Embankment Modeling for the Clive DU PA Model

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FIGURES

TABLES

1.0 Summary of Parameter Values

The parameters that define the characteristics of the Class A South embankment at the Clive facility are summarized in Table 1. Following this summary are sections describing the basis for these values. Of principal interest to the model are the interior dimensions of the volume occupied by waste, and the thicknesses of the various layers in the engineered cover.

Table 1. Summary of embankment engineering parameters

parameter	value	units	reference / comment
average original grade elevation	4272	ft amsl*	USGS (1973) see §4.1 below
elevation of top of the waste at the ridgeline	4317.25	ft amsl	EnergySolutions (2009) see eq. (1) in §3.1.1
elevation of top of the waste at the break in slope	4299.20	ft amsl	EnergySolutions (2009) see eq. (2) in §3.1.1
average elevation of the bottom of the waste	4264.17	ft amsl	EnergySolutions (2009) see eq. (3) in §3.1.1
average elevation of the bottom of the clay liner	4262.17	ft amsl	see eq. (6)(3) in §3.1.2
length overall	1429.6	ft	EnergySolutions (2009) see eq. (4) in §3.1.1
width overall	1775.0	ft	EnergySolutions (2009) see eq. (5) in §3.1.1
length from edge to the break in slope	153.2	ft	EnergySolutions (2009) see §3.1.1
width from edge to the break in slope	152.1	ft	*ibid*.
length along the ridge	542.1	ft	*ibid*.
type A rip rap thickness	18	in	EnergySolutions (2009) see Table 2
type B rip rap thickness	18	in	*ibid*.
type A filter zone thickness	6	in	*ibid*.
sacrificial soil thickness	12	in	*ibid*.
type B filter zone thickness (top slope only)	6	in	*ibid*.
type B filter zone thickness (side slope only)	18	in	*ibid*.
5×10^{-8} cm/s radon barrier clay thickness	12	in	*ibid*.
1×10^{-6} cm/s radon barrier clay thickness	12	in	*ibid*.
clay liner thickness	24	in	Whetstone (2000) see end of §3.1.2

* above mean sea level

2.0 Introduction

The safe storage and disposal of depleted uranium (DU) waste is essential for mitigating releases of radioactive materials and reducing exposures to humans and the environment. Currently, a radioactive waste facility located in Clive, Utah (the "Clive facility") operated by the company Energy*Solutions* Inc. is being considered to receive and store DU waste that has been declared surplus from radiological facilities across the nation. The Clive facility has been tasked with disposing of the DU waste in a manner that protects humans and the environment from future radiological releases.

To assess whether the proposed Clive facility location and containment technologies are suitable for protection of human health, specific performance objectives for land disposal of radioactive waste set forth in Utah Administrative Code (UAC) Rule R313-25 *License Requirements for Land Disposal of Radioactive Waste - General Provisions* must be met—specifically R313-25-8 *Technical Analyses*. In order to support the required radiological performance assessment (PA), a probabilistic computer model has been developed to evaluate the doses to human receptors and concentrations in groundwater that would result from the disposal of radioactive waste, and conversely to determine how much waste can be safely disposed at the Clive facility. The GoldSim systems analysis software (GTG, 2010) was used to construct the probabilistic PA model.

The site conditions, chemical and radiological characteristics of the wastes, contaminant transport pathways, and potential human receptors and exposure routes at the Clive facility that are used to structure the quantitative PA model are described in the conceptual site model documented in the white paper entitled *Conceptual Site Model for Disposal of Depleted Uranium at the Clive Facility* (Clive DU PA CSM.pdf).

The purpose of this white paper is to address specific details relating to the dimensional components of the Class A South (CAS) section of the Federal Cell, located at the Clive facility. This paper is organized to give a brief overview of where the CAS section is located at the Clive facility followed by a description of the parameters and calculations used to estimate the various dimensional components of the CAS embankment.

This probabilistic PA takes into account uncertainty in many input parameters, but the dimensions of the CAS embankment are not considered to be uncertain. Given that the disposal cell is carefully designed and constructed, any uncertainty in its dimensions is considered insignificant. Stochastic representation of parameters is reserved for those values about which there is uncertainty.

3.0 Physical Dimensions

The Clive DU PA model considers only a single embankment. For the purposes of this PA, only the CAS section of the Federal Cell is considered for disposal (Figure 1).

3.1 Class A South Embankment Dimensions

The CAS embankment, or cell, is the western fraction of the Federal Cell (Figure 1). The eastern section is occupied by the 11e.(2) cell, which is dedicated to the disposal of uranium processing by-product waste, but not considered in this analysis. A stylized drawing of the CAS and its relationship to the 11e.(2) cell is shown in Figure 2.

The general aspect of the CAS embankment is that of a hipped cap, with relatively steeper sloping sides nearer the edges. The upper part of the embankment, known as the top slope, has a moderate slope, while the side slope is markedly steeper (20% as opposed to 2.4%). These two distinct areas, shown in different colors in Figure 2, are modeled separately in the Clive DU PA model. Each is modeled as a separate one-dimensional column, with an area equivalent to the embankment footprint. The embankment is also constructed such that a portion of it lies below-grade (Figure 2).

Figure 1. The Clive Facility, with the location of the Class A South embankment outlined in green. This orthophotograph is roughly 1 mile across, and north is up.

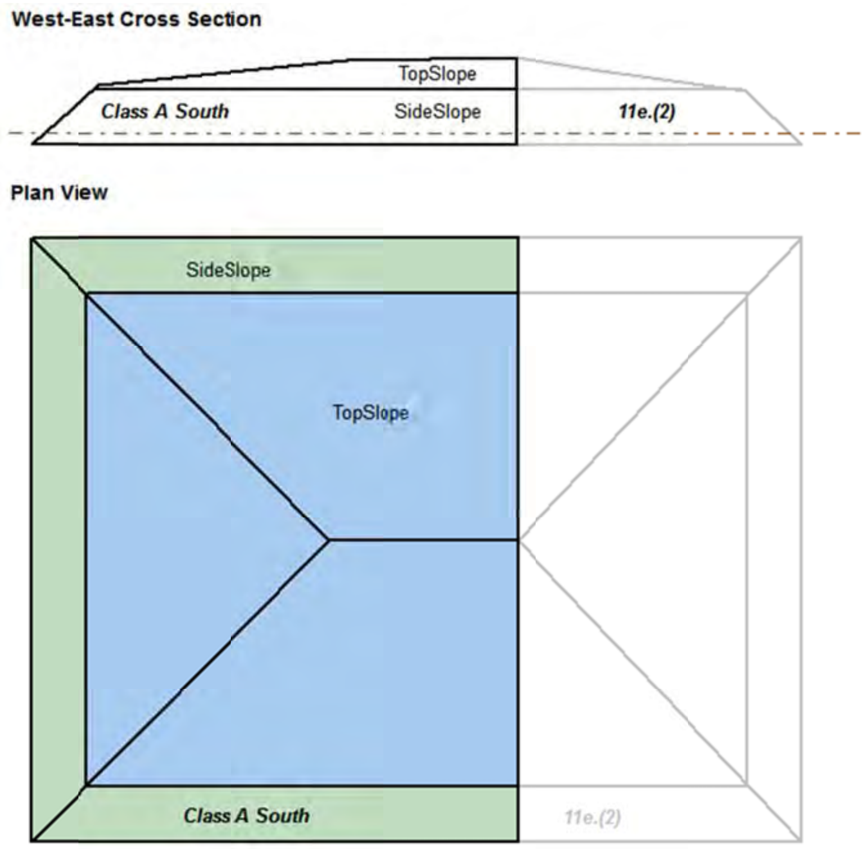


Figure 2. Section and Plan views of the Class A South embankment, with top slope shown in blue and side slope in green. The brown dotted line in the West-East Cross section represents below-grade (below the line) and above-grade (above the line) regions of the embankment.

3.1.1 Class A South Embankment Interior Waste

The Clive DU PA model requires information about embankment dimensions to be able to determine the footprint areas and the volumes of waste within each area. From this, an average thickness of the waste is determined, since the 1-D column has but one thickness over its entire area. All dimensions provided in this white paper are with respect to the waste itself, and do not include the liner or cover materials. The dimensions of interest that are used in the Clive DU PA model are shown in Figure 3. The values of the dimensions shown in Figure 3 are derived from various engineering drawings in Energy*Solutions* (2009) which are herein referred to in this white paper as drawings 07021 V1, 07021 V3, and 07021 V7. These drawings are all reproduced from Energy*Solutions* (2009) in Figures 4 through Figure 6.

As shown in the engineering drawings, the exact dimensions of the CAS are somewhat irregular, with a gently sloping bottom and ridge line. The shape of the cell has been somewhat idealized to facilitate calculations, and it is assumed to have a horizontal floor and ridge line. Elevations for the top of the waste are derived from drawing 07021 V1 (Figure 4), which has the note "*1. All elevations shown are for top of waste...*". Elevation of the bottom of waste is derived from drawing 07021 V3 (Figure 5). Details on each of these values are provided below.

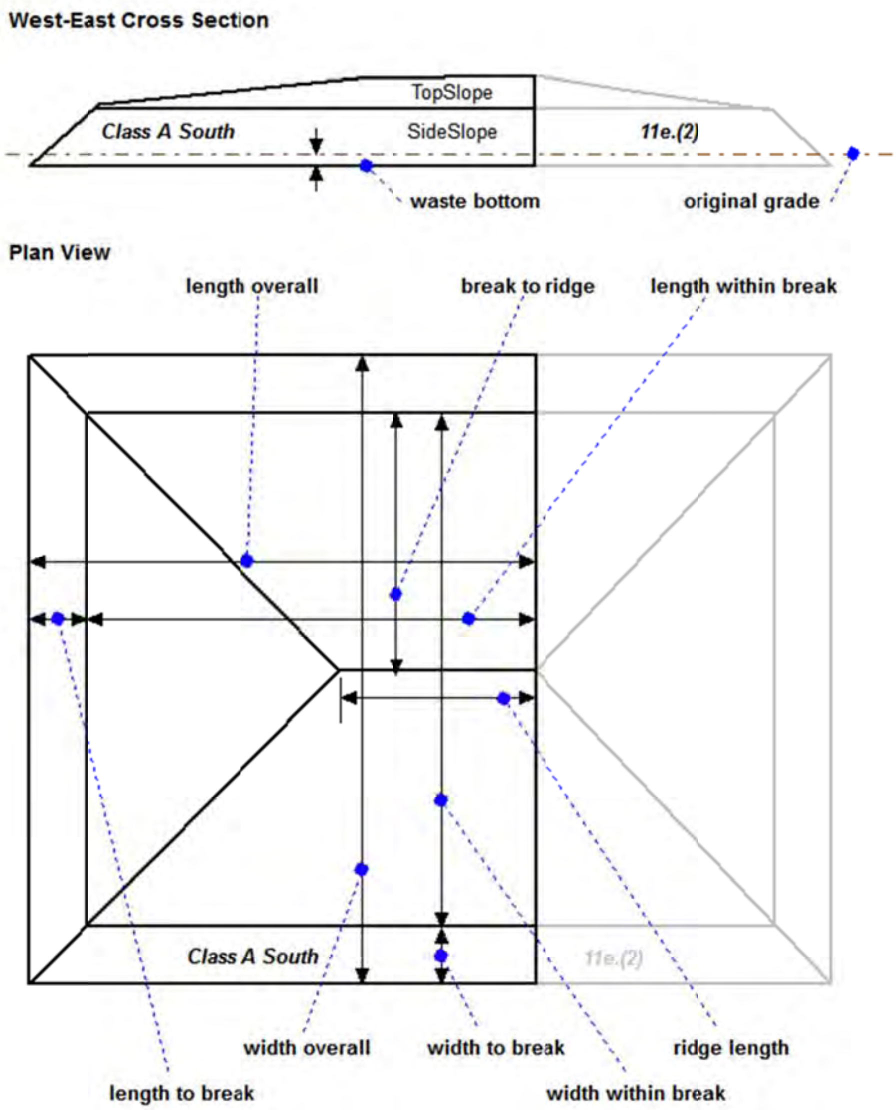


Figure 3. Dimensions of the Class A South embankment that are used in the Clive DU PA model.

Elevation of the top of the waste at the ridge line: This is calculated as an average of the values from drawing 07021 V3 (Figure 5), West-East Cross Section A, accounting for the 2-ft thick radon barrier. The thickness of the radon barrier, 24 in. (2 ft) is shown in the CAS top slope and CAS side slope sections of drawing 07021 V7 (Figure 6). The top of the radon barrier at the west peak is at 4318.80 ft, so the top of the waste is 2 ft lower at an elevation of 4316.80 ft.

Likewise, the top of the radon barrier at the east peak is 4319.70 ft, so the top of the waste is 2 ft lower at an elevation of 4317.70 ft, after adjusting for the thickness of the radon barrier. The average of the west and east peak elevations is:

$$(4316.80 \text{ ft} + 4317.70 \text{ ft}) / 2 = 4317.25 \text{ ft} \quad (1)$$

Elevation of the top of the waste at the slope break: The elevation of the top of the radon barrier derived from the upper drawing 07021 V3 (Figure 5), West-East Cross Section A, is 4301.20 ft. Subtracting the 2-ft thick radon barrier as described above shows the elevation of the top of the waste to be:

$$4301.20 \text{ ft} – 2 \text{ ft} = 4299.20 \text{ ft} \quad (2)$$

Elevation of the bottom of the waste: This is calculated as the average of the values derived from the lower drawing 07021 V3 (Figure 5), West-East Cross Section A. The top of the clay liner is at an elevation of 4262.14 ft at the west end, and 4266.19 ft at the east end, which includes the area under the 11e.(2) section of the Federal Cell. The average of these elevations is:

$$(4262.14 \text{ ft} + 4266.19 \text{ ft}) / 2 = 4264.17 \text{ ft} \quad (3)$$

Length (east-west) overall: The overall length of the CAS is the sum of the values derived from drawing 07021 V1 (Figure 4). Following along the dimensions shown just below the centerline running west-east, the length is:

$$153.2 \text{ ft} + 734.3 \text{ ft} + 542.1 \text{ ft} = 1429.6 \text{ ft} \quad (4)$$

Width (north-south) overall: The overall width of the CAS is the sum of values from drawing 07021 V1 (Figure 4). Following along the dimensions shown down the centerline running north-south, the width is:

$$152.1 \text{ ft} + 735.4 \text{ ft} + 735.4 \text{ ft} + 152.1 \text{ ft} = 1775.0 \text{ ft} \quad (5)$$

Length from edge to break in slope: This is derived from drawing 07021 V1 (Figure 4) at the western slope which is 153.2 ft.

Width from edge to break in slope: This is derived from drawing 07021 V1 (Figure 4) at the north or south slope which is 152.1 ft.

Length along the ridge: The length along the ridge is derived from drawing 07021 V1 (Figure 4) which is 542.1 ft.

3.1.2 Class A South Cover and Liner Dimensions

The engineered cover designs for the top slope and side slope sections of the CAS are shown in drawing 07021 V7 (Figure 6). The values chosen from the sections labeled "*Class A South Top Slopes*" and "*Class A South Side Slopes*" are summarized in Table 2. The properties of the various layers within the engineered cover and liner are discussed in detail in *Unsaturated Zone Modeling* white paper.

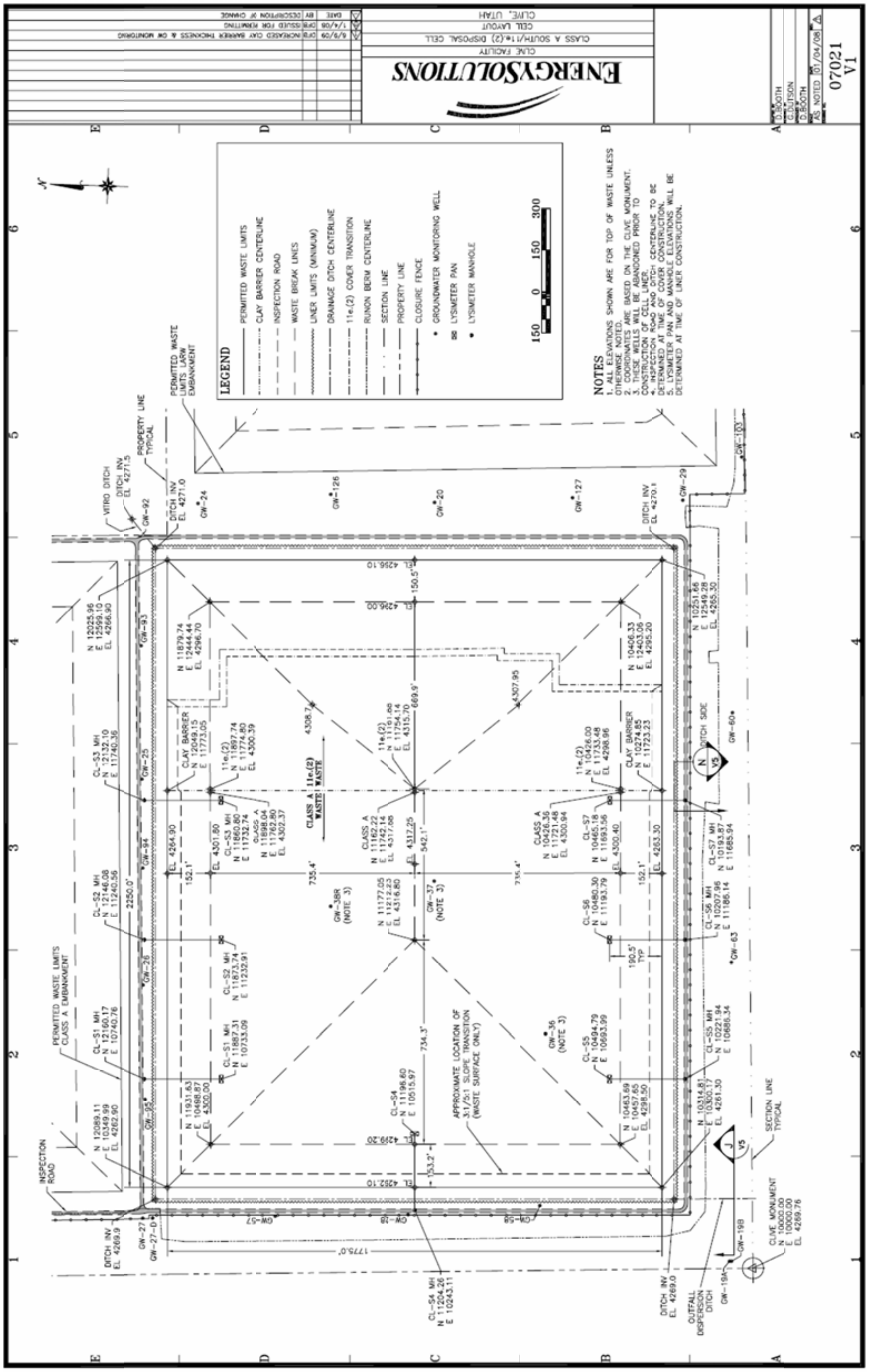


Figure 4. Class A South and 11e.(2) cell engineering drawing 07021 V1

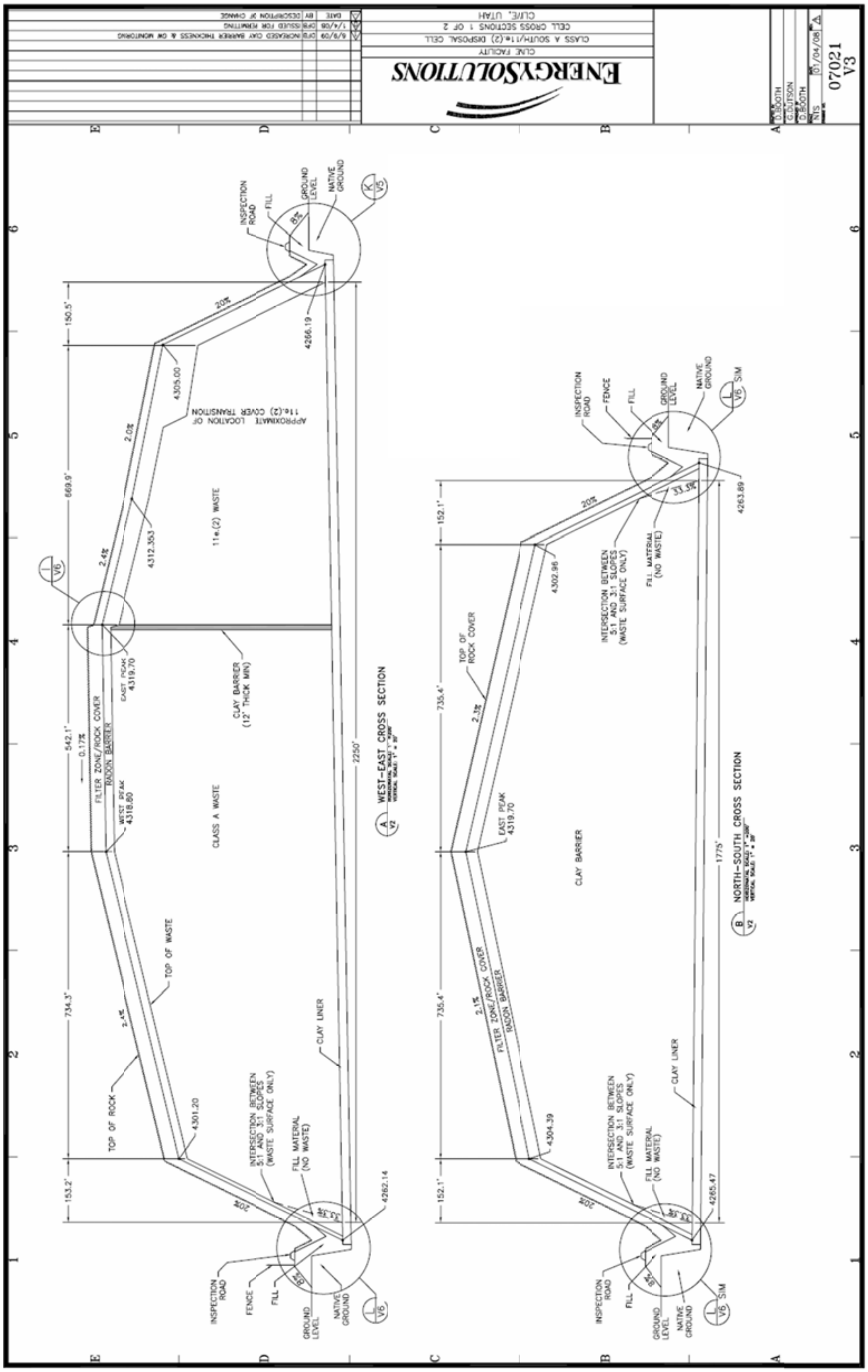


Figure 5. Class A South and 11e.(2) cell engineering drawing 07021 V3

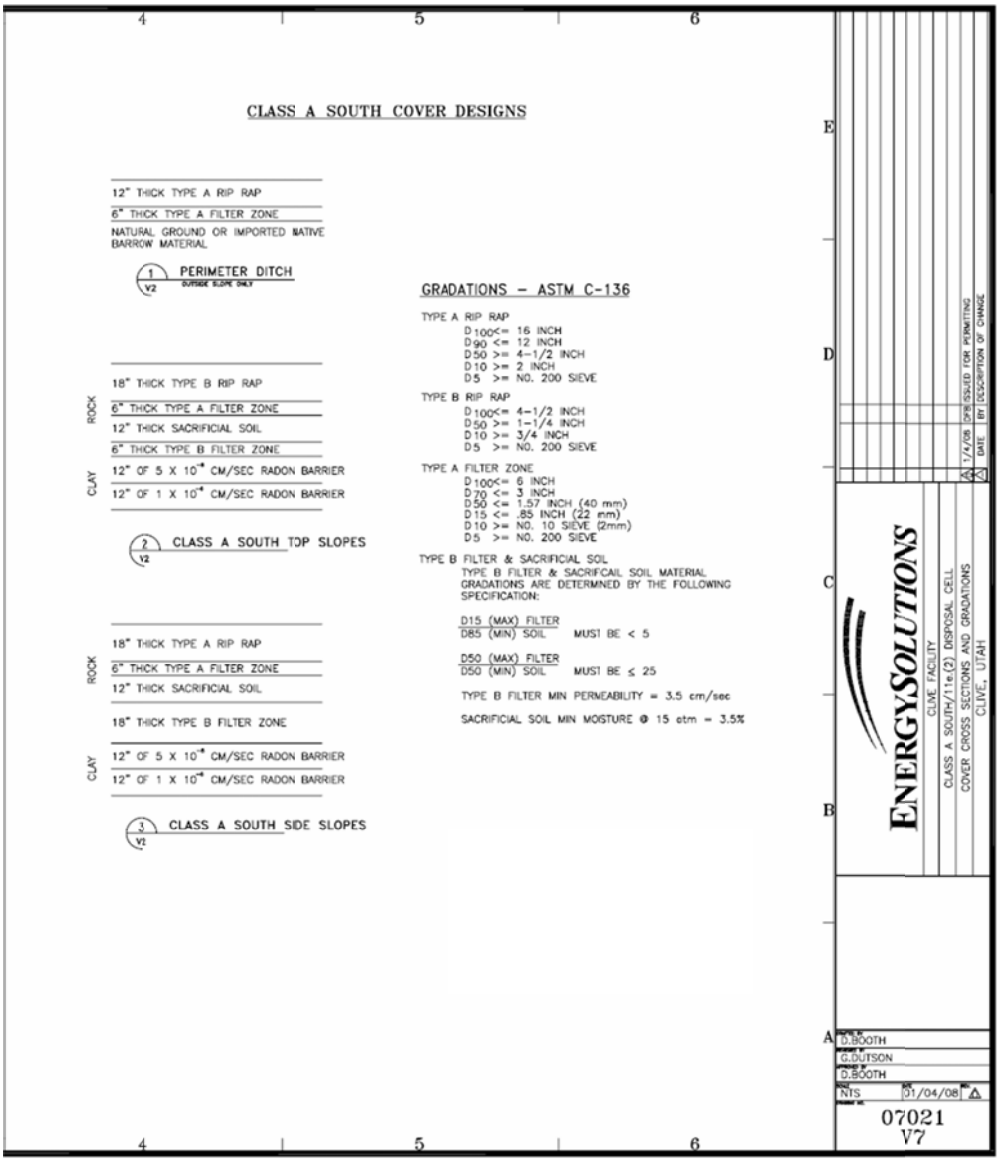


Figure 6. Class A South cell engineering drawing 07021 V7: cap dimensions

Table 2. Cover layer thicknesses for the CAS cell

layer	thickness (in)	
	top slope	side slope
type A rip rap	—	18
type B rip rap	18	—
type A filter zone	6	6
sacrificial soil	12	12
type B filter zone	6	18
5×10^{-8} cm/s radon barrier clay	12	12
1×10^{-6} cm/s radon barrier clay	12	12

The waste layers of the embankment are underlain by a clay liner, as shown in Figure 5, but no thickness is provided in this engineering drawing set. The thickness of the clay liner is defined in a previous modeling report as 24 in (2 ft) (Table 7 in Whetstone, 2000).

Elevation of the bottom of the clay liner: This is calculated simply the average elevation of the bottom of the waste in eq. (3) minus the thickness of the liner. The elevation of the bottom of the clay liner is then is:

$$4264.17 \text{ ft} - 2 \text{ ft} = 4262.17 \text{ ft} \qquad (6)$$

Note that this is also the elevation of the top of the unsaturated zone.

4.0 Original Grade Elevation

The original grade is of interest in determining the vertical location of wastes inside the embankment. One might consider any above-ground waste or other material to be erodible, and conversely below-ground portions to be inherently not erodible. It is therefore of interest to determine the disposal volume that lies below grade since placing waste below grade greatly reduces the potential for erosion during lake cycles. Again, only the CAS is considered at this time.

4.1 Class A South Embankment Original Grade

The elevation of the original grade is interpreted from the elevations indicated on a 1:24,000 scale quadrangle map for Aragonite, UT (USGS, 1973). The relevant section of this map as it applies to the CAS embankment is shown in Figure 7. This 1-square mile section, Section 32, is the site of the Clive Facility (Figure 7). The southwest corner of Section 32 is at elevation 4270 ft amsl (above mean sea level) while the ground surface (original grade) slopes gently and fairly uniformly up to the northeastern corner, crossing the 4280-ft amsl contour.

The CAS occupies the southwestern corner of Section 32 (refer to Figure 1), and its center is approximately at an elevation of 4272 ft amsl. This is the value used for original grade of the CAS.

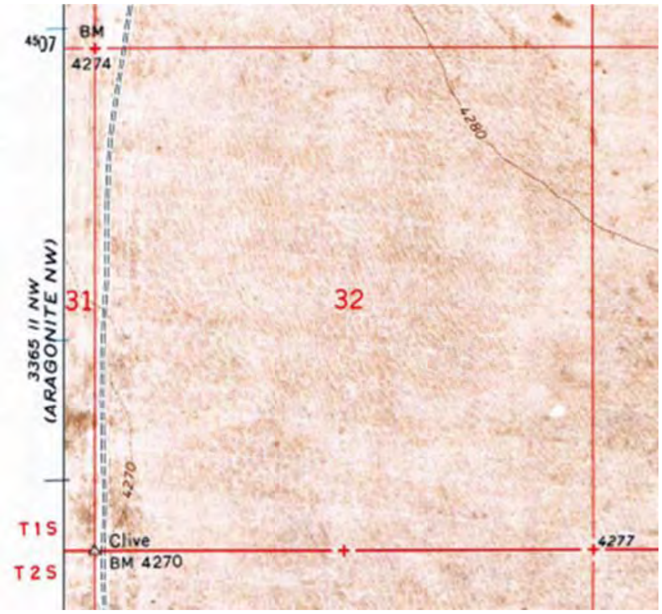


Figure 7. Section 32 within the Aragonite quadrangle, as it appeared in 1973, before construction of the Clive Facility. Note elevation contours at 4270 and 4280 ft amsl. *ARAGONITE NW* is the next quadrangle to the west.

5.0 Implementation in the GoldSim Model

5.1 Representation of the CAS Embankment

The representation of the CAS embankment in the Clive DU PA Model is essentially one-dimensional (1-D), and is therefore necessarily simplified. The top slope and side slope sections of the embankment are modeled as independent 1-D columns, as discussed below. The volumes of waste and each layer of engineered cap and liner are preserved. Since the cap and liner are laterally continuous and do not vary in dimension within a column, the thicknesses in the model correspond directly to thicknesses in the real world. The waste layers, however, are of a shape that changes in the horizontal, and must be rearranged to produce a shape that is a rectangular prism of equal volume to the actual waste volume.

5.1.1 CAS Embankment Dimensions

The dimensions developed in Section 3.1.1 are documented in the model in the container \Disposal\ClassASouthCell\ClassASouth_Cell_Dimensions. The calculation of the waste volumes within the side slope and within the top slope, as identified in Figure 2, is done within the GoldSim model by assembling pieces that have volumes that are easily calculated using basic geometry, as shown in Figure 8. Once the waste volumes for top and side slope are known, the average waste thicknesses are calculated. These are used as the waste thicknesses in the columns within the GoldSim model, as described in the following section.

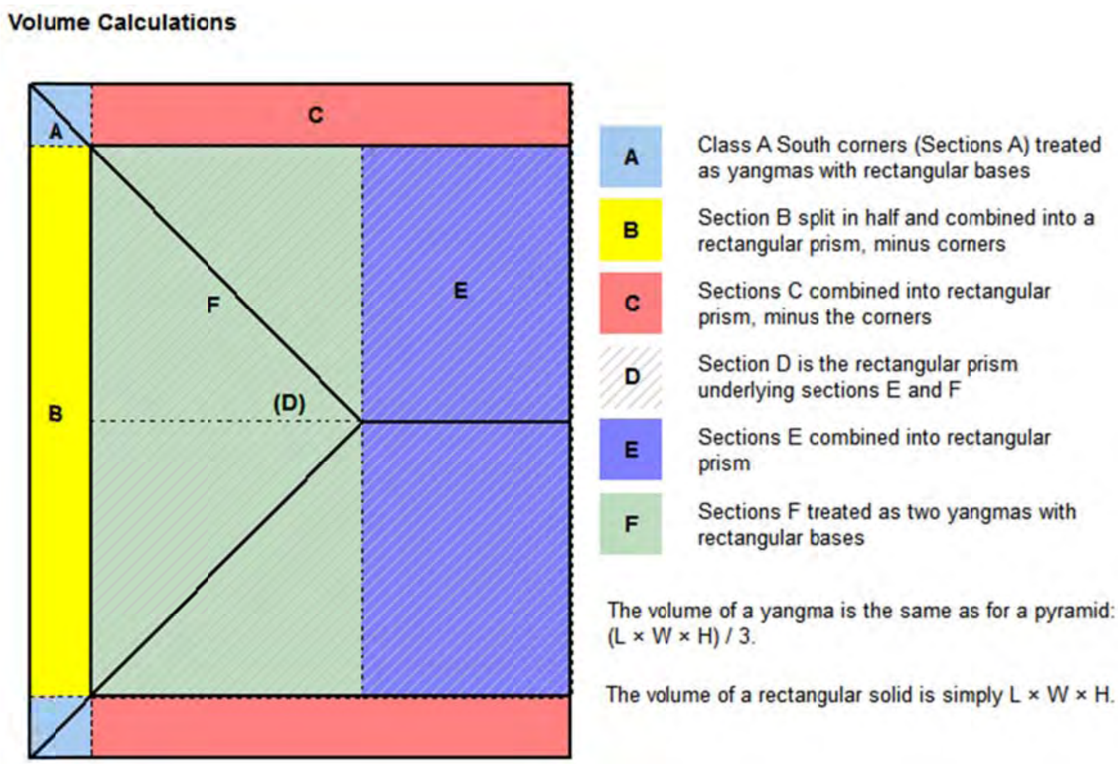


Figure 8. Geometrical deconstruction of the CAS cell waste volumes

5.1.2 CAS Columns

The top slope and side slope columns are modeled in parallel, since they have different waste and cap layer thicknesses. That is, each column has primarily vertical flow of water, with some lateral flows in the cover. Both feed into the unsaturated zone and thence to groundwater at the bottom. The top slope column has a much thicker waste layer than the side slope, and this is reflected in the overall thickness of the two columns. In order to capture the flexibility available in locating waste during disposal operations, the user can select which waste types go where in the top slope column, using the Waste Layering Definition dashboard. No DU wastes are to be disposed in the side slope column in this model. An example of this selection is shown in Figure 9.

Definition of Waste Layering for the Class A South Embankment

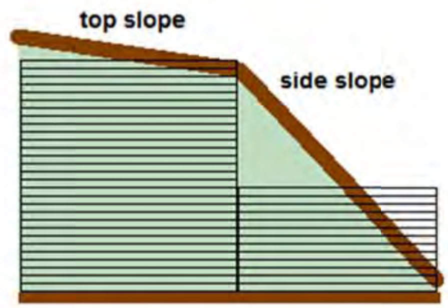
The embankment consists of top slope and side slope sections, each of which is represented by a column of cells with a total thickness equal to the average thickness of the respective column. Each column is broken down into cells of like thickness (within the column), roughly 0.5 m. Each cell may

Top Slope column

	Top Slope Waste Cell Contents
Waste01	no waste (clean soil)
Waste02	no waste (clean soil)
Waste03	no waste (clean soil)
Waste04	no waste (clean soil)
Waste05	no waste (clean soil)
Waste06	no waste (clean soil)
Waste07	DUOx: GDP (contaminated)
Waste08	DUOx: GDP (contaminated)
Waste09	DUOx: GDP (contaminated)
Waste10	DUOx: GDP (contaminated)
Waste11	DUOx: GDP (contaminated)
Waste12	DUO3: SRS (contaminated)
Waste13	DUOx: GDP (clean uranium)
Waste14	DUOx: GDP (clean uranium)
Waste15	DUOx: GDP (clean uranium)
Waste16	DUOx: GDP (clean uranium)
Waste17	DUOx: GDP (clean uranium)
Waste18	DUOx: GDP (clean uranium)
Waste19	DUOx: GDP (clean uranium)
Waste20	DUOx: GDP (clean uranium)
Waste21	DUOx: GDP (clean uranium)
Waste22	DUOx: GDP (clean uranium)
Waste23	DUOx: GDP (clean uranium)
Waste24	DUOx: GDP (clean uranium)
Waste25	DUOx: GDP (clean uranium)
Waste26	DUOx: GDP (clean uranium)
WasteOut	DUOx: GDP (clean uranium)

	thickness	volume
each waste cell	0.504 m	8.79e4 m3
entire waste layer	13.61 m	2.373e6 m3

Exit to Top Slope Wastes



Side Slope column (currently disabled)

No DU wastes are allowed in the side slope in this model.

	thickness	volume
each waste cell	0.483 m	2.961e4 m3
entire waste layer	5.792 m	3.553e5 m3

Exit to Side Slope Wastes

Summary information

	Top slope volume	Side slope volume	CAS total volume		bare waste volume	packing efficiency (should be <= 1)	
no waste	5.274e5 m3	3.553e5 m3	8.827e5 m3				
Class A Low-Level Waste	0 m3	0 m3	0 m3	✓			
DUO3: SRS (contaminated)	8.79e4 m3	0 m3	8.79e4 m3	✓	2182 m3	0.0248	✓
DUOx: GDP (contaminated)	4.395e5 m3	0 m3	4.395e5 m3	✓	8.833e4 m3	0.201	✓
DUOx: GDP (clean uranium)	1.318e6 m3	0 m3	1.318e6 m3	✓	2.559e5 m3	0.194	✓

A red X indicates that an inventory volume problem requires resolution.

Go to Material Properties | CAS Inventory Definitions | Exit to Class A South | Control Panel

Figure 9. Waste layering definitions within the two columns of the CAS cell

6.0 References

Energy*Solutions*, 2009. *EnergySolutions License Amendment Request: Class A South/11e.(2) Embankment, Revision 1*, 9 June 2009 (file: Class A South-11e.(2) Eng Drawings.pdf)

GTG (GoldSim Technology Group), 2010. *GoldSim: Monte Carlo Simulation Software for Decision and Risk Analysis*, http://www.goldsim.com

USGS (United States Geological Survey), 1973. 1:24,000 topographic quadrangle map for Aragonite, UT, revised 1973 (file: UT_Aragonite_1973_geo.pdf)

Whetstone (Whetstone Associates, Inc.), 2000. Revised Envirocare of Utah Western LARW Cell Infiltration and Transport Modeling (file: 2000, July 19 - Whetstone, Western LARW Cell Infiltration Modeling.pdf)