

Design and Evaluation of an Irrigation Storage Reservoir

By

Jimmy Tomac

**BioResource and Agricultural Engineering
BioResource and Agricultural Engineering Department
California Polytechnic State University
San Luis Obispo
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AUTHORS : Jimmy Tomac

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Mr. G.W. Bates
Senior Project Advisor

Signature

Date

Dr. Art MacCarley
Department Head

Signature

Date

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ABSTRACT

The goal of this project is to design a 20 Acre foot reservoir for Dave Alford in Los Osos, Ca. This reservoir will allow Alford to have more flexibility with his irrigation scheduling. The storage reservoir will be designed to County and NRCS standards. This project will also include a cost analysis of various reservoir options and sizes. The cost analysis will consist of costs for earthwork, permits, liners and many other costs. The cost analysis should serve as a tool to decide between reservoir options.

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INTRODUCTION

Agriculture is a large part of the economy along the Central Coast and throughout California. Due to the current drought conditions, future considerations have to be made in order to provide enough water storage in order to irrigate crops and meet their evapotranspiration needs. Dave Alford, a local rancher and farmer, owns farm and rangeland in Los Osos, Ca. Dave farms lettuce, squash, snap peas, and many other varieties of vegetables. He has a variety of drip tape systems and sprinkler systems. On the east side of Dave's property there are currently five pumps that produce approximately 50 gpm each (250 gpm total). This current pumping system is sufficient to irrigate only small blocks at a time. In order to obtain more irrigation flexibility and water storage, there is a need for an irrigation storage reservoir on the east side of his property.

The scope of this project is to supply Dave with an irrigation storage reservoir design. This design will include aspects such as site selection, permitting, sizing, grading design, outlet design and cost analysis. This reservoir must store enough water to be able to irrigate the east side of Dave's property. Currently, to irrigate all or most of Dave's fields at once, he must import water from a storage reservoir on the West Side of his property. A storage reservoir will be designed using survey equipment and AutoCad Civil 3d. The reservoir will be designed to comply with Natural Resources Conservation Services and San Luis Obispo County Standards. This report will consist of a literature review covering the background and standards for reservoir design. It also contains detailed procedures of the grading and design of the reservoir and a cost comparison for a couple different reservoir options.



Figure 1 Alford's Property and Proposed Reservoir Site

LITERATURE REVIEW

The design of drainage basins and storage reservoirs involves both hydraulic and earthwork considerations. The geometry of the basin and the outlet structures need to be determined for hydraulics. The geometry of the basin is often dictated by the optimization of earthwork. To design a basin, prospective sites are analyzed before selection. The desired storage of the new basin and the outflow capacity need to be determined (Guo, 2004). Irrigation storage basins are also very common on farms and ranches. These storage reservoirs can provide irrigation flexibility for the farmer while also increasing groundwater recharge in some cases. Although in many cases where water is scarce, recharge and seepage into groundwater is unwanted. The standards, design process, and all aspects of creating an irrigation storage reservoir will be covered in the following sections.

Irrigation Storage Reservoirs

An irrigation reservoir is defined as “an irrigation water storage structure made by constructing a dam, embankment, pit, or tank” (NRCS, 2011). Storage reservoirs can provide a consistent supply of irrigation water, provide storage for farms with tail water recovery, and reduce energy costs. These reservoirs are used in cases where pumps are insufficient to provide enough water for irrigation requirements, where water can be taken from streams, surface runoff, or groundwater. In order for a reservoir to be useful, the existing water supply must be insufficient to meet crop requirements, water is available for storage from some source and a site is available for the reservoir (NRCS, 2011a).

Design Considerations

There are a few different reasons for an irrigation reservoir to be utilized including frost protection and irrigation flexibility. It must also be designed to state and local standards. Design considerations for irrigation storage reservoirs include site selection, permitting requirements, sizing, grading design, outlet design, and liner selection.

Frost Protection. A reservoir designed for freeze protection must supply enough water to operate for 3 or 4 nights in a row. Extreme weather data for the area must be evaluated in order to determine the exact amount of hours and nights that the sprinklers have to run. Generally a reservoir should be designed to account for 7-12 hours a night for 3 consecutive nights. The first step to designing a reservoir for frost protection is to figure out the time of operation. The most essential step in design is comparing the amount of water that goes into the reservoir versus what goes out. The water that goes into a reservoir is the wells flow rate times the amount of time the well is operating. The water that goes out of the reservoir is the time of operation times the flow rate out of the pond. The reservoir size is the water out minus the water in. Typically the reservoir is sized in acre-feet (Burt, 2012).

The amount of water that the plants need for freeze protection is determined by a few factors. The size of the fields, type of crop, and the Distribution Uniformity of the system affect how much water needs to be applied. The net application rate can be determined from a relationship between Wind Speed and Temperature. The gross application rate can be determined by the equation:

$$\text{Gross (in/hr)} = \text{Net} / (\text{CCDU} * \text{GPMDU}) \quad (1)$$

Where: CCDU= Catch Can Distribution Uniformity
GPM DU= Gallons per minute distribution Uniformity

The flow rate per sprinkler can then be determined by the formula (Burt, 2012):

$$\text{GPM out} = \text{Gross application rate} * (\text{Sprinkler Area} / 96.3) * \# \text{sprinkler/acre} \quad (2)$$

The reservoir sizing must also take into account crop evapotranspiration requirements, evaporation, seepage, and leaching (NRCS, 2011a).

Irrigation Storage. To determine the capacity of a reservoir based on irrigation needs, one must decide how much flexibility they want. For example, a farmer's pumps may only be able to irrigate one block at a time. With a properly sized storage reservoir, more or all of the blocks could be irrigated at one time. It is most important for the storage reservoir to be able to provide the necessary irrigation application rates for a certain set time (NRCS, 2011a). The application rate for a system can be determined by the equation:

$$\text{Application Rate (in/hr)} = (\text{Flow} * 96.3) / \text{Area} \quad (3)$$

Where: Q=Flow in GPM
A = Area in Square Feet

Once the application rate is determined, the total flow of the system can be calculated. This calculated flow along with a given set time can yield the volume required per acre per set. This number multiplied by the total farmed acreage will yield the required reservoir storage to irrigate all of the fields in one day.

Pond Capacity. Once the irrigation storage reservoir is designed, the storage capacity can be determined from the dimensions of the reservoir. The first step is to determine the high water level of the pond. Next, the width of the pond must be measured at multiple locations. These measurements can then be used to determine the surface area. The surface area is typically measured in acres. The surface area is then multiplied by 0.4 of the high water depth in feet. The resulting volume is measured in acre-feet (NRCS, 1997). The pond capacity may also be determined using AutoCAD. The Stage Storage extension in AutoCAD can be used to calculate volume of ponds and basins.

Design Standards

Height. The design height of the walls of the reservoir must be high enough to prevent overtopping with the design hydrograph. The design height is defined as “the vertical height from the lowest normal ground point along the centerline of the dam and the top of the dam.” (USDA, 2000). The height must also be high enough to allow for a certain amount of freeboard in the reservoir (NRCS, 2005). Other than local standards, the depth of the reservoir depends on the amount of storage required by the irrigation needs.

Top Width of embankment. The bank width may depend on state and local standards, roadway access, and structural stability (NRCS, 2005). According to SLO county Standards, the bench around the perimeter of the basin must be at least 5 feet wide (SLO County Public Works, 2011) Although wider embankments reduce the chances of the embankment failing when overtopped (NRCS, 2005). The top width of the embankment for NRCS pond standards can be determined from the table in figure 1 (USDA, 2000).

Table 1. Embankment Top Width (Minimum)

<u>Total Height of Dam (Ft.)</u>	<u>Top Width (Ft.)</u>	<u>Top Widths (Farm Roads) (Ft.)</u>	<u>Top Width (Public Road)</u>	
			<u>1 Way (Ft.)</u>	<u>2 Way (Ft.)</u>
less than 10	6	12	16	28
10 to 14.9	8	12	16	28
15 to 19.9	10	12	16	28
20 to 24.9	12	14	16	28
25 to 34.9	14	14	16	28
35	15	16	16	28

Figure 2 Minimum Top Width of Embankment (USDA, 2000)

Embankment Stability. All earthfill dams and reservoirs should be designed in order to be safe during the course of its life. According to the Department of Water Resources, these design considerations must be followed (DWR, 1993):

1. The slopes must be stable under all possible conditions. This includes rapid reservoir drawdown.
2. Seepage must be controlled in the reservoir so that erosion does not occur in the interior of the embankments.
3. The embankments must be designed in order to not overtop.
4. The reservoir must be able to withstand earthquakes.
5. The embankment slopes must not be affected or damaged by rain.

The borrow material must be suitable for safe embankments. Course bower material shall be placed at the outer slope of the embankment, while finer material such as clay should be placed towards the center of the dam. The embankment material should also be compacted to about 97% (DWR, 1993).

The embankment stability must be evaluated for a few different design conditions. At the end of construction, the soil in the embankment will have large pore pressures. Shear tests

should be done to determine sufficient sizing of embankments. For embankments, a safety factor of 1.3 should be used for slope stability calculations. In the case of rapid drawdown, there is a chance of the walls collapsing due to the sudden pressure change. A minimum safety factor of 1.2 should be used for these calculations. To design for steady seepage, a safety factor of 1.5 should be used (NRCS, 2005).

Side Slopes. The side slopes should be “no flatter than those needed to obtain slope stability.” The side slope of reservoirs is a function of the soil type present. The side slopes based on embankment materials can be seen in figure 3 (USDA, 2000).

Embankment Material	Minimum Slopes Horizontal to Vertical Both Slopes*
Clayey Sand (SC), Sandy Clay (CL), Silty Clay (CL), Silty Sand (SM), Clayey Gravel (GC), Silty Gravel (GM)	5 to 1
Silt (ML), Fat Clay (CH), Clayey Silts (MH)	6 to 1
Fine Sand (SM-SP) (Minimum one side 3.5 to 1)	8 to 1
*Dams to be mowed should have 3:1 side slopes or flatter on back side.	

Figure 3 (USDA, 2000)

Slope Bank Protection. Embankments need to be protected from erosion. Vegetation can be an effective means for erosion control if the vegetation has good coverage and can be sustained without irrigation. Structural protection such as rip rap can be used where vegetation is not possible. It is also very useful for the outlet or spillway of the reservoir to reduce the erosive energy (NRCS, 2005).

Overflow path. The engineer of drainage basins and storage reservoirs must identify the overflow path and determine the best strategy for erosion control. The overflow path should be designed so that during the 100-year storm, the outflow does not cause erosion (SLO County Public Works, 2011). The purpose of an overflow path is to keep the water under a certain level. The recommended freeboard for a pond is 1 ft or more from the water surface to the top of bank (USDA, 2000). When the water reaches the design overflow level, it will enter the spillway and exit the reservoir (NRCS, 2005). Spillways can either be made of earth, concrete, or conduit. A common type of spillway is the drop inlet spillway as seen in Figure 4.

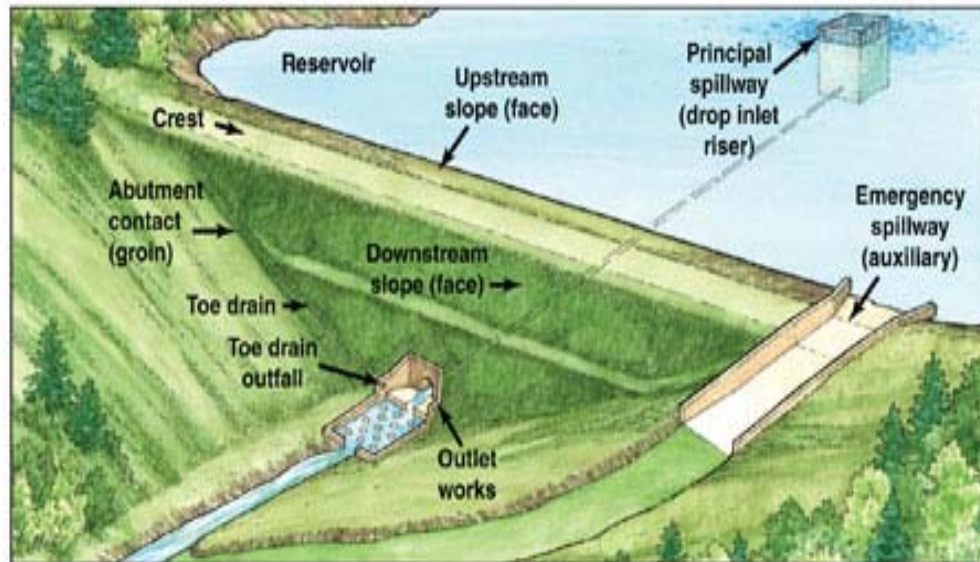


Figure 4 Drop Inlet Riser and Auxiliary Spillway (USDA, 2000)

Drop inlet spillways typically consist of a vertical pipe section and a horizontal section that goes through the embankment. The spillway can be made out of many materials including corrugated and smooth pipe, but it must be able to withstand the external forces it encounters typically, a reservoir must have a principal and an auxiliary spillway. An auxiliary outlet type can be an earthen or civil structure designed to be a part of the embankment. Auxiliary spillways are usually placed 12 inches or more above the principle spillway (NRCS, 1997).

The inlet of this type of spillway must have a straight inlet, a crest, and a protected outlet (NRCS, 2005). A drop inlet spillway or pipe spillway is often used along with an emergency earth spillway to control the overflow (NRCS, 1997).

Spillway Sizing. For a drainage area of 20 or less acres with an embankment height of less than 20 ft, the minimum design storm for the spillway is a 10 year storm with a 24 hour duration (NRCS, 1997). The rational method is a very common method to determine peak flows for hydrologic designs. The rational method considers the entire drainage area as one unit and estimates the peak flow at the point furthest downstream.

$$Q = CIA$$

(4)

Where: Q= max runoff (cfs)
 C=Runoff Coefficient
 I=Average Intensity
 A= Area (acres)

The runoff coefficient values are tabulated. These values depend on the type of land use and the type of soil and slope (Knox, 2008). Next, the average rainfall for an area in San Luis Obispo County should be determined either by rainfall charts or latitude/longitude data. Once the average rainfall is found, the I, average intensity, can be looked up in Table H-4 of

the SLO County Design Standards (SLO County Public Works, 2011). Now the max runoff, Q , can be determined.

Table 3-6. Recommended Runoff Coefficient Values for Rational Method

Land Use	Runoff Coefficient (C) by Hydrologic Soil Group and Ground Slope											
	A			B			C			D		
	<2%	2 - 6%	>6%	<2%	2 - 6%	>6%	<2%	2 - 6%	>6%	<2%	2 - 6%	>6%
Forest	0.08	0.11	0.14	0.10	0.14	0.18	0.12	0.16	0.20	0.15	0.20	0.25
Meadow	0.14	0.22	0.30	0.20	0.28	0.37	0.26	0.35	0.44	0.30	0.40	0.50
Pasture	0.15	0.25	0.37	0.23	0.34	0.45	0.30	0.42	0.52	0.37	0.50	0.62
Farmland	0.14	0.18	0.22	0.16	0.21	0.28	0.20	0.25	0.34	0.24	0.29	0.41
Res. 1 acre	0.22	0.26	0.29	0.24	0.28	0.34	0.28	0.32	0.40	0.31	0.35	0.46
Res. 1/2 acre	0.25	0.29	0.32	0.28	0.32	0.36	0.31	0.35	0.42	0.34	0.38	0.46
Res. 1/3 acre	0.28	0.32	0.35	0.30	0.35	0.39	0.33	0.38	0.45	0.36	0.40	0.50
Res. 1/4 acre	0.30	0.34	0.37	0.33	0.37	0.42	0.36	0.40	0.47	0.38	0.42	0.52
Res. 1/8 acre	0.33	0.37	0.40	0.35	0.39	0.44	0.38	0.42	0.49	0.41	0.45	0.54
Industrial	0.85	0.85	0.86	0.85	0.86	0.86	0.86	0.86	0.87	0.86	0.86	0.88
Commercial	0.88	0.88	0.89	0.89	0.89	0.89	0.89	0.89	0.90	0.89	0.89	0.90
Streets: ROW	0.76	0.77	0.79	0.80	0.82	0.84	0.84	0.85	0.89	0.89	0.91	0.95
Parking	0.95	0.96	0.97	0.95	0.96	0.97	0.95	0.96	0.97	0.95	0.96	0.97
Disturbed Area	0.65	0.67	0.69	0.66	0.68	0.70	0.68	0.70	0.72	0.69	0.72	0.75

Figure 5 Runoff Coefficients (Knox, 2008)

Once the maximum flow is determined, the spillway can be designed. For earthen and vegetative spillways, the discharge head, H_p , and the discharge velocity, V , can be determined from figure 5 if the ground slope and flow are known (NRCS, 1997).

Table 10 H_p discharge and velocities for natural vegetated spillways with 3:1 end slope (Z_1)

Natural ground slope Z_1 (%)	H_p (ft)	Retardance										Slope	
	A.....	B.....	C.....	D.....	E.....		Min.	Max.
		Q (ft ³ /s)	V (ft/s)	Q (ft ³ /s)	V (ft/s)	Q (ft ³ /s)	V (ft/s)	Q (ft ³ /s)	V (ft/s)	Q (ft ³ /s)	V (ft/s)	(%)	(%)
0.5	1.0	19	0.3	28	0.5	47	1.3	68	1.8	130	2.8	0.5	3
	1.1	21	.3	35	.5	76	1.5	108	2.1	154	3.0		
	1.2	29	.4	39	.6	97	1.6	122	2.3	204	3.2		
	1.3	36	.4	53	.6	125	2.0	189	2.5	250	3.4		
	1.5	61	.4	87	1.1	210	2.2	291	2.9	393	3.8		
	1.8	81	.5	187	1.8	384	2.9	454	3.5	651	4.5		
	2.0	110	.5	286	2.1	524	3.3	749	3.8	860	4.8		
1	1.0	10	0.4	16	0.5	31	2.0	45	2.6	64	3.4	1	3
	1.1	13	.4	18	.6	50	2.3	63	2.8	90	3.7		
	1.2	15	.5	21	.8	62	2.5	78	3.1	99	4.0		
	1.3	22	.6	39	1.0	86	2.7	144	3.4	139	4.3		
	1.5	40	.7	75	1.8	133	3.1	186	4.0	218	5.1		
	1.8	56	.8	126	2.3	280	3.8	296	4.5				
	2.0	98	1.1	184	2.8	328	4.3	389	5.0				
2	1.0	6	0.5	9	0.8	18	2.5	27	3.3	36	4.2	1	3
	1.1	7	.7	14	1.0	29	2.8	39	3.6	50	4.5		
	1.2	9	.8	19	1.1	40	3.1	51	3.9	64	4.9		
	1.3	13	.9	26	1.6	50	3.4	70	4.3	85	5.3		
	1.5	21	1.0	39	2.0	70	3.9	109	5.1	127	6.3		
	1.8	26	1.1	74	2.5	126	4.8	194	5.9				
	2.0	52	1.3	111	3.2	190	5.4	229	6.4				
3	1.0	4	0.7	7	0.8	15	2.8	21	3.7	28	4.8	1	3
	1.1	5	.8	10	.9	24	3.2	31	4.0	38	5.2		
	1.2	7	.9	14	1.1	33	3.6	41	4.4	49	5.6		
	1.3	10	1.0	20	1.5	42	3.8	57	4.8	67	6.1		
	1.5	16	1.2	34	2.8	62	4.4	89	5.7	104	7.2		
	1.8	23	1.3	57	3.0	112	5.5	143	6.7				
	2.0	39	1.5	81	3.7	163	6.2	194	7.2				
4	1.2	6	1.0	11	1.4	25	3.9	31	4.8	38	6.1	1	4
	1.5	15	1.3	29	3.1	49	4.8	69	5.5	81	7.9		
	1.8	20	1.4	47	4.1	98	6.1	116	7.3				
	2.0	30	1.6	65	4.7	139	6.7	161	7.8				
	2.5	72	3.3	167	6.6	238	8.5						
5	1.5	13	1.4	23	3.3	38	5.2	55	6.7	63	8.4	1	5
	1.8	17	1.5	37	4.4	76	6.5	95	7.9				
	2.0	23	1.7	48	5.1	112	7.1	130	8.1				
	2.5	64	3.7	149	7.1	191	9.2						

Figure 6 Discharge Head and Velocity (NRCS, 1997)

The discharge head determines how high the embankment must be above the spillway in order to keep a design freeboard. For example, if the freeboard of a pond is 2 feet and the discharge head is 1 foot, then the spillway should be made 3 feet below the embankment. The width of the spillway can be determined with the head, velocity, and flow of the system. The pipe spillway should also be designed to pass the design discharge flow (NRCS, 1997).

Trash Racks. Trash Racks must be implemented on spillways in order to prevent the clogging of the spillway. The velocity of the flow through trash racks must not exceed 2.5 feet per second (NRCS, 2005).

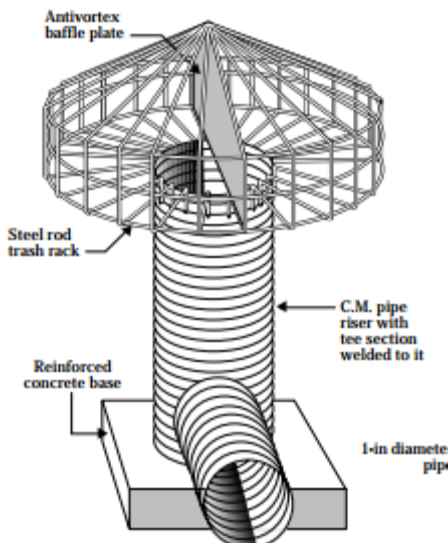


Figure 7 Typical Trash Rack and Riser Design for Pipe Spillways (NRCS, 1997)

Seepage. Poor soil at the chosen reservoir site can cause excess seepage of water into the soil to occur. Seepage is unwanted in storage reservoirs because it can result in the loss of much of stored water. There are a few methods to help prevent seepage in poor soils and essentially seal the pond. One method is compaction. Compaction can help make the soil impervious if done correctly. Compaction is the least expensive method to prevent seepage. Adding a liner to the pond is also an option. Another method is the use of Bentonite clay. Bentonite clay is a very fine clay soil. It absorbs much more water than other types of clay. Bentonite should be mixed in with coarse material and compacted. Then when water is introduced to the reservoir, the clay swells up and becomes impervious. Bentonite is only useful in applications where the water level of the reservoir does not fluctuate often (NRCS, 1997).

Permitting

In San Luis Obispo County a construction permit is needed when building a home, a barn, demolishing a building, or grading or moving dirt. To apply for a standard construction/grading permit the following need to be submitted (SLO County, 2014):

- Completed Application
- Vicinity Map
- Three sets of construction and grading plans.
- Verification of Water, Sewer and Fire Services.
- Filing Fee

It is often common for projects around coastal California to fall within the coastal zone. According to the California Coastal Commission, “Permitted development shall be sited and designed to protect views to and along the ocean and scenic coastal areas, to minimize the alteration of natural land forms, to be visually compatible with the character of surrounding areas, and where feasible, to restore and enhance visual quality in visually degraded areas.”

The Coastal Commission also aims to protect water quality and environmentally sensitive areas. A coastal development permit or CDP must be acquired for any type of grading in a coastal zone. These permits are typically acquired through a local government such as a county (California Coastal Commission, 2014).

Although agriculture is typically exempt from the Construction General Permit, some construction sites may need a construction storm water permit through the State Water Resources Control Board. Grading which disturbs one or more acre of land is subject to the Construction General Permit. The legally responsible person for this project must electronically submit the required Permit Registration Documents prior to construction. The PRD's include a Notice of Intent, Risk Assessment, Post-Construction calculations, a site map, a Storm water Pollution Prevention Plan (SWPPP), and an annual fee. Most of these documents can be found on the Water Boards website. A SWPPP must be developed by a Qualified SWPPP Developer or a Qualified SWPPP Practitioner. After these documents are submitted, a WDID number is terminated and the construction can begin. The permit will last until a Notice of Termination is filed and the site is deemed as completed

This site may also require a CEQA permit. A California Environmental Quality Act requires state and local agencies identify possible environmental impacts resulting from their actions and how to avoid these impacts. A CEQA project is a project done by a public or private agency which may cause a change to the environment. A pre-project review of potential environmental impacts must be completed. If the impacts are significant, then an Environmental Impact Report must be completed

PROCEDURES AND METHODS

Introduction

The following procedures and methods section contains all of the aspects of this irrigation storage reservoir design. For this project, a grading design for a 20 acre-foot storage reservoir was completed based on landowner requirements and NRCS/SLO County Standards. A cost analysis was also completed. This cost analysis compares the construction and permitting costs for two different liner types and is meant to help the landowner decide whether constructing this reservoir is feasible or not.

Design Constraints

It is critical to get enough information from a client in order to complete a quality design. For this design, many factors needed to be considered including existing water supply, soil type, desired water storage, existing distribution system and desired cost.

For this design the givens supplied by the land owner are:

Location: Los Osos, Ca

Water Source: 5 groundwater wells with a flow rate of approximately 50 gpm each.

Crop: Varies

Spacing: 24 inches

Irrigation System: Drip Tape, medium flow,

The first design constraint is that this system is only going to have one pipeline going to it. This means that the reservoir can only be either by filled or emptied at one time. This project is also located in the coastal zone. This means that a different permit such as a minor use permit may be required other than a County Grading Permit. The landowner also specified that this reservoir must not receive any water from runoff. This is so that the pond does not take any water that the creek was supposed to receive. The landowner also specified that the final reservoir design must have approximately 20 acre-feet of storage.

Topographic Survey

Once all of the design constraints were determined, a topographic survey had to be done. The GPS survey equipment was provided by the Coastal San Luis Resource Conservation District. Trimble survey equipment was used to complete the survey. In order to get an accurate representation of the field, data points needed to be taken at key points. Data points were taken approximately every 50-75 feet throughout the field. Key shots were taken at rock outcroppings and flow lines. The temporary benchmark (TBM) used for this survey was the bottom of the fencepost at the North East corner of the field. Once the survey equipment was set up, the fence line and benchmark were shot in order to create a point of reference so that the survey would be coordinate correct. Next, all of the rock outcroppings were shot. These outcroppings were included in the survey so that they could easily be seen in the completed surface. It was important to know where these rocks were so that the reservoir would not be designed on top of them. The flow line of the field was then shot.

This was also included so that the reservoir would not encroach on the flow line and disturb the drainage of the field. After all of the key points were surveyed, points were taken throughout the field.



Figure 8 Setting up Survey Equipment

After all of the data was recorded, it was downloaded onto a computer in a CSV format. The excel file was then imported into AutoCAD Civil 3d 2010. The points are brought in using a Northing, Easting and Elevation format. A contour surface was then created using AutoCAD. The existing ground surface can be seen in figure 9.

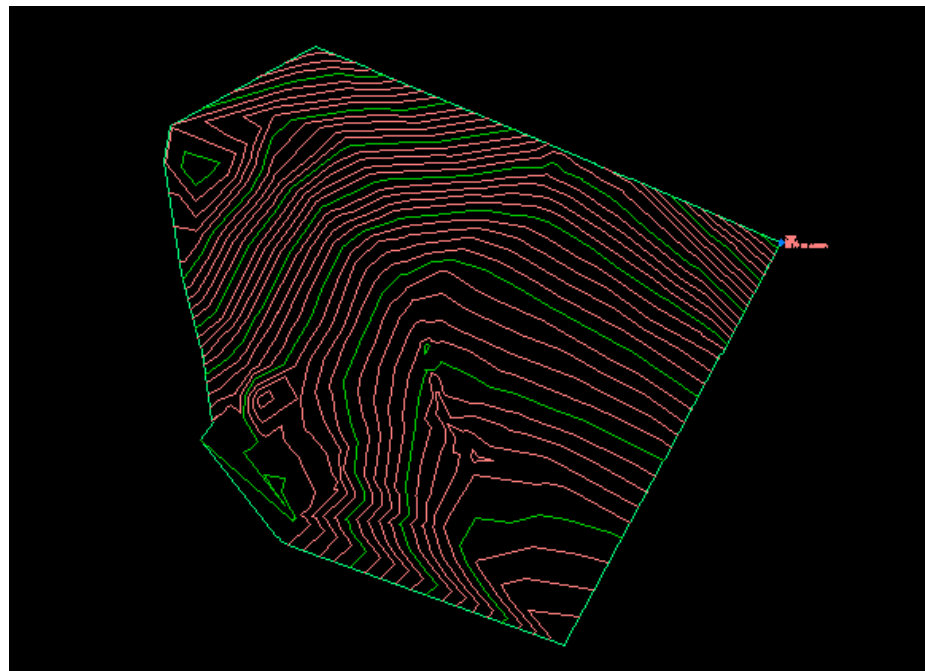


Figure 9 Existing Ground Surface

Total Required Water Storage

The total storage volume of the reservoir needed to be determined to meet the requirements of the crops. It was determined that in order to irrigate all of Alford's fields on the West side of his property in one day, a 16.4 acre-feet reservoir would be needed. These calculations can be seen in figure 11. Alford also requested that the size of the reservoir be approximately 20 acre-feet. Since the client requested a larger reservoir than the 16.4 acre-foot reservoir shown in the calculations, a 20 acre-foot reservoir will be sufficient for this design.

AR= Flow x 96.3/Area	
Drip tape=	0.34gpm/100ft
Farmed area=	1 acres
Area of Farm=	300 acres
AR for drip tape=	0.164in/hr
Flow of system=	74.1gpm/acre
If irrigated for 4 hours/set:	
Volume/acre=	2376CF/acre
Required Reservoir Size=	16.4AF

Figure 10 Sizing Calculations

Reservoir Design

This grading design involved many different iterations in order for the completed project to comply with all of the design requirements. The first step in a design was to use AutoCAD Civil 3d coupled with the survey data to create a reservoir. Each component of the reservoir had to be designed in order to conform to the requirements of the landowner and the NRCS and County Standards. After an initial design was completed, it could be modified in order to balance earthwork and result in the correct storage volume.

Initial Design. After the topographic survey was completed and the surface was made in AutoCAD Civil 3d, the reservoir needed to be designed and modeled in Civil 3d. This design had to conform NRCS and local county standards. These standards include specifications for items such as embankment height, embankment slope, outfall sizing, and many other design factors. The standards used for this design are summarized below in Table 1.

Table 1 Design Requirements and Standards

Design Requirements and Standards	
Storage Volume	20 AF
Footprint	2 to 3 acres
Interior Embankment Slope	4 to 1
Exterior Embankment Slope	2 to 1
Bench Width	8 to 10 ft
Freeboard	2 ft

A Web Soil Survey (WSS) through the Natural Resources Conservation Service (NRCS) website was used in order to determine the type of soils that were going to be used to construct the reservoir. The WSS allows anyone to determine the type of soil at any location throughout the country. The WSS generates a soils report which contains information about the type of soil, available water holding capacity, field slope, and many other important items of information.



Figure 11 WSS Map

San Luis Obispo County, California, Coastal Part (CA664)			
Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
128	Cropley clay, 2 to 9 percent slopes	13.1	33.4%
163	Los Osos-Diablo complex, 9 to 15 percent slopes	25.6	65.2%
164	Los Osos-Diablo complex, 15 to 30 percent slopes	0.6	1.4%
Totals for Area of Interest		39.2	100.0%

Figure 12 WSS Soils Information

From this report, the field has fairly steep slopes and a large percentage of clay. This information can be very important while designing a storage pond. Different soil types can have different requirements for embankment slope and height.

The first thing that had to be determined for this design was an approximate storage volume desired. The client specified that he would like to have approximately 20 acre feet of storage. In order to obtain a storage volume of 20 AF, the reservoir was first designed to be approximately 1.5 Acres in Surface Area and 12-15 feet deep. The first step in modeling this reservoir was to create a feature line for the top of the reservoir. The location of the reservoir was chosen because it contains fairly mild slopes and it allowed for the earthwork to be balanced easily. A feature line is created by specifying an elevation and a distance. For this project, a rectangle was created and set at a constant elevation. This feature line representing the outline of the pond can be seen in figure 13. The initial dimensions of the reservoir were set to be 250' x 250'.

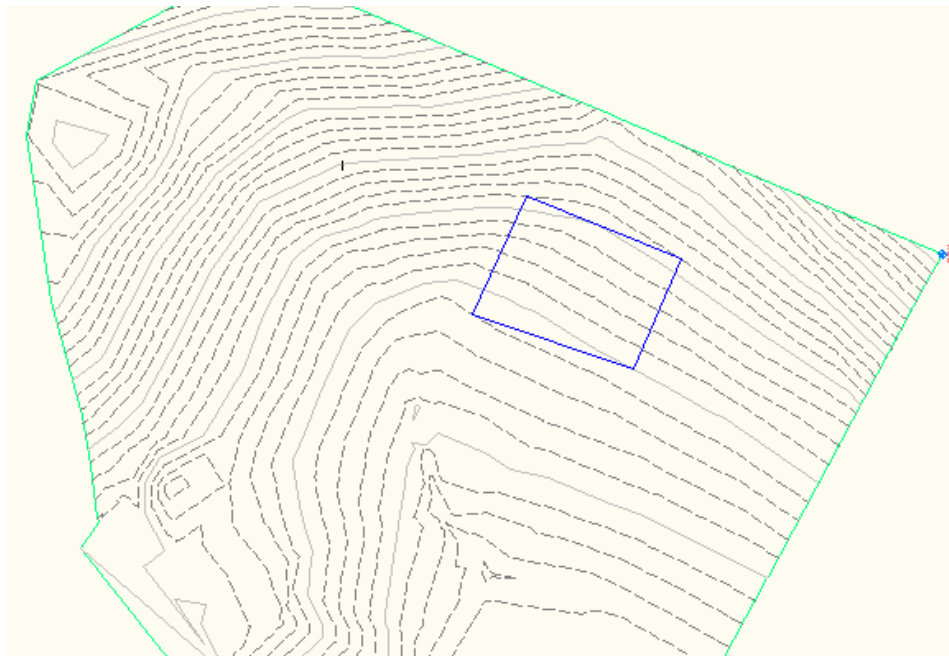


Figure 13 Feature Line

Once the top of bank feature line was created, the Grading Creation Tools had to be utilized in Civil 3d. A Grading Group should be made before utilizing the grading creation tools. For this design, the grading group was set to automatically generate a surface. Now, the grading creation tools can be used to create the embankments of the reservoir. The grading creation tools were utilized to create the embankments seen in Figure 14.

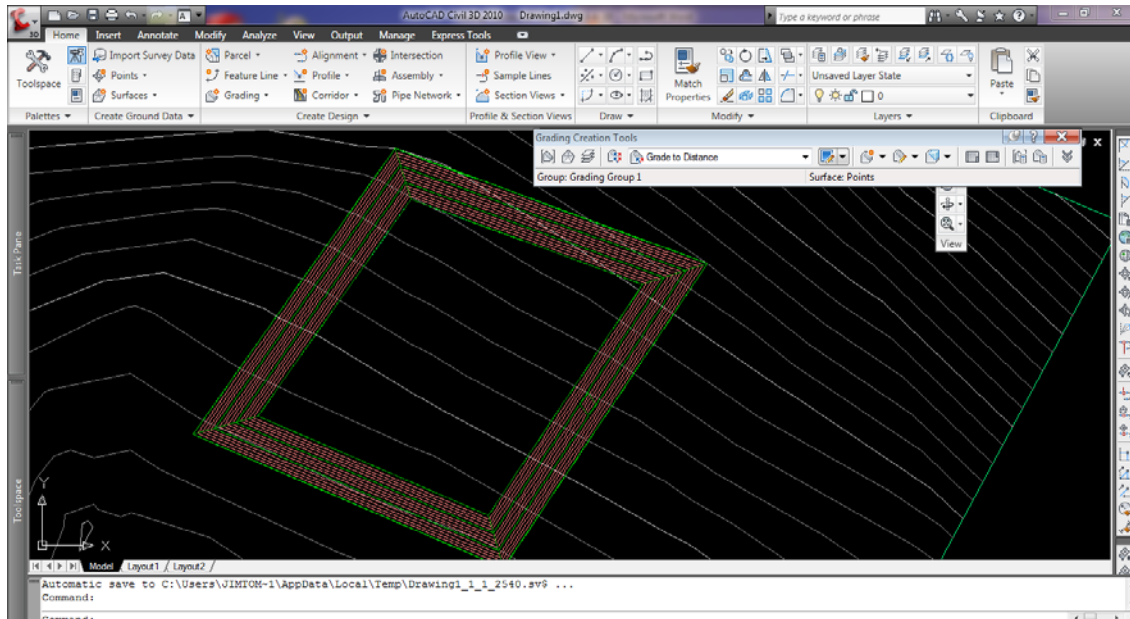


Figure 14 Grading Creation Tools

The Grading Creation Tools allow the user to grade to a certain distance at a certain slope, grade to an elevation, or grade to an existing surface. In this case, both grade to distance and grade to surface were utilized. In Figure 15, the slope banks were graded to a distance of 30 feet at a 2:1 slope. This resulted in the desired pond depth of 15 feet.

Next, the top of the bank had to be created. The top of bank was designed to be 6 feet wide at a 2% slope. This 2% slope was added to the top of bank so that water would not pool and cause damage to the embankments. After the top of bank was created, the outer embankments were created. These side slopes were set at a 3:1 slope. A 3:1 slope was chosen in order to ensure slope stability and to comply with NRCS Code 378 which states that outer slopes must be 3:1 or flatter. The top of bank feature line was graded down to the surface at a 3:1 slope.

Initially, the uphill side of the reservoir was set to the existing surface elevation of 30'. This would result in the reservoir capturing runoff from the surrounding watershed. In order to make this reservoir up to local standards, it must not capture any runoff. A 2 foot bank was created on the uphill side of the reservoir in order to divert water during rain events. The design of this channel will be discussed later in the report.

After the basic shape of the reservoir was created, the earthwork volumes needed to be calculated. It is good practice to try to balance cut and fill. The "cut" is the amount of borrow material taken out of the existing ground. The "fill" is the amount of material used

to create the reservoir. A fill factor had to be used in order to account for the borrow material compacting when used for fill. A fill factor for this job was assumed to be 15%.

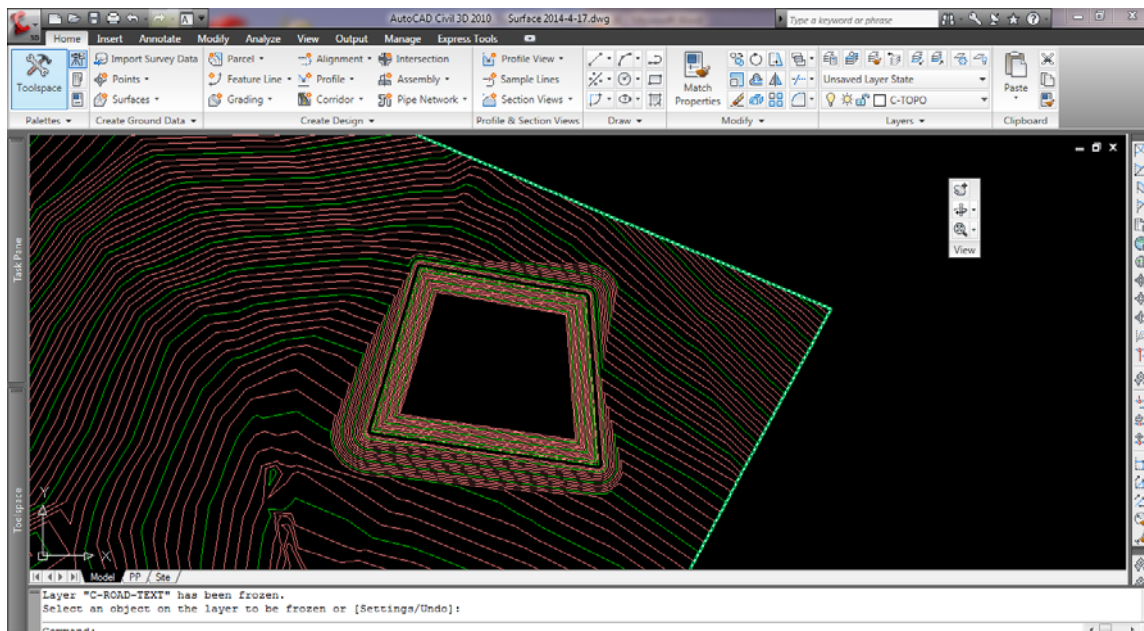


Figure 15 Initial Design of Pond

Initial Design Statistics:

Storage Volume = 13 AF
 Inner Embankment Slopes = 2:1
 Reservoir Depth = 15 feet
 Outer Embankment Slopes = 3:1
 Footprint = 2.17 Acres
 Max Cut= 12,527 CY
 Adjusted Fill=10,329 CY
 Net Cut=1,165 CY

This initial design had some design problems associated with it. First, the maximum embankment height was too high. High embankments can be difficult to construct and unsafe. The net earthwork volume was also far too high. In order to reduce costs, the earthwork needed to be balanced.

Final Design. The initial design of the irrigation storage reservoir had some small problems. First, the cut and fill needed to be balanced in order to simplify construction. Secondly, the downstream embankment height was too high for practical construction of the pond. For this iteration, the design plan involved creating a shallower reservoir with a larger surface area. This design also needed to follow the existing ground contours in order to reduce cut and fill.

The first step of the new design was to layout the bottom of the pond. Once the bottom of the pond was established, the inner banks were graded up to an elevation of 32 feet at a

slope of 2:1. Next, the banks were graded at a 2% slope at a distance of 10 feet. The bench width was increased from 2 to 10 feet in order to increase the amount of fill needed and improve the embankment stability.

After the bench was designed, a drainage channel similar to the initial design was created. Then the embankments were graded to existing ground at a slope of 4:1. A flatter slope was chosen for this iteration in order to increase bank stability and reduce the chances of bank failure.

For this iteration, the pond was designed to follow the contours of the existing ground rather than creating a rectangular pond. Following the contours allowed the earthwork to be balanced easier. Following the contours resulted in an irregular shaped reservoir.

Final Design Statistics:

Storage Size = 20.4 AF

Footprint = 4.0 Acres

Interior Embankment Slope = 2 to 1

Exterior Embankment Slope = 4 to 1

Bench Width = 10 feet

Depth = 12 feet

Freeboard = 2 feet

WS Elevation = 30 feet

Top of Bank = 32 feet

Reservoir Bottom = 20 feet

Max Cut= 10 feet

Max Fill = 13 feet

Cut= 18000 CY

Adjusted Fill=18134 CY

Net Earthwork = 134 CY Fill



Figure 16 Final Design in Model Space

This final design conformed to all of the NRCS and SLO county design standards seen in Table 1 and also satisfied Dave Alford's needs. This design has a maximum height of 13 feet while the initial design had a maximum dam height of 19 feet. This smaller maximum height will be much easier and safer to construct. The final net earthwork was also reduced from over 1000 CY to 134 CY. This will greatly reduced the material hauling costs.

Spillway Sizing

In order to prevent the banks from overtopping during large storm events, a reservoir must have some sort of spillway. According to the SLO County Standards, a spillway must be designed to handle a 10 year storm with a 10 hour duration. This is for reservoirs with an embankment height of less than 20 feet. The hydrology method used for this design was the rational method. The runoff coefficient for this design was assumed to be 1. A runoff coefficient of 1 means that there is zero water infiltrating into the soil. This situation would have a runoff coefficient of 1 because of the area is all water. The surface area of the reservoir was 1.7 acres and the Intensity was 0.350 from table H-4 in the SLO County Standards. This resulted in a flow of 1 CFS. These calculations can be seen in Appendix D.

A channel analysis was also done using AutoCAD Civil 3d 2010 Hydraflow Express. Hydraflow express is a tool that allows channel sizing calculations to be done with a known flow. Using this program, a circular corrugated conduit spillway was designed with a 0.75 foot diameter pipe. A 10 inch pipe will be used for the spillway. A Mannings n value of 0.024 was used (FHWA, 2011). This resulted in an exit velocity of 3.12 fps.

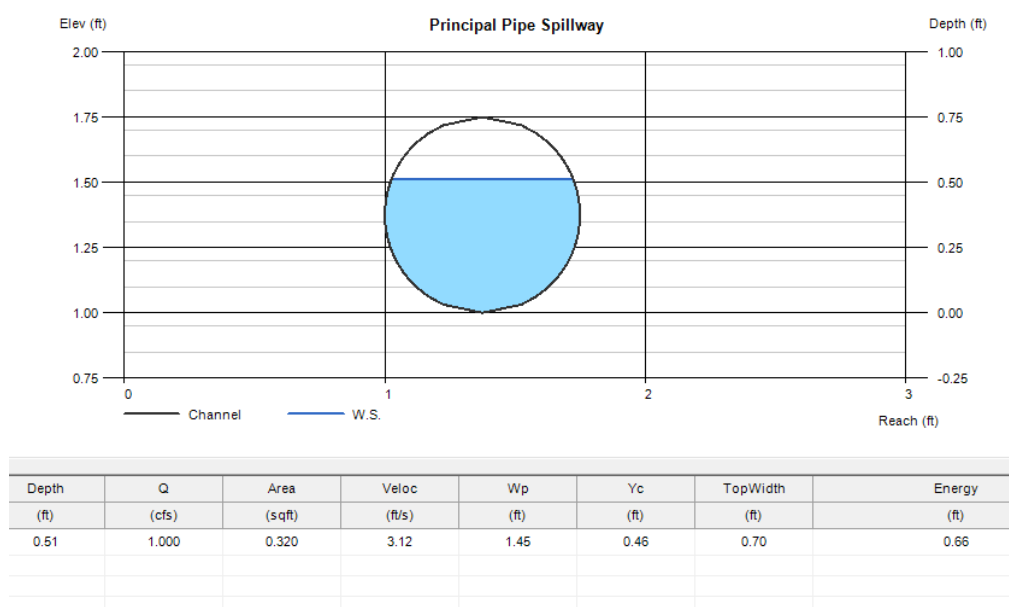


Figure 17 Hydraflow Express Results

After the principal spillway was designed, an auxiliary spillway needed to be designed in order to account for larger storms and flows. Examples of principal and auxiliary spillways can be seen in figure 4. In order to account for a 100 year 10 hour storm, the auxiliary spillway needed to handle an extra 0.24 CFS. Once again using Hydraflow Express to model

the auxiliary spillway, the spillway in Figure 19 was created. This spillway was created with a Mannings n value of 0.030 (FHWA, 2011). The depth of the spillway had to be set at 2 feet in order to keep the freeboard of the reservoir at 2 feet. The bottom width was set at 1 foot. As Figure 18 shows, this spillway does not get very full.

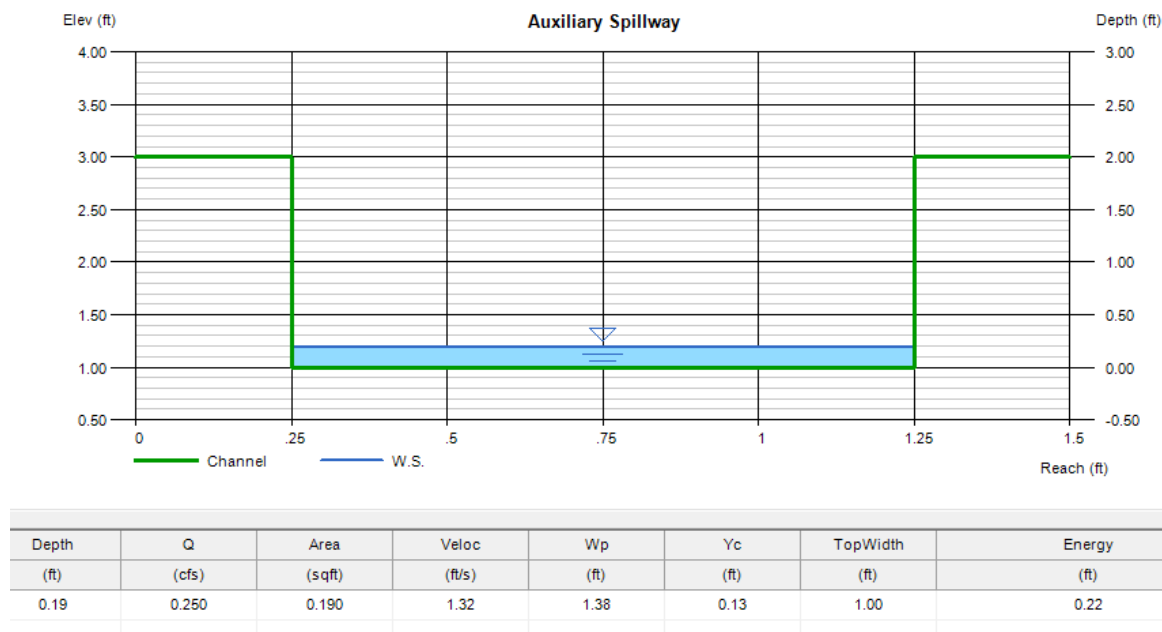


Figure 18 Auxiliary Spillway

Drainage Channel Design

One of the design criteria that this reservoir had to meet was to not capture any runoff. In order to prevent water from entering the reservoir, a channel had to be designed on the uphill side of the reservoir. This channel needed to take the runoff from the surrounding watershed and direct the flow around the reservoir. The first step in designing this channel was to complete hydrology calculations for the surrounding watershed. Using the rational method once again, an area, runoff coefficient, and intensity needed to be determined. For this fairly small watershed, the area was determined to be 12 acres. The area was found using AutoCAD and an aerial photo of the site. This drainage area can be seen in figure 19.



Figure 19 Drainage Area

The runoff coefficient found in Table H-2 of the SLO County Standards was determined to be 0.57. This runoff coefficient is very high because of the clay soils in the area and the fact that there is very little vegetation on the hills. The intensity was determined to be 0.50 for a 10 year 10 hour storm event. This resulted in a flow of 4.85 CFS. These calculations can be seen in Appendix E.

After the design flow was determined, a channel could be designed using Hydraflow Express in Civil 3d. The channel measurements such as height, width slope, and Manning's Roughness value had to be plugged into the program. A Manning's n value of 0.038 was used assuming that this channel would be lined with riprap (FHWA, 2011). The design flow rate was plugged into Express and the channel was modeled. Once again, the channel was oversized in order to be conservative and to accommodate larger storm events. This channel had a velocity of 3.15 fps and a water depth of 1.24 feet.

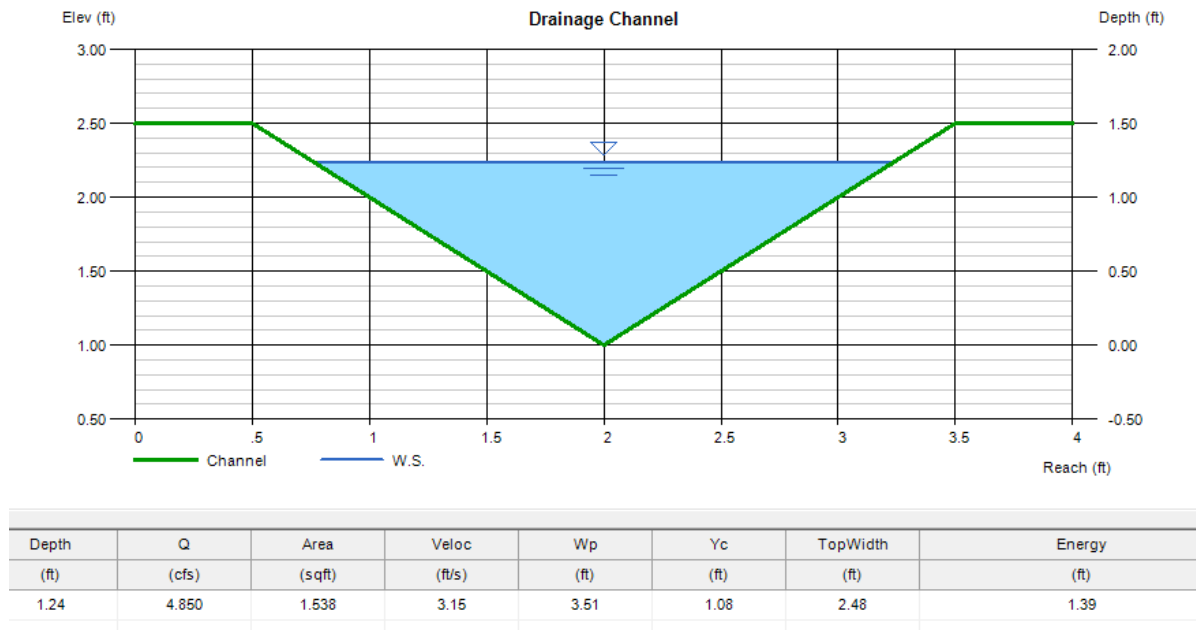


Figure 20 Drainage Channel Sizing

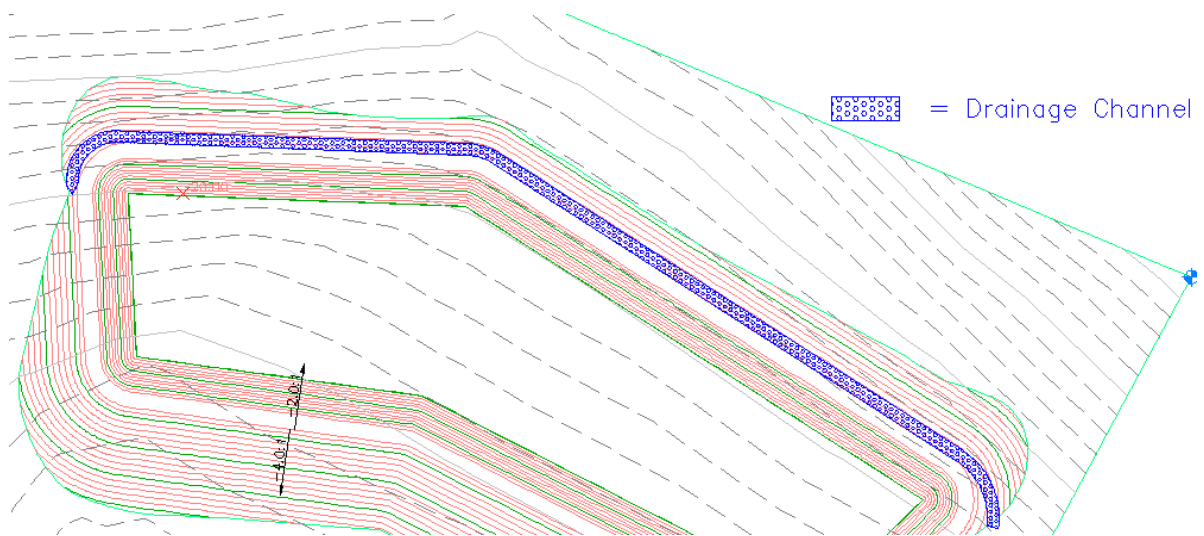


Figure 21 Final Drainage Channel Design

Erosion Control Design

The drainage channel and the earthen spillway both control water and are very susceptible to erosion. In order to prevent erosion and to break up some of the energy contained in the water, rip rap will be used in these channels. The rip rap can be sized using the formula:

$$d = 0.0126V^2 \quad (4)$$

Where:

d=Rock Diameter in Feet

V=Velocity in FPS

OR:

$$W = 0.0000568V^6 \quad (5)$$

Where:

W=Stable Rock Weight

V=Velocity in FPS

According to the NRCS engineering handbook, the minimum rock size used for bank stabilization should be a D50 rock with a diameter of 10 inches. The minimum thickness of the rock should be 2 feet thick. The NRCS also recommends that a geotextile fabric be placed underneath the rock (NRCS, 2003). From the calculations, the rock size needed was very small so a D50 rock with 10 inch diameter was chosen for both the spillway and drainage channel.

Reservoir Liner Selection

When designing a storage reservoir, the reservoir needs to either be sealed or lined in order to prevent seepage losses. This reservoir is either going to be treated with Bentonite Clay or lined with a HDPE liner. A liner is necessary in this situation because of the high amount of cracking clays in the area. This soil type would result in high seepage rates.

According to NRCS code 521C, for a water depth of 10 feet, the Clay liner must be at least 12 inches thick. The NRCS also requires that there be 0.75 lbs of bentonite per square foot of pond. The NRCS recommends that for an HDPE pond, a minimum geomembrane thickness should be 30 mil for clear water. For this design, a 40 mil liner was analyzed in order to increase the lifespan of the liner.

Cost Analysis

A cost analysis of this design was completed in order to provide the client with enough information to decide whether constructing this reservoir is feasible or not. The first step in the cost analysis was to determine the quantities of all of the items that were needed to

construct the pond. The total quantities of earthwork, excess material, rip rap and liner were determined. The types of permits required for this project were also determined. After contacting the San Luis Obispo Planning Department, it was determined that this project would need a County Grading Permit, a Storm Water Pollution Prevention Plan from the Regional Water Quality Control Board, and possibly a Minor Use Permit because of this projects location in the Coastal Zone. Through contact with the County and from permit prices on their website, costs were determined for each of these permits. Then, a unit cost analysis was done for all of the items. The earthwork costs were found using an RS Means Construction Estimator book. The earthwork cost includes all of the equipment, labor and fuel costs. The prices of the other items were determined from various other online sources.

A cost analysis was completed for both a Bentonite Clay Liner and a HDPE liner. It was determined that the reservoir with the HDPE liner would cost approximately \$221,000 and the reservoir with the clay liner would cost approximately \$125,000. The cost analysis for this project can be seen in Appendix C.

A separate cost analysis was completed for a situation in which a smaller reservoir is desired. A smaller reservoir would be much cheaper because of reduced amounts of earthwork and liner. Also, permit costs would be much lower for a smaller reservoir. A 10 acre foot reservoir with a HDPE liner would cost approximately \$118,000 and it would cost about \$70,000 with a Bentonite Clay Sealer.

RESULTS

A 20.4 acre foot reservoir was designed for Dave Alford in Los Osos, California. The reservoir will be located on the North East corner of his property. The design ended up meeting the required storage with a storage capacity of 20.4 acre-feet. This reservoir has outer banks with a 4 to 1 slope and inner banks with 2 to 1 slopes. The top of the reservoir or bench is 10 feet wide with a 2% slope. A 10 inch principal pipe spillway was designed in order to prevent overtopping of the embankments and to handle a flow of 1 CFS. The auxiliary earthen spillway was designed to be 1 foot wide by 2 feet deep and be able to handle a maximum flow capacity of 0.24 CFS. The drainage channel that diverts water around the reservoir was designed to be a triangular channel, 3 feet wide by 1.5 feet deep. Both the spillway and drainage channel will be lined with 10 inch diameter riprap.

The cost analysis was completed and should be used as a decision tool for deciding between multiple reservoir options. This cost analysis is an engineering estimate. It was determined that the reservoir with the HDPE liner would cost approximately \$221,000 and the reservoir with the clay liner would cost approximately \$125,000. It was also determined that this project would require a grading permit from the county and also a minor use permit from the county. Since this project lies within the Coastal Zone an additional permit may be necessary.

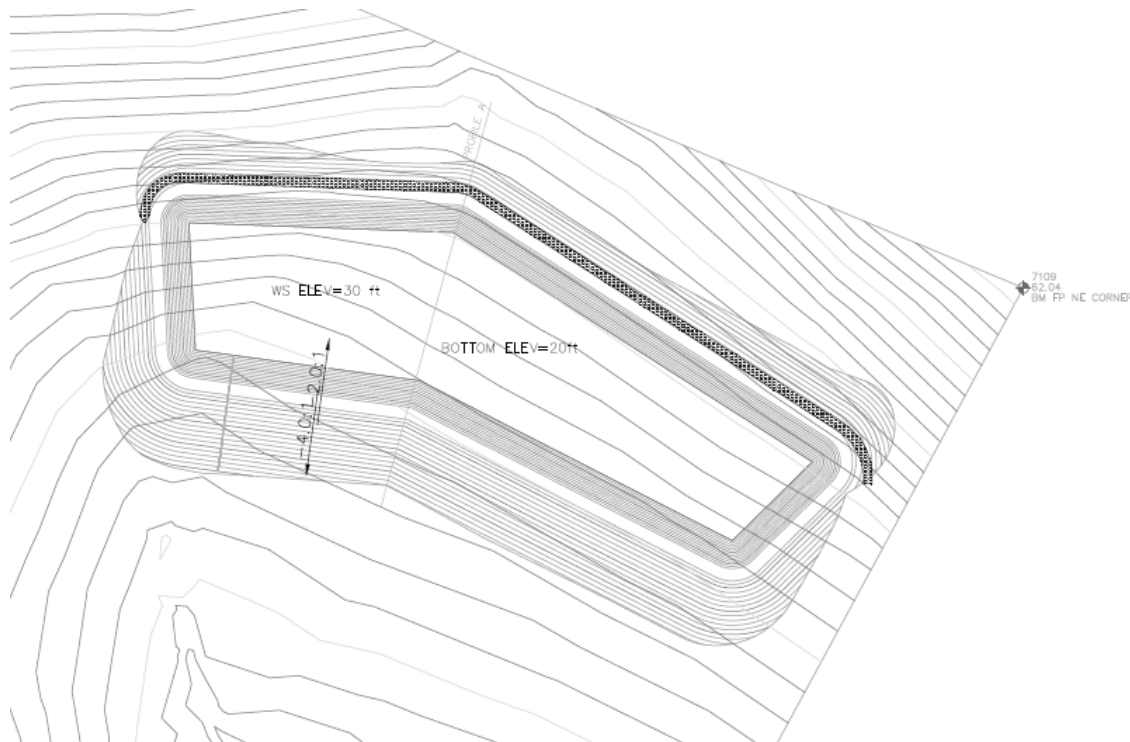


Figure 22 Final Design

DISCUSSION

This project involved completing many iterations of the design in order to reduce costs and increase constructability of the project. Many designs were created and analyzed. The initial design had many problems associated with it. First, there was a large excess of cut material which would result in thousands of dollars in hauling costs. The dam height was also too high. Although the embankment height was under the design standard of 25 feet, it was high enough to result in failure if built. The higher an embankment gets, the greater the chance for failure. Also, a tall embankment may need to be keyed into the hill which could result in additional costs for the client.

The cost estimate for this design is an estimate and should only be used to weigh the options between different liner types and different sized reservoirs. For this project, the SLO County Planners were contacted in order to determine which permits were needed. The planners supplied me with some rough costs for the permits that they thought may be necessary. In reality, the design engineer would need to sit down and meet with the County Planning department in order to determine the actual permits needed for this project and their associated costs.

From the results of the cost estimate, it seems that the best choice would be to construct the 20.4 AF reservoir with a Bentonite Clay Liner. This reservoir would cost approximately \$125,000. The reservoir with a HDPE liner would cost approximately \$221,000. While the Bentonite reservoir has a lower initial cost, the HDPE may have a longer lifespan than the Bentonite. Seepage rates may also be higher with a Bentonite liner. All of these factors need to be considered in order to determine the best option for the client.

RECOMMENDATIONS

This design went very smoothly and few problems were encountered. Eventually, calculations need to be completed in order to determine the highest allowable embankment and the steepest allowable slope. A geotechnical report should be completed prior to these calculations in order to complete a safe and accurate design. A geotech report may also determine whether or not the fill slopes need to be keyed in. If there was more time available, it would have been nice to have this information in order to do these calculations. Although a geotech report was not supplied, the reservoir was still designed to San Luis Obispo County Standards and NRCS Engineering Standards.

Another item that needs to be considered in the future is the pumping and distribution system for this reservoir. Currently, only the grading design of the reservoir was completed. In order for the reservoir to be utilized, it would need to be tied into Alford's existing 6 inch mainline. The mainline is located approximately $\frac{1}{4}$ mile from the reservoir site. Currently, the plan would be to fill the reservoir through the existing mainline and also use that mainline to distribute water. This technique could limit the availability and flexibility of water in the reservoir. The best but more expensive option for this situation would be to install another 6" pipe that would solely distribute water to the fields. This way the reservoir could be filled while simultaneously sending water to the fields. This reservoir is located in an area where the water could be gravity fed to the fields. Some sort of filter system may need to be installed downstream of the reservoir to prevent clogging of the drip tape.

The final issue with this design would be permits necessary to complete the project. This project lies in the Coastal Zone. Projects that lie within the Coastal Zone often require additional permits on top of a County Grading Permit. These additional permits are often very difficult to get approved because of the projects proximity to a creek that flows to Morro Bay estuary. It is recommended that if the client decides to go forward with this project, a meeting with the county should take place in order to determine which additional permits may be needed.

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APPENDIX A

HOW PROJECT MEETS REQUIREMENTS FOR THE BRAE MAJOR

Major Design Experience

The BRAE senior project must incorporate a major design experience. The design process usually involves the fundamental elements as outlined below.

Establishment of Objectives and Criteria. The objective of this project is to supply the client with a design and cost analysis of an Irrigation Storage Reservoir.

Synthesis and Analysis. This project included an analysis of the following: Soil types, survey data, hydrologic data and earthwork volumes.

Construction, Testing, and Evaluation. This project will have no construction or testing involved with it. The reservoir will be designed to local standards and a cost analysis will be done for the reservoir.

Incorporation of Applicable Engineering Standards. This project was designed to San Luis Obispo County and NRCS engineering standards.

Capstone Project Experience. The project will incorporate many concepts that were introduced in previous engineering classes. The project will also utilize many concepts that had to be researched further. The relevant classes include: BRAE 133, BRAE 151, BRAE 312, SS 121, ENGL 149 and BRAE 331.

Design Parameters and Constraints. This project addresses a significant number of the categories of constraints listed below.

Physical

This storage reservoir design must have an approximate storage volume of 20 Acre Feet.

Economic

This storage reservoir must be designed with reducing costs in mind.

Environmental

This project must be designed and built to conform to a Storm Water Pollution Prevention Plan.

Ergonomical

N/A

Manufacturability

This design is specific to Turri Ranch in Los Osos, California.

Health and Safety

This reservoir was designed with safety in mind. Embankment heights were minimized in order to reduce the risk of failure.

Ethical

N/A

Political

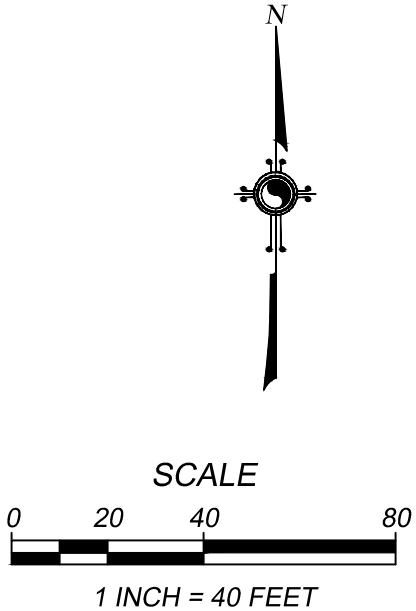
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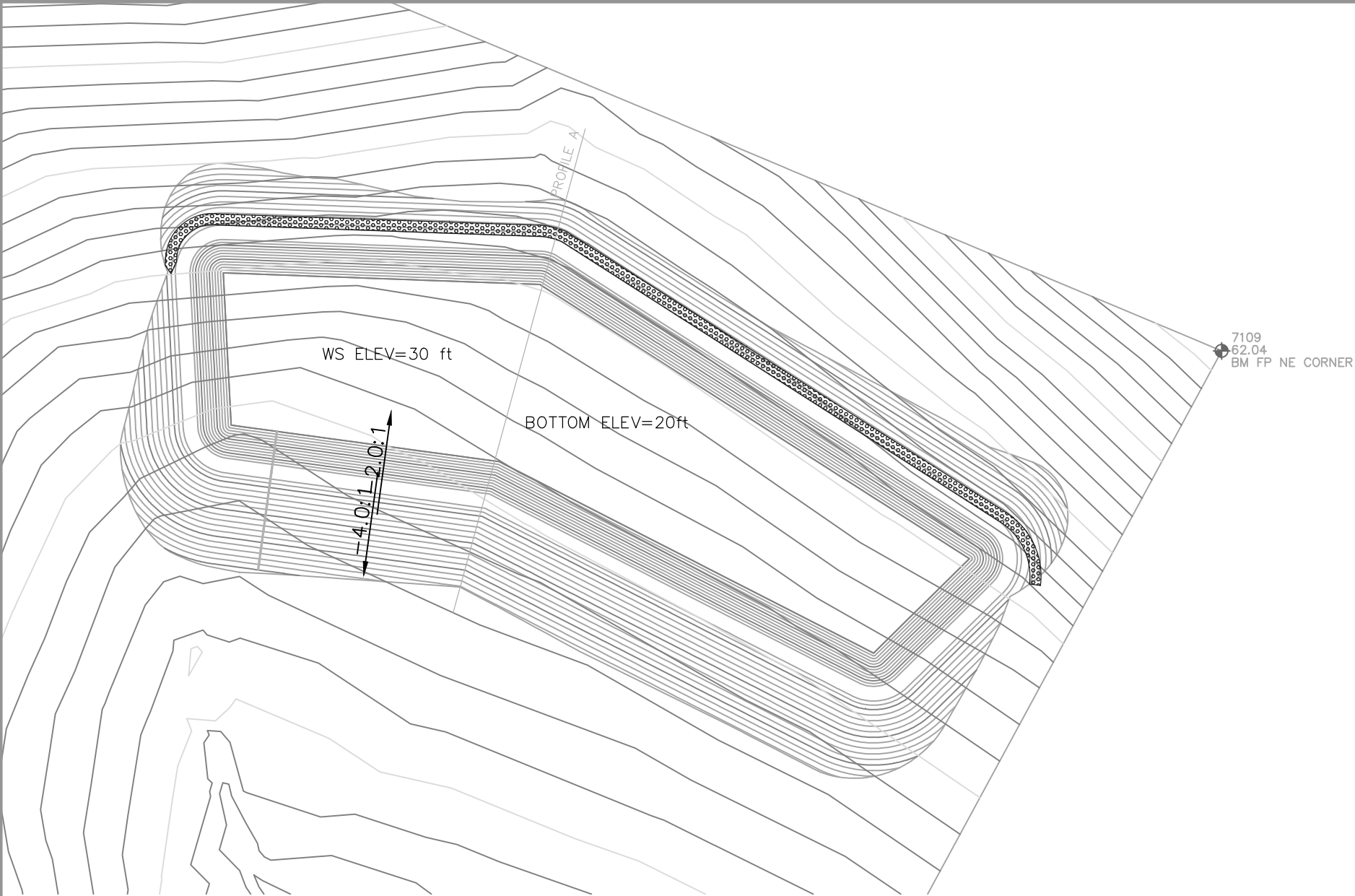
Productivity

This design will need to have enough storage in order for it to be useful to the client.

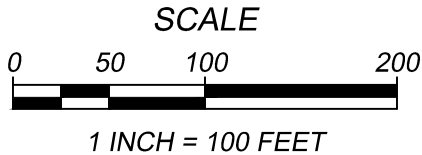
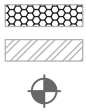
APPENDIX B

DRAWINGS



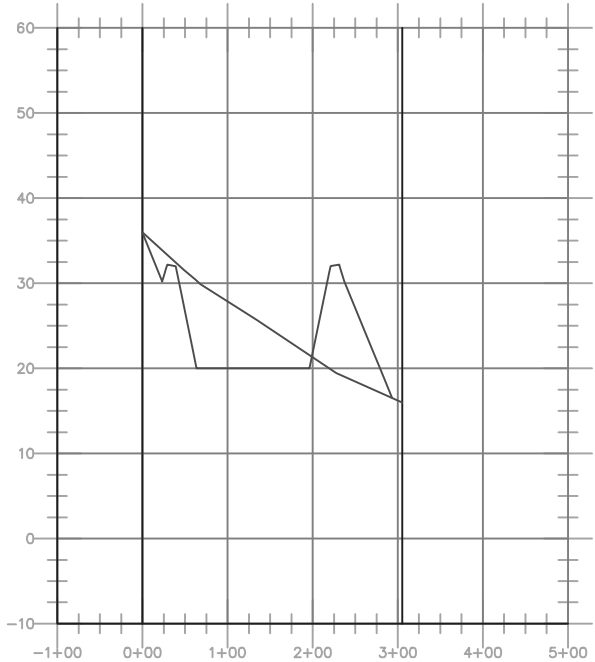


LEGEND:
DRAINAGE CHANNEL
SPILLWAY
BENCHMARK



SECTION A PROFILE

Elevation



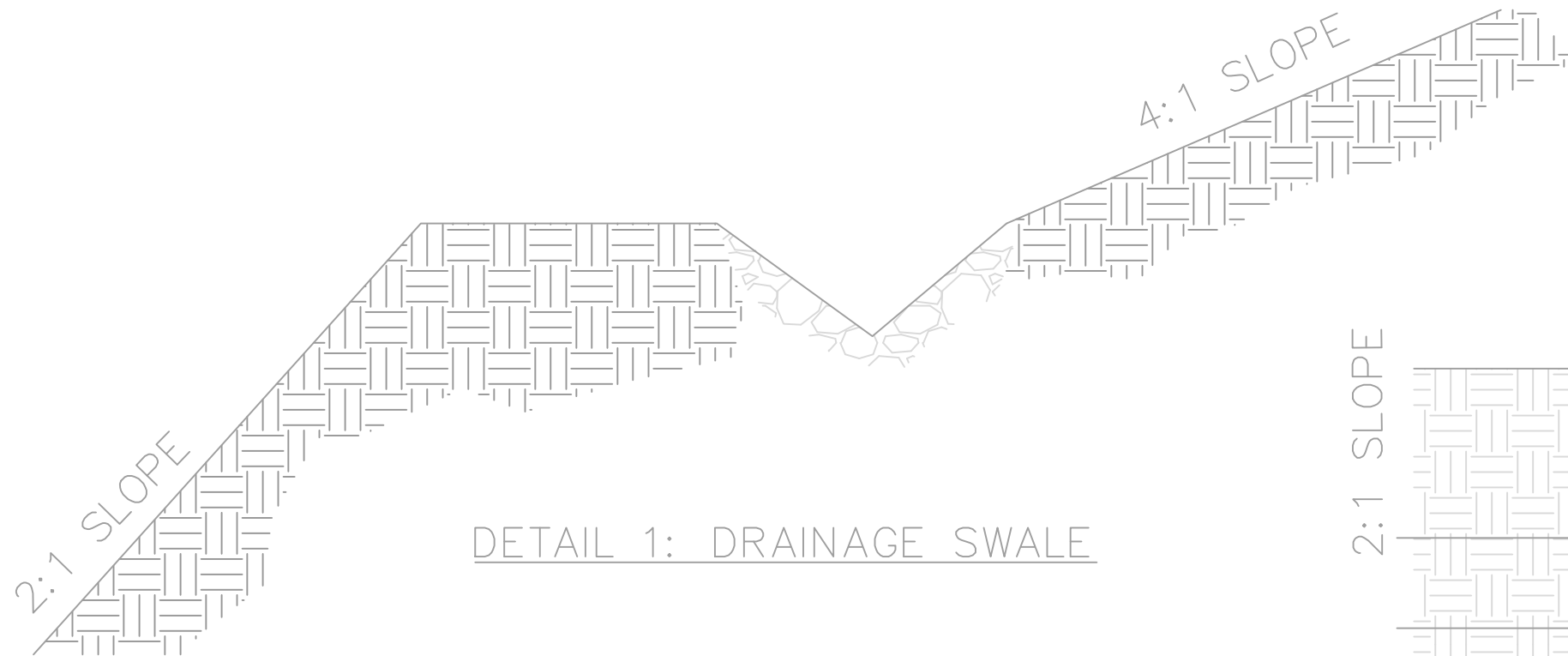
	27.86	27.855	21.30	21.297	16.23
					16.233

Storage Size =	20.4 AF
Footprint =	4.0 Acres
Interior Embankment Slope=	2 to 1
Exterior Embankment Slope=	m
Bench Width =	10 feet
Freeboard =	2 feet

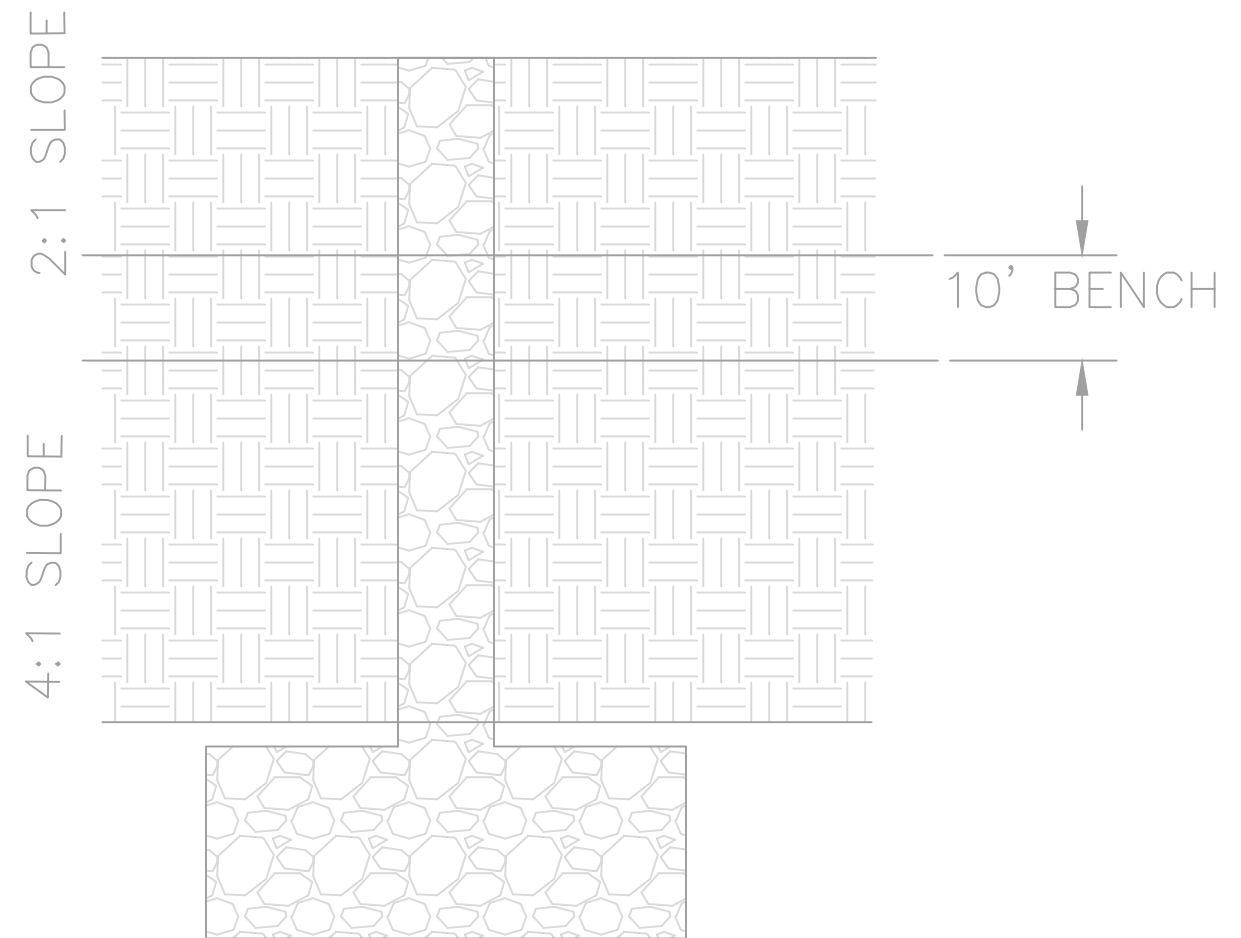
Cut	Fill	Net Fill
18000	18134	134 CY

Designed Jimmy Tomac
Drawn Jimmy Tomac
Checked _____
Approved _____

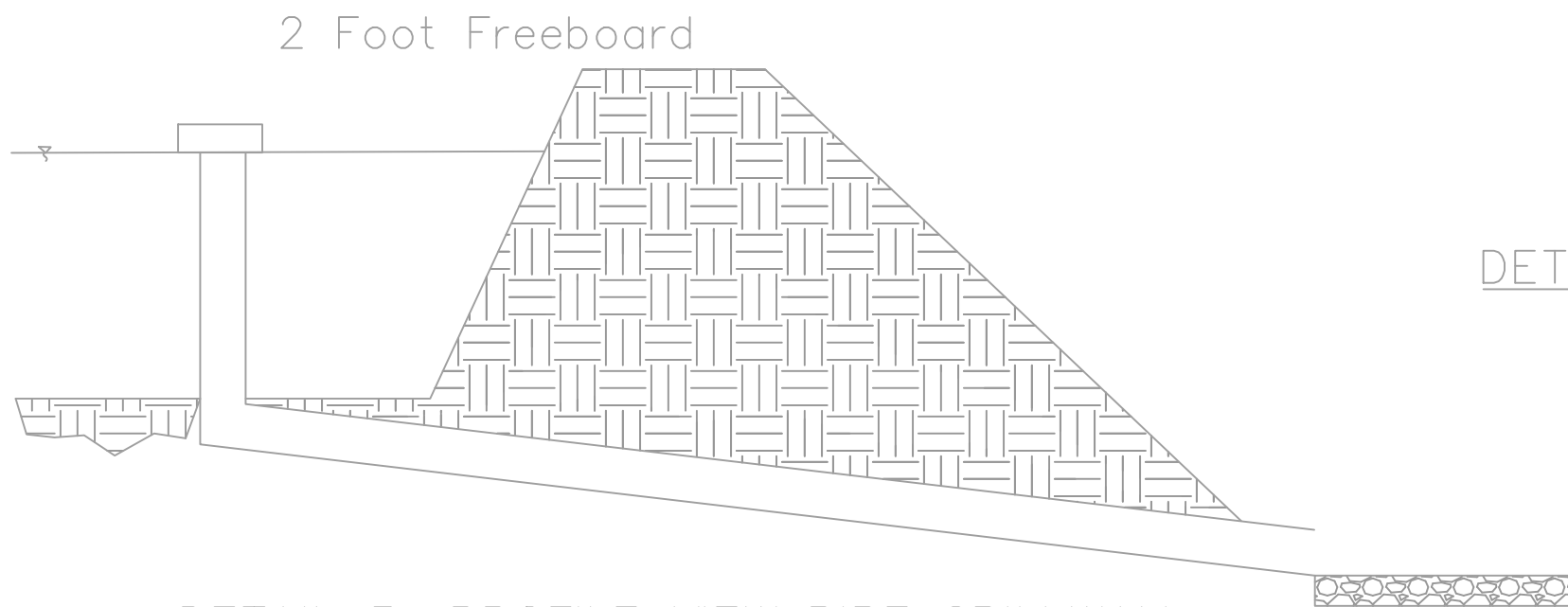
Irrigation Storage Reservoir
Los Osos, Ca



DETAIL 1: DRAINAGE SWALE



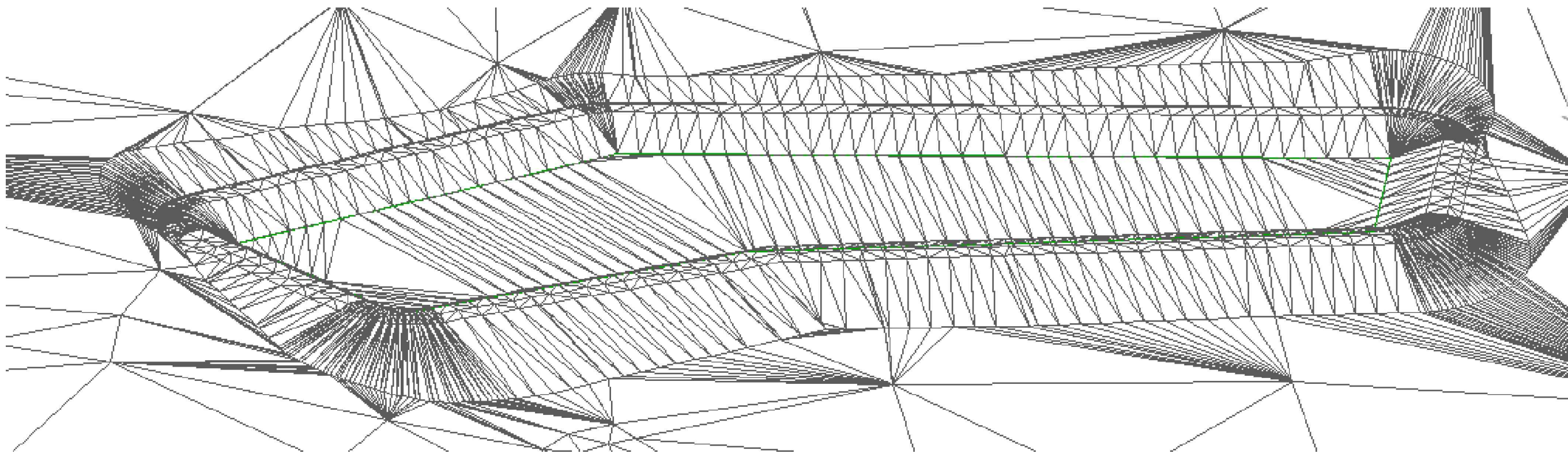
DETAIL 2: PLAN VIEW AUXILIARY SPILLWAY



DETAIL 3: PROFILE VIEW PIPE SPILLWAY

Designed	Jimmy Tomac
Drawn	Jimmy Tomac
Checked	
Approved	

Detail Sheet
Los Osos, Ca



Irrigation Storage Reservoir
Los Osos, Ca

Designed	<u>Jimmy Tomac</u>
Drawn	<u>Jimmy Tomac</u>
Checked	<u> </u>
Approved	<u> </u>

APPENDIX C
COST ESTIMATE

Cost Estimate - 20.4 AF Irrigation Storage Reservoir w/ HDPE Liner

Item No.	Item	Quantity	Unit	Cost/Unit	Cost	Assumptions:
1	Earthwork	18000	CY	\$ 4.00	\$ 72,000.00	Using RS Means Estimator
2	Material Removal	134	CY	\$ 0.45	\$ 60.30	Articulated truck with 19 CY capacity and travel distance of 2000 feet
3	Rip Rap	700	SF	\$ 1.85	\$ 1,296.30	Using RS Means Estimator
4	40 mil HDPE Liner	60000	SF	\$ 1.50	\$ 90,000.00	Using RS Means Estimator
5	Geocomposite underlay	60000	SF	\$ 0.70	\$ 42,000.00	Waterboards.ca.gov
6	Grading Permit	1	LS	\$ 10,000.00	\$ 10,000.00	Personal Contact w/ SLO County Planning (Including Plan Check and all other fees)
7	Tier I Minor Use Permit	1	LS	\$ 2,397.00	\$ 2,397.00	Minor use permit plus application fee
8	SWPPP	1	LS	\$ 3,700.00	\$ 3,700.00	Caltrans Estimating Guide for CGP
Total:					\$ 221,453.60	

Cost Estimate -20.4 AF Irrigation Storage Reservoir w/ Bentonite Clay Liner

Item No.	Item	Quantity	Unit	Cost/Unit	Cost	Assumptions:
1	Earthwork	18000	CY	\$ 4.00	\$ 72,000.00	Using RS Means Estimator
2	Material Removal	134	CY	\$ 0.45	\$ 60.30	Articulated truck with 19 CY capacity and travel distance of 2000 feet
3	Rip Rap	700	SF	\$ 1.85	\$ 1,296.30	Using RS Means Estimator
4	Bentonite Clay Sealer	45000	lb	\$ 0.13	\$ 5,850.00	NRCS Code 521A Requires 0.75 lb/sqft, Online price
5	Installing Bentonite	60000	SF	\$ 0.50	\$ 30,000.00	Assumption
6	Grading Permit	1	LS	\$ 10,000.00	\$ 10,000.00	Personal Contact w/ SLO County Planning (Including Plan Check and all other fees)
7	Tier I Minor Use Permit	1	LS	\$ 2,397.00	\$ 2,397.00	Minor use permit plus application fee
8	SWPPP	1	LS	\$ 3,700.00	\$ 3,700.00	Caltrans Estimating Guide for CGP
Total:					\$ 125,303.60	

Cost Estimate - 10 AF Irrigation Storage Reservoir w/ HDPE Liner

Item No.	Item	Quantity	Unit	Cost/Unit	Cost	Assumptions:
1	Earthwork	10000	CY	\$ 4.00	\$ 40,000.00	Using RS Means Estimator
2	Material Removal	34	CY	\$ 0.45	\$ 15.30	Articulated truck with 19 CY capacity and travel distance of 2000 feet
3	Rip Rap	700	SF	\$ 1.85	\$ 1,296.30	Using RS Means Estimator
4	40 mil HDPE Liner	30000	SF	\$ 1.50	\$ 45,000.00	Using RS Means Estimator
5	Geocomposite underlay	30000	SF	\$ 0.70	\$ 21,000.00	Waterboards.ca.gov
6	Grading Permit	1	LS	\$ 5,000.00	\$ 5,000.00	Personal Contact w/ SLO County Planning (Including Plan Check and all other fees)
7	Tier I Minor Use Permit	1	LS	\$ 2,397.00	\$ 2,397.00	Minor use permit plus application fee
8	SWPPP	1	LS	\$ 3,700.00	\$ 3,700.00	Caltrans Estimating Guide for CGP
				<u>Total:</u>	<u>\$ 118,408.60</u>	

Cost Estimate -10 AF Irrigation Storage Reservoir w/ Bentonite Clay Liner

Item No.	Item	Quantity	Unit	Cost/Unit	Cost	Assumptions:
1	Earthwork	10000	CY	\$ 4.00	\$ 40,000.00	Using RS Means Estimator
2	Material Removal	34	CY	\$ 0.45	\$ 15.30	Articulated truck with 19 CY capacity and travel distance of 2000 feet
3	Rip Rap	700	SF	\$ 1.85	\$ 1,296.30	Using RS Means Estimator
4	Bentonite Clay Sealer	22500	lb	\$ 0.13	\$ 2,925.00	NRCS Code 521A Requires 0.75 lb/sqft, Online price
5	Installing Bentonite	30000	SF	\$ 0.50	\$ 15,000.00	Assumption
6	Grading Permit	1	LS	\$ 5,000.00	\$ 5,000.00	Personal Contact w/ SLO County Planning (Including Plan Check and all other fees)
7	Tier I Minor Use Permit	1	LS	\$ 2,397.00	\$ 2,397.00	Minor use permit plus application fee
8	SWPPP	1	LS	\$ 3,700.00	\$ 3,700.00	Caltrans Estimating Guide for CGP
				<u>Total:</u>	<u>\$ 70,333.60</u>	

APPENDIX D

SPILLWAY SIZING CALCULATIONS

Spillway Sizing Calculations

For a 10 year storm with a 10 hour duration and embankment height of less than 20 feet.

$$Q = CIA$$

$$C = 1 \text{ Assuming zero infiltration}$$

$$A = 2 \text{ acres}$$

$$I = 0.5 \text{ from table H-4 SLO County Design Standards for 20" annual rainfall}$$

$$Q = 1 \text{ cfs}$$

$$Q = 448.8 \text{ gpm}$$

For a 25 year with a 10 hour duration.

$$Q = CIA$$

$$C = 1 \text{ Assuming zero infiltration}$$

$$A = 2 \text{ acres}$$

$$I = 0.62 \text{ from table H-4 SLO County Design Standards for 20" annual rainfall}$$

$$Q = 1.24 \text{ cfs}$$

$$Q = 556.512 \text{ gpm}$$

$$\text{Additional Flow to be handled by auxiliary spillway} = 0.24 \text{ CFS}$$

APPENDIX E

DRAINAGE CHANNEL SIZING

Hydrology Calculations

From Table H-2 in SLO County Standards

Rational Method Runoff Coefficients

Relief=	0.25
Infiltration=	0.08
Cover=	0.14
Surface Storage=	0.1
Runoff Coefficient, C=	0.57

Drainage area approximately: 17 acres

Intensity from Table H-4 assuming
18 to 21 inches of annual rainfall: 0.5 for 10 year, 10 hour storm event

$Q = CIA$

$Q = 4.845 \text{ cfs}$

APPENDIX F

RIPRAP SIZING

Riprap Calculations

$$d = 0.0126V^2$$

$$W = 0.0000568V^6$$

Drainage Channel

V= 2.99 fps

d= 0.11 feet

d= 1.35 inches

W= 0.040586

Choose 10 inch D50 rock (Smallest that NRCS recommends)

Spillway

V= 3.12 fps

d= 0.12 feet

d= 1.47 inches

W= 0.052393

Choose 10 inch D50 rock

APPENDIX G

WEB SOIL SURVEY



United States
Department of
Agriculture

NRCS

Natural
Resources
Conservation
Service

A product of the National
Cooperative Soil Survey,
a joint effort of the United
States Department of
Agriculture and other
Federal agencies, State
agencies including the
Agricultural Experiment
Stations, and local
participants

Custom Soil Resource Report for **San Luis Obispo County, California, Coastal Part**



May 4, 2014

Preface

Soil surveys contain information that affects land use planning in survey areas. They highlight soil limitations that affect various land uses and provide information about the properties of the soils in the survey areas. Soil surveys are designed for many different users, including farmers, ranchers, foresters, agronomists, urban planners, community officials, engineers, developers, builders, and home buyers. Also, conservationists, teachers, students, and specialists in recreation, waste disposal, and pollution control can use the surveys to help them understand, protect, or enhance the environment.

Various land use regulations of Federal, State, and local governments may impose special restrictions on land use or land treatment. Soil surveys identify soil properties that are used in making various land use or land treatment decisions. The information is intended to help the land users identify and reduce the effects of soil limitations on various land uses. The landowner or user is responsible for identifying and complying with existing laws and regulations.

Although soil survey information can be used for general farm, local, and wider area planning, onsite investigation is needed to supplement this information in some cases. Examples include soil quality assessments (<http://www.nrcs.usda.gov/wps/portal/nrcs/main/soils/health/>) and certain conservation and engineering applications. For more detailed information, contact your local USDA Service Center (<http://offices.sc.egov.usda.gov/locator/app?agency=nrcs>) or your NRCS State Soil Scientist (http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/contactus/?cid=nrcs142p2_053951).

Great differences in soil properties can occur within short distances. Some soils are seasonally wet or subject to flooding. Some are too unstable to be used as a foundation for buildings or roads. Clayey or wet soils are poorly suited to use as septic tank absorption fields. A high water table makes a soil poorly suited to basements or underground installations.

The National Cooperative Soil Survey is a joint effort of the United States Department of Agriculture and other Federal agencies, State agencies including the Agricultural Experiment Stations, and local agencies. The Natural Resources Conservation Service (NRCS) has leadership for the Federal part of the National Cooperative Soil Survey.

Information about soils is updated periodically. Updated information is available through the NRCS Web Soil Survey, the site for official soil survey information.

The U.S. Department of Agriculture (USDA) prohibits discrimination in all its programs and activities on the basis of race, color, national origin, age, disability, and where applicable, sex, marital status, familial status, parental status, religion, sexual orientation, genetic information, political beliefs, reprisal, or because all or a part of an individual's income is derived from any public assistance program. (Not all prohibited bases apply to all programs.) Persons with disabilities who require alternative means

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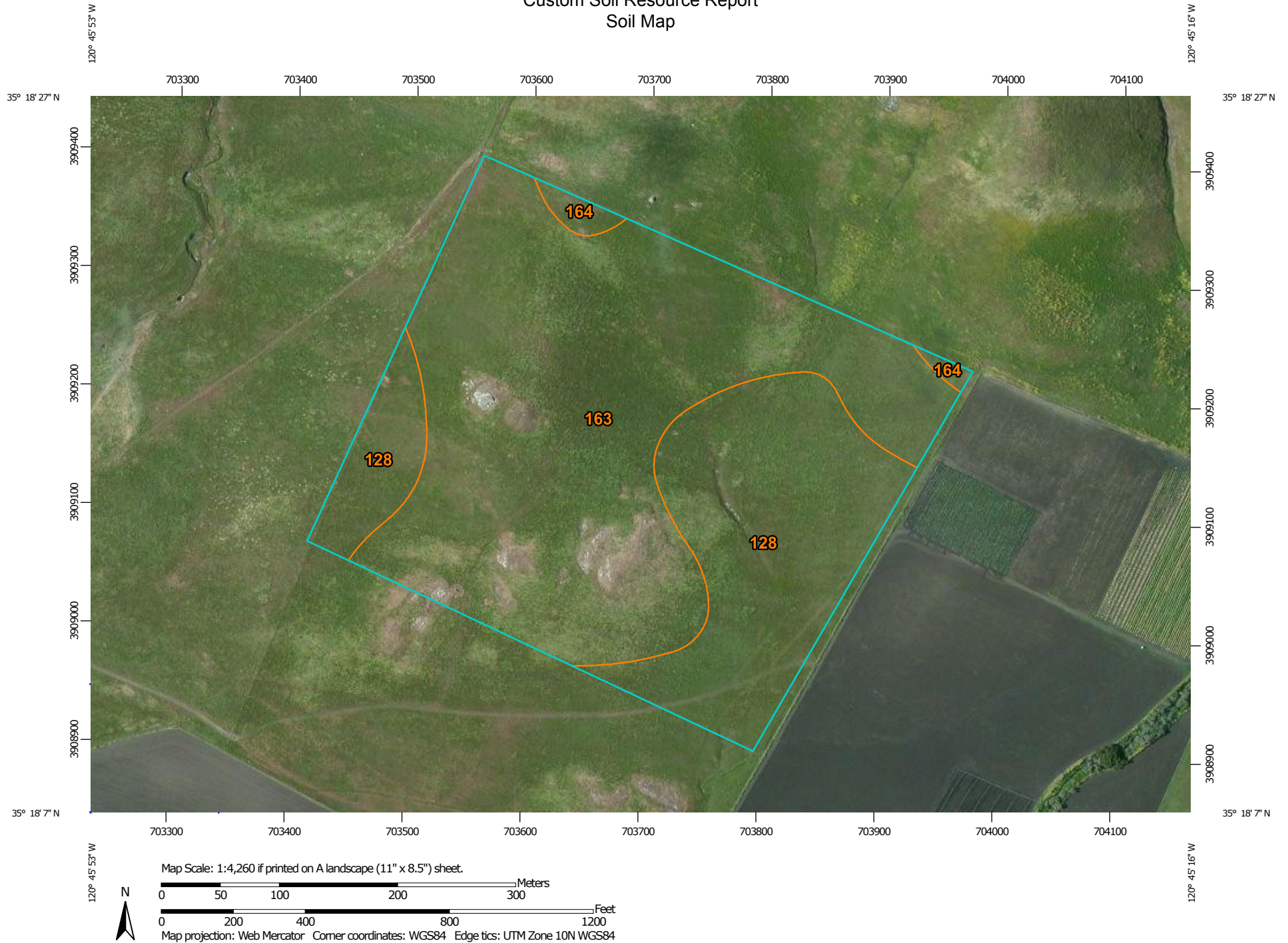
Contents

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Map Unit Legend.....	8
Map Unit Descriptions.....	8
San Luis Obispo County, California, Coastal Part.....	10
128—Cropley clay, 2 to 9 percent slopes.....	10
163—Los Osos-Diablo complex, 9 to 15 percent slopes.....	11
164—Los Osos-Diablo complex, 15 to 30 percent slopes.....	12

Soil Map

The soil map section includes the soil map for the defined area of interest, a list of soil map units on the map and extent of each map unit, and cartographic symbols displayed on the map. Also presented are various metadata about data used to produce the map, and a description of each soil map unit.

Custom Soil Resource Report Soil Map



Custom Soil Resource Report


MAP LEGEND

Area of Interest (AOI)

 Area of Interest (AOI)

Soils

 Soil Map Unit Polygons

 Soil Map Unit Lines

 Soil Map Unit Points

Special Point Features

 Blowout

 Borrow Pit

 Clay Spot


 Closed Depression

 Gravel Pit

 Gravelly Spot


 Landfill

 Lava Flow

 Marsh or swamp

 Mine or Quarry


 Miscellaneous Water


 Perennial Water

 Rock Outcrop


 Saline Spot

 Sandy Spot

 Severely Eroded Spot

 Sinkhole


 Slide or Slip

 Sodic Spot

 Spoil Area

 Stony Spot


 Very Stony Spot

 Wet Spot

 Other

 Special Line Features

Water Features

 Streams and Canals


Transportation

 Rails

 Interstate Highways

 US Routes

 Major Roads

 Local Roads

Background

 Aerial Photography

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:24,000.

Warning: Soil Map may not be valid at this scale.

Enlargement of maps beyond the scale of mapping can cause misunderstanding of the detail of mapping and accuracy of soil line placement. The maps do not show the small areas of contrasting soils that could have been shown at a more detailed scale.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL: <http://websoilsurvey.nrcs.usda.gov>
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: San Luis Obispo County, California, Coastal Part
Survey Area Data: Version 5, Dec 14, 2013

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: May 8, 2010—May 21, 2010

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Map Unit Legend

San Luis Obispo County, California, Coastal Part (CA664)			
Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
128	Cropley clay, 2 to 9 percent slopes	13.1	33.4%
163	Los Osos-Diablo complex, 9 to 15 percent slopes	25.6	65.2%
164	Los Osos-Diablo complex, 15 to 30 percent slopes	0.6	1.4%
Totals for Area of Interest		39.2	100.0%

Map Unit Descriptions

The map units delineated on the detailed soil maps in a soil survey represent the soils or miscellaneous areas in the survey area. The map unit descriptions, along with the maps, can be used to determine the composition and properties of a unit.

A map unit delineation on a soil map represents an area dominated by one or more major kinds of soil or miscellaneous areas. A map unit is identified and named according to the taxonomic classification of the dominant soils. Within a taxonomic class there are precisely defined limits for the properties of the soils. On the landscape, however, the soils are natural phenomena, and they have the characteristic variability of all natural phenomena. Thus, the range of some observed properties may extend beyond the limits defined for a taxonomic class. Areas of soils of a single taxonomic class rarely, if ever, can be mapped without including areas of other taxonomic classes. Consequently, every map unit is made up of the soils or miscellaneous areas for which it is named and some minor components that belong to taxonomic classes other than those of the major soils.

Most minor soils have properties similar to those of the dominant soil or soils in the map unit, and thus they do not affect use and management. These are called noncontrasting, or similar, components. They may or may not be mentioned in a particular map unit description. Other minor components, however, have properties and behavioral characteristics divergent enough to affect use or to require different management. These are called contrasting, or dissimilar, components. They generally are in small areas and could not be mapped separately because of the scale used. Some small areas of strongly contrasting soils or miscellaneous areas are identified by a special symbol on the maps. If included in the database for a given area, the contrasting minor components are identified in the map unit descriptions along with some characteristics of each. A few areas of minor components may not have been observed, and consequently they are not mentioned in the descriptions, especially where the pattern was so complex that it was impractical to make enough observations to identify all the soils and miscellaneous areas on the landscape.

The presence of minor components in a map unit in no way diminishes the usefulness or accuracy of the data. The objective of mapping is not to delineate pure taxonomic classes but rather to separate the landscape into landforms or landform segments that have similar use and management requirements. The delineation of such segments

Custom Soil Resource Report

on the map provides sufficient information for the development of resource plans. If intensive use of small areas is planned, however, onsite investigation is needed to define and locate the soils and miscellaneous areas.

An identifying symbol precedes the map unit name in the map unit descriptions. Each description includes general facts about the unit and gives important soil properties and qualities.

Soils that have profiles that are almost alike make up a *soil series*. Except for differences in texture of the surface layer, all the soils of a series have major horizons that are similar in composition, thickness, and arrangement.

Soils of one series can differ in texture of the surface layer, slope, stoniness, salinity, degree of erosion, and other characteristics that affect their use. On the basis of such differences, a soil series is divided into *soil phases*. Most of the areas shown on the detailed soil maps are phases of soil series. The name of a soil phase commonly indicates a feature that affects use or management. For example, Alpha silt loam, 0 to 2 percent slopes, is a phase of the Alpha series.

Some map units are made up of two or more major soils or miscellaneous areas. These map units are complexes, associations, or undifferentiated groups.

A *complex* consists of two or more soils or miscellaneous areas in such an intricate pattern or in such small areas that they cannot be shown separately on the maps. The pattern and proportion of the soils or miscellaneous areas are somewhat similar in all areas. Alpha-Beta complex, 0 to 6 percent slopes, is an example.

An *association* is made up of two or more geographically associated soils or miscellaneous areas that are shown as one unit on the maps. Because of present or anticipated uses of the map units in the survey area, it was not considered practical or necessary to map the soils or miscellaneous areas separately. The pattern and relative proportion of the soils or miscellaneous areas are somewhat similar. Alpha-Beta association, 0 to 2 percent slopes, is an example.

An *undifferentiated group* is made up of two or more soils or miscellaneous areas that could be mapped individually but are mapped as one unit because similar interpretations can be made for use and management. The pattern and proportion of the soils or miscellaneous areas in a mapped area are not uniform. An area can be made up of only one of the major soils or miscellaneous areas, or it can be made up of all of them. Alpha and Beta soils, 0 to 2 percent slopes, is an example.

Some surveys include *miscellaneous areas*. Such areas have little or no soil material and support little or no vegetation. Rock outcrop is an example.

San Luis Obispo County, California, Coastal Part

128—Cropley clay, 2 to 9 percent slopes

Map Unit Setting

Elevation: 100 to 700 feet

Mean annual precipitation: 14 to 20 inches

Mean annual air temperature: 57 degrees F

Frost-free period: 250 to 330 days

Map Unit Composition

Cropley and similar soils: 85 percent

Minor components: 6 percent

Description of Cropley

Setting

Landform: Alluvial fans, alluvial flats

Landform position (two-dimensional): Footslope, toeslope

Landform position (three-dimensional): Tread

Down-slope shape: Linear

Across-slope shape: Linear

Parent material: Alluvium derived from sedimentary rock

Properties and qualities

Slope: 2 to 9 percent

Depth to restrictive feature: More than 80 inches

Drainage class: Moderately well drained

Capacity of the most limiting layer to transmit water (Ksat): Moderately low to moderately high (0.06 to 0.20 in/hr)

Depth to water table: More than 80 inches

Frequency of flooding: None

Frequency of ponding: None

Calcium carbonate, maximum content: 5 percent

Maximum salinity: Nonsaline (0.0 to 2.0 mmhos/cm)

Available water capacity: Moderate (about 8.0 inches)

Interpretive groups

Farmland classification: Prime farmland if irrigated

Land capability classification (irrigated): 2s

Land capability (nonirrigated): 3s

Hydrologic Soil Group: C

Ecological site: CLAYEY (R014XD001CA)

Typical profile

0 to 36 inches: Clay

36 to 60 inches: Silty clay loam

Minor Components

Los osos, loam

Percent of map unit: 3 percent

Salinas, silty clay loam

Percent of map unit: 3 percent

163—Los Osos-Diablo complex, 9 to 15 percent slopes

Map Unit Setting

Elevation: 200 to 1,500 feet

Mean annual precipitation: 15 to 25 inches

Mean annual air temperature: 59 degrees F

Frost-free period: 275 to 350 days

Map Unit Composition

Los osos and similar soils: 35 percent

Diablo and similar soils: 30 percent

Minor components: 35 percent

Description of Los Osos

Setting

Landform: Hills, ridges

Landform position (two-dimensional): Backslope, summit

Landform position (three-dimensional): Mountaintop, crest, side slope

Down-slope shape: Convex

Across-slope shape: Convex, linear

Parent material: Residuum weathered from sandstone and shale

Properties and qualities

Slope: 9 to 15 percent

Depth to restrictive feature: 20 to 40 inches to paralithic bedrock

Drainage class: Well drained

Capacity of the most limiting layer to transmit water (Ksat): Very low (0.00 in/hr)

Depth to water table: More than 80 inches

Frequency of flooding: None

Frequency of ponding: None

Available water capacity: Low (about 5.6 inches)

Interpretive groups

Farmland classification: Not prime farmland

Land capability classification (irrigated): 4e

Land capability (nonirrigated): 4e

Hydrologic Soil Group: D

Ecological site: LOAMY CLAYPAN (R015XD049CA)

Typical profile

0 to 14 inches: Loam

14 to 32 inches: Clay

32 to 39 inches: Sandy loam

39 to 59 inches: Weathered bedrock

Description of Diablo

Setting

Landform: Hills, mountains

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Landform position (two-dimensional): Backslope, summit

Landform position (three-dimensional): Mountainflank, crest, side slope

Down-slope shape: Convex, linear

Across-slope shape: Convex

Parent material: Residuum weathered from mudstone, sandstone and/or shale

Properties and qualities

Slope: 9 to 15 percent

Depth to restrictive feature: 45 to 58 inches to paralithic bedrock

Drainage class: Well drained

Capacity of the most limiting layer to transmit water (Ksat): Very low (0.00 in/hr)

Depth to water table: More than 80 inches

Frequency of flooding: None

Frequency of ponding: None

Calcium carbonate, maximum content: 2 percent

Maximum salinity: Nonsaline (0.0 to 2.0 mmhos/cm)

Available water capacity: High (about 9.8 inches)

Interpretive groups

Farmland classification: Not prime farmland

Land capability classification (irrigated): 3e

Land capability (nonirrigated): 3e

Hydrologic Soil Group: C

Ecological site: CLAYEY (R015XD001CA)

Typical profile

0 to 38 inches: Clay

38 to 58 inches: Clay

58 to 62 inches: Weathered bedrock

Minor Components

Cibo, clay

Percent of map unit: 9 percent

Lodo, clay loam

Percent of map unit: 9 percent

Millsap, loam

Percent of map unit: 9 percent

Unnamed

Percent of map unit: 8 percent

164—Los Osos-Diablo complex, 15 to 30 percent slopes

Map Unit Setting

Elevation: 200 to 3,000 feet

Mean annual precipitation: 15 to 28 inches

Mean annual air temperature: 59 degrees F

Frost-free period: 275 to 350 days

Map Unit Composition

Los osos and similar soils: 35 percent

Diablo and similar soils: 30 percent

Minor components: 35 percent

Description of Los Osos

Setting

Landform: Hills, mountains

Landform position (two-dimensional): Backslope, summit

Landform position (three-dimensional): Mountainflank, crest, side slope

Down-slope shape: Convex, linear

Across-slope shape: Convex

Parent material: Residuum weathered from sandstone and shale

Properties and qualities

Slope: 15 to 30 percent

Depth to restrictive feature: 20 to 40 inches to paralithic bedrock

Drainage class: Well drained

Capacity of the most limiting layer to transmit water (Ksat): Very low (0.00 in/hr)

Depth to water table: More than 80 inches

Frequency of flooding: None

Frequency of ponding: None

Available water capacity: Low (about 5.6 inches)

Interpretive groups

Farmland classification: Not prime farmland

Land capability classification (irrigated): 6e

Land capability (nonirrigated): 6e

Hydrologic Soil Group: D

Ecological site: LOAMY CLAYPAN (R015XD049CA)

Typical profile

0 to 14 inches: Loam

14 to 32 inches: Clay

32 to 39 inches: Sandy loam

39 to 59 inches: Weathered bedrock

Description of Diablo

Setting

Landform: Mountains, hills

Landform position (two-dimensional): Backslope, summit

Landform position (three-dimensional): Mountainflank, crest, side slope

Down-slope shape: Linear, convex

Across-slope shape: Convex

Parent material: Residuum weathered from mudstone, sandstone and/or shale

Properties and qualities

Slope: 15 to 30 percent

Depth to restrictive feature: 45 to 58 inches to paralithic bedrock

Drainage class: Well drained

Capacity of the most limiting layer to transmit water (Ksat): Very low (0.00 in/hr)

Depth to water table: More than 80 inches

Frequency of flooding: None

Frequency of ponding: None

Custom Soil Resource Report

Calcium carbonate, maximum content: 2 percent
Maximum salinity: Nonsaline (0.0 to 2.0 mmhos/cm)
Available water capacity: High (about 9.8 inches)

Interpretive groups

Farmland classification: Not prime farmland
Land capability classification (irrigated): 4e
Land capability (nonirrigated): 4e
Hydrologic Soil Group: C
Ecological site: CLAYEY (R015XD001CA)

Typical profile

0 to 38 inches: Clay
38 to 58 inches: Clay
58 to 62 inches: Weathered bedrock

Minor Components

Lompico, loam

Percent of map unit: 5 percent

Rock outcrop

Percent of map unit: 5 percent

Gazos, clay loam

Percent of map unit: 5 percent

Lodo, clay loam

Percent of map unit: 5 percent

Mcmullin, loam

Percent of map unit: 5 percent

Unnamed

Percent of map unit: 5 percent

Cibo, clay

Percent of map unit: 5 percent