SRMC-CWDA-2022-00025
Revision 3

Leak Rate Considerations Related to the SDU 6 Sumps

June 2022

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REVISION SUMMARY

REV. #	DESCRIPTION	DATE OF ISSUE
0	Initial issue.	June 6, 2022
1	Minor changes to clarify the leak history discussions in Section 3.	June 14, 2022
2	Correction made to the sump volume estimate.	June 27, 2022
3	Corrections to typos in Section 3.3.	June 30, 2022

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ACRONYMS/ABBREVIATIONS

ACI	American Concrete Institute
DCS	Distributed Control System
DSS	Decontaminated Salt Solution
GCL	Geosynthetic Clay Liner
gpm	Gallons per Minute
HDPE	High Density Polyethylene
PA	Performance Assessment
SA	Special Analysis
SDF	Saltstone Disposal Facility
SDU	Saltstone Disposal Unit
SEE	Systems Engineering Evaluation
SPF	Saltstone Production Facility

1.0 INTRODUCTION

Construction of Saltstone Disposal Unit 6 (SDU 6) began in late 2014 and initially completed in 2015. A first leak tightness test was performed in late October to early November 2015 per American Concrete Institute (ACI) test specifications (ACI 350.1-10). For this test, SDU 6 was filled with water (with a dye additive) to a height of 41 feet and observed for evidence of leaks. Even though there was no measurable loss in the height of the water during observation, and the walls of the SDU exhibited no signs of dye (from the leak tests), this initial test failed because dyed water was observed at several locations along the floor-to-upper mud mat interface (Y-AES-Z-00002, G-ESR-Z-00019).

After the initially failed leak tightness test, remediation actions included sealing observed cracks in the SDU 6 floor and applying impermeable liners to the interior of the SDU. A second leak tightness test was performed in December 2016 and this time the test passed as there were no observed leak sites.

Despite the remediation actions and passed leak tightness test, models developed in support of the Saltstone Disposal Facility (SDF) Performance Assessment (PA) (SRR-CWDA-2019-00001) assumed that (1) there was no interior liner and (2) the floor concrete would continue to leak. These assumptions were applied to ensure maximum defensibility of the SDF PA model results.

Disposal of saltstone into SDU 6 began in August 2018. In March 2022, contamination was observed in an SDU 6 leak detection sump indicating that waste had a leak path out of the SDU 6 containment system (SRNL-STI-2022-00216).

1.1 Purpose

The purpose of this report is to provide context for various leak rate considerations relative to the contamination found within the SDU 6 sump. Specifically, this report compares the field observations to the assumed modeling conditions to demonstrate that conditions are within the bounds of the critical conditions assumed for the SDF PA (SRR-CWDA-2019-00001).

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2.0 SDU 6 SUMP DESIGN

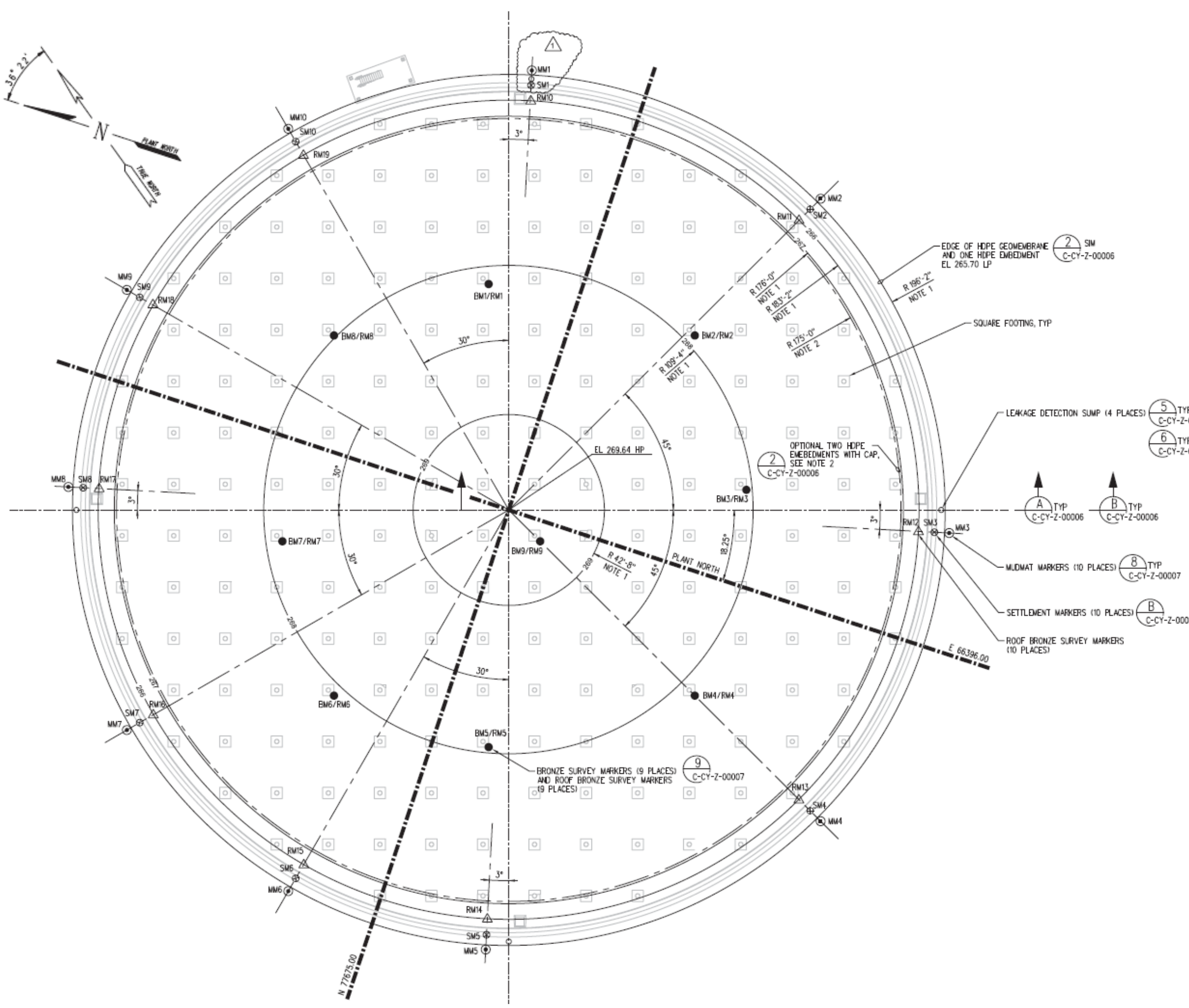
SDU 6 is a 375-foot diameter, 43-foot tall concrete cylindrical tank that is designed to contain the saltstone wasteform. The following describes the relevant design features associated with the SDU 6 sumps.

2.1 SDU 6 Layout View

Figure 2.1-1 shows the design of SDU 6 in layout view, including the SDU floor, walls, and mud mats (C-CY-Z-00005). Since this drawing is difficult to read without zooming in closely, Figure 2.1-2 has been adapted from the design drawing to provide a simplified representation of the relevant information, focused in on one side of SDU 6.

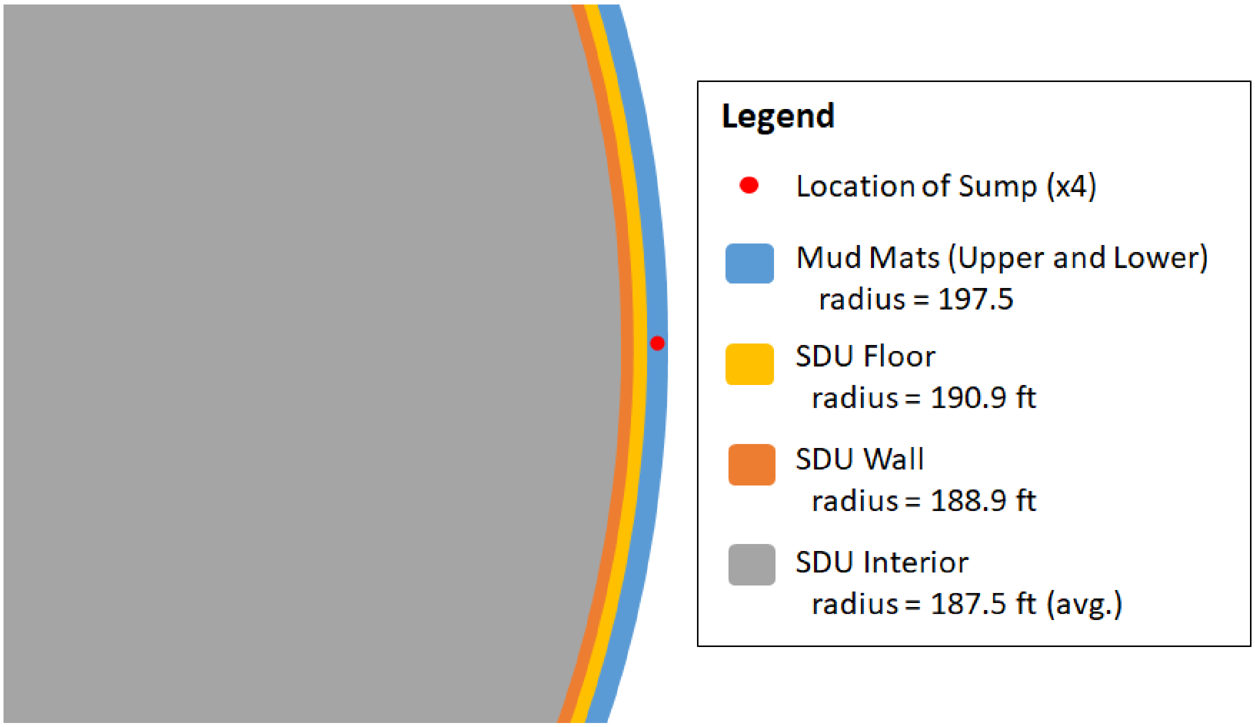
As shown, aside from the SDU sumps, each of the relevant features form concentric circles when observed in plan view (i.e., from above). From the interior to the exterior, these features include the SDU interior (gray), the SDU walls (orange), the SDU floor (yellow), and the upper and lower mud mats (light blue).

Figure 2.1-1: Plan View of SDU 6 Floor, Walls, and Mud Mats



[Source: C-CY-Z-00005]

Figure 2.1-2: Simplified Plan View of SDU 6 Floor, Walls, and Mud Mats



[Source: Adapted from C-CY-Z-00005]

Table 2.1-1 provides a summary of these concentric circles. It also delineates between the upper and lower mud mats based on the detailed cross section provided in Section 2.2.

Table 2.1-1: Summary of Relevant SDU 6 Geometry

SDU Design Feature	Diameter (ft)	Radius (ft)	Extent Beyond Overlying Feature (ft)	Area of Entire Feature (ft^2)	Area of Exposed [d] Portion of Feature (ft^2)
Interior [a]	375.0	187.5	N/A	110,447	N/A
SDU Wall [b]	377.8	188.9	1.4	112,122	1,675.3
SDU Floor	381.8	190.9	2.0	114,508	2,386.6
Upper Mud Mat [c]	384.4	192.2	1.3	116,073	1,564.7
Lower Mud Mat	395.0	197.5	5.3	122,542	6,468.5

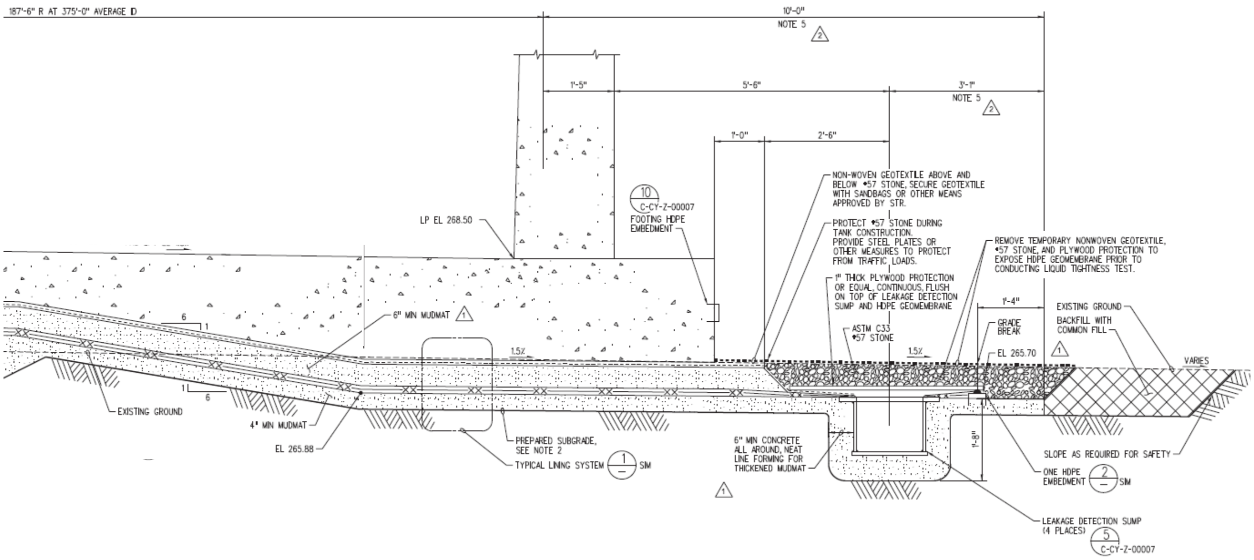
Sources: C-CY-Z-00006, C-CY-Z-00007, and C-CC-Z-00042.

Notes: (a) Values are based on the average interior diameter since the interior of the SDU wall is tapered with a base thickness of 24 inches and a top thickness of 10 inches.
(b) Values are based on an average wall thickness of 1 foot 5 inches.
(c) The Upper Mud Mat has a tapered edge. The top extends 1 ft beyond the SDU floor while the bottom of the Upper Mud Mat extends 1.5 ft beyond the SDU floor. For this table, the extent is assumed to be 1.3 ft.
(d) Exposed feature during leak tightness testing. After leak tightness testing, the mud mats are covered with fill material to the bring the surrounding grade to be level with the floor.

2.2 SDU 6 Cross Section View at the Sump

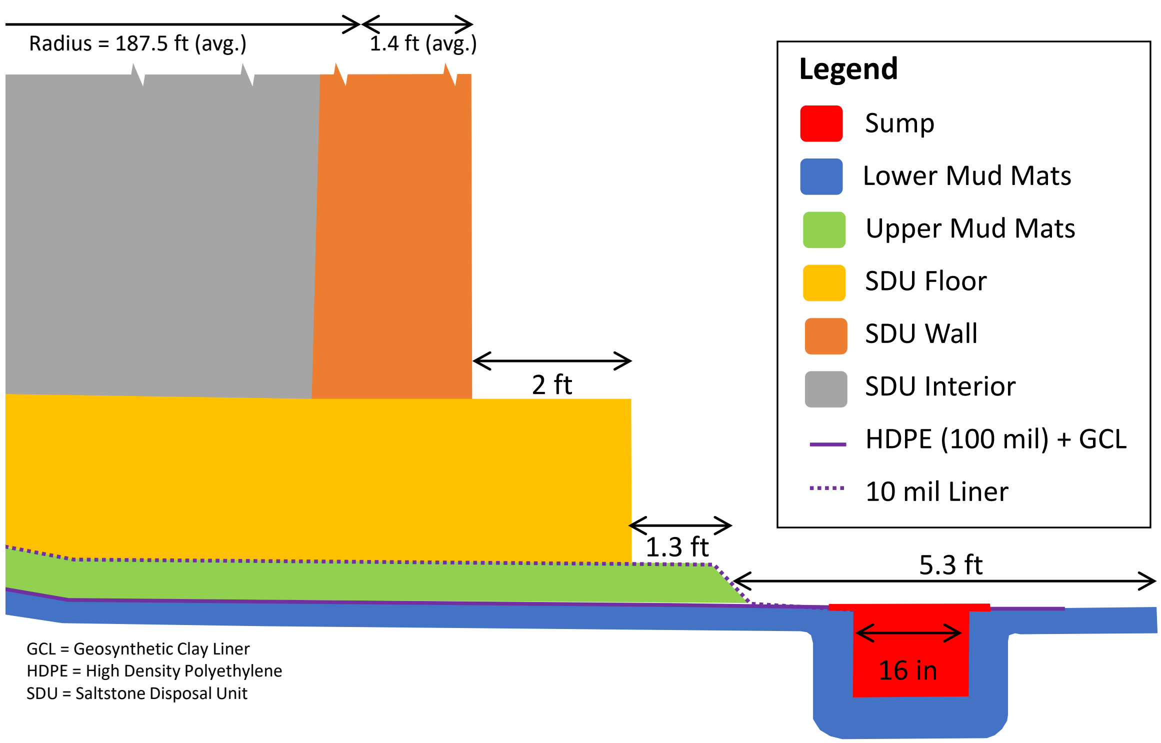
Figure 2.2-1 shows the design of the lower corner of SDU 6 in a cross section view that includes the SDU floor, walls, mud mats, and a sump (C-CY-Z-00006). Since this drawing is difficult to read without zooming in closely, Figure 2.2-2 has been adapted from the design drawing to provide a simplified representation of the relevant information. These drawings show the design features prior to the application of pre-stressing wires and shotcrete around the SDU walls and prior to the leak tightness testing of SDU 6.

Figure 2.2-1: Cross Section View of SDU 6 Floor, Walls, and Mud Mats at the East Sump



[Source: C-CY-Z-00006]

Figure 2.2-2: Simplified Cross Section View of SDU 6 Floor, Walls, and Mud Mats at the East Sump

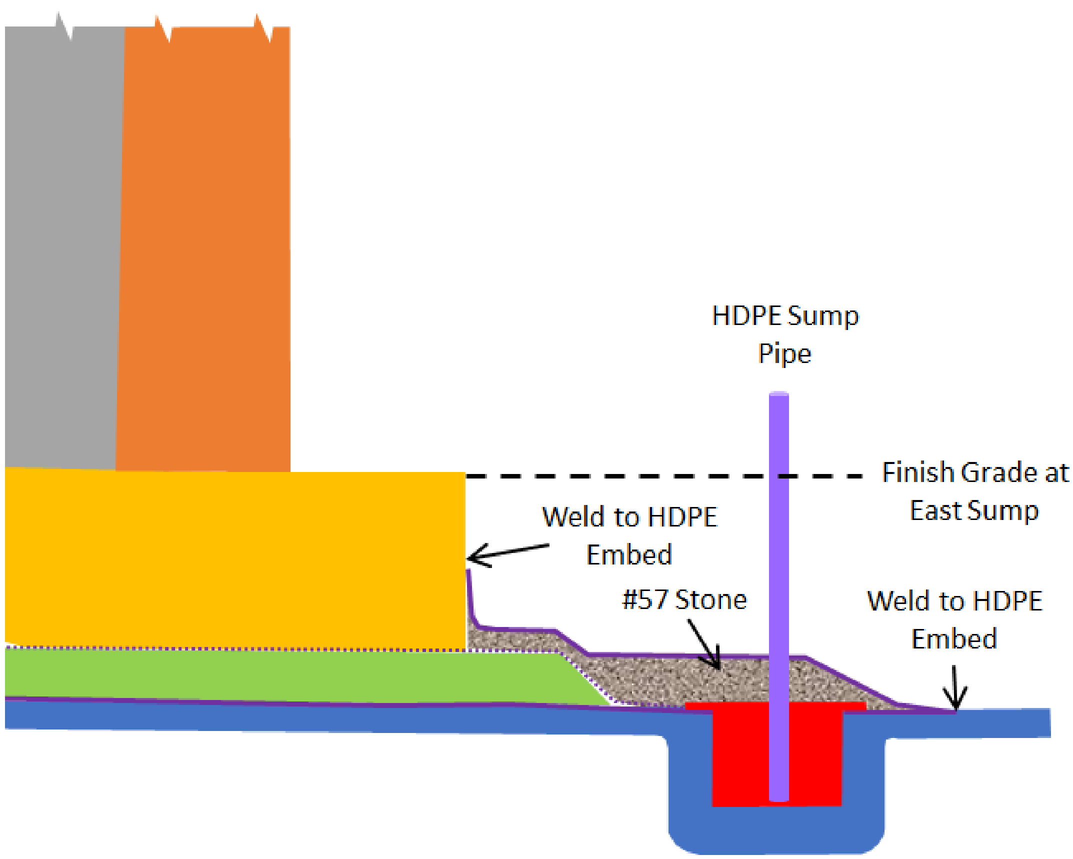


[Source: Adapted from C-CY-Z-00006]

As shown, the floor extends 2 feet beyond the outer edge of the SDU wall. The dimension labels in Figure 2.2-2 also indicate that the upper mud mat extends 1.3 feet beyond the edge of the SDU floor. However, as depicted in the figure, this feature has a tapered edge wherein the top of the upper mud mat only extends 1 foot from the SDU floor while the bottom of the upper mud mat extends 1.5 feet from the SDU floor. The value of 1.3 represents a simplifying assumption for the purpose of this report. Finally, the lower mud mat is shown to extend 5.3 feet from the assumed edge of the upper mud mat. Collectively, the wall, floor, and mud mats extend 10 feet beyond the average radius of the SDU interior. The solid purple line between the mud mats represents the composite barrier: a 100-mil high density polyethylene (HDPE) sheet on top of a low permeability geosynthetic clay liner (GCL). Finally, the dotted line between the SDU floor and the upper mud mat represents a 10-mil liner. Although it is not labeled, the center of the sump is 3.5 feet from the outer edge of the SDU floor.

After the leak tightness testing, a 2-inch diameter HDPE pipe was installed through the cap of the sump (C-CY-Z-00006). Then the upper mud mat, sump, and portion of the lower mud mat were buried under 3 to 8 inches of "#57 stone" (i.e., gravel). The stone was then covered with HDPE that was welded to an HDPE embed on the outer edge of SDU floor and to an HDPE embed along the surface of the lower mud mat, beyond the sump (Figure 2.2-3). These welds, and other HDPE welds related to SDU 6 construction are discussed further in Section 2.3

Figure 2.2-3: Simplified Cross Section View of SDU 6 Floor, Walls, and Mud Mats at the East Sump After Leak Tightness Testing



[Source: Adapted from C-CY-Z-00006]

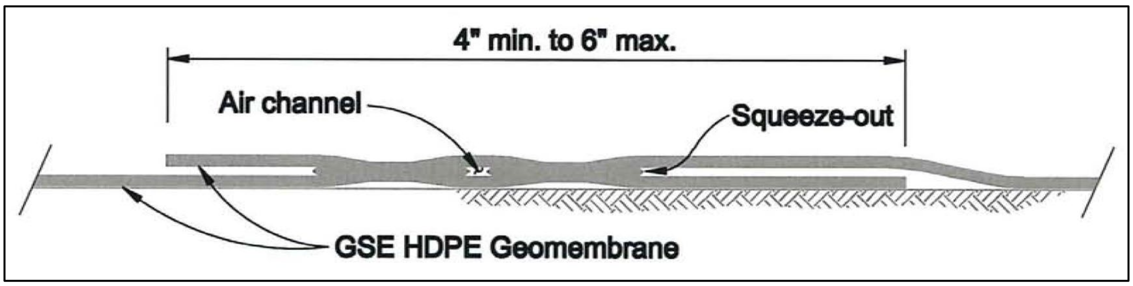
2.3 HDPE Welds for SDU 6 Construction

With respect to the HDPE connections, there are generally two types of welds that were used during the construction of SDU 6 to weld HDPE surfaces together:

- the "hot wedge double track fusion weld," also known as a "double wedge weld" or "fusion weld" (Figure 2.3-1) or
- the "fillet extrusion weld," also known as an "extrusion weld" (Figure 2.3-2).

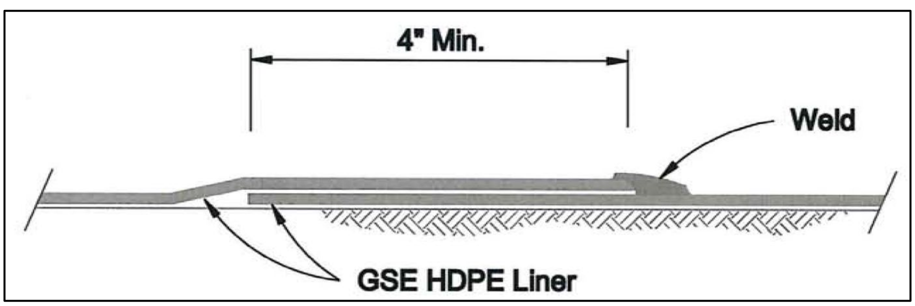
Regardless of the weld type, HDPE installation plans typically require a minimum of 4 inches of overlap when seaming the HDPE together (e.g., C-CY-Z-00006). Exceptions to this overlapping requirement include welds to objects with more complex geometry where overlapping the sheets is not possible, such as connections to the HDPE embeds, HDPE pipes, or to the leak detection boxes (e.g., C-CY-Z-00007). For these connections, only extrusion welds are possible.

Figure 2.3-1: Cross Section View of a Typical Hot Wedge Double Track Fusion Weld



[Source: SRRA075160-000004]
Note: GSE is a supplier of HDPE. Figure is not to scale.

Figure 2.3-2: Cross Section View of a Typical Fillet Extrusion Weld



[Source: SRRA075160-000004]
Note: GSE is a supplier of HDPE. Figure is not to scale.

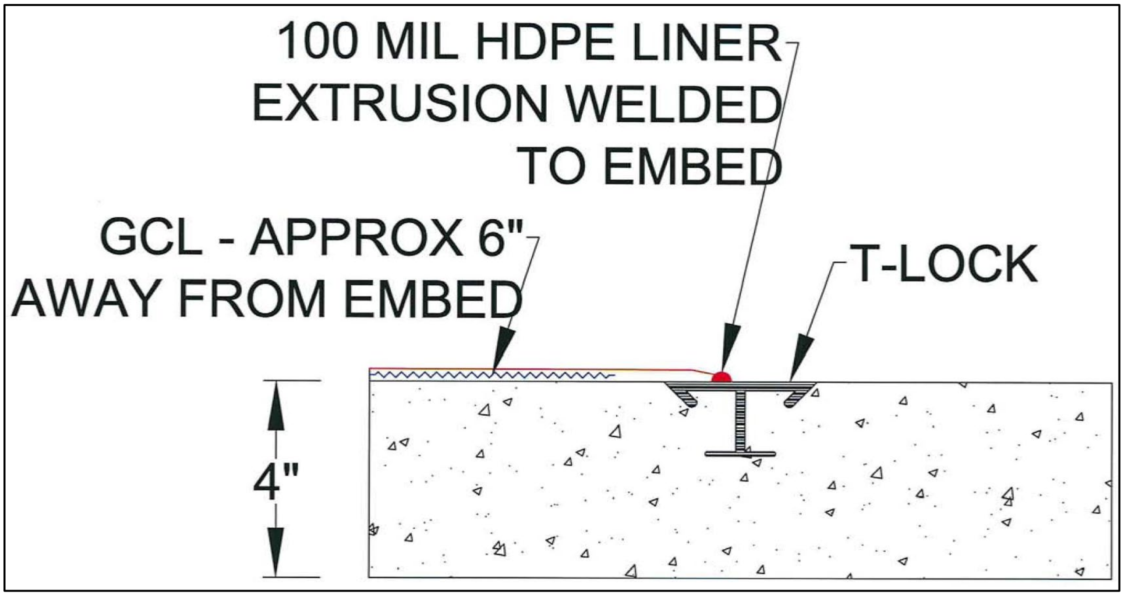
For the installation of the HDPE liner between the SDU 6 mud mats, the double wedge weld was deployed to connect the HDPE sheets together and the seams were all vacuum box tested by passing air through the air channel (Figure 2.3-1) and any defective seams were repaired (C-CY-Z-00006, SRRA075160-000004, C-SPP-Z-00008). Figure 2.3-3 shows the HDPE as it was being installed over the lower mud mat of SDU 6. Note that white HDPE was used (rather than typical black HDPE) to reduce the influence of thermal expansion.

Figure 2.3-3: Installation of HDPE above the Lower Mud Mat of SDU 6

[Source: SRMC-CWDA-2022-00003]

HDPE embeds (or "T-Locks") were installed into the concrete as part of the form installation; the HDPE embeds become encased within the concrete when it is poured. These can be found on both the outer edge of the SDU floor slab and on the top surface of the lower mud mat. Figure 2.3-4 provides an example of the HDPE embed design and Figure 2.3-5 shows a photograph of the HDPE embed in the side of the outer edge of the SDU 6 floor. After installation, the embeds appear as dark strips. Note that this photograph was taken during the first leak tightness test of SDU 6, which is discussed in Section 3.1, and does not represent the leak tightness of the system that was demonstrated during the second leak tightness test.

Figure 2.3-4: Cross Section View of a Typical Fillet Extrusion Weld to an HDPE Embed



[Source: SRRA075160-000004]
Note: Figure is not to scale.

Figure 2.3-5: Edge of SDU 6 Floor Showing the HDPE Embed (Photo Taken During 1st Leak Tightness Test)

[Source: SRR-SDU-2017-00004]

After the first leak tightness test failed, an interior liner was installed (as discussed in Section 3.2) and then the second leak tightness test was performed (as discussed in Section 3.3). After the success of the second test, HDPE was attached to the embeds in the floor (per the design illustrated by Figure 2.2-3) and to the embeds in the lower mud mat, to create an HDPE skirt around the perimeter of the SDU. These welds to the embeds were all continuous extrusion welds.

Figure 2.3-6 shows a photograph of this HDPE during installation. Finally, after the HDPE installation, additional backfill was used to cover the HDPE and to bring the finish grade up to the same elevation as the top of the SDU floor.

Figure 2.3-6: Installation of HDPE Over the Mud Mats

The four sumps include a single pipe that penetrates through the top HDPE to allow water to be removed from the sumps. At the East Sump of SDU 6, the leak detection systems also include a second pipe for a liquid detection probe per design drawing C-CY-Z-00006 (Figure 2.3-7). These pipes are all made of 2-inch diameter HDPE. Continuous extrusion welds were used to seal the extrusions through the HDPE.

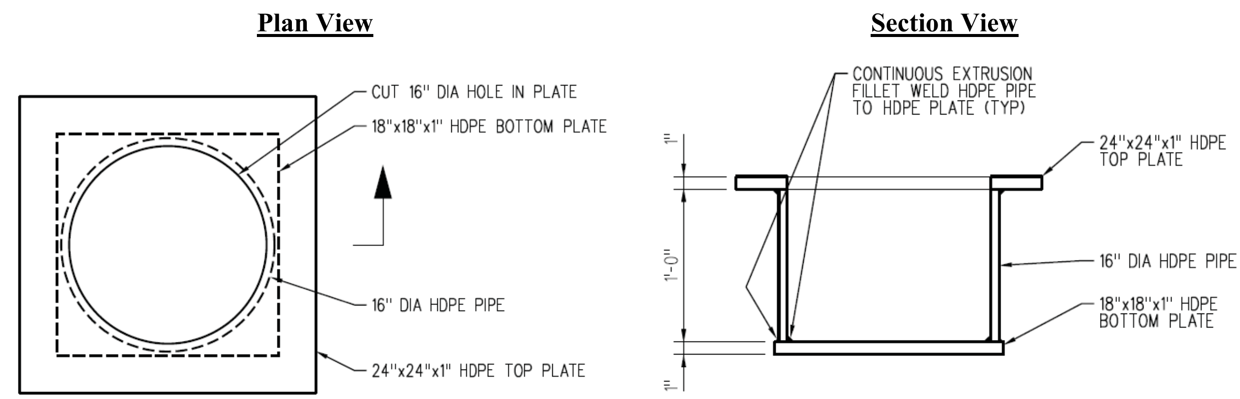
Figure 2.3-7: Installation of HDPE Over the Mud Mats at East Sump

After the welds to the HDPE embeds were complete, the perimeter of the SDU was backfilled to bring the grade up to the level of the SDU floor. Figure 2.3-8 shows the backfill around the SDU 6 East Sump. This figure also shows a dewatering pump that is discussed further in Section 3.4.

Figure 2.3-8: East Sump After Construction

The sump itself is also constructed from HDPE material. They are each made using a 16-inch diameter HDPE pipe that is cut to be 1 foot deep (providing a volume of approximately 10 gallons), then continuous extrusion welds are used to connect the bottom edge of the sump to a 1-inch thick HDPE plate (Figure 2.3-9). Similarly, the top edge of the sump was extrusion welded to another 1-inch thick HDPE plate, but this plate was cut to leave the top of the sump open.

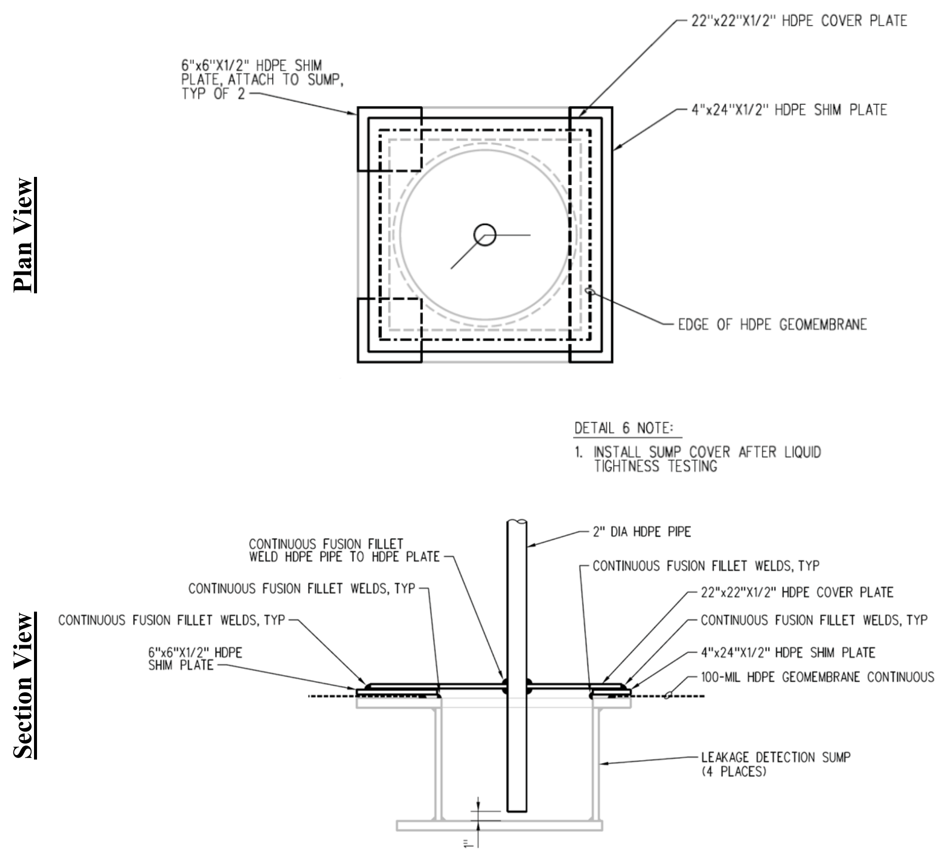
Figure 2.3-9: SDU 6 Sump Design (1 of 2)



[Source: C-CY-Z-00007]

Next, 0.5-inch-thick HDPE shims were attached to the top plate at two corners and one side (Figure 2.3-10), using continuous extrusion welds, then another 0.5-inch thick HDPE cover plate was attached to the shims to cover the top of the sump, also using continuous extrusion welds. Finally, a 2-inch diameter hole was cut through the top cover plate and the 2-inch diameter HDPE pipe was inserted into the sump and attached to the cover plate with continuous extrusion welds.

Figure 2.3-10: SDU 6 Sump Design (2 of 2)



[Source: C-CY-Z-00007]

As described, the installation of the liner system between the mud mats used double wedge welds, while installation of the leak detection system that includes the sumps generally relied on extrusion welds. Because the seams of the liner system were installed with specialized HDPE seam welding equipment (rather than relying on the skill of the craft), and because this equipment applies two welds per seam which were vacuum tested, there is higher confidence that these seams were leak-tight compared to the extrusion welds used for the leak detection system.

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3.0 SDU 6 LEAK HISTORY

As previously mentioned, two leak tightness tests were performed for SDU 6 in accordance with ACI 350.1-10 (and amended by C-SPP-Z-00008 to incorporate the use of dye). Then approximately five years after the start of disposal operations into SDU 6, contamination was detected in the East Sump indicating a leak from the interior of the SDU. The following provides additional details related to the SDU 6 leak history.

3.1 First Leak Tightness Test

Details of the first leak tightness test are provided in LWDP-SUTP-SSF-122, Rev. 1, Attachment 11.13, and summarized as follows.

For the first leak tightness test of SDU 6, the disposal unit was filled with water to a height of 41 feet. Filling started on October 12, 2015 and finished on November 4, 2015. Once filling was complete the fill level was measured. No measurable loss of water was detected (the measurement precision of $1/16^{th}$ of an inch per ACI 350.1-10, Section 2.3.3.2).

Red dye was added to the water (in accordance with the dye sequencing required in C-SPP-Z-00008) on the morning of November 5, 2015 with the intent of recirculating the dyed water for 24 hours to ensure the dye was well mixed with the large volume of water within the SDU. Adding this dye allows for the identification of water coming from inside the SDU during the filling process (as opposed to water coming from other sources). However, in the afternoon of November 5, 2015, dyed water was already observed coming out of the bottom of SDU 6 at the interface between the floor and the upper mud mat. Based on observations, it was estimated that less than 4 liters per minute was leaking from the SDU while it was filled to 41 feet (SRR-SDU-2017-00004).

Despite the no measurable loss of water, the presence of dye at the SDU floor-to-upper mud mat interface resulted in a failed leak tightness test for SDU 6.

Additional testing continued until November 11, 2015, at which point the dyed water within the SDU was pumped out.

3.2 Repairs to SDU 6

After the first leak tightness test failed, a Systems Engineering Evaluation (SEE) was performed to assess repair options (Y-AES-A-00002). As a result of this SEE, a synthetic liner was installed inside SDU 6 per *SDU6 Interior Coating/Liner and Elevation Marking Statement of Work* (C-SPP-Z-00013). The liner material was a 3-mm-thick vulcanized rubber (CHEMOLINE 4 CN) which was attached to the interior concrete surfaces of the SDU using an epoxy.

Figure 3.2-1 shows the interior of SDU 6 after the liner installation. The liners are visible as black panels on the walls and floors.

Figure 3.2-1: Interior of SDU 6 After Liner Installation (Fall 2016)

[Source: SRR-SDU-2017-00004]

3.3 Second Leak Tightness Test

Details of the second leak tightness test are provided in LWDP-SUTP-SSF-122, Rev. 1 and summarized as follows.

For the second leak tightness test of SDU 6, the disposal unit was again filled with water to a height of 41 feet. Filling started on December 15, 2016 and finished on December 27, 2016. Based on lessons learned from the first leak tightness test, dye was added to the water while the SDU was being filled to ensure that any water coming from inside the SDU during the filling process could be isolated from other water sources. Once filling was complete, the fill level was measured. No measurable loss of water was detected (the measurement precision of 1/16th of an inch per ACI 350.1-10, Section 2.3.3.2).

Green dye was added to the water on December 18, 2016 in accordance with C-SPP-Z-00008, when the fill height was between 5 and 15 feet. Inspections were performed periodically through December 28, 2016. No dye was detected.

Because there was no measurable loss of water and because no dye was detected, SDU 6 successfully passed leak tightness testing on December, 29, 2016 at which point the dyed water was pumped out of the SDU.

3.4 Disposal Operations

Prior to discussing the leaks during disposal operations, it is helpful to first provide some context for the history of SDU 6 disposal.

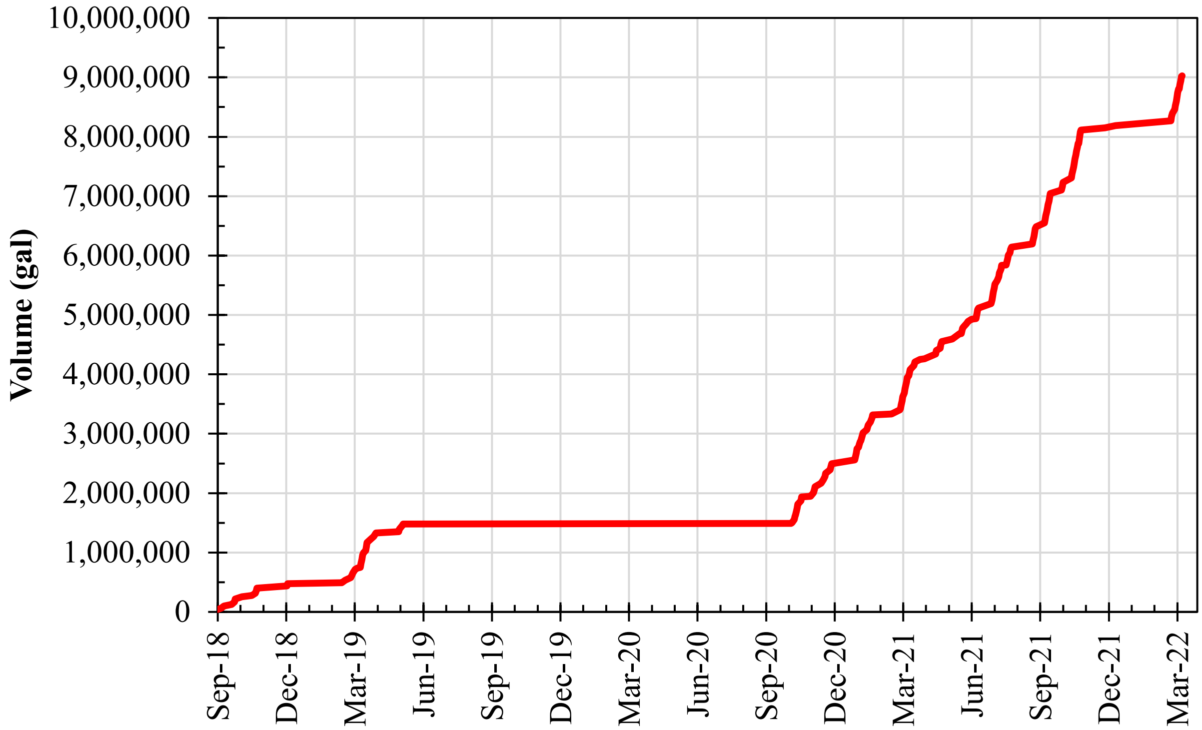
SDUs are designed to store saltstone, a radioactive waste form that is made by mixing decontaminated salt solution (DSS) with dry feeds to form a flowable grout. The radioactive grout is mixed at the Saltstone Production Facility (SPF) and then pumped out to the nearby SDUs. Once it is poured into the SDUs, the radioactive grout cures into the final cement-like waste form.

Prior to start of radioactive disposal into SDU 6, as part of startup testing an initial clean cap (i.e., grout prepared without radioactive DSS) was poured into SDU 6. The initial pours included approximately 3,000 gallons of clean cap grout on March 22, 2018 and approximately 2,200 gallons of clean cap grout on March 28, 2018 (X-CLC-Z-00085, Appendix C). The startup sequence uses clean water, followed by clean grout, then transitions to radioactive grout. Therefore, some amount of water is also included as part of the startup process.

On August 28, 2018, SDU 6 received its first pour of radioactive waste when approximately 8,500 gallons of DSS from the saltstone feed tank (Tank 50 in the H-Area Tank Farm) was transferred to the SPF and the resulting grout was pumped into SDU 6 (X-CLC-Z-00086, Table 1). Note that when the dry feeds are added to the DSS, the volume of the material generally increases by a factor of approximately 1.76 (SRR-LWP-2009-00001), so this first transfer was equivalent to approximately 15,000 gallons of saltstone.

Disposal operations continued until March of 2022 when contamination detected in the East Sump of SDU 6 exceeded the screening threshold for worker protection (per 5Q1.2-302). As of March 2022, SDU 6 had been filled with approximately 9M gallons of saltstone (Figure 3.4-1).

Figure 3.4-1: Fill Volume History for SDU 6



After each transfer, flush water is also passed through the transfer line from the SPF to the SDU to prevent accumulation of material within the transfer line. Assuming approximately 900 gallons of water is used to flush the line after each day when transfers occurred, and assuming that none of the transfer line water has been consumed by the saltstone during hydration and/or curing processes, there is approximately 150,000 gallons of flush water inside SDU 6.

3.5 Leaks During Disposal Operations

Section 2.3 indicated that the East Sump of SDU 6 included a second pipe for a liquid detection probe. Specifically, the sump is equipped with a monitoring level switch with a Distributed Control System (DCS) control room alarm (M-M6-Z-00129).

In March 2017, only a few months after the second leak tightness test, SDU 6 was transferred from the SDU 6 Project Team (construction) to the SDF Operations. It was immediately noted that the East Sump alarm was actuated almost continuously (Riley, 2022). When the sump was pumped and the alarm cleared, it would re-actuate within an hour (Riley, 2022). It was assumed that the water in the sump was due to construction water and rainwater that had been received during the sealing the of HDPE liner around the perimeter of the SDU after the leak tightness testing had been completed (Riley, 2022). It may be noted that the soils surrounding the HDPE appear to be damp in Figure 2.3-6, supporting this hypothesis.

Given the combined area of the upper and lower mud mats beyond the SDU floor (approximately 8,000 ft^2 per Table 2.1-1), hypothetically if only 2 inches of water had accumulated over the mud mats prior to the installation of the HDPE, then up to 10,000 gallons could have been trapped within the leak detection system.

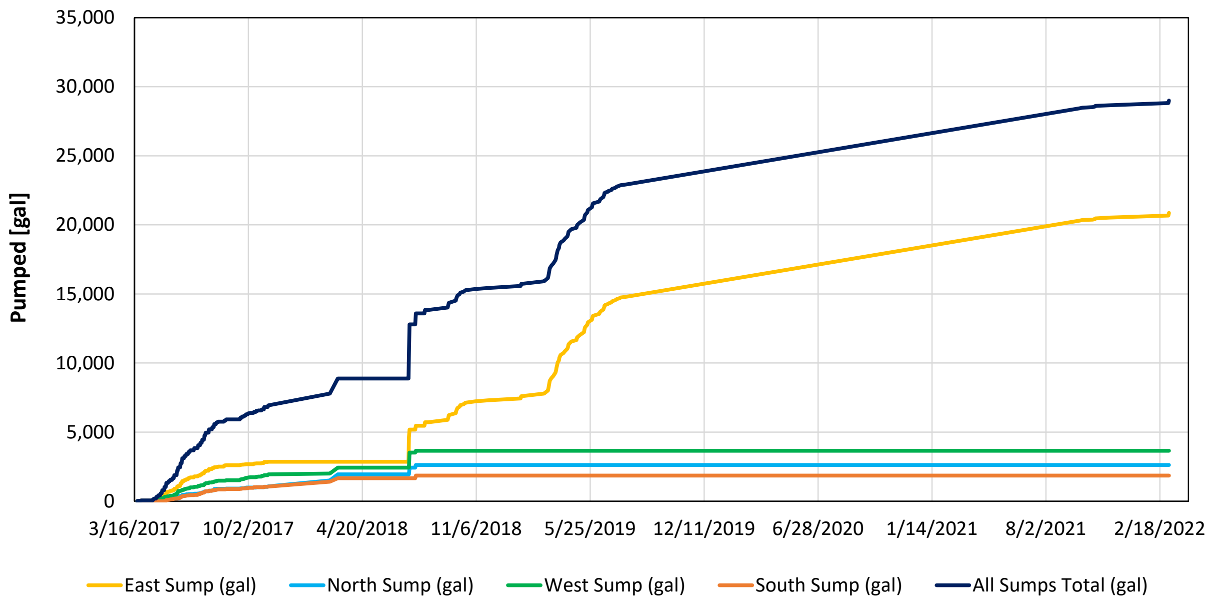
The sumps are each 16 inches in diameter and 12 inches deep, resulting in a volume of approximately 10 gallons each. The actual capacity of each sump will be less than 10 gallons, because the void space within the sumps were filled with #57 stone (i.e., gravel) prior to backfilling (C-CY-Z-00007) to help prevent the sumps from collapsing under the weight of the fill material. Ignoring the volume displaced by this gravel, the four sumps offer a combined capacity of approximately 40 gallons. So, if the hypothetical 2 inches of water were trapped within the leak detection system, the sumps would each have to be emptied more than 200 times to remove the entire 10,000-gallon volume. While these values are merely hypothetical, they help to illustrate the problem. It remains unknown how much water was initially trapped within the system.

Given that annual rainfall at the Savannah River Site is approximately 48 to 50 inches per year (SRR-CWDA-2021-00036), and the SDU 6 roof covers an area of more than 110,000 square feet, a significant amount of rainwater can shed from the roof to the perimeter of the SDU each year. If there are any leaks in the extrusion welds of the HDPE in the leak detection system, rainwater could account for thousands of gallons of in-leakage each year. Regardless, the sumps would be pumped dry, and the alarm would be cleared. In July 2018, a semi-permanent pump was installed at the East Sump to reduce the effort required for dewatering the sump (shown in Figure 2.3-8) (SSF-TMC-18-003).

Additionally, after disposal of saltstone began, samples of the sump water would routinely be tested per the alarm response procedure (ARP-LAH-6100) to ensure the water was not contaminated. The tests consistently indicated that the water was free of contamination until 2022. This process continued until March 2022, when the test indicated that contamination in the East Sump exceeded the screening threshold for worker protection (per 5Q1.2-302). Additional analyses were performed on the sump water to characterize the nature of this contamination (SRNL-STI-2022-00216).

When the contamination of the East Sump occurred, an investigation was performed to better understand how the water became contaminated. As part of the investigation, the cumulative volume of water pumped out of the SDU 6 sumps was estimated (Figure 3.5-1) (SRMC-2022-WSE-0010). Based on pump data it was estimated that 29,000 gallons had been pumped out over the 5-year period.

Figure 3.5-1: Cumulative Volume of Water Pumped from SDU 6 Sumps as of March 2022



[Source: SRMC-2022-WSE-0010]

Note, however, that this estimate was not based on measuring the actual volumes but, instead, was based on the number of minutes that the pumps were run for multiplied by the flow rate of each pump (11 gallons per minute (gpm)) (McCoy, 2022). If the pumps were run continuously, even after the sump ran dry, then these estimates have the potential to be high. For example, it was noted that one day from this data set reported 5,480 gallons pumped out of the East Sump in a single day; coincidentally, this is approximately equal to the volume that could be pumped over an 8-hour shift at the set rate of 11 gpm. However, this volume is much higher than the approximately 10-gallon capacity of the sump. With this insight, the 29,000-gallon estimate over this five-year period is expected to be a bounding estimate. It is very likely that a smaller volume than this has actually been removed from the system.

Similarly, it is possible that the sump water has multiple sources: existing construction water, rainwater from the SDU roof and the soils external to the HDPE, or from inside the SDU itself. If only a portion of the water is from the inside of SDU 6, then assuming that the estimated volume of 29,000 gallons comes entirely from inside of SDU 6 is likely to be an overestimate.

Using this bounding volume of 29,000 gallons over a 5-year period, the long-term average pump rate is estimated to be approximately 16 gal/day pumped from the leak detection system.

4.0 SDF PA MODELING OF SDU 6

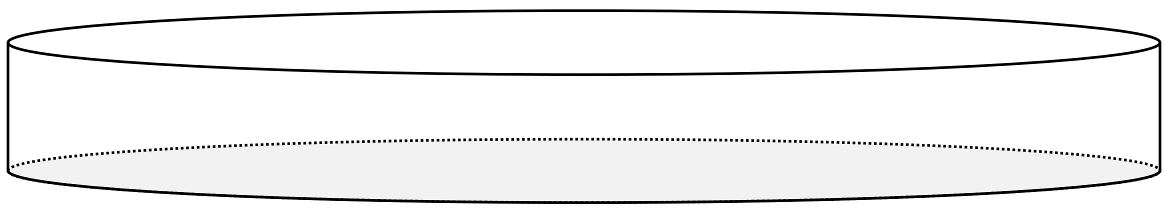
The SDF PA (SRR-CWDA-2019-00001) describes several models that were used to evaluate the performance of the SDF closure system and to demonstrate that the system would meet performance objectives defined by DOE M 435.1-1.

As part of this modeling effort, a model of SDU 6 was developed. The following describes how SDU 6 was modeled in the context of the SDU design and leak-tightness tests.

4.1 SDU 6 Model Design

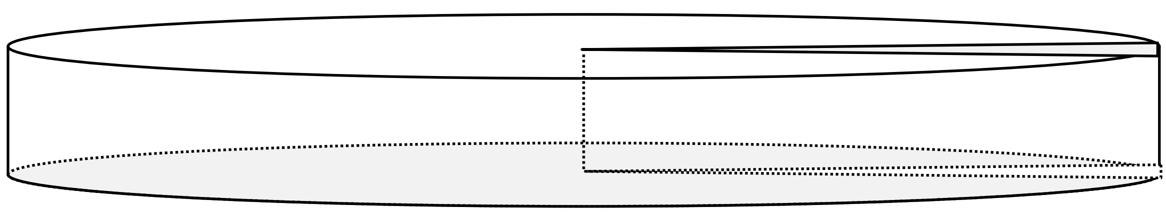
Conceptually, the SDU 6 model may be thought of as a single cylinder (Figure 4.1-1).

Figure 4.1-1: Conceptual SDU 6 Cylinder



However, because cylinders have internal symmetry, the models developed within the PORLFOW modeling software, took advantage of this internal symmetry. Specifically, rather than modeling the SDU system as a fully three-dimensional system, it was modeled as a quasi-three-dimensional system by simulating a single two-dimensional slice (or "pie wedge") from the cylinder (Figure 4.1-2), then extrapolating the results from this slice into three-dimensions.

Figure 4.1-2: Wedge Sliced from the Conceptual SDU 6 Cylinder



Accordingly, representations of the SDU 6 PORFLOW models always show the face of this wedge, in which the left axis represents the center of the SDU (Figure 4.1-3).

Figure 4.1-3: Example of the Vertical Cross Section of SDU 6 as Modeled in PORFLOW

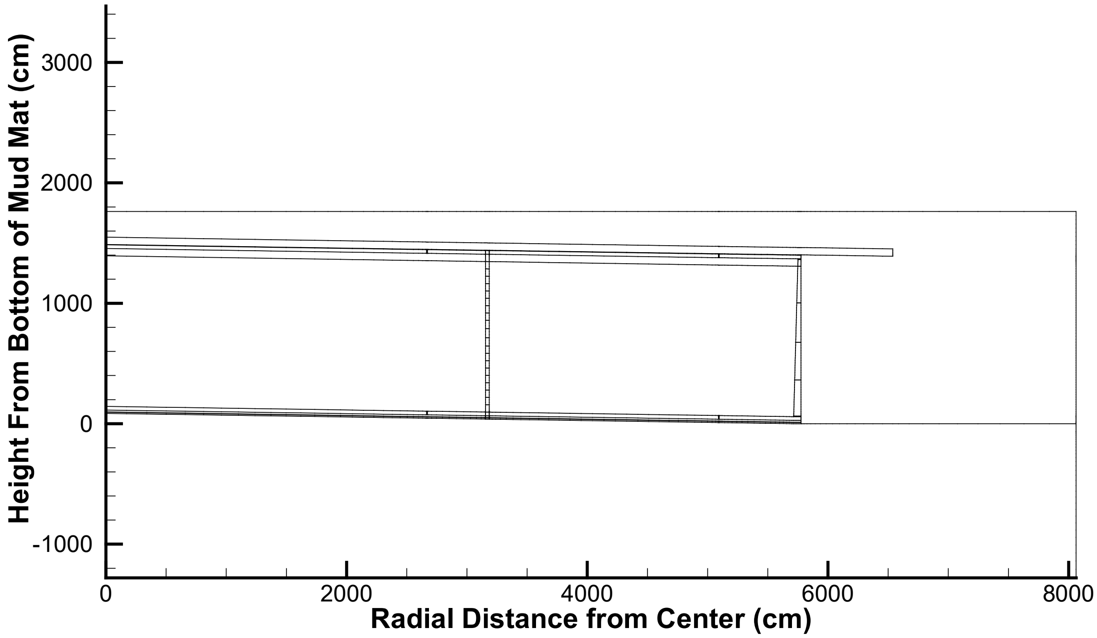
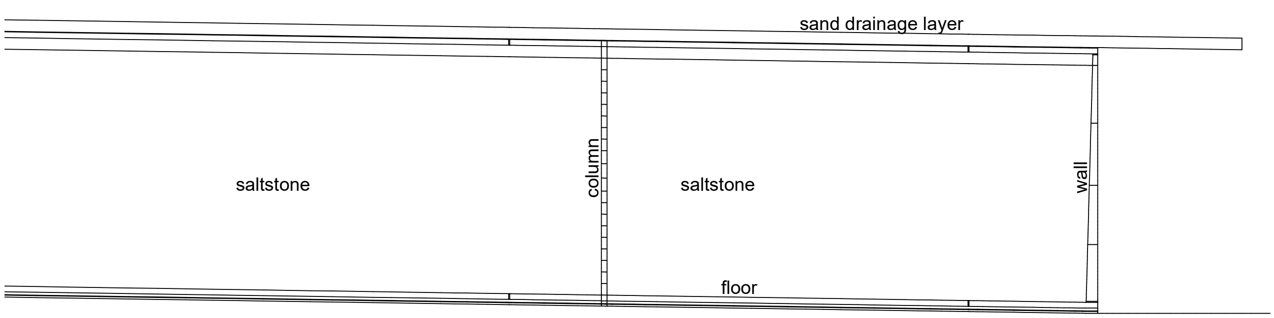


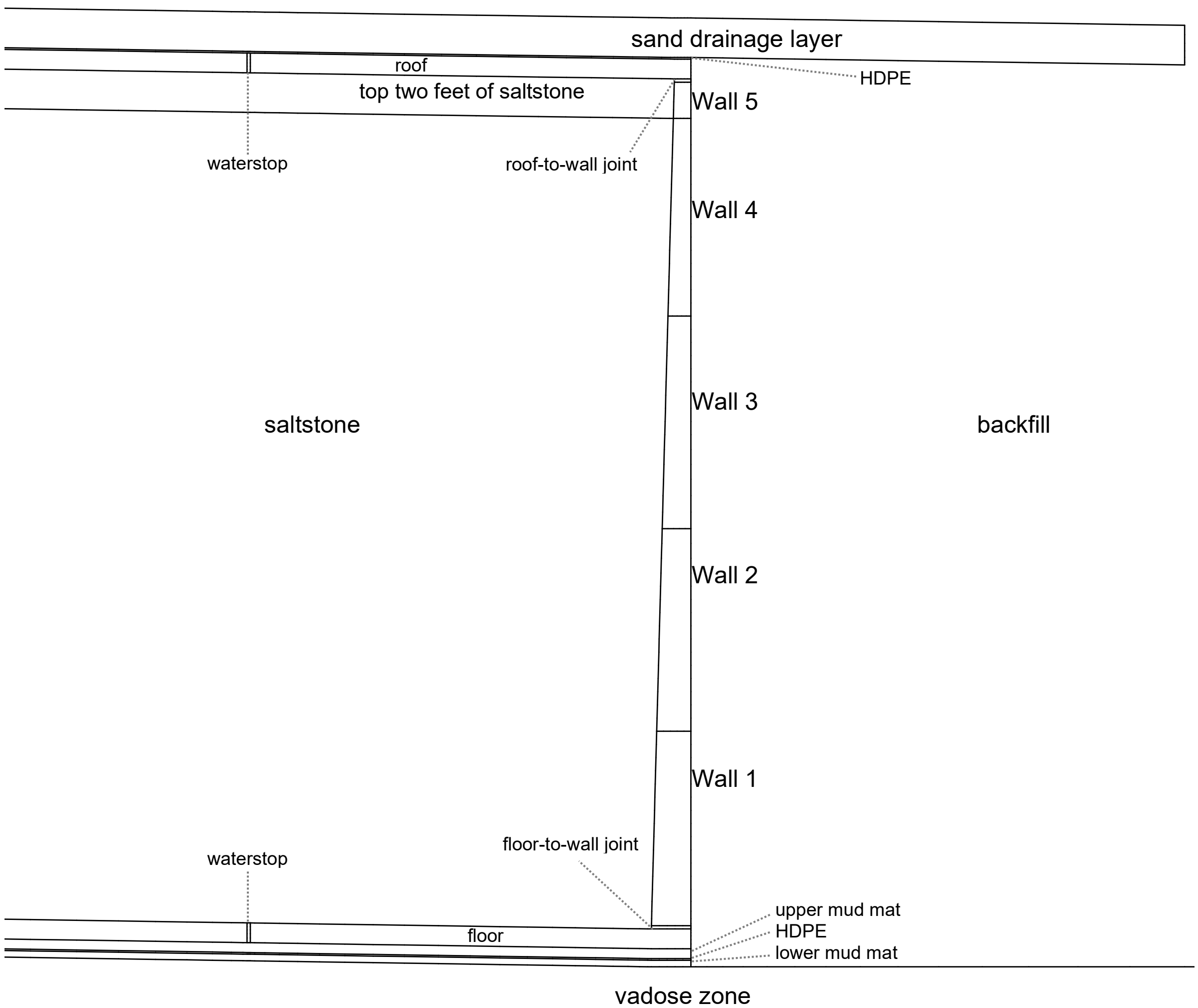
Figure 4.1-4 identifies a number of the larger features that appear within these vertical cross-sections. Similarly, Figure 4.1-5 provides a more detailed view of the outer edge of the SDU and identifies more of the modeled features.

Figure 4.1-4: Vertical Cross-Section of SDU 6, Identifying Larger Features



Note that only a single roof-support column is shown in Figure 4.1-4. When this two-dimensional representation of the column is extrapolated into three-dimensions, this column translates into an interior SDU wall. This modeling approach is a simplification; in reality, there are 208 unique columns, each with a 2-foot diameter. The dimensions of the modeled column were set to ensure that the surface area (in plan view) of the column was equal to the combined surface area of all 208 columns.

Figure 4.1-5: Vertical Cross-Section of the Outer Edge of SDU 6, Identifying Features



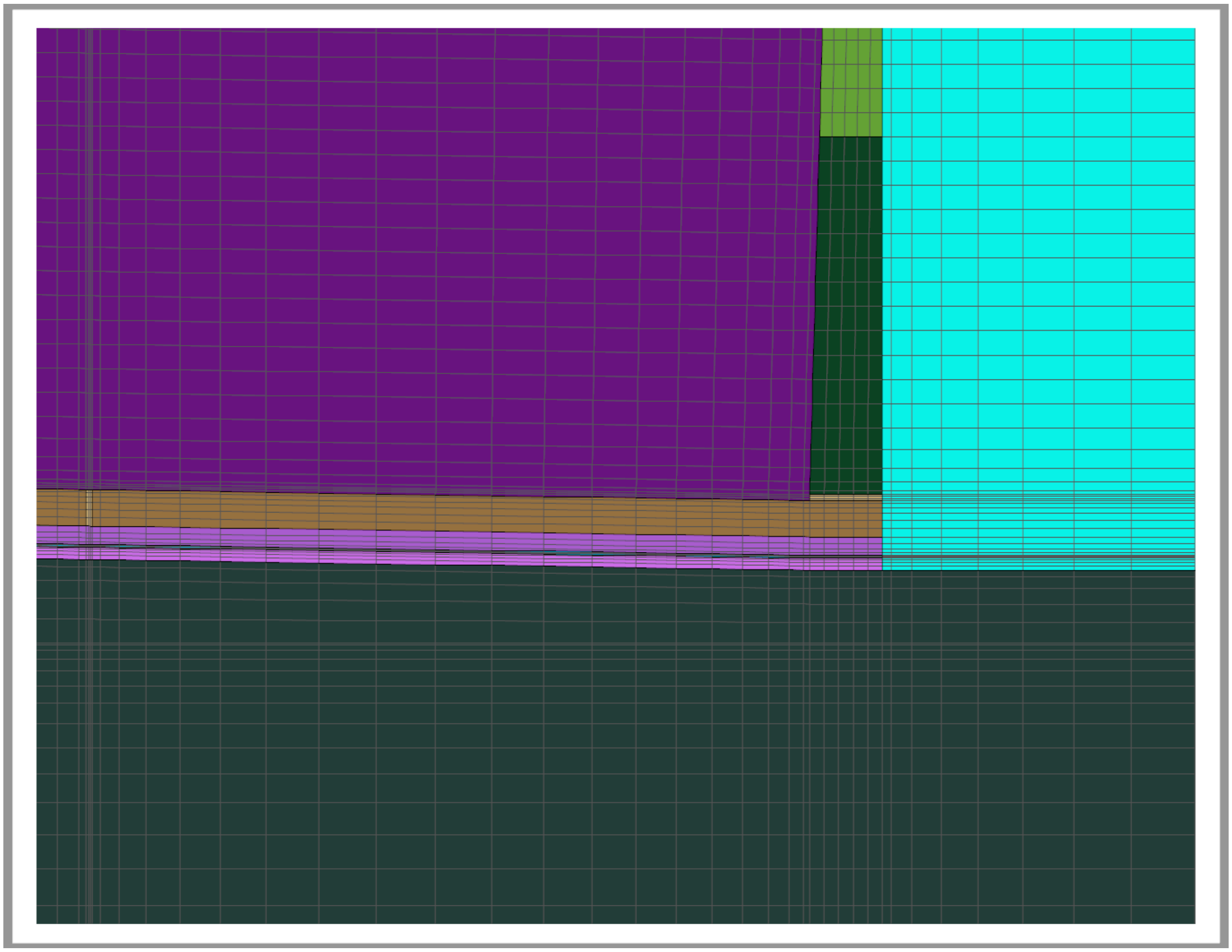
4.2 SDU 6 Interior Liner Modeling

As previously discussed, an interior liner was installed inside SDU 6 (Figure 3.2-1) after the first leak tightness test. However, the material properties of the 3-mm-thick vulcanized rubber have not undergone rigorous testing and the long-term degradation properties are not known. Therefore, as a modeling simplification, the presence (and the associated performance) of this interior liner was not credited (SRR-CWDA-2019-00001, Section 2.7.5). Since the liner was not credited, the SDF PA already accounts for potential leaks through the interior liner.

4.3 SDU 6 Modeling Extent

As shown in Figure 4.1-5, the lateral extent of the SDU 6 floor, upper mud mat, HDPE, and lower mud mat in the lower, outer corner of the SDU do not extend beyond the SDU 6 wall. As a modeling simplification, all of these design features were assumed not to extend past the wall. This model simplification was also illustrated in Figure 4.4-57 of the SDF PA (SRR-CWDA-2019-00001), which is reproduced here as Figure 4.3-1.

Figure 4.3-1: SDU 6 Lower Corner Detail for PORFLOW Vadose Zone Modeling



[Source: SRR-CWDA-2019-00001, Figure 4.4-57]
Note: Colors were arbitrarily assigned to the SDU features. The deep purple that dominates this image represents the saltstone that will fill the interior of SDU 6. The brown area represents the SDU 6 floor, the two shades of lighter purple represent the upper and lower mud mats, while the shades of green represent the SDU 6 wall. The blue field to the right of the SDU represents backfill material, while the dark gray beneath the SDU represents natural soils.

Because the floor, mud mats, and HDPE all terminate at the extent of the wall, it means that the external face of the floor and the mud mats are all modeled as being exposed to backfill material and the SDF PA did not credit any of the design features or HDPE beyond the wall. Effectively, this is equivalent to the model assuming that any design features that relied on extrusion welds of the HDPE are assumed to be initially failed and all of the cementitious materials beyond the extent of the SDU wall are initially assigned the hydraulic and chemical properties of backfill.

4.4 SDU 6 Floor Concrete

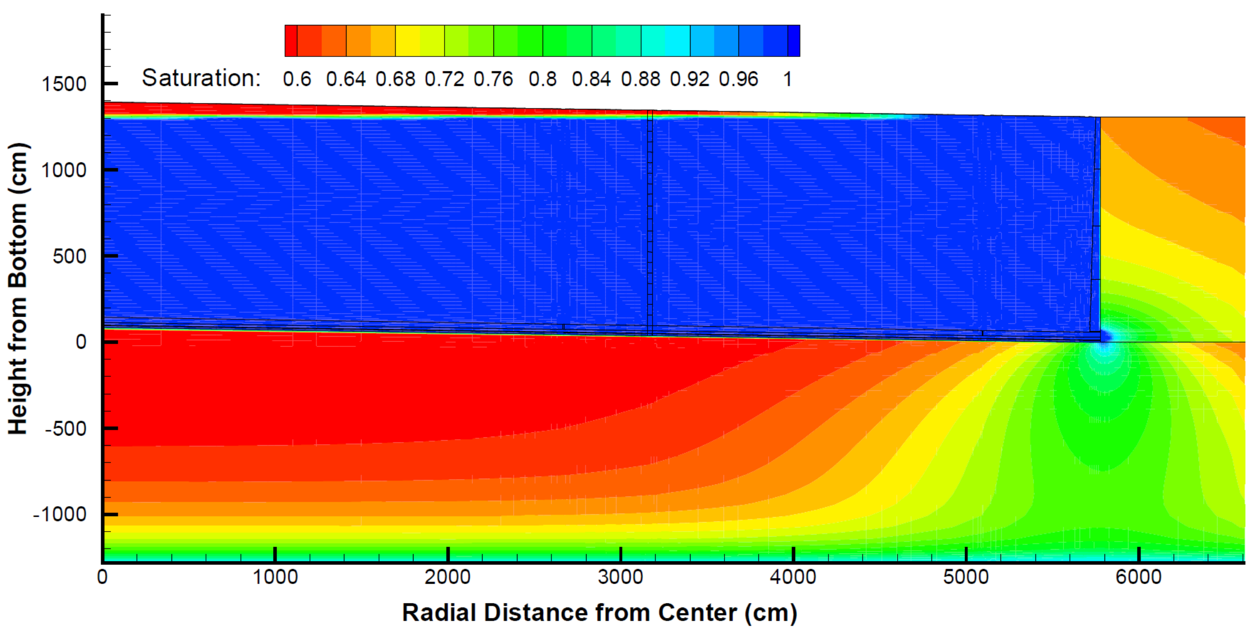
Section 4.3.1.2.1 of the SDF PA (SRR-CWDA-2019-00001) states:

> "… after observing cracks in the roof and floor of SDU 6 post-construction, the FY2016 SDF SA [Special Analysis] was developed based on the observed 'as-built' conditions of SDU 6. [SRR-CWDA-2016-00072] These 'as-built' conditions assumed an initially degraded floor and roof for SDU 6 based on a bounding assumption for a leak rate as described in the *Evaluation of Revised Future Saltstone Disposal Unit Locations by PORFLOW Simulations*. [SRNL-STI-2016-00534] For the PA, these 'as-built' conditions shall continue to be applied to the modeling of SDU 6."

Specifically, SRNL-STI-2016-00534 assumed that the SDU 6 floor leaked at a rate of 2 gpm. This assumption of 2 gpm was developed based on the measurement precision of $1/16^{th}$ of an inch per ACI 350.1-10. Applying double the measurement precision ($1/16^{th}$ of an inch × 2 = $1/8^{th}$ of an inch) to the internal area SDU 6 (approximately 110,450 ft^2) gives a volume of approximately 8,600 gallons. To lose this volume over a period of 72 hours (i.e., the observation period from the first leak tightness test), the loss rate would be 8,600 gal/72 hrs or approximately 2 gpm. Note that this estimate is bounding because the leak tightness test did not actually measure any loss of water (see Section 3.1).

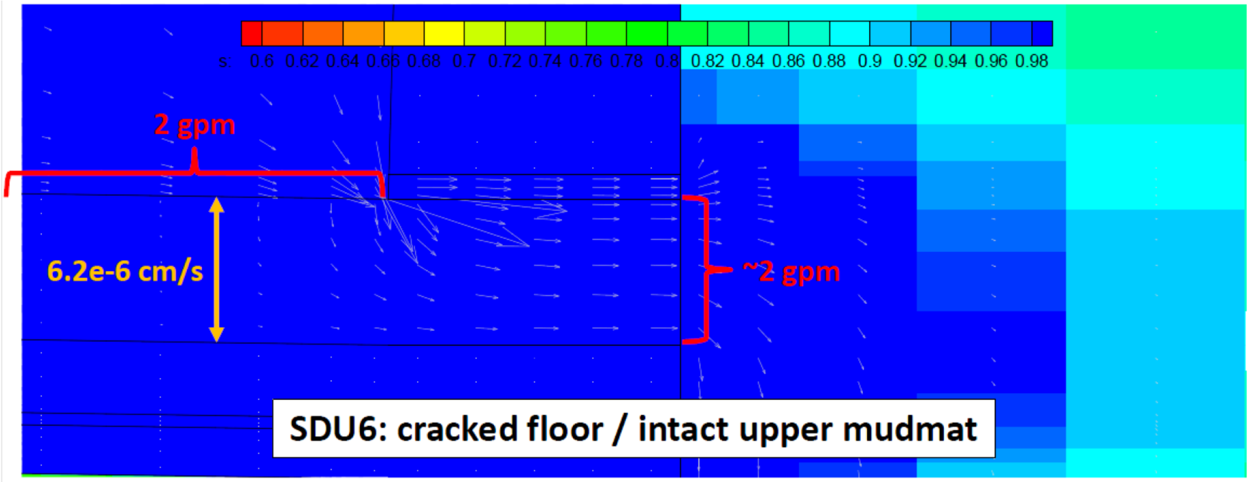
The calibration model described in SRNL-STI-2016-00534 (Figure 4.4-1) was developed to evaluate different values for the initial saturated hydraulic conductivity of the SDU 6 floor concrete so as to determine which value would result in this 2 gpm rate under 41 feet of head. Figure 4.4-2 shows the lower corner and includes arrows to indicate the direction of flow through the system.

Figure 4.4-1: SDU 6 Calibration Model Showing Saturation



[Source: SRNL-STI-2016-00534, Figure 2-2]

Figure 4.4-2: SDU 6 Calibration Model Showing Saturation (Floor Outflow)



[Source: SRNL-STI-2016-00534, Figure 2-3]

From this calibration model, the initial saturated hydraulic conductivity of the SDU 6 roof and floor was increased from an undegraded value of 1.4E-10 cm/s (per SRR-CWDA-2019-00001, Table 4.3-3 (for Compliance Modeling)) to an initially cracked value of 6.2E-06 cm/s (per SRNL-STI-2016-00534, Section 2.4). This initial saturated hydraulic conductivity was applied to the SDU 6 models of the SDF PA (SRR-CWDA-2019-00001, Table 4.4-80). With no HDPE enclosing the floor or mud mats (see Section 4.3), flow from the initially degraded floor is modeled to exit directly into the surrounding backfill material.

Note that the calibration estimate of 2 gpm is equivalent to more than 2,800 gal/day.

The undegraded value of 1.4E-10 cm/s was used for modeling other SDUs using the same concrete mix as was used for SDU 6 (i.e., SDUs 2A, 2B, 3A, 3B, 5A, and 5B). However, based on the lessons learned from SDU 6 (SRR-SDU-2016-00010), subsequent SDUs were constructed using a different pouring and curing approach with an SDU concrete mix that was designed to reduce the extent of potential cracking (SRR-SDU-2016-00027, SRR-SDU-2017-00008). The modified SDU concrete mix has a slightly higher initial saturated hydraulic conductivity of 7.8E-10 cm/s (per SRR-CWDA-2019-00001, Table 4.3-3 (for Compliance Modeling)). Since these lessons learned have been applied, the SDF PA did not model the roofs and floors of SDUs 7 through 12 as having the same initially degraded condition as SDU 6. So, if leaks from these other SDUs are observed in the future, they will need to be evaluated separately.

5.0 SUMMARY

Following the confirmation of contaminants in the East Sump of SDU 6, it was important to evaluate the potential impacts of a leak from SDU 6 relative to the SDF PA models. Due to modeling assumptions and model simplifications applied during the development of the SDU 6 flow models, the SDF PA modeled SDU 6 as though it already had initially leaking conditions. No credit was taken for the interior liner applied to the inside of SDU 6, no credit was taken for any HDPE in the leak detection system beyond the outer edge of the SDU 6 walls, and the floors and roof of SDU 6 were assumed to be initially degraded. (Note that the initially degraded conditions of the SDU floors and roof were only assumed for SDU 6; the SDF PA models assume that the application of lessons learned from SDU 6 will ensure that SDUs 7 through 12 will not leak.)

Despite the bounding approach for estimating the volume of water that has leaked from SDU 6 since the start of disposal operations (Section 3.5), the estimated leak rate of 16 gal/day is much less than the modeled leak rate of 2,800 gal/day based on the model inputs applied for the SDF PA (Section 4.4). Accordingly, the observed leak conditions for SDU 6 are all within the bounds of how SDU 6 was modeled for the SDF PA, and it is not necessary to develop any new models to evaluate the SDU 6 leak(s).

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