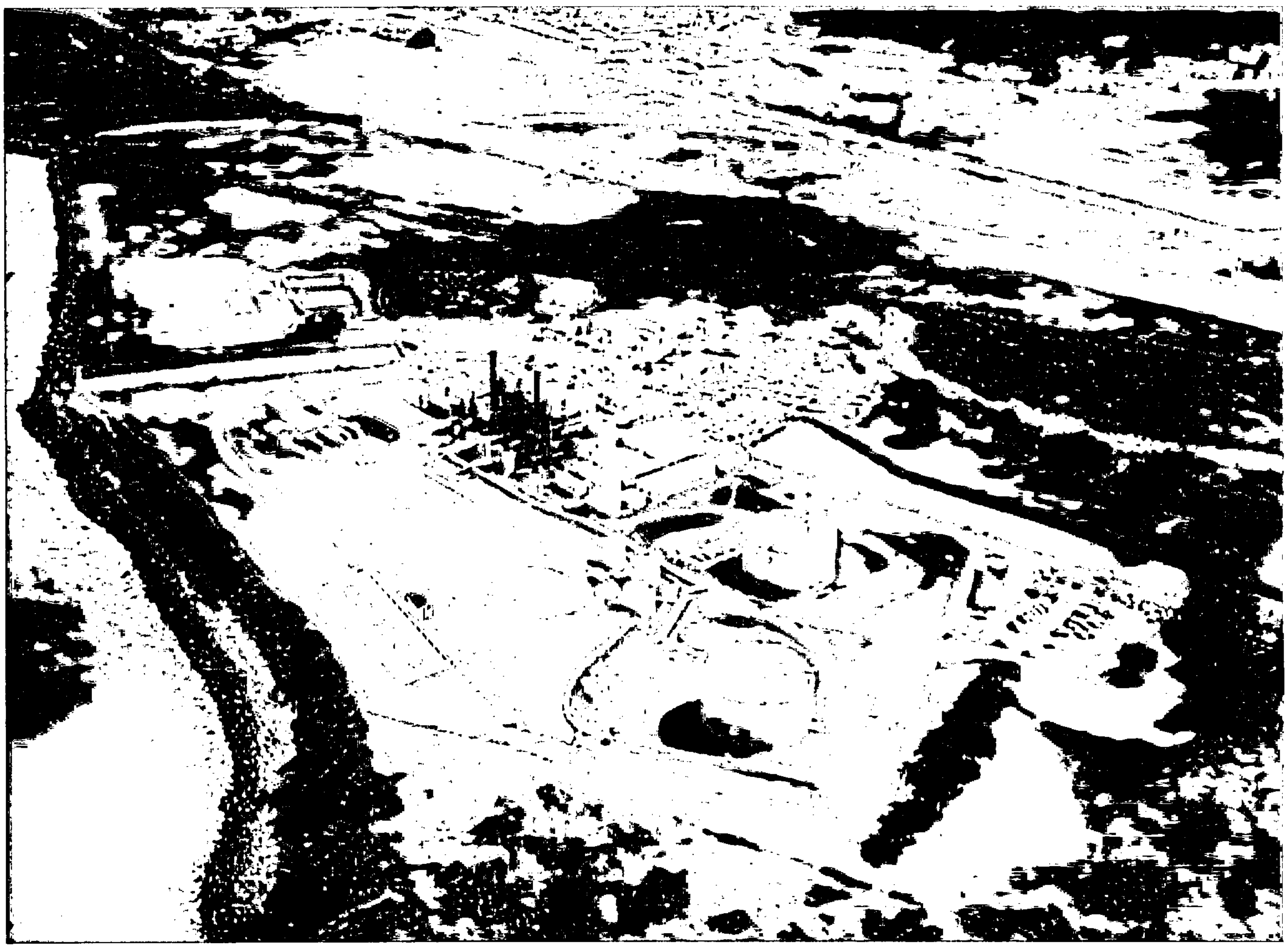
HUMBOLDT BAY

INDEPENDENT SPENT FUEL STORAGE INSTALLATION



CALCULATIONS

PG&E

PACIFIC GAS AND ELECTRIC COMPANY

HUMBOLDT BAY POWER PLANT
CALCULATION COVER SHEET

File No. : ______________
Calculation No.: GEO.HBIP.02.03

☐ Preliminary

☒ Final

Department/Group: HBPP/Geosciences

Unit(s) 0 Structure, System or Component: ISFSI Geotechnical

Type or Purpose of Calculation: Development of Maximum Credible Earthquake Magnitudes and Distances for the HBIP

No. of Sheets: 18

	Signature	Discipline/Dept	Date
Prepared by:	*By Geosciences*		10/6/2002
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Registered Engineer Approval: (Complete section A for Civil calcs. Complete A or B for others)

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	Registration Number: ______________
Expiration Date:	Expiration Date: ______________

RECORDS OF REVISIONS

Revision Number	Date	Reasons for Revision	Prepared By	Checked By	Approval Regis. Engr.	Approval Supvr.
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PACIFIC GAS AND ELECTRIC
GEOSCIENCES DEPARTMENT
CALCULATION DOCUMENT

Calc Number: GEO.HBIP.02.03
Revision: 0
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TITLE: Development of Maximum Credible Earthquake Magnitudes and Distances for the HBIP

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Expires June 30, 2003

Development of Maximum Credible Earthquake Magnitudes and Distances for the HBIP

Record of Revisions

Rev. No.	Reason for Revision	Revision Date
0	Initial Issue	10/04/02

Title: Development of Maximum Credible Earthquake Magnitudes and Distances for the HBIP

2. PURPOSE

The purpose of this calculation is to determine the magnitude and the closest distance to the HBIP site for the Maximum Credible Earthquake (MCE) on the Little Salmon Fault and the Cascadia interface subsources based on the Carver (2002) source characterization. These parameters will be used in the calculation of the deterministic ground motions as described in the Work Plan (GEO 2002-01, Rev 1).

3. ASSUMPTIONS

3.1 Magnitude-area scaling relations for crustal earthquakes

The Wells and Coppersmith (1994) magnitude-area scaling relations for all fault types is assumed to be applicable to crustal faults. The basis for this assumption is that it is a well-documented and widely used model.

3.2 Magnitude-area scaling relations for subduction zone earthquakes

The Geomatrix (1994) and Abe (1981; 1984) magnitude-area scaling relations for subduction zones are assumed to be applicable to the Cascadia subduction zone. The basis for this assumption is that the relations were developed for subduction zone earthquakes.

3.3 Magnitude-fault displacement scaling relations for crustal earthquakes

The Wells and Coppersmith (1994) magnitude-displacement scaling relation for all fault types is assumed to be applicable to crustal faults. The basis for this assumption is that it is a well-documented and widely used model.

3.4 Location of "Change in Fold Trends"

Geomatrix (1995, p. 2-14) states that the change in fold trends is located 30 km landward of the deformation front. Later (p. 2-21) they show the downdip width of the rupture is 25 km less using the change in fold trends as compared to the deformation front. The location of the deformation front is assumed to be 30 km seaward of the change in fold trends. The basis for this assumption is that is slightly conservative but not significant.

3.5 Width of interface

Carver (2002) does not give models for the downdip width of the interface. The Geomatrix (1995) model for the width of the interface is assumed to be applicable to the Carver (2002) model. The basis for this is assumption is that the Geomatrix (1995) is the most up-to-date characterization of the width of the interface.

4. DESIGN INPUTS

4.1 Width Approaches for Cascadia Interface

The width of the Cascadia interface depends on the location of the updip (shallowest point) and downdip (deepest point) limits of potential seismogenic rupture. Geomatrix (1995, page 2-21) gives two alternative models for the location of the updip limit and two alternative models for the location of the downdip limit.

The updip extent is defined by either the location of the deformation front or the location of the change in structural trends near the slope break (change in fold trends). Geomatrix (1995, p 2-21) estimates that fault width using the change in fold trends boundary is 25 km less than using the deformation front boundary. Geomatrix (1995, page 2-21) gives relative weights of 0.7 to the change in fold trends model and 0.3 to the deformation front model.

The downdip extent is defined by either the location of the zero isobase line or the midpoint of the transition zone defined by the thermal and geodetic modeling. Geomatrix (1995, page 2-21) gives relative weights of 0.6 to the zero isobase model and 0.4 to the thermal-geodetic model.

On page 2-21 of Geomatrix (1995), the width of the Cascadia interface is given for the four combinations of the locations of the updip and down-dip limits, but the values are not correct. It appears that they incorrectly used the location of the change in fold trends as the location of the deformation front and the change in the fold trends was placed 25 km east of the misplaced deformation front. The result of this error is that interface widths listed in Geomatrix (1995) are too small (see Attachment 1, R. Youngs, 2002, written communication). New calculations of the width of the interface are made in section 7 of this calculation package.

4.2 Dimensions of the Cascadia Interface

4.2.1 Rupture Lengths

Carver (2002) models the Cascadia interface as a combination of the Cascadia interface, Little Salmon fault zone, and Table Bluff fault. The alternative models for the lengths of the Cascadia interface ruptures and the weights for the alternatives given by Carver (2002) are listed in Table 4-1.

Table 4-1. Alternative segment lengths and weights for the Cascadia interface using the Carver model (Carver, 2002, page 5A-3).

Rupture Extent	Segment Length (km)	Weight
Eureka to the middle of Washington	700	0.5
Eureka to the Explorer plate	1050	0.5

4.2.2 Dip

Cohee et al. (1991, P. 37, caption to Fig. 3) give the dip of the interface of 11° in Washington and 21° in Oregon. The average value of 16° degrees is used for the fault rupture.

4.3 Little Salmon Fault Zone

4.3.1 Rupture Length

Carver (2002) defines the Little Salmon fault zone as extending from the Yager fault to the Thompson Ridge fault (PGE, Fig. 2-5). The length of the zone is 310 km (Carver 2002, pg 5A-6).

4.3.2 Dip

Carver (2002) gives three possible dips of the fault of 40, 45, and 50 degrees; weights on each are 0.2, 0.6 and 0.2, respectively.

4.3.3 Crustal Thickness

The thickness of the crust in the HBIP region is given as 15 km (Carver, 2002).

4.3.4 Displacement per Event

The fault displacement is given as 7m or 9.3m (equally likely) (Carver, 2002).

4.3.5 Style of Faulting

The Little Salmon fault is a reverse slip fault (Carver, 2002).

5. METHOD AND EQUATION SUMMARY

5.1 Methods

The magnitude of the Maximum Credible Earthquake is computed based on the mean magnitude determined for the maximum rupture area or fault displacement

5.2 Equations

5.2.1 Magnitude-Area Relations

The Wells and Coppersmith (1994; Table 2A, p. 990) scaling relation for magnitude as a function of rupture area for crustal faults (using all fault types) is given by

$$M = 0.98 \, \text{Log}(A) + 4.07 \tag{5-1}$$

where A is the rupture area in km^2 and M is moment magnitude.

The Abe (1981;1984) relation for magnitude as a function of rupture area for subduction zones is given by (Geomatrix, 1995, p. 2-29)

$$M = \text{Log}(A) + 3.99. \tag{5-2}$$

The Geomatrix (1993) relation for magnitude as a function of rupture area for subduction zones is given by (Geomatrix, 1995, p. 2-29)

$$M = 0.81 \, \text{Log}(A) + 4.7 \tag{5-3}$$

5.2.2 Magnitude-Displacement Relations

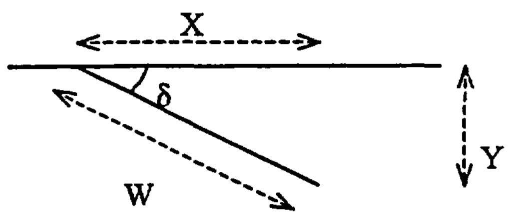
The Wells and Coppersmith (1994; Table 2B, p. 991) scaling relation for magnitude as a function of average fault displacement for crustal faults (using all fault types) is given by

$$M = 0.82 \, \text{Log}(D) + 6.93 \tag{5-4}$$

where D is the average displacement over the rupture surface in m.

5.2.3 Downdip Width

The following illustration is used for Eqns. 5-5 and 5-6.



For a fault with dip δ and horizontal extent X, the downdip width, W, is given by

$$W = \frac{X}{\cos(\delta)} \quad (5\text{-}5)$$

For a fault with dip δ and vertical extent Y, the downdip width, W, is given by

$$W = \frac{Y}{\sin(\delta)} \quad (5\text{-}6)$$

Eq. (5-5) and (5-6) are well known trigonometric relations.

5.2.4 Weighted Average

Given N values X_i with weights wt_i, the weighted mean is (Bevington, 1969, p. 73)

$$Mean = \frac{\sum_{i=1}^{N} X_i \, wt_i}{\sum_{i=1}^{N} wt_i} \quad (5\text{-}7)$$

6. SOFTWARE

No specialized computer software was used in these calculations.

7. BODY OF CALCULATIONS

7.1 Magnitude for the Cascadia Interface

7.1.1 Horizontal Extent of Updip Boundary

The downdip widths of the interface given by Geomatrix (1995, p. 2-21) are not consistent with the plots on Fig. 2-17. To resolve this inconsistency, other sources of this information were reviewed.

The locations of the Cascadia subduction zone's Deformation Front (Geomatrix, 1995, Fig. 2-16 and Plate 1) were compared to the location of the Cascadia Subduction Zone mapped by the National Geographic Society (NGS, 1995). Geomatrix (1995, Fig. 2-16) shows locations from California to north of the Explorer plate (about 40° to 52° N); Geomatrix (1995, Plate 1) extends only along the Oregon coast (about 42° to 46° N); NGS (1995) plots the zone only along the U. S. coastline and ends at the Canadian border (south of Eureka to about 48.5° N)

All three sets of distances were measured as distances due west of the U. S. coastline and are shown in Table 7-1. Additionally, the location of the Change in Fold Trends (Geomatrix, 1995, Plate 1) is included in Table 7-1.

Table 7-1. Distance* (km) from U. S. coastline to 4 updip reference boundaries of the Cascadia subduction zone.

N Latitude (°)	Deformation Front (Geom., Fig. 2-16)	Deformation Front (Geom., Plate 1)	Cascadia Subduction Zone (NGS)	Change in Fold Trends (Geom., Plate 1)
41	44	N/A	73	N/A
42	61	87	85	59
43	39	63	64	37
44	67	94	97	76
45	83	113	109	76
46	94	119	116	81
47	100	N/A	135	N/A
48	94	N/A	138	N/A

* Accuracy of the distances is approximately: ± 5 km for Geomatrix Fig. 2-16, ± 1 km for Geomatrix Plate 1, and ± 2 km for NGS.

The distance to the updip subduction zone boundary measured from NGS agrees well with the deformation front boundary plotted in Geomatrix Plate 1 but not at all with the deformation front plotted in Geomatrix Fig. 2-16. The distance to the deformation front plotted in Geomatrix Fig. 2-16 agrees well with the change in fold trends plotted in Geomatrix Plate 1. Because the NGS is a data source independent of Geomatrix (1995), the boundaries in Geomatrix Plate 1 appear correct. The boundary plotted in Geomatrix Fig. 2-16 should be labeled as the change in fold trends boundary, and not as the deformation front.

7.1.2 Width

The horizontal extent of the Cascadia interface was measured from Geomatrix (1995, Fig. 2-16) using the change in fold trends boundary (identified incorrectly in Fig. 2-16 as the deformation front) as the updip margin and both the zero isobase and transition zone boundaries as the downdip margins (Table 7-2). The Transition Zone plotted in Geomatrix Fig. 2-16 is used by Geomatrix (1995) as the Thermal/Geodetic boundary (p. 2-21). The distances measured were along lines approximately normal to the updip and downdip margins and intersected the coastline at the latitudes listed in Table 7-2.

The horizontal extent using the deformation front as the updip boundary is computed by adding 30 km (assumption 3.4) to the extent using the change in fold trends as the updip boundary.

Table 7-2. Horizontal extent (km) of the Cascadia interface using the change in fold trends (Fig. 2-16) as the updip interface boundary.

N Latitude (°)	Change in Fold Trends		Deformation Front	
	Zero Isobase	Transition Zone	Zero Isobase	Transition Zone
41	100	65	130	95
42	100	57	130	87
43	87	52	117	82
44	83	52	113	82
45	74	57	104	87
46	78	78	108	108
47	83	117	113	147
48	70	126	100	156
49	39	83	69	113

The downdip width of the Cascadia interface between the change in fold trends and the zero isobase and the transition zone boundaries was computed from the horizontal extent (Table 7-2) using Eqn. 5-5 and the dip of 16° (input 4.2.2). The resulting downdip widths are shown in Table 7-3.

Table 7-3. Downdip width (km) of the Cascadia interface.

N Latitude (°)	Change in Fold Trends		Deformation Front	
	Zero Isobase	Transition Zone	Zero Isobase	Transition Zone
41	104	68	135	99
42	104	59	135	91
43	91	54	122	85
44	86	54	118	85
45	77	59	108	91
46	81	81	112	112
47	86	122	118	153
48	73	131	104	162
49	41	86	72	118
Average (41° to 47°)	90	71	121	102
Average (41° to 49°)	82	79	114	111

The interface widths were averaged over latitudes corresponding to the segment rupture length models (Table 4-2) - between Eureka and the middle of Washington (41° to 47°) and between Eureka and the Explorer plate (41° to 49°). These averaged values were then rounded to the nearest 5 km to reflect the accuracy of the measurements. The resulting widths are listed in Table 7-4.

Table 7-4. Maximum rupture downdip width (km) of the Cascadia Interface averaged along the rupture length.

Updip Model	Downdip Model	Rupture Model: Eureka to Middle of Washington	Rupture Model: Eureka to the Explorer Plate
Deformation Front	Zero Isobase	120	115
	Thermal/Geodetic	100	110
Change in Fold Trends	Zero Isobase	90	80
	Thermal/Geodetic	70	80

7.1.3 Magnitude

The magnitude of the characteristic earthquake for the main Cascadia interface is estimated using the two alternative relations between magnitude and rupture area for subduction events (eq. 5-2 and 5-3) with equal weights. The rupture area is computed by multiplying the segment lengths given in input 4.2 and the downdip widths listed in Table 7-4. All possible combinations of widths and segment lengths are considered; the 16 permutations are listed in Table 7-5. The total weight is the product of the weights for the updip extent, downdip extent, length, and magnitude-area (M(A) model) relation. The mean magnitude listed at the bottom of Table 7-5 is computed by summing the wt*Mag values (eq. 5-7).

Table 7-5 Mean Characteristic Magnitudes for the Cascadia Interface using the Carver Segmentation Model (input 4.2).

Updip Extent	Downdip Extent	Width (km)	Rupture Model	Length (km)	M(A) Model	Mag	Weights: Updip Extent	Weights: Downdip Extent	Weights: Length	Weights: M(A) Model	Weights: Total	Wt * Mag
Zero Isobase	Def. Front	120	Eureka to Mid Wash.	700	Geomatrix	8.69	0.3	0.6	0.5	0.5	0.045	0.39
Zero Isobase	Def. Front	115	Eureka to Expl. Plate	1050	Geomatrix	8.82	0.3	0.6	0.5	0.5	0.045	0.40
Zero Isobase	Fold Trends	90	Eureka to Mid Wash.	700	Geomatrix	8.59	0.7	0.6	0.5	0.5	0.105	0.90
Zero Isobase	Fold Trends	80	Eureka to Expl. Plate	1050	Geomatrix	8.69	0.7	0.6	0.5	0.5	0.105	0.91
Thermal-geodetic	Def. Front	100	Eureka to Mid Wash.	700	Geomatrix	8.62	0.3	0.4	0.5	0.5	0.03	0.26
Thermal-geodetic	Def. Front	110	Eureka to Expl. Plate	1050	Geomatrix	8.80	0.3	0.4	0.5	0.5	0.03	0.26
Thermal-geodetic	Fold Trends	70	Eureka to Mid Wash.	700	Geomatrix	8.50	0.7	0.4	0.5	0.5	0.07	0.60
Thermal-geodetic	Fold Trends	80	Eureka to Expl. Plate	1050	Geomatrix	8.69	0.7	0.4	0.5	0.5	0.07	0.61
Zero Isobase	Def. Front	120	Eureka to Mid Wash.	700	Abe	8.91	0.3	0.6	0.5	0.5	0.045	0.40
Zero Isobase	Def. Front	115	Eureka to Expl. Plate	1050	Abe	9.07	0.3	0.6	0.5	0.5	0.045	0.41
Zero Isobase	Fold Trends	90	Eureka to Mid Wash.	700	Abe	8.79	0.7	0.6	0.5	0.5	0.105	0.92
Zero Isobase	Fold Trends	80	Eureka to Expl. Plate	1050	Abe	8.91	0.7	0.6	0.5	0.5	0.105	0.94
Thermal-geodetic	Def. Front	100	Eureka to Mid Wash.	700	Abe	8.84	0.3	0.4	0.5	0.5	0.03	0.27
Thermal-geodetic	Def. Front	110	Eureka to Expl. Plate	1050	Abe	9.05	0.3	0.4	0.5	0.5	0.03	0.27
Thermal-geodetic	Fold Trends	70	Eureka to Mid Wash.	700	Abe	8.68	0.7	0.4	0.5	0.5	0.07	0.61
Thermal-geodetic	Fold Trends	80	Eureka to Expl. Plate	1050	Abe	8.91	0.7	0.4	0.5	0.5	0.07	0.62
											Mean	8.76

7.1.3 Distance

The updip location of the Cascadia interface in the region near the HBIP, as described by Carver (2002), is given by the Table Bluff fault. Using Figure 3-3 from PGE (2001), the horizontal distance between the HBIP site and the surface expression of the Table Bluff fault is measured as 5.5 km. The Table Bluff fault has a change in dip direction as shown in Fig. 3-4 from PGE (2001). In the top 2 km, the fault has a shallow dip to the southwest, whereas below 2 km, the fault has a shallow dip to the northeast. The part of the fault below 2 km dipping to the northeast is consistent with the dip direction of the subduction zone. Therefore, the distance to the fault is measured to the part of the fault dipping to the northeast. Using the cross-section (Fig 3-4 from PGE 2001), the closest distance between the site and the northeast dipping part of the fault is measured to be 7 km.

7.2 Magnitude for the Little Salmon Fault System

7.2.1 Magnitude

The magnitude of the characteristic earthquake for the Little Salmon fault zone is estimated using the relations between magnitude and rupture area for crustal faults (eq. 5-1) and between magnitude and fault displacement (eq. 5-4). The two alternative approaches (area or distance) are given equal weight.

Using the dip (column #2 in Table 7-6) from input 4.3.2 and the thickness (column #4) from input 4.3.3, the downdip width (column #5) is computed using eq. 5-6. The segment length (column #6) is from input 4.3.1. The area (column #8) is computed by multiplying the downdip width and the length. The magnitude (column #11) is computed using eq. 5-1 and the area in column #8. The total weight (column #12) is the product of weights for the different approaches (column #1), the segment weight (column #7), and the dips (column #3).

Using the displacement approach, the magnitude (column #11) is computed using eq. 5-4 with the displacement per event value listed in column #9 (input 4.3.4). The total weight (column #12) is the product of the approach weight (column #1) and the displacement per event weight (column #10).

The magnitude is multiplied by the weight (column #13). The mean magnitude is computed using eq. 5-7 (sum of values in column #13). The mean weighted magnitude of 7.74 from the Table 7-6 is rounded to 7.7 for defining the mean characteristic magnitude.

Table 7-6. Mean Characteristic Magnitudes for the Little Salmon Fault System.

	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	#11	#12	#13
Approach	**Approach Wt**	**Dip**	**Dip Wt**	**Thickness (km)**	**Downdip Width (km)**	**Segment Length (km)**	**Seg Wt**	**Area (km^2)**	**Disp (m)**	**Disp Wt**	**Mag**	**Total Wt**	**Wted Mag**
Area	0.5	40	0.2	15	23.3	310	1	7223	N/A	N/A	7.85	0.10	0.79
Area	0.5	45	0.6	15	21.2	310	1	6572	N/A	N/A	7.81	0.30	2.34
Area	0.5	50	0.2	15	19.6	310	1	6076	N/A	N/A	7.78	0.10	0.78
Disp.	0.5					N/A	N/A		7	0.5	7.62	0.25	1.91
Disp.	0.5					N/A	N/A		9.3	0.5	7.72	0.25	1.93
												Mean	7.74

7.2.2 Distance

The Bay Entrance fault is the closest strand of the Little Salmon fault to the HBIP site. The approximate location of the Bay Entrance fault is shown in the cross section in PG&E (2002, Figure 4-16). Based on this Figure, the shortest distance between the HBIP site and the Bay Entrance Fault is measured to be 0.5 km.

8. RESULTS

The Little Salmon fault zone and the Cascadia interface are assumed to rupture synchronously. The magnitude and closest distance of the maximum credible earthquakes for the two subources are listed below:

Table 8-1. MCE for Cascadia interface and Little Salmon fault subsource.

Subsource	**Source Type**	**Moment Magnitude**	**Rupture Distance (km)**
Little Salmon Fault Zone	Crustal Reverse	7.7	~0.5
Cascadia Interface	Subduction Interface	8.8	7

9. CONCLUSIONS

The source types, magnitudes, and rupture distances listed in Table 8-1 represent the MCE for these two subsources. They should be used for deterministic evaluations of the ground motion at HBIP.

Limitations:
The magnitudes and distances are for use in a deterministic approach only.

10. REFERENCES

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Attachment A

5 September 2002 Letter from R. Youngs, Geomatrix to R. White, PG&E

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Oakland, CA 94612
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GEOMATRIX

September 30, 2002
Project 5117.009, Task 9

Robert K. White
Pacific Gas and Electric Company
Geosciences Department
245 Market Street, Room 418B
Mail Code N4C
P.O. Box 770000
San Francisco CA 94177

Dear Rob:

I am writing to acknowledge a potential error you may have identified in your letter dated September 11, 2002. Comparison of Plate 1 in the January 1995 report "Seismic Design Mapping, State of Oregon" with Figures 2-16 and 2-17 indicates that the Deformation Front identified in these Figures may be mislabeled and may correspond to the Change in Fold Trends line as mapped in Plate 1. As a result, the interface widths listed on page 2-21 may be too small by about 25 km.

Thank you for bringing this matter to my attention.

Sincerely,
GEOMATRIX CONSULTANTS, INC.

Robert R. Youngs
Principal Engineer

I:\Project\5000s\5117.009\CORESPON\Youngs-Ltr_093002.doc

Geosciences HBPP ISFSI Geotechnical Calculation Verification Report

Calculation Title: Development of Maximum Credible Earthquake Magnitudes and Distances for the HBIP
Calculation No.: GEO.HBIP.02.03
Revision No.: 0
Calculation Author: Norman Abrahamson
Calculation Date: 10/4/02
Verifier: Stuart Nishenko
Verification Date: 10/16/02

Introduction

As required by Geosciences Work Plan GEO 2002-01, Rev 1 and Geosciences Calculation Procedure GEO.001, Rev. 6, I have performed an independent technical review (ITR) and peer review of the above listed calculation. In addition to performing a step-by-step check of the calculation (Verification Method A), I also verified the calculations using an Excel spreadsheet program (Verification Method B). Those alternate verification files are attached to this ITR Report. This ITR report is structured with the same Section headings as the Calculation.

2. Purpose

I determined that the purpose of this calculation is clearly stated as per NUREG 1567 section 2.4.6.1-2.4.6.2 and NUREG 0800 section 2.5.2.

3. Assumptions

I reviewed the assumptions for this calculation and find them reasonable and consistent with current seismological practice and understanding of earthquake hazards in the region.

I specifically reviewed the original data cited in Geomatrix (1995, p. 2-14) for Assumption 3.4 (e.g. Goldfinger, C., et al., 1992, Neotectonic Map of the Oregon Continental Margin and Adjacent Abyssal Plain, DOGAMI Open File Rpt. 0-92-4) and agree that 30 km is a more conservative (and accurate) estimate of the location of the change in fold trends with respect to the Deformation Front.

4. Data Inputs

4.1 Width Approaches for the Cascadia Interface

Geomatrix (1995) is the primary reference for establishing the width of the Cascadia interface. I verified that the weights for the alternative estimates of the updip and downdip extent of the Cascadia interface were correctly cited and used in the calculations.

The determination that p. 2-21 of Geomatrix (1995) contains an error in mapping the width of the interface resulted in the need to independently recalculate the width (see Section 7 of this calculation). Given the critical nature of this parameter for these calculations, I suggest that a letter of confirmation, as to the cause of this error (as stated in Section 4.1 of the calculation), from Geomatrix be attached to the calculation.
Resolution: A letter has been obtained from R. Youngs of Geomatrix acknowledging this issue and is attached to the Calculation Package.

4.2 /4.3 Dimensions of Cascadia Interface and Little Salmon Fault Zone

I reviewed the parameters listed in these two sections based on a July 12, 2002 version of Appendix 5A [Carver (2002) [memo from L. Pulley to G. Carver, 7/12/02]]. While I find them to be correctly cited, I note that these numbers are preliminary and will need to be checked against the final Appendix 5A when it is issued.
Resolution: Values used in this calculation package are consistent with those cited in Appendix 5A, Rev. 0 (September 5, 2002)

I note that rupture length for the Little Salmon Fault is listed as 310 km in the calculation (Section 4.3 and Table 7-7) and 330 km in Figure 2-5 (PGE, 2001) and Carver (2002, p. 5A-6). I measured the along-strike length of the Little Salmon fault zone from Figure 2-5 and found it to be 300 km at the center, 330 km along the western (seaward) edge and 280 km along the eastern (landward) edge. To minimize confusion, the estimates in this Calculation should be consistent with the text for Figure 2-5 and Appendix 5A.
Resolution: A rupture length of 310 km has been consistently adopted for the Little Salmon fault and is used in all calculations.

The estimate of 7 to 8 meters displacement per event on the Little Salmon fault system (Appendix 5A, Carver (2002)) needs to be clarified.
Resolution: The estimated displacements per event for the Little Salomon fault has been clarified in Appendix 5A, Rev. 0 and the resultant numbers carried through the calculations.

5. Method and Equation Summary

I reviewed the equations listed in Section 5.2 for accuracy by checking the original references.

Equation 5-7 is missing a $1/\Sigma w_i$ term (see Bevington, 1969, p. 73).
Resolution: The equation has been corrected

6. Software

No specialized software is required for these calculations.

7. Calculations

7.1 Magnitude for the Cascadia Interface

To resolve the inconsistency in the Geomatrix (1995) estimates of the width of the Cascadia interface, an independent data source was used (Living on the Edge, the April 1995 National Geographic Society (NGS) map of the Cascadia subduction zone). While this map is an independent source, the lack of geographic coordinates makes me question the accuracy of this map for use in this calculation. I crosschecked the National Geographic map against the original scientific references that were used to compile the map (see maps attached to this ITR - Clarke, S.H., 1990, Geologic Structures, Northern California Continental Margin, USGS Map MF-210; and Goldfinger, C., et al., 1992, Neotectonic Map of the Oregon Continental Margin and Adjacent Abyssal Plain, DOGAMI Open File Rpt. 0-92-4). The width of the margin, defined as the distance between the Deformation Front and the coastline on the NGS map is consistent, to within a few km, with these references. I judge the NGS map to be an accurate presentation suitable for this calculation, based on this comparison.

I also checked the measurements listed in Tables 7-1 and 7-2 against the calculation computation sheets (A.M. Becker, attached), Plate 1 and Figure 2-16 (Geomatrix, 1995) and the NGS map and found them to be accurate and suitable for estimating the downdip width of the Cascadia interface. These data support the conclusion that the boundary listed in Figure 2-16 of Geomatrix (1995) is mislabeled.

I independently calculated the downdip width based on these parameters to verify the values listed in Table 7-3 (see attached Excel Spreadsheet).

I note that either Table 7-4 is missing or Table 7-5 (and all subsequent Tables) is (are) mislabeled.
Resolution: Table numbers have been corrected

Comparison of Tables 7-3 and 7-5 show a number of discrepancies in the estimates of the *maximum* downdip width of the Cascadia interface. The heading for Table 7-5 should be changed to – *Average* Maximum Rupture Downdip Width of the Cascadia Interface to resolve this confusion.
Resolution: Table 7-4 title changed to indicate that down dip widths are averaged along the rupture length

I independently calculated the mean characteristic magnitudes for the Cascade interface using the values from Section 4 and the equations from Section 5 to verify the values listed in Table 7-6 (see attached Excel Spreadsheet). Differences are noted in red.
Resolution: Differences noted in the ITR have been corrected and resolved.

I verified that 5.5 km is the closest horizontal distance to the HBIP from the Table Bluff fault from Figure 3-3 (PGE, 2001) and 7 km is the closest distance (at depth) from the cross-section in Figure 3-4 (PGE, 2001). I note that these figures are preliminary and these values will need to be checked against the final figures when they are issued.

Resolution: These distances have been checked and verified against the final versions of Figure 3-3 and 3-4 (Rev. 0, Sept 11, 2002).

7.2 Magnitude for the Little Salmon Fault System

I independently calculated the mean characteristic magnitude for Little Salmon fault system using the values from Section 4 and the equations from Section 5 to verify the values listed in Table 7-7 (see attached Excel Spreadsheet). Differences are noted in red. While the math is correct, application of these values is subject to resolution of the length of the Little Salmon fault system (310 or 330 km – see comments for Section 4.3). Note, that in the attached spreadsheet for Table 7-7, the difference in the final weighted magnitude is 0.01 unit (7.74 vs. 7.73)
Resolution: Length of the Little Salmon fault is now consistently defined as 310 km throughout this Calculation Package as per Appendix 5A, Rev. 0. The final weighted magnitude for the mean characteristic event is rounded to M 7.7.

I verified that 0.5 km is the shortest distance to the HBIP from the Bay Entrance fault from Figure 4-16 (PGE, 2002). I note that these figures are preliminary and these values will need to be checked against the final figures when they are issued.
Resolution: This distance has been checked and verified against the final version of Figure 4-16 (Rev. 0, Sept 16, 2002).

8. & 9. Results/ Conclusions

I verified that the results of this calculation are consistent with the analysis and that the conclusions of the calculation are well supported by the results, subject to resolution of the comments raised in this ITR. The purpose of the calculation (as described in the Purpose section) has been met.

10. References

I verified that all the references are appropriately cited and note that a reference is needed for Carver (2002).
Resolution: Reference for Carver (2002) was added.

11. Attachments

Verification spreadsheets, Method B, for Tables 7-3, 7-6 (revised 7-5), and 7-7 (revised 7-6).

Verifier Name (print): Stuart Nishenko

Signature: [signature]

Date: 10/16/02

Table 7-3

Latitude	Change in Fold Trends				Deformation Front			
	Zero Isobase		Trans Zone		Zero Isobase		Trans Zone	
	Horiz W	Downdip W	Horiz W	Downdip W	Horiz W	Downdip W	Horiz W	Downdip W
41	100	**104**	65	**68**	130	**135**	95	**99**
42	100	**104**	57	**59**	130	**135**	87	**91**
43	87	**91**	52	**54**	117	**122**	82	**85**
44	83	**86**	52	**54**	113	**118**	82	**85**
45	74	**77**	57	**59**	104	**108**	87	**91**
46	78	**81**	78	**81**	108	**112**	108	**112**
47	83	**86**	117	**122**	113	**118**	147	**153**
48	70	**73**	126	**131**	100	**104**	156	**162**
49	39	**41**	83	**86**	69	**72**	113	**118**
Average 41-47		**90**		**71**		**121**		**102**
41-49		**83**		**79**		**114**		**111**

Table 7-6

Updip	Downdip	Width	Length	M(A)	Mag	Updip Wt	Down Wt	Length Wt	Model Wt	Total Wt	Wt*Mag	
Zero	Def	120	700	Geo	8.69	0.30	0.6	0.5	0.5	0.045	0.39	
Zero	Def	115	1050	Geo	8.82	0.30	0.6	0.5	0.5	0.045	0.40	
Zero	Fold	90	700	Geo	8.59	0.70	0.6	0.5	0.5	0.105	0.90	
Zero	Fold	85	1050	Geo	8.71	0.70	0.6	0.5	0.5	0.105	0.91	
Thermal	Def	100	700	Geo	8.62	0.30	0.4	0.5	0.5	0.03	0.26	
Thermal	Def	110	1050	Geo	8.80	0.30	0.4	0.5	0.5	0.03	0.26	
Thermal	Fold	70	700	Geo	8.50	0.70	0.4	0.5	0.5	0.07	0.59	
Thermal	Fold	80	1050	Geo	8.69	0.70	0.4	0.5	0.5	0.07	0.61	
Zero	Def	120	700	Abe	8.91	0.30	0.6	0.5	0.5	0.045	0.40	
Zero	Def	115	1050	Abe	9.07	0.30	0.6	0.5	0.5	0.045	0.41	
Zero	Fold	90	700	Abe	8.79	0.70	0.6	0.5	0.5	0.105	0.92	
Zero	Fold	85	1050	Abe	8.94	0.70	0.6	0.5	0.5	0.105	0.94	
Thermal	Def	100	700	Abe	8.84	0.30	0.4	0.5	0.5	0.03	0.27	
Thermal	Def	110	1050	Abe	9.05	0.30	0.4	0.5	0.5	0.03	0.27	
Thermal	Fold	70	700	Abe	8.68	0.70	0.4	0.5	0.5	0.07	0.61	
Thermal	Fold	80	1050	Abe	8.91	0.70	0.4	0.5	0.5	0.07	0.62	
										1	8.77	Mean

Little Salmon Fault Zone

Table 7-7

Approach	Wt	Dip	Dip Wt	Thickness	Width	Seg Lengt	Seg Wt	Area	Disp	Disp Wt	Mag	Total Wt	Wt*Mag
Area	0.5	40	0.2	15	23.3	310	1	7223			7.85	0.1	0.79
Area	0.5	45	0.6	15	21.2	310	1	6572			7.81	0.3	2.34
Area	0.5	50	0.2	15	19.6	310	1	6076			7.78	0.1	0.78
Disp	0.5								7	0.5	7.62	0.25	1.91
Disp	0.5								9.3	0.5	7.72	0.25	1.93
											7.8	Mean	7.74
												1	

Mag(Area) is Eqn 5-1, Wells and Coppersmith(94)
Mag(Disp) is Eqn 5-4, Wells and Coppersmith(94)

Approach	Wt	Dip	Dip Wt	Thickness	Width	Seg Lengt	Seg Wt	Area	Disp	Disp Wt	Mag	Total Wt	Wt*Mag
Area	0.5	40	0.2	15	23.3	330	1	7689			7.88	0.1	0.79
Area	0.5	45	0.6	15	21.2	330	1	6996			7.84	0.3	2.35
Area	0.5	50	0.2	15	19.6	330	1	6468			7.80	0.1	0.78
Disp	0.5								7	0.5	7.62	0.25	1.91
Disp	0.5								9.3	0.5	7.72	0.25	1.93
											7.8	Mean	7.76
												1	

Mag(Area) is Eqn 5-1, Wells and Coppersmith(94)
Mag(Disp) is Eqn 5-4, Wells and Coppersmith(94)