IV.A.

Site-Specific Seismic Hazard Analyses and Development of Time Histories for the Port of Alaska

Ivan Wong, Nora Lewandowski, Brian Gray, Nesrin Yenihayat, Qimin Wu, and Arash Zandieh

Lettis Consultants International, Inc.

1000 Burnett Ave., Suite 350
Concord, CA 94520

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Anchorage, Alaska
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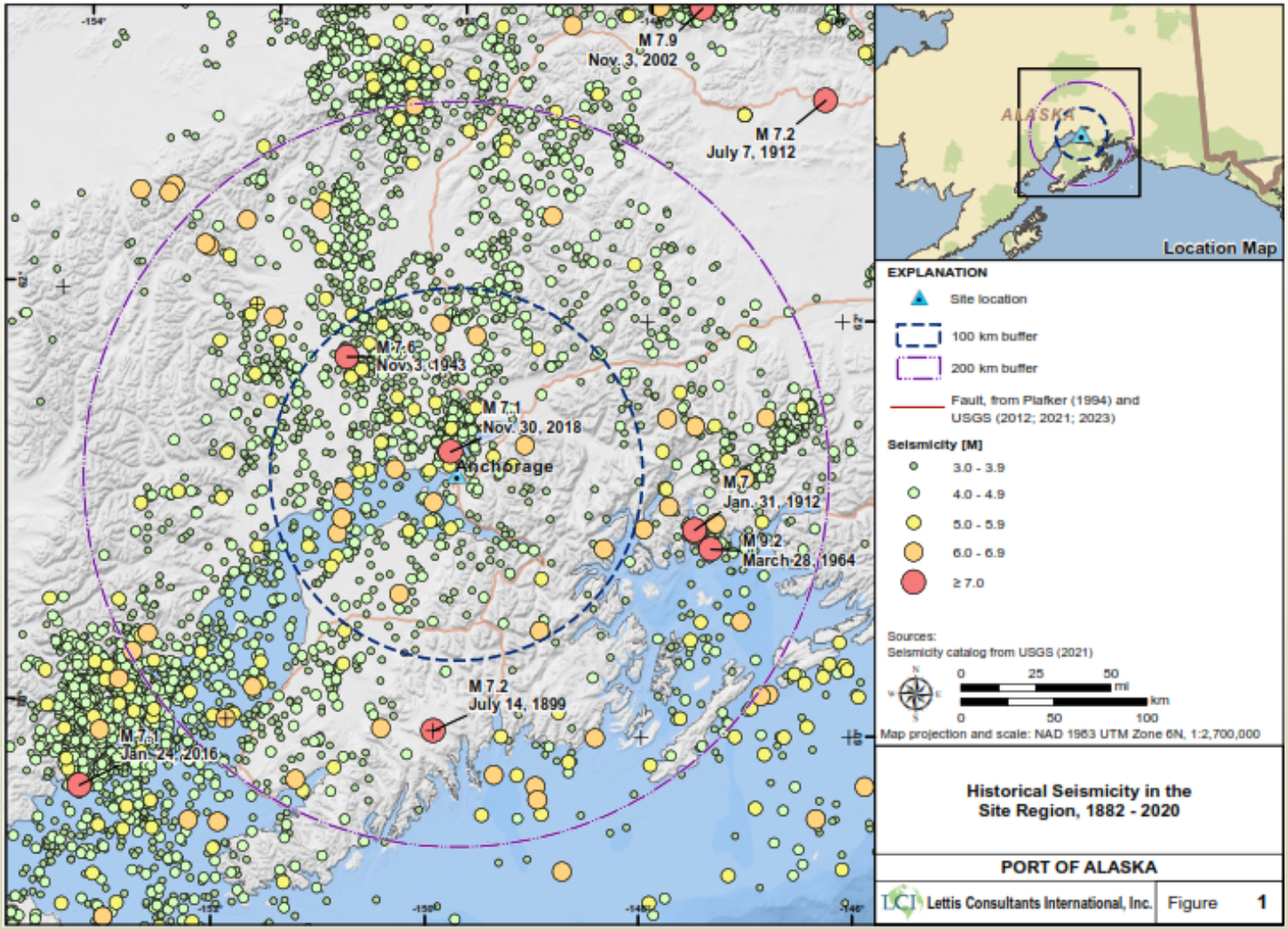
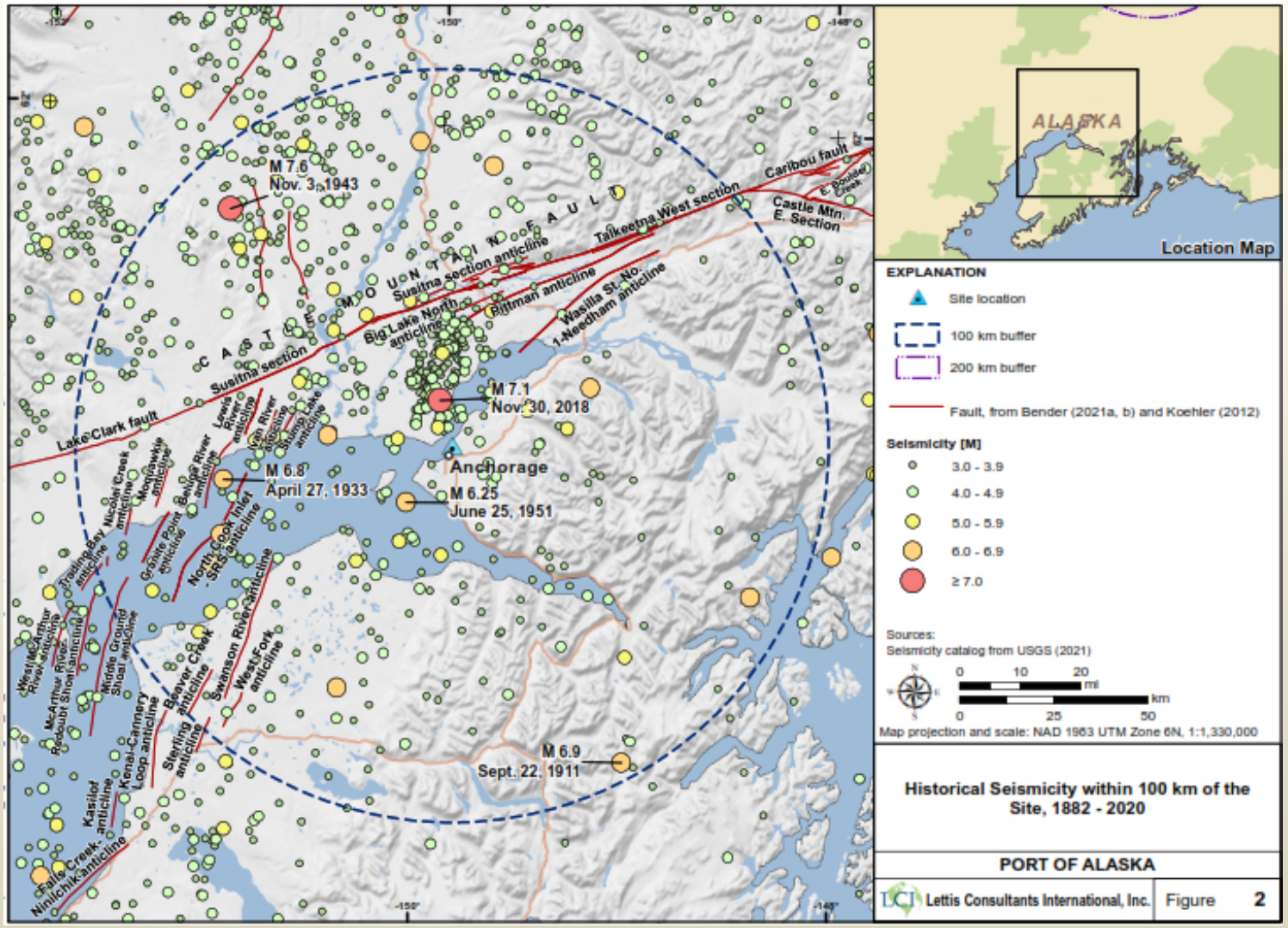
Introduction

- Performed site-specific probabilistic and deterministic seismic hazard analyses
- Purpose was to develop the following design ground motions consistent with ASCE 61-23 and ASCE 7-22:
  - MCE – Maximum Considered Earthquake (2,475-Year Return Period)
  - DE – Design Earthquake (975-Year RP)
  - CLE – Contingency Level Earthquake (475-Year RP)
  - OLE – Operating Level Earthquake (72-Year RP)
- Hazard was calculated assuming Vs30 of 760 m/sec (firm rock) which was input into site response analyses
- CMS and time histories were also developed

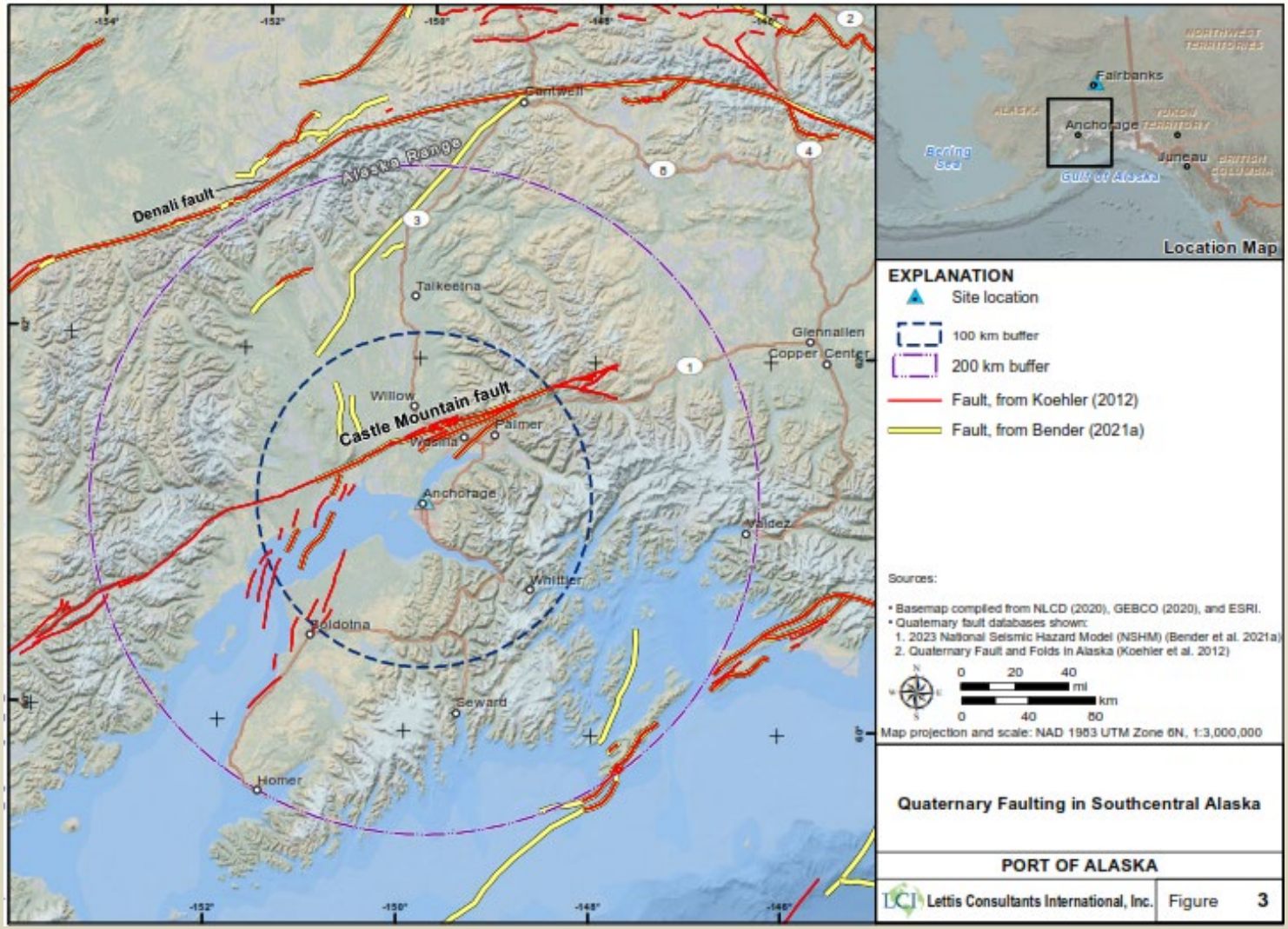
Historical Seismicity in the Site Region, 1882-2020



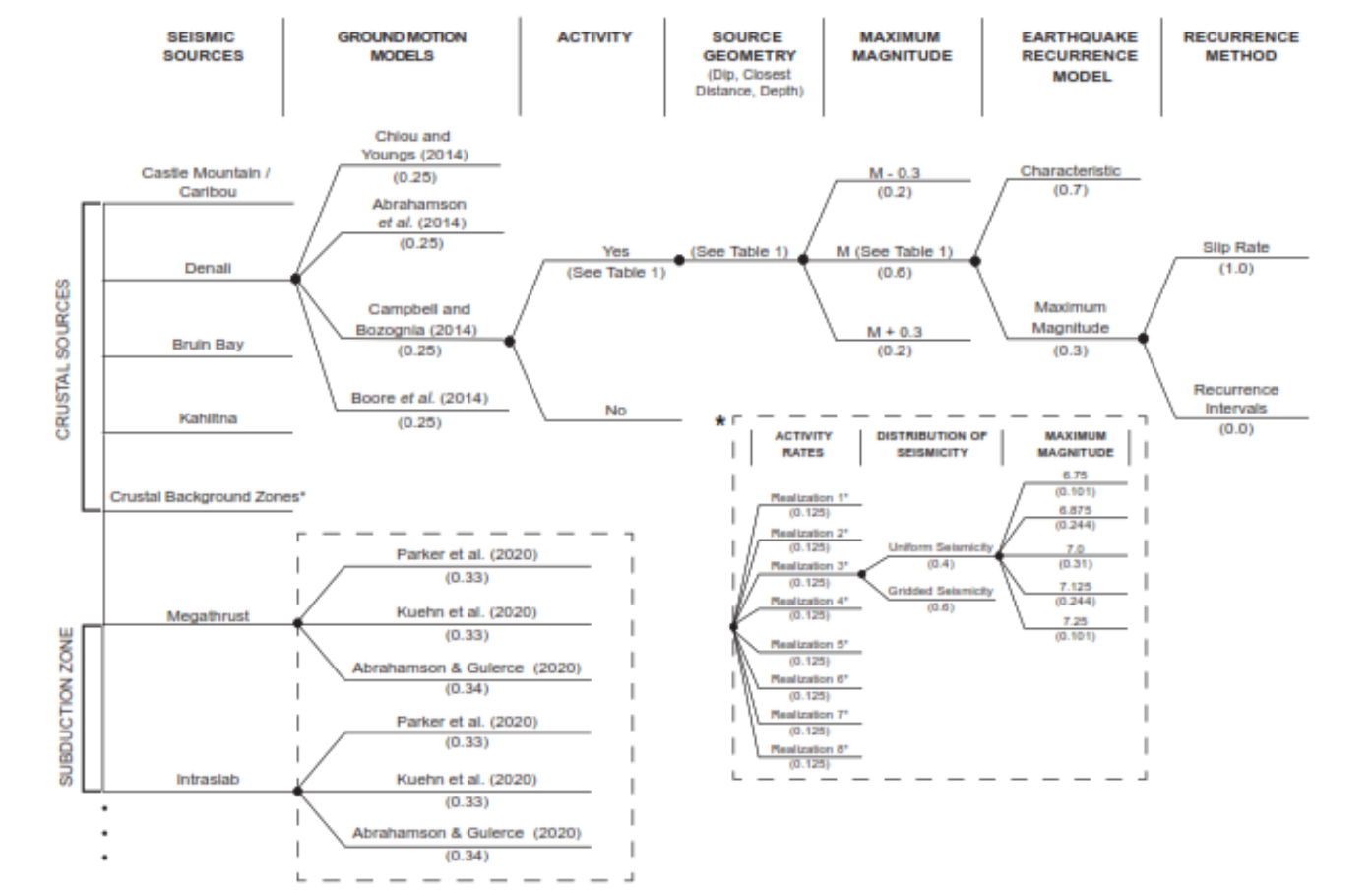
Historical Seismicity within 100 km of the Site, 1882-2020



Quaternary Faulting in South-Central Alaska



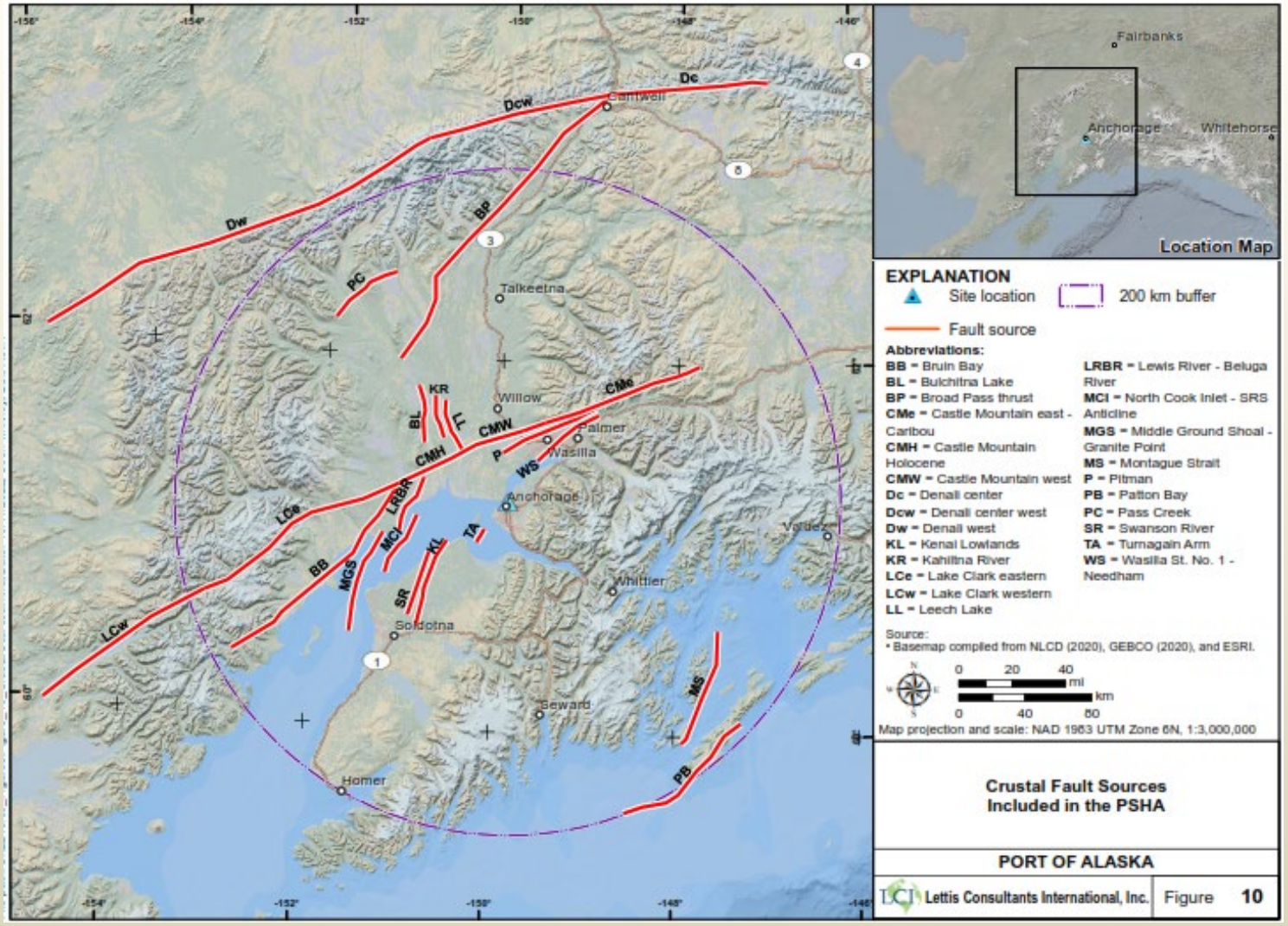
Generalized Seismic Hazard Model Logic Tree



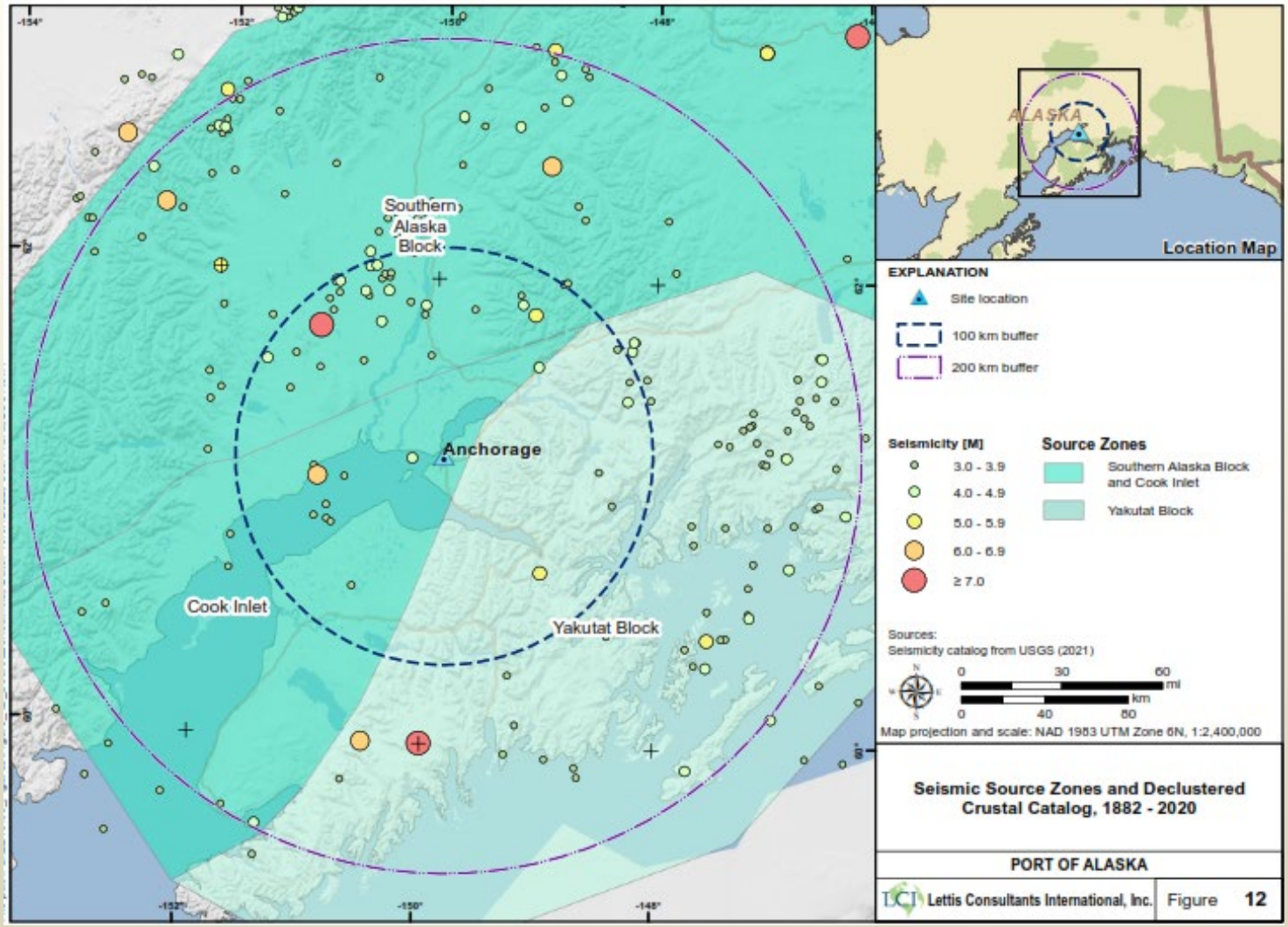
Notes:

1. Additional epistemic uncertainty added to NGA-West2 GMMs using Al Atik and Youngs (2014).
2. Global median NGA-Sub GMMs are used and additional epistemic uncertainty was added following the approach of Al Atik and Youngs (2014).

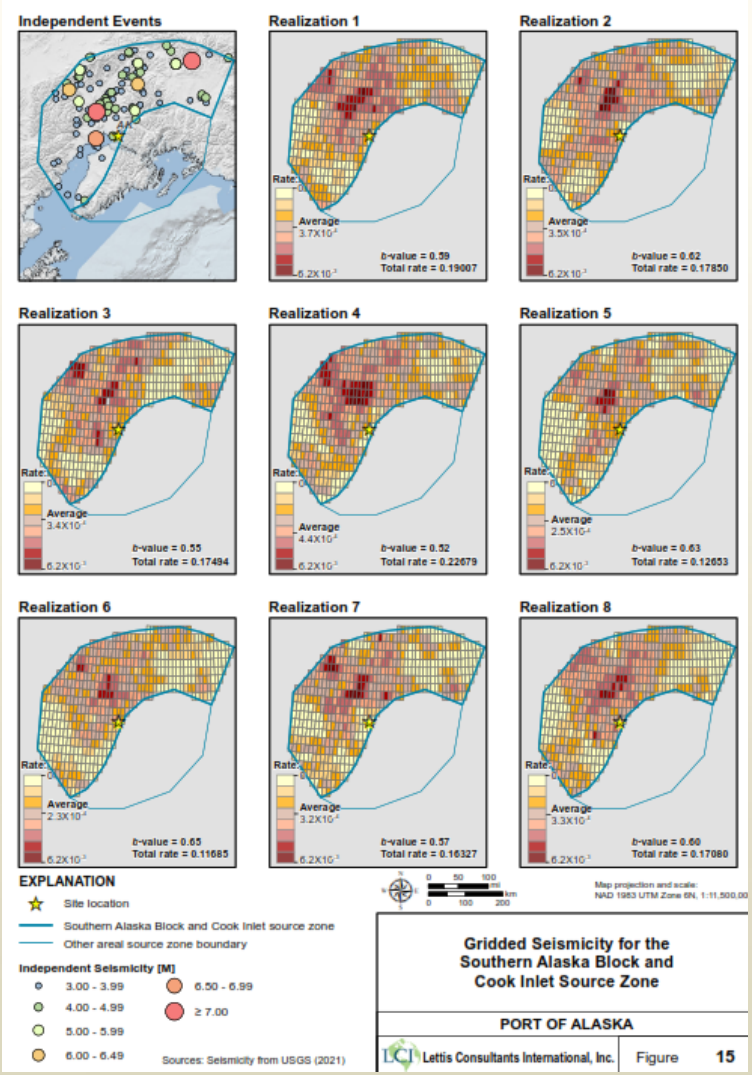
Crustal Fault Sources Included in the PSHA



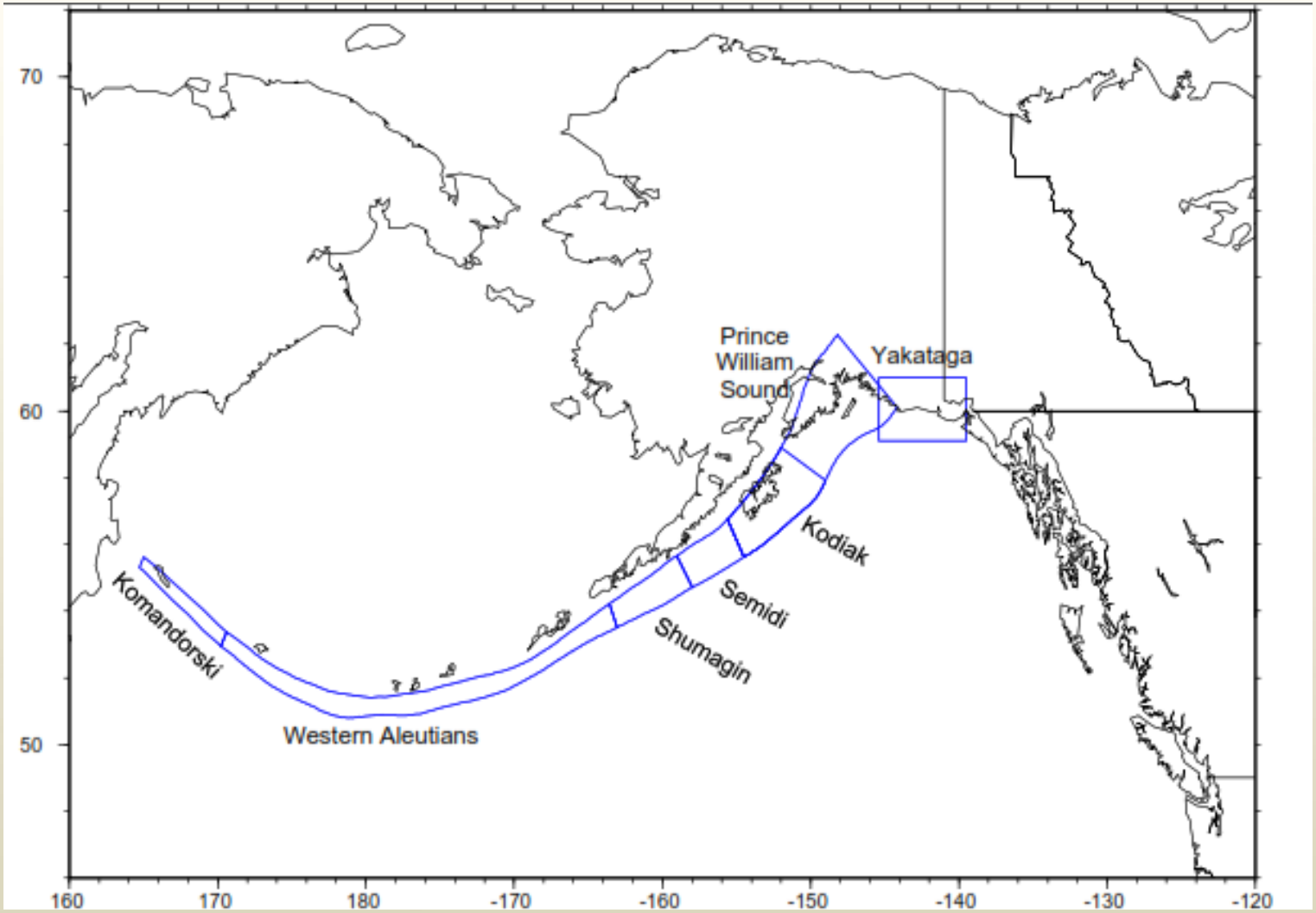
Seismic Source Zones and Declustered Crustal Catalog, 1882-2020



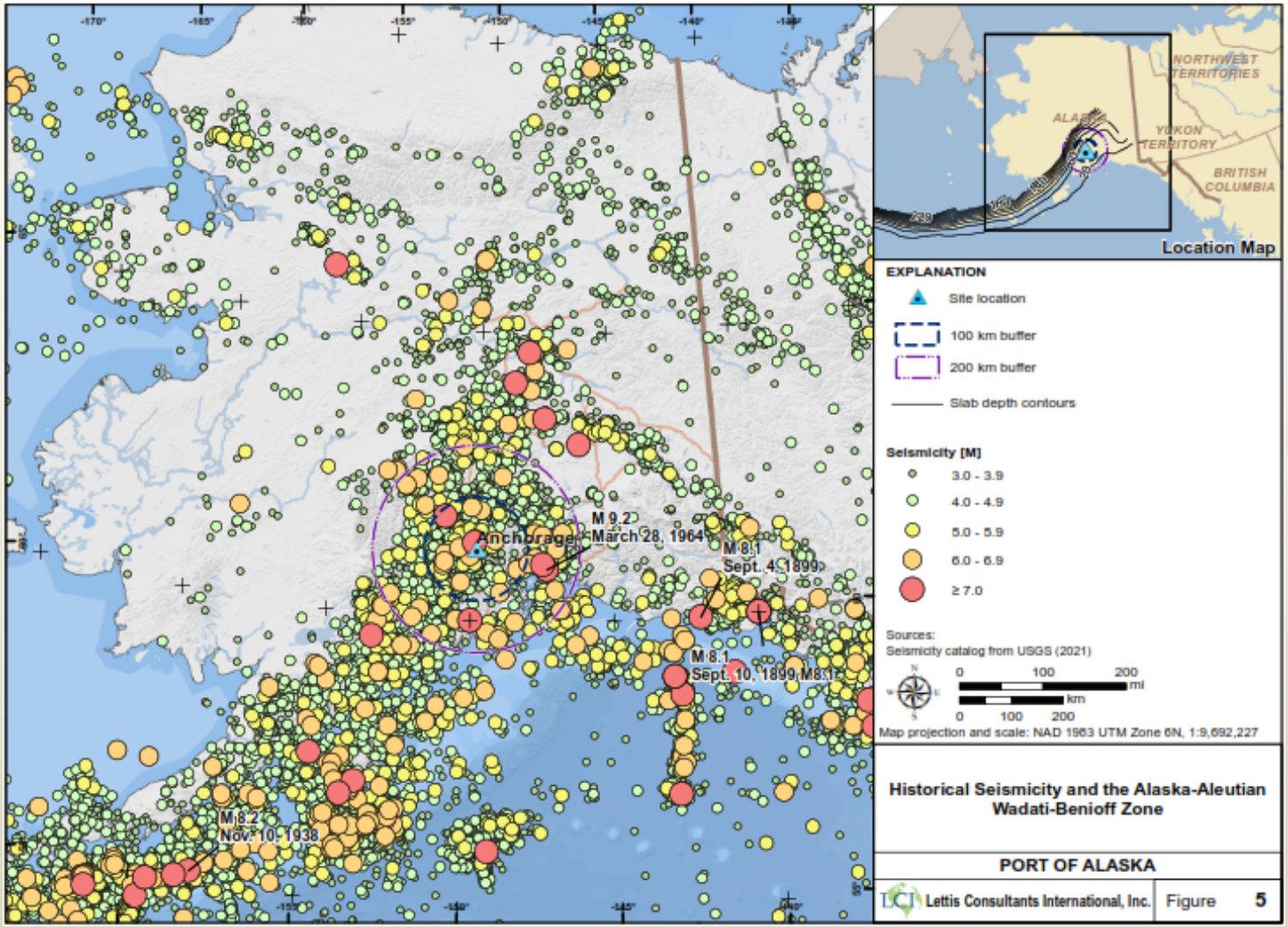
Gridded Seismicity for the Southern Alaska Block and Cook Inlet Source Zone



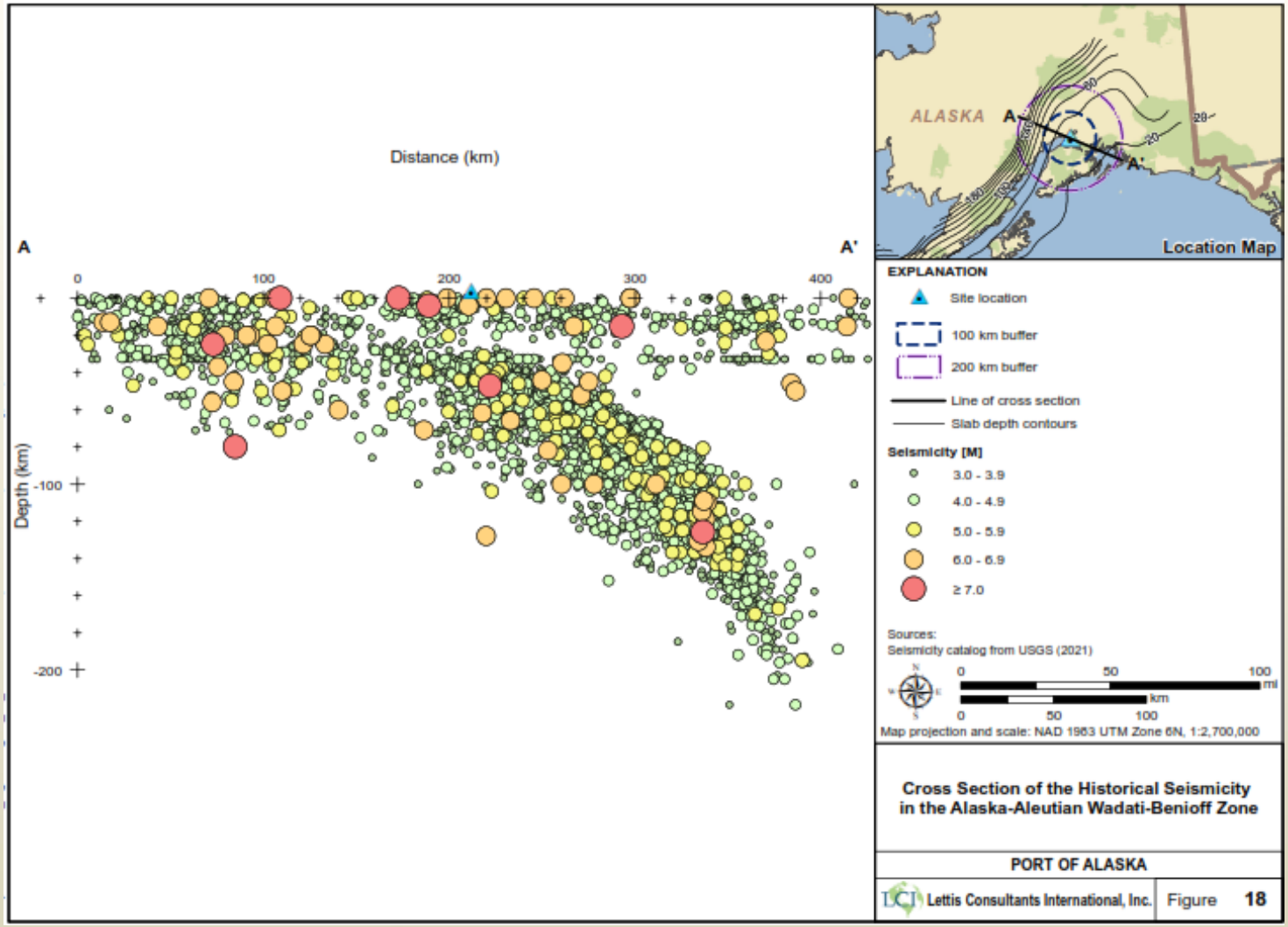
Segmentation of the Alaska-Aleutian Subduction Zone



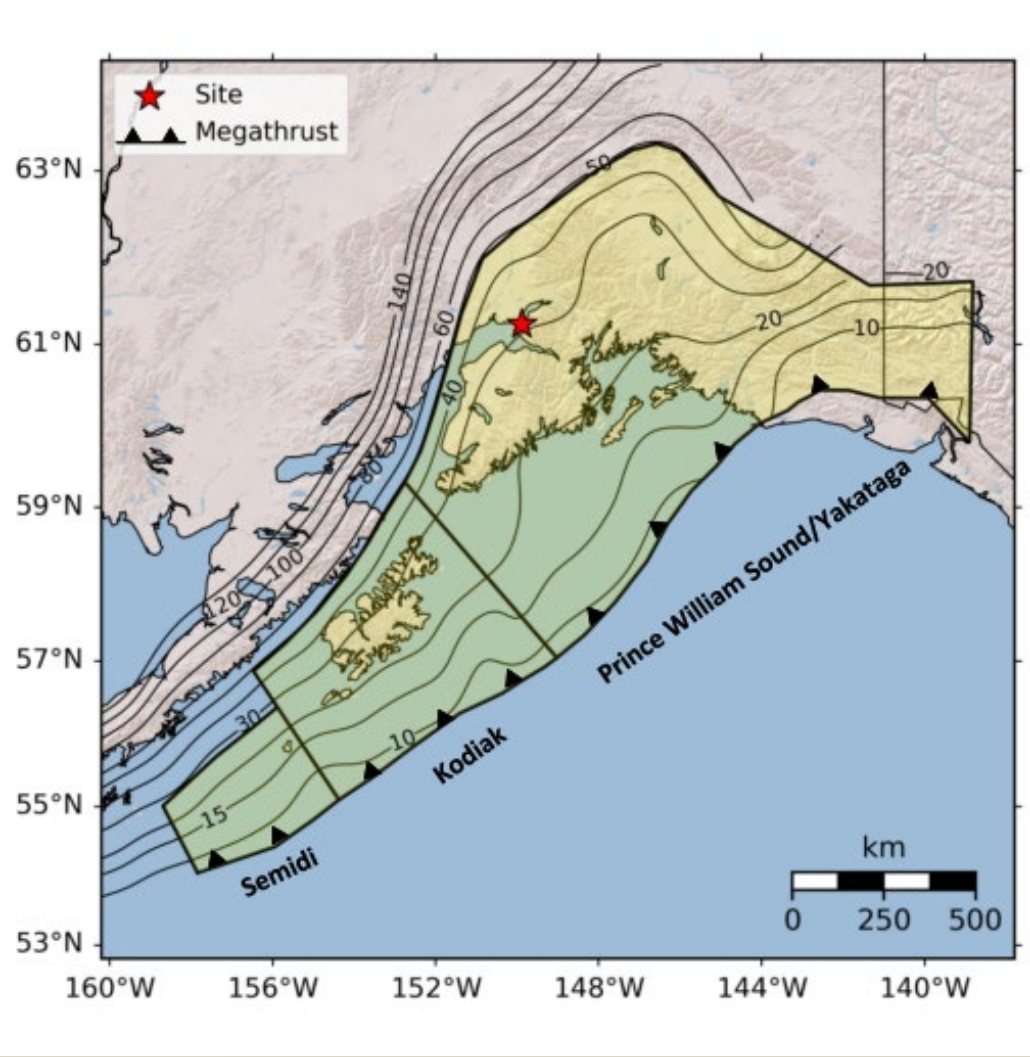
Historical Seismicity and the Alaska-Aleutian Wadati-Benioff Zone



Cross Section of the Historical Seismicity in the Alaska-Aleutian Wadati-Benioff Zone



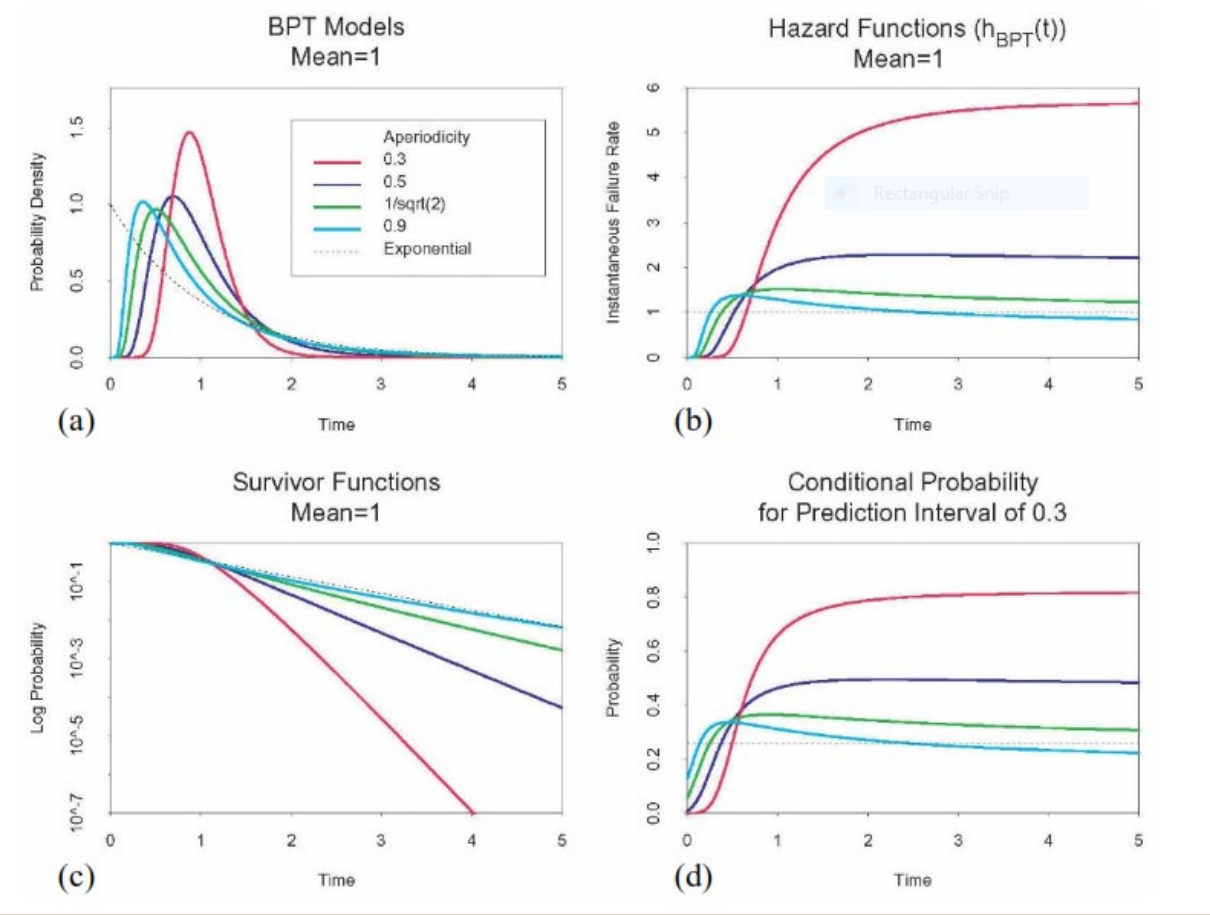
Contour Map of Top of Megathrust and Wadati-Benioff Zone



Seismic Source Parameters for Alaskan Subduction Zone

Fault Name	Probability of Activity	Rupture Model	Source	Preferred Mmax (M)	b-value	Dip (degrees)	Rupture Depth (km)	Recurrence Interval (Yrs)	Comments
Eastern section (Western Yakutat/Prince William Sound/Kodiak)	1.0	Unsegmented (0.7)	Kodiak + PWS/WY	9.1 (0.2) 9.2 (0.6) 9.3 (0.2)	1.00	3.0 N (0.2) 6.0 N (0.6) 9.0 N (0.2)	25 (0.2) 35 (0.6) 50 (0.2)	500 (0.2) 600 (0.6) 700 (0.2)	1964 Earthquake
		Segmented (0.3)	PWS/WY	8.8 (0.2) 9.0 (0.6) 9.2 (0.2)	1.00	3.0 N (0.2) 6.0 N (0.6) 9.0 N (0.2)	25 (0.2) 35 (0.6) 50 (0.2)	500 (0.2) 600 (0.6) 700 (0.2)	
			Kodiak	8.5 (0.2) 8.8 (0.6) 9.1 (0.2)	1.00	5.0 N (0.2) 7.0 N (0.6) 9.0 N (0.2)	30 (0.5) 50 (0.5)	400 (0.2) 500 (0.6) 600 (0.2)	Ruptured independently at least 4 times in past 2000 years. One to two times ruptured in the same time period with PWS.
Semidi	1.0	Unsegmented (1.0)		7.9 (0.2) 8.2 (0.6) 8.5 (0.2)	0.71	6 N (0.5) 10 N (0.5)	20 (0.2) 24 (0.6) 28 (0.2)	180 (0.2) 225 (0.6) 270 (0.2)	Ruptured in 1788 and 1938. RI 180-270 years.

BPT Model


BPT Models
Mean=1
Probability Density
Aperiodicity
0.3
0.5
1/sqrt(2)
0.9
Exponential
Time
(a)
Hazard Functions ($h_{BPT}(t)$)
Mean=1
Instantaneous Failure Rate
Time
(b)
Survivor Functions
Mean=1
Log Probability
Time
(c)
Conditional Probability
for Prediction Interval of 0.3
Probability
Time
(d)

Paleoseismic Event Ages and Recurrence Intervals for 1964 Earthquakes (Source: Shennan et al., 2014)

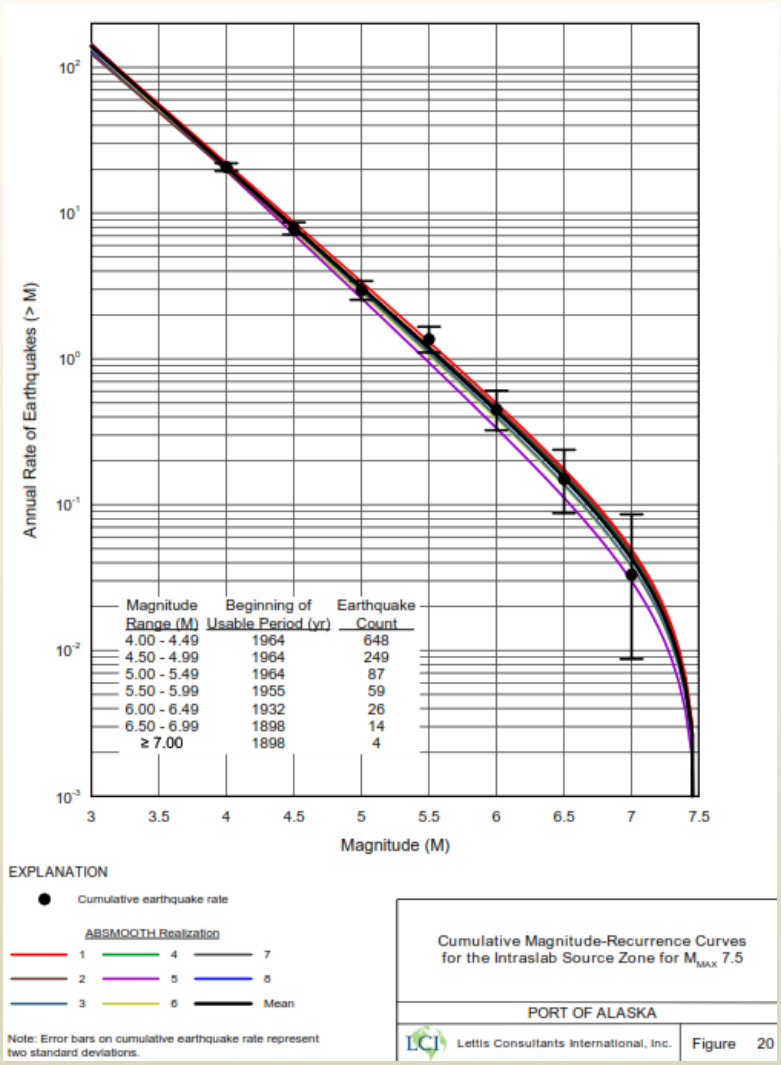
Modelled age (years BP)	**from**	**to**	**%**	**μ**	**σ**	**m**	**n_{sites}**	**$n_{samples}$**
EQ1	902	837	95.4	870	17	871	9	34
EQ2	1484	1397	95.4	1440	21	1441	7	17
EQ3	2102	2006	95.4	2052	27	2050	6	9
EQ4	2685	2540	95.4	2615	38	2618	5	13
EQ5	3216	3037	95.4	3131	43	3131	2	5
EQ6	3662	3475	95.4	3550	47	3541	1	7
Modelled interval (years)								
AD1964 to EQ1	850	915	95.4	883	17	885		
EQ1 to EQ2	517	625	95.4	571	27	571		
EQ2 to EQ3	545	680	95.4	611	35	611		
EQ3 to EQ4	470	653	95.4	563	47	565		
EQ4 to EQ5	403	635	95.4	517	58	516		
EQ5 to EQ6	299	550	95.4	419	64	415		
Mean interval AD1964 to EQ6	518	558	95.4	536	10	535		
Mean interval EQ1 to EQ6	579	612	95.4	594	8	593		

Time-Dependent Equivalent Poisson Recurrence Intervals

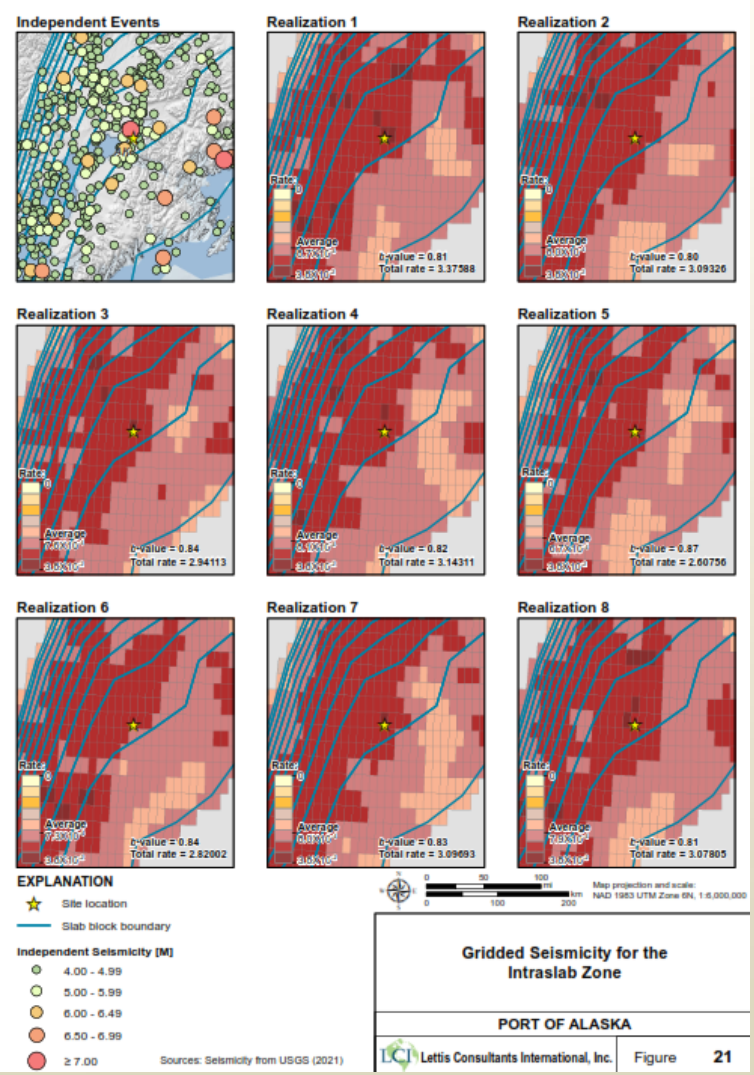
Source	Poisson Recurrence Interval (yr)	*Poisson Recurrence Interval Weight*	COV	*COV Weight*	BPT Probability	Equivalent Poisson Rate (1/yr)	Equivalent Poisson Recurrence Interval (yr)	*Equivalent Poisson Recurrence Interval Weight*
Kodiak+PWS/WY	500	*0.2*	0.3	*0.5*	1.65E-08	3.29E-10	> 100,000,000	*0.1*
	600	*0.6*	0.3	*0.5*	1.09E-10	2.17E-12	> 100,000,000	*0.3*
	700	*0.2*	0.3	*0.5*	6.50E-13	1.30E-14	> 100,000,000	*0.1*
	500	*0.2*	0.5	*0.4*	6.33E-04	1.27E-05	78,989	*0.08*
	600	*0.6*	0.5	*0.4*	9.80E-05	1.96E-06	509,954	*0.24*
	700	*0.2*	0.5	*0.4*	1.48E-05	2.96E-07	3,382,171	*0.08*
	500	*0.2*	0.7	*0.1*	1.34E-02	2.71E-04	3,695	*0.02*
	600	*0.6*	0.7	*0.1*	5.03E-03	1.01E-04	9,908	*0.06*
	700	*0.2*	0.7	*0.1*	1.86E-03	3.72E-05	26,857	*0.02*
Kodiak	400	*0.2*	0.3	*0.5*	2.33E-06	4.66E-08	21,445,466	*0.1*
	500	*0.6*	0.3	*0.5*	1.65E-08	3.29E-10	> 100,000,000	*0.3*
	600	*0.2*	0.3	*0.5*	1.09E-10	2.17E-12	> 100,000,000	*0.1*
	400	*0.2*	0.5	*0.4*	4.04E-03	8.10E-05	12,339	*0.08*
	500	*0.6*	0.5	*0.4*	6.33E-04	1.27E-05	78,989	*0.24*
	600	*0.2*	0.5	*0.4*	9.80E-05	1.96E-06	509,954	*0.08*
	400	*0.2*	0.7	*0.1*	3.57E-02	7.27E-04	1,375	*0.02*
	500	*0.6*	0.7	*0.1*	1.34E-02	2.71E-04	3,695	*0.06*
	600	*0.2*	0.7	*0.1*	5.03E-03	1.01E-04	9,908	*0.02*

Note: Recurrence intervals for Segmented PWS/WY are the same as those for Kodiak+PWS/WY.

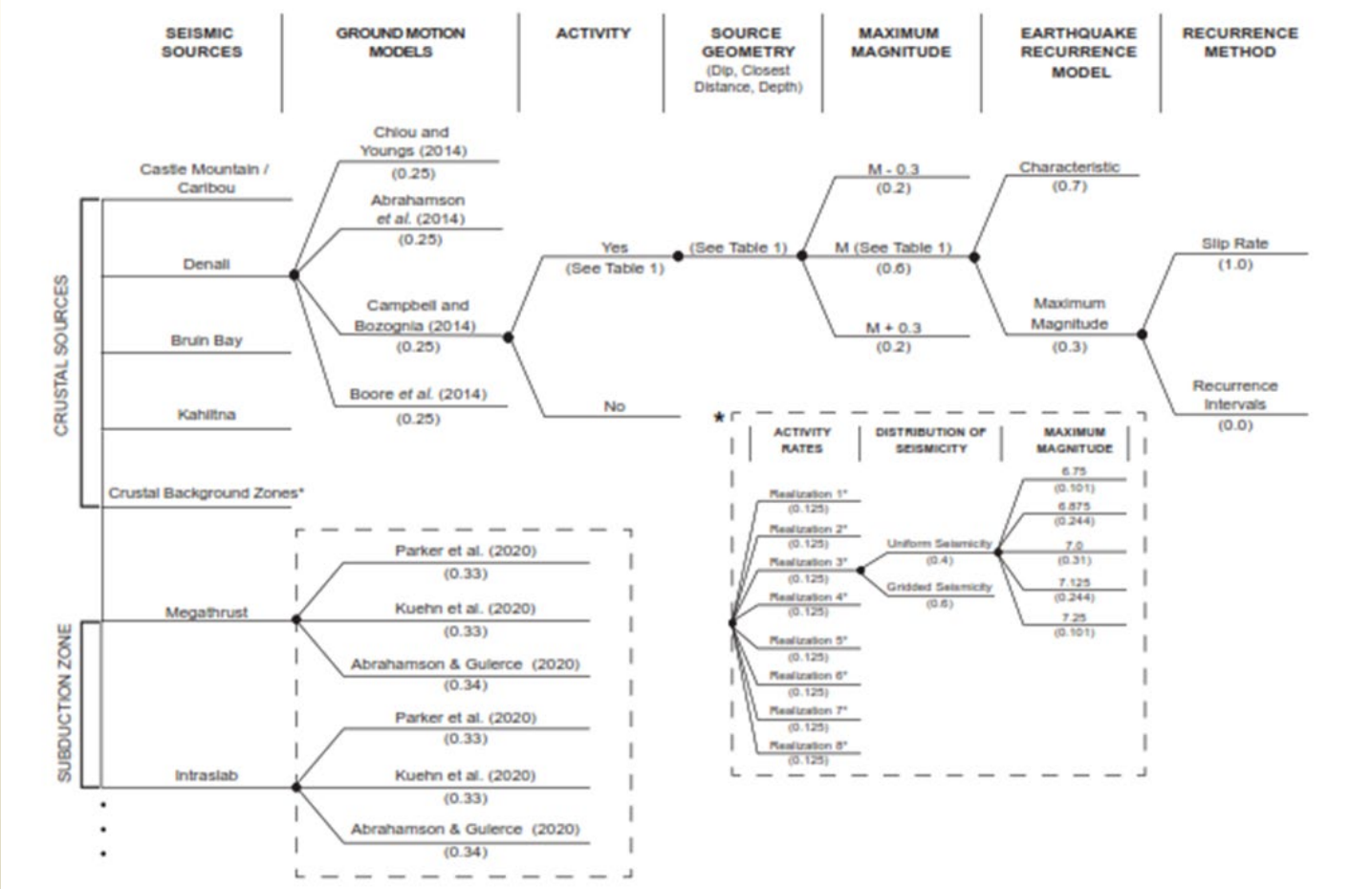
Cumulative Magnitude-Recurrence Curves for the Intraslab Source Zone for Mmax 7.5



Gridded Seismicity for the Intraslab Zone



Ground Motion Models



Notes:

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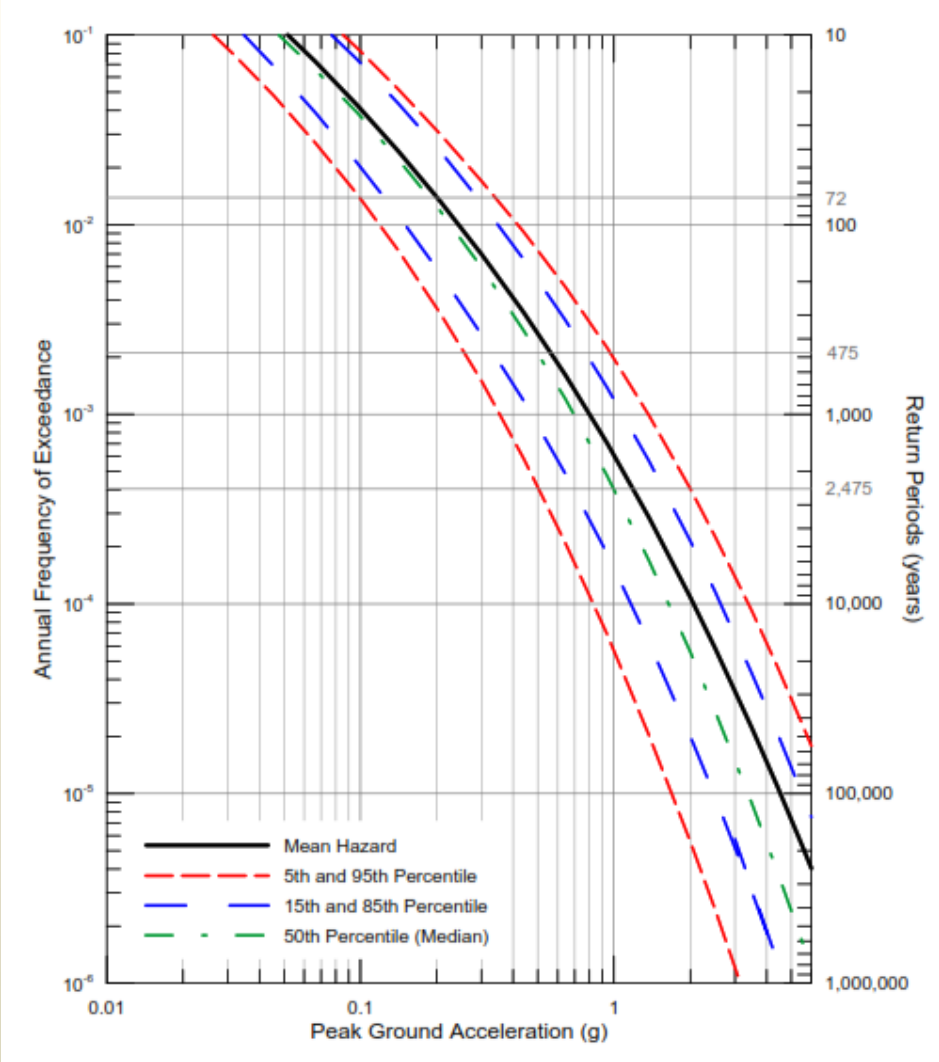
2. Global median NGA-Sub GMMs are used and additional epistemic uncertainty was added following the approach of Al Atik and Youngs (2014).

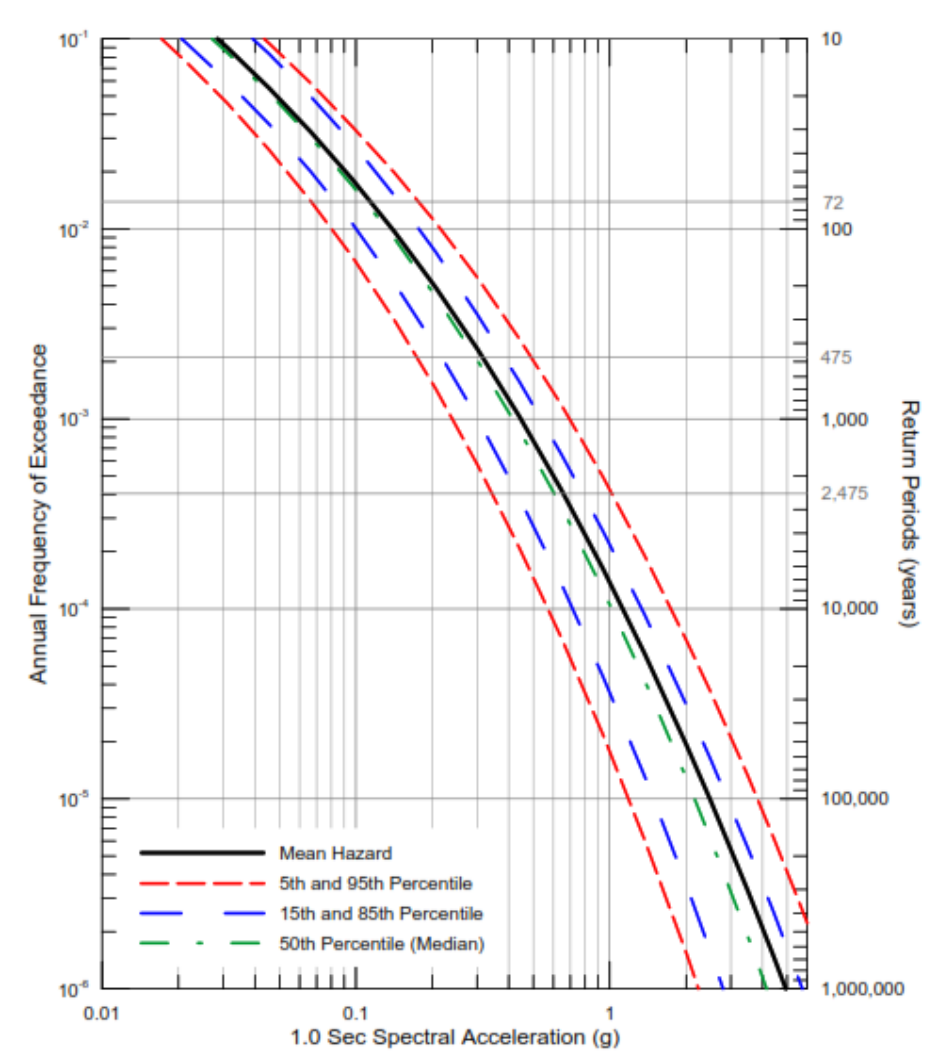
Basin Effects

- Moschetti et al. (2021) computed ground motion residuals from 44 intermediate earthquakes and suggested significant basin amplification in Cook Inlet that scales with basin depth and exhibits maximum amplification of about two at 1 sec.
- Based on Shellenbaum et al. (2010), we estimated the depth to basement rock beneath the Port is about 1.0 km (Z2.5).
- The NGA-Sub GMMs (global or Alaska) do not have basin factors.
- Based on discussions with Morgan Moschetti (USGS), we used the Puget Sound basin amp factors and included them in the global models.

Seismic Hazard Curves for Peak Horizontal Acceleration for Vs30 760 m/sec



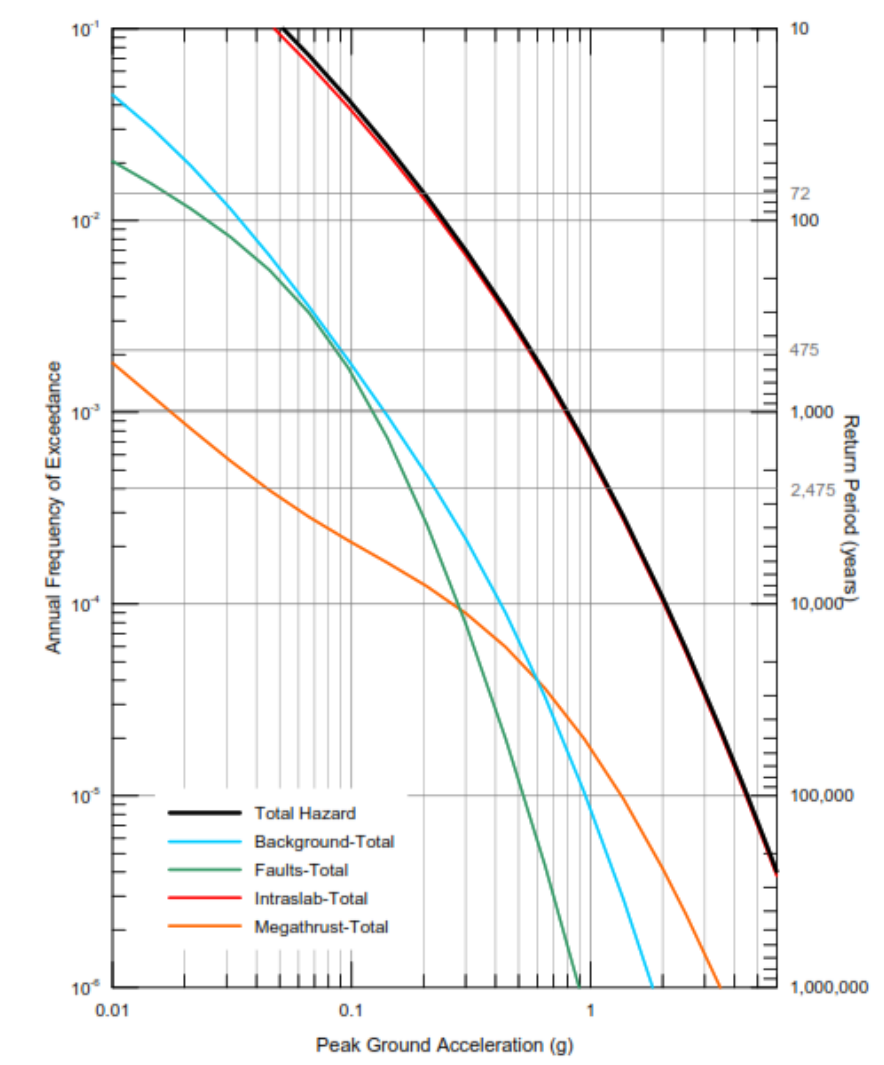
Seismic Hazard Curves for 1.0 Sec Horizontal Spectral Acceleration for Vs30 760 m/sec



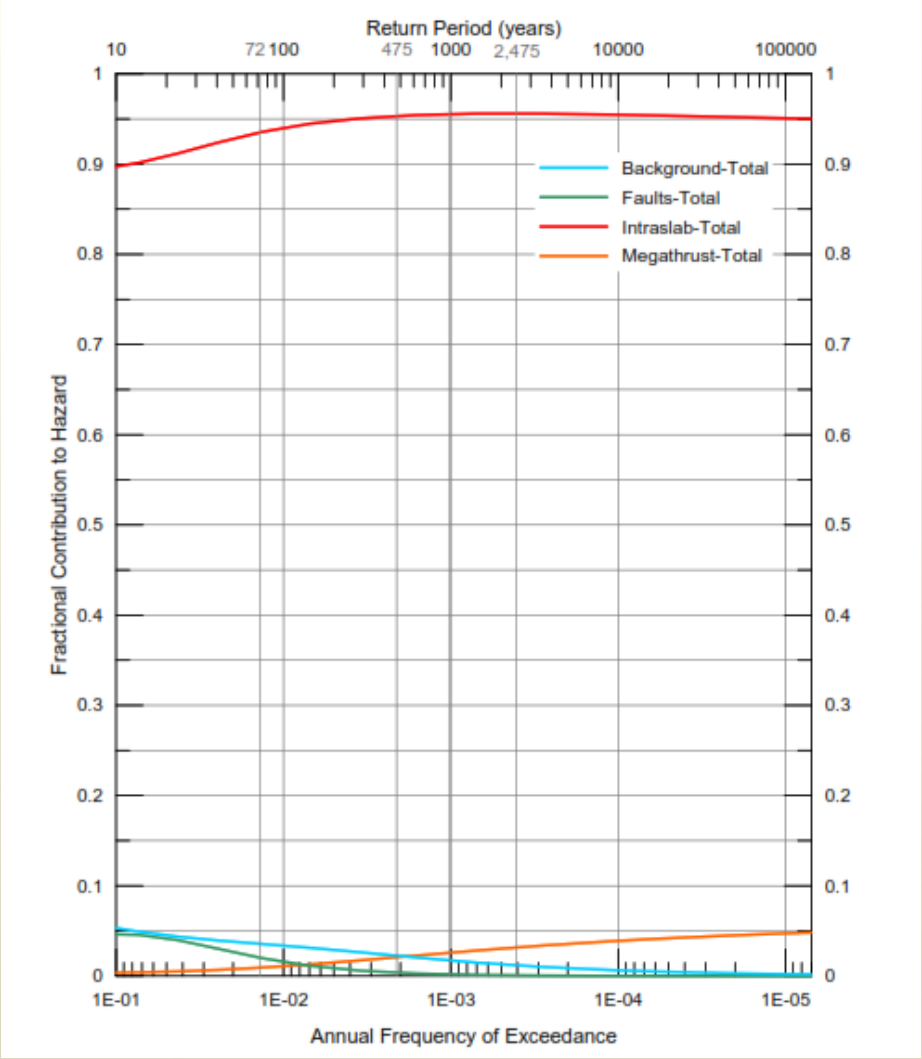
Probabilistic Ground Motions at Selected Return Periods

Return period (years)	PGA (g) Mean [5th, 95th percentiles]	1.0 Sec SA (g) Mean [5th, 95th percentiles]
72	0.201 [0.099,0.340]	0.115 [0.067,0.176]
475	0.563 [0.257,0.967]	0.320 [0.174,0.490]
975	0.791 [0.350,1.349]	0.449 [0.237,0.686]
2,475	1.187 [0.504,2.000]	0.671 [0.344,1.019]

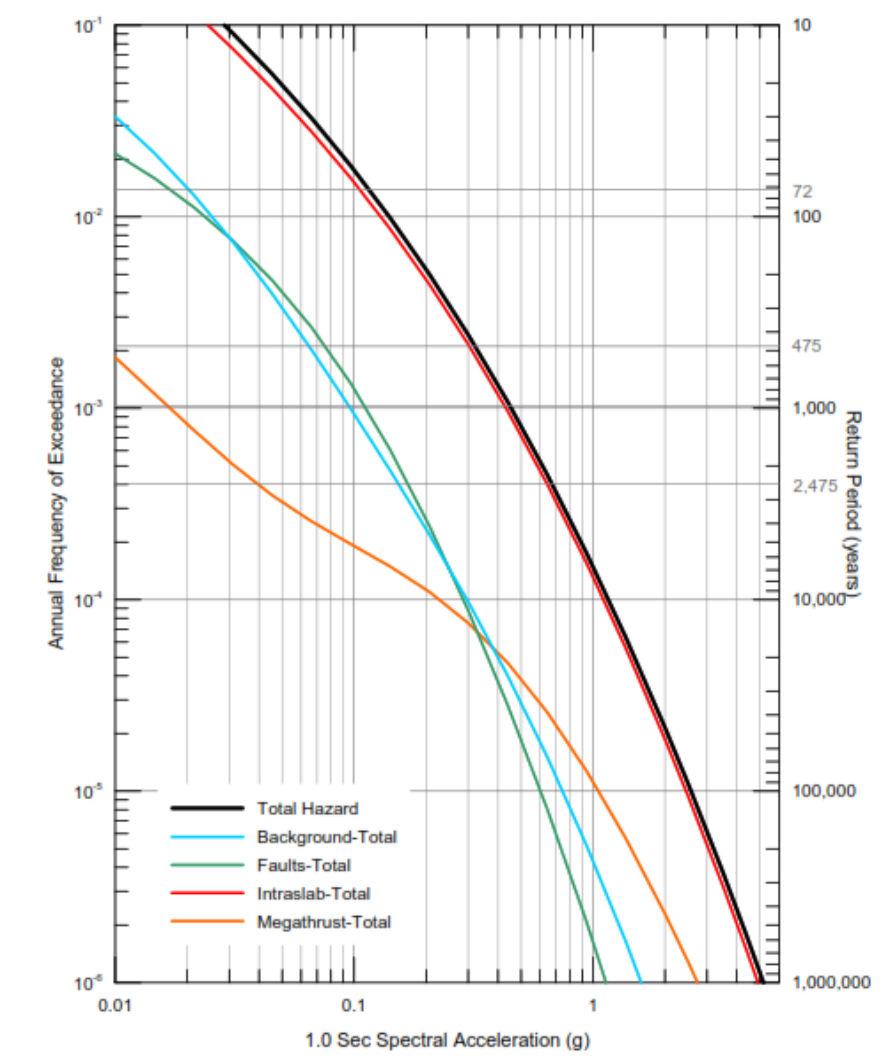
Seismic Source Contributions to Mean Peak Horizontal Acceleration Hazard for Vs30 760 m/sec



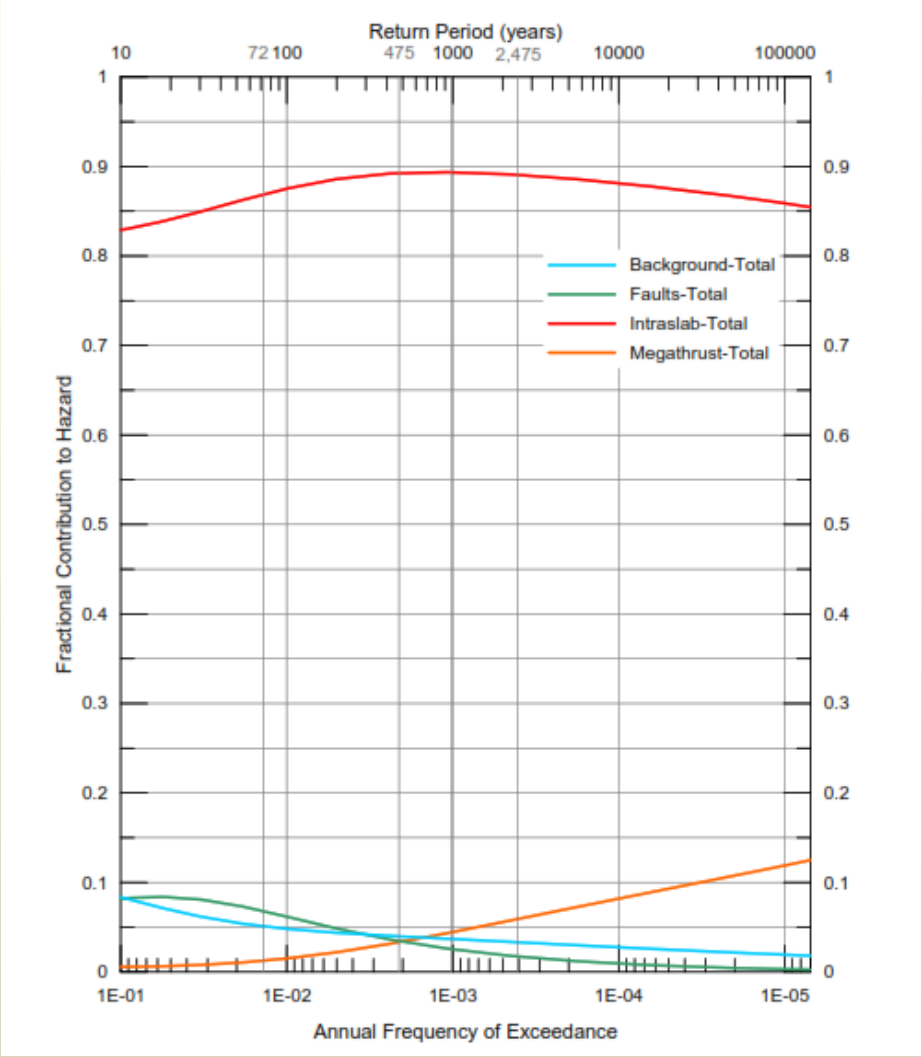
Seismic Source Fractional Contributions to Mean Peak Horizontal Acceleration Hazard for Vs30 760 m/sec



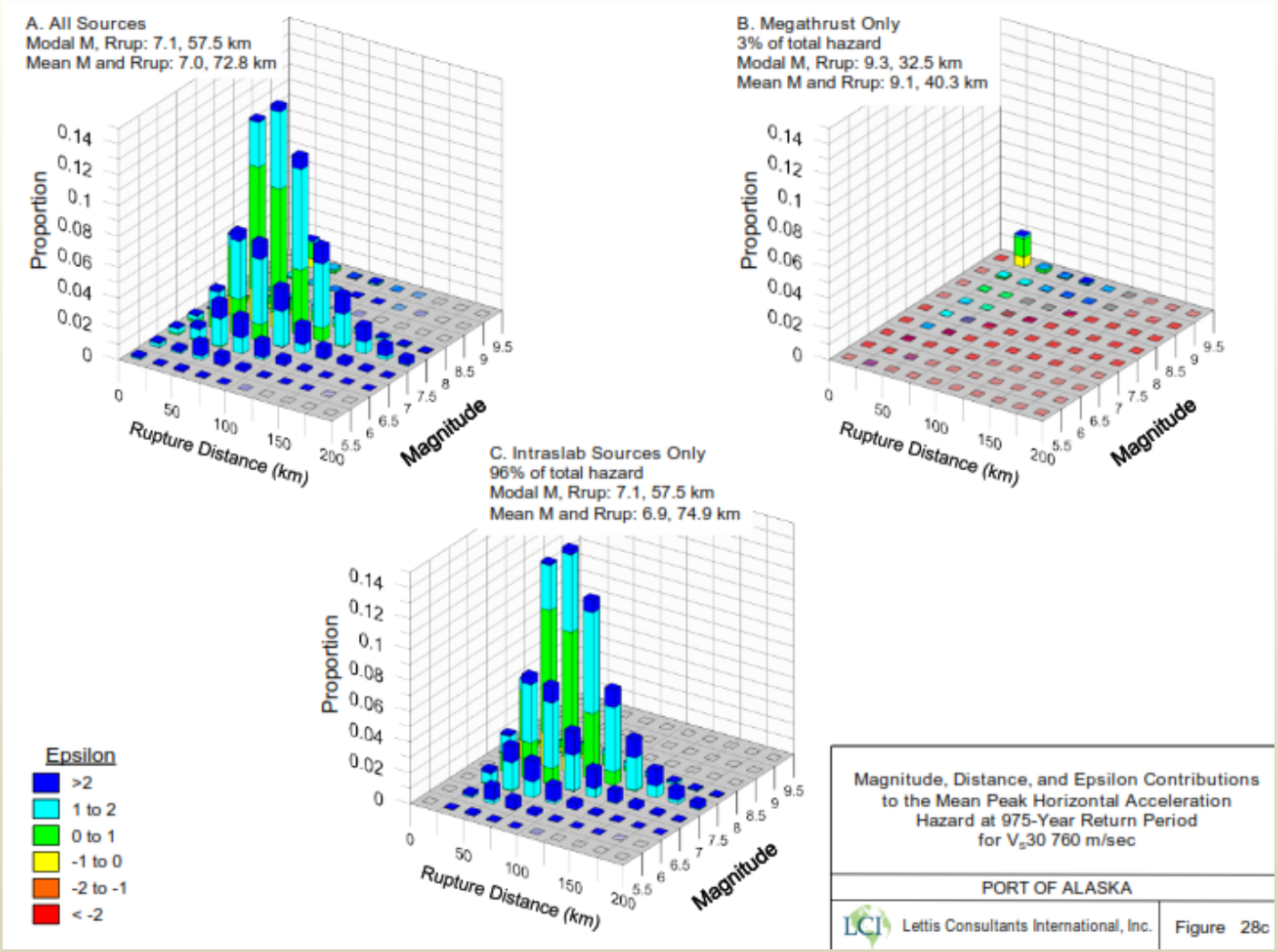
Seismic Source Contributions to Mean 1.0 Sec Horizontal Acceleration Hazard for Vs30 760 m/sec



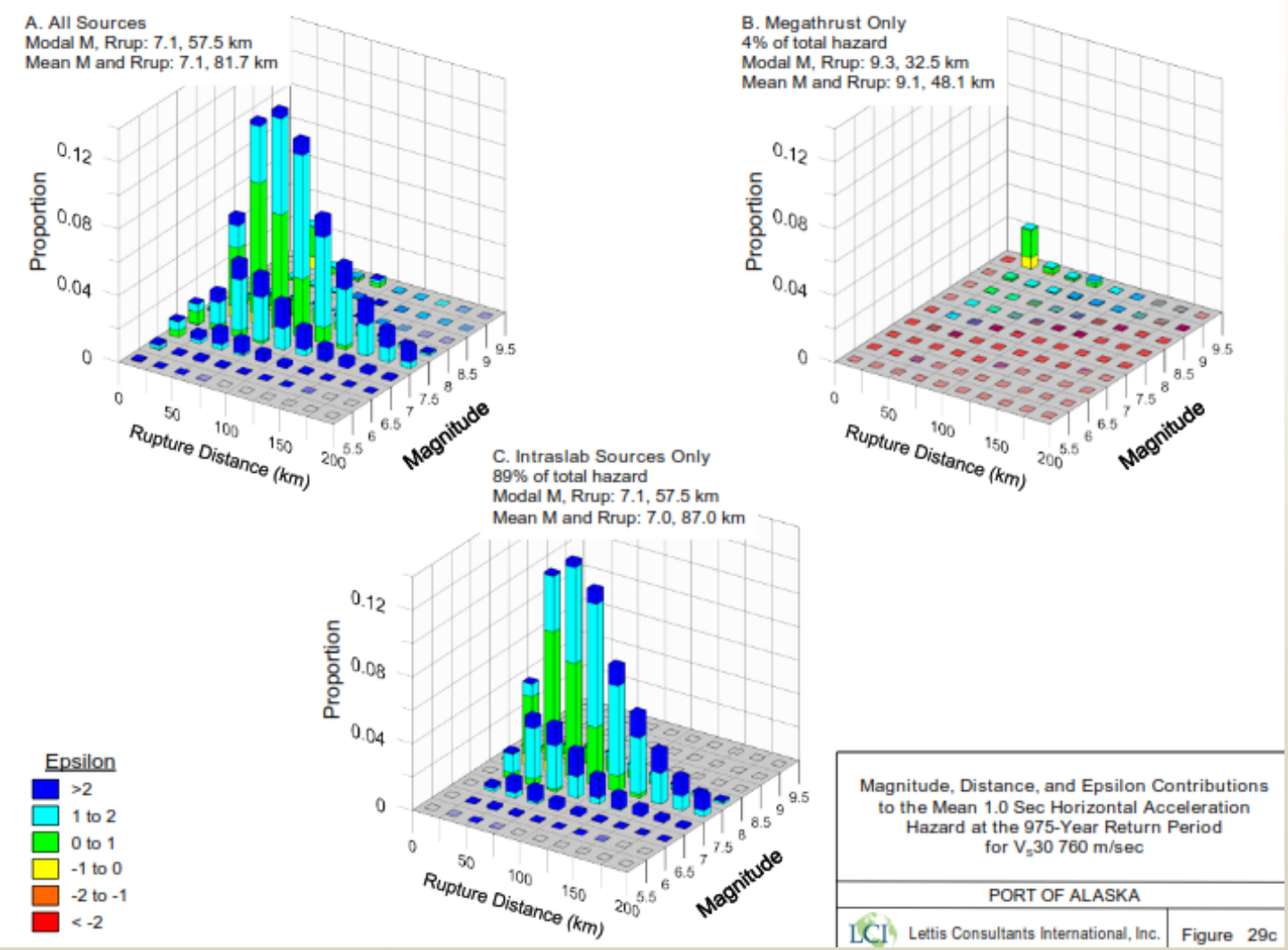
Seismic Source Fractional Contributions to Mean 1.0 Sec Horizontal Acceleration Hazard for Vs30 760 m/sec



Magnitude, Distance, and Epsilon Contributions to the Mean Peak Horizontal Acceleration Hazard at 975-Year Return Period for Vs30 760 m/sec



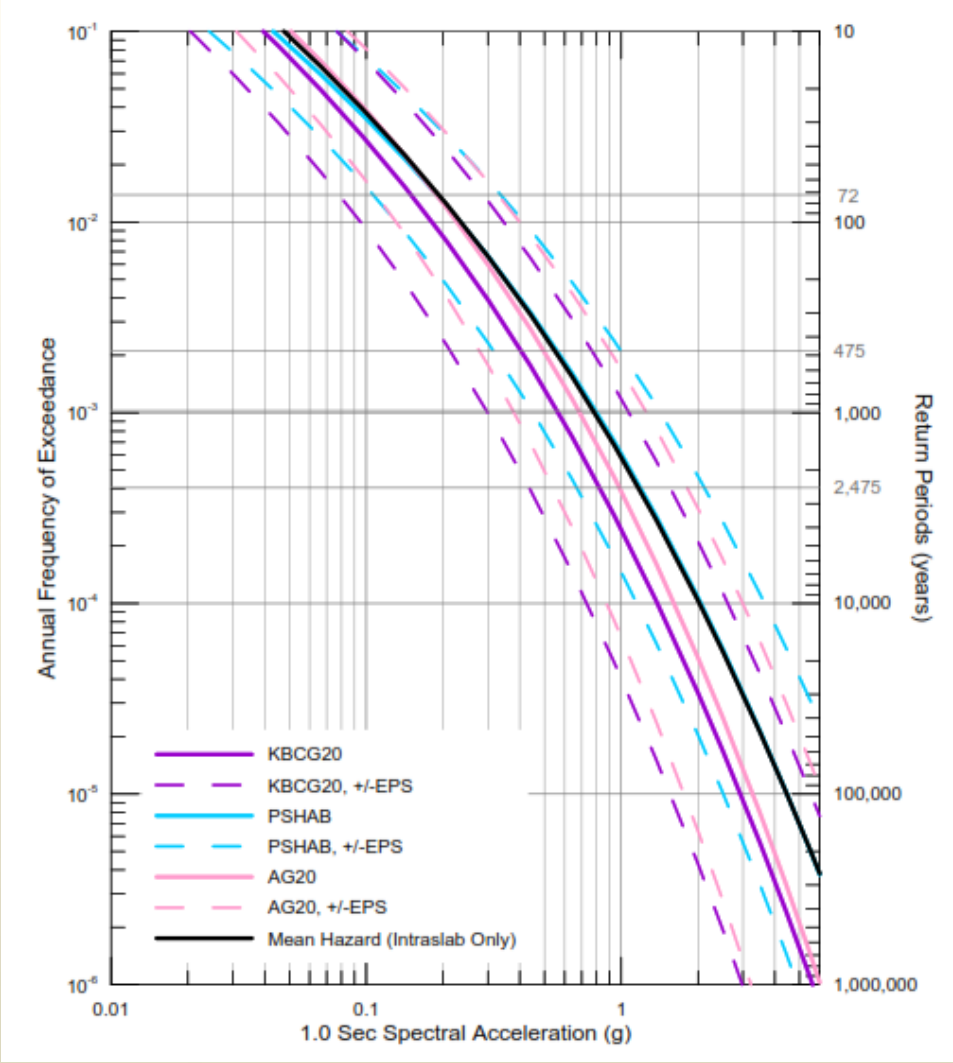
Magnitude, Distance, and Epsilon Contributions to the Mean 1.0 Sec Horizontal Acceleration Hazard at the 975-Year Return Period for Vs30 760 m/sec



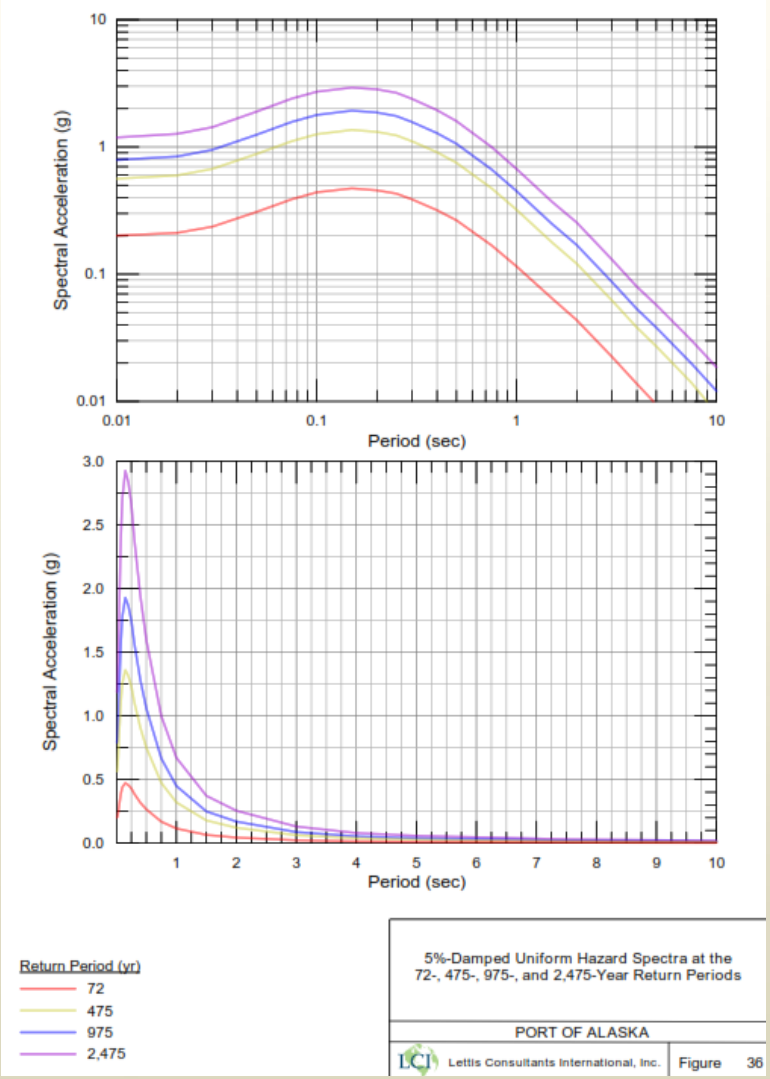
Controlling Earthquakes

Period		Return Period (Years)			
		72	475	975	2,475
PGA	M*	7.1	7.1	7.1	7.1
	D*	92.5	67.5	57.5	57.5
	M-BAR	6.7	6.9	6.9	7.0
	D-BAR	90.6	76.7	72.8	68.5
0.2 SEC	M*	7.1	7.1	7.1	7.1
	D*	92.5	67.5	57.5	57.5
	M-BAR	6.7	6.9	6.9	7.0
	D-BAR	92.3	78.2	74.2	69.7
1.0 SEC	M*	7.1	7.1	7.1	9.3
	D*	37.5	37.5	57.5	32.5
	M-BAR	6.9	7.1	7.1	7.1
	D-BAR	105.8	87.2	81.7	75.6
1.5 SEC	M*	7.1	7.1	7.1	9.3
	D*	37.5	37.5	37.5	32.5
	M-BAR	7.0	7.1	7.1	7.1
	D-BAR	107.4	87.2	81.2	74.5
2.0 SEC	M*	7.1	7.1	7.1	9.3
	D*	37.5	37.5	37.5	32.5
	M-BAR	7.0	7.1	7.2	7.2
	D-BAR	109.6	88.7	82.3	75.2

Sensitivity of Mean 1.0 Sec Horizontal Spectral Acceleration to Intraslab GMMs for Vs30 760 m/sec



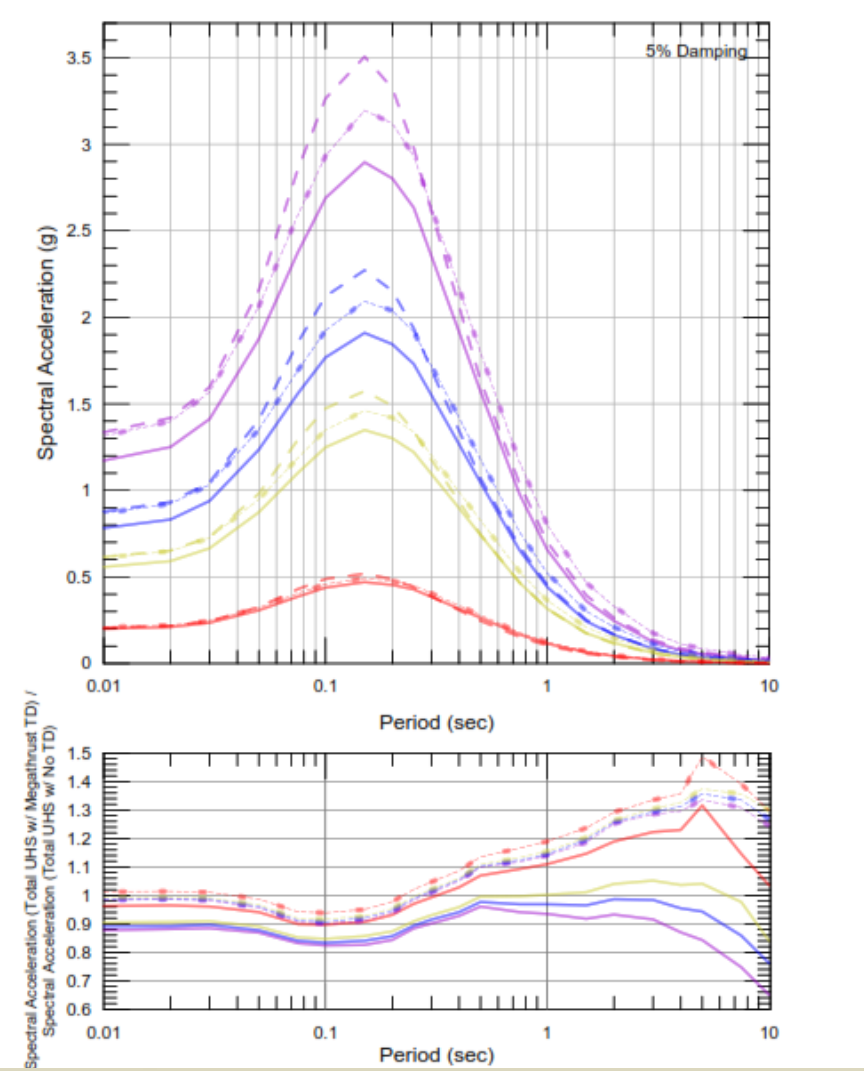
5%-Damped Uniform Hazard Spectra at the 72-, 475-, 975-, and 2,475-Year Return Periods



Horizontal UHS for Vs30 760 m/sec

Period (sec)	Horizontal Spectral Acceleration (g)			
	72-Year Return Period	475-Year Return Period	975-Year Return Period	2,475-Year Return Period
0.01	0.201	0.563	0.791	1.187
0.02	0.211	0.597	0.841	1.266
0.03	0.236	0.672	0.949	1.428
0.05	0.308	0.881	1.247	1.895
0.075	0.388	1.109	1.573	2.398
0.1	0.440	1.259	1.784	2.715
0.15	0.472	1.361	1.929	2.927
0.2	0.456	1.313	1.864	2.835
0.25	0.430	1.232	1.749	2.664
0.3	0.387	1.106	1.568	2.385
0.4	0.318	0.908	1.283	1.943
0.5	0.265	0.750	1.058	1.595
0.75	0.168	0.473	0.665	0.997
1.0	0.115	0.320	0.449	0.671
1.5	0.065	0.178	0.249	0.372
2.0	0.044	0.121	0.169	0.255
3.0	0.022	0.062	0.087	0.130
4.0	0.014	0.038	0.053	0.080
5.0	0.0095	0.027	0.038	0.057
7.5	0.0041	0.014	0.020	0.030
10.0	0.0023	0.0081	0.012	0.019

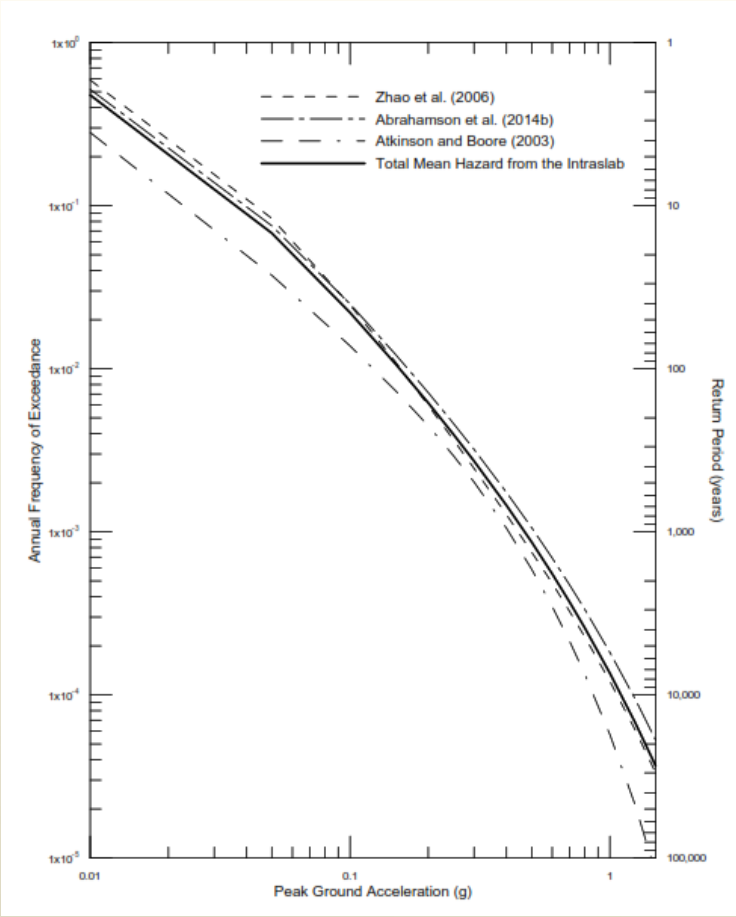
Sensitivity of UHS at the 72-, 475-, 975-, and 2,475-Year Return Periods to Z2.5 and Megathrust Time Dependence

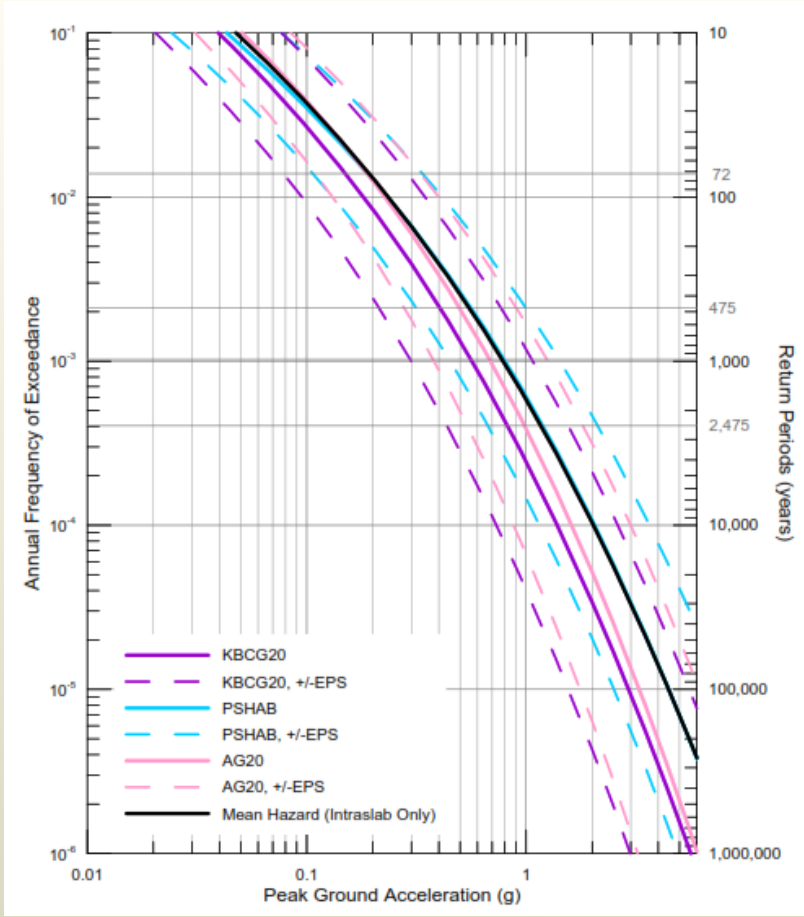


Comparison with the 2007 USGS National Seismic Hazard Map

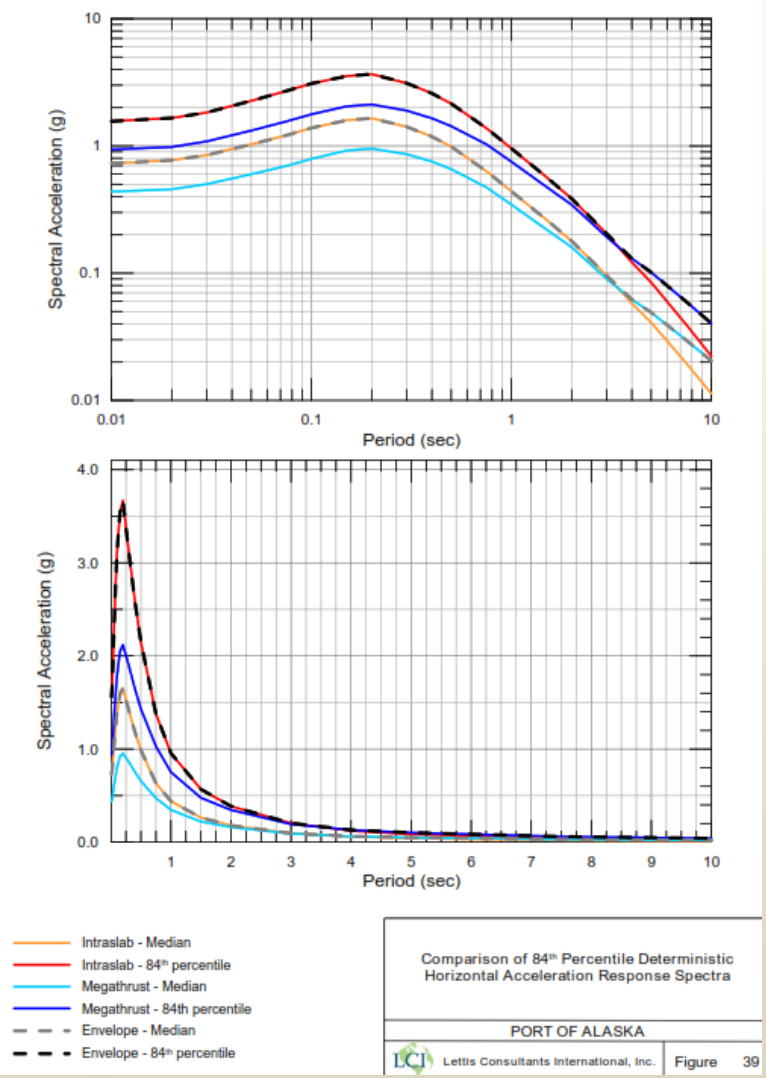
Period (sec)	Study	Horizontal Spectral Acceleration (g)			
		72-Year Return Period	475-Year Return Period	975-Year Return Period	2,475-Year Return Period
PGA	USGS 2007	0.211	0.435	0.543	0.691
	This Study	0.201	0.563	0.791	1.187
	Comparison	-5%	29%	46%	72%
1.0	USGS 2007	0.148	0.345	0.454	0.615
	This Study	0.115	0.320	0.449	0.671
	Comparison	-22%	-7%	-1%	9%

Comparison Between 2014 and 2023 Analyses

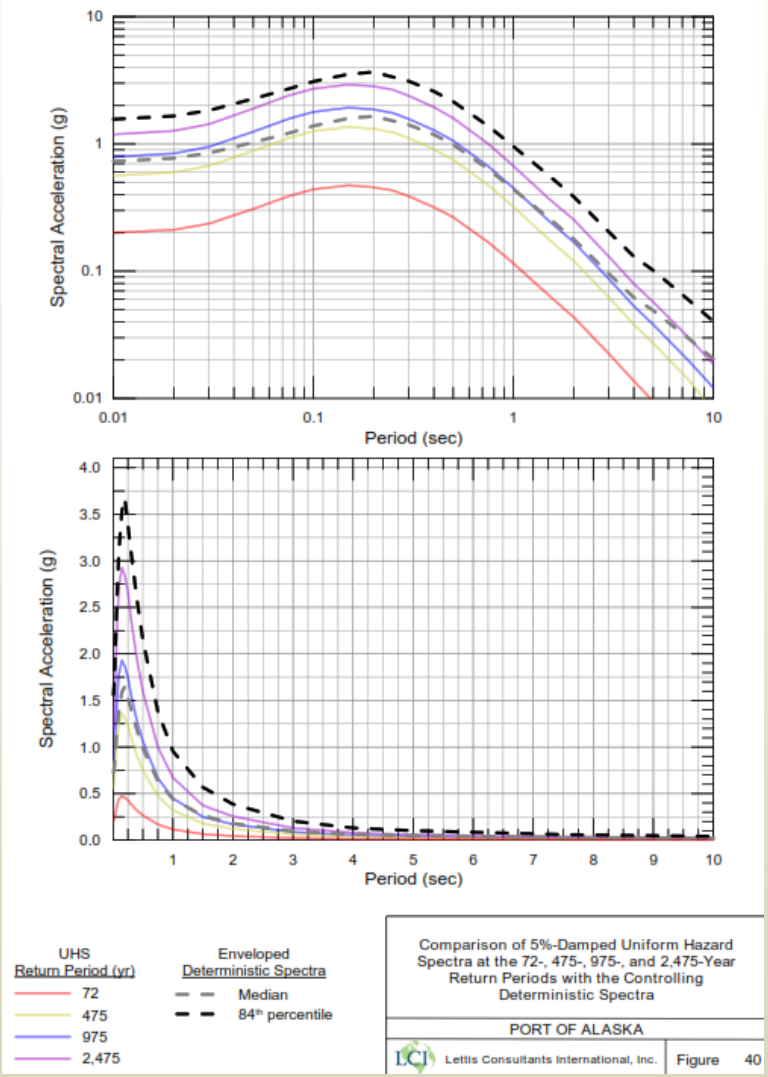




Comparison of 84th Percentile Deterministic Horizontal Acceleration Response Spectra

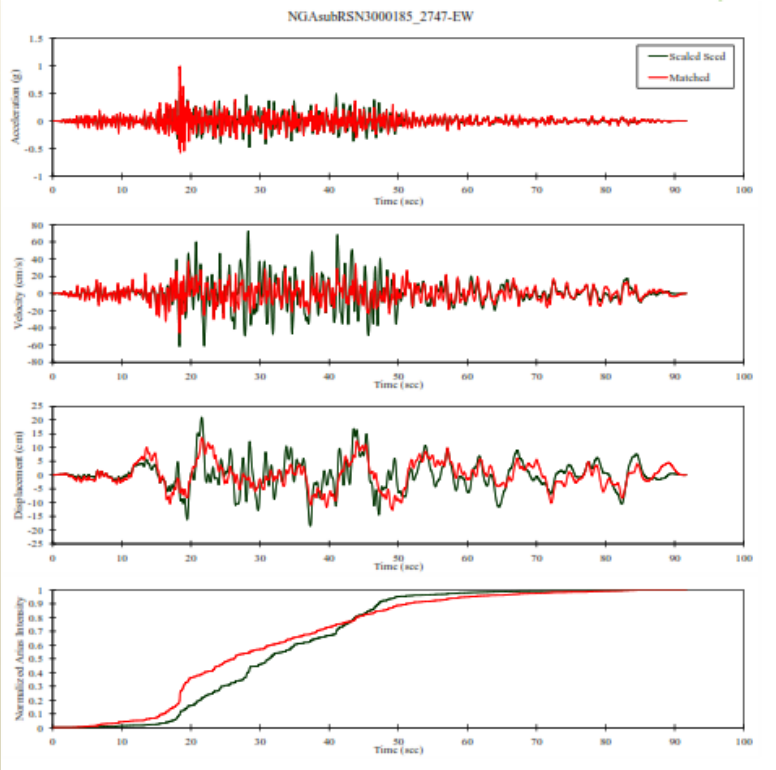


Comparison of 5%-Damped Uniform Hazard Spectra at the 72-, 475-, 975-, and 2,475-Year Return Periods with the Controlling Deterministic Spectra



Time Histories

- 11 sets of three-component were developed for the MCE, DE, CLE, and OLE design levels through spectral matching.
- Seed time histories were selected based on spectral shape and target Arias intensities and durations



Conclusions

- Computed the probabilistic and deterministic hazard for firm rock.
- The PSHA includes time-dependent behavior for the 1964 megathrust earthquakes and basin effects unlike the USGS National Seismic Hazard Maps for Alaska
- Hence the intraslab earthquakes control the hazard at the Port.
- We have used the global versions of the NGA-Sub GMMs and this is a source of significant uncertainty.
- Use of the NGA-Sub GMMs either the Alaskan or global versions result in increased hazard for southern Alaska due in part to the large aleatory sigmas.
- The site-specific probabilistic PGA hazard results are significantly higher than the 2007 National Seismic Hazard Maps but generally within 10% at 1 sec SA. It will be interesting to compare the site-specific results against the 2023 maps although the comparisons will not be apples-to-apples.