APPENDIX A
COVER SOIL VOLUME ESTIMATE

TETRA TECH

Project HPS, Parcel B, Site IR-07 and IR-18		Component/System Cover Soil Volume Estimate	
Prepared by: AJ	Date 4-15-09	Checked by: SF	Date 4-28-09

Site Area:

IR-07	407,856 ft^2
IR-18	210,725 ft^2
Total	618,581 ft^2 14.2 acres

Soil fill volumes by potential radionuclide and non-radionuclide areas

Potential Radiologically Impacted Area

473,785 ft^2

3 feet of cover soil

1,421,355 ft^3

52,642 bank cubic yards (bcy)

~ 53,000 bcy

Non-radiologically Impacted Area

144,796 ft^2

2 feet of cover soil

289,592 ft^3

10,726 bcy

~11,000 bcy

Total Estimated Cover Soil Requirement (in-place after compaction)

63,367 bcy

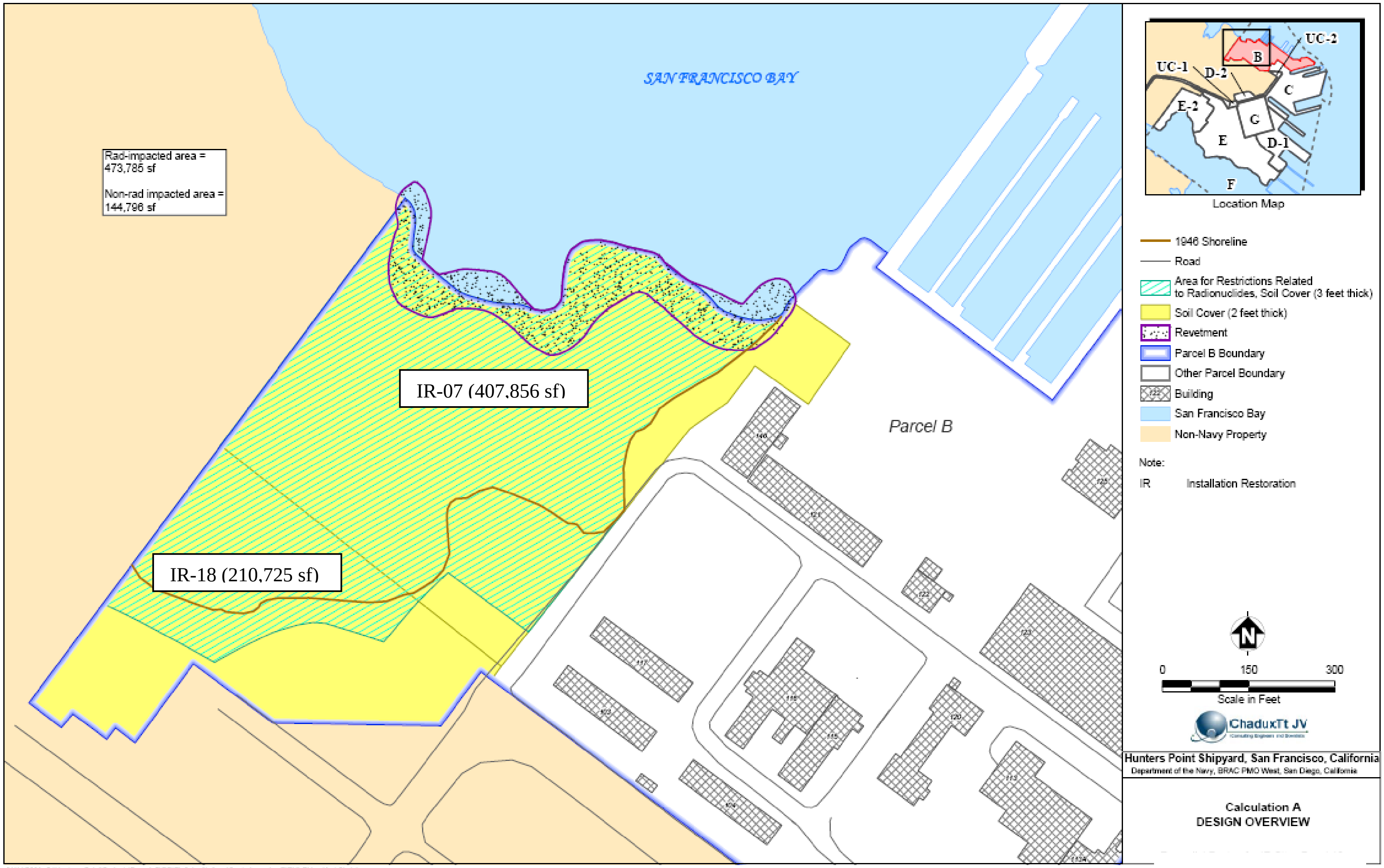
~64,000 bcy

TETRA TECH

Project		Component/System	
HPS, Parcel B, Site IR-07 and IR-18		Cover Soil Volume Estimate	
Prepared by: AJ	Date 4-15-09	Checked by: SF	Date 4-28-09

These calculations assume compacted soil. A bulking factor of 1.3 or 30% will be used to calculate the loose cubic yardage (lcy) when appropriate – for instance in calculations for acquisition and transport.

Refer to the figures of the DBR and the design drawings for the areas referenced in the calculation.



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APPENDIX B
SOIL LOSS DUE TO EROSION CALCULATION

TETRA TECH

Project HPS, Parcel B, Site IR-07 and IR-18		Component/System Soil Loss due to Erosion Calculation	
Prepared by: AJ	Date 4-15-09	Checked by: SF	Date 4-28-09

Each year a certain amount of soil will be lost from the site as a result of erosion from wind and runoff. Koerner and Daniel suggest that most designers follow the general guideline of 2.45 tons/acre/year (ASCE 1997) in Final Covers for Solid Waste Landfills and Abandoned Dumps, published by the American Society of Civil Engineers (ASCE) in 1997. A more conservative value of 2 tons/acre/year was suggested at an ASCE conference, Design of Waste Containment Liner and Final Closure Systems, presented in 1997. These estimates reflect a balance between topsoil generation and topsoil loss from erosion – or what can be considered the sustainable loss. Erosion losses at or less than these rates would be offset by topsoil formed resulting in an estimated net gain of soil.

The following pages present the wind and runoff erosion calculations to determine whether the designed cover will meet these minimum erosion requirements. A summary of the results are in the following table.

Soil Loss Estimates

	Soil Loss Due to Runoff	**Soil Loss Due to Wind**	**Total Annual Soil Loss**	**Total Annual Soil Loss**
No Established Vegetation	**2.4 tons/acre/year**	**2.9 tons/acre/year**	**5.3 tons/acre/year**	**0.034 inches/year**
With Established Vegetation	**0.07 tons/acre/year**	**0 tons/acre/year**	**0.07 tons/acre/year**	**0.00045 inches/year**

TETRA TECH

Project		Component/System	
HPS, Parcel B, Site IR-07 and IR-18		Soil Loss due to Erosion Calculation	
Prepared by: AJ	Date 4-15-09	Checked by: SF	Date 4-28-09

The total annual soil loss was calculated for two scenarios; soil loss before vegetation is established and soil loss after vegetation is established. Before vegetation is established soil loss is greater than the accepted 2 tons/acre/year. To ensure soil loss is minimized in the short period before vegetation is established, the soil cover will need to have erosion controls.

The erosion caused by runoff was determined using the widely accepted Revised Universal Soil Loss Equation (RUSLE). The erosion due to wind was determined using the United States Department of Agriculture Wind Erosion Forces in the United States and Their Use in Predicting Soil Loss; Agriculture Handbook 346. All calculations and explanations for the runoff and wind erosion are contained in the following calculations:

Project HPS, Parcel B, Site IR-07 and IR-18		Component/System Soil Loss due to Water Erosion Calculation	
Prepared by: AJ	Date	Checked by: SF	Date

Revised Universal Soil Loss Equation (calculation of soil loss from runoff)

A = R*k*(Ls)*C*P

From: Water Quality, Vladimir Novotny/ Harvey Olem

Where:

A= annual soil loss due to runoff (tons/acre/year)
R= rainfall energy factor (tons/acre)
k= soil erodibility factor
Ls= length-slope factor
C= cropping management factor
P= erosion control factor

R (tons/acre) from Isoerodent map of California (EPA 2001).

at Hunters Point Shipyard, San Francisco, CA
R= 40 tons/acre

k from Table 5.3 (Novotny and Olem)

Value based on conservative k value from an estimate of suitable cover soil based on performance and availability. A Fine Sandy Loam was chosen with an organic content less than 0.5%
k= 0.35

Ls from Figure 5.14 (Novotny and Olem)

Refer to the Figure 4 of design basis report for determination of the length. The prevailing wind direction for HPS is west.

Slope	Length	**LS Factor**
S_1 = 2%	L_1 = 250m	**0.38**

C from Table A1

Source: Reference not available. Downloaded from: http://ecn.www.ecn.purdue.edu/~sedspec/sedspec/doc/usleapp.doc

Prior to vegetation being established the percent ground cover value of 0 is used.

C = 0.45

Project HPS, Parcel B, Site IR-07 and IR-18		Component/System Soil Loss due to Water Erosion Calculation	
Prepared by: AJ	Date	Checked by: SF	Date

After vegetation is established a conservative percent ground cover of 80% is used; when vegetation is fully established the percent ground cover should be in the 95 to 100% range.

C = 0.013

P if no erosion control practice is in place (conservative)

P= 1

Determine Soil Loss with a bare ground surface

R	k	LS	C	P =	A
40 *	0.35 *	0.38 *	0.45	*1 =	**2.39 tons/acre/year**

Determine Soil Loss with a vegetative cover

R	k	LS	C	P =	A
40 *	0.35 *	0.38 *	0.013	*1 =	**0.07 tons/acre/yea**

Project HPS, Parcel B, Site IR-07 and IR-18		Component/System Soil Loss due to Water Erosion Calculation	
Prepared by: AJ	Date	Checked by: SF	Date

Calculation of Soil Loss from Wind

Reference: USDA. Handbook 346 - Wind Erosion Forces in the United States and their Use in Predicting Soil Loss.

$$E = f\,(I, K, C, L, V)$$

Where:

I = Soil Erodibility Factor
K = Soil Ridge Roughness Factor
C = Local Average Monthly or Annual Climate Factor
L = Median Unsheltered Field Length along Direction of Prevailing Wind
V = Equivalent Vegetative Cover in Pounds per Acre

Let $E_1 = I$

Assuming at least 25% of the soil retained on number 20 sieve (0.84 mm), from Table 3, the soil erodibility factor is 86. The table recommends for a fully crusted soil surface, values are approximately shown. A conservative approach is to use values shown, knowing that the site is represented neither by a fully crusted soil surface nor by tilled or disturbed soil. Therefore:

$$\mathbf{E_1 = 86\ tons/acre * 1/3 = 29\ tons/acre}$$

Let $E_2 = E_1 K$

From Figure 7, conservatively assume the field is flat and smooth, soil ridge roughness K_r = 0 and therefore K' = 1.0. Therefore:

$$\mathbf{E_2 = 29\ tons/acre * 1.0 = 29\ tons/acre.}$$ Let $E_3 = E_2 C$

Where C = 10 percent per month per the C factor isoline map developed by the NRCS in 1987

$$\mathbf{E_3 = 29\ tons/acre * 0.1/year = 2.9\ tons/acre\ year}$$

Let $E_4 = f\,(E_2, E_3, L)$

Since the longest unobstructed distance L is greater than 10,000 feet, using Figure 23 we get $E_4 = E_3$. Therefore:

$$\mathbf{E_4\ 2.9\ tons/acre\ year}$$

Project		Component/System	
HPS, Parcel B, Site IR-07 and IR-18		Soil Loss due to Water Erosion Calculation	
Prepared by: AJ	Date	Checked by: SF	Date

Prior to vegetation being established the weight of vegetation covering the soil is zero. On figure 24 the lines for E_4 = 2.9 tons per acre per year and $V = 0$ lbs per acre intersect at a value of:

$$\mathbf{E_5 = 2.9\ tons/acre/year}$$

V is determined from the actual weight of vegetation and the type of stand of grass. Assuming a percent coverage of established vegetation at Hunters Point Shipyard of 90 percent and using the expert opinion of a seed specialist from Pacific Coast Seeds, the small grain mass coverage is taken as 3,570 lbs of residue per acre from the table entitled "Percent ground cover to pounds residue." Vegetation at Hunters Point Shipyard was conservatively approximated as a combination of 45 percent blue grama, 30 percent buffalo grass, and 25 percent ungrazed western wheatgrass from NRCS guidance shown on the table titled "Properly grazed range grass mixtures." From this table, an equivalent flat small grain residue value of 3,570 corresponds to 900 lbs per acre of the chosen vegetation mixture. From Figure 9 then, a weight ***R'*** of 900 lbs per acre on smooth ground yields that V =7,600 lbs per acre.

On Figure 24, the lines for E_4 = 2.9 tons per acre per year and V = 7,600 lbs per acre do not intersect, therefore the soil loss due to wind with an established vegetative cover is negligible.

$$\mathbf{E_5 = 0\ tons/acre/year}$$

TETRA TECH

Project HPS, Parcel B, Site IR-07 and IR-18		Component/System Soil Loss due to Water Erosion Calculation	
Prepared by: AJ	Date	Checked by: SF	Date

Assumptions:

1. Soil Dry Density = 85 lb/ft3 (typical of a loam to sandy loam soil, consistent with the expected site conditions)
2. Soil loss of 1.02 Tons/Acre/Year (based on soil loss calculations above)

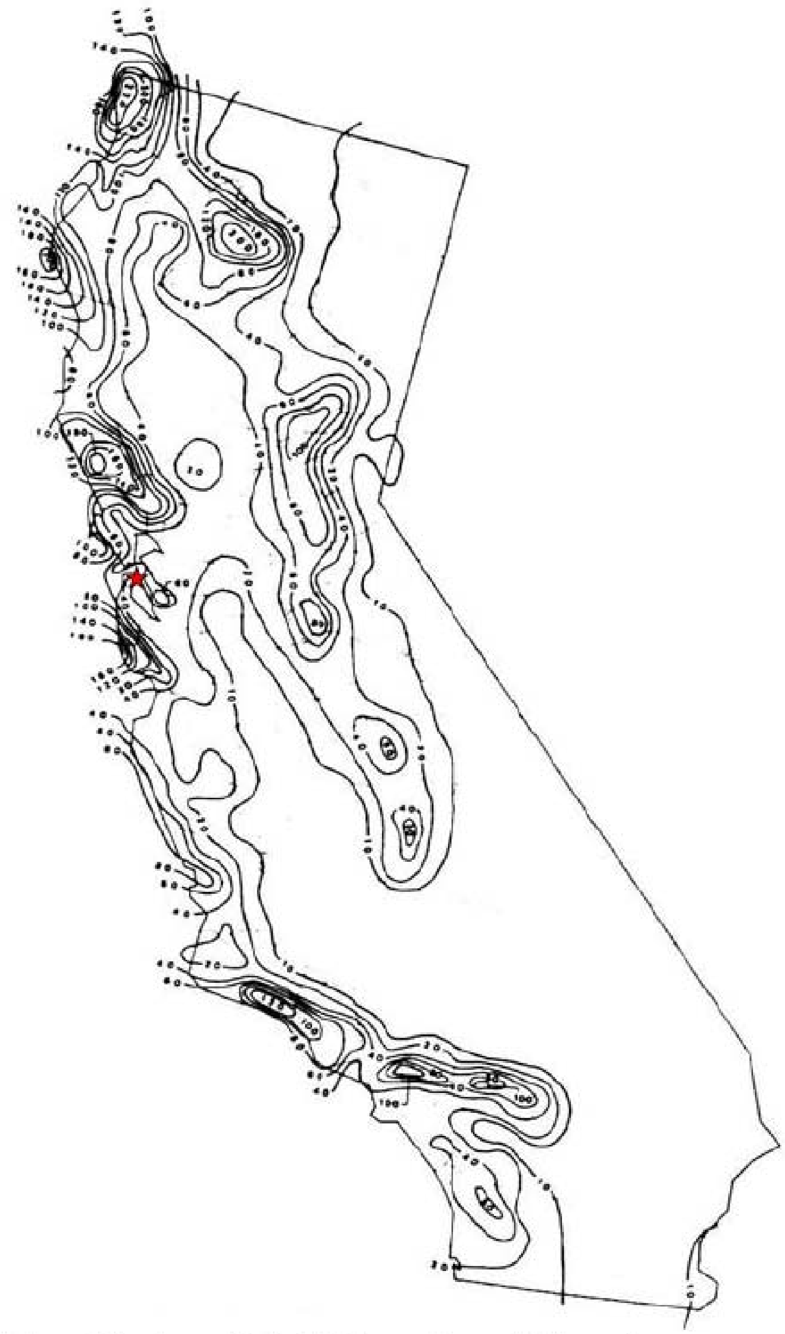
Depth of soil loss per year with no established vegetative cover

5.3 Tons/Acre/Year * 2,000 lb/Ton	=	10,600 lb/Acre/Year
10,600 lb/Acre/Year * 1Acre/43,560 ft2	=	0.243 lb/ft2/Year
0.243 lb/ft2/Year / 85 lb/ft3	=	0.0029 ft/Year
	=	**0.034 in/Year**

Depth of soil loss per year with an established vegetative cover

0.07 Tons/Acre/Year * 2,000 lb/Ton	=	140 lb/Acre/Year
140 lb/Acre/Year * 1Acre/43,560 ft2	=	0.0032 lb/ft2/Year
0.0032 lb/ft2/Year / 85 lb/ft3	=	0.000038 ft/Year
	=	**0.00045 in/Year**

B-1: WATER EROSION REFERENCES



Values of the Annual Rainfall Energy Factor (R) in tons/acre

Isoerodent Map of California
Source: California EPA (2001)

TABLE 5.3 Magnitude of Soil Erodibility Factor, K

Technical Class	*K* for Organic Matter Content (%) 0.5	2	4
Sand	0.05	0.03	0.02
Fine sand	0.16	0.14	0.10
Very fine sand	0.42	0.36	0.28
Loamy sand	0.12	0.10	0.16
Loamy fine sand	0.24	0.20	0.16
Loamy very fine sand	0.44	0.38	0.30
Sandy loam	0.27	0.24	0.19
Fine sandy loam	0.35	0.30	0.24
Very fine sandy loam	0.47	0.41	0.35
Silt loam	0.48	0.42	0.33
Silt	0.60	0.52	0.42
Sandy clay loam	0.27	0.25	0.21
Clay loam	0.28	0.25	0.21
Silty clay loam	0.37	0.32	0.26
Sandy clay	0.14	0.13	0.12
Silty clay	0.25	0.23	0.19
Clay		0.13–0.2	

Source: After Steward et al. (1975)

Note: The values shown are the estimated averages of broad ranges of specific soil values. When a texture is near the borderline of two texture classes, use the average of the two *K* values.

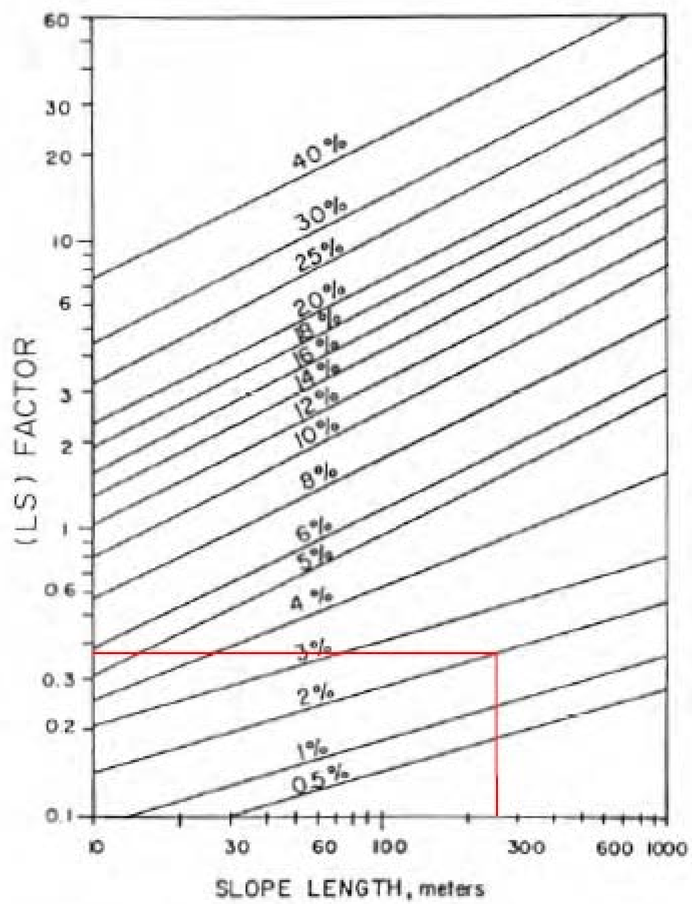


FIGURE 5.14. Slope-length factor (LS) for different slopes. (From Stewart et al., 1975.)

The cover and management factor, C, is the ratio of soil loss from land use under specified conditions to that from continuously fallow and tilled land. The USLE was developed for use on agricultural fields. It is adapted to use in nonagricultural conditions by appropriate selection of the C factor. This is often done by relating the land use conditions to some agricultural situation. For example, a firing range with a grass cover might be assumed to be similar to a pasture. Annual values of C for various cover and management conditions applicable to Army land uses are presented in Table A1.

Table A1 Cover management, "C" factors for permanent pasture, rangeland, and idle land.

Vegetal Canopy			Cover That Contacts the Surface					
					Percent Ground Cover			
Type and Height of Raised Canopy[2]	Canopy Covers[3] %	Type[4]	0	20	40	60	80	95-100
No appreciable canopy		G	.45	.20	.10	.042	.013	.003
		W	.45	.24	.15	.090	.043	.011
Canopy of tall weeds or short brush, 0.5 m (1.6 ft.) fall ht.	25	G	.36	.17	.09	.038	.012	.003
		W	.36	.20	.13	.082	.041	.011
	50	G	.26	.13	.07	.035	.012	.003
		W	.26	.16	.11	.075	.039	.011
	75	G	.17	.10	.06	.031	.011	.003
		W	.17	.12	.09	.068	.038	.011
Appreciable brush or bushes, 2 m 6.6 ft. fall ht.	25	G	.40	.18	.09	.040	.013	.003
		W	.40	.22	.14	.085	.042	.011
	50	G	.34	.16	.085	.038	.012	.003
		W	.34	.19	.13	.081	.041	.011
	75	G	.28	.14	.08	.036	.012	.003
		W	.28	.17	.12	.077	.040	.011
Trees but no appreciable, low brush , 4 m (13.1 ft.) fall ht.	25	G	.42	.19	.10	.041	.013	.003
		W	.42	.23	.14	.087	.042	.011
	50	G	.39	.18	.09	.040	.013	.003
		W	.39	.21	.14	.085	.042	.011
	75	G	.36	.17	.09	.039	.012	.003
		W	.36	.20	.13	.083	.041	.011

[1]All values shown assume: (1) random distribution of mulch or vegetation, and (2) mulch of appreciable depth where it exists. Idle land refers to land with undisturbed profiles for at least a period of three consecutive years.
[2]Average fall height of waterdrops from canopy to soil surface.
[3]Portion of total-area surface that would be hidden from view by canopy in a vertical projection (a birds's-eye view).
[4]G: Cover at surface is grass, grasslike plants, decaying compacted duff, or litter at least 2 inches deep. W: Cover at surface is mostly broadleaf herbaceous plants (as weeds with little lateral-root network near the surface, and/or undecayed residue).

Source: Reference not available. Downloaded from:
http://ecn.www.ecn.purdue.edu/~sedspec/sedspec/doc/usleapp.doc

B-2: WIND EROSION REFERENCES

TABLE 3.—*Soil erodibility I′ for soils with different percentages of nonerodible fractions as determined by standard dry sieving* [1]

Dry soil fractions >0.84 mm. (percent) Units → Tens ↓	0	1	2	3	4	5	6	7	8	9
	Tons per acre	*Tons per acre*	*Tons per acre*	*Tons per acre*	*Tons per acre*	*Tons per acre*	*Tons per acre*	*Tons per acre*	*Tons per acre*	*Tons per acre*
0	------	310	250	220	195	180	170	160	150	140
10	134	131	128	125	121	117	113	109	106	102
20	98	95	92	90	88	86	83	81	79	76
30	74	72	71	69	67	65	63	62	60	58
40	56	54	52	51	50	48	47	45	43	41
50	38	36	33	31	29	27	25	24	23	22
60	21	20	19	18	17	16	16	15	14	13
70	12	11	10	8	7	6	4	3	3	2
80	2	------	------	------	------	------	------	------	------	------

[1] For fully crusted soil surface, regardless of soil texture, erodibility *I* is, on the average, about one-sixth of that shown.

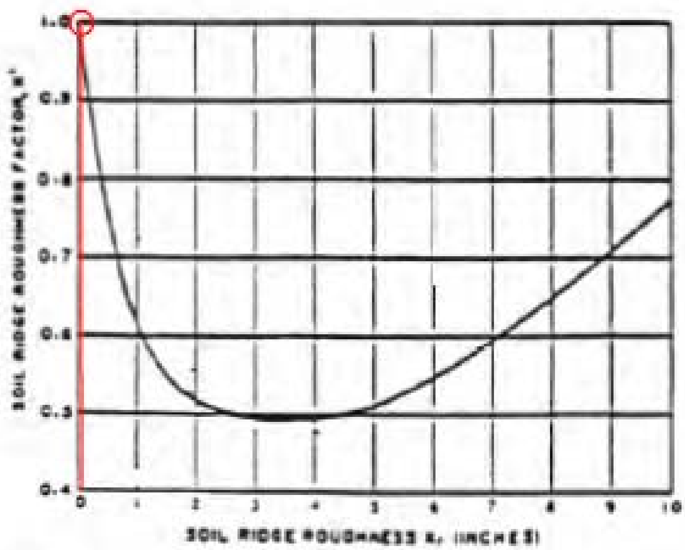
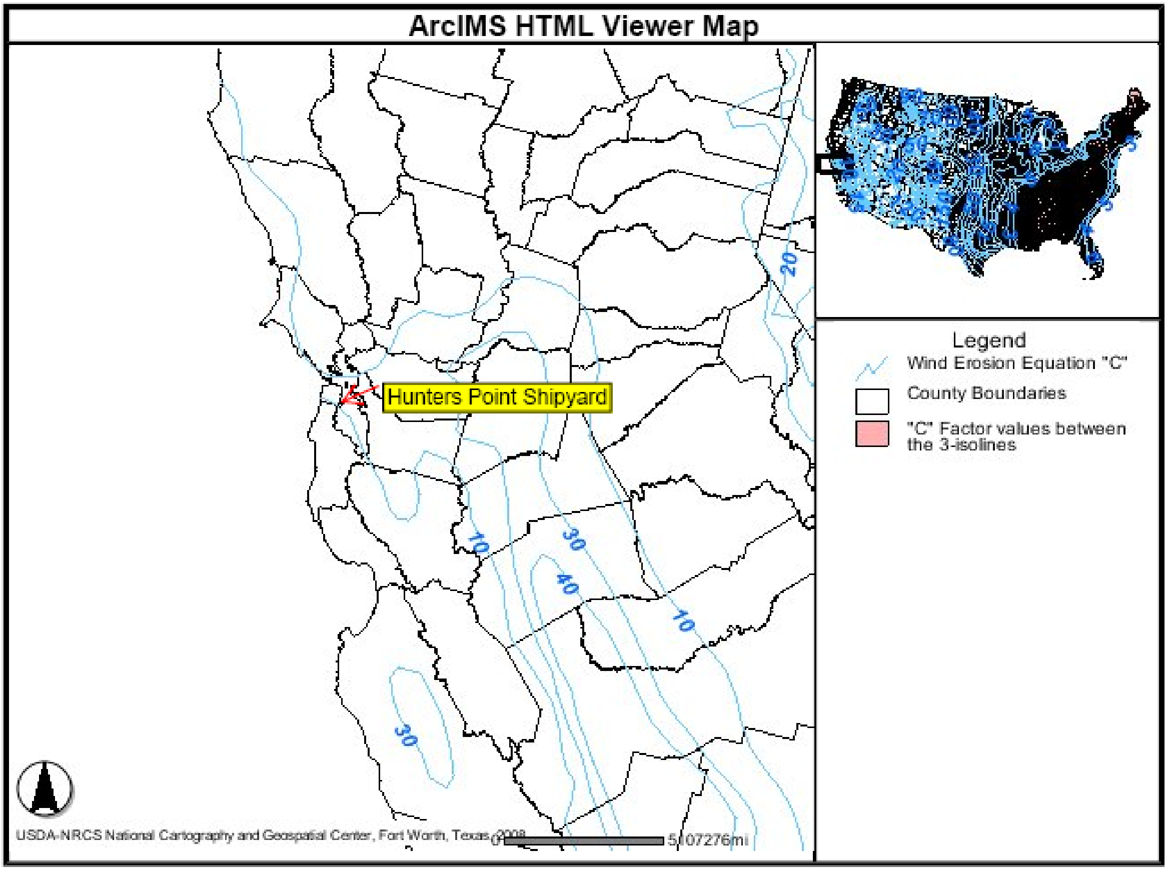


FIGURE 7.—Chart to determine soil ridge roughness factor K' from soil ridge roughness K_r.


ArcIMS HTML Viewer Map
Hunters Point Shipyard
20
10
30
40
10
30
Legend
Wind Erosion Equation "C"
County Boundaries
"C" Factor values between the 3-isolines
USDA-NRCS National Cartography and Geospatial Center, Fort Worth, Texas 2008
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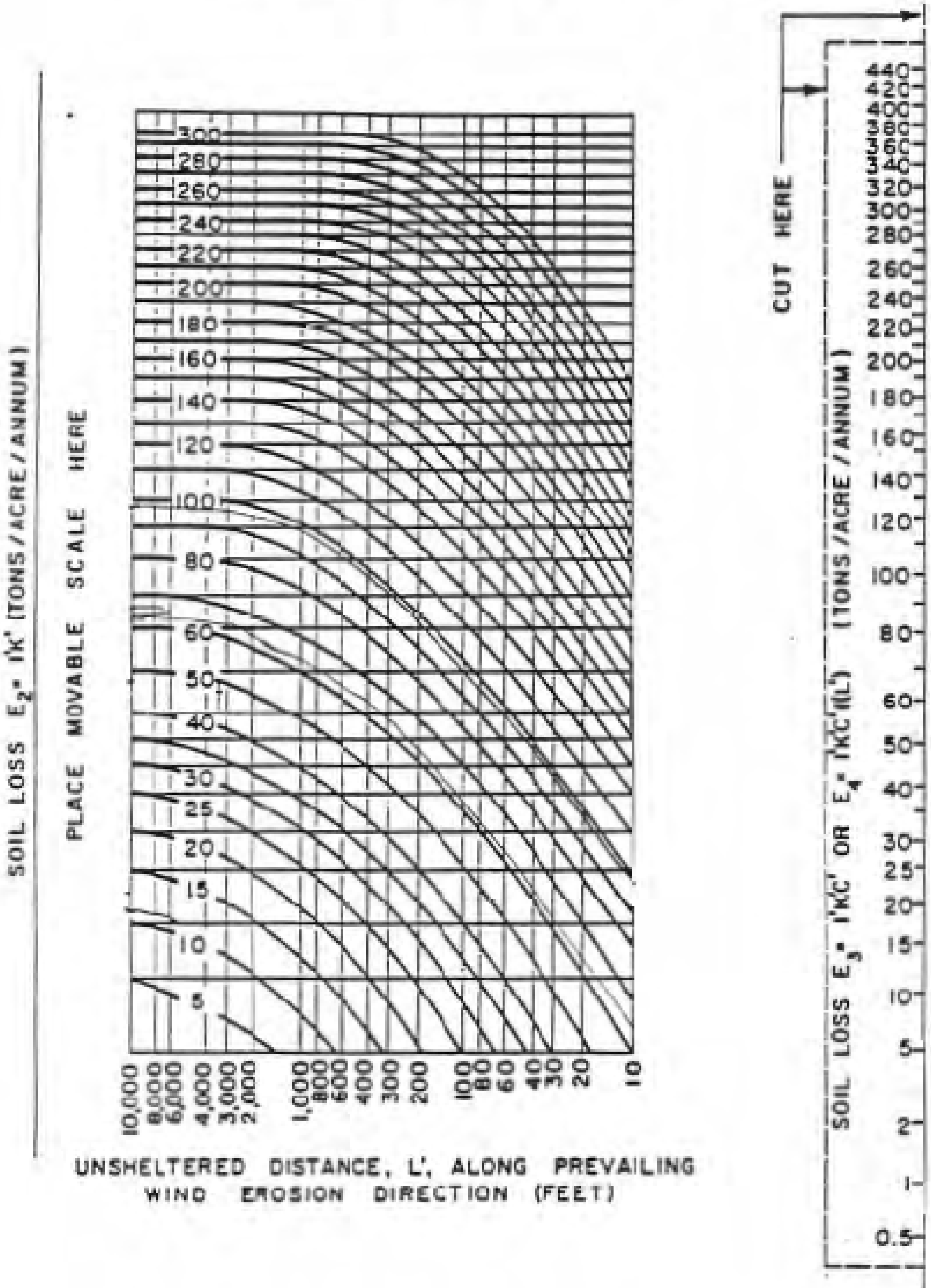

FIGURE 23.—Chart to determine soil loss $E_4 = I'K'C'f(L')$ from soil loss $E_2 = I'K'$ and $E_3 = I'K'C'$ and from unsheltered distance L' across field.

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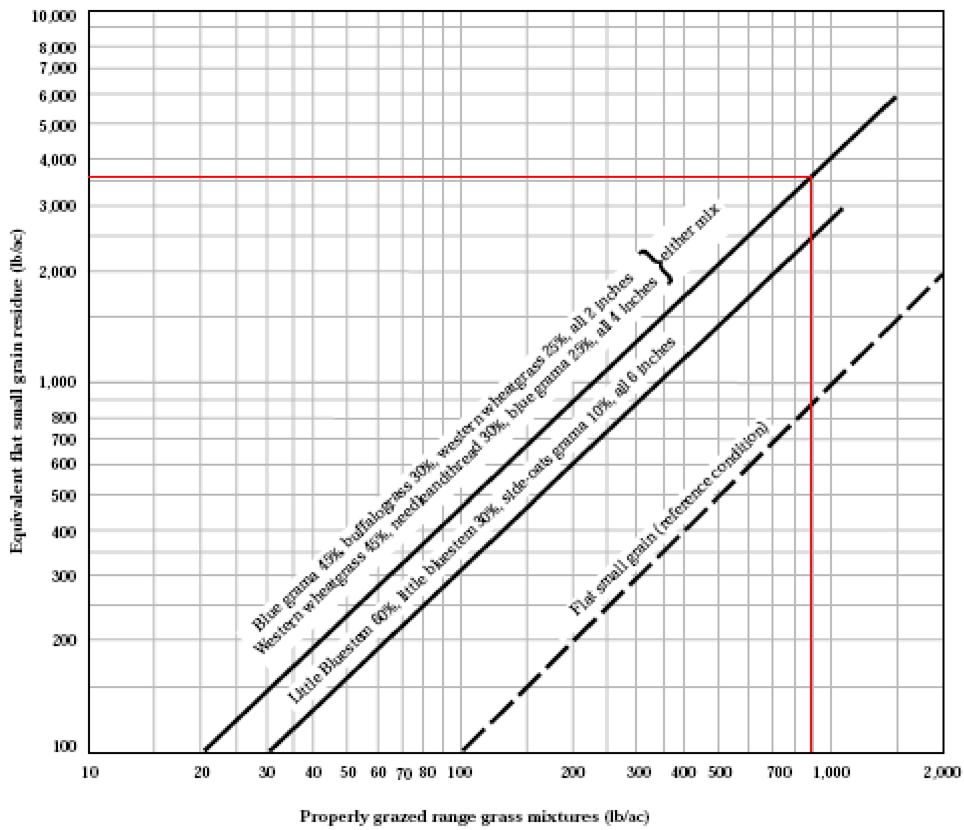
Percent ground cover to pounds residue				
The required crop residue may be expressed in percent ground cover in some plans and in pounds per acre in other plans. This table should be used to make the conversion from percent ground cover to pounds of residue. Residue weight varies with the variety of small grain grown. Some varieties might convert to more pounds than indicated on the table. Your SCS office may have a table that better represents the small grain varieties grown in your area	% cover	lbs. per acre	% cover	lbs. per acre
	5	80	55	1240
	10	160	60	1420
	15	250	65	1630
	20	350	70	1870
	25	450	75	2150
	30	550	80	2500
	35	670	85	2940
	40	790	90	3570
	45	930	95	4650
	50	1080	99	7140

New Mexico AGRONOMY TECHNICAL NOTE NO.73
http://www.nm.nrcs.usda.gov/technical/tech-notes/agro/ag73.doc

Flat small grain equivalent charts — Continued

Figure d-4 Flat small grain equivalents of properly grazed range grass mixture



Reference condition: Dry small grain stalks 10 inches long, lying flat on the soils surface in 10-inch rows perpendicular to wind direction, stalks oriented to wind direction.

Source: Lyles and Allison – 1980 Journal Range Management, 33(2), pages 143–146.

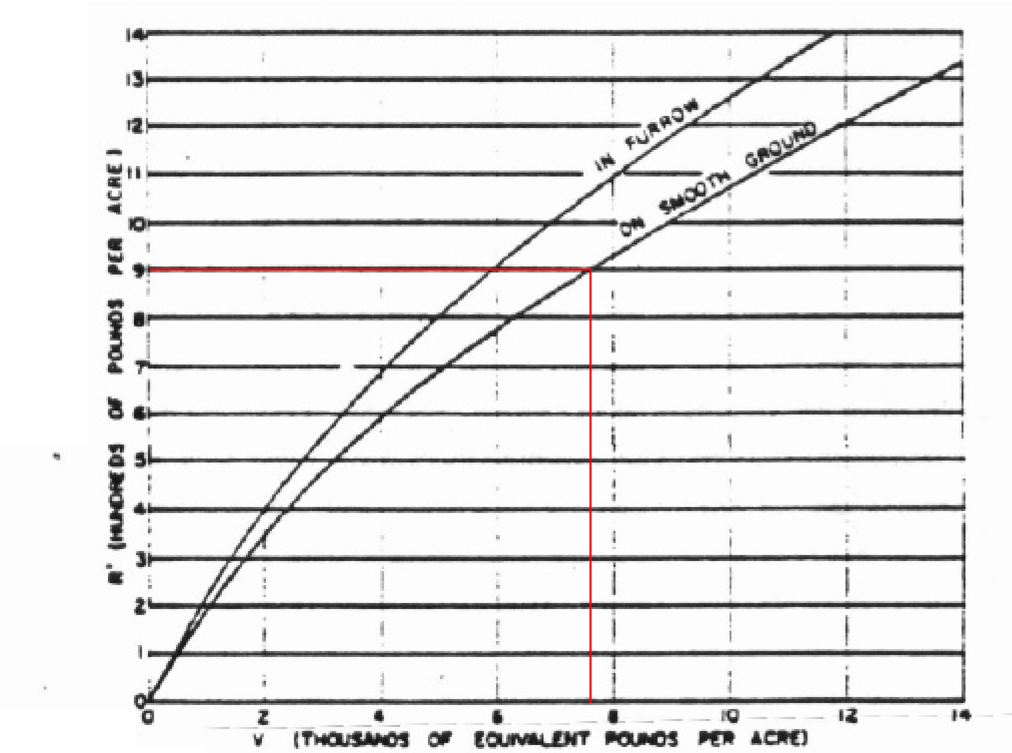


FIGURE 9.—Chart to determine V from R' or R' from V of live or dead small grain crops in seedling and stooling stage, above surface of ground, for crop in 3-inch-deep furrow as created by deep-furrow drill on smooth ground.

276-724 O-68—2

AGRICULTURE HANDBOOK 346, U.S. DEPT. OF AGRICULTURE

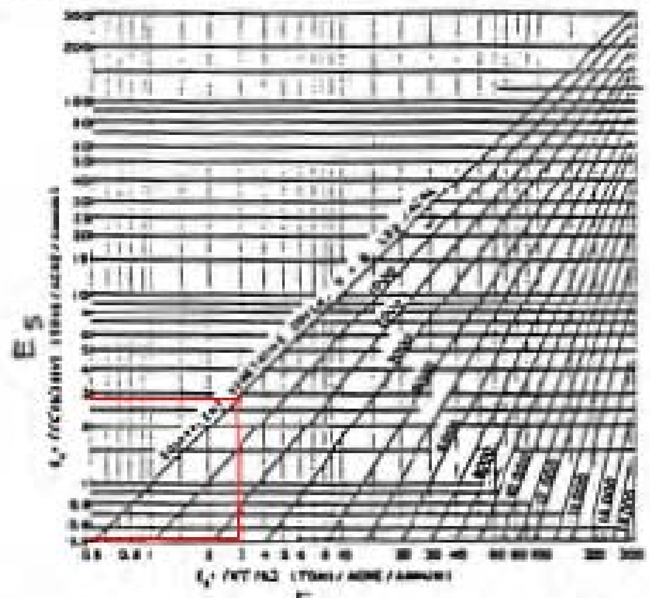


FIGURE 24.—Chart to determine soil loss $E = I'K'C'f(L')f(V)$ from soil loss $E_1 = I'K'C'f(L')$ and from vegetative cover factor V. Chart can be used in reverse to determine V needed to reduce soil loss to any degree.

APPENDIX C
WATERSHED SURFACE FLOW CALCULATION

TETRA TECH

Project		Component/System	
HPS, Parcel B, Site IR-07 and IR-18		Watershed Surface Flow Calculation	
Prepared by: JBL	Date 4-24-09	Checked by: SF	Date 4-28-09

Drainage calculations for the watershed areas affecting the remedy for IR Sites 7 and 18 were developed using the rational method for the hydrologic analysis and the time of concentration as calculated using the kinematic wave formula for overland flow and is based on the methodology explained in "Applied Hydrology" (Chow and others, 1988) and the Natural Resource Conservation Service (NRCS) "Urban Hydrology for Small Watersheds – Technical Release (TR) -55" (NRCS, 1986).

A 100-year return interval storm has been used for calculation to provide a conservative estimate.

A drainage swale was deemed necessary to divert flow and protect the cover from overland flow originating from upgradient of the proposed cover. Refer to Appendix D for the swale design and Figure 1 of this appendix for the location of the swale. For the watershed that drains to the swale from south of the site the longest flow length is approximately 400 feet prior to channel flow divided as follows. The first 100 feet of flow is modeled as uniform sheet flow or shallow overland flow. The flow then turns into concentrated flow prior to entering the constructed diversion structure or swale, a distance of 300 ft. Using the flow generated from this watershed the swale/channel is designed as shown in Appendix D.

The drainage provisions and curbing along Innes Avenue provide an effective diversion of the majority of flow toward the site from upgradient. Therefore Innes Avenue is considered the upgradient limits of the watershed to the proposed swale or in essence the watershed divide. The total watershed area draining to the cover area is approximately 5 acres.

The time of concentration for the sheet flow overland flow portion of this watershed is calculated using an iterative process based on the kinematic wave formula below:

$$t_c = \frac{0.94 L^{0.6} n^{0.6}}{(i^{0.4} S^{0.3})}$$

Where:

t_c = time of concentration (minutes)

L = water course flow length for overland flow (ft)

TETRA TECH

Project HPS, Parcel B, Site IR-07 and IR-18		Component/System Watershed Surface Flow Calculation	
Prepared by: JBL	Date 4-24-09	Checked by: SF	Date 4-28-09

n = Manning's roughness coefficient
i = storm intensity (in/hr)
S = average slope (ft/ft)

Assumptions:
1. Shallow steady uniform flow
2. Constant intensity of rainfall excess – rain available for runoff
3. Minor effect of infiltration on travel time
4. The first 100 ft of flow is in sheet flow prior to concentrated flow
5. The watershed is grass covered without full coverage. Manning's n = 0.24 (NRCS, 1986)
6. Average slope over the overland flow portion of the flow length is .14 ft/ft

An iterative process is used where the equation is solved for the conditions when the precipitation from the duration-frequency-depth curves and its corresponding time of concentration is equal to the time of concentration solved using that precipitation. The precipitation duration-frequency-depth curves have been included in this appendix

Time of concentration overland sheet flow

$$t_c = \frac{0.94 L^{0.6} n^{0.6}}{(i^{0.4} S^{0.3})}$$

t_c	**6.97**	time of concentration (min)
L	100	flow length (ft)
n	0.24	manning's roughness for grasses not fully covered
i	3.43	storm intensity (in)
S	0.14	average slope along flow length (ft/ft)

From Depth-Duration-Frequency Curves
0.4 inches in 7 minutes

t_c ~ 7 min

TETRA TECH

Project HPS, Parcel B, Site IR-07 and IR-18		Component/System Watershed Surface Flow Calculation	
Prepared by: JBL	Date 4-24-09	Checked by: SF	Date 4-28-09

After the first 100 feet of sheet flow over the watershed the flow continues as shallow concentrated flow until the flow enters the diversion. The velocity, and thus the travel time, is calculated using the following figure.

Assumptions:

1. 300 ft of flow along the longest watercourse prior to entering swale
2. The water course is not paved
3. Average slope along the watercourse is 0.063 ft/ft

Using the above figure and the given assumptions yields an average flow of rate along the water course of 4.1 ft/sec.

$$\frac{300\,\text{ft}}{4.1\,\frac{\text{ft}}{\text{sec}}} = 73\,\text{sec}$$

Total time of concentration for overland flow

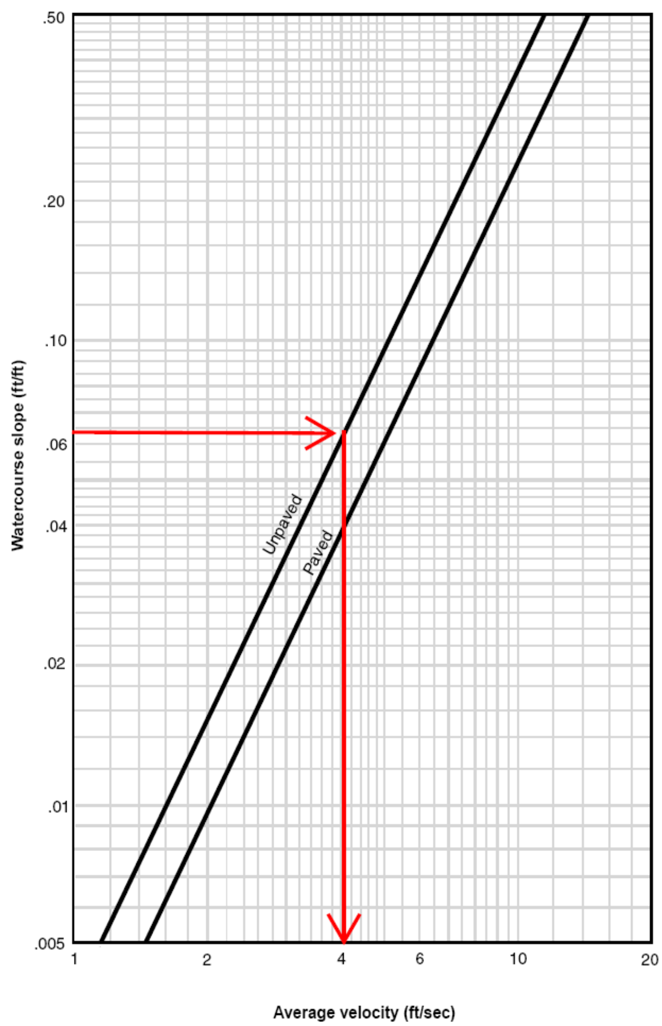
t_c sheet flow + t_c concentrated flow

7 min + 1.2 min = **8.2 minutes**

TETRA TECH

Project	Component/System
HPS, Parcel B, Site IR-07 and IR-18	Watershed Surface Flow Calculation

Prepared by:	Date	Checked by:	Date
JBL	4-24-09	SF	4-28-09



From: NRCS, 1986

TETRA TECH

Project		Component/System	
HPS, Parcel B, Site IR-07 and IR-18		Watershed Surface Flow Calculation	
Prepared by: JBL	Date 4-24-09	Checked by: SF	Date 4-28-09

Using the provided Precipitation Duration-Frequency-Depth Curves (provided as attachment) the rainfall intensity for the time of concentration is determined.

Assumptions:
1. Average annual rainfall of 21.5 inches/year (NOAA 1995)
2. The duration-frequency-depth curves were established for Contra Costa County and it is assumed they are reasonable for estimation for San Francisco. Precipitation patterns between the 2 locations should not vary significantly given their relative proximity.

From the precipitation duration-frequency-depth curves the rainfall intensity for a 100-year return interval is corresponding to the 8.2 minute time of concentration is:

0.44 inches/8.2 minutes

or an intensity of: **3.2 in/hr**

The flow rate entering the channel is calculated using the Rational Equation

$$Q = CiA$$

Where:
Q = flow (cubic feet per second, cfs)
C = runoff coefficient (0.55 see attached runoff coefficient table)
i = rainfall intensity (in/hr)
A = watershed area (acres)

Project HPS, Parcel B, Site IR-07 and IR-18		Component/System Watershed Surface Flow Calculation	
Prepared by: JBL	Date 4-24-09	Checked by: SF	Date 4-28-09

Assumptions:

1. Average slope over the area is greater than 7%
2. The condition of the watershed vegetation is relatively poor with grass covering less than 55% of the area – this is conservative scenario.
3. Calculation is based on a 100-year return interval storm

$$Q = (0.55)(3.2\ in/hr)(3\ acres)$$
$$Q = \mathbf{5.3\ cfs}$$

This is considered the peak flow rate entering the upper portion of the channel associated with a 100-year return interval storm. This flow rate will be used for the design of the swale channel as explained in Attachment D.

TETRA TECH

Project HPS, Parcel B, Site IR-07 and IR-18		Component/System Watershed Surface Flow Calculation	
Prepared by: JBL	Date 4-24-09	Checked by: SF	Date 4-28-09

The change in the watershed flow as a result of the cover was calculated using a similar methodology as described above. The majority of the existing site flows toward the north to the natural channel along the northwestern property boundary or over the shoreline as shown in the attached Figure 2 of this attachment. The general flow of the area will be maintained by the cover however the drainage swale will divert a portion of the flow that originates from to south to the east as shown in the figure. The change in flow to the northwestern property boundary was calculated as described below. First the flow for the proposed cover was calculated followed by the flow for the existing conditions.

Assumptions for both scenarios:

1. Shallow steady uniform flow
2. Constant intensity of rainfall excess – rain available for runoff
3. Minor effect of infiltration on travel time
4. The proposed cover will be maintained and the first 300 ft of flow is modeled as sheet flow. The remainder as shallow overland flow (520 ft). A Manning's n of 0.3 has been used for grass covered area (NRCS, 1986)
5. The existing cover is not maintained to promote sheet flow and the first 100 ft of flow is modeled as sheet flow. The remainder as shallow overland flow (1,100 ft). A Manning's n of 0.011 has been used for smooth gravel surface (NRCS, 1986).
6. Average slope over the overland flow portion of the flow length is .025 ft/ft for both the existing conditions and the proposed cover.

For the watershed over the proposed cover a time of concentration of 34 minutes was calculated as shown below.

TETRA TECH

Project	Component/System
HPS, Parcel B, Site IR-07 and IR-18	Watershed Surface Flow Calculation

Prepared by:	Date	Checked by:	Date
JBL	4-24-09	SF	4-28-09

Time of concentration overland sheet flow

t_c	**34.40**	time of concentration (min)
L	300	flow length (ft)
n	0.3	manning's roughness for grasses
i	1.68	storm intensity (in)
S	0.025	average slope along flow length (ft/ft)

From Depth-Duration-Frequency Curves
0.95 inches in 34 minutes

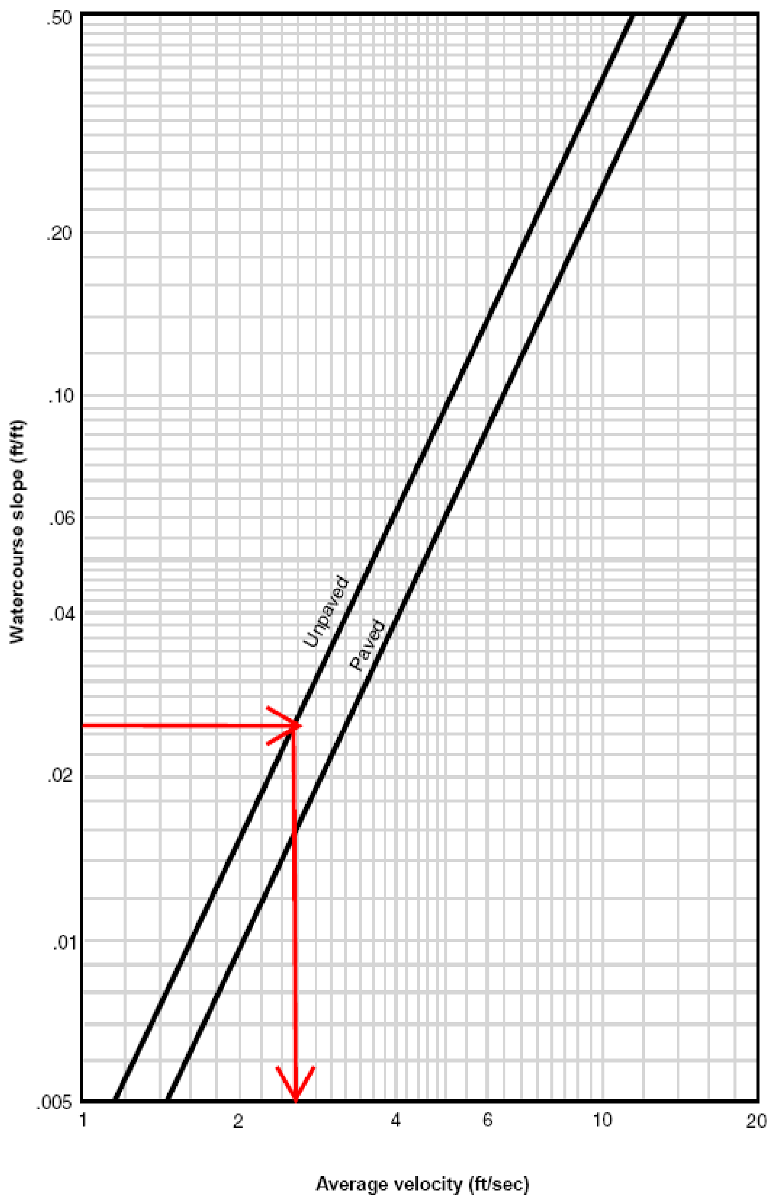
After the first 300 feet of sheet flow over the watershed the flow continues as shallow concentrated flow until discharge to the bay from the natural channel at the watershed discharge point. The velocity, and thus the travel time, is calculated using the following figure.

Assumptions:

1. 520 ft of flow along the longest watercourse over the remainder of the cover and through the channel
2. The water course is unpaved
3. Average slope along the watercourse is 0.025 ft/ft

TETRA TECH

Project HPS, Parcel B, Site IR-07 and IR-18		Component/System Watershed Surface Flow Calculation	
Prepared by: JBL	Date 4-24-09	Checked by: SF	Date 4-28-09



TETRA TECH

Project		Component/System	
HPS, Parcel B, Site IR-07 and IR-18		Watershed Surface Flow Calculation	
Prepared by: JBL	Date 4-24-09	Checked by: SF	Date 4-28-09

Using the above figure and the given assumptions yields an average flow of rate along the water course of 2.5 ft/sec.

$$\frac{520\,\text{ft}}{2.5\,\dfrac{\text{ft}}{\text{sec}}} = 208\,\text{sec}$$

Total time of concentration for overland flow

t_c sheet flow + t_c concentrated flow

34 min + 3.5 min = **37.5 minutes**

Using the provided Precipitation Duration-Frequency-Depth Curves (provided as attachment) the rainfall intensity for the time of concentration is determined.

Assumptions:

1. Average annual rainfall of 21.5 inches/year (NOAA 1995)
2. The duration-frequency-depth curves were established for Contra Costa County and it is assumed they are reasonable for estimation for San Francisco. Precipitation patterns between the 2 locations should not vary significantly given their relative proximity.

From the precipitation duration-frequency-depth curves the rainfall intensity for a 100-year return interval is corresponding to the 37.9 minute time of concentration is:

1.0 inches/38 minutes

or an intensity of: **1.6 in/hr**

The flow rate from the watershed is calculated using the Rational Equation

$Q = CiA$

TETRA TECH

Project HPS, Parcel B, Site IR-07 and IR-18		Component/System Watershed Surface Flow Calculation	
Prepared by: JBL	Date 4-24-09	Checked by: SF	Date 4-28-09

Where:
Q = flow (cubic feet per second, cfs)
C = runoff coefficient (0.41 for moderate condition, see attached runoff coefficient table)
i = rainfall intensity (in/hr)
A = watershed area (acres)

Q = (0.41)(1.6 in/hr)(4.5 acres)
Q = ***3.0 cfs***

This is considered the peak flow rate entering from the watershed created by the proposed cover and swale at the discharge point associated with a 100-year return interval storm.

For the watershed over the existing area the first 100 ft of flow along the longest flow path is the same as for the watershed associated with the swale because that area will not be affected by the cover and thus has the same associated time of concentration of 7 minutes.

Time of concentration overland sheet flow

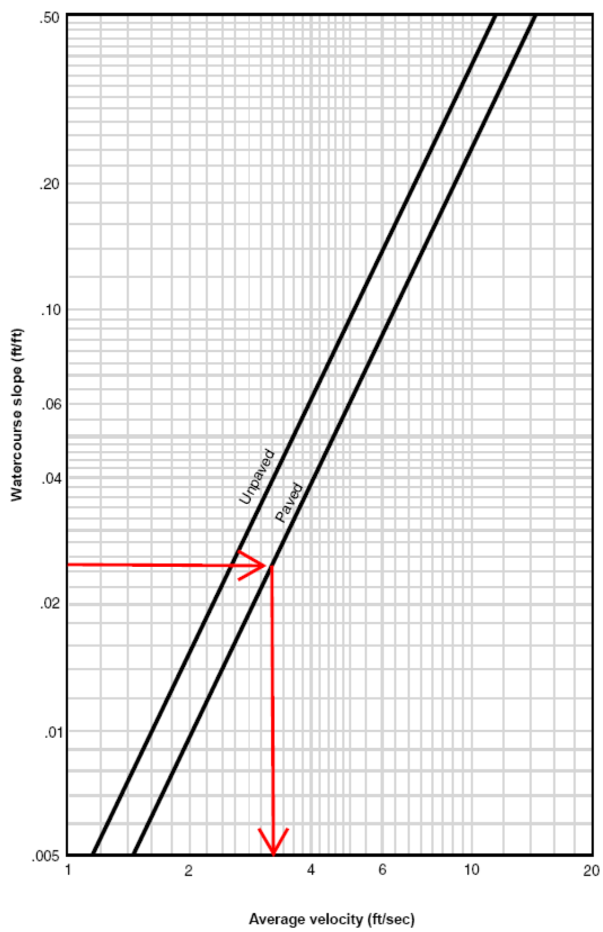
t_c	6.97	time of concentration (min)
L	100	flow length (ft)
n	0.24	manning's roughness for grasses not fully covered
i	3.43	storm intensity (in)
S	0.14	average slope along flow length (ft/ft)

From Depth-Duration-Frequency Curves
0.4 inches in 7 minutes

After the first 100 feet of sheet flow over the watershed the flow continues as shallow concentrated flow until discharge to the bay from the natural channel at the watershed discharge point. The velocity, and thus the travel time, is calculated using the following figure.
Assumptions:

Project HPS, Parcel B, Site IR-07 and IR-18		Component/System Watershed Surface Flow Calculation	
Prepared by: JBL	Date 4-24-09	Checked by: SF	Date 4-28-09

1. 1,100 ft of flow along the longest watercourse over the remainder of the cover and through the channel
2. The water course is not improved but the existing cover is similar to being paved
3. Average slope along the watercourse is 0.025 ft/ft



TETRA TECH

Project		Component/System	
HPS, Parcel B, Site IR-07 and IR-18		Watershed Surface Flow Calculation	
Prepared by: JBL	Date 4-24-09	Checked by: SF	Date 4-28-09

The average flow rate over the existing watershed will be:

$$\frac{1100\,\text{ft}}{3.2\,\frac{\text{ft}}{\text{sec}}} = 344\text{sec}$$

Total time of concentration for overland flow

t_c sheet flow + t_c concentrated flow

7 min + 5.7 min = **12.7 minutes**

Using the provided Precipitation Duration-Frequency-Depth Curves (provided as attachment) the rainfall intensity for the time of concentration is determined.

Assumptions:

1. Average annual rainfall of 21.5 inches/year (NOAA 1995)
2. The duration-frequency-depth curves were established for Contra Costa County and it is assumed they are reasonable for estimation for San Francisco. Precipitation patterns between the 2 locations should not vary significantly given their relative proximity.

From the precipitation duration-frequency-depth curves the rainfall intensity for a 100-year return interval is corresponding to the 12.7 minute time of concentration is:

0.55 inches/13 minutes

or an intensity of: **2.5 in/hr**

The flow rate from the watershed is calculated using the Rational Equation

$Q = CiA$

TETRA TECH

Project HPS, Parcel B, Site IR-07 and IR-18		Component/System Watershed Surface Flow Calculation	
Prepared by: JBL	Date 4-24-09	Checked by: SF	Date 4-28-09

Where:
Q = flow (cubic feet per second, cfs)
C = runoff coefficient (0.95 for developed asphaltic, see attached runoff coefficient table)
i = rainfall intensity (in/hr)
A = watershed area (acres)

$$Q = (0.95)(2.5\ in/hr)(8.8\ acres)$$
$$Q = \mathbf{20.9\ cfs}$$

This is considered the peak flow rate entering from the watershed as the discharge point associated with a 100-year return interval storm.

As a result of the proposed cover and the drainage swale (see Appendix D) the peak flow to the unimproved channel along the northwestern property boundary will be approximately 15% of the existing peak flow, or about 3 cfs under 100-year return interval storm scenario. This decrease is due to proposed swale and the reduced drainage size to that portion of the site and the maintained cover which will has a larger Manning's roughness coefficient and greater infiltration than the current conditions. Because of the significantly decreased peak flows and proximity to the discharge to the bay drainage improvements were not investigated along the boundary.

TETRA TECH

Project		Component/System	
HPS, Parcel B, Site IR-07 and IR-18		Watershed Surface Flow Calculation	
Prepared by: JBL	Date 4-24-09	Checked by: SF	Date 4-28-09

References:

Chow, V., Maidment, D., and Mays, L. 1988. "Applied Hydrology." McGraw-Hill Publishing

Contra Costa County, Department of Public Works. Flood Control and Water Conservation District. Precipitation Duration-Frequency-Depth Curves.

US National Oceanographic and Atmospheric Administration (NOAA). 1995. "Climate of San Francisco." January.

US Department of Agriculture, Natural Resource Conservation Service (NRCS), 1986. "Urban Hydrology for Small Watersheds – Technical Release 55." June.

TETRA TECH

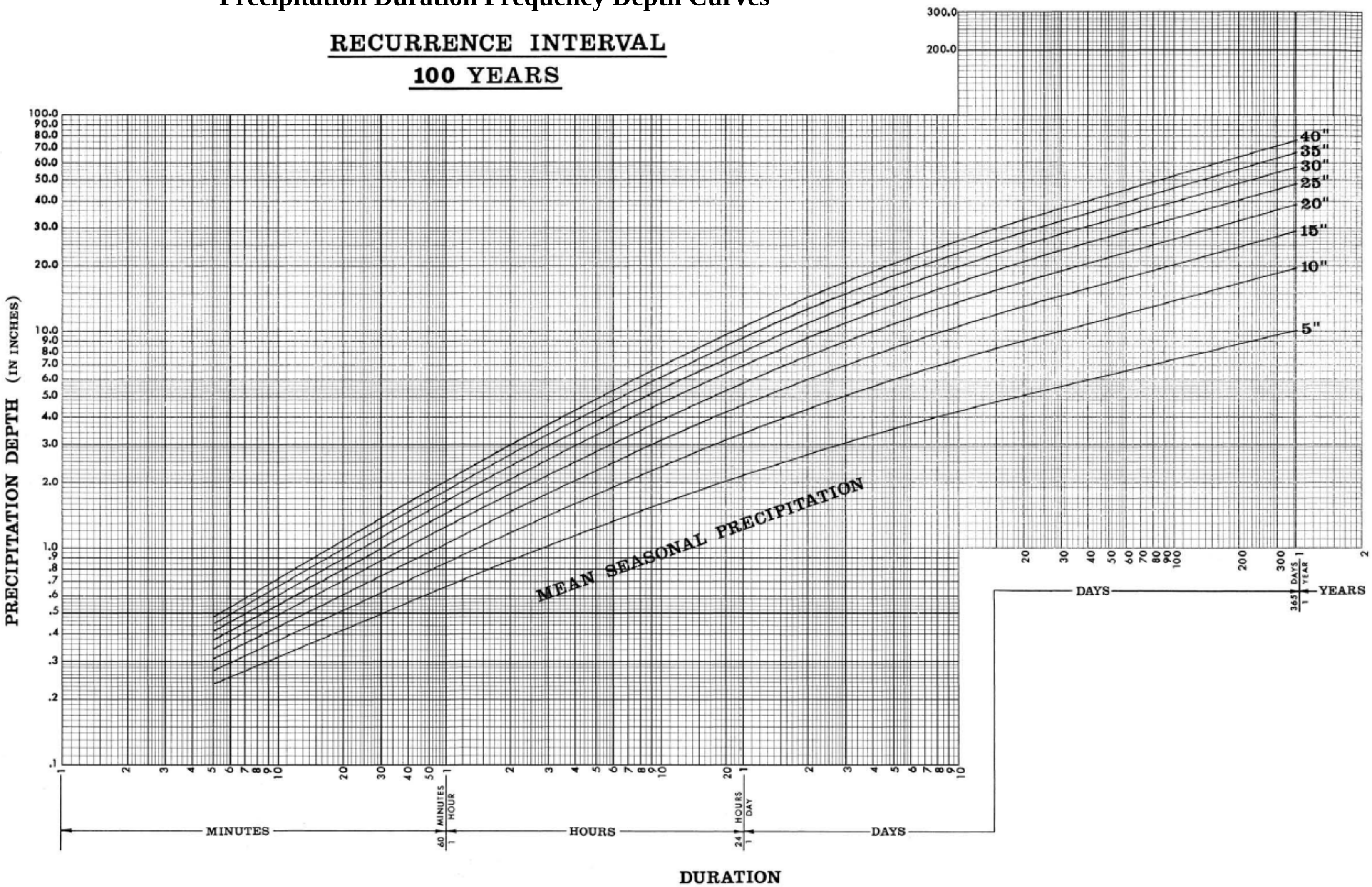
Project HPS, Parcel B, Site IR-07 and IR-18		Component/System Watershed Surface Flow Calculation	
Prepared by: JBL	Date 4-24-09	Checked by: SF	Date 4-28-09

Runoff Coefficients for use in the Rational Method

Character of Surface	Return Period						
	2 Years	5 Years	10 Years	25 Years	50 Years	100 Years	500 Years
DEVELOPED							
Asphaltic	0.73	0.77	0.81	0.86	0.90	0.95	1.00
Concrete	0.75	0.80	0.83	0.88	0.92	0.97	1.00
Grass Areas (Lawns, Parks, etc.)							
Poor Condition* Flat, 0-2% Average, 2-7% Steep, over 7%	 0.32 0.37 0.40	 0.34 0.40 0.43	 0.37 0.43 0.45	 0.40 0.46 0.49	 0.44 0.49 0.52	 0.47 0.53 0.55	 0.58 0.61 0.62
Fair Condition** Flat, 0-2% Average, 2-7% Steep, over 7%	 0.25 0.33 0.37	 0.28 0.36 0.40	 0.30 0.38 0.42	 0.34 0.42 0.46	 0.37 0.45 0.49	 0.41 0.49 0.53	 0.53 0.58 0.60
Good Condition*** Flat, 0-2% Average, 2-7% Steep, over 7%	 0.21 0.29 0.34	 0.23 0.32 0.37	 0.25 0.35 0.40	 0.29 0.39 0.44	 0.32 0.42 0.47	 0.36 0.46 0.51	 0.49 0.56 0.58
UNDEVELOPED							
Cultivated Flat, 0-2% Average, 2-7% Steep, over 7%	 0.31 0.35 0.39	 0.34 0.38 0.42	 0.36 0.41 0.44	 0.40 0.44 0.48	 0.43 0.48 0.51	 0.47 0.51 0.54	 0.57 0.60 0.61

Ref: Chow, 1988

Precipitation Duration Frequency Depth Curves



Ref: Contra Costa Public Works

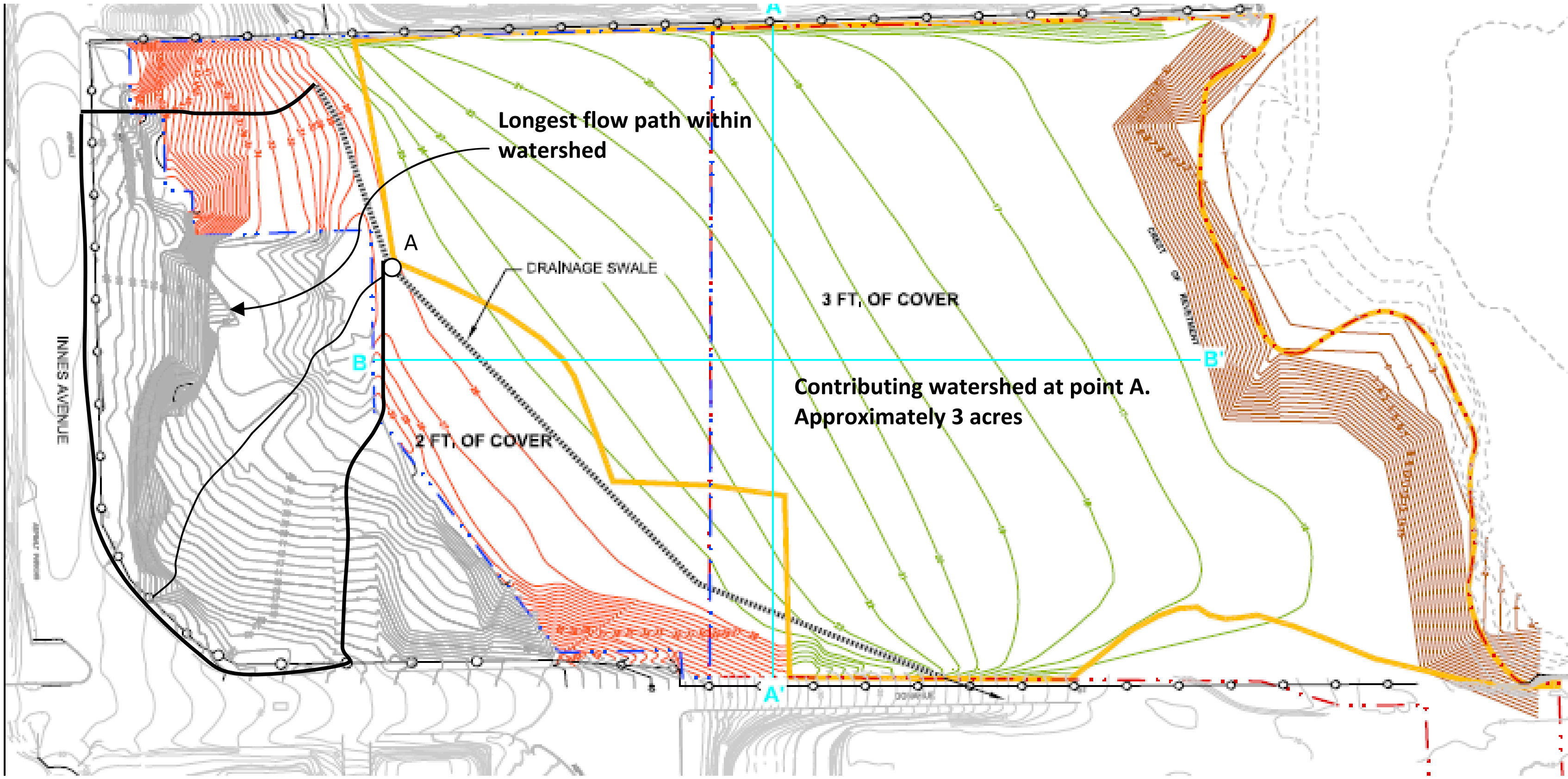


Figure 1
Drainage Area to the Upper Portion of the Swale (used for swale design see Appendix D)

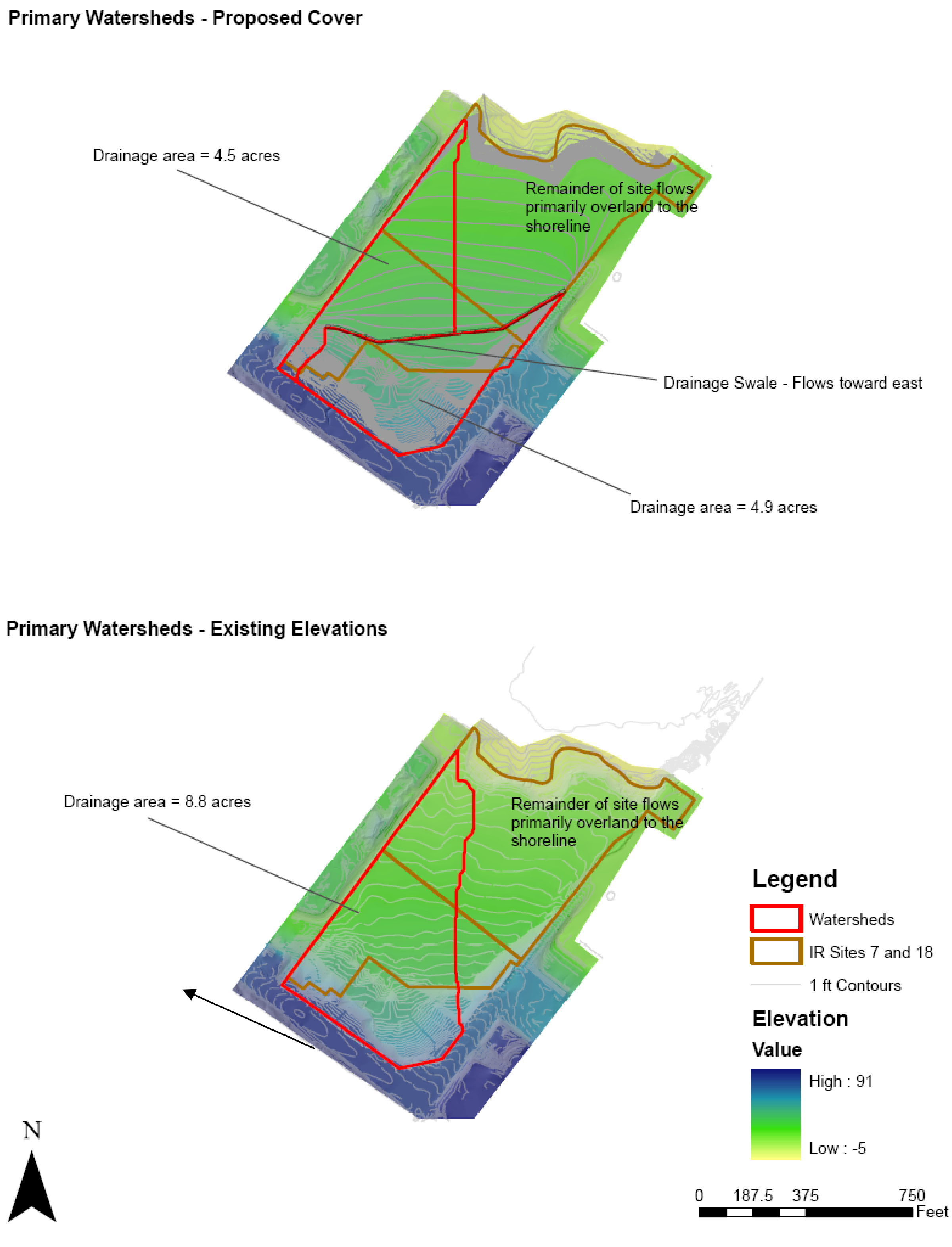

Primary Watersheds - Proposed Cover
Drainage area = 4.5 acres
Remainder of site flows primarily overland to the shoreline
Drainage Swale - Flows toward east
Drainage area = 4.9 acres
Primary Watersheds - Existing Elevations
Drainage area = 8.8 acres
Remainder of site flows primarily overland to the shoreline
Legend
Watersheds
IR Sites 7 and 18
1 ft Contours
Elevation
Value
High : 91
Low : -5
0
187.5
375
750
Feet
N

Figure 2

APPENDIX D
DRAINAGE SWALE CALCULATIONS AND DESIGN

TETRA TECH

Project		Component/System	
HPS, Parcel B, Site IR-07 and IR-18		Drainage Swale Calculations and Design	
Prepared by: JBL	Date 4-24-09	Checked by: SWF	Date 4-28-09

The drainage swale is designed based on the anticipated peak flows associated with a 100-year return interval storm throughout the channel. The calculation of the dimensions of the grass lined swale is an iterative process using the Rational Method for small watersheds (Appendix C) and Manning's equation and adjusting the swale slope and height for the conveyance of the estimated peak flow.

An estimation of the channel/swale geometry is calculated from manning's equation for flow using the flow rate entering the upper portion of the channel (calculation Appendix C) of 5.3 cfs and solving for water depth while adjusting the slopes and bottom width for that portion of the channel. The flow rate is then recalculated to account for additional inflow into the channel and the selected channel geometry is tested against total flow given the change in channel slope. This process is continued to ensure that the peak flow is conveyed to the channel outlet point.

The swale was broken into 2 segments along the longest flow path based on flow characteristics. The upper potion of the channel (segment A) has an average slope along the segment of 0.2% and a segment length of 425 ft. The lower portion of the channel (segment B) has an average slope of 1.8% and a length of 250 ft. Shallower slopes will be associated with deeper water depths and steeper slopes will be associated with increased water velocity and greater shear forces along the channel. A figure showing the channel segments has been attached to this calculation.

The following variation of Manning's equation is used equation to estimate channel geometry along the channel segments:

TETRA TECH

Project HPS, Parcel B, Site IR-07 and IR-18		Component/System Drainage Swale Calculations and Design	
Prepared by: JBL	Date 4-24-09	Checked by: SWF	Date 4-28-09

$$Q = \frac{1.49}{n} S_{A,B}^{\frac{1}{2}} A R^{\frac{2}{3}}$$

Where:

Q = flow rate (cfs)

n = manning's roughness coefficient (0.045 for grass lined channels intermittent flow)

S_A = average slope along channel/swale segment A (0.2% or 0.002 ft/ft)

S_B = average slope along channel/swale segment B (1.8% or 0.018 ft/ft)

A = cross sectional area of flow (see below)

R = hydraulic radius (see below)

$$A = B_w y + \left[\frac{(z_1 + z_2)}{2}\right] y^2$$

$$R = \frac{B_w y + \left[\frac{(z_1 + z_2)}{2}\right] y^2}{B_w + \sqrt{(z_1 y)^2 + y^2} + \sqrt{(z_2 y)^2 + y^2}}$$

Where:

B_w = channel bottom width

z_1 = channel side slope (1/*z)* of upgradient side slope

z_2 = channel side slope (1/*z)* of swale side slope

y = water depth (ft)

Using the above formulas an iterative process was used to solve for water depth for a variety of swale geometry options for the channel influent to segment A. The following shows the results of the process:

TETRA TECH

Project	Component/System
HPS, Parcel B, Site IR-07 and IR-18	Drainage Swale Calculations and Design

Prepared by:	Date	Checked by:	Date
JBL	4-24-09	SWF	4-28-09

Flow in channel at A (irregular trapezoid)

$$Q = \frac{1.49}{n} S^{\frac{1}{2}} A R^{\frac{2}{3}}$$

$$A = B_w y + \left[\frac{(z_1 + z_2)}{2}\right] y^2$$

$$R = \frac{B_w y + \left[\frac{(z_1 + z_2)}{2}\right] y^2}{B_w + \sqrt{(z_1 y)^2 + y^2} + \sqrt{(z_2 y)^2 + y^2}}$$

n	0.045	Mannings roughness
B_w	2	Bottom width (ft)
z_1	17	Average updradient slope
z_2	3	Swale side slope
S	0.002	Water course slope (ft/ft)
Q	5.3	Flow rate (cfs) incoming channel
y	**0.74**	Solve for y using Q
	5.30	Flow rate (cfs)

Using the flow rate of 5.3 cfs (see appendix C) and a bottom width of 2 ft and side slopes of 1V:3H for the swale downgradient of the flow path and 1V:17H upgradient of the swale yields a water depth of 0.74 ft.

The time of concentration for the swale portion of the water course is calculated using Manning's equation for velocity using the following equation based on the swale/channel geometry from above:

$$V = \frac{1.49 r^{\frac{2}{3}} s^{\frac{1}{2}}}{n}$$

Where:
V = average velocity (ft/sec)
r = hydraulic radius (ft)
s = slope of the gradient line (ft/ft)
n = manning's roughness coefficient

TETRA TECH

Project		Component/System	
HPS, Parcel B, Site IR-07 and IR-18		Drainage Swale Calculations and Design	
Prepared by: JBL	Date 4-24-09	Checked by: SWF	Date 4-28-09

The hydraulic radius *(r)* is calculated from:

$$R = \frac{B_w y + \left[\frac{(z_1 + z_2)}{2}\right] y^2}{B_w + \sqrt{(z_1 y)^2 + y^2} + \sqrt{(z_2 y)^2 + y^2}}$$

Where:

B_w = channel bottom width

z_1 = channel side slope (1/*z*) of upgradient side slope

z_2 = channel side slope (1/*z)* of swale side slope

y = water depth (ft)

Velocity along upper channel segment points A-B

$$\boxed{V = \frac{1.49 r^{\frac{2}{3}} s^{\frac{1}{2}}}{n}}$$

V	$\boxed{\mathbf{0.95}}$	average velocity in channel (ft/sec)
r	0.51	hydraulic radius (ft)
s	0.002	channel slope (ft/ft)
n	0.045	mannings roughness

Using the above relationships yields a velocity along the drainage of **0.95 ft/sec**.

TETRA TECH

Project		Component/System	
HPS, Parcel B, Site IR-07 and IR-18		Drainage Swale Calculations and Design	
Prepared by: JBL	Date 4-24-09	Checked by: SWF	Date 4-28-09

The flow length along the upper channel segment is approximately 360 ft. The time of concentration along the channel of the entering flow is calculated using the associated velocity of 1.12 ft/sec as shown below.

t_c = (distance)/(velocity)
t_c = (425 ft)/(0.95 ft/sec)
t_c = 7.4 min

Using the times of concentration calculated entering the channel the total time of concentration along the longest flow path is calculated.

8.2 min =	t_c peak flow entering channel (from Appendix C)
<u>7.4 min</u> =	t_c along the channel segment A
15.6 min	

From the precipitation duration-frequency-depth curves the rainfall intensity for a 100-year return interval corresponding to the 13.6 minute total time of concentration for the water course is:

0.63 inches/15.6 minutes
or an intensity of: **2.4 in/hr**

The maximum flow rate along segment A or in influent of segment B is calculated using the Rational Equation

$$Q = CiA$$

Where:
Q = flow (cubic feet per second, cfs)
C = runoff coefficient (0.55 see following table)
i = rainfall intensity (in/hr)
A = watershed area (4.5 acres)

TETRA TECH

Project		Component/System	
HPS, Parcel B, Site IR-07 and IR-18		Drainage Swale Calculations and Design	
Prepared by: JBL	Date 4-24-09	Checked by: SWF	Date 4-28-09

Assumptions:

1. Average slope of the watershed is steep greater than 1%
2. The condition of the vegetation over the entire watershed associated with the location is considered relatively poor with grass covering less than 55% of the channel (assumption used for conservation and yields a higher flow – the channel vegetation would be maintained according to the O&M Plan)
3. Calculation is based on a 100-year return interval storm

Q = (0.55)(2.4 in/hr)(4.5 acres)

Q = ***5.9 cfs***

This flow of 5.9 cfs is considered the influent to segment B of the channel. Using the same process described above the channel geometry along segment B is tested and the velocity is calculated.

Flow in channel at B (irregular trapezoid)

$$\boxed{Q = \frac{1.49}{n} S^{\frac{1}{2}} A R^{\frac{2}{3}}}$$

$$\boxed{A = B_w y + \left[\frac{(z_1 + z_2)}{2}\right] y^2}$$

$$\boxed{R = \frac{B_w y + \left[\frac{(z_1 + z_2)}{2}\right] y^2}{B_w + \sqrt{(z_1 y)^2 + y^2} + \sqrt{(z_2 y)^2 + y^2}}}$$

n	0.045	Mannings roughness
B_w	2	Bottom width (ft)
z_1	4	Average updradient slope
z_2	3	Swale side slope
S	0.018	Water course slope (ft/ft)
Q	5.9	Flow rate (cfs) incoming channel
y	**0.66**	Solve for y using Q
	5.90	Flow rate (cfs)

TETRA TECH

Project	Component/System
HPS, Parcel B, Site IR-07 and IR-18	Drainage Swale Calculations and Design

Prepared by:	Date	Checked by:	Date
JBL	4-24-09	SWF	4-28-09

A peak water depth of 0.66 ft is estimated using the same channel geometry as the calculation for the previous segment. It should be noted that the upgradient slopes are steeper than for the previous segment which has been accounted for in the equation. Using this data the channel velocity is calculated.

Velocity along upper channel segment points A-B

$$V = \frac{1.49 r^{\frac{2}{3}} s^{\frac{1}{2}}}{n}$$

V	**2.57**	average velocity in channel (ft/sec)
r	0.51	hydraulic radius (ft)
s	0.018	channel slope (ft/ft)
n	0.045	mannings roughness

The velocity along the lower channel portion, channel B, is **2.6 ft/sec**.

The flow length along the lower channel segment is approximately 250 ft. The time of concentration along the channel of the entering flow is calculated using the associated velocity of 2.6 ft/sec as shown below.

t_c = (distance)/(velocity)
t_c = (250 ft)/(2.6 ft/sec)
t_c = 1.6 min

Using the times of concentration calculated entering the channel the total time of concentration along the longest flow path is calculated.

8.2 min = t_c peak flow entering channel (from Appendix C)
7.4 min = t_c along the channel segment A
1.6 min = t_c along the channel segment B
17.2 min

TETRA TECH

Project HPS, Parcel B, Site IR-07 and IR-18		Component/System Drainage Swale Calculations and Design	
Prepared by: JBL	Date 4-24-09	Checked by: SWF	Date 4-28-09

From the precipitation duration-frequency-depth curves the rainfall intensity for a 100-year return interval is corresponding to the 17.2 minute total time of concentration for the water course is:

0.65 inches/17.2 minutes
or an intensity of: **2.3 in/hr**

The peak flow rate along segment B or channel effluent is calculated using the Rational Equation

$Q = CiA$

Where:
Q = flow (cubic feet per second, cfs)
C = runoff coefficient (0.55 see following table)
i = rainfall intensity (in/hr)
A = watershed area (5 acres)

Assumptions:
4. Average slope of the watershed is steep greater than 1%
5. The condition of the vegetation over the entire watershed associated with the location is considered relatively poor with grass covering less than 55% of the channel (assumption used for conservation and yields a higher flow – the channel vegetation would be maintained according to the O&M Plan)
6. Calculation is based on a 100-year return interval storm

$Q = (0.55)(2.3\ in/hr)(5\ acres)$

$Q = \mathbf{6.3\ cfs}$

TETRA TECH

Project HPS, Parcel B, Site IR-07 and IR-18		Component/System Drainage Swale Calculations and Design	
Prepared by: JBL	Date 4-24-09	Checked by: SWF	Date 4-28-09

Based on these results and the corresponding peak flows associated with the 100-year return interval storm the following swale geometry will be used in the design. The upgradient slopes vary over the length of the channel which has been accounted for in the design.

Swale height of: **1 ft**
Swale slope of: **33% or 1V:3H**

Peak depth of: **.74 ft**

The 100 year return interval storm will result in a peak water depth of 0.74 ft along the drainage swale in both channel segment A and B and thus an overall swale height of 1 ft gives significant freeboard given the shallow water depth. The upgradient slopes leading to the swale vary over the channel which has been accounted for in the design calculations.

It should be noted that this method of calculation where flow rates are calculated along the channel was used given the length of travel time along the swale portion of the water course relative to drainage size. If the travel time along the channel is assumed to be negligible a peak flow of 8.8 cfs would be calculated. The given channel geometry would be able to covey this flow with a peak depth of approximately 0.8 ft along the channel for the 100-year storm event.

TETRA TECH

Project		Component/System	
HPS, Parcel B, Site IR-07 and IR-18		Drainage Swale Calculations and Design	
Prepared by: JBL	Date 4-24-09	Checked by: SWF	Date 4-28-09

The channel will be grass lined underlain with a composite turf reinforced mat. The assessment of the channel material is based on the susceptibility of the channel to the shearing imposed by the water flowing through the channel as calculated above.

Shear stress increases with slope and velocity. Channel B has a slope of 1.8% and the calculated velocity is 2.57 ft/sec which is greater than the associated values of channel A. The depth of 0.74 ft associated with channel A is used to yield the greatest shear force.

The equation used for calculating the shear stress is:

$$\tau = wys$$

Where:

τ = unit tractive force in lbs/ft^2

w = unit weight of water (62.4 lbs/ft^3

y = water depth (0.74 ft)

s = average slope (0.018 ft/ft)

$$\tau = (62.4)(0.71)(0.018)$$

Using the above relationship yields a shear stress of **0.83 lbs/ft^2** when using the maximum depth and slope along the drainage channel.

Appropriate shear stress for a grass lined reinforced channel is 3.2 lbs/ft^2 for short duration unvegetated channels and 8 lbs/ft^2 for established vegetation for short and long duration flows (North American Green). Therefore the channel and vegetative stability is ensured based on the described geometry and a reinforced lining.

TETRA TECH

Project		Component/System	
HPS, Parcel B, Site IR-07 and IR-18		Drainage Swale Calculations and Design	
Prepared by: JBL	Date 4-24-09	Checked by: SWF	Date 4-28-09

References:

Chow, V., Maidment, D., and Mays, L. 1988. "Applied Hydrology." McGraw-Hill Publishing

Contra Costa County, Department of Public Works. Flood Control and Water Conservation District. Precipitation Duration-Frequency-Depth Curves.

North American Green. http://www.nagreen.com/ Manufacturer

US National Oceanographic and Atmospheric Administration (NOAA). 1995. "Climate of San Francisco." January.

US Department of Agriculture, Natural Resource Conservation Service (NRCS), 1986. "Urban Hydrology for Small Watersheds – Technical Release 55." June.

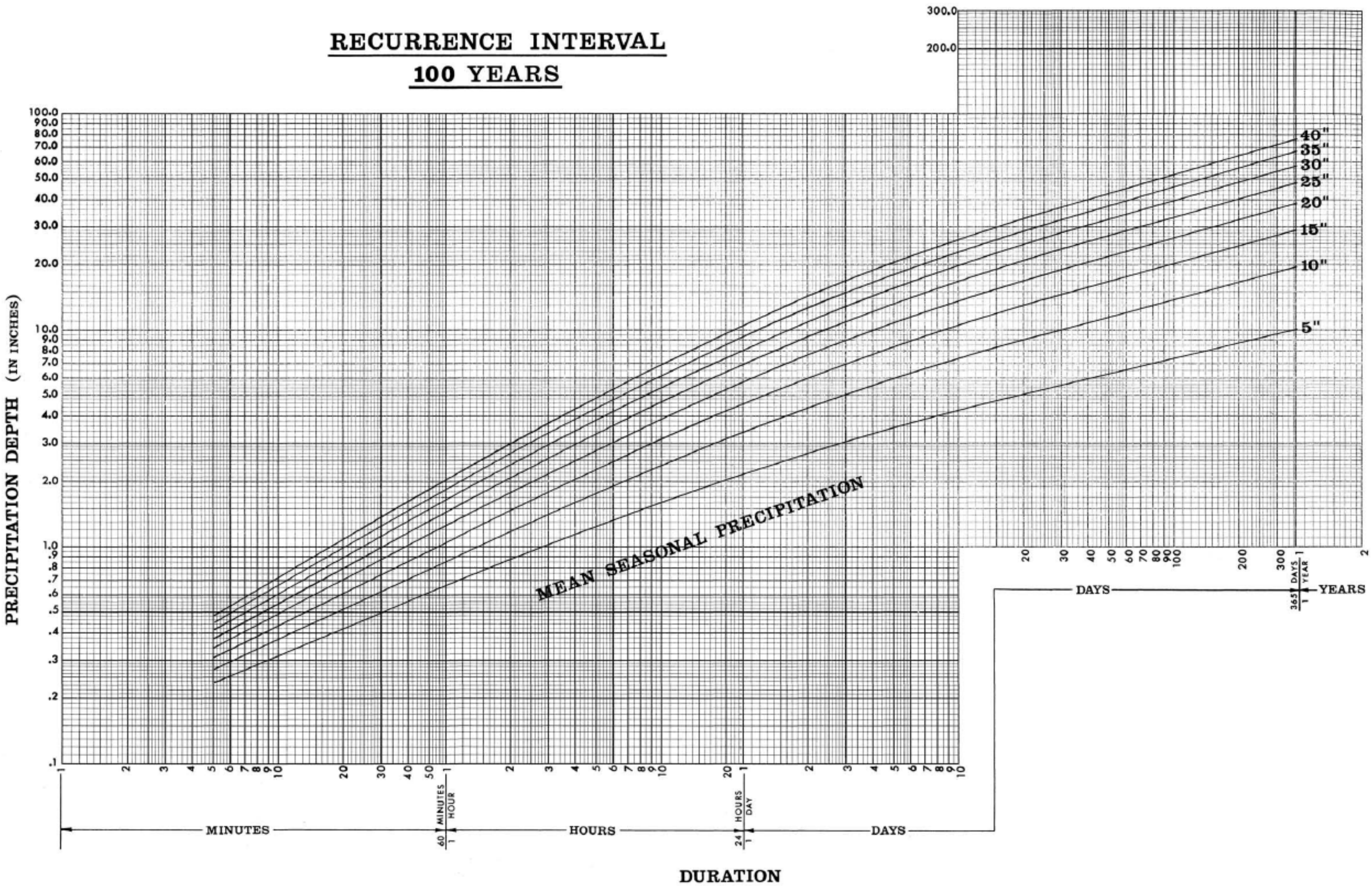
TETRA TECH

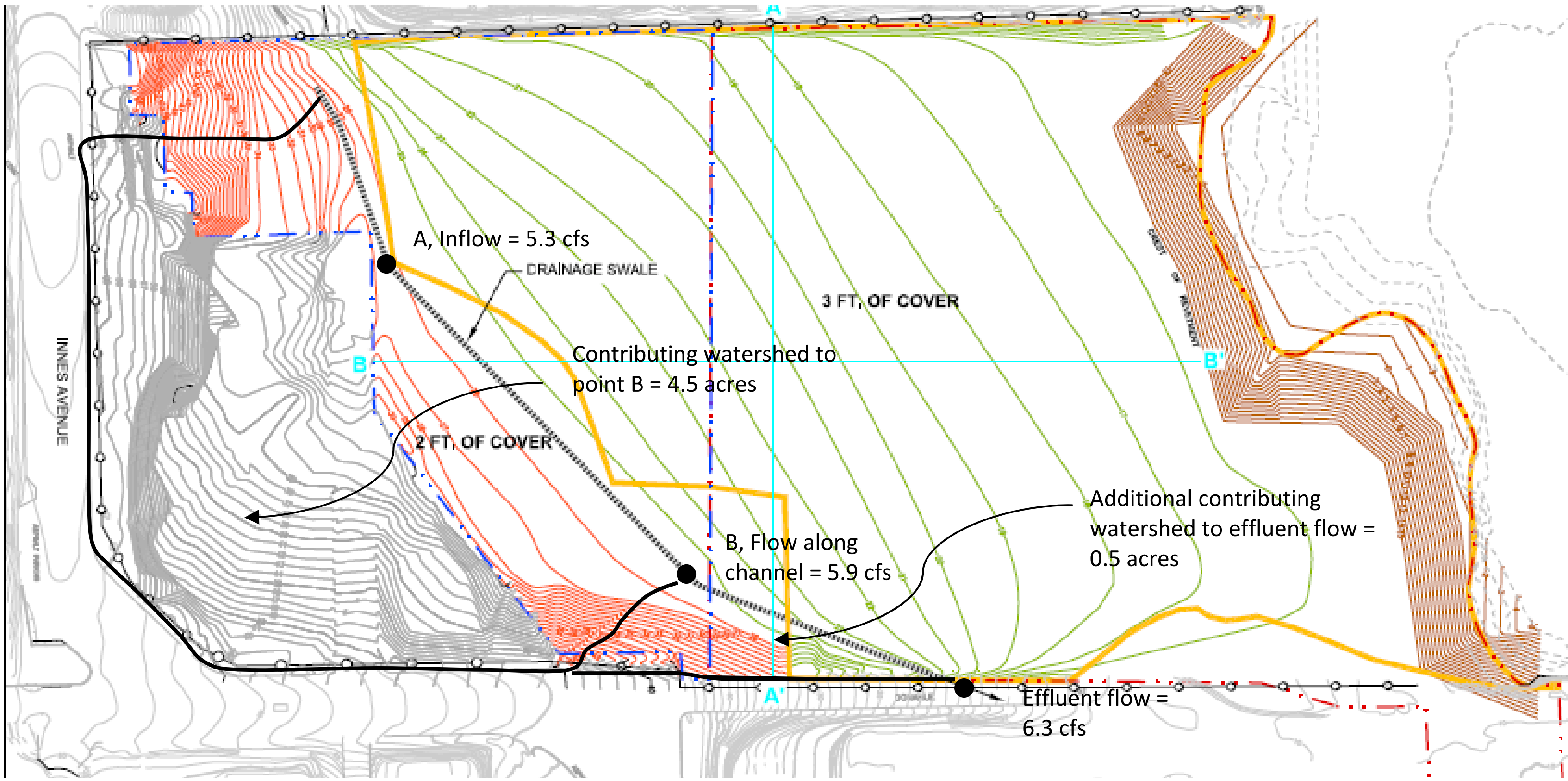
Project		Component/System	
HPS, Parcel B, Site IR-07 and IR-18		Drainage Swale Calculations and Design	
Prepared by: JBL	Date 4-24-09	Checked by: SWF	Date 4-28-09

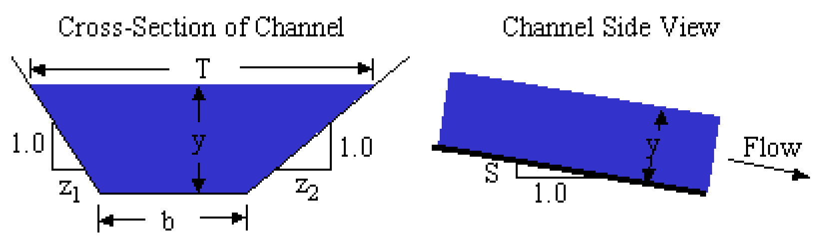
TABLE 2-2
RATIONAL METHOD RUNOFF COEFFICIENTS FOR COMPOSITE ANALYSIS
Runoff Coefficient (C)

Character of Surface	Return Period						
	2 Years	5 Years	10 Years	25 Years	50 Years	100 Years	500 Years
DEVELOPED							
Asphaltic	0.73	0.77	0.81	0.86	0.90	0.95	1.00
Concrete	0.75	0.80	0.83	0.88	0.92	0.97	1.00
Grass Areas (Lawns, Parks, etc.)							
Poor Condition*							
Flat, 0-2%	0.32	0.34	0.37	0.40	0.44	0.47	0.58
Average, 2-7%	0.37	0.40	0.43	0.46	0.49	0.53	0.61
Steep, over 7%	0.40	0.43	0.45	0.49	0.52	0.55	0.62
Fair Condition**							
Flat, 0-2%	0.25	0.28	0.30	0.34	0.37	0.41	0.53
Average, 2-7%	0.33	0.36	0.38	0.42	0.45	0.49	0.58
Steep, over 7%	0.37	0.40	0.42	0.46	0.49	0.53	0.60
Good Condition***							
Flat, 0-2%	0.21	0.23	0.25	0.29	0.32	0.36	0.49
Average, 2-7%	0.29	0.32	0.35	0.39	0.42	0.46	0.56
Steep, over 7%	0.34	0.37	0.40	0.44	0.47	0.51	0.58

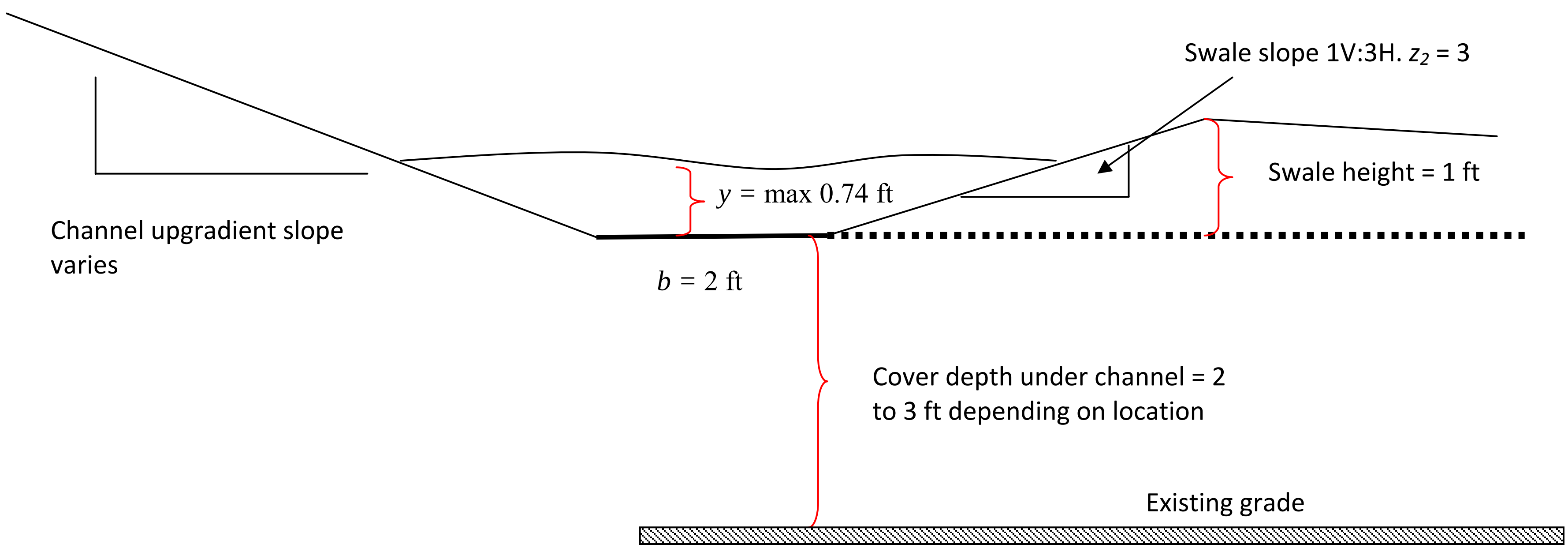
Precipitation Duration Frequency Depth Curves




A, Inflow = 5.3 cfs
DRAINAGE SWALE
3 FT. OF COVER
Contributing watershed to
point B = 4.5 acres
INNES AVENUE
2 FT. OF COVER
Additional contributing
watershed to effluent flow =
0.5 acres
B, Flow along
channel = 5.9 cfs
Effluent flow =
6.3 cfs
A
A'
B
B'



Typical swale channel cross section



APPENDIX E
TIDAL DATUMS

TETRA TECH

Project	Component/System
HPS, Parcel B, Site IR-07 and IR-18	Tidal Datums

Prepared by:	Date	Checked by:	Date
JBL	4-24-09	SWF	4-28-09

There are three primary tidal datums that are used for the site based on NOAA National Ocean Service data sheets from which both the land based topographic and ocean based bathymetric surveys were completed. Surveys completed for the Hunters Point Site 7 and 18 are based on the tidal elevation benchmark: HUNTER WEST 1 1941; PID# HT0613; Station ID 9414358 (lat: 37° 43.8’ N and long: 122° 21.4’ W). These elevations are based on the tidal epoch 1960 to 1978. The actual tidal data sheets are provided.

The tidal elevation data is summarized below with references to the Mean Lower Low Water (MLLW), National Geodetic Vertical Datum (NGVD), 1929, and the actual mean sea level at the site.

Tidal Datum	**Reference Datum**		
	MLLW	**NGVD**	**MSL**
Extreme	+9.7[1]	+6.58	+6.14
MHHW	+6.73	+3.61	+3.17
MHW	+6.10	+2.98	+2.54
MSL	+3.56	+0.44	0
NGVD	+3.12	0	-0.44
MLW	+1.12	-2.06	-2.44
MLLW	0	-3.12	-3.56

[1] From “Candlestick Point/Hunters Point development Project – Initial Shoreline Assessment”.

The highest observed tide for the site as recorded at the above referenced station was 8.16 ft MLLW recorded on in December 1974. The extreme water level was obtained from long term monitoring in the bay area and corresponding projects and reflects a 100-year return interval (Moffatt & Nichol, 2009).

The Mean Sea Level (MSL) is specific for the site and was established during the survey of the property based on correspondence with NOAA.

TETRA TECH

Project		Component/System	
HPS, Parcel B, Site IR-07 and IR-18		Tidal Datums	
Prepared by: JBL	Date 4-24-09	Checked by: SWF	Date 4-28-09

Conversion factors between references:

MLLW to NGVD:	-3.12 ft (interpretation: MLLW reported as -3.12 NGVD)
NGVD to MLLW:	+3.12 ft
MLLW to MSL:	-3.56 ft (interpretation: MLLW reported as -3.56 MSL)
MSL to MLLW:	+3.56 ft
NGVD to MSL:	-0.44 ft
MSL to NGVD:	+0.44 ft

Note: A second tidal datum summary is available from NOAA for tidal epoch 1983 to 2001, however, the data is incomplete. Tidal ranges and heights are about equal to the ranges available for the 1960 to 1978 epoch but there is no reference to either NGVD or NAVD.

References:

U.S. Department of Commerce, National Oceanic and Atmospheric Administration (NOAA), National Ocean Service. Tidal Datums for Station ID 9414358. Published 06/24/1983. **(Attached)**

Correspondence with Juan Lovato of Espinosa Surveying, 11/12/2008. Responsible party for the IR Site 7 and 18 topographic survey.

Moffatt & Nichol. 2009. “Candlestick Point/Hunters Point Development Project.”

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Ocean Service

PUBLICATION DATE: 06/24/1983

Station ID: 9414358
Name: HUNTERS POINT, SAN FRANCISCO BAY CALIFORNIA
NOAA Chart: 18649 **Latitude: 37° 43.8' N**
USGS Quad: HUNTERSPOINT **Longitude: 122° 21.4' W**

To reach the tidal bench marks from I-280 and U.S. Highway 101 interchange proceed 1.4 miles (2.2 km) south to Bayshore Blvd., Third Street exit, left onto Third Street, north 1.8 miles (2.9 km) to Evans Street, right turn on Evans Street, 0.7 mile (1.1 km) SE on Evans Street, one block south on Evans Street to Fairfax Street, right on Hunters Point Boulevard, 0.2 mile (0.3 km) after left turn on Innes Avenue and then 0.4 mile (0.6 km) to entrance to guard house with dry dock area at bottom of hill. The tide gage was located 50 feet (15.2 m) NW of NW corner of drydock No. 2 and the staff was located on an adjacent pier.

BENCH MARK STAMPING: HUNTER WEST 1 1941

MONUMENTATION: Survey Disk VM#: 8102
AGENCY: PID#: HT0613
SETTING CLASSIFICATION: Concrete Post

The bench mark is set in a concrete post at the head of drydock, No. 2, covered with a steel handhole and cover plate, 108 feet (32.9 m) south by east of center of capstan at head of drydock, 95 feet (29 m) west by north of fireplug on south side and near west end of drydock, 6 feet (1.8 m) west of inner rail of 50 ton crane, and 0.7 foot (0.2 m) below the pavement.

NOAA Chart: 18649 **Latitude: 37° 43.8' N**
USGS Quad: HUNTERSPOINT **Longitude: 122° 21.4' W**

T I D A L   D A T U M S

Tidal datums at HUNTERS POINT, SAN FRANCISCO BAY based on:

LENGTH OF SERIES:	13 MONTHS
TIME PERIOD:	NOV 1974-FEB 1976
TIDAL EPOCH:	1960-1978
CONTROL TIDE STATION:	9414760 ALAMEDA, CA

Elevations of tidal datums referred to Mean Lower Low Water (MLLW), in FEET:

HIGHEST OBSERVED WATER LEVEL (12/27/1974)	=	8.16
MEAN HIGHER HIGH WATER (MHHW)	=	6.73
MEAN HIGH WATER (MHW)	=	6.10
MEAN TIDE LEVEL (MTL)	=	3.61
* NATIONAL GEODETIC VERTICAL DATUM-1929 (NGVD)	=	3.12
MEAN LOW WATER (MLW)	=	1.12
MEAN LOWER LOW WATER (MLLW)	=	0.00
LOWEST OBSERVED WATER LEVEL (12/01/1975)	=	-1.86

* NGVD reference based on adjustment of 1958 and NOS levels of1974-1976.
National Geodetic Vertical Datum (NGVD 29)

Bench Mark Elevation Information — In FEET above:

Stamping or Designation	MLLW	MHW
HUNTERS POINT BM 2 1917	11.88	5.78
HUNTERS POINT BM 3 1917	12.14	6.04
4 1941	15.33	9.23
5 1941	15.38	9.28
HUNTER WEST 1 1941	11.32	5.22
HUNTER EAST 1941	10.65	4.55

APPENDIX F
WIND PARAMETERS

TETRA TECH

Project HPS, Parcel B, Site IR-07 and IR-18		Component/System Wind Parameters	
Prepared by: JBL	Date 4-24-09	Checked by: SWF	Date 4-28-09

Wave height is largely dependent on the velocity of wind over the water, the duration of the sustained wind, and the wind fetch (the uninterrupted over-water distance where wind can affect the water surface). Data on wind can be summarized by a wind rose, which is a radial plot of sustained wind speed by cardinal direction.

Peak wind speeds often are stated in terms of "fastest-mile," which is the speed of a parcel of wind 1-mile long as it passes a gauge 10 meters above the ground. The sustained duration of the wind generally is 1 to 2 minutes. The figure below shows a fastest-mile wind rose for the former Naval Air Station (NAS) Alameda. Fastest-mile speeds for several cardinal points were also compiled for the San Francisco International Airport (SFO), which is near HPS and has very similar wind exposures. Using the SFO data and the geometry of the wind rose for NAS Alameda, a fastest-mile wind rose was predicted for HPS.

Analysis of fetch distances for HPS indicated that sustained winds of approximately 1-hour duration would be appropriate for wave analysis at the site. Therefore, fastest-mile wind speeds were used to predict "fastest-hour" wind speeds, the fastest average wind speed for a wind event that lasts one hour. The provided figure shows the predicted fastest-hour wind rose for the general area of HPS. The greatest wind speed potentially affecting wave size at the site (fastest hour) is anticipated to be from the northeast at about 40 miles per hour (mph).

Assumptions

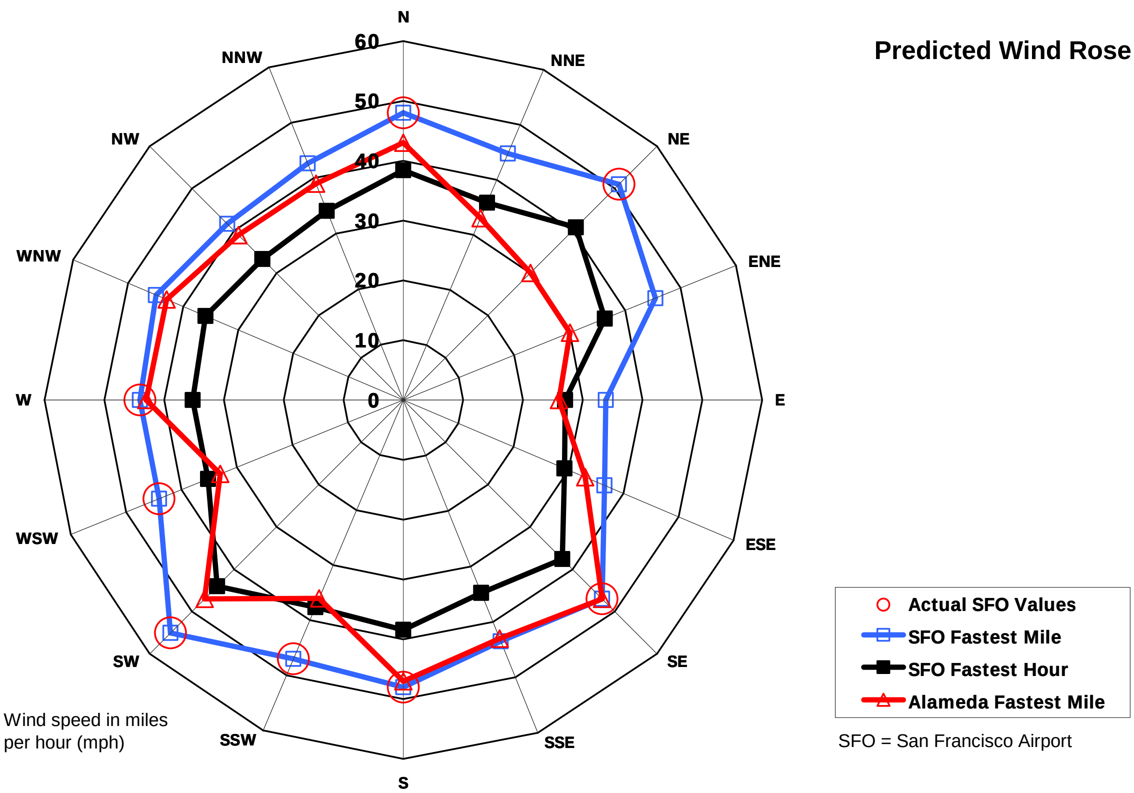
1. Wind speeds were obtained from land based meteorological stations at the SFO which is located approximately 8 miles south of Hunters Point. The airport receives unobstructed winds from the north and northeast which is similar to the wind exposure and wave generating winds applicable to Sites 7 and 18. Based on the similarities between the two locations no corrections of the wind speeds were necessary.

TETRA TECH

Project	Component/System
HPS, Parcel B, Site IR-07 and IR-18	Wind Parameters

Prepared by:	Date	Checked by:	Date
JBL	4-24-09	SWF	4-28-09

2. Winds at the SFO are overwater and unobstructed to the north and northeast direction, which is the same as Sites 7 and 18. Therefore, no corrections were made to account for differences in the velocity measured overland versus over-water.
3. Fastest hour winds assumed to be 80% of fastest-mile based on guidance from JCSS (2001).



TETRA TECH

Project HPS, Parcel B, Site IR-07 and IR-18		Component/System Wind Parameters	
Prepared by: JBL	Date 4-24-09	Checked by: SWF	Date 4-28-09

Direction	Actual Fastest-mile Data, SFO			Actual Fastest-mile Alameda NAS		Predicted SFO Wind Rose		
	NOAA SRCC Data	Golden Gate Weather Service	Max	Wind Rose	Ratio to avg of adjacent directions	Fastest-mile	Fastest Hour	Ratio to avg of adjacent directions
	"Fastest-mile", mph			mph	%	mph	mph	%
N	48	38	48	43	119%	48.0	38.4	110%
NNE				33	90%	44.8	35.8	90%
NE		51	51	30	95%	51.0	40.8	113%
ENE				30	107%	45.4	36.4	107%
E				26	83%	33.8	27.1	83%
ESE				33	90%	36.5	29.2	90%
SE		47	47	47	124%	47.0	37.6	118%
SSE				43	91%	43.5	34.8	91%
S	47	48	48	47	119%	48.0	38.4	106%
SSW	47		47	36	77%	47.0	37.6	91%
SW	55		55	47	136%	55.0	44.0	121%
WSW	44		44	33	73%	44.0	35.2	89%
W	44	40	44	43	113%	44.0	35.2	99%
WNW				43	105%	44.9	35.9	105%
NW				39	95%	41.6	33.3	95%
NNW				39	95%	42.6	34.1	95%

Note: Grey area indicates directions from which the wind is obstructed by land and does not generate waves that will affect the site

Wind data obtained from National Oceanographic and Atmospheric Administration (NOAA) Southern Region Climate Center (http://www.srcc.lsu.edu/index.php) and Golden Gate Weather Service (http://ggweather.com/) and corresponds with other completed studies (Moffatt and Nichol. 2009).

TETRA TECH

Project HPS, Parcel B, Site IR-07 and IR-18		Component/System Wind Parameters	
Prepared by: JBL	Date 4-24-09	Checked by: SWF	Date 4-28-09

References:

Joint Committee on Structural Safe (JCSS). 2001. “JCSS Probabilistic Model Code”.

Linsley, Ray K., and Franzini, Joseph B. 1979. “Water-Resources Engineering”. McGraw-Hill Book Company.

Moffatt and Nichol. 2009. “Candlestick Point / Hunters Point Development Project, Initial Shoreline Assessment.” February.

U.S. Army Corps of Engineers. 1995. “Design of Coastal Revetments, Seawalls, and Bulkheads”.

U.S. Army Corps of Engineers. 2006. “Coastal Engineering Manual”.

APPENDIX G
AVAILABLE FETCH DISTANCES

TETRA TECH

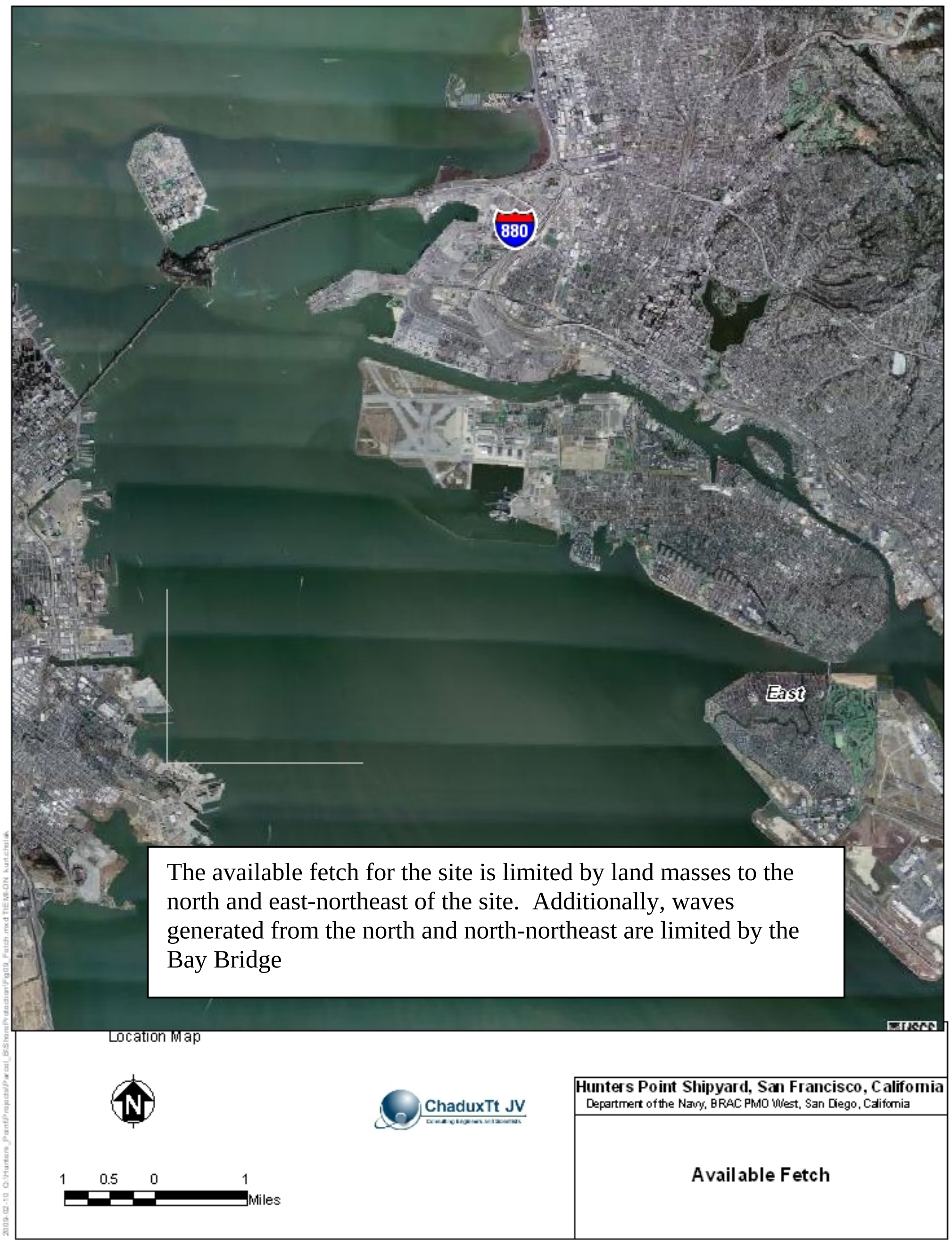
Project		Component/System	
HPS, Parcel B, Site IR-07 and IR-18		Available Fetch Distances	
Prepared by: JBL	Date 4-24-09	Checked by: SWF	Date 4-28-09

Fetch distance is the length of exposed surface water available to a coastal location over which an unobstructed wind can blow. Fetch distances are used in the calculation of waves that could affect a coastal location. The longest fetch distance for HPS Sites 7 and 18 is approximately 6.2 miles to the north-northeast of the site. The following table summarizes the fetch distances available at the HPS Sites 7 and 18.

Summary of Available Fetch Distances

Direction	Degrees from North	Fetch Distance from Site (miles)
N	0°	5.2
N	6°	5.7
NNE	12°	6.2
NNE	18°	5.4
NNE	24°	5.1
NNE	30°	4.1
NE	36°	4.3
NE	42°	4.4
NE	48°	4.7
NE	54°	4.9
ENE	60°	5.2
ENE	66°	5.9

Fetch distances producing waves are available to the site in cardinal directions from north to the east-northeast and are limited (effectively blocked) by land masses in the other cardinal directions. Additionally, the fetch is obstructed to the north by the Bay Bridge.


880
East
The available fetch for the site is limited by land masses to the north and east-northeast of the site. Additionally, waves generated from the north and north-northeast are limited by the Bay Bridge
Location Map
N
1 0.5 0 1
Miles
ChaduxTt JV
Hunters Point Shipyard, San Francisco, California
Department of the Navy, BRAC PMO West, San Diego, California
Available Fetch

APPENDIX H
SIGNIFICANT WAVE HEIGHT

TETRA TECH

Project		Component/System	
HPS, Parcel B, Site IR-07 and IR-18		Significant Wave Height	
Prepared by: JBL	Date 4-24-09	Checked by: SWF	Date 4-28-09

Wave height and wave period is governed primarily by the wind speed and fetch for a given cardinal direction. The calculation for open water waves and wave period is estimated based on the following relationships (Army Corps of Engineers, 2006):

$$\frac{gH_{m_0}}{u_*^2} = 4.13 \times 10^{-2} * \left(\frac{gX}{u_*^2}\right)^{\frac{1}{2}}$$

and

$$\frac{gT_p}{u_*} = 0.751\left(\frac{gX}{u_*^2}\right)^{\frac{1}{3}}$$

$$C_D = \frac{u_*^2}{U_{10}^2}$$

$$C_D = 0.001(1.1 + 0.035U_{10})$$

Where:

X	= straight line fetch distance over which wind blows (m)
H_{m0}	= energy-based significant wave height (m)
C_D	= drag coefficient
U_{10}	= wind speed at 10 m elevation (m/sec)
U_*	= friction velocity (m/sec)
g	= gravitational acceleration (m/sec/sec)
T_p	= wave period (sec)

TETRA TECH

Project		Component/System	
HPS, Parcel B, Site IR-07 and IR-18		Significant Wave Height	
Prepared by: JBL	Date 4-24-09	Checked by: SWF	Date 4-28-09

Assumptions:

1. Waves generated from winds originating north of the Bay Bridge are obstructed by the bridge and reform south of the bridge (see Fetch Distance Calculation).

Using these relationships, wave periods and wave heights were generated as summarized in the following table.

Estimated Peak Wave Distribution by Direction

Cardinal Direction	Fetch (miles)	Fetch (km)	Fastest Hour Wind (mph)	Fastest Hour Wind (m/sec)	Drag Coefficient (dimensionless)	Friction Velocity (m/sec)	Period (sec)	Wave Height (m)	Wave Height (ft)
N	5.7	9.2	38.4	16.9	0.00169	0.695	3.0	0.88	2.9
NNE	6.2	10.0	35.8	15.8	0.00165	0.64	3.0	0.84	2.8
NE	4.9	7.9	40.8	18.0	0.00173	0.747	2.9	0.87	2.9
ENE	5.9	9.5	36.4	16.0	0.00166	0.653	3.0	0.84	2.8

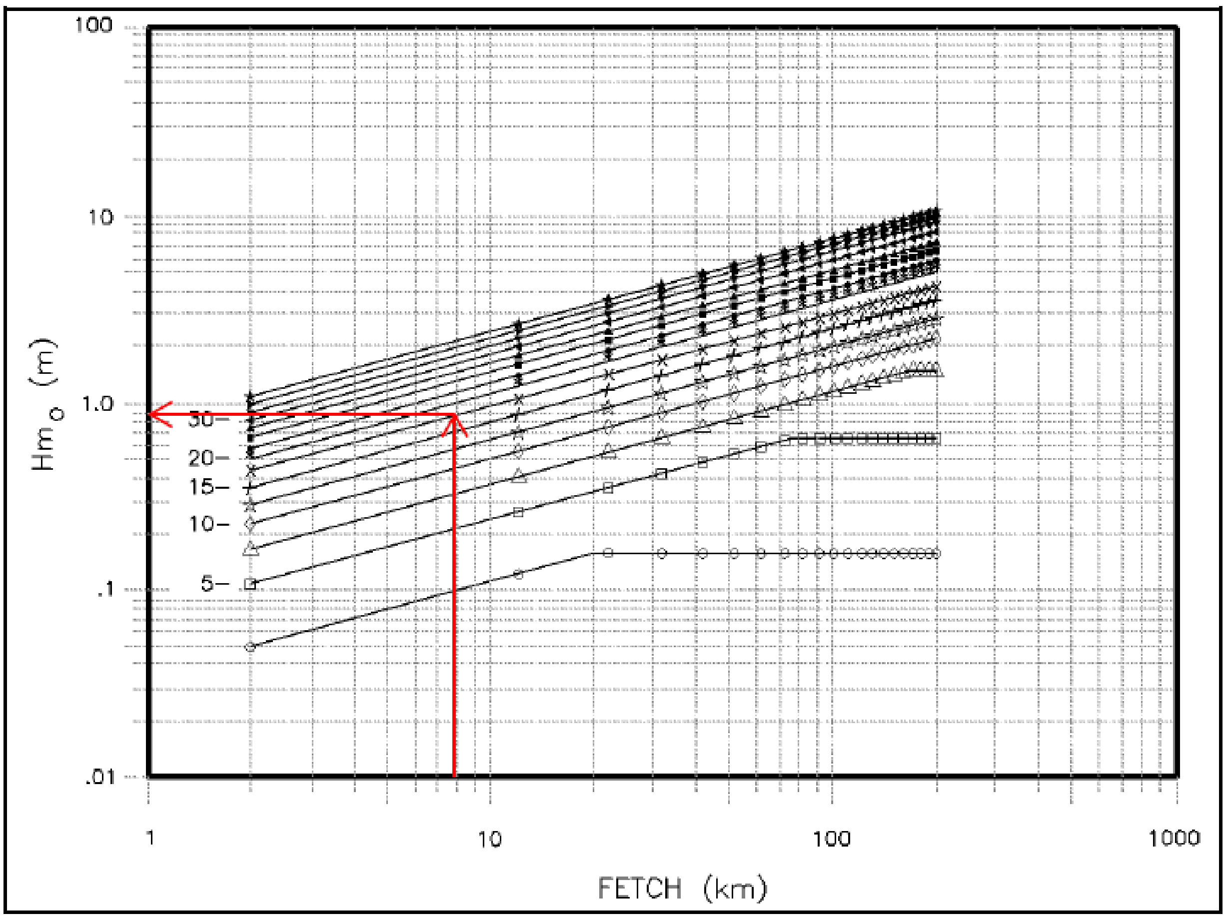
The table shows the highest wave anticipated for the site is 2.9 ft with a wave period of 2.9, originating from northeast of the site. **For simplicity in calculations, a height of 3.0 ft will be used as the significant wave height**.

It should be noted that these equations yield an anticipated open water wave height which can be used as a conservative estimate for the significant wave height in revetment designs. Actual waves anticipated to reach the shoreline of the site would be smaller than this height due to off-shore breaking and energy dissipation as waves approach the site.

Project		Component/System	
HPS, Parcel B, Site IR-07 and IR-18		Significant Wave Height	
Prepared by: JBL	Date 4-24-09	Checked by: SWF	Date 4-28-09

The following nomograms can also be used to estimate wave heights under fetch-limited and duration-limited conditions.

Wave Height Estimation Nomogram



(Army Corps of Engineers, 2006)

TETRA TECH

Project		Component/System	
HPS, Parcel B, Site IR-07 and IR-18		Significant Wave Height	
Prepared by: JBL	Date 4-24-09	Checked by: SWF	Date 4-28-09

References:

U.S. Army Corps of Engineers. 2006. "Coastal Engineering Manual".

APPENDIX I
WAVE CRASH DEPTH

TETRA TECH

Project		Component/System	
HPS, Parcel B, Site IR-07 and IR-18		Wave Crash Depth	
Prepared by: JBL	Date 4-24-09	Checked by: SWF	Date 4-28-09

According to the Army Corps of Engineers Coastal Engineering Manual for depth limited situations, a wave will crash when:

$$0.78 = \frac{h}{d}$$

Where:

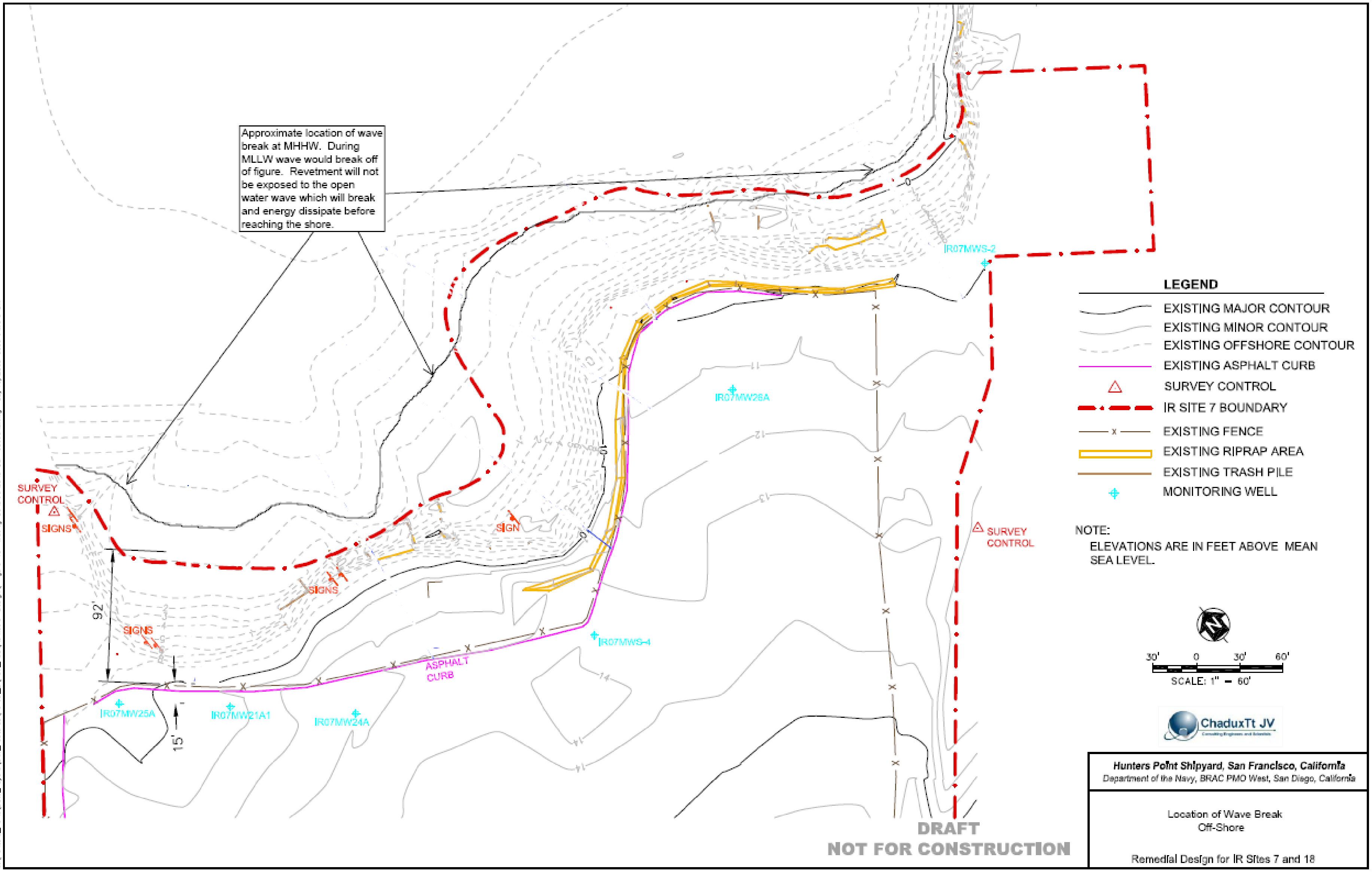
h = wave height
d = water depth

Using this relationship, a 3.0 foot wave will crash when water depth is 3.8 feet. At mean higher high water (MHHW) this will occur as a wave passes over the approximate -1 feet mean sea level (msl) contour which approximates the property boundary, or 20 to 50 ft from the MHHW elevation along the shore as shown in the figure below. At mean lower low water (MLLW), the same wave would crash more than 100 ft from the property line at approximately the -7.0 foot contour line (This line occurs beyond the limit of the figure below).

The revetment will not be exposed to the open water wave. The open water wave will crash off-shore and its energy will dissipate before reaching the shoreline and the revetment. Therefore, use of the open water wave for the design of the revetment for IR-7 and 18 is considered conservative.

References:

U.S. Army Corps of Engineers. 2006. “Coastal Engineering Manual”.



Approximate location of wave break at MHHW. During MLLW wave would break off of figure. Revetment will not be exposed to the open water wave which will break and energy dissipate before reaching the shore.
SURVEY CONTROL
SIGNS
SIGNS
SIGNS
SIGN
92'
15'
IR07MWS-2
IR07MW26A
IR07MWS-4
IR07MW25A
IR07MW21A1
IR07MW24A
ASPHALT CURB
SURVEY CONTROL
LEGEND
EXISTING MAJOR CONTOUR
EXISTING MINOR CONTOUR
EXISTING OFFSHORE CONTOUR
EXISTING ASPHALT CURB
SURVEY CONTROL
IR SITE 7 BOUNDARY
EXISTING FENCE
EXISTING RIPRAP AREA
EXISTING TRASH PILE
MONITORING WELL
NOTE:
ELEVATIONS ARE IN FEET ABOVE MEAN SEA LEVEL.
30' 0 30' 60'
SCALE: 1" = 60'
ChaduxTt JV
DRAFT
NOT FOR CONSTRUCTION
Hunters Point Shipyard, San Francisco, California
Department of the Navy, BRAC PMO West, San Diego, California
Location of Wave Break Off-Shore
Remedial Design for IR Sites 7 and 18

APPENDIX J
REVETMENT EXCAVATION VOLUMES

TETRA TECH

Project HPS, Parcel B, Site IR-07 and IR-18		Component/System Revetment Excavation Volumes	
Prepared by: JBL	Date 4-24-09	Checked by: SWF	Date 4-28-09

The following approach was used for the calculation of the shoreline excavation and fill volumes.

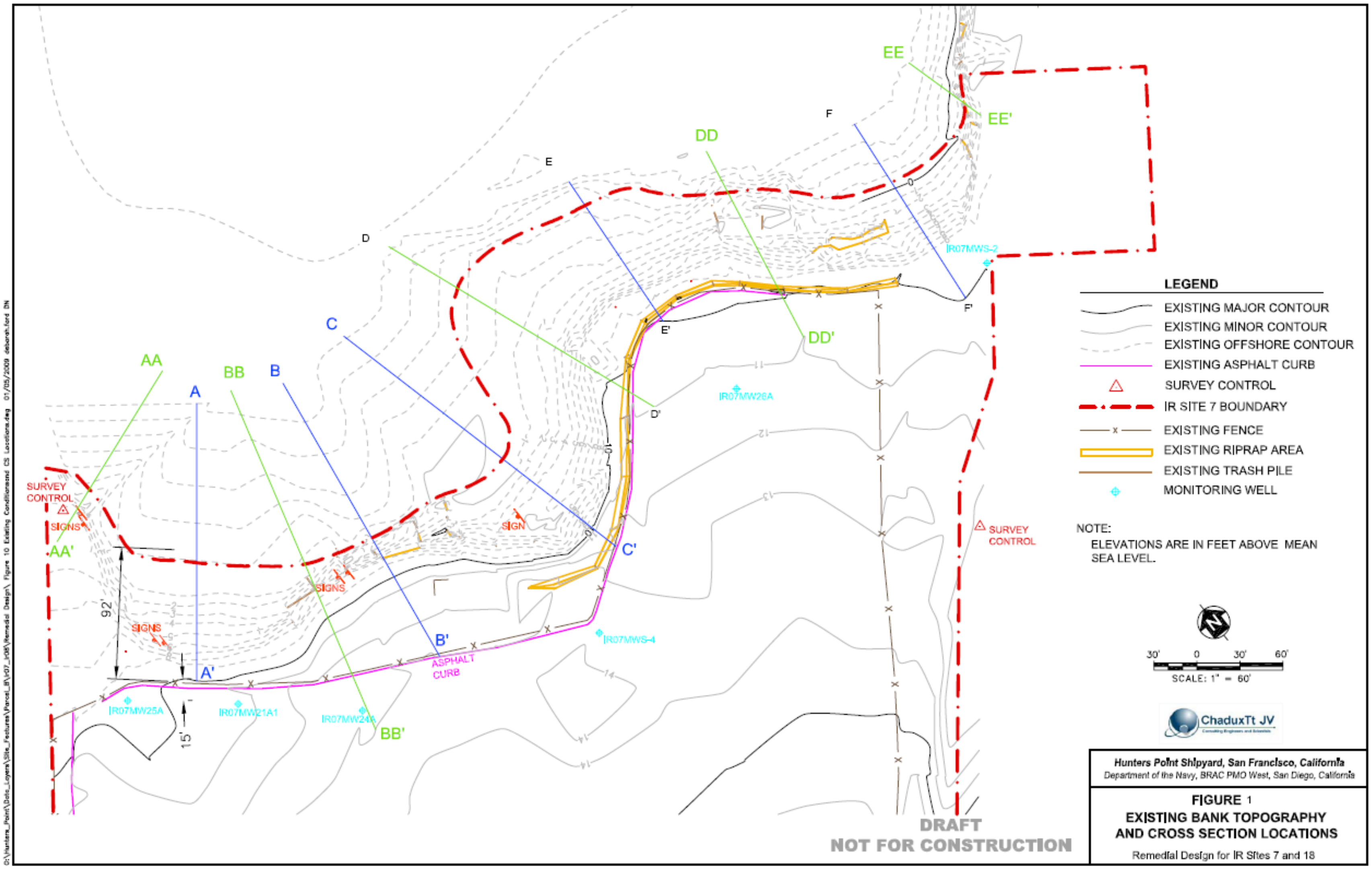
The cross sectional areas of the excavation and fill were calculated in CAD based on the existing shoreline topography and the geometry of the revetment. Those cross sectional areas were then multiplied by the length of shoreline appropriate for that cross section to produce the approximate volumes. Refer to the attached shoreline and cross section figures used in the calculations.

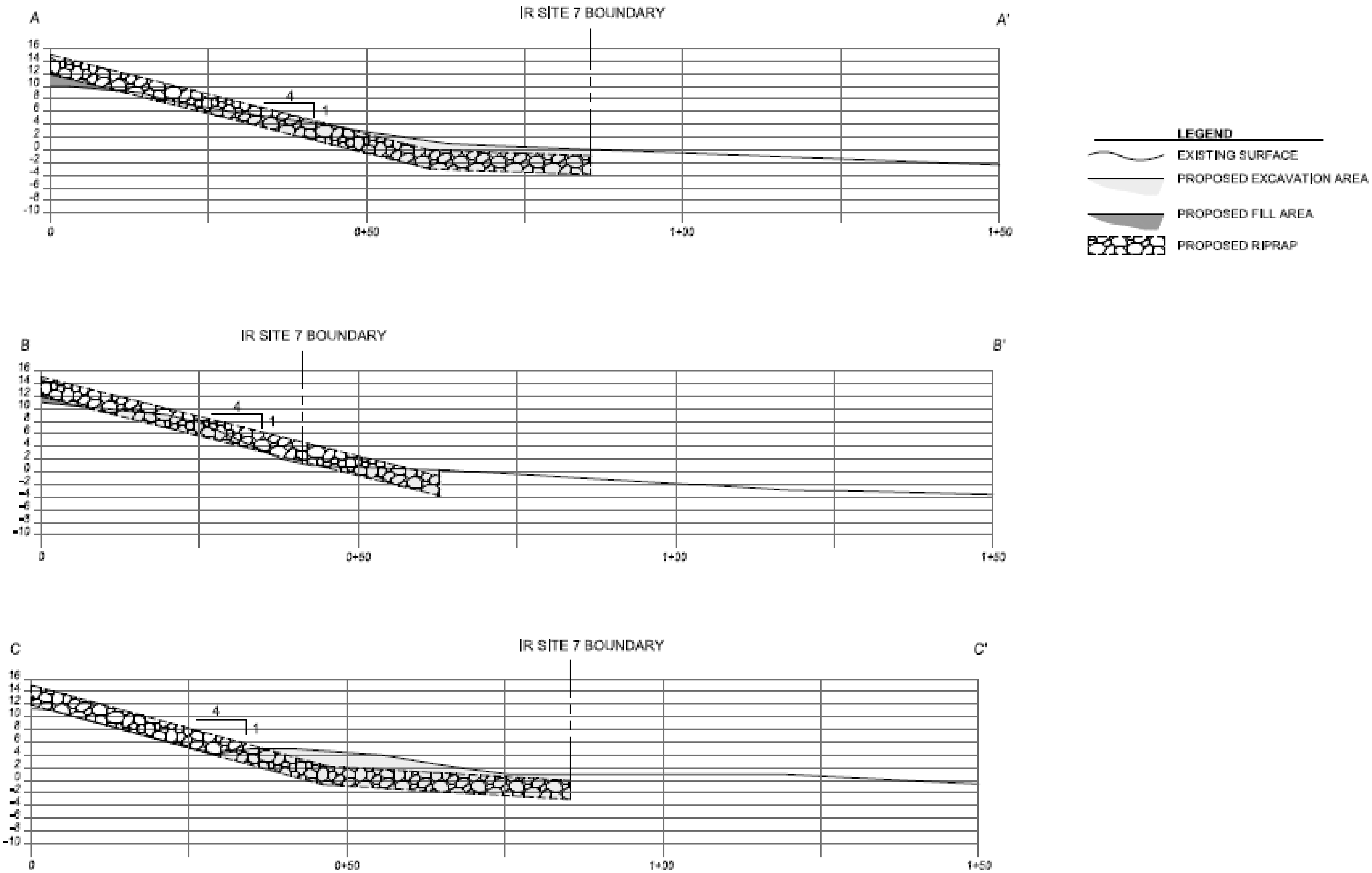
The following table summarizes the results of the calculations. Cross sections provided below.

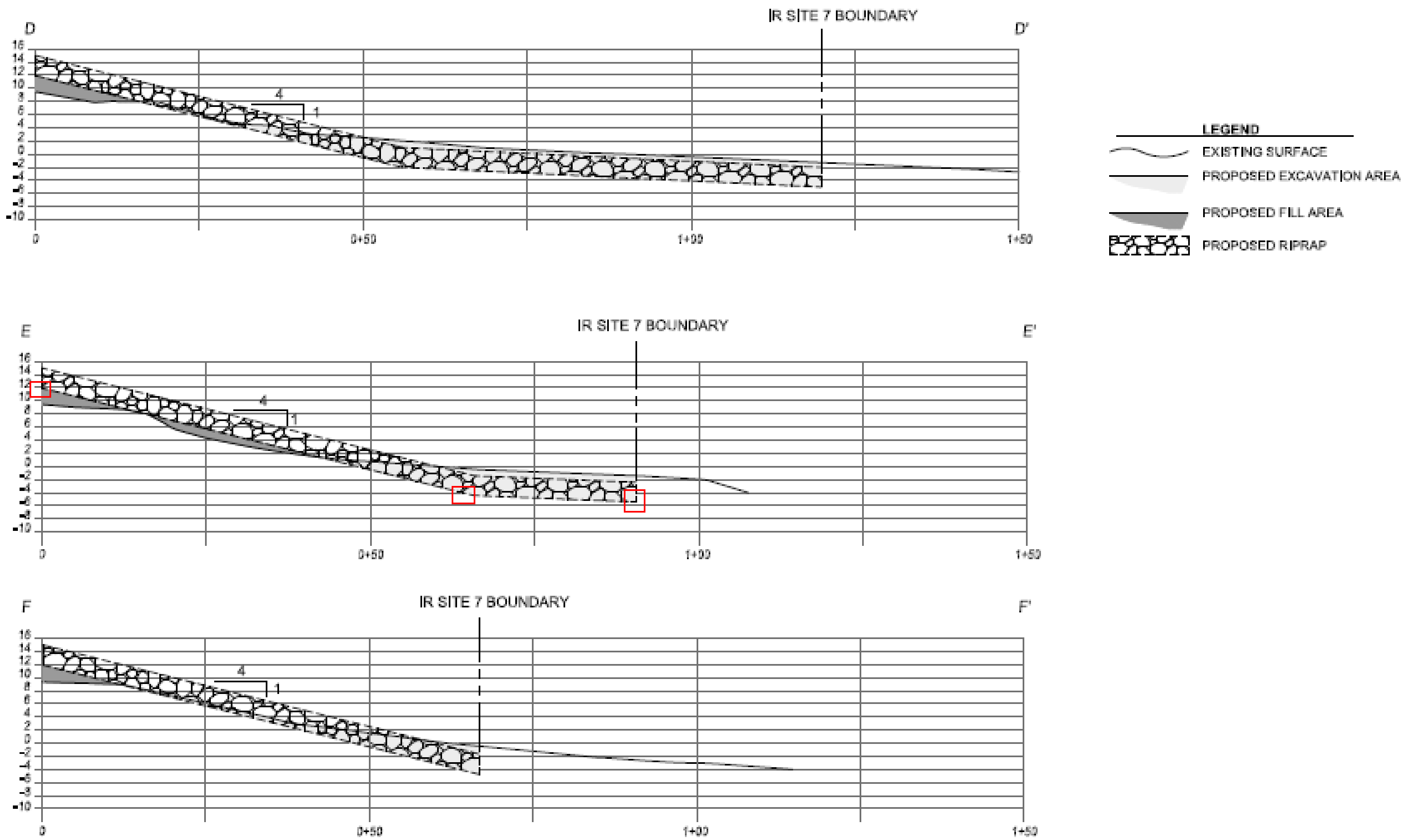
Shoreline Cut and Fill Volumes

	Excavation Cross Sectional Area	Fill Cross Sectional Area	Shoreline Length	Total Excavated Volume	Fill Volume
Cross Section	**ft^2**	**ft^2**	**ft**	**yd^3**	**yd^3**
A	204	9	117	884	39
B	75	5	57	158	11
C	231	11	137	1,172	56
D	292	25	82	887	76
E	145	40	92	494	136
F	75	15	87	242	48
AA	81	84	107	321	333
BB	68	12	57	144	25
DD	123	29	137	624	147
EE	58	36	77	165	103
			950	**5,100**	**970**

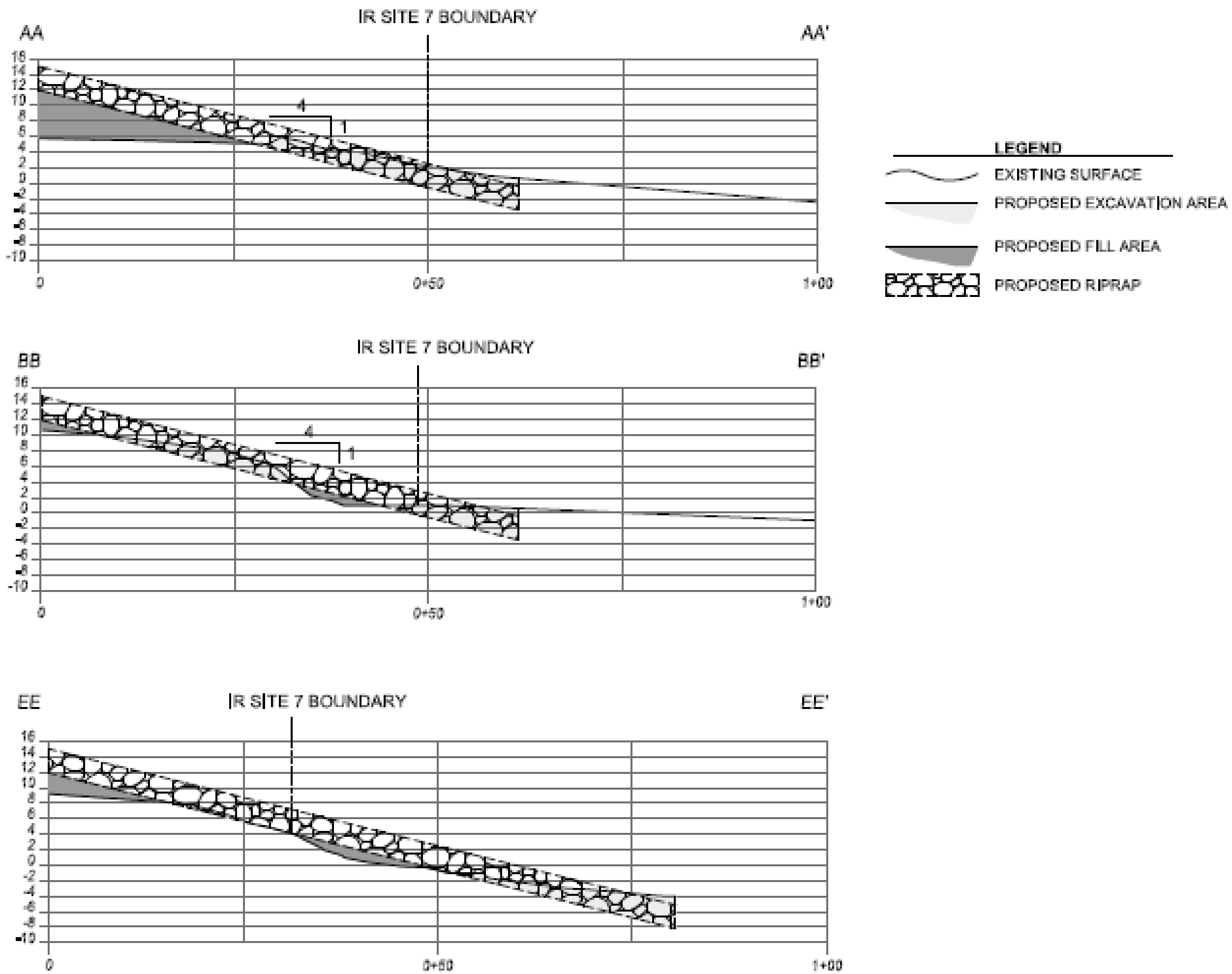
The calculated volumes are in bank cubic yard and do not include bulking factors. A portion of the excavated volume (approximately 1,100 cubic yards) is boulders, concrete, and other debris.


LEGEND
EXISTING MAJOR CONTOUR
EXISTING MINOR CONTOUR
EXISTING OFFSHORE CONTOUR
EXISTING ASPHALT CURB
SURVEY CONTROL
IR SITE 7 BOUNDARY
EXISTING FENCE
EXISTING RIPRAP AREA
EXISTING TRASH PILE
MONITORING WELL
NOTE:
ELEVATIONS ARE IN FEET ABOVE MEAN SEA LEVEL.
SCALE: 1" = 60'
AA
AA'
A
A'
BB
BB'
B
B'
C
C'
D
D'
DD
DD'
E
E'
EE
EE'
F
F'
SURVEY CONTROL
SIGNS
SIGN
92'
15'
ASPHALT CURB
IR07MW25A
IR07MW21A1
IR07MW24A
IR07MWS-4
IR07MW26A
IR07MWS-2
ChaduxTt JV
Hunters Point Shipyard, San Francisco, California
Department of the Navy, BRAC PMO West, San Diego, California
FIGURE 1
EXISTING BANK TOPOGRAPHY AND CROSS SECTION LOCATIONS
Remedial Design for IR Sites 7 and 18
DRAFT
NOT FOR CONSTRUCTION


A
IR SITE 7 BOUNDARY
A'
4
1
B
IR SITE 7 BOUNDARY
B'
4
1
C
IR SITE 7 BOUNDARY
C'
4
1
0
0+50
1+00
1+50
LEGEND
EXISTING SURFACE
PROPOSED EXCAVATION AREA
PROPOSED FILL AREA
PROPOSED RIPRAP



IR SITE 7 BOUNDARY
D
D'
4
1
0
0+50
1+00
1+50
LEGEND
EXISTING SURFACE
PROPOSED EXCAVATION AREA
PROPOSED FILL AREA
PROPOSED RIPRAP
IR SITE 7 BOUNDARY
E
E'
IR SITE 7 BOUNDARY
F
F'


IR SITE 7 BOUNDARY
AA
AA'
16
14
12
10
8
6
4
2
0
-2
-4
-6
-8
-10
4
1
0
0+50
1+00
LEGEND
EXISTING SURFACE
PROPOSED EXCAVATION AREA
PROPOSED FILL AREA
PROPOSED RIPRAP
IR SITE 7 BOUNDARY
BB
BB'
16
14
12
10
8
6
4
2
0
-2
-4
-6
-8
-10
4
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1+00
EE
IR SITE 7 BOUNDARY
EE'
16
14
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-8
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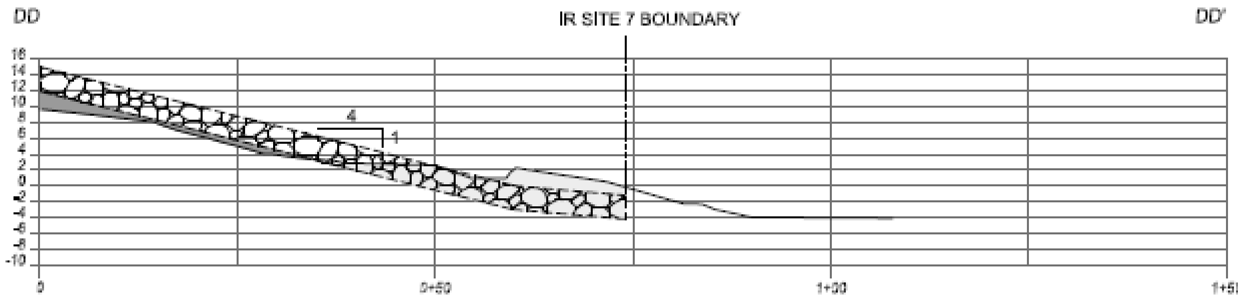
DD
IR SITE 7 BOUNDARY
DD'
16
14
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10
8
6
4
2
0
-2
-4
-6
-8
-10
4
1
0
0+50
1+00
1+50

APPENDIX K
REVETMENT ARMOR UNIT SIZING

TETRA TECH

Project		Component/System	
HPS, Parcel B, Site IR-07 and IR-18		Revetment Armor Unit Sizing	
Prepared by: JBL	Date 4-24-09	Checked by: SWF	Date 4-28-09

Sizing of the revetment armor stone is based on the geometry of the revetment, anticipated wave energy, material used, and the intended use of the area. In situations where there is a high degree of public access a stone size of at least 400 to 500 pounds (lbs) is recommend by the US Army Corps of Engineers, Coastal Engineering Research Center (USACE, 1985). Additionally, experience at other similar project sites has shown that 500 lbs is more appropriate than 400 lbs. This consideration is relevant for HPS Sites 7 and 18 revetment design given the intended future use of the area as a public park. When public access is not a consideration the Hudson formula, below, is used alone. Using these two criteria for armor unit sizing the method that yields the largest and most conservative stone size was used for the design.

The Hudson Formula for the determination of revetment armor sizing using the largest projected anticipated open water wave.

From: USACE Design of Coastal Seawalls, and Bulkheads, Revetments

$$W = \frac{\gamma_r H^3}{K_D \left(\frac{\gamma_r}{\gamma_w} - 1 \right)^3 \cot\theta}$$

Where:

W = required individual armor unit weight, lb (or W_{50} for graded riprap)
γ_r = specific weight of the armor unit, lb/ft^3 = 165 lb/ft^3
H = wave height ft = 3 ft
K_D = stability coefficient = 2.2 for randomly placed riprap at slopes from 2.0 to 6.0. (see table below)
$\cot\theta$ = slope = 1 vertical to 4 horizontal
γ_w = specific weight of saltwater = 64 lbs/ft

TETRA TECH

Project		Component/System	
HPS, Parcel B, Site IR-07 and IR-18		Revetment Armor Unit Sizing	
Prepared by: JBL	Date 4-24-09	Checked by: SWF	Date 4-28-09

Assumptions

1. The slope of the revetment is 1 horizontal to 4 vertical (1V:4H). This is based on the existing shoreline grade and the need for the revetment to extend to at least the site boundary with Parcel F off-shore.
2. A stability coefficient of 2.2 is used for randomly placed riprap at a slope of 1V:4H (refer to included figure).
3. The open water wave of 3 feet has been used. This is a conservative estimate of the wave energy the revetment will be exposed to, given the bathymetry of the near-shore area.
4. The specific weights of the armor unit material and water are generally accepted values and are not site specific.

$$W = \frac{165 * 3^3}{2.2\left(\frac{165}{64} - 1\right)^3 4}$$

$$W = W_{50} = 128.8\,lb$$

A stone of about 130 lbs will have a volume of 0.79 cf and have an approximate nominal diameter of 0.93 feet ($0.79^{0.33}$).

TETRA TECH

Project HPS, Parcel B, Site IR-07 and IR-18		Component/System Revetment Armor Unit Sizing	
Prepared by: JBL	Date 4-24-09	Checked by: SWF	Date 4-28-09

Table 2-3
Suggested Values for Use in Determining Armor Weight (Breaking Wave Conditions)

Armor Unit	n[1]	Placement	Slope (cot θ)	K_D
Quarrystone				
Smooth rounded	2	Random	1.5 to 3.0	1.2
Smooth rounded	>3	Random	1.5 to 3.0	1.6
Rough angular	1	Random	1.5 to 3.0	Do Not Use
Rough angular	2	Random	1.5 to 3.0	2.0
Rough angular	>3	Random	1.5 to 3.0	2.2
Rough angular	2	Special[2]	1.5 to 3.0	7.0 to 20.0
Graded riprap[3]	2[4]	Random	2.0 to 6.0	2.2
Concrete Armor Units				
Tetrapod	2	Random	1.5 to 3.0	7.0
Tripod	2	Random	1.5 to 3.0	9.0
Tripod	1	Uniform	1.5 to 3.0	12.0
Dolos	2	Random	2.0 to 3.0[5]	15.0[6]

[1] n equals the number of equivalent spherical diameters corresponding to the median stone weight that would fit within the layer thickness.
[2] Special placement with long axes of stone placed perpendicular to the slope face. Model tests are described in Markle and Davidson (1979).
[3] Graded riprap is not recommended where wave heights exceed 5 ft.
[4] By definition, graded riprap thickness is two times the diameter of the minimum W_{50} size.
[5] Stability of dolosse on slope steeper than 1 on 2 should be verified by model tests.
[6] No damage design (3 to 5 percent of units move). If no rocking of armor (less than 2 percent) is desired, reduce K_D by approximately 50 percent.

The Hudson formula yields a median stone weight considerably less than the 500-pound stone weight recommend by the USACE. Therefore, a stone weight of 500 lbs was selected as the median stone weight for the design of the revetment.

A riprap revetment with a median stone weight of 500 lbs would yield a design wave of about 4.7 feet when using the same formula and solving for H. This wave height is greater than any of the projected heights for the site and would be significantly greater than both open water waves and the waves anticipated to actually reach the shore. A gradation table has been provided with this calculation to show an appropriate gradation of this size rock based on the California Department of Transportation specifications.

TETRA TECH

Project		Component/System	
HPS, Parcel B, Site IR-07 and IR-18		Revetment Armor Unit Sizing	
Prepared by: JBL	Date 4-24-09	Checked by: SWF	Date 4-28-09

References:

State of California Department of Transportation Engineering Service Center. 2000. California Bank and Shore Rock Slope Protection Design.

U.S. Army Corps of Engineers. 1985. "Coastal Engineering Technical Note – Riprap Revetment Design." CETN-III-1.

U.S. Army Corps of Engineers. 1995. "Design of Coastal Revetments, Seawalls, and Bulkheads".

U.S. Army Corps of Engineers. 2006. "Coastal Engineering Manual".

TETRA TECH

Project		Component/System	
HPS, Parcel B, Site IR-07 and IR-18		Revetment Armor Unit Sizing	
Prepared by: JBL	Date 4-24-09	Checked by: SWF	Date 4-28-09

STANDARD Rock SIZE or Rock MASS or Rock WEIGHT		GRADING OF ROCK SLOPE PROTECTION **PERCENTAGE LARGER THAN**											
		RSP-Classes [A]											
		Method A Placement					Method B Placement						
		RSP-Classes other than Backing									Backing No.		
US unit		8 ton	4 ton	2 ton	1 ton	1/2 ton	1 ton	1/2 ton	1/4 ton	Light	1 [B]	2	3
	SI unit	8 T	4 T	2 T	1 T	1/2 T	1 T	1/2 T	1/4 T	Light	1 [B]	2	3
16 ton	14.5 tonne	0-5											
8 ton	7.25 tonne	50-100	0-5										
4 ton	3.6 tonne	95-100	50-100	0-5									
2 ton	1.8 tonne		95-100	50-100	0-5		0-5						
1 ton	900 kg			95-100	50-100	0-5	50-100	0-5					
1/2 ton	450 kg				95-100	50-100	-----	50-100	0-5				
1/4 ton	220 kg					95-100	95-100	-----	50-100	0-5			
200 lb	90 kg							95-100	-----	50-100	0-5		
75 lb	34 kg								95-100	-----	50-100	0-5	
25 lb	11 kg									95-100	90-100	25-75	0-5
5 lb	2.2 kg											90-100	25-75
1 lb	0.4 kg												90-100

[A] US customary names (units) of RSP-Classes listed above SI names, example US is "2 ton" metric is "2 T".
[B] "Facing" has same gradation as "Backing No. 1". To conserve space "Facing" is not shown .

APPENDIX L
ARMOR LAYER THICKNESS

TETRA TECH

Project		Component/System	
HPS, Parcel B, Site IR-07 and IR-18		Armor Layer Thickness	
Prepared by: JBL	Date 4-24-09	Checked by: SWF	Date 4-28-09

The layer thickness of graded riprap must be at least twice the nominal diameter of the W_{50} stone defined as the cube root of the stone volume. Additionally, it should be at least 25% than the nominal diameter of the W_{100} stone and it should always be greater than 1 ft. The following equation summarizes the relationship.

Ahrens 1975 Formula – from: USACE Design of Coastal Revetments Seawalls, and Bulkheads.

$$r_{\min} = \max\left[2.0\left(\frac{W_{50}}{\gamma_r}\right)^{1/3};1.25\left(\frac{W_{100}}{\gamma_r}\right)^{1/3};1\,ft\right]$$

Where:

W = riprap unit weight, lb (W_{50} or W_{100})

γ_r = specific weight of the armor unit, lb/ft^3 = 165 lb/ft^3

$r_{\min}$ = minimum layer thickness perpendicular to the slope

Assumptions

1. 500 lb W_{50} median rock weight (see calculation for Revetment Armor Unit Sizing)
2. 1,000 lb W_{100} rock weight based on California Department of Transportation specifications (see below)
3. Specific weights of the armor unit materials are generally accepted values and are not site specific.

Project HPS, Parcel B, Site IR-07 and IR-18		Component/System Armor Layer Thickness	
Prepared by: JBL	Date 4-24-09	Checked by: SWF	Date 4-28-09

$$r_{\min} = \max\left[2.0\left(\frac{500}{165}\right)^{1/3}; 1.25\left(\frac{1000}{165}\right)^{1/3}; 1\,\text{ft}\right]$$

$$r_{\min} = \max\left[2.89\text{ ft}; 2.27\text{ ft}; 1\,\text{ft}\right]$$

The minimum layer thickness is obtained by using the W_{50} rock which yields a thickness of 2.89 ft. For simplification, a thickness of 3.0 ft will be used in the design.

Gradation ¼ Ton Rip Rap

STANDARD Rock SIZE or Rock MASS or Rock WEIGHT		GRADING OF ROCK SLOPE PROTECTION PERCENTAGE LARGER THAN											
		RSP-Classes [A]											
		Method A Placement					Method B Placement						
		RSP-Classes other than Backing									Backing No.		
US unit		8 ton	4 ton	2 ton	1 ton	1/2 ton	1 ton	1/2 ton	1/4 ton	Light	1 [B]	2	3
	SI unit	8 T	4 T	2 T	1 T	1/2 T	1 T	1/2 T	1/4 T	Light	1 [B]	2	3
16 ton	14.5 tonne	0-5											
8 ton	7.25 tonne	50-100	0-5										
4 ton	3.6 tonne	95-100	50-100	0-5									
2 ton	1.8 tonne		95-100	50-100	0-5		0-5						
1 ton	900 kg			95-100	50-100	0-5	50-100	0-5					
1/2 ton	450 kg				95-100	50-100	-----	50-100	0-5				
1/4 ton	220 kg					95-100	95-100	-----	50-100	0-5			
200 lb	90 kg							95-100	-----	50-100	0-5		
75 lb	34 kg								95-100	-----	50-100	0-5	
25 lb	11 kg									95-100	90-100	25-75	0-5
5 lb	2.2 kg											90-100	25-75
1 lb	0.4 kg												90-100

[A] US customary names (units) of RSP-Classes listed above SI names, example US is "2 ton" metric is "2 T".
[B] "Facing" has same gradation as "Backing No. 1". To conserve space "Facing" is not shown .

TETRA TECH

Project HPS, Parcel B, Site IR-07 and IR-18		Component/System Armor Layer Thickness	
Prepared by: JBL	Date 4-24-09	Checked by: SWF	Date 4-28-09

References:

Linsley, Ray K., and Franzini, Joseph B. 1979. "Water-Resources Engineering." McGraw-Hill Book Company.

U.S. Army Corps of Engineers. 1995. "Design of Coastal Revetments, Seawalls, and Bulkheads.

State of California Department of Transportation Engineering Service Center. 2000. California Bank and Shore Rock Slope Protection Design.

APPENDIX M
MAXIMUM WAVE RUNUP

TETRA TECH

Project HPS, Parcel B, Site IR-07 and IR-18		Component/System Maximum Wave Runup	
Prepared by: JBL	Date 4-24-09	Checked by: SWF	Date 4-28-09

The wave runup on a structure is derived using the Ahrens and Heimbaugh Formula for maximum run-up from irregular waves.

From: USACE Design of Coastal Revetments, Seawalls, and Bulkheads.

$$\frac{R_{\max}}{H_{mo}} = \frac{a\xi}{1+b\xi}$$

Where:

- R_{max} = maximum vertical height in feet of the runup of wave on riprap
- H_{mo} = wave height in feet at zeroth moment of the wave spectrum
- a, b = regression coefficients determined as 1.022 and 0.247, respectively (constant)
- ξ = surf parameter defined as:

$$\frac{\tan\theta}{\left(\dfrac{2\pi H_{mo}}{gT_p^2}\right)^{1/2}}$$

Where:

- θ = the angle of the revetment slope with the horizontal (see attached figure)
- T_p = wave period in seconds of peak energy density of the wave spectrum

TETRA TECH

Project HPS, Parcel B, Site IR-07 and IR-18		Component/System Maximum Wave Runup	
Prepared by: JBL	Date 4-24-09	Checked by: SWF	Date 4-28-09

And

$$\frac{H_s}{H_{mo}} = \exp\left[C_0\left(\frac{d}{gT_p^2}\right)^{-C_1}\right]$$

Where:

H_s = design wave height
C_0, C_1 = regression coefficients given as 0.00089 and 0.834 respectively
g = gravitational acceleration = 32.2 ft/sec
d = water depth on structure = 10 ft max

Assumptions

1. Design wave H_s height of 3 ft
2. Max water depth at toe of 10 ft. The average depth of the water over the revetment toe at MHHW + 5 ft for conservation or +2 feet over the highest anticipated tide of approximately 6 ft above msl.
3. Revetment slope of 1V:4H
4. Wave period of 3 seconds as previously calculated (see calculation for Significant Wave Height)

TETRA TECH

Project	Component/System
HPS, Parcel B, Site IR-07 and IR-18	Maximum Wave Runup

Prepared by:	Date	Checked by:	Date
JBL	4-24-09	SWF	4-28-09

To calculate H_{mo}

$$\frac{3.0}{H_{mo}} = \exp\left[0.00089\left(\frac{10}{32.2*3.0^2}\right)^{-0.834}\right]$$

$H_{mo} = 2.92$ ft

Calculation of the surf parameter ξ

$$\frac{\tan\theta}{\left(\frac{2\pi H_{mo}}{gT_p^2}\right)^{1/2}} = \frac{\tan(14.03)}{\left(\frac{2\pi 2.92}{32.2*3.0^2}\right)^{1/2}} = 0.99$$

Calculation of maximum runup

$$\frac{R_{\max}}{H_{mo}} = \frac{a\xi}{1+b\xi} \qquad \frac{R_{\max}}{2.92} = \frac{1.022*0.99}{1+0.247*0.99}$$

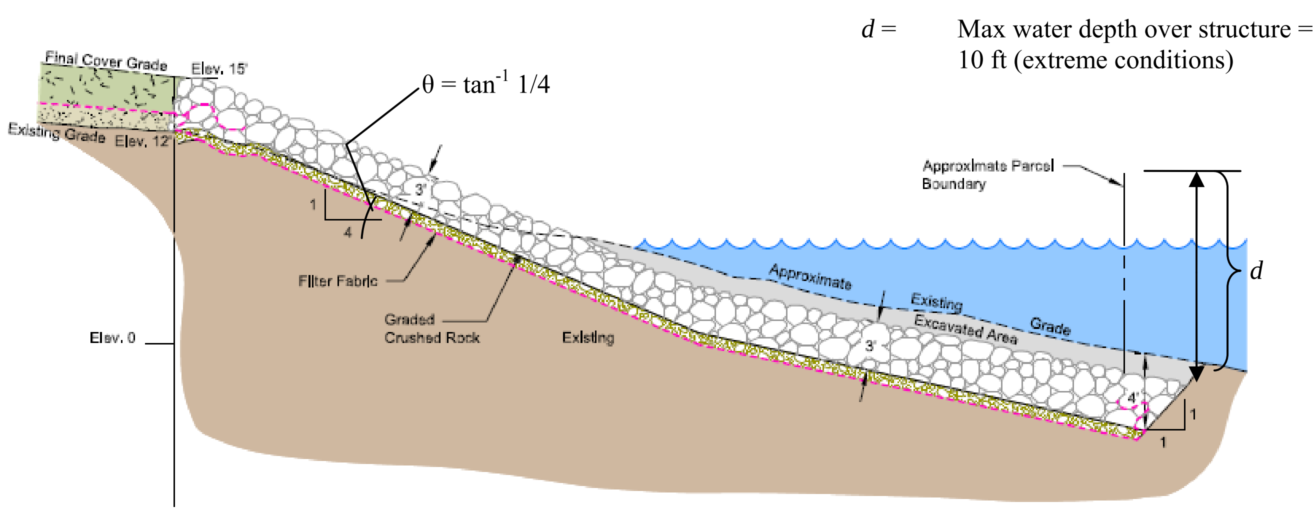
= Rmax = 2.37 ft

For simplicity an R_{max} of 2.5 has been used in the design.

Project	Component/System		
HPS, Parcel B, Site IR-07 and IR-18	Maximum Wave Runup		
Prepared by: JBL	Date 4-24-09	Checked by: SWF	Date 4-28-09

References:

U.S. Army Corps of Engineers. 1995. "Design of Coastal Revetments, Seawalls, and Bulkheads.



APPENDIX N
TOE UNIT SIZING

TETRA TECH

Project		Component/System	
HPS, Parcel B, Site IR-07 and IR-18		Toe Unit Sizing	
Prepared by: JBL	Date 4-24-09	Checked by: SWF	Date 4-28-09

Hudson Formula for Revetment Toe (submerged)

$$W_{\min} = \frac{\gamma_r H^3}{N_S^3 \left(\frac{\gamma_r}{\gamma_w} - 1 \right)^3}$$

From: USACE Design of Coastal Revetments, Seawalls, and Bulkheads.

Where:

W_{min} = minimum required individual armor unit weight, lbs
γ_r = specific weight of the armor unit, lbs/ft^3 = 165 lb/ft^3
H = wave height = 3 ft
N_s^3 = design stability number for rubble toe protection = 35 (USACE, 1995)
γ_w = specific weight of saltwater = 64 lbs/ft^3

Assumptions

1. The open water wave of 3 ft has been used. This is a conservative estimate of the wave energy the revetment will be exposed to, given the bathymetry of the near-shore area.
2. Lower water conditions will yield a higher more conservative estimate than higher water conditions. The revetment will be above the water level when the tide is at or below the mean sea level elevation.
3. Specific weights of the armor unit materials and water are generally accepted values and are not site specific.
4. The stability number of 35 is used based on the average depth of 1 foot to the top of the toe of the revetment and 4 feet to the base of toe. (See figure below for determination of the stability number)

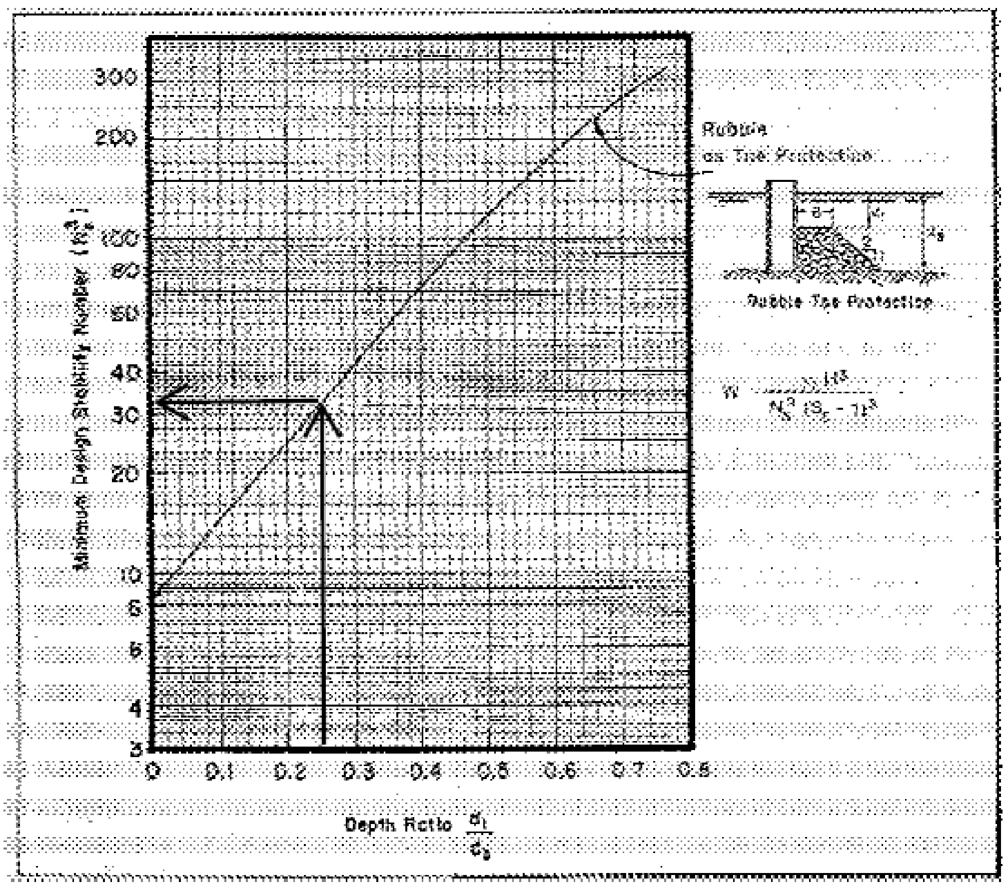
TETRA TECH

Project		Component/System	
HPS, Parcel B, Site IR-07 and IR-18		Toe Unit Sizing	
Prepared by: JBL	Date 4-24-09	Checked by: SWF	Date 4-28-09

$$W_{\min} = \frac{165 * 3^3}{35\left(\frac{165}{64} - 1\right)^3}$$

$$W_{\min} = 32.4\,lbs$$

Stability Number (N)



U.S. Army Corps of Engineers. 1995

It should be noted that this calculation yields a minimum stone weight rather than a median

TETRA TECH

Project		Component/System	
HPS, Parcel B, Site IR-07 and IR-18		Toe Unit Sizing	
Prepared by: JBL	Date 4-24-09	Checked by: SWF	Date 4-28-09

weight which is calculated using the Hudson formula for the selection of riprap armor size. Using a median rock weight of 500 lbs (1/4 ton) will require gradation as specified by the California Department of Transportation and shown in the following table. The material is readily obtainable in the vicinity of the project.

STANDARD Rock SIZE or Rock MASS or Rock WEIGHT		GRADING OF ROCK SLOPE PROTECTION **PERCENTAGE LARGER THAN**											
		RSP-Classes [A]											
		Method A Placement					Method B Placement						
		RSP-Classes other than Backing									Backing No.		
US unit		8 ton	4 ton	2 ton	1 ton	1/2 ton	1 ton	1/2 ton	1/4 ton	Light	1 [B]	2	3
	SI unit	8 T	4 T	2 T	1 T	1/2 T	1 T	1/2 T	1/4 T	Light	1 [B]	2	3
16 ton	14.5 tonne	0-5											
8 ton	7.25 tonne	50-100	0-5										
4 ton	3.6 tonne	95-100	50-100	0-5									
2 ton	1.8 tonne		95-100	50-100	0-5		0-5						
1 ton	900 kg			95-100	50-100	0-5	50-100	0-5					
1/2 ton	450 kg				95-100	50-100	-----	50-100	0-5				
1/4 ton	220 kg					95-100	95-100	-----	50-100	0-5			
200 lb	90 kg							95-100	-----	50-100	0-5		
75 lb	34 kg								95-100	-----	50-100	0-5	
25 lb	11 kg									95-100	90-100	25-75	0-5
5 lb	2.2 kg											90-100	25-75
1 lb	0.4 kg												90-100

[A] US customary names (units) of RSP-Classes listed above SI names, example US is "2 ton" metric is "2 T".
[B] "Facing" has same gradation as "Backing No. 1". To conserve space "Facing" is not shown .

TETRA TECH

Project		Component/System	
HPS, Parcel B, Site IR-07 and IR-18		Toe Unit Sizing	
Prepared by: JBL	Date 4-24-09	Checked by: SWF	Date 4-28-09

References:

State of California Department of Transportation Engineering Service Center. 2000. California Bank and Shore Rock Slope Protection Design.

U.S. Army Corps of Engineers. 1995. “Design of Coastal Revetments, Seawalls, and Bulkheads.

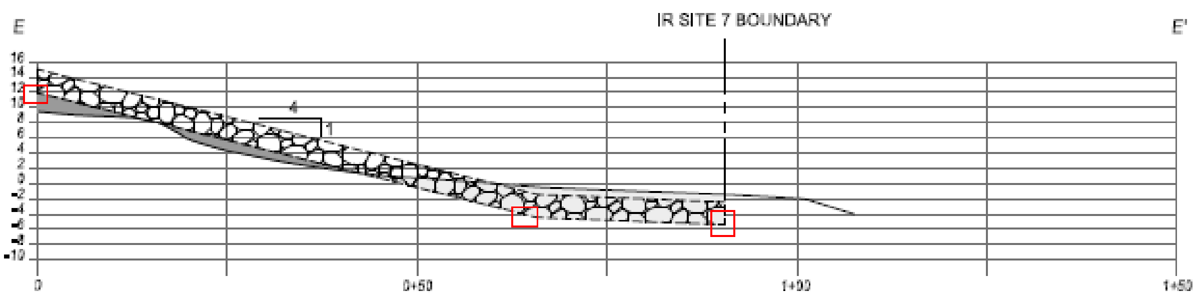
APPENDIX O
REVETMENT MATERIALS CALCULATION

Appendix O

Project HPS, Parcel B, Site IR-07 and IR-18		Component/System Revetment Materials Calculations	
Prepared by: JBL	Date	Checked by:	Date

The following approach was used for the calculation of materials quantities necessary for the construction of the revetment.

The elevations and the distances of the key points along the revetment were taken from the CAD drawings of the revetment cross sections. The key points along the revetment for the calculation of the materials quantities are: 1) the crest, 2) the toe, and 3) the location where the slope of the changes between the upper portion of the revetment and the lower portion toward the toe. A typical cross section of the revetment with these key locations is shown below.



Using these points the and uniform thicknesses of 3 ft for the riprap and 0.5 ft for the crushed rock filter layer the upper and lower cross sectional areas were calculated. These cross sectional areas were then multiplied by the appropriate shoreline length applicable to the specific cross section to yield the approximate volume of material. The area of coverage for the geotextile filter layer was calculated using a similar methodology.

The following tables summarize the materials quantities calculations.

Revetment Riprap Quantities Calculation

Cross Section	Distance (ft)	Elevation (ft msl)
X-Section A		
Crest	0	15
Slope Transition	62	0
Toe end	85	-1
X-Section B		
Crest	0	15
Slope Transition		
Toe end	62	-1
X-Section C		
Crest	0	15
Slope Transition	50	2
Toe end	86	0
X-Section D		
Crest	0	15
Slope Transition	64	0
Toe end	120	-3
X-Section E		
Crest	0	15
Slope Transition	67	-2
Toe end	91	-3
X-Section F		
Crest	0	15
Slope Transition		
Toe end	67	-2
X-Section AA		
Crest	0	15
Slope Transition		
Toe end	62	-1
X-Section BB		
Crest	0	15
Slope Transition		
Toe end	66	-1
X-Section DD		
Crest	0	15
Slope Transition	60	-1
Toe end	74	-1
X-Section EE		
Crest	0	15
Slope Transition		
Toe end	79	-5

	Upper Area	Lower Area	Shoreline Length	Revetment Volume[1]	Rock Weight[2]
	ft^2	ft^2	ft	yd^3	Tons
X-Section A	191	69	117	1,127	1,757.3
X-Section B	192	0	57	405	631.5
X-Section C	155	108	137	1,334	2,080.7
X-Section D	197	168	82	1,109	1,728.5
X-Section E	207	72	92	951	1,482.4
X-Section F	207	0	87	667	1,040.0
X-Section AA	192	0	107	761	1,186.4
X-Section BB	204	0	57	431	671.6
X-Section DD	186	42	137	1,157	1,803.8
X-Section EE	244	0	77	696	1,085.0
			Totals	8,637.0	13,467.2

Assumptions
from: "Design of Coastal Revetments, Seawalls, and Bulkheads"

Graded riprap porosity	0.3
Unit weight of rock	165 lb/ft^2
	4455 lb/ft^3

Riprap layer thickness 3 ft

Notes:

1 Volume including pore space
2 Accounds for pore space
msl = mean sea level

Crushed Rock Quantities Calculations

Cross Section	Distance (ft)	Elevation (ft msl)
X-Section A		
Crest	0	12
Slope Transition	62	-3
Toe end	85	-4
X-Section B		
Crest	0	12
Slope Transition	0	0
Toe end	62	-4
X-Section C		
Crest	0	12
Slope Transition	50	-1
Toe end	86	-3
X-Section D		
Crest	0	12
Slope Transition	64	-3
Toe end	120	-6
X-Section E		
Crest	0	12
Slope Transition	67	-5
Toe end	91	-6
X-Section F		
Crest	0	12
Slope Transition	0	0
Toe end	67	-5
X-Section AA		
Crest	0	12
Slope Transition	0	0
Toe end	62	-4
X-Section BB		
Crest	0	12
Slope Transition	0	0
Toe end	66	-4
X-Section DD		
Crest	0	12
Slope Transition	60	-4
Toe end	74	-4
X-Section EE		
Crest	0	12
Slope Transition	0	0
Toe end	79	-8

	Upper area	Lower area	Shoreline Length	Revetment Volume[1]	Rock Weight[2]
	ft^2	ft^2	ft	yd^3	Tons
X-Section A	31.89	11.51	117	188	293.1
X-Section B	32.02	0	57	68	105.4
X-Section C	25.83	18.03	137	223	347.0
X-Section D	32.87	28.04	82	185	288.5
X-Section E	34.56	12.01	92	159	247.5
X-Section F	34.56	0	87	111	173.7
X-Section AA	32.02	0	107	127	197.8
X-Section BB	33.96	0	57	72	111.8
X-Section DD	31.05	7	137	193	300.9
X-Section EE	40.75	0	77	116	181.1
			Totals	1,441.1	2,246.9

Assumptions
from: "Design of Coastal Revetments, Seawalls, and Bulkheads"

Porosity	0.3	Porosity of gravel
Unit weight	165	lb/ft^2
	4455	lb/ft^3
Gravel layer thickness	0.5	ft

Notes:

1 Volume including pore space
2 Accounds for pore space
msl = mean sea level

Geotextile Quantities Calculation

	Distance (ft)	Elevation (ft msl)
X-Section A		
Crest	0	11.5
Slope Transition	62	-3.5
Toe end	85	-4.5
X-Section B		
Crest	0	11.5
Slope Transition	0	0
Toe end	62	-4.5
X-Section C		
Crest	0	11.5
Slope Transition	50	-1.5
Toe end	86	-3.5
X-Section D		
Crest	0	11.5
Slope Transition	64	-3.5
Toe end	120	-6.5
X-Section E		
Crest	0	11.5
Slope Transition	67	-5.5
Toe end	91	-6.5
X-Section F		
Crest	0	11.5
Slope Transition	0	0
Toe end	67	-5.5
X-Section AA		
Crest	0	11.5
Slope Transition	0	0
Toe end	62	-4.5
X-Section BB		
Crest	0	11.5
Slope Transition	0	0
Toe end	66	-4.5
X-Section DD		
Crest	0	11.5
Slope Transition	60	-4.5
Toe end	74	-4.5
X-Section EE		
Crest	0	11.5
Slope Transition	0	0
Toe end	79	-8.5

	Upper Length	Lower Length	Shoreline Length	Area Covered	Fabric Area[1]
	ft	ft	ft	ft^2	ft^2
X-Section A	63.79	11.51	117	979	1,275
X-Section B	64.03	0	57	406	539
X-Section C	51.66	18.03	137	1,061	1,395
X-Section D	65.73	28.04	82	854	1,087
X-Section E	69.12	12.01	92	829	1,071
X-Section F	69.12	0	87	668	880
X-Section AA	64.03	0	107	761	1,012
X-Section BB	67.91	0	57	430	567
X-Section DD	62.1	7	137	1,052	1,385
X-Section EE	81.49	0	77	697	900
			Totals	7,737.5	10112

Notes

1 Includes 2 ft of overlay between sections and 10 ft for anchoring

msl = mean sea level