STUDENT SUMMER INTERNSHIP TECHNICAL REPORT

Calculating the Retention Storage Volume of Surface Water within a Predetermined Contour Area in Los Alamos County

DOE-FIU SCIENCE & TECHNOLOGY
WORKFORCE DEVELOPMENT PROGRAM

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ABSTRACT

On September 13, 2013 a 1000 year storm event occurred throughout the Southwestern United States affecting Los Alamos, New Mexico. During this event 89 site monitoring areas (SMAs) did not collect samples at the Los Alamos National Laboratory (LANL) site. Under an upcoming permit one option for corrective action measures, for these SMAs is to retain a volume of storm water runoff that is equivalent to a 3-year, 24-hour storm event. The purpose of this study is to identify which SMAs did not sample during the 1000 year storm event and determine which ones were functional and contained earthen berms. Using Geographic Information Systems (GIS) and a TR-55 model, volume available and volume required were calculated of the remaining SMAs. It was determined that some met the requirement while others did not for a 3-year, 24-hour storm event. These findings are significant because it would be inefficient to go back out into the field to reevaluate and redesign the earthen berms.

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1. INTRODUCTION

Los Alamos National Laboratory (LANL) is one of the national laboratories in the United States where classified work towards the design of weapons has been conducted historically. These historic activities have resulted in potential releases of constituents of potential concern (CPOCs) to the environment through air deposition, liquid releases, and/or disposal. These potential releases occurred into canyon systems and on mesa tops above the Rio Grande. Since the end of the Cold War, LANL went through a process of intense scientific diversification in their research programs to adapt to the changing political conditions. This has led the lab to increase research in science and become currently involved in an extensive clean-up/remediation initiative and legacy cleanup to address historic LANL operations.

Around LANL's 43-square-mile property are 2,000 potential release sites (PRSs) which may have impacted the environment. These PRSs are also referred to either as (1) solid waste management units (SWMUs) and areas of concern (AOCs) or (2) Sites. The transport of CPOCs such as perchlorate, plutonium and tritium in surface water and groundwater are of concern because of the potential effects they can have on human health and the environment. To address these PRSs LANL has a complex set of regulatory requirements. One of these is the Clean Water Act, as amended. An evaluation of the PRSs has resulted in LANL having a National Pollutant Discharge Elimination System (NPDES) permit for industrial point source discharges for 405 of the PRSs which could potentially impact water resources in and around LANL. At these 405 PRSs LANL is required to implement control measures to address potential water quality concerns resulting from storm water runoff from the identified SWMUs and AOCs.

Corrective action measures for storm water control must be accounted for when designing site monitoring areas (SMAs), which are the watersheds within which these SWMUs/AOCs are located. The completion of corrective action is indicated by the following: (a) No applicable target action level (TAL) exceedances are reasonably expected to be Site-related as demonstrated by the U.S. Environmental Protection Agency (EPA)-approved site-specific demonstration (SSD); (b) The installation of enhanced control measures with confirmation from monitoring of analytical results that they are less than the applicable TALs; (c) The installation of control measures that totally eliminate exposure of site-related pollutants to storm water; (d) The installation of control measures that retain a volume of storm water runoff or that minimize discharges from a Site or SMA that is equivalent to a 3-yr, 24-hr storm event. The focus of this report is on item (d) where the available storage volumes of the SMAs, specifically the earthen berms, were calculated using LIDAR data and GIS tools, and the storage volumes required calculated using a TR-55 model.

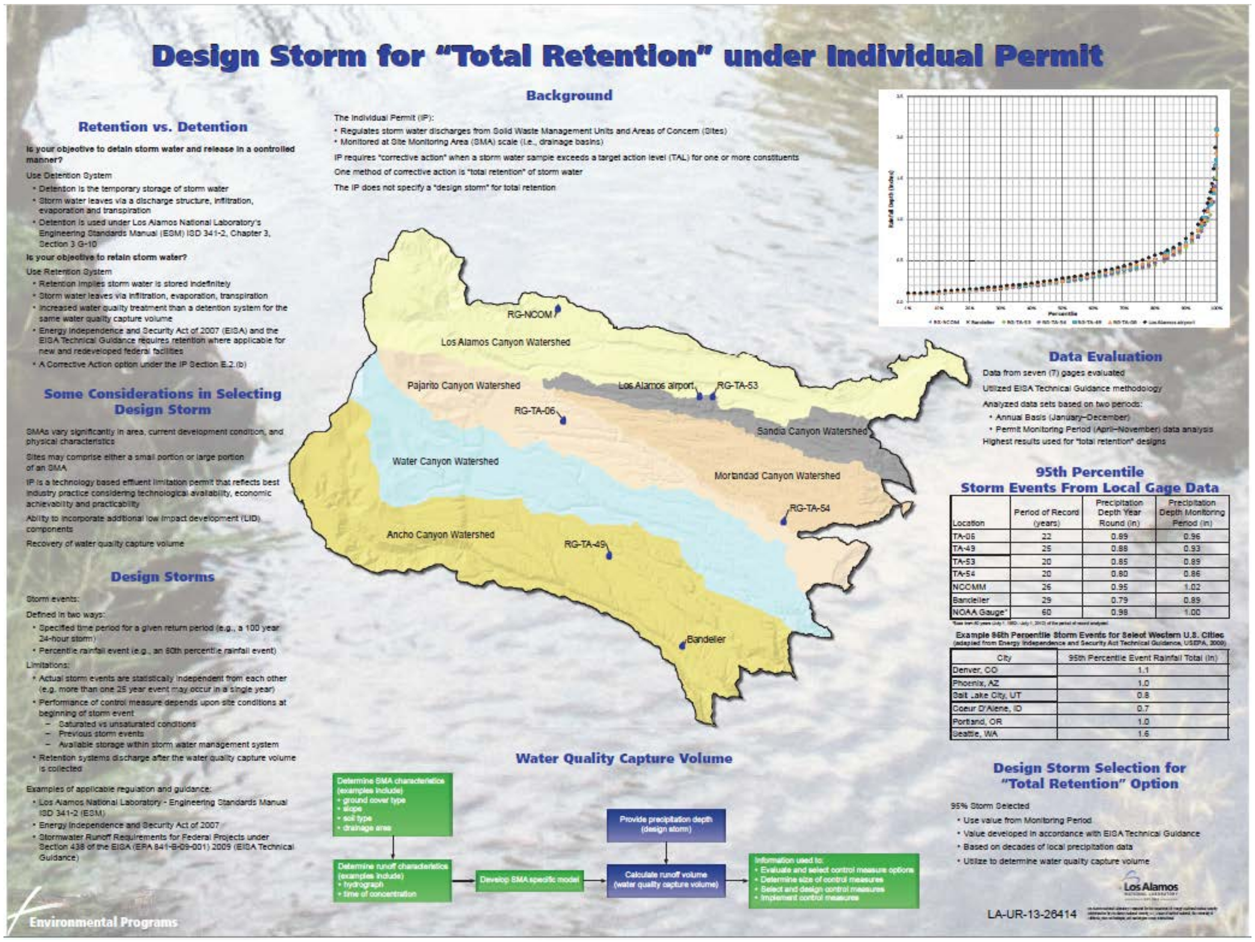

Figure 1. Design Storm for "Total Retention."

2. EXECUTIVE SUMMARY

This research work has been supported by the DOE-FIU Science & Technology Workforce Initiative, an innovative program developed by the US Department of Energy's Environmental Management (DOE-EM) and Florida International University's Applied Research Center (FIU-ARC). During the summer of 2016, a DOE Fellow intern, Christopher Strand, spent 10 weeks doing a summer internship at Los Alamos National Laboratory (LANL) in Los Alamos, NM under the supervision and guidance of William Foley. The intern's project was initiated on June 6, 2016, and continued through August 12, 2016 with the objective of calculating the retention storage volume behind earthen berms to meet permit standards and corrective action measures.

3. RESEARCH DESCRIPTION

Evaluation of Site Monitoring Areas (SMAs)

The first step in the process for determining if the earthen berms provide sufficient storage for a 3-year, 24-hour storm event was to identify which SMAs did not sample throughout the 1000 year storm event on September 13, 2013, which turned out to be a total 89 SMAs. The second step was to identify which of the 89 SMAs that did not sample were still operational and in good condition during the time of this event. This lowered the number of fully functional SMAs to a total of 79, with 10 SMAs not being operational. The next important step was to identify which of the remaining 79 SMAs contained earthen berms that were in place on September 13, 2013 and to ensure if these earthen berms are currently still in place. After gathering copious amounts of data, it was determined that a total of 38 SMAs (Figure 2) would need to be evaluated.

	A	B	E	H	I	N	O	P	Q	R
1	Edit	SMA	Activity Start Date	Name/Title Of Data Sourc	Complianc e Stage Monitoring Allowe	Last Modified E	Date Last Modified	Operational	Earthen Berms	Earthen Berms Before 13SEP13 & Current
4	964	3M-SMA-0.2	11/01/2011	CCN-29644	Y	markp	12/21/2015 08:45:01	Y	Y	Y
7	971	ACID-SMA-2.01	05/01/2012	CCN-29644	Y	markp	12/21/2015 09:34:34	Y	Y	Y
9	975	A-SMA-2.5	05/01/2012	CCN-29644	Y	markp	12/21/2015 09:36:08	Y	Y	Y
10	976	A-SMA-2.8	05/01/2012	CCN-29644	Y	markp	12/21/2015 09:36:03	Y	Y	Y
11	979	A-SMA-4	05/01/2012	CCN-29644	Y	markp	12/21/2015 09:30:57	Y	Y	Y
12	985	CDB-SMA-1.15	11/01/2011	CCN-29644	Y	markp	12/21/2015 08:46:15	Y	Y	Y
13	986	CDB-SMA-1.35	11/01/2011	CCN-29644	Y	markp	12/21/2015 08:46:20	Y	Y	Y
14	987	CDB-SMA-1.54	11/01/2011	CCN-29644	Y	markp	12/21/2015 08:46:24	Y	Y	Y
15	988	CDB-SMA-1.55	11/01/2011	CCN-29644	Y	markp	12/21/2015 08:45:10	Y	Y	Y
16	989	CDB-SMA-1.65	11/01/2011	CCN-29644	Y	markp	12/21/2015 08:45:16	Y	Y	Y
17	1000	CDV-SMA-4	05/01/2012	CCN-29644	Y	markp	12/21/2015 09:37:03	Y	Y	Y
18	1004	CDV-SMA-8.5	05/01/2012	CCN-29644	Y	markp	12/21/2015 09:40:58	Y	Y	Y
19	1005	CDV-SMA-9.05	05/01/2012	CCN-29644	Y	markp	12/21/2015 09:22:45	Y	Y	Y
24	1018	DP-SMA-0.6	05/01/2012	CCN-29644	Y	markp	12/21/2015 09:39:34	Y	Y	Y
26	1020	DP-SMA-2	11/01/2011	CCN-29644	Y	markp	12/21/2015 08:43:40	Y	Y	Y
27	1022	DP-SMA-4	05/01/2012	CCN-29644	Y	markp	12/21/2015 09:41:04	Y	Y	Y
33	1029	LA-SMA-5.01	05/01/2012	CCN-29644	Y	markp	12/21/2015 09:33:56	Y	Y	Y
43	1044	LA-SMA-6.36	05/01/2012	CCN-29644	Y	markp	12/21/2015 09:36:57	Y	Y	Y
45	1035	LA-SMA-5.53	05/01/2012	CCN-29644	Y	markp	12/21/2015 09:23:26	Y	Y	Y
47	1050	M-SMA-1.21	05/01/2012	CCN-29644	Y	markp	12/21/2015 09:33:14	Y	Y	Y
54	1063	M-SMA-3.5	05/01/2012	CCN-29644	Y	markp	12/21/2015 09:39:17	Y	Y	Y
57	1073	PJ-SMA-13	05/01/2012	CCN-29644	Y	markp	12/21/2015 09:34:57	Y	Y	Y
58	1074	PJ-SMA-14	05/01/2012	CCN-29644	Y	markp	12/21/2015 09:38:16	Y	Y	Y
62	1078	PJ-SMA-14.6	11/01/2011	CCN-29644	Y	markp	12/21/2015 08:45:47	Y	Y	Y
63	1084	PJ-SMA-2	11/01/2011	CCN-29644	Y	markp	12/21/2015 08:43:35	Y	Y	Y
64	1088	PJ-SMA-7	11/01/2011	CCN-29644	Y	markp	12/21/2015 08:44:09	Y	Y	Y
65	1089	PJ-SMA-8	11/01/2011	CCN-29644	Y	markp	12/21/2015 08:44:16	Y	Y	Y
68	1096	P-SMA-2.2	05/01/2012	CCN-29644	Y	markp	12/21/2015 09:24:39	Y	Y	Y
70	1106	S-SMA-2.8	05/01/2012	CCN-29644	Y	markp	12/21/2015 09:35:27	Y	Y	Y
71	1107	S-SMA-3.51	05/01/2012	CCN-29644	Y	markp	12/21/2015 09:32:57	Y	Y	Y
72	1108	S-SMA-3.52	05/01/2012	CCN-29644	Y	markp	12/21/2015 09:33:08	Y	Y	Y
74	1110	S-SMA-3.71	05/01/2012	CCN-29644	Y	markp	12/21/2015 09:33:20	Y	Y	Y
75	1113	S-SMA-4.5	05/01/2012	CCN-29644	Y	markp	12/21/2015 09:31:40	Y	Y	Y
80	1122	T-SMA-5	05/01/2012	CCN-29644	Y	markp	12/21/2015 09:42:51	Y	Y	Y
81	1124	T-SMA-7	05/01/2012	CCN-29644	Y	markp	12/21/2015 09:30:52	Y	Y	Y
82	1125	T-SMA-7.1	05/01/2012	CCN-29644	Y	markp	12/21/2015 09:35:08	Y	Y	Y
83	1126	W-SMA-12.05	05/01/2012	CCN-29644	Y	markp	12/21/2015 09:31:54	Y	Y	Y
87	1132	W-SMA-7.8	05/01/2012	CCN-29644	Y	markp	12/21/2015 09:35:44	Y	Y	Y

Figure 2. Total remaining SMAs for evaluation.

Using LiDAR Topography and GIS to Calculate the Retention Storage Volume Available

In this step, Light Detection and Ranging (LiDAR) data and Geographic Information Systems (GIS) geoprocessing tools were used to assist in calculating the retention volume of these earthen berms. LiDAR is a remote sensing method that uses light in the form of a pulsed laser to measure ranges to the Earth. These light pulses combined with other data generate precise, three-dimensional information about the shape of the Earth and its surface characteristics. LIDAR systems allow scientists and mapping professionals to examine both natural and manmade environments with accuracy, precision, and flexibility. When LiDAR data is imported into

ArcMap, it shows up as a digital elevation model (DEM), which is a spaced grid of elevation points.

After importing the DEM, it was necessary to determine the available storage retention volume behind the berms from the SMAs remaining. Due to the limitation of time and the number of field visits that would be required, only 5 of the total 38 SMAs remaining were strategically chosen to be analyzed and for calculation of retention volume.

The first step in determining the available storage volume behind the earthen berms is to identify the contour elevation of interest. This is done by digitizing the feature of interest using "Interpolate Line" and "Profile Graph" on the ArcGIS 3D Analyst extension toolbar. Once the image is received, it is important to choose and log the lowest elevation between the two end points of the earthen berm. This will help set the correct contour of elevation in the next step, which is to find the contour list using the Spatial Analyst tools and using the elevation logged earlier to input into the contour values. This will set a contour line of interest around the earthen berm chosen.

It is necessary to convert this contour line into a polygon by creating a waterbody out of the earthen berm and contour line. This is done through the "Editor" and the "Advanced Editing" toolbars to construct a polygon. This will make the contour line and earthen berm one single piece, making it more accessible to click on and manage later in the process. The next step is to create a site domain around the area of interest, which is done by creating a square using the "Drawing" toolbar and converting the graphic into a feature.

Random points are then created within the site domain using one of the "Data Management" tools from ArcToolbox. It is important to choose an accurate amount of points to fill the site domain. With these points created, extracting elevation values to these points is achieved by using Spatial Analyst "Extraction" tools in ArcToolbox. For every point created in the site domain, an associated elevation number is generated. This is attributed to the presence of the underlying LiDAR data being in the form of a digital elevation model. Different raster values should be viewed and applied to each point in the attribute table for the site domain.

In order to find the elevation of the spaces between the points in the site domain, a triangulated irregular network (TIN) was used. This determines the elevation in the empty spaces using triangulation. "Create TIN" was found under "3D Analyst - Data Management" in ArcToolbox.

The last step to finding the storage volume available in the earthen berm of interest is found using the "Polygon Volume" tool. This is found in ArcToolbox under "Triangulated Surface" in "3D Analyst - Data Management". Once this was applied, the volume available and surface area were calculated and found in the attribute table of the area of interest.

Running TR-55 Model to Determine Volume Required for a 3-yr, 24-hr Storm Event

The Technical Release 55 (TR-55) computer model is based on a curve number method developed by the USDA Natural Resources Conservation Service. This method can provide data related to peak discharge rates, runoff volumes, and storm hydrographs with input parameters including curve number, rainfall amount, time of concentration and area data. Area data refers to land cover, vegetation type and density, soil parameters, topography, and topographically related properties such as slope, watershed boundary, etc. All hydrological analysis methods require land cover, soil properties, and topography. Land cover will be determined in ArcMap using automated classification of the most recent, highest resolution orthophotos, such as LiDAR.

With an Excel file spreadsheet, the TR-55 model can be implemented. Firstly, the soil hydrologic groups need to be identified for each of the 5 chosen SMAs to run the model. The soil along with the vegetation type will affect the curve number. The soil hydrologic group is based on a scale from A to D. Group A soils have low runoff potential when thoroughly wet. Water is transmitted freely through the soil. Group B soils have moderately low runoff potential when thoroughly wet. Water transmission through the soil is unimpeded. Group C soils in this group have moderately high runoff potential when thoroughly wet. Water transmission through the soil is somewhat restricted. Group D soils have high runoff potential when thoroughly wet. Water movement through the soil is restricted or very restricted.

In this study, all 5 SMAs of interest were of Group D soil type, with a high runoff potential and water movement being very restricted. The varied vegetation types in each SMA will result in the application of different curve numbers. The TR-55 runoff coefficients (curve numbers) are available in Table 1.

Table 1. Curve Numbers Based on Land Cover and Soil Hydrologic Groups for Use in TR-55

Land Cover		Curve Number Based on Soil Hydrologic Group			
		A	B	C	D
Vegetated Areas	Cottonwood (woods)	45	66	77	83
	Ponderosa (woods)	45	66	77	83
	Fruit trees/orchards with grass	57	73	82	86
	Pinon/juniper	-	75	85	89
	Sagebush	-	67	80	85
	Gambel oak brush	-	66	74	79
	Chamisa/desert shrub	63	77	85	88
	Dense herbaceous grassland (good hydrologic condition)	-	62	74	85
	Fair herbaceous grassland (fair hydrologic condition)	-	71	81	89
	Sparse herbaceous grassland (poor hydrologic condition)	-	80	87	93
Urban/impervious areas	Bare soil	77	86	91	94
	Gravel	76	85	89	91
	Bare rock, laydown areas, pavement, buildings, etc.	98	98	98	98
Artificial land-cover applications	Seeded straw matting (bare soil to sparse grassland)	77	83	89	94
	Mulch cover (very coarse tree mulch for fire suppression)	74	79	85	89

Field visits can be used to verify land cover classification, vegetation cover (or hydrologic condition of poor, fair, or good), and watershed boundaries. Once verification is complete and the GIS data is updated, the land cover can be used for hydrological analysis. Soil infiltration rates, soil hydrological groups, and other soil properties will be determined using the most recent, highest resolution soil classification data available (typically produced by the USDA Natural Resources Conservation Service). Flow properties (direction, length, etc.), slope, and other topographically related properties will be determined using algorithms in ArcGIS.

After obtaining this data, Figure 3 is an example of the storage volume that is required for a 3-year, 24-hour storm event for LA-SMA-2.1:

SMA: LA-SMA-2.1

Subbasin: 1

3-yr, 24-h Retention Evaluation Summary

Id	Veg_Type	Subarea	Acres	Sqft	% of Total Area	CN	CN*Area	S	Ia	Q (in)	CN Volume (ft^3)	
Soil Type A												
1	N/A		0.0000	0.00	0.0%	98	0.0	0.2	0.04		0	
Soil Type B												
1	N/A		0.0000	0.00	0.0%	98	0.0	0.2	0.04		0	
2	N/A		0.0000	0.00	0.0%	98	0.0	0.2	0.04		0	
Soil Type C												
1	N/A		0.0000	0.00	0.0%	91	0.0	1.0	0.20			
2	N/A		0.0000	0.00	0.0%	98	0.0	0.2	0.04			
Soil Type D											0	
1	Bare Ground	D1	0.3605	15702.77	8.0%	94	33.9	0.6	0.13	0.95	1237	
2	Bare Rock	D2	0.1419	6180.78	3.1%	98	13.9	0.2	0.04	1.29	664	
3	Fair Grass	D3	0.4544	19792.96	10.1%	89	40.4	1.2	0.25	0.64	1053	
4	Pinion/juniper	D4	0.9395	40926.50	20.8%	89	83.6	1.2	0.25	0.64	2177	
5	Sparse Grass	D5	2.6158	113946.28	58.0%	93	243.3	0.8	0.15	0.88	8309	
			4.5122	196549					**Total Volume**		**13440**	**ft³**
											498	**yd³**
											0.309	**acre-ft**

Hydrologic Soil Type - No soil type defined. Use soil type D as most conservative (highest runoff potential)

Precip.	**1.51 inches**
CN	NRCS Curve Number (ranges from 0 to 100, 100 being totally impervious)
S	Total Storage - potential storage after runoff begins
Ia	Initial Abstration - losses before runoff begins

Required Retention Volumes

	24-hour design storms (inches)			
	95th Percentile	3-yr	25-yr	100-yr
RG055.5	1.17	1.51	2.32	2.82
Total Volume (ft³)	8,903	13,440	25,164	32,748

	24-hour design storms (inches)			
	95th %-ile	3-yr	25-yr	100-yr
S SMA 3.6	1.08	1.45	2.43	3.03
Total Volume (ft³)	3948	18486	35126	67536

Gage inches

Total Volume (ft3)

Date

Sampled inches

Total Volume (ft3)

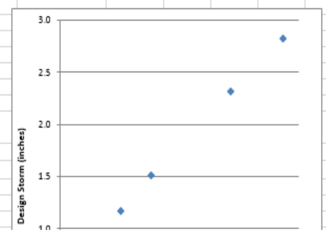

Figure 3. LA-SMA-2.1 required retention storage volume for a 3-yr, 24-hr storm event.

After gathering the data and acquiring the retention storage volumes for all 5 chosen SMAs (LA-SMA-5.53, CDB-SMA-1.54, CDB-SMA-1.35, CDB-SMA-1.15, S-SMA-4.5) it was essential to collect the total retention volume available determined using GIS and compare it to the total retention volume required calculated using the TR-55 model. These results will determine if changes need to be done to the SMAs to meet requirements for corrective action measures. The 5 SMAs and their earthen berms with watersheds are shown below.

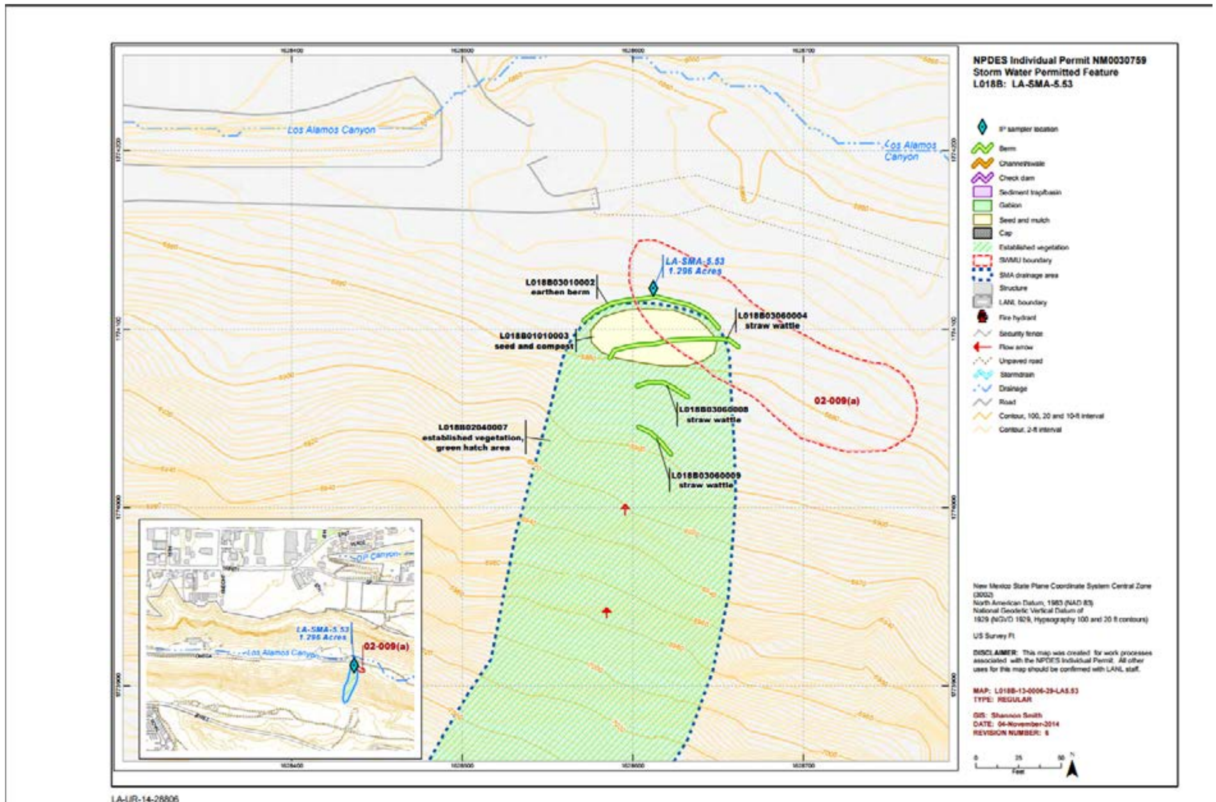

Figure 4. LA-SMA-5.53 earthen berm(s) and watershed.

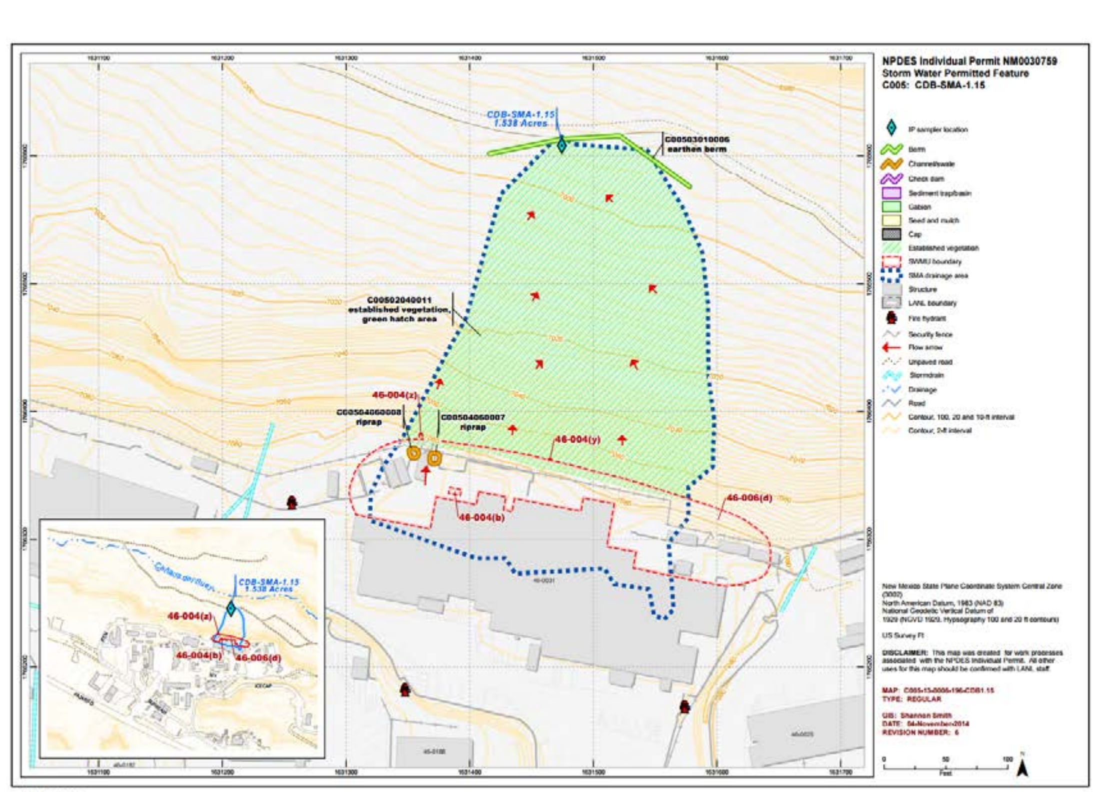

Figure 5. CDB-SMA-1.15 earthen berm(s) and watershed.

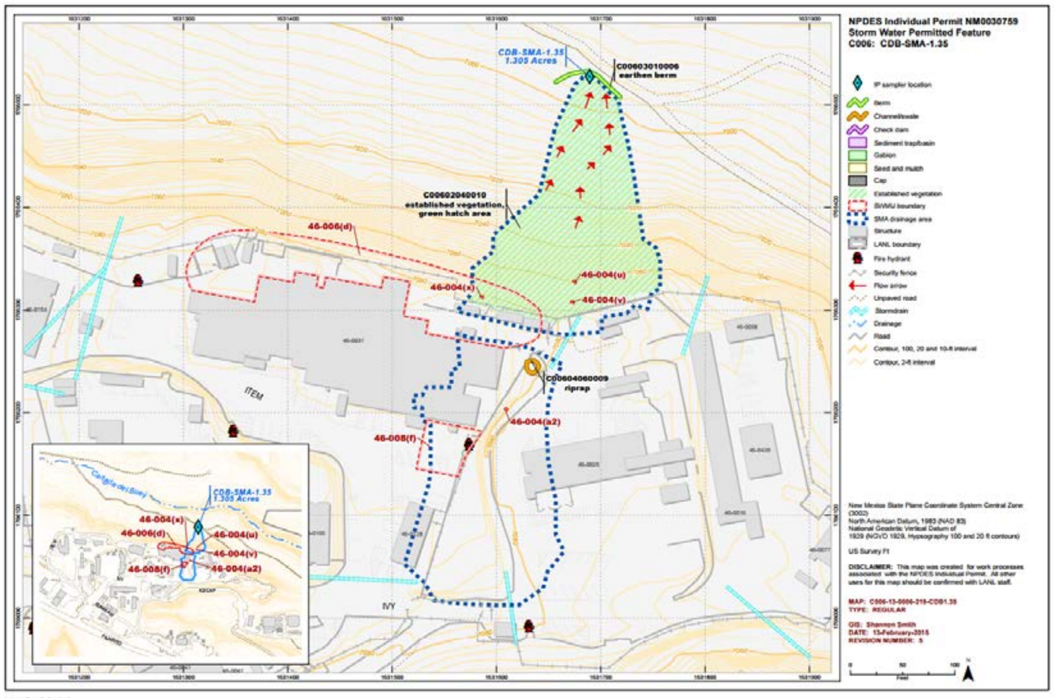

Figure 6. CDB-SMA-1.35 earthen berm(s) and watershed.

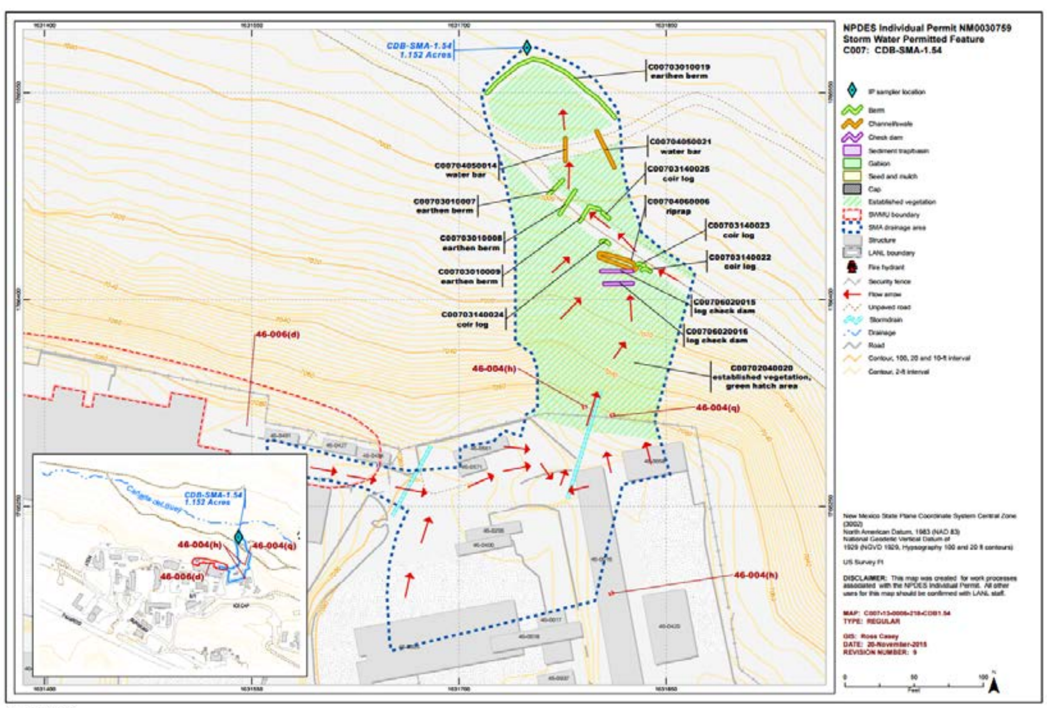

Figure 7. CDB-SMA-1.54 earthen berm(s) and watershed.

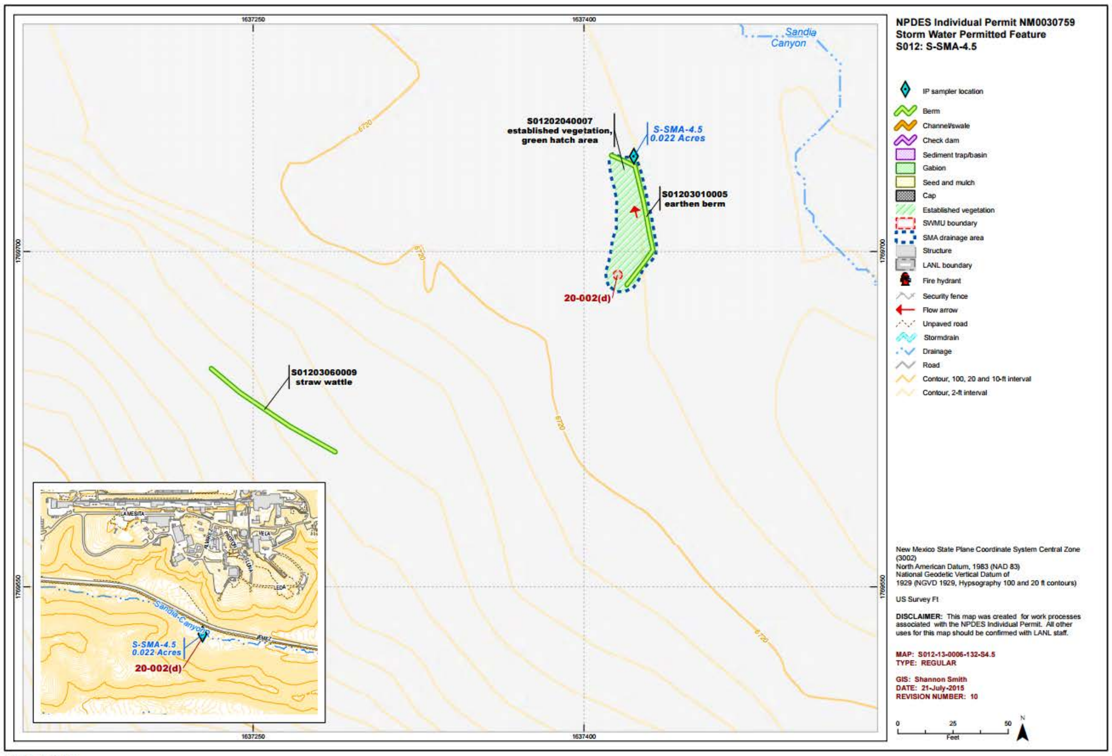

Figure 8. S-SMA-4.5 earthen berm(s) and watershed.

4. RESULTS AND ANALYSIS

Using LiDAR Topography and GIS to Calculate the Retention Storage Volume Available

A total of 5 SMAs were strategically chosen out of the 38 SMAs to be evaluated for total retention volume available. This was done in GIS and it was calculated that for S-SMA-4.5, LA-SMA-5.53, CDB-SMA-1.15 and CDB-SMA-1.35 the earthen berms were capable of retaining a volumes of 171 ft^3, 435 ft^3, 1,367 ft^3 and 890 ft^3respectively. As for CDB-SMA-1.54, this SMA has 4 earthen berms, however the main focus was on the downstream earthen berm because of its size and water flow. This earthen berm was capable of retaining a volume of 1732 ft^3 (Figure 9).

Running TR-55 Model to Determine Volume Required for a 3-yr, 24-hrStorm Event

After collecting copious amounts of data from running the TR-55 model, the requirements of each SMA to retain surface water volume for a 3-year, 24-hour storm event was determined. It was calculated that for S-SMA-4.5 the earthen berm was required to retain a volume of 38 ft^3. For LA-SMA-5.53, the earthen berm was required to retain a volume of 944 ft^3. For CDB-SMA-1.15, the earthen berm was required to retain a volume of 1,561 ft^3. For CDB-SMA-1.35 the earthen berm was required to retain a volume of 2,088 ft^3. As for CDB-SMA-1.54, this SMA has 4 earthen berms, however the main focus was on the downstream earthen berm because of its size and water flow. This earthen berm was required to retain a volume of 1,793 ft^3 (Figure 9).

Volume Available vs. Volume Required

As shown in Figure 9, only one SMA (S-SMA-4.5) met the corrective action measure of meeting the volume that was required for a 3-year, 24-hour storm. However, from the few that were left, 2 SMAs (CDB-SMA-1.15 and CDB-SMA-1.54) achieved above 85% in almost reaching their goal of the required volume. With a few field changes, such as vegetation cover, land cover etc. this can reach the required volume.

SMA	BMP	Volume Available (ft^3)	Volume Required (ft^3)	Surface Area (ft^2)	% Provided	Volume Short	Notes
S-SMA-4.5	S01203010005	171	38	719	449.2%	N/A	
LA-SMA-5.53	L018B03010002	435	944	509	46.1%	508.763	
CDB-SMA-1.15	C00503010006	1367	1561	1592	87.6%	194.331	
CDB-SMA-1.35	C00603010006	890	2088	853	42.6%	1198.159	
CDB-SMA-1.54	C00703010019	1732	1793	1425	97.4%	46.829	Downstream
	C00703010007						3rd Upstream
	C00703010008	6		43			2nd Upstream
	C00703010009	8		256			Upstream

Figure 9. SMAs volume available and volume required for 3-yr, 24-hr storm event.

5. CONCLUSION

The summer research, “Calculating the Retention Storage Volume of Surface Water within a Predetermined Contour Area in Los Alamos County,” was conducted to determine if the SMAs that did not collect samples on the September 13, 2013, 1000 year storm event obtained enough retention storage volume for a 3-year, 24-hour storm event. This was done to follow given guidelines and permits for corrective action measures. The methodology to obtain these results included the use of ArcGIS tools and the TR-55 model. In conclusion, it was determined that one SMA met the requirement while others did not for a 3-year, 24-hour storm event. These findings are significant because it would be inefficient to go back out into the field to reevaluate and redesign the earthen berms. These findings will be used to help better understand how to use GIS and LiDAR data to calculate the storage volume of any predetermined contour area. In addition, these findings may help guide future decisions for operational procedures for earthen berms. Future work could include obtaining the retention storage volume available and required for the rest of the 33 SMAs that have not been analyzed. If this proves successful, it could save time and money on field visits and redesign of the SMAs.

6. REFERENCES

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