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North of the Delta
Offstream Storage Investigation

Progress Report

Appendix P: Sites and Colusa Reservoir Projects, Construction Materials Sampling and Testing

August 2000

Integrated
Storage
Investigations

CALFED
BAY-DELTA
PROGRAM

North of the Delta
Offstream Storage Investigation

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Report

Appendix P:

Sites and Colusa Reservoir Projects, Construction Materials Sampling and Testing

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Introduction

This report presents the results of ongoing and previous investigations of construction materials for the proposed Sites Dam, Golden Gate Dam, and associated saddle dams for Sites Reservoir, and to a lesser extent the proposed Hunters Dam and Logan Dam for Colusa Reservoir. This investigation is part of the analysis of several alternative dam/reservoir sites being proposed for offstream storage as part of the North of the Delta Offstream Storage Investigation. The investigation focused on the materials required for earthfill and rockfill structures. Issues addressed include the geology of the site vicinity; occurrence of impervious materials in terrace deposits; suitability of sandstone for random fill, aggregate, and riprap; and occurrence of appropriate aggregate sources within a reasonable haul distance.

The proposed Sites Dam and Golden Gate Dam would impound a reservoir (Sites Reservoir) with a capacity of 1.8 million acre-feet and the addition of Hunters Dam and Logan Dam would result in a reservoir (Colusa Reservoir) with a capacity of 3.0 million acre-feet. The location of the proposed reservoirs is shown on Figure 1.

Previous Work

Sites and Golden Gate dam sites were previously investigated by the United States Bureau of Reclamation in 1969 and 1980. The Hunters and Logan dam sites have only had reconnaissance-level work performed by the Department of Water Resources. Several studies have investigated the availability and suitability of construction materials for these dam sites.

A report entitled *Engineering Geology Appendix-Part II* (USBR, Project Development Division, Geology Branch, 1969) provides geologic data for USBR's use in preparing cost estimates for proposed canals, dams, and a pumping-generating plant. That report includes: 1) descriptions of the sandstone units and terrace deposits proposed for use as aggregate, riprap, random fill, and impervious material; 2) maps of the units and locations of trench and auger sites; 3) results of laboratory testing; and 4) estimates of the volume of construction materials located near each proposed dam site. The USBR investigation included mapping proposed impervious materials from terrace deposits in the valley upstream from each site and delineating proposed rock quarrying at the old Sites Quarry and on the southeast ridge at Golden Gate. Summary results of the USBR testing and analysis, and volume estimates are presented in Table 1 and areas investigated are shown on Figure 2.

USBR conducted additional studies on saddle dams and rock testing and published a report *Construction Materials Report for Sites Dam, Golden Gate Dam, and Dike Sites* (USBR, Mid-Pacific Region Geology Branch) in 1980. The results of this testing are presented in Table 2. DWR reviewed data from previous work and submitted a Memorandum Report entitled "Colusa Reservoir Complex" in 1978. This report gives preliminary cost estimates for dam and spillway construction for the proposed Colusa Reservoir.

Table 1. Construction Materials Summary from USBR (1969)

Designation (Figure 1)	Stripping Depth (ft)	Avg. Thickness (ft)	Depth to Water (ft)	Oversize	Volume of Material (cu. yd.)	Lithology	Source	Liquid Limits	Plasticity Indices	Compacted Density lb/ft ³
IMPERVIOUS SOURCES										
Area 1	0.5-1	10.5	8.0-15.7	0-5% 5"max.	9,800,000	Lean clay (CL), minor clayey gravelly sand (SC)	Quaternary Terrace Deposits	35.8-36.3	16.4-17.5	106.4-107.8
Area 1a		9	9.0-11.7	None encountered	2,800,000	Lean clay (CL)	Quaternary Terrace Deposits			
Area 2	0.5-1	9	5.5-30	None encountered	13,700,000	Lean clay (CL), minor Sandy Clay (CL-ML) and silty Sand (SM-GM)	Quaternary Terrace Deposits and Alluvium	30.2-34.9	10.9-16.2	105.7-110.0
Area 2a		10.7	6.5-30	None encountered	4,400,000	Same	Same			
Area 3	0.5	8	Not in Alluvium	None encountered	2,400,000	Lean Clay (CL)	Quaternary Alluvium	35.5-40.7	15.7-21.6	106.8
Area 4	0.5	7.5	7.5-10.5	Trace 5" max.	2,900,000	Lean Clay (CL), minor Clayey Gravelly Sand (SC)	Quaternary Terrace Deposits	NA	NA	NA
RIPRAP - ROCKFILL, BEDDING										
Area 5	5.0-10	250	Not in quarry area	NA	15,000,000	Lightly weathered to fresh cemented sandstone	Venado Formation			
					2,000,000	Slopewash, moderately weathered sandstone, siltstone, claystone, thin bedded sandstone				
Area 6	5.0-10	250		NA	6,000,000	Lightly weathered to fresh cemented sandstone	Venado Formation			
					800,000	Slopewash, moderately weathered sandstone, siltstone, claystone, thin bedded sandstone				
Area 7	5.0-10	250	Not in quarry area	NA	11,900,000	Lightly weathered to fresh cemented sandstone	Venado Formation			
					1,800,000	Slopewash, moderately weathered sandstone, siltstone, claystone, thin bedded sandstone				

Proposed Sites And Colusa Reservoirs

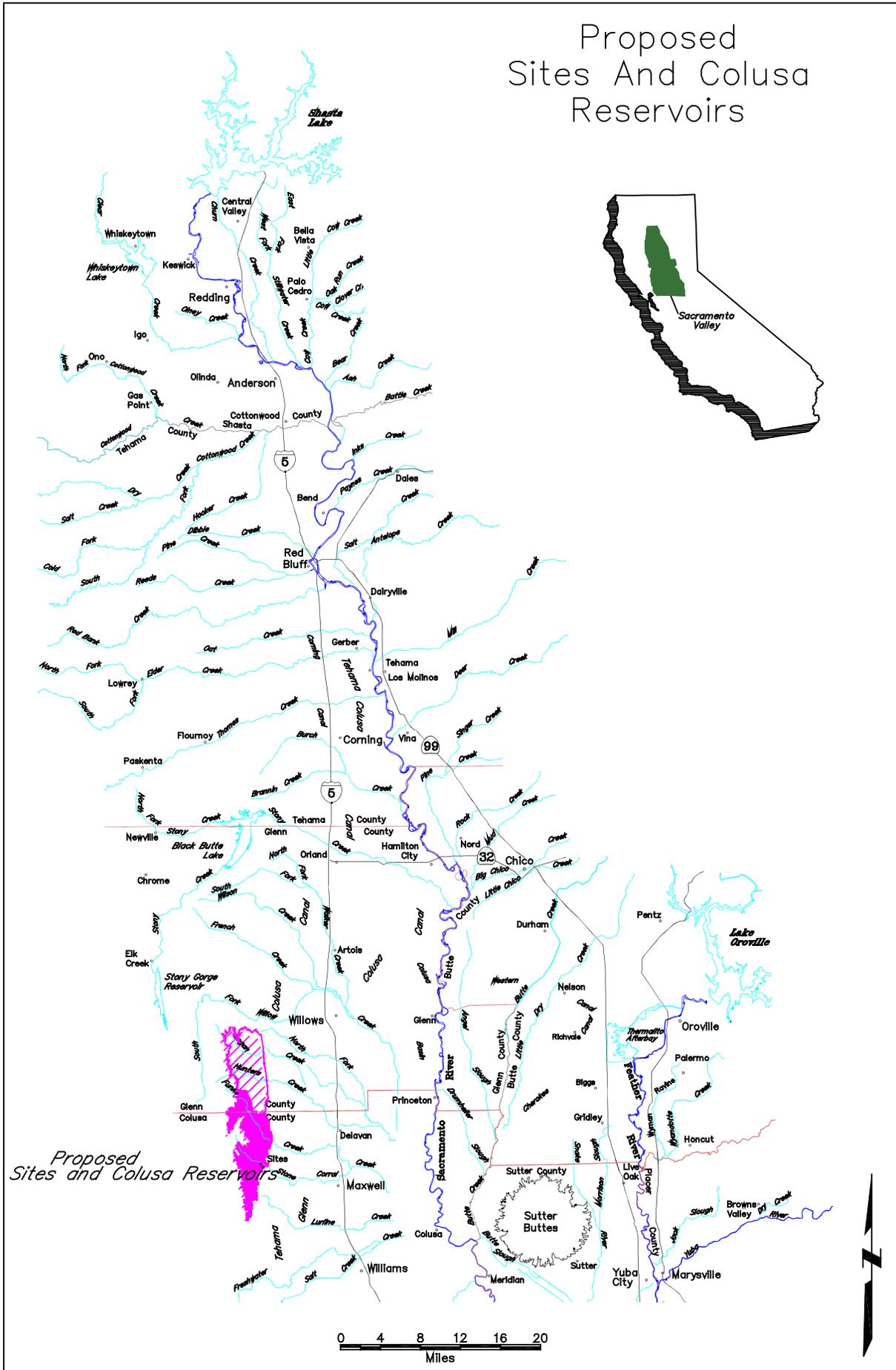


Figure 1. Sites and Colusa Reservoirs Regional Location Map

Table 2. Historic Rock Test Data from USBR, 1969 and 1980

Date of Sampling	Sample	Specific Gravity S.S.D.	Absorption	Abrasion (L.A. Rattler)	Soundness (Mg SO4)	Wetting and Drying	Notes
1962	#1 Weathered Sandstone	2.44	3.4%	45% loss	Relatively High Loss	"after 15 cycles in fresh & salt water a noticeable softening and loosening of surface grains is evident"	Samples from old Sites Quarry tested by the U.S. Army Corps of Engineers for use as riprap on Sacramento River levees.
	#2 Fresh Sandstone	2.58	3.3%	39.1% loss	92.50%	"Slight surface sloughing"	
	#3 Fresh Sandstone	2.5	3.5%	34.1% loss	15% loss	Not Reported	
1972	Poorer of The Brown #1	2.42	6.1%				Sample of 500 pounds of rock from Sites Quarry 1 mile east of Sites, California. Samples analyzed by USACE
	#2	2.37	7.0%				
	#3	2.41	6.3%				
	Better of The Brown #1	2.44	4.8%	39%		"Better of the Brown" specimens flaked during the entire test.	
	#2	2.44	4.8%				
	#3	2.41	4.1%				
	Blue #1	2.43	4.1%	26%		"blue" rock parted along joints during the twelfth cycle. Minor flaking occurred to all "Blue" specimens throughout the test	
	#2	2.5	2.9%				
	#3	2.45	3.1%				
1974	1.5"-.75"	2.47	4.4%	18.9%/100			Sample of quarry rock from Sites Quarry South tested by Bureau of Reclamation Denver, CO. Sample from lower in quarry
	.75"-.375"	2.47	5.1%	52.6%/500			
	.375"-#4	2.45	6.0%				

Scope of Study

This study assessed the availability of adequate construction materials for the proposed earthfill dams. This was accomplished by reviewing the available data, performing field investigations, sampling, laboratory testing, and compiling the data into this report. The types of construction materials required for dam construction include impervious materials, rock and random fill, filter and drain material, and concrete aggregate. The geologic materials investigated include terrace deposits, sandstone, and commercial or developable sand and gravel deposits.

This study concentrated on refining the volume estimates and boundaries of the terrace and sandstone deposits previously investigated, performing additional laboratory testing of the materials to ensure conformance to the necessary standards, and evaluating additional rock sources for Golden Gate Dam.

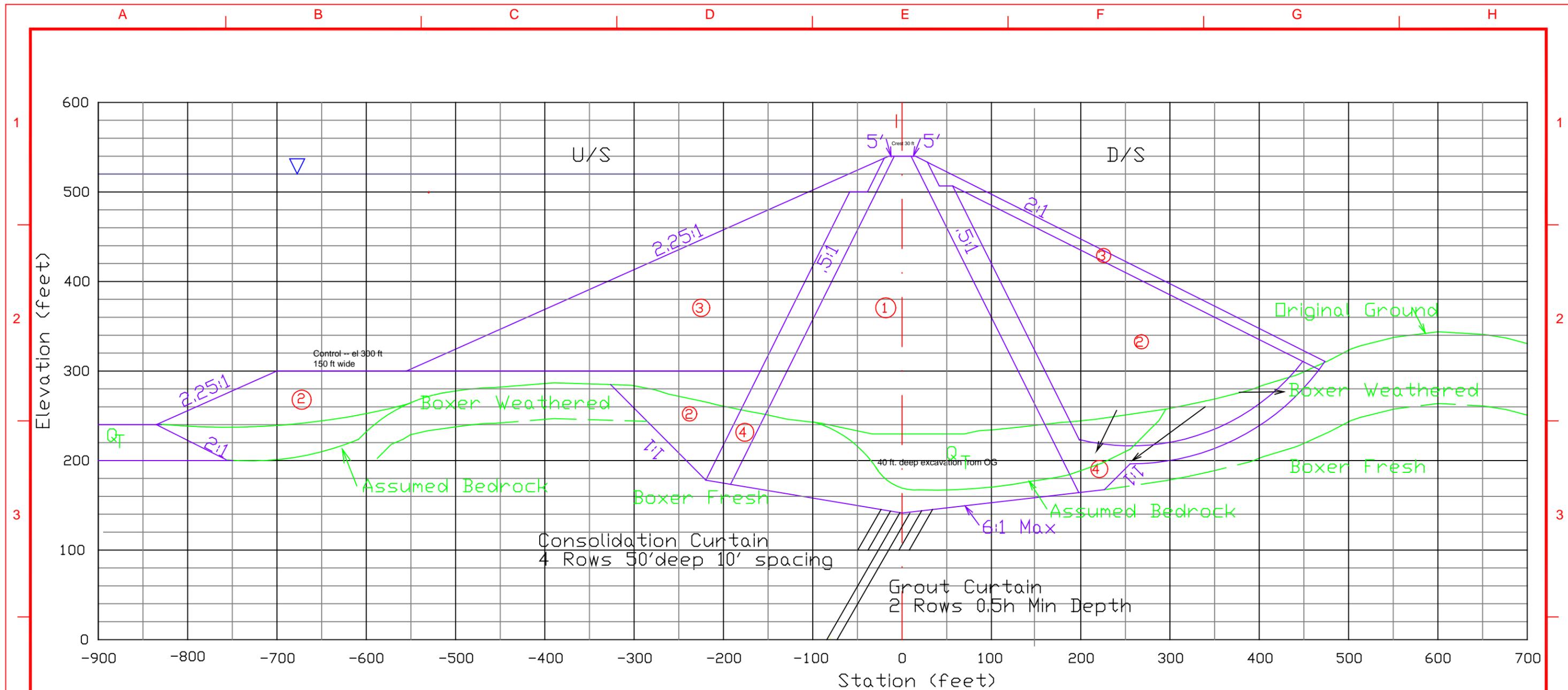
Previous investigations for the Logan and Hunter dam sites were limited, so this study provides preliminary mapping of source areas, field reconnaissance, and limited laboratory testing to confirm the suitability of the material.

Aggregate studies were done because it was questionable that available on-site materials were of satisfactory quality. These studies included an assessment of gravel mining operations currently operating, historic operations, and other potential sources.

Field investigations for impervious materials included measuring the thicknesses of terrace deposits exposed in stream channels, confirming terrace deposit boundaries, confirming depths and soil types using test pits, and sampling test pits for materials testing. The field investigation of rock sources included mapping sandstone units, measuring the thickness of sandstone and mudstone interbeds, and assessing the amount of weathering.

Material Requirements

Based on preliminary studies, each of the earthfill structures contains four zones of material. Current design studies for the Golden Gate Dam and Sites Dam (see Offstream Storage Investigation Progress Report) calls for impervious core, random rock, shell zone, and filter and drain (see Figure 3). The most recent design for Hunters Dam, Logan Dam, and the saddle dams (Northern District 1999) includes impervious core, random fill, filter, and drain. The estimated volume requirements of these materials for each dam are presented in Tables 3, 4 (Northern District), and 5 (DOE). Recommended laboratory tests and preferred material properties of each construction material zone are presented in Tables 6 and 7.



- Zone 1 Core
- Zone 2 Random
- Zone 3 Shell and Rockfill
- Zone 4 Filter and Drain

Source: DOE June 1999

GOLDEN GATE DAM
 CROSS-SECTIONS
 CURVED ALIGNMENT
 DOWNSTREAM LOCATION
 6/10/99

			DRAWING SCALES		GEOLOGY REPORT No.		GEOLOGIC MAPPING AND/OR LOGGING BY:		STATE OF CALIFORNIA THE RESOURCES AGENCY DEPARTMENT OF WATER RESOURCES DIVISION OF PLANNING & LOCAL ASSISTANCE NORTHERN DISTRICT GEOLOGY SECTION		Figure 3 Typical Golden Gate Dam Cross-section (Looking Northerly)		RELEASE DATE:
					CONSTRUCTION SPEC. No.						SHEET No.		
					GEOLOGY DRAWING No.		DRAWING PREPARED BY: DATE: 06/30/99				PLATE		
REV.	DATE	DESCRIPTION											

Table 3. Sites Reservoir Required Construction Materials Quantities (in cubic yards)

	Sites Dam	Golden Gate Dam	Saddle Dam 1	Saddle Dam 2	Saddle Dam 3	Saddle Dam 4
Excavation	731,941	1,556,621	72,267	146,240	1,398,431	33,208
Stripping:	641,211	1,337,940	61,139	124,033	1,189,128	28,180
Cutoff Trench:	90,730	218,682	11,128	22,206	209,302	5,028
Fill	4,745,177	11,276,180	130,854	208,429	4,665,816	39,607
Zone 1 - Impervious Core:	970,723	2,551,828	42,514	67,472	1,199,498	39,607
Zone 2 - Random:	3,217,399	7,374,246	43,586	57,352	2,586,890	
Drains:	289,090	700,653	21,908	40,927	430,503	
Transition:	267,965	649,453	22,846	42,678	448,925	
	Saddle Dam 5	Saddle Dam 6	Saddle Dam 7	Saddle Dam 8	Saddle Dam 9	Sites Reservoir Total
Excavation	615,743	123,126	45,835	901,482	56,051	5,700,000
Stripping:	508,002	102,697	37,415	761,967	45,640	4,800,000
Cutoff Trench:	107,741	20,429	8,420	139,514	10,411	800,000
Fill	1,843,907	248,596	62,992	2,118,213	78,578	25,400,000
Zone 1 - Impervious Core:	533,357	78,421	26,800	606,304	31,816	6,100,000
Zone 2 - Random:	863,684	88,732	4,131	939,140	6,454	15,200,000
Drains:	218,752	39,869	15,695	280,385	19,732	2,100,000
Transition:	228,113	41,575	16,366	292,383	20,576	2,000,000

Sites Reservoir Summary--Earthfill Dam with a crest of 540 feet

Water Surface Elevation=520 feet

Capacity=1,800 taf

Source: DWR Northern District, 1999

Table 4. Colusa Reservoir Required Construction Material Quantities (in cubic yards)

	Sites Dam	Golden Gate Dam	Colusa Saddle Dam 1	Prohibition Dam	Owens Dam	Hunters Dam	Colusa Saddle Dam 2
Excavation	731,941	1,556,621	104,753	2,549,068	2,856,598	5,247,086	727,234
Stripping:	641,211	1,337,940	92,262	2,349,513	2,672,818	4,841,493	687,076
Cutoff Trench:	90,730	218,682	12,491	199,556	183,780	405,593	40,158
Fill	4,745,177	11,276,180	214,004	11,333,934	11,679,831	24,766,228	2,283,531
Zone 1 - Impervious Core:	970,723	2,551,828	51,152	1,630,785	1,577,253	3,341,283	173,205
Zone 2 - Random:	3,217,399	7,374,246	113,600	8,494,550	8,991,069	18,965,043	1,949,320
Drains:	289,090	700,653	24,110	627,216	576,830	1,276,594	78,817
Transition:	267,965	649,453	25,142	581,383	534,679	1,183,308	82,189

	Logan Dam	Colusa Saddle Dam 3	Colusa Saddle Dam 4	Colusa Saddle Dam 5	Colusa Saddle Dam 6	Colusa Saddle Dam 7	Colusa Reservoir Total
Excavation	5,345,029	490,790	145,981	378,760	21,859	604,022	20,800,000
Stripping:	4,736,104	409,376	120,798	319,774	17,989	502,162	18,700,000
Cutoff Trench:	608,925	81,414	25,182	58,986	3,870	101,860	2,000,000
Fill	30,573,933	1,579,686	351,868	1,306,592	26,760	1,575,250	101,700,000
Zone 1 - Impervious Core:	5,043,213	423,807	109,428	334,297	26,760	469,192	16,700,000
Zone 2 - Random:	21,808,058	815,237	139,572	723,316	0	687,248	73,300,000
Drains:	1,931,918	166,753	50,357	121,882	0	205,018	6,000,000
Transition:	1,790,744	173,888	52,511	127,097	0	213,791	5,700,000

Colusa Reservoir Summary-Earthfill Crest--540 feet
 Water Surface Elevation=520 feet capacity=3,100 taf

**Table 5. Updated Dam Volumes for the Revised Section for Sites and Golden Gate Dams
(in cubic yards)**

	Sites Dam	Golden Gate Dam*	Description
Core (Zone 1)	1,068,600	3,459,600	Impervious core from reservoir site deposits consisting predominately of lean clay (CL), with some sandy clay and clayey sand (SC)
Random (Zone 2)	1,085,400	2,796,900	Random rock consisting of moderately to slightly weathered rock up to 30-inch maximum particle size, with fines not to exceed 35% minus No. 4.
Total Shell (Zone 3)	1,180,500	2,866,300	Shell zone of fresh rock up to 30-inch maximum particle size, with fines not to exceed 20% minus No. 4.
Filter/Drain (Zone 4)	501,400	1,467,300	Filter and drain consisting of fresh rock processed to various sizes, generally 1-1/2-inch maximum particle size (3% limit on minus No. 200 sieve material).
	3,835,900	10,590,100	

*Volumes for Golden Gate Dam are for the downstream curved alignment.

Source: DWR, DOE, 1999 (refer to Figure 3)

Table 6. Construction Materials Tests and Preferred Properties

	Atterberg Limits		Gradation	Organic Content	Compaction	Permeability	Triaxial Shear	Specific Gravity	Classification
	Liquid Limit	Plastic Limit							
ASTM	D 4318	D 4318	D 422	D 2974	D 1557	D 5084	D 4767	D 854	D 422
Impervious Core (Zone 1)	36%	17%	Less than 15-35% sand		107pcf@18 %moisture	1 X 10-6cm/sec	F30		Predominately lean clay (CL), with some sandy clay and clayey sand (SC).
	Unconfined Compression	Wet Dry test	Abrasion-L.A. Rattler	Soundness	Specific Gravity and Absorption	Bulk Density	Splitting Tensile Strength	Bulk Density	Classification
ASTM	D 3148	D 5313	C 131/535	C 88	C 127/128	C 29	C 496	C 29	C 136
Random Rock Zone 2	Not Specified	Not Specified	Not Specified	Not Specified	Not Specified	138	Not Specified	Not Specified	Moderately to slightly weathered rock up to 30-inch maximum particle size, with fines not to exceed 35% minus No. 4.
Shell and Rockfill Zone 3	Not Specified	Not Specified	Not Specified	Not Specified	Not Specified	145	Not Specified	Not Specified	Fresh rock up to 30-inch maximum particle size, with fines not to exceed 20% minus No. 4.
Filter and transition Zone 4	Not Specified	Not Specified	Not Specified	Not Specified	Not Specified	125	Not Specified	Not Specified	Fresh rock processed to various sizes, generally 1 1/2-inch maximum particle size (3% limit on minus No. 200 sieve material).

Table 7. Preferred Embankment Material Properties and Description

Material	Shear Strength Parameters				Dens			Description
	Effective		Total		Dry	Moist	Saturated	
	F'	c" (psf)	F	c (psf)				
Impervious Core (Zone 1)	34	0	16	800	107	111	131	Predominately lean clay (CL), with some sandy clay and clayey sand (SC).
Random Rock (Zone 2)	39	0	Not Specified	Not Specified	138	Not Specified	Not Specified	Moderately to slightly weathered rock up to 30-inch maximum particle size, with fines not to exceed 35% minus No. 4.
Shell and Rockfill (Zone 3)	42	0	Not Specified	Not Specified	145	Not Specified	Not Specified	Fresh rock up to 30-inch maximum particle size, with fines not to exceed 20% minus No. 4.
Filter and Drain (Zone 4)	42	0	Not Specified	Not Specified	125	Not Specified	Not Specified	Fresh rock processed to various sizes, generally 1-1/2-inch maximum particle size (3% limit on minus No. 200 sieve material).

Source: Bill Verigin Memo, February 1999