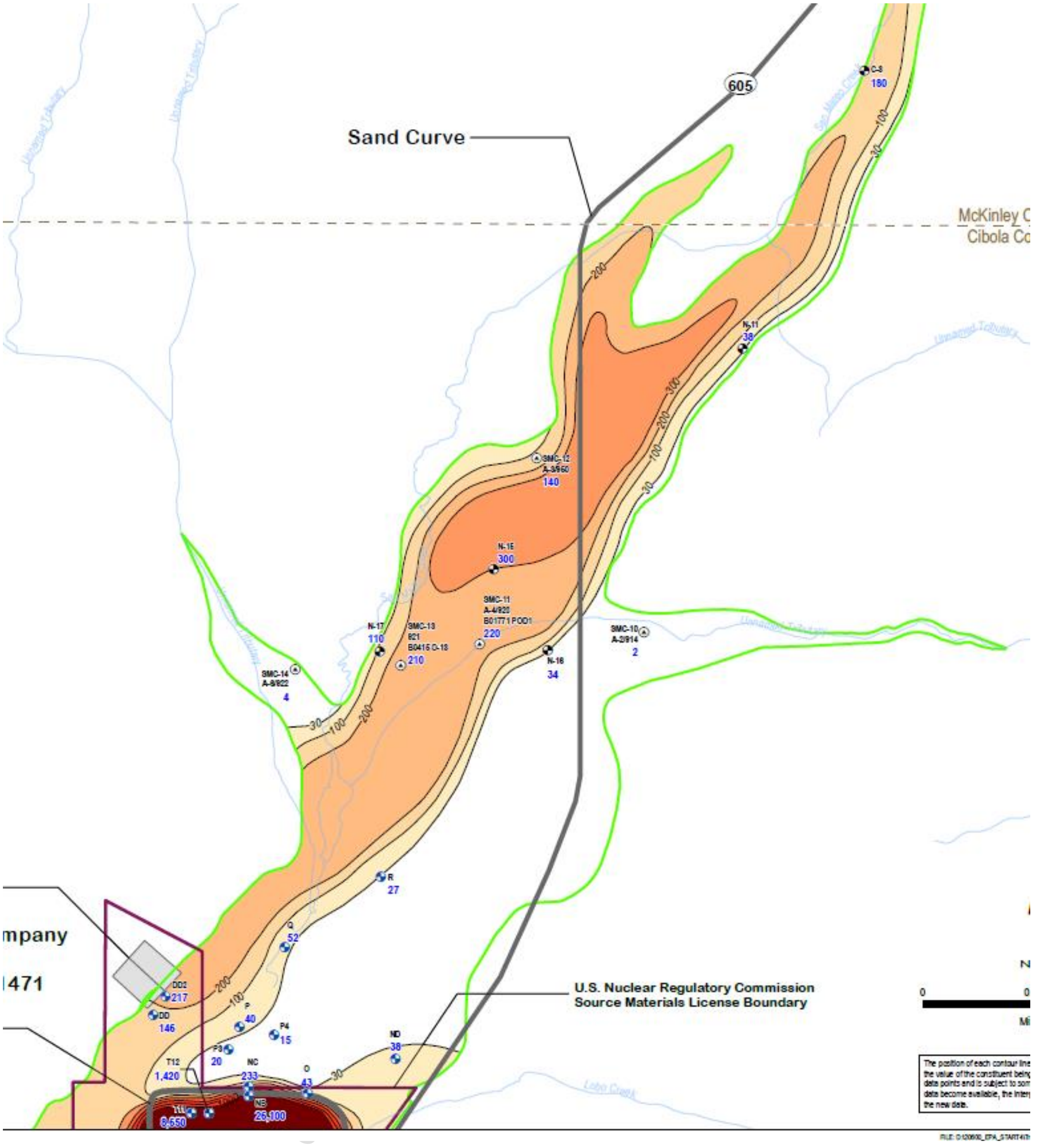


Figure 8: Uranium concentrations (mg/l) for groundwater in the Lower Basin alluvium. Source: EPA (2018) Figure A4-13.

EPA’s interpretation of the temporal plots for U is partially incorrect, and not simply because of the linear regression plots discussed above (note that the figure references are not always correct). EPA correctly interprets the U increase from 1981 through 2015 for well 920 SMC-11 shown in Figure A4-16. This well is about two mile north of the LTP and its trend directly correlates with the expanding plumes. Closer to the LTP, the interpretation is not as straightforward.

Wells P, R and Q all show relatively low U concentrations, many less than 0.03 mg/l, in the 1980s and trend to higher values in the 1990s. Well P concentrations have decreased into the 2000s while concentration at the other wells have remained relatively constant. All of the wells show several relatively high peaks in the 1970s and a few more in the late 1980s and 1990s. The wells range from ¼ (P) to ¾ (Q) to 1 (R) mile from the LTP, along the San Mateo channel. During the 1980s, well R had many values less than half of 0.02 mg/l whereas in the 2000s the concentrations had increased to about 0.02 mg/l, almost a doubling of the values. U concentrations at well Q increased from an average around 0.3-.4 mg/l in the 1980s to more than 0.5 mg/l in the 2000s. U concentrations at well P peaked in the 1970s (Figure A4-14, incorrectly labeled A4-16 in the report), but were primarily less than 0.025 mg/l from the late 1970s to the 1980s. Concentrations increased to about 0.05 mg/l in the 1990s, before falling again to near 0.025 mg/l in the 2000s. statistical comparison for each well between decades would likely show a significant increase from the 1980s to the 2000s, if the high outliers are ignored.

The high values in the 1970s could be a result of high flow events moving high-U discharge water from the Crossroads area to the San Mateo channel within two miles of the LTP. These anomalous peaks are not as high as observed at wells further upstream and closer to the Crossroads. Alternatively, the peaks in the 1970s could have been caused by a reversal of gradient due to mounding under the LTP (Myers 2015). Some peaks, including those occurring later, could have been due to surface flow events moving MDW over the area.

The many low values during the 1980s likely represent background with the peaks due to an influence from the LTP or surface flows of MDW. The period corresponds with increasing saturated thickness within 2 miles of the LTP (Figure A4-11); peak groundwater elevations were upstream of this point in the 1970s. High flows with high U concentration percolating into the ground during the 1970s would have had more of an effect because there would have been less groundwater in place to dilute the percolation. Both the slug of groundwater causing saturated thickness to increase and the slug of U moving downgradient with the groundwater that would eventually cause the concentration to increase began to reach these wells in the 1980s. The 1970s were a relatively wet period (Figure A1-9), so the runoff would have carried high U loads. By the late 1980s and 1990s, an even wetter period, the MDW discharges had ceased and therefore high flows would not have had high U concentration. Therefore, the combination of MDW with wet climatic periods could coincide with MDW discharge to cause U peaks in the groundwater. The low U concentrations of the 1980s therefore likely represent background in the alluvium just upgradient of the LTP.

Concentrations at well DD have increased consistently from the 1970s through the mid-2000s, with a minor decrease since then (Figure A4-14). Well DD lies northwest of the LTP in the deeper paleochannel. The trending high concentrations probably reflects the plume movement along the west margin of the San Mateo paleochannel discussed above. The lack of peaks at well DD could be due to the well being west of the lower points of the surface channel so that it did not receive recharge from the high flows. The trend at DD may reflect any plume from the MDW missing the LTP to the west.

The temporal plots and plume maps reflect that a plume originating with the discharge of mine-impacted water above the confluence and Crossroad area has caused high U concentrations to move downstream along the San Mateo channel toward the LTP. The increases from the 1980s to the 2000s at wells R, Q, P, and DD are likely due to plume movement from further upstream, or mound expansion from the LTP, and are evidence that lower value in the 1980s are background.

The Se plume maps show a high concentration of Se in the middle of the north-south pathway along the Lower Basin alluvium (Figure A4-17, -18). The plume does not show substantial movement downgradient similar to the U plume movement. The Se concentration peaks in the mid-range of the San Mateo channel, within 1 to 3 miles upgradient of the LTP. The high concentrations occur at the same location but they increased substantially in the intervening 40 years. The temporal changes at wells DD and R, near the LTP, show increases commencing in the late 1980s. The trends in the wells near the LTP are consistent with a mound under the LTP, which has very high Se concentrations in the 1970s (Figure A4-17), which could cause upgradient movement of Se. For this to be the case, the Se would have to be more mobile than U for which there is no evidence of movement that far upstream. The high concentrations in the middle of the plume could be caused by a delayed effect of upstream dewatering discharge that could possibly relate to the different chemistry.

The trends in the SO4 plume shape are consistent with a plume moving downgradient due to dewatering discharge (Figures A4-22 and -23). The graphs of change with time are for wells near the LTP and generally show an increase (Figures A4-24 to -26), rather than reflect the significant decrease upstream shown in the plume maps. Concentrations at the LTP are much higher in the 1970s than in 2015, probably because of the ongoing injection of clean water at the LTP. The TDS plume maps show high salt concentration along the western portion of the San Mateo paleochannel for each time period, but there is a modest increase between the late 1970s and 2015. This could be due to movement of dissolved solids with groundwater flow and to concentration resulting from the reduced groundwater levels at points along the channel.

Recent Concentration Spatial Trends

Section 5 reviews trends in the chemistry revealed by recent Phase I and Phase II sampling, meaning data from 2015 and 2016. Most of the alluvium throughout the study area has been affected by mine discharge. Section 5 presents a series of bar charts comparing concentration at wells for many constituents broken out by formation and region which allows for an easy comparison of potential source. Figure numbers in this section refer to the EPA figure numbers. The wells are shown in Figure 9.

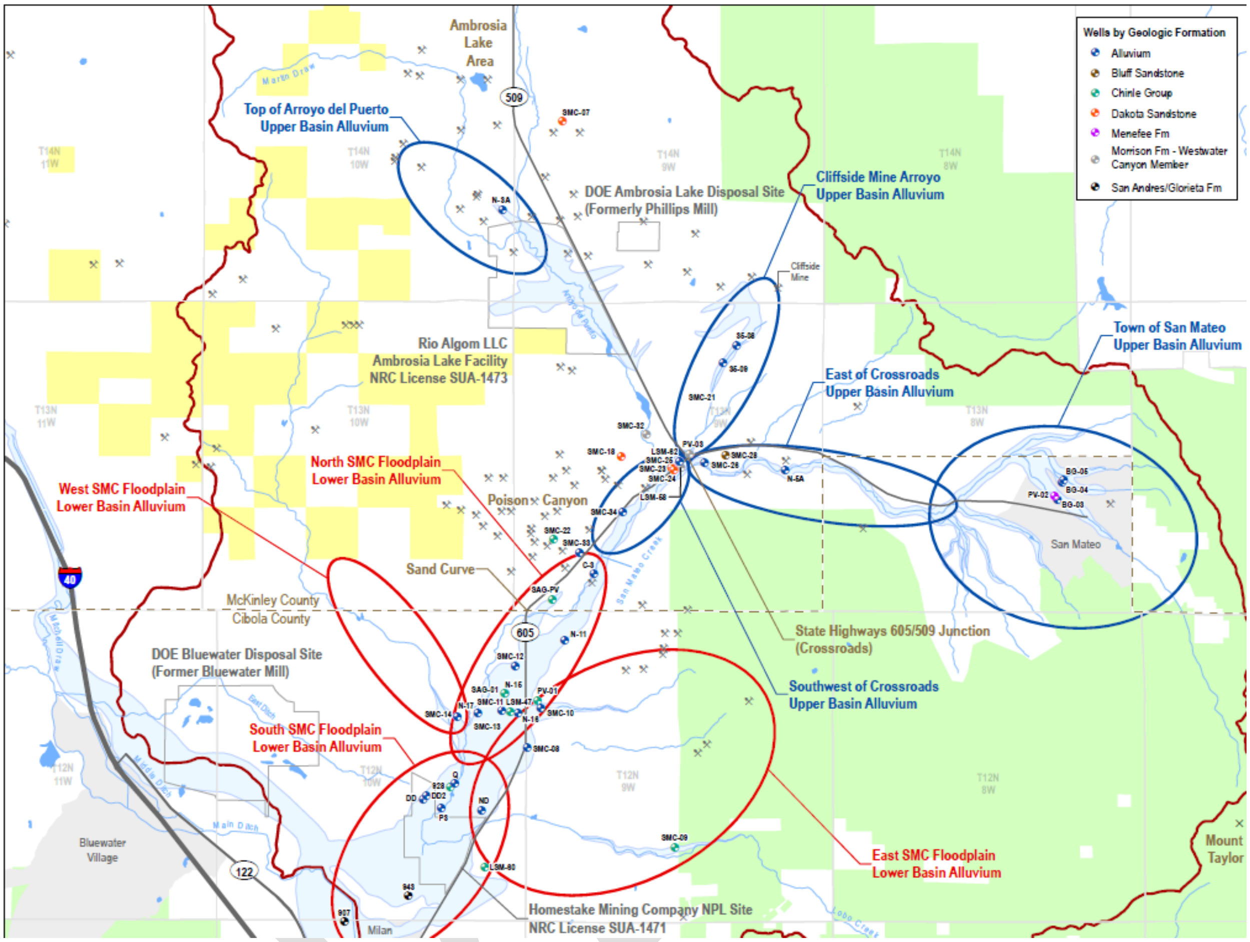


Figure 9: Wells by geographic subarea used in geochemical analysis. Source: EPA (2018) Figure A1-13.

MDW is the source of all saturation along the Arroyo del Puerto and is responsible for substantial increases in saturated thickness and temporal changes in constituent concentrations along the lower San Mateo. Groundwater in the northeast portion of the basin, near San Mateo, has low TDS which likely reflects periodic fresh water recharge (p A5-4). The high concentrations of major cations, Cl, and SO4 shown in Figure A5-3 and A5-4 reflect that freshwater recharge is likely the source. Downstream from San Mateo but east of the Crossroads, alluvial groundwater has SO4 and Cl concentrations similar to very early mining chemistry, where SMC-26 had Cl and SO4 equal to 20 and 189 mg/l in 1957 (p A5-5).

In the Lower Basin, the earliest data from about 1960 show that SO4 and Cl concentrations have not changed significantly, and do not prove that MDW controls the concentrations. The report states it is not known whether MDW could have reached the Lower Basin by 1960. Regardless, there are no early U concentrations for comparison to current values.

Most alluvium east of Crossroads has low ion concentrations due to substantial recharge, which is why the alluvium was saturated pre-mining. West of the Crossroads, MDW impacted the alluvium, as evidenced by the high concentration of many ions and of course also the fact there was no saturation pre-mining. The Lower Basin alluvium has high ion concentrations, but this does not prove a MDW influence because ions can also result from a long travel distance through the ground where it can dissolve salts.

Upper Basin bedrock is primarily affected by MDW only where there is recharge due to faulting beneath the saturated alluvium. The bedrock contamination in the Upper Basin is relatively limited for this reason. In the Lower Basin, the Chinle formation subcrops beneath the saturated alluvium and downward contaminant flow has contaminated those bedrock formations.

Trilinear diagrams show Arroyo del Puerto MDW water may be the source of both North and South San Mateo floodplain water. Underlying Chinle water is much more variable and quite different from MDW water (Figure A5-12 and -14). This implies the contamination of the Chinle is due to mixing of background bedrock water with MDW seeping from the alluvium.

Stable isotopes are useful for determining the source of an element. For water, fractionation due to evaporation or other processes will cause more lighter water to escape leaving behind a heavier water. Isotopic signatures are based on conservative mixing of water from different sources, such as precipitation, groundwater flow and MDW. Water that has gone through a tailings impoundment would have been depleted of lighter molecules due to evaporation.

Stable isotopes show substantial difference between Upper and Lower Basin Alluvium. The lines on Figure A5-15 essentially parallel each other, with the line for the Upper Basin being isotopically lightest. This means that precipitation entered the groundwater with little evaporation and reflects that it is sourced from winter recharge. The exceptions shown for wells MW-35-8 and MW-35-9 are discharge from the Cliffside Mine which would have been fractionated due to evaporation in that mine's treatment pond (p A5-26). Alternatively, the line for the Lower Basin shows more fractionation and heavier isotopes, likely due to summer recharge, which could result from storm runoff.

Underlying Chinle Formation samples are substantially different from the overlying alluvium. This indicates a general different sourcing for most water in the Chinle.

TDS is high throughout the basin, except in the Lower Basin bedrock (Chinle). The report argues the elevated TDS in the Lower Basin alluvium is due to natural causes (p A5-31). One reason this may not be correct is that the saturation is mostly due to the discharge of MDW water, which also has high TDS. It may be that the MDW water simply had TDS similar to that existing in 1960. The Upper Basin bedrock has high TDS primarily near the Crossroads region possibly due to the San Mateo fault zone.

Sampling included the activity[1] of total radium (Ra), the sum of ^{226}Ra and ^{228}Ra, the sources for which would "include natural material, mill tailings seepage, and MDW" (p A5-34). Radium differs from other constituents analyzed by EPA because it does not easily dissolve and does not move far from the point of release. Total radium was high in alluvial samples in the San Mateo area which generally did not show other contamination. This likely is the result of high background Ra. In general, throughout the San Mateo basin, the bedrock had higher Ra due to there being a greater abundance of naturally occurring radioactive materials in the bedrock. Near the millsites, higher Ra activity results from technologically enhanced Ra concentration.

There is a significant variation in U concentration in the Upper Basin, based primarily on the proximity to mine discharge and tailings seepage. EPA cites a 1986 reference that concluded that Se concentrations exceeding 0.15 mg/l and U concentrations exceeding 0.03 mg/l in the alluvial groundwater in Upper Basin is evidence of the influence of MDW (p A5-37). This is tantamount to setting a background

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[1] Total activity is the sum of alpha and beta particle activity.

concentration the Upper Basin. In Lower Basin alluvium, Se and U concentrations are generally higher than in the Upper Basin, especially in the north and south floodplain (p A5-37). EPA notes that elevated concentrations indicate the presence of MDW recharge, but does not set an indicator value for U or Se.

There is no explanation or evidence presented supporting the contention that background U and Se concentration should be higher in Lower Basin than in Upper Basin alluvium. In general, bedrock U concentrations generally represent unmined bedrock unless connected to surface drainage and are less than 0.03 mg/l (Figure A5-21, with a few exceptions). In other words, the natural background U in the bedrock is lower than the standards. In the Upper Basin, the groundwater in the alluvium not affected by MDW (in the northeast portion) has generally low U concentrations as well. Bedrock in the Lower Basin also has U concentrations mostly less than 0.03 mg/l (Id.). EPA has identified no source of U that would naturally cause the U concentration in Lower Basin alluvium to naturally exceed standards. Unmined bedrock throughout the basin does not appear to be a good source of U to the alluvial groundwater. Although without the MDW discharge and leakage from the LTP the alluvial groundwater saturated thickness could be much lower than at present, it would likely also have a much lower U concentration. High U concentrations in the north and south floodplain in the Lower Basin is most likely due to MDW recharge from the Upper Basin (p A5-39). There is no reason background U concentration in the lower basin should not be the same as in the Upper Basin.

Consideration of the uranium activity ratio (UAR) yields similar conclusions. UAR is the ratio $^{234}U/^{238}U$, and values less than 1.34 are considered to indicated uranium mill tailings seepage present in groundwater (p A5-40). Groundwater with the highest U concentrations, mostly in the Lower Basin alluvium, generally has UAR less than 1.34 (Figure A5-22), further indicating the source is MDW. None of the Upper Basin alluvial or Lower Basin bedrock wells have UAR less than 1.34, and only two Upper Basin bedrock wells have low UAR (Figure A5-4). Many of the Lower Basin alluvial wells have UAR less than 1.34 (Id.), and the majority plot in the middle of the San Mateo channel from north to south (Figure A5-25), further demonstrating the effect that MDW has on the U in the alluvium north of the LTP. Wells on the east and west floodplains of the channel have higher UAR, probably reflecting the input of non-MDW water.

Sulfur isotopes also indicate MDW recharge in the San Mateo basin alluvium. The $\delta^{34}S\text{-}SO_4$ values in Lower Basin alluvial groundwater are at or below -8 ‰, a cutoff value that demonstrates MDW influence. A very low value collected at the Faith Mine in Poison Canyon suggests that mine as another source of MDW in the Lower Basin. During very early mining days, this mine discharged dewatering water at about 1,000,000 gallons per day into a channel which would have entered the channel north of the LTP prior to MDW from the Ambrosia Lake mines (p A5-46). The map of the sulfate activity ratio also shows that the center of the Lower Basin channel has mostly MDW-impacted water and that east and west of the center channel, the groundwater has not been affected by MDW (p A5-48).

Part B: Comparison of Concentrations with Standards

Part B of the report compares concentrations for U, Se, adjusted gross alpha radioactivity, combined radium-226 and radium 228, SO4, and TDS determined during the Phase 1 (2014) and Phase II (2015) data collection to regulatory standards (p B1-1). Depending on the standard, the constituent was either total or dissolved. The standards are EPA national primary drinking water MCLs, EPA national secondary drinking water MCLs, or New Mexico Water Quality Control Standards. The report documents exceedances for different portions of the alluvium (in the upper and lower basin), and for four different bedrock types and locations, including Dakota Sandstone, Morrison Formation, Chinle Group, and San Andres Limestone-Glorieta Sandstone.

The report provides lengthy discussion about individual wells and sections of aquifers (EPA 2018, Part B), but the figures are the best way to review the spatial trends, recognizing that the data was collected in 2014 and 2015 (Figures B1-1 through B1-5).

Figure B1-1 shows results for the alluvial monitoring wells. Throughout the basin, most of the standards are violated with three exceptions. First, total radium does not exceed standards anywhere, but it must be noted that the wells presented are upstream of the LTP and not likely affected by upgradient flow from it. Second, most standards are not violated on the east and west San Mateo Creek floodplain wells (SMC-14, SMC-10, SMC-09); the exceptions are for TDS and SO4, which was not caused by MDW. Third, three wells near San Mateo Creek also do not violate standards except for TDS in a couple incidences and two exceedances for total gross alpha; these are generally upstream of mining influence. The exceedances for total gross alpha correspond to the high total Ra in this area. The remaining alluvial wells, in most of the upper San Mateo basin and along the main channel of the Lower San Mateo basin, violate standards for most constituents.

Wells in the Dakota Sandstone in the Upper Basin violate standards only for SO4 and TDS (Figure B1-2) in the Crossroads area. In the Morrison Formation, the only well reported violates standards only for total and dissolved U (Figure B1-3). There are too few wells to establish trends for the Upper Basin bedrock, other than to note that if the U is due to MDW, it reflects the presence of vertical transport along the San Mateo Fault, shown explicitly in the detailed geologic map of the Crossroads Area in Figure A2-5.

Two of three wells completed in the Chinle formation violate standards for U and adjusted gross alpha (Figure B1-4), probably due to the formations subcropping into contaminated alluvium. All three wells violate SO4 and TDS standards (Id.), which are probably naturally high since high values occur in the alluvium. The two wells screened in the San Andreas-Glorieta Formation have several exceedances for U and adjusted gross alpha which may reflect vertical transport due to faulting or along a poorly sealed well. The violations may also reflect transport from the Bluewater Mill, as discussed in the next section.

Part C: Operational and Corrective Actions at the Mine Facilities

The report describes the administrative procedures that the EPA, Department of Energy (DOE) and Nuclear Regulatory Commission (NRC) have gone through to remediate the four sites in the area and to establish background for Homestake Site. Figure 10 shows areas of aquifers in the vicinity of the Bluewater and Homestake Mill area that violate various groundwater standards, including the NRC standards (Figure 11). Figure 12 shows the conceptual cross-section of formations south of and through the LTP. Figures 10 and 12 provide additional hydrogeologic and geochemical evidence regarding groundwater flow and background water quality in the study area.

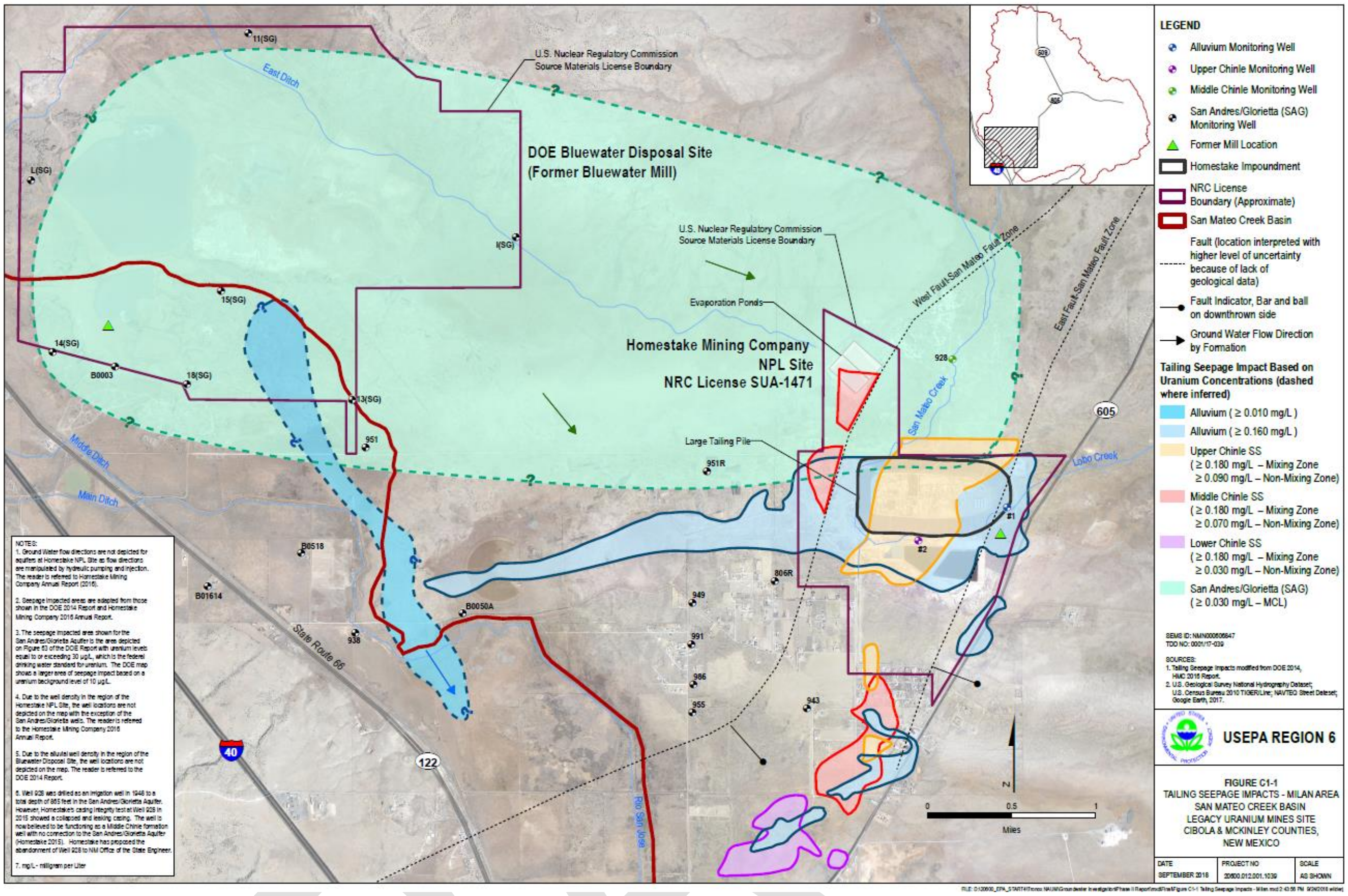
The Bluewater Mill has caused a huge plume of U-contaminated groundwater in the San Andres-Glorietta aquifer, shown as the green area in the north of Figure 10. This probably resulted from the "[s]everal billion gallons of tailing fluid [that] seeped from the bottom of the tailing impoundment and not the underlying alluvial aquifer and the Perrmian San Andres Limestone and Glorieta Sandstone" (p C1-4) beneath the site. The plume has moved south of east and now contaminates the SAG aquifer beneath the Homestake site (Figure 10). There is also contaminated alluvium south of the Bluewater

Mill, although Figure 10 lists the concentration as exceeding 0.010 mg/l, which is less than the standard; it is not clear why this plume is important or shown on this figure.

The LTP is the source of a U plume with concentration exceeding 0.16 mg/l that covers an area about ¾ mile north-south at the LTP about 4 miles east-west (Figure 10). The mass of high-U groundwater at the LTP is the source for high U values further south and southwest (Myers 2015). Three additional plumes of high-U concentration groundwater occur in alluvium for several miles south of the LTP (Figure 10). Although these plumes are on the general flow path, there is no obvious explanation for the variable concentrations along the flow path. There are exceedances also shown in the upper, middle, and lower Chinle formation (exceedance level shown in the figure legend) that appear to coincide with areas of high U in the overlying alluvium. The cross-section (Figure 12) shows that the alluvium is likely the source for high U in the Chinle, with a mixing zone in each.

The report should explain the following aspects of these observations:

- Why does the U plume extend several miles west of the LTP even though this direction is generally upgradient for flow in the alluvium (Figure 10)?
- What causes the highly variable U concentration in the alluvium southwest of the LTP, as evidenced by the variable high concentration areas? Does flood irrigation and other farming practice in the area contribute to the variation?



NOTES:

1. Ground Water flow directions are not depicted for aquifers at Homestake NPL Site as flow directions are manipulated by hydraulic pumping and injection. The reader is referred to Homestake Mining Company Annual Report (2016).

2. Seepage impacted areas are adapted from those shown in the DOE 2014 Report and Homestake Mining Company 2016 Annual Report.

3. The seepage impacted area shown for the San Andres/Glorietta Aquifer is the area depicted on Figure 63 of the DOE Report with uranium levels equal to or exceeding 30 µg/L, which is the federal drinking water standard for uranium. The DOE map shows a larger area of seepage impact based on a uranium background level of 10 µg/L.

4. Due to the well density in the region of the Homestake NPL Site, the well locations are not depicted on the map with the exception of the San Andres/Glorietta wells. The reader is referred to the Homestake Mining Company 2016 Annual Report.

5. Due to the alluvial well density in the region of the Bluewater Disposal Site, the well locations are not depicted on the map. The reader is referred to the DOE 2014 Report.

6. Well 928 was drilled as an irrigation well in 1948 to a total depth of 865 feet in the San Andres/Glorietta Aquifer. However, Homestake's casing integrity test at Well 928 in 2015 showed a collapsed and leaking casing. The well is now believed to be functioning as a Middle Chinle formation well with no connection to the San Andres/Glorietta Aquifer (Homestake 2015). Homestake has proposed the abandonment of Well 928 to NM Office of the State Engineer.

7. mg/L - milligram per Liter

SOURCES:
1. Tailing Seepage Impacts modified from DOE 2014, HMC 2016 Report.
2. U.S. Geological Survey National Hydrography Dataset; U.S. Census Bureau 2010 TIGER/Line; NAVTEQ Street Dataset; Google Earth, 2017.

Figure 10: Tailing seepage impacts in the Milan area from the DOE Bluewater Disposal Site (Bluewater Mill) and Homestake Mining Company NPL Site. Source: EPA (2018) Figure C1-1

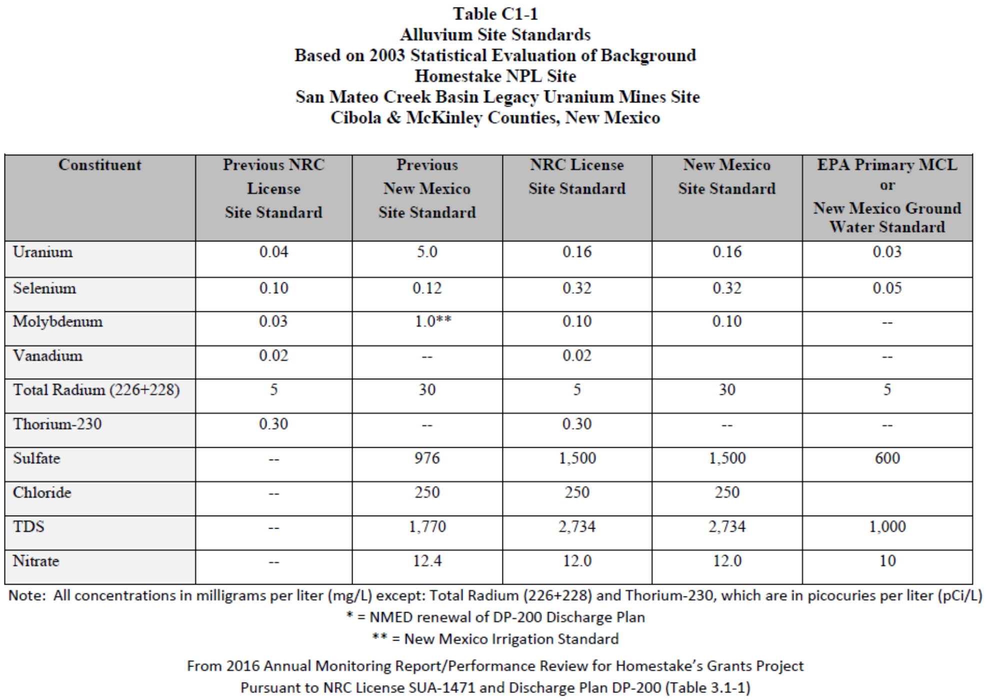


Table C1-1
Alluvium Site Standards
Based on 2003 Statistical Evaluation of Background
Homestake NPL Site
San Mateo Creek Basin Legacy Uranium Mines Site
Cibola & McKinley Counties, New Mexico

Constituent	Previous NRC License Site Standard	Previous New Mexico Site Standard	NRC License Site Standard	New Mexico Site Standard	EPA Primary MCL or New Mexico Ground Water Standard
Uranium	0.04	5.0	0.16	0.16	0.03
Selenium	0.10	0.12	0.32	0.32	0.05
Molybdenum	0.03	1.0**	0.10	0.10	--
Vanadium	0.02	--	0.02		--
Total Radium (226+228)	5	30	5	30	5
Thorium-230	0.30	--	0.30	--	--
Sulfate	--	976	1,500	1,500	600
Chloride	--	250	250	250	
TDS	--	1,770	2,734	2,734	1,000
Nitrate	--	12.4	12.0	12.0	10

Note: All concentrations in milligrams per liter (mg/L) except: Total Radium (226+228) and Thorium-230, which are in picocuries per liter (pCi/L)
* = NMED renewal of DP-200 Discharge Plan
** = New Mexico Irrigation Standard

From 2016 Annual Monitoring Report/Performance Review for Homestake's Grants Project
Pursuant to NRC License SUA-1471 and Discharge Plan DP-200 (Table 3.1-1)

Figure 11: Figure showing various standards for constituents found in groundwater near the San Mateo Creek basin, including the NRC background level for the Homestake Site (NRC License Site Standard). Source: EPA (2018) Table C1-1

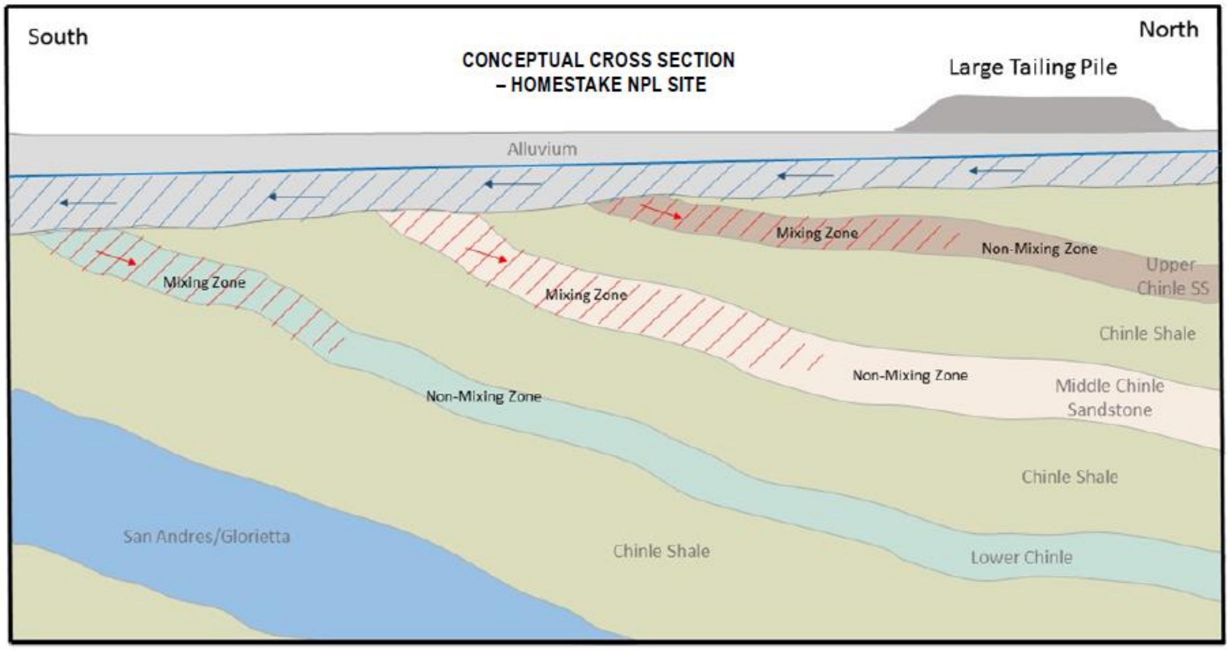


Figure 12: Conceptual cross-section through and south of the Homestake Mill Large Tailing Pile. Source: EPA (2018) Figure C1-2.

Conclusion: The EPA Report Supports a Lower Basin Background U Concentration Equal to 0.03 mg/l

The report describes the process by which the NRC accepted Homestake's site standards, shown on Figure 11 and including the U value of 0.16 mg/l (p C1-9, -10). This resulted from Homestake's inability to achieve a previous standard of 0.04 mg/l. EPA references the studies and wells used by Homestake to establish the new background levels, but does not describe them. The data and analysis presented in this report show that background throughout the San Mateo Creek alluvium, including throughout the Lower Basin, is much less than 0.16 mg/l, and probably less than the current MCL. Support for this conclusion includes the following:

The alluvium in the Upper Basin not directly affected by MDW has U concentration less than 0.03 mg/l. Also, bedrock in the Upper Basin generally has low U values if not in an area that has been mined. This suggests the unmined bedrock is not a source for U in the alluvium.

The bedrock in the Lower Basin only has high U concentration where an aquifer subcrops into the alluvium and receives U from that alluvium. The bedrock in the Lower Basin is not a natural source of U.

The area and volume of saturated alluvium in the Lower Basin expanded substantially due to the mine dewatering water discharged into the dry arroyos and the lower San Mateo wash.

The Lower Basin alluvium groundwater quality has been affected by MDW, but the trends along the alluvium indicate that without the LTP, the U concentrations near the millsite would be much lower if the LTP was not there. In other words, there is no evidence the MDW would have substantially elevated the U concentrations at the LTP and that Homestake is primarily, if not solely, responsible for U in the groundwater at and south of the LTP. Evidence for this includes the fact that some of the wells in the 1 to 2 mile upstream range from the LTP have predominantly not had concentrations that exceed about 0.04 mg/l.

Groundwater in the middle of the Lower Basin paleochannel is more likely to be affected by MDW than is groundwater on the sides of the channel. This reflects the prevalence of MDW flow across and seeping into the middle of the channel. Wells on the sides are more likely to represent pre-mine conditions.

The many low values recorded during the 1980s in the Lower Basin alluvium represents background for the alluvium. Neither the occasional peaks nor the increases in concentration in the 1990s and 2000s are evidence that counter that argument. Peaks may be due to floods coinciding with MDW to cause slugs of U to enter the groundwater. The long-term increase is due to slugs of U flowing downgradient through the alluvial channel.

The distinct low concentration area between the LTP and the near and far-upgradient wells is evidence that the MDW from the Ambrosia Basin does not affect the concentrations at the LTP. Even if contaminants have reached the area of the LTP, they have become too diluted to represent a significant source of mass in the groundwater at the LTP.

The temporal trends document a slug moving downgradient, but there is no evidence that U concentrations would be high at or downgradient of the LTP if the LTP had not been constructed. Any U flowing through the alluvial channel would have passed west of the LTP, as observed at well DD.

The San Mateo Fault is a source of vertical transport of contaminants into possibly both the Upper and Lower Basin.

The EPA report provides substantial evidence that the background U concentration near the Homestake LTP should be same as in the Upper Basin, about 0.03 mg/l.

References

Environmental Protection Agency (EPA) (2018) Phase 2 Ground-Water Investigation Report for the San Mateo Creek Basin Legacy Uranium Mines Site, Cibola and McKinley Counties, New Mexico. Prepared for US Environmental Protection Agency. Weston Solutions Inc., Houston TX

Myers T (2015) *Conceptual Flow and Transport Model Uranium Plume Near the Homestake Millsite, Milan, NM*. Prepared for Bluewater Valley Downstream Alliance, Reno, Nevada, 83 p.