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Goldfield Heap Leach Project: 100 Year Heap Leach Effluent Closure Configuration

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Abstract

The Goldfield Mine was a heap leach operation that entered its final closure stage in late 1998 and has been in post-closure monitoring since April of 2003. This project is located north of the town of Goldfield, Nevada, USA and consists, in part, of a heap leach pad and two evaporation ponds. Water management of heap leach effluent has involved evaporation in the pond system for the past 12 years. Over that period, approximately 1.4 million gallons of effluent have been managed through evaporation with no system overflows. The system generally exhibits standing water in the early spring during freshet when evaporation is weakest, but quickly evaporates as spring temperatures rise. In late 2014 a water balance for 100 years of infiltration, evaporation, and associated salts precipitation was assessed for the system. The assessment assumes evaporation pond inflow from two sources: precipitation and effluent runoff. An extensive evaluation was conducted to provide for a permanent heap leach effluent closure configuration that would require minimal maintenance which included historical heap flow records collected over a 15-year period, meteorological inputs encompassing 38 years of evaporation and precipitation records, and long-term drainage computer simulation with the Hydrus 2D software.

The results of the hydrologic evaluation indicate that the passive evaporation system, as designed for the Goldfield Project, would have the capacity to handle the probable long-term flows associated with heap drain down, during all periods of the year, including the seasonally wet winter period. The available pond volume represents a large quantity in relation to the cumulative volume of water that will be accumulated by precipitation and runoff during the year. As a result, volume lost over time due to precipitate deposition in system pore space presents a negligible impact to the overall ability of the system to accept water during the 100-year period. The objective of this paper is to present the Goldfield Project long-term drain-down information and discuss the evaporation pond design and performance.

Introduction

The Goldfield Mine is located approximately a half-mile north of the town of Goldfield, Esmeralda County, Nevada in the historic Goldfield mining district. Mining of ore and leaching operations have been completed since late 1998 with post-closure monitoring currently ongoing. Decommissioning Services LLC, a subsidiary of Kappes, Cassiday & Associates (KCA), is the responsible party for the closure plan and its implementation. During its active life the Goldfield Mine consisted of a 22-acre heap leach pad, four open pits (Jumbo, Sheet-Ish, Combination, and Red Top), one waste rock dump, four ponds, a process facility, and associated structures and roads. Ore material was processed by heap leach cyanidation and precious metal recovery by carbon adsorption. The mine property encompassed approximately 242 acres, of which 174 acres are private and 68 acres are public Bureau of Land Management (BLM) managed lands.

Part of the closure program involved converting one pond into a long-term heap draindown evaporation cell and constructing a second evaporation pond. The heap leach pad and the evaporation cells are the only process components remaining. The pad currently receives meteoric water, a small portion of which infiltrates the heap through a compacted clay cover. This water passes through the heap and then flows to a partially backfilled evaporation pond where the solution is managed through evaporation. Given the observed drainage flows and chemistry from the heap, a design for a permanent heap leach effluent closure configuration was implemented that would require minimal maintenance for a minimum of 100 years.

Mine Overview

Pits

Ore and waste was mined from four separate pits, the Sheet-Ish, Combination, Red Top and Jumbo pits. These pits are located in the Goldfield historical mining district. Three pits remain as open pits while the Sheet-Ish pit has been backfilled and regraded. None of the pits intercepted the groundwater table and no dewatering of the pits was required during active mining.

Closure monitoring of the Combination, Red Top, and Jumbo pits require annual inspection for ponded water, surface run-on controls, stability, safety, and access restriction.

Geology

The waste rock consists of sedimentary breccia, volcanic conglomerate, tuffaceous conglomerate, sandstone and shale, comprised of locally derived porphyritic rhyodacite and andesite. During active mining, composite samples were collected from each pit, to include both ore and waste rock, and subjected to acid-base accounting (ABA) analysis and humidity cell testing. These tests indicated that sulfides were present in both the ore and waste rock.

Waste Rock Dump

The site consists of a single main waste rock dump, the Red Top dump. This dump contains approximately 5.5 Million tons of material. Due to the known sulfide waste being excavated and relocated into a waste rock dump, a waste dump management plan was put into place. This plan involved the placement of the highly acid generating material in the interior of the dump with less acid generating material being placed at the edges of the dump, resulting in encapsulation of the higher acid generating material in the center of the dump.

Studies concluded that the majority of the moisture received by the site during the winter months would be consumed by evapotranspiration and/or sublimation or will runoff the surface. No drainage through the main waste dump is expected. To date, no discharge or drainage from the waste dump has been noted. As part of the closure monitoring, annual inspections of the waste rock dump is conducted and checked for physical stability and any potential seepage.

Heap Leach Pad

Approximately 1.8 Million tons of ore was processed on the single heap leach pad covering approximately 22 acres. Material was mined from the four open pits and historic waste dumps. The heap contains three cells. All ore placed on the pads was crushed, ranging from 3/8-inch to 3-inch, with approximately 1.3 Million tons agglomerated with 10 to 15 pounds of cement per ton of ore and the remaining 0.5 Million tons agglomerated using lime and Betz non-ionic polymer at rates of 16 pounds per ton and 0.5 pounds per ton, respectively. The heap was closed in 1999, covered with a nominal 12-inch clay cap and nominal 12-inch topsoil cover.

Process Ponds

There were a total of four ponds on site: precipitation, barren, pregnant and storm event. The precipitation pond was closed in-place by folding the liner in on itself and placing topsoil over the entire area. The barren and pregnant ponds, which contained significant amounts of sludge, were sampled and closed in place by placement of a clay cap overlain by geomembrane and then a topsoil cover. All ponds, with the exception of the storm event pond, had leak detection systems which consisted of gravel filled sumps. All leak detection systems were closed and covered during closure activities. During closure, the embankment of the storm event pond was decreased by six feet and backfilled and a small double-lined evaporation cell with leak detection was developed.

Decommissioning Services LLC constructed a second evaporation cell designed such that solution can flow between the two cells. The second evaporation cell was constructed as a double-lined pond with leak detection.

Site Map

The site map for the Goldfield Mine is illustrated in Figure 1.

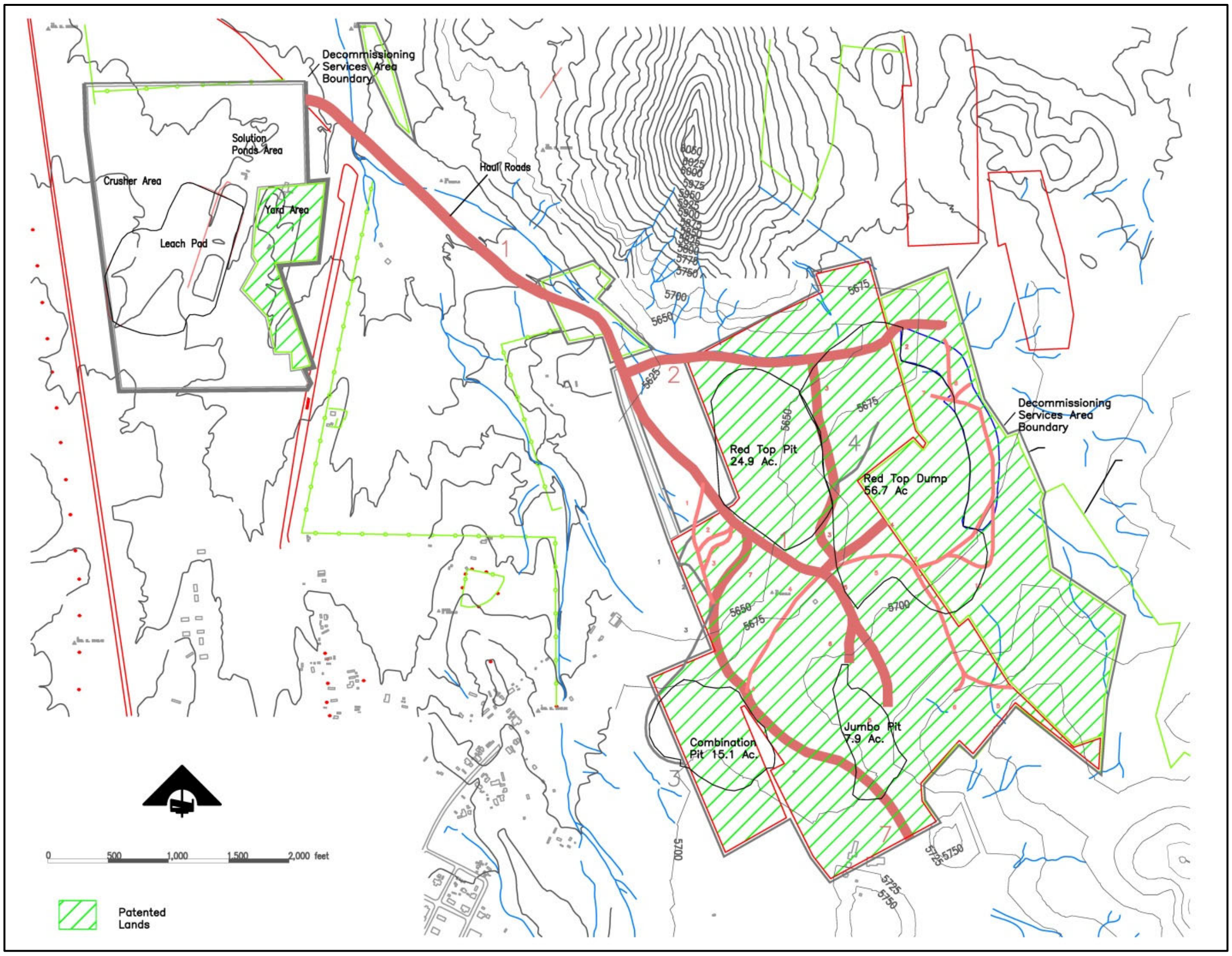

Figure 1: Goldfield Mine Site Map

Current Mine Site Configuration

The heap leach pad has been re-contoured to achieve final 3H:1V slopes with a convex configuration on the top of the heap. The surface has been covered with a minimum of one-foot of compacted clay material, which in turn has been covered with 12 inches of growth media and seeded for re-vegetation. Re-vegetation efforts on the heap have been of limited success, leading to erosion rills observed at the surface of the heap, which has required ongoing maintenance.

There are currently two evaporation ponds connected by an overflow piping system, as presented in Figure 2. The system, as currently designed and configured, accommodates a total of 13,247 cubic feet of solution and meteoric runoff, while maintaining a minimum of one-foot of freeboard at all times. The Evaporation Pond #1 is illustrated in Figure 3 and Evaporation Pond #2 in Figure 4.

The larger of the two evaporation ponds, Evaporation Pond #1, receives effluent discharge directly from the heap. It covers approximately 8,984 square feet, including the outer berm, and with maintenance of one-foot of freeboard, has a maximum capacity of 6,837 cubic feet. Evaporation Pond #1 was constructed in 2002 within the original primary heap overflow pond as a double-lined system with leak detection. The primary heap overflow pond was partially backfilled, and the evaporation pond was constructed in the remaining cavity. The current structure of Evaporation Pond #1 consists of, at its base, an high-density polyethylene (HDPE) liner recovered and reused from the base of the original pond, which in turn is overlain by six feet of local area soil. This soil layer is in turn overlain by a second HDPE liner, a one-foot layer of compacted fines to protect the HDPE lining, 1.5 feet of sandy soil, and finally six inches of two-inch rock fill as shown in Figure 2. The bottom of the overflow pipe is a minimum of 1.1 feet from the top of the layer of rock fill. This profile yields roughly 1.6 feet of available pond depth, consisting of six inches of two-inch rock fill, and 1.1 feet of open containment.

The second evaporation pond, Evaporation Pond #2, was constructed in 2005 with the same base fill and liner profile as Pond #1, with the exception that no backfill underlies the base HDPE liner. Evaporation Pond #2 is 2.8 feet deep from the base of the pond to the berm crest, and does not contain any rock fill. This profile yields a rough containment volume of 6,410 cubic feet with maintenance of one-foot of freeboard.

The pond system was modified in 2010 to replace and reconfigure the pipe overflow system between the two evaporation ponds to increase the available volume of Evaporation Pond #1. The overflow is lined with the same HDPE liner and one-foot layer of compacted fines as the two evaporation ponds. Two Polyvinyl chloride (PVC) pipes laid side-by-side connect the ponds through the ditch. The overflow height is a minimum of 12 inches from the top of Evaporation Pond #1, which constitutes the minimum operational one-foot of freeboard described above.

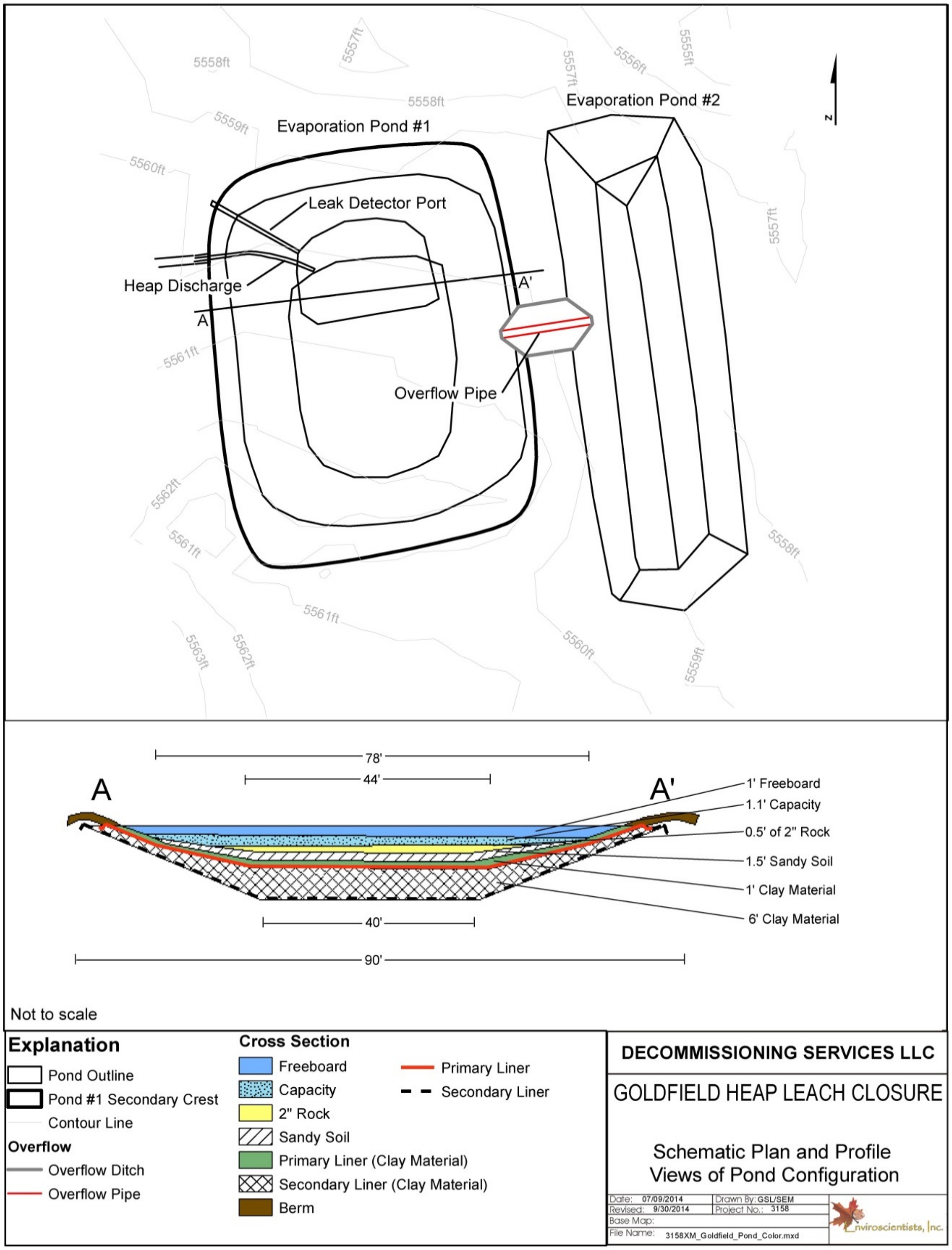

Figure 2: Goldfield Mine Evaporation Ponds

Figure 3: Evaporation Pond #1

Figure 4: Evaporation Pond #2

Evaporation Pond System Water Balance

Water management of heap leach effluent has involved evaporation in the pond system for the past 12 years. Over that period, approximately 1.4 million gallons of effluent have been managed through evaporation with no system overflows. The system generally exhibits standing water in the early spring during freshet when evaporation is weakest, but quickly evaporates as spring temperatures rise.

A water balance for 100 years of infiltration, evaporation, and associated salts precipitation was assessed for the system. The assessment assumes evaporation pond inflow from two sources: precipitation and effluent runoff.

Meteorological Inputs

Enviroscientists analyzed 38 years of evaporation and precipitation records collected between 1967 and 2005 at meteorological monitoring stations at Silverpeak, Nevada, and Goldfield, Nevada, respectively. The station at Silverpeak is located 18 miles due west-northwest of the Project area, and the station at Goldfield is located one mile due south-southwest of the Project area. Pan evaporation data from Silverpeak, Nevada, is available only in monthly averages over this time period; therefore, the precipitation data from Goldfield, Nevada, where daily measurements over the period are available, have been manipulated to create monthly average values for the same time period to make the data comparable.

Based on the records at Silverpeak and Goldfield, average monthly pan evaporation and average total monthly precipitation measurements show total annual evaporation more than 15 times the precipitation rate. Due to the seasonality of the climatic response, there will necessarily be times when precipitation is greater than evaporation, particularly in the winter months, and therefore an accumulation of solution in the ponds will occur. However, the active meteorological forces over the year will lead to net evaporation and ultimately result in the removal of all water from the ponds, likely by the end of spring. Provided that there is zero evaporation from December and January, inclusive, an annual average of 999 cubic feet of water would collect in the ponds from meteoric events alone, prior to resumption of evaporation in the month of February.

Heap Flow Rates

Historical flow records collected over the period 1999 to the present (15 years) have been used in this assessment. Over this period, the most recently recorded flow measurement was 0.029 gallons per minute (gpm), which was collected on August 14, 2014. The average discharge in the summer over the last three years has been 0.037 gpm with a 46 percent decrease in flow over the 15-year period. Over the same time period the average winter discharge has been 0.046 gpm with a 39 percent decrease in flow over the 15-year period. The trend for both the winter and summer discharges is that the flows are decreasing, summer flows are greater than winter flows, and there is not a meaningful difference (less than ten percent) in flows seasonally. The difference in flows between summer and winter in 2014 was less than six percent.

The heap drain down measured to-date represents the net heap flow associated with drainage of the residual volume of solution in the heap leach pad when monitoring began, plus the net balance of precipitation and evaporation through the cover material. During the initial stages of the project closure the heap draindown rates were computer simulated for the first ten years using the Hydrus 2D software. Figure 5 shows the recorded values for the heap effluent drain down rates along with the predicted values provided by the Hydrus 2D software, and Figure 6 provides a more detailed view of the flowrates below 0.5 gpm. Using meteorological inputs encompassing 38 years of evaporation/precipitation records and historical drainage data collected over a 15 year period the Hydrus 2D software simulated heap draindown that exhibited good correlation with the actual effluent flow values. The trend of heap drain down volumes over the period of monitoring follows a pattern consistent with first-order decay (R^2 = 0.90). This is representative of what has been observed at other mining-related facilities including heaps, tailings impoundment, and waste rock facilities. The projection that heap flows will continue to decrease consistent with the established pattern of flow to-date is a sound assertion based on industry experience. However, in the future it will also be important to accurately measure heap flows as the success of the passive water management system evaluation hinges, to some degree, on valid measurements of the low flow predicted.

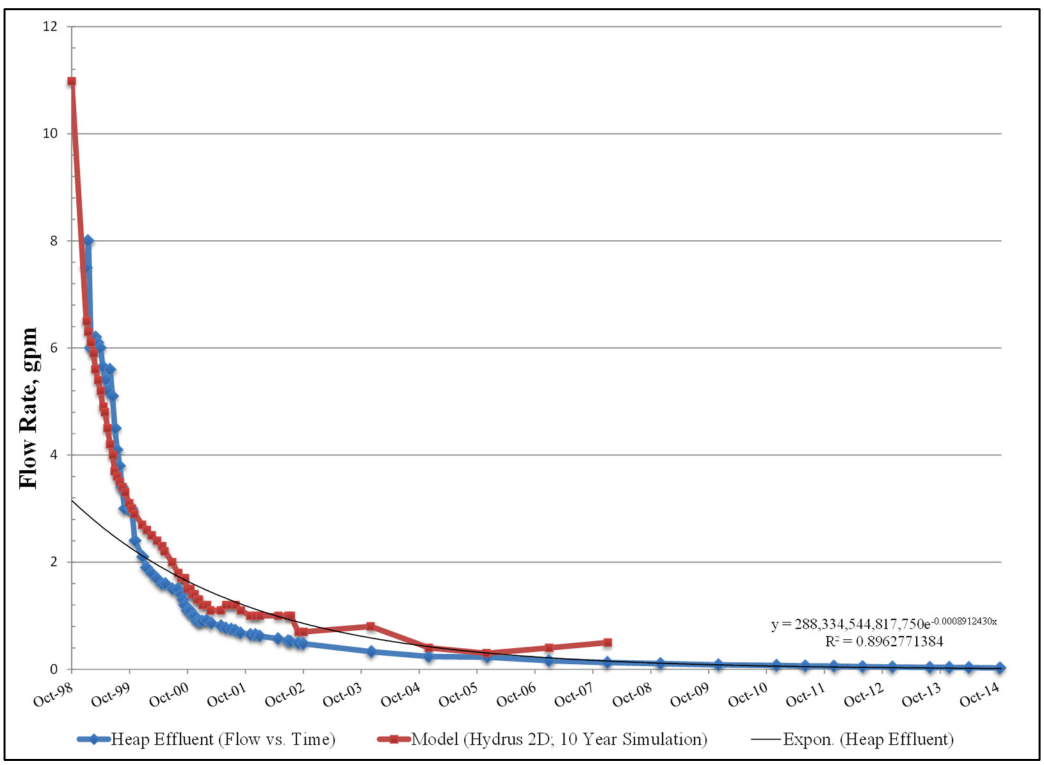

Figure 5: Heap Effluent Drain Down with Simulated Model, 1998 – 2014

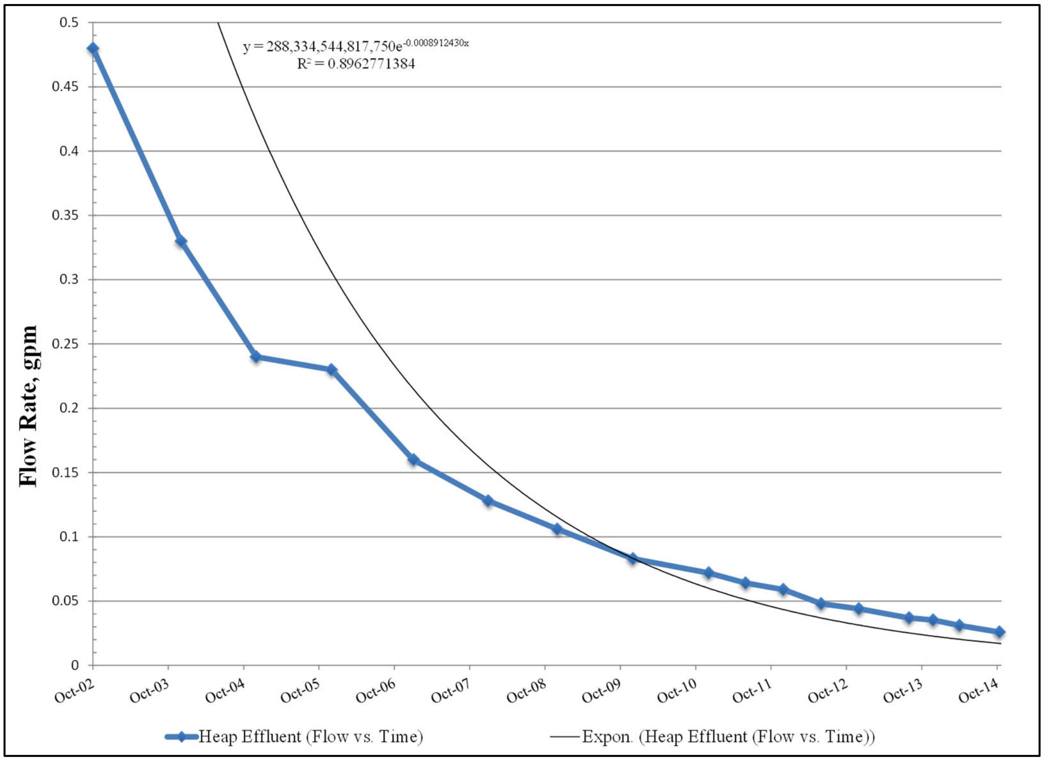

Figure 6: Heap Effluent Drain Down (Below 0.5 gpm)

To conservatively project the volume of water generated by the heap leach pad, the most recent flow measurement of heap solution flow rate has been used, instead of modelled projections of heap drain down decay. This highly conservative approach ensures that predictions in flow rates are higher than those which could be reasonably expected as described above. The data shows a discharge rate of 0.029 gpm as monitored on August 14, 2014. Given this flow rate, the maximum total volume of solution and precipitation that would initially collect in the pond catchment area over the course of a year is 1,345 cubic feet, as presented in Table 1. At year 100, the expected water balance would see 1,345 cubic feet of solution and meteoric runoff collected by the end of January, which would constitute 31 percent of the total capacity of the ponds at that time as shown in Table 2.

Table 1: Goldfield Mine Evaporation System Model, Year One

VARIABLE	Source	UNITS	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT
Days		days/month	30	31	31	28	31	30	31	30	31	31	30	31
Pond #1 volume	Estimate	cubic feet	3,494	3,494	3,494	3,494	3,494	3,494	3,494	3,494	3,494	3,494	3,494	3,494
Pond #2 volume	As-built Drawing	cubic feet	2,885	2,885	2,885	2,885	2,885	2,885	2,885	2,885	2,885	2,885	2,885	2,885
Total volume	Calculated	cubic feet	6,379	6,379	6,379	6,379	6,379	6,379	6,379	6,379	6,379	6,379	6,379	6,379
Average Monthly Pan Evaporation, 1967-2005	Silverpeak, NV	Inches	2.94	0	0	3.84	7.26	10.13	13.60	16.31	17.98	15.92	11.32	6.88
	Silverpeak, NV	cubic feet	1,835	0	0	2,396	4,530	6,321	8,486	10,177	11,220	9,934	7,064	4,293
Average Monthly Precipitation, 1967 - 2005	Goldfield, NV	Inches	0.36	0.31	0.66	1.02	0.79	0.61	0.66	0.45	0.49	0.60	0.54	0.50
	Goldfield, NV	cubic feet	372	319	680	1,044	815	624	675	458	499	618	552	509
Heap discharge flow rate	Site Measurements	gpm	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
		gallons/month	1,253	1,295	1,295	1,169	1,295	1,253	1,295	1,253	1,295	1,295	1,253	1,295
		cu ft/month	167	173	173	156	173	167	173	167	173	173	167	173
Net Inflow by Month	Calculated	cubic feet	0	492	853	0	0	0	0	0	0	0	0	0
Cumulative Inflow	Calculated	cubic feet	0	492	1,345	149	0	0	0	0	0	0	0	0
End of Month Available Volume	Calculated	cubic feet	6,379	5,886	5,034	6,229	6,379	6,379	6,379	6,379	6,379	6,379	6,379	6,379
		percent	100%	92%	79%	98%	100%	100%	100%	100%	100%	100%	100%	100%

Table 2: Goldfield Mine Evaporation System Model, Year 100

VARIABLE	Source	UNITS	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT
Days		days/month	30	31	31	28	31	30	31	30	31	31	30	31
Pond #1 volume	Estimate	cubic feet	3,494	3,494	3,494	3,494	3,494	3,494	3,494	3,494	3,494	3,494	3,494	3,494
Pond #2 volume	As-built drawing	cubic feet	2,885	2,885	2,885	2,885	2,885	2,885	2,885	2,885	2,885	2,885	2,885	2,885
Precipitate Accumulation, Year 100	Calculated	cubic feet	2,088	2,088	2,088	2,088	2,088	2,088	2,088	2,088	2,088	2,088	2,088	2,088
Total volume	Calculated	cubic feet	4,291	4,291	4,291	4,291	4,291	4,291	4,291	4,291	4,291	4,291	4,291	4,291
Average Monthly Pan Evaporation, 1967-2005	Silverpeak, NV	Inches	2.94	0	0	3.84	7.26	10.13	13.60	16.31	17.98	15.92	11.32	6.88
	Silverpeak, NV	cubic feet	1,835	0	0	2,396	4,530	6,321	8,486	10,177	11,220	9,934	7,064	4,293
Average Monthly Precipitation, 1967 - 2005	Goldfield, NV	Inches	0.36	0.31	0.66	1.02	0.79	0.61	0.66	0.45	0.49	0.60	0.54	0.50
	Goldfield, NV	cubic feet	372	319	680	1,044	815	624	675	458	499	618	552	509
Heap discharge flow rate	Site measurements	gpm	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
		gallons/month	1,253	1,295	1,295	1,169	1,295	1,253	1,295	1,253	1,295	1,295	1,253	1,295
		cu ft/month	167	173	173	156	173	167	173	167	173	173	167	173
Net Inflow by Month	Calculated	cubic feet	0	492	853	0	0	0	0	0	0	0	0	0
Cumulative Inflow	Calculated	cubic feet	0	492	1,345	149	0	0	0	0	0	0	0	0
End of Month Available Volume	Calculated	cubic feet	4,291	3,798	2,946	4,141	4,291	4,291	4,291	4,291	4,291	4,291	4,291	4,291
		percent	100%	89%	69%	97%	100%	100%	100%	100%	100%	100%	100%	100%

Pond Precipitates

The hydrologic evaluation suggests that the passive evaporation system as currently designed would have the capacity to handle the probable long-term flows associated with the Project heap leach pad; however, chemistry of the drain down solution has the potential to impact the success of the system through deposition of solids in the form of an evaporative sludge.

Long-term oxidation and leaching of chemical constituents in the heap can lead to solids formation on substrates in the pond system. The density and chemistry of potential precipitates has not been assessed; therefore, it is not possible to accurately predict the volume of lost pond space to precipitation over the life of the system; however, the hydrologic evaluation suggests that on an annual basis, all pore space would be available to precipitates, with the exception of a brief period during freshet, at the end of the winter.

KCA has evaluated the potential effect on available pond volume over a 100-year period as the result of salts precipitation. Based on projected heap solution flow rate decay, as discussed above, precipitate accumulation is expected to collect very rapidly over the first ten years of the project life, reaching 93 percent of the total expected deposition by the year 2024. Over the next 20 years, by 2044, cumulative pond precipitate deposition will achieve 100 percent of the total expected deposition. The volume of solids represented by the total volume is projected to be approximately 100 cubic feet, as shown in Figure 7, which is less than three percent of the total available pond volume.

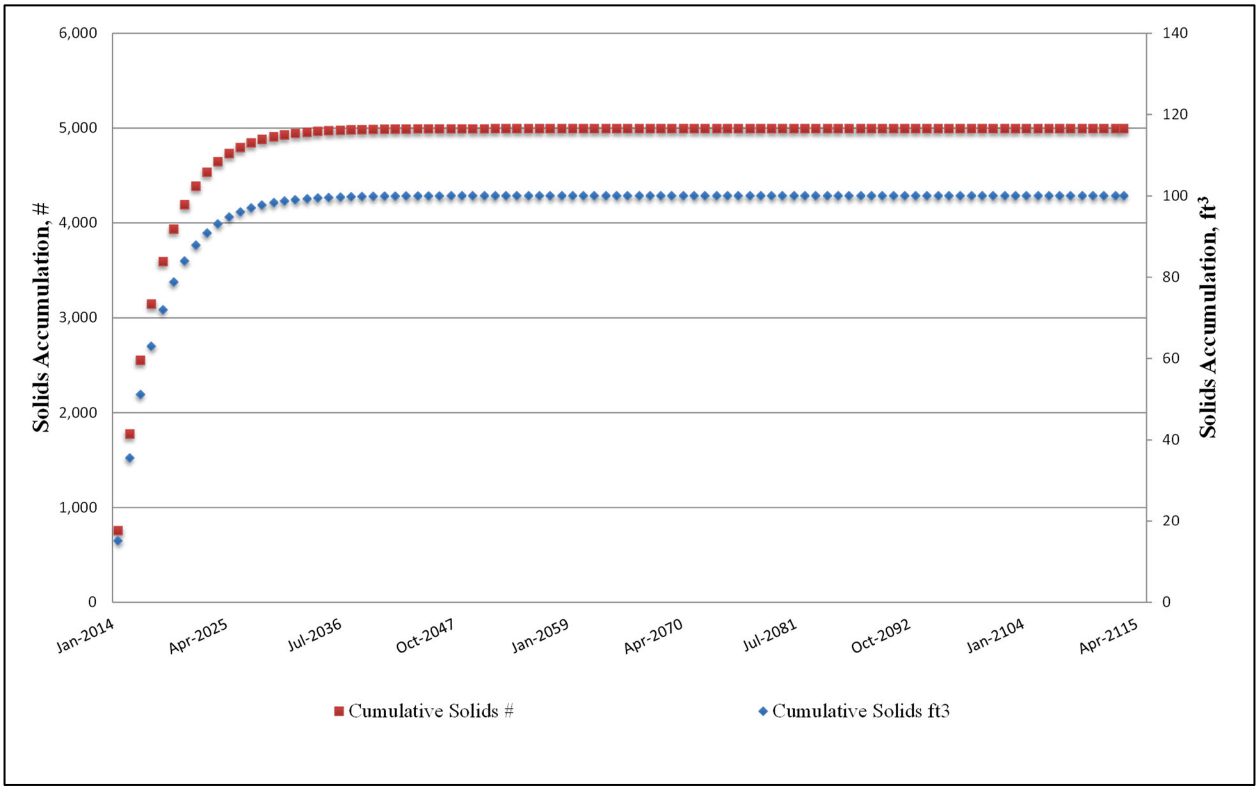

Figure 7: Cumulative Solids Accumulation Forecast, 2014 – 2114

To conservatively project pond volume at the end of the project life Enviroscientists, Inc. has recalculated the potential pond volume given a constant heap effluent flow rate based on the most recent effluent flow measurement, with no drain down decay. This has the benefit of being both highly conservative, and congruent with the approach taken to model the quantity of effluent runoff in the system. This approach results in a constant, linear accumulation rate of solids in the pond to year 100. At year 100, the quantity of sludge that would accumulate under these assumptions is 2,088 cubic feet, or 33 percent of the year one total available pond volume.

Passive Evaporation System

A passive evaporation system will be constructed and maintained within the existing Evaporation Ponds #1 and #2. Construction will involve the removal of bird netting over Evaporation Pond #1 and placement of limestone rip rap in the cavity of both ponds to deter wildlife access. Rip rap will be placed to top height of the overflow pipes. Water in the ponds will be evaporated from the open spaces between the two-inch rock fill, and the limestone will assist in maintaining alkaline chemistry in the pond water. Evaporation is limited in the interstitial space in the soil layer below the aggregate fill.

The proposed system configuration yields roughly 6,379 cubic feet of available pond space, divided between Pond #1 (3,494 cubic feet) and Pond #2 (2,885 cubic feet).

Conclusion

Given constant climatic inputs and a constant flow rate, the expected water balance at year 100 would see 1,345 cubic feet of solution and meteoric runoff collected by the end of January, which would constitute 31 percent of the total capacity of the ponds at that time.

The hydrologic evaluation indicates that the passive evaporation system, as described above, would have the capacity to handle the probable long-term flows associated with heap drain down, during all periods of the year, including the seasonally wet winter period. The available pond volume represents a large quantity in relation to the cumulative volume of water that will be accumulated by precipitation and runoff during the year. As a result, volume lost over time due to precipitate deposition in system pore space presents a negligible impact to the overall ability of the system to accept water during the 100-year period.