

## SUPPLEMENTARY MATERIAL

## DETERMINATION OF PATH ATTENUATION AND SITE CHARACTERISTICS OF THE NORTH-WEST HIMALAYAN REGION AND ADJOINING REGIONS WITHIN THE INDIAN TERRITORY USING GENERALIZED INVERSION METHOD

Nelliparanbil Hareeshkumar Harinarayan<sup>1</sup> and Abhishek Kumar<sup>\*,2</sup>

<sup>1</sup> Research Scholar, Department of Civil Engineering, Indian Institute of Technology Guwahati, Assam, India.

<sup>2</sup> Assistant Professor, Department of Civil Engineering, Indian Institute of Technology Guwahati, Assam, India

### Table

**Table 1: Detail of strong motion recording stations**

Si. no.	Station Code	Lat.(°)(N)	Lon .(°)(E)	GINV		HVSR		S C #	Si. no.	Station Code	Lat.(°)(N)	Lon .(°)(E)	GINV		HVSR		S C #
				$f_{peak}$	$A_{pea}$	$f_{peak}$	$A_{pea}$						$f_{peak}$	$A_{pea}$	$f_{peak}$	$A_{pea}$	
Himachal Pradesh									Uttarakhand								
1	AMB	31.7	76.1	1.5	4.3	1.2	9.3	E	1	ALM	29.6	79.7	2.1	3.0	2.8	4.4	D
2	BHA	31.6	77.9	4.5	4.0	4.1	4.4	C	2	BAG	29.8	79.8	1.5	4.7	1.5	5.2	E
3	CHM	30.4	79.3	1.4	5.4	1.5	7.5	E	3	BAR	30.8	78.2	3.0	4.5	2.8	7.0	D
4	DEH	31.9	76.2	6.8	3.5	10	5.4	B	4	CHM	32.6	76.1	3.6	2.4	2.0	2.9	C
5	DHH	32.2	76.3	2.7	4.5	2.7	4.9	D	5	CHP	29.3	80.1	5.4	5.2	5.6	6.5	C
6	HAM	31.7	76.5	2.9	3.3	3.1	6.6	D	6	CKR	30.7	77.9	2.1	3.8	2.0	4.5	D
7	JUB	31.1	77.7	5.8	3.3	5.6	4.9	C	7	CMB							
8	KLG	32.6	77.0	8.0	1.8	8.3	2.2	B	7	B	30.0	79.5	8.3	2.7	8.3	6.3	B
9	KUL	32.0	77.1	3.3	2.3	3.1	3.0	C	8	DHA	29.8	80.5	3.1	3.3	2.7	5.5	C
10	MAN	31.7	76.9	2.5	3.4	2.3	5.3	D	9	DNL	30.4	78.2	2.8	3.3	2.0	7.1	D
11	RAM	31.4	77.6	2.8	4.2	2.7	5.6	D	10	DUN	30.3	78.0	2.9	5.8	3.1	7.1	D
12	SAL	32.7	76.1	2.7	3.0	2.7	5.8	D	11	GAR	30.1	79.3	2.4	3.4	2.3	4.5	D
13	SND	31.5	76.9	5.0	3.5	5.0	4.2	C	12	GHA	30.4	78.7	5.2	2.3	4.5	5.5	C
14	SOL	30.9	77.1	0.5	2.6	0.6	4.6	E	13	GLTR	30.3	79.1	2.9	3.5	2.8	6.1	D
15	UNA	31.5	76.3	1.5	3.9	1.8	6.0	E	14	JSH	30.5	79.6	1.4	2.2	1.5	3.0	E
16	KJK	30.9	76.9	0.7	6.4	0.4	12.0	E	15	KAP	29.9	79.9	3.7	6.4	3.3	9.2	C
17	PLM	32.1	76.5	1.7	1.8	1.6	2.2	D	16	KHA	28.9	80.0	1.3	4.2	2.0	8.0	E
									17	KKHR	30.2	78.9	9.5	3.5	9.5	9.3	B

Punjab								
1	ANS	31.2	76.5	0.9	4.9	0.9	17.0	E
2	ASR	31.6	74.9	1.0	2.9	1.0	8.0	E
3	GSK	31.2	76.1	0.8	2.3	0.8	3.8	E
4	JAL	31.3	75.6	2.9	1.5	2.9	1.7	D
5	KAT	31.4	75.4	2.0	3.1	3.0	3.4	D
6	MOG	30.8	75.2	2.2	2.3	2.2	3.9	D
7	MUK	31.9	75.6	1.4	4.7	1.4	15.9	E
8	NAW	31.1	76.1	1.4	3.6	1.4	3.5	E
9	NKD	31.1	75.5	1.2	2.2	1.3	3.4	E
10	PHG	31.2	75.8	2.7	2.7	2.7	5.2	D
11	TAR	31.4	74.9	2.6	2.7	2.7	4.6	D
Delhi								
1	ARI	26.1	77.5	2.7	3.2	2.5	7.0	D
2	IGN	28.5	77.2	3.6	2.6	4.5	3.9	C
3	JNU	28.5	77.2	9.0	2.1	8.7	3.5	B
4	DJB	28.7	77.2	2.2	3.2	10	4.5	D
5	NDI	28.7	77.2	6.8	2.5	7.2	3.7	B
6	IMD	28.7	77.2	6.0	2.0	6.3	2.9	C
7	NTPC	28.5	77.3	2.8	3.6	2.8	5.4	D
8	ANC	28.5	77.3	4.6	3.2	4.5	4.5	C
9	JAMI	28.6	77.3	4.7	3.2	4.5	7.3	C
10	LDR	28.6	77.2	0.7	4.3	0.9	7.0	E
11	VCD	28.6	77.2	4.6	2.7	4.6	3.6	C
12	IIT	28.6	77.3	4.3	2.9	4.5	4.3	C
13	NSIT	28.6	77.0	2.4	2.5	2.3	3.9	D
14	RGD	28.7	77.1	2.3	2.1	2.9	3.8	D
15	GGI	28.7	77.2	15	5.3	15	8.4	A
16	DLU	28.7	77.2	1.8	3.2	1.9	3.7	D
17	DCE	28.8	77.1	3.8	3.1	4.7	4.2	C
18	IGI	28.6	77.1	2.2	2.4	2.2	3.8	D
19	ZAKI	28.6	77.2	3.9	3.5	3.9	8.4	C
20	ALIP	28.8	77.1	2.3	3.2	2.5	6.9	D
21	ROI	28.6	77.2	1.4	3.1	2.0	4.6	E
Haryana								
18	KOT	29.7	78.5	0.7	2.4	0.7	3.3	E
19	KSK	29.2	79.0	3.1	3.8	3.2	9.9	C
20	KSL	30.9	77.0	3.0	3.9	2.1	19.4	D
21	LANG	30.3	79.3	7.7	2.8	7.9	5.7	B
22	LAN	29.8	78.7	1.4	2.8	1.4	6.1	E
23	MUN	30.1	80.2	4.3	2.8	7.0	3.6	C
24	PAU	30.2	78.8	5.9	2.1	3.1	3.7	C
25	PTH	29.6	80.2	8.0	2.7	4.6	3.1	B
26	PTI	29.4	79.9	4.0	6.6	3.6	8.0	C
27	RIS	30.1	78.3	3.8	3.0	3.4	6.4	C
28	ROO	29.9	77.9	1.2	4.4	1.3	5.2	E
29	RUD	30.3	79.0	1.3	2.8	1.5	4.2	E
30	SMLI	30.2	79.3	9.1	3.3	8.7	6.1	B
31	TAN	29.1	80.1	5.4	3.4	5.0	6.3	C
32	THE	30.4	78.4	1.6	2.8	1.5	3.6	D
33	UDH	29.0	79.4	2.7	6.9	2.2	10.1	D
34	UTK	30.7	78.4	2.4	2.9	2.3	4.4	D
35	VIK	30.5	77.8	2.3	3.8	2.3	10.4	D
36	GDRI	30.2	78.7	6.0	3.4	5.1	4.8	C
37	TLWR	30.3	79.0	1.1	2.1	1.0	4.6	E
38	UKMB	30.3	79.1	1.0	2.9	1.4	10.0	E
39	ADIB	30.2	79.2	6.4	12.7	6.3	17.8	A
40	NUTY	30.2	79.2	4.8	2.4	4.7	4.3	C
41	KHIB	30.2	78.8	7.7	3.3	8.0	8.7	B
42	STRK	30.3	79.0	4.7	2.8	4.7	5.8	C
43	NANP	30.3	79.3	3.9	3.5	3.8	9.1	C
SC# Site Class								
1	PAL	28.1	77.3	2.8	2.7	2.9	3.4	D
2	JAFR	28.6	76.9	6.0	2.0	7.1	2.6	C
3	GUR	28.4	77.0	1.0	4.1	1.0	5.2	E
4	REW	28.2	76.6	2.5	2.1	2.5	3.7	D
5	SON	29.0	77.0	1.0	3.5	2.8	4.0	E
6	ROH	28.6	77.2	1.4	3.1	2.0	4.6	E
7	CRRI	29.0	77.1	4.3	3.5	4.4	9.3	C
8	BAL	28.3	77.3	1.5	3.0	1.4	5.8	E
9	KAI	29.8	76.4	1.2	3.0	1.2	6.5	E

**Table 2: Details of earthquakes considered for estimation of site parameters in this work**

Event No.	dd/mm/yyyy	Lat.	Long.	Depth	Magnitude	Event No.	dd/mm/yyyy	Lat.	Long.	Depth	Magnitude
1	14-12-2005	30.9	79.3	25.7	5.2	44	24-09-2011	30.9	78.3	10.0	3.0
2	07-05-2006	28.7	76.6	20.2	4.1	45	26-10-2011	31.5	76.8	3.0	3.5
3	29-11-2006	27.6	76.7	13.0	3.9	46	16-01-2012	29.7	78.9	10.0	3.6
4	10-12-2006	31.5	76.7	33.0	3.5	47	12-03-2012	28.9	77.3	5.0	3.5
5	22-07-2007	29.9	77.9	33.0	5.0	48	26-02-2012	29.6	80.8	10.0	4.3
6	25-11-2007	28.6	77.0	20.3	4.3	49	27-03-2012	26.1	87.8	12.0	3.5
7	04-10-2007	32.5	76.0	10.0	3.8	50	05-03-2012	28.7	76.6	14.0	4.9
8	18-10-2007	28.3	77.6	5.6	3.6	51	28-07-2012	29.7	80.7	10.0	4.5
9	19-08-2008	30.1	80.1	15.0	4.3	52	23-08-2012	28.4	82.7	5.0	5.0
10	19-10-2008	29.1	76.9	7.0	3.2	53	02-10-2012	32.4	76.4	10.0	4.9
11	21-10-2008	31.5	77.3	80.0	4.5	54	03-10-2012	32.4	76.3	10.0	3.6
12	31-01-2009	32.5	75.9	10.0	3.7	55	06-11-2012	32.3	76.2	5.0	4.1
13	09-01-2009	31.7	78.3	16.0	3.8	56	11-11-2012	29.3	80.1	5.0	5.0
14	25-02-2009	30.6	79.3	10.0	3.7	57	15-11-2012	30.2	80.1	5.0	3.0
15	18-03-2009	30.9	78.2	10.0	3.3	58	27-11-2012	30.9	78.4	12.0	4.8
16	04-09-2008	30.1	80.4	10.0	5.1	59	19-12-2012	28.6	76.8	10.0	2.9
17	01-05-2009	29.9	80.1	10.0	4.6	60	02-01-2013	29.4	81.1	10.0	4.8
18	15-05-2009	30.5	79.3	15.0	4.1	61	09-01-2013	29.8	81.7	2.0	5.0
19	17-07-2009	32.3	76.1	55	3.7	62	10-01-2013	30.1	80.4	5.0	3.2
20	27-08-2009	30.0	80.0	14.0	3.9	63	29-01-2013	30.0	81.6	7.0	4.0
21	21-09-2009	30.9	79.1	13.0	4.7	64	11-02-2013	31.0	78.4	5.0	4.3
22	03-10-2009	30.0	79.9	15.0	4.3	65	17-02-2013	30.9	78.4	10.0	3.2
23	06-12-2009	35.8	77.3	60.0	5.3	66	01-05-2013	33.1	75.8	15.0	5.8
24	11-01-2010	29.7	80.0	15.0	3.9	67	05-09-2013	30.9	78.5	11.0	3.5
25	22-02-2010	30.0	80.1	2.0	4.7	68	11-11-2013	28.5	77.2	10.0	3.1
26	24-02-2010	28.6	76.9	17.0	2.3	69	11-11-2013	28.4	77.2	11.0	2.3
27	14-03-2010	31.7	76.1	29.0	4.6	70	11-11-2013	28.4	77.2	12.0	2.5
28	03-05-2010	30.4	78.4	8.0	3.5	71	11-11-2013	28.4	77.2	13.0	3.1
29	28-05-2010	31.2	77.9	43.0	4.8	72	16-04-2013	28.0	62.1	16.0	7.8
30	31-05-2010	30.0	79.8	10.0	3.6	73	04-06-2013	32.7	76.7	18.0	4.8
31	06-07-2010	29.8	80.4	10.0	5.1	74	05-06-2013	32.8	76.3	10.0	4.5
32	10-07-2010	29.9	79.6	10.0	4.1	75	09-07-2013	32.9	78.4	10.0	5.1
33	26-01-2011	29.0	77.2	10.0	3.2	76	13-07-2013	32.2	76.3	10.0	10.0
34	14-03-2011	30.5	79.1	8.0	3.3	77	15-07-2013	32.6	76.7	30.0	4.4
35	18-02-2011	28.6	77.3	5.0	2.3	78	02-08-2013	33.5	75.5	20.0	5.4
36	09-02-2011	30.9	78.2	10.0	5.0	79	29-08-2013	31.4	76.1	10.0	4.7
37	04-04-2011	29.6	80.8	10.0	5.7	80	20-10-2013	35.8	77.5	80.0	5.5
38	15-06-2011	30.6	80.1	10.0	3.6	81	25-12-2013	31.2	78.3	10.0	4.0
39	20-06-2011	30.5	79.4	12.0	4.6	82	17-06-2014	32.2	76.1	10.0	4.1
40	23-06-2011	30.0	80.5	5.0	3.2	83	21-08-2014	32.3	76.5	10.0	5.0
41	28-07-2011	33.3	76.0	21.0	4.4	84	29-11-2015	30.6	79.6	15.0	4.0
42	07-09-2011	28.6	77.0	8.0	4.2	85	25-09-2016	30.0	79.5	11.0	3.7
43	21-09-2011	30.9	78.3	10.0	3.1	86	01-12-2016	30.6	79.6	19.0	4.0

**Table 3: List of Earthquakes and the corresponding stations considered for the estimation of path parameter**

Earthquake Event	Stations
25-11- 2007	HGR, NDI, CRRI, PAL, REW, NDI , CRRI, LDR, JAFR, IIT
19-08-2008	CHP, PTH, KAP, MUN
04-09- 2008	MUN, CHP, PTH, DHA , KAP, GHA, JSH
01-05-2009	MUN, BAG, KAP, GAR, CHM
17-07-2009	DHA, KLG
27-08-2009	KAP, BAG, MUN
03-08-2009	KAP, CHP, BAG
11-01-2010	PTH, CHP, DHA
22-02-2010	KAP, BAG, DHA, ROO, UDH
24-02-2010	RGD, IGN, ROH, DJB, CHP, ANC, JAMI, GGI, DLU, DCE
14-03-2010	DEH, JUB, SND, BHA, HAM, GAR, JAL, KAP, AMB, ROO
03-04-2010	THE, BAR, DNL, ROO
28-05-2010	JUB, BAR, ROO, UNA
06-06-2010	MUN, CHP
10-07-2010	BAG, KAP, GAR, ROO
18-02-2011	DJB, ANC
09-02-2011	UTK, SND, KUL, CKR
04-04-2011	JSH, CHP, PTI, PTH, ALM, DDH, BAG, DHA, GAR, MUN, RUD, THE, CHM, BAR, SND, KOT, DNL, LDR, ROO, TAN, KHA, UDH, KSH, DUD
12-03-2012	GGI, ANC, DLU, DCE
27-03-2012	ARI, ANC
05-03-2012	JAFR, JNU, DJB, IMD, PLW, GUR, NOI, NTPC, ANC, IIT, NSIT, ZAKI, ROO, RGD, GGI, DLU, DCE, ALIP, SON, BAR, KAI, NKD,
02-10-2012	CHA, RAM
11-11-2012	CHA, CHP, PTH
27-11-2012	UTK, THE, DNL, CKR
02-01-2013	CHP, PTI, PTH
09-01-2013	CHP, PTI, PTH, TAN
11-02-2013	UTK, ROO
11-11-2013 (19:11:18)	NTPC, IGN, JNU, DJB, IMD, VCD, IGI, RGD, GGI, DLU, DCE, ALIP
11-11-2013 (22,10,42)	IGN, JNU, DJB, VCD, RGD, DCE, ALIP
11-11-2013 (20:11:30)	IGN, JNU, DJB, VCD, RGD, GGI, DLU, DCE
29-08- 2013	GSK, RAM, ROO, NKD, ANS, KAT
25-09-2016	UKMB, CMBB, GDRI, DURD

**Table 4: Resulting parameters of Eq. 8**

f (Hz)	m	$Q_0 = \frac{(\pi f)}{(\beta m)}$
0.50	0.0095	51.65
1.00	0.0101	97.15
1.75	0.0115	149.32
2.50	0.0096	255.53
3.12	0.0089	344.54
3.57	0.0093	376.67
4.50	0.0098	450.57
5.00	0.0074	663.01
5.50	0.0089	606.39
6.25	0.0084	730.09
7.14	0.011	636.92
8.00	0.013	603.84
10.00	0.0172	570.49
11.76	0.0124	930.60
12.50	0.0102	1202.51
13.33	0.0098	1334.70
14.28	0.0115	1218.46
15.00	0.0108	1362.85

**Table 5: NEHRP site classification provisions**

Site Class	General description	Shear wave velocity	$f_{peak}$ (Hz)
<b>A</b>	Hard rock	>1500 m/sec	>12.70 Hz
<b>B</b>	Rock	760 m/sec-1500 m/sec	6.35Hz-12.70
<b>C</b>	Very dense soil and soft rock	360 m/sec-760 m/sec	3.05Hz-6.35
<b>D</b>	Stiff soil	180 m/sec-360 m/sec	1.52Hz-3.05Hz
<b>E</b>	Soft soil	<180 m/sec	<1.52Hz

**Table 6:  $f_{\text{peak}}$ , and  $V_{s30}$  values for 27 stations located in Terai region of Uttarakhand and Delhi region**

Station Code	GINV	
	$f_{\text{peak}}$ (Hz)	$V_{s30}$ (m/s)
IGN	3.6	493*
JNU	6.5	565*
DJB	5.2	543*
NDI	6.8	493*
IMD	6.0	543*
NTPC	2.8	345*
ANC	4.6	564*
JAMI	4.7	346*
LDR	0.7	270*
VCD	5.6	550*
IIT	4.3	332*
NSIT	2.4	391*
RGD	2.3	346*
DLU	1.81	323*
DCE	3.78	328*
IGI	2.2	360*
ZAKI	3.0	337*
ROI	2.3	303*
ALIP	1.4	338*
DUN	2.9	289**
KHA	1.3	218**
KSK	3.13	208**
RIS	3.8	331**
ROO	1.1	218**
TAN	5.4	434**
UDH	2.7	198**
VIK	2.2	424**

\*\*Pandey et al. 2016a; \* Pandey et al. 2016b