

Supplementary Material

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Introduction

This supporting information includes a figure (FigureS1) showing lengths of survey line profiles and distances between benchmarks. The supporting information also includes tables which show the results of precise deformation surveys (Table S1), a summary of annual groundwater extraction data since the 1970s (Table S2), and a list of the wells and their corresponding capacity (Table S3).

1 Supplementary Figure

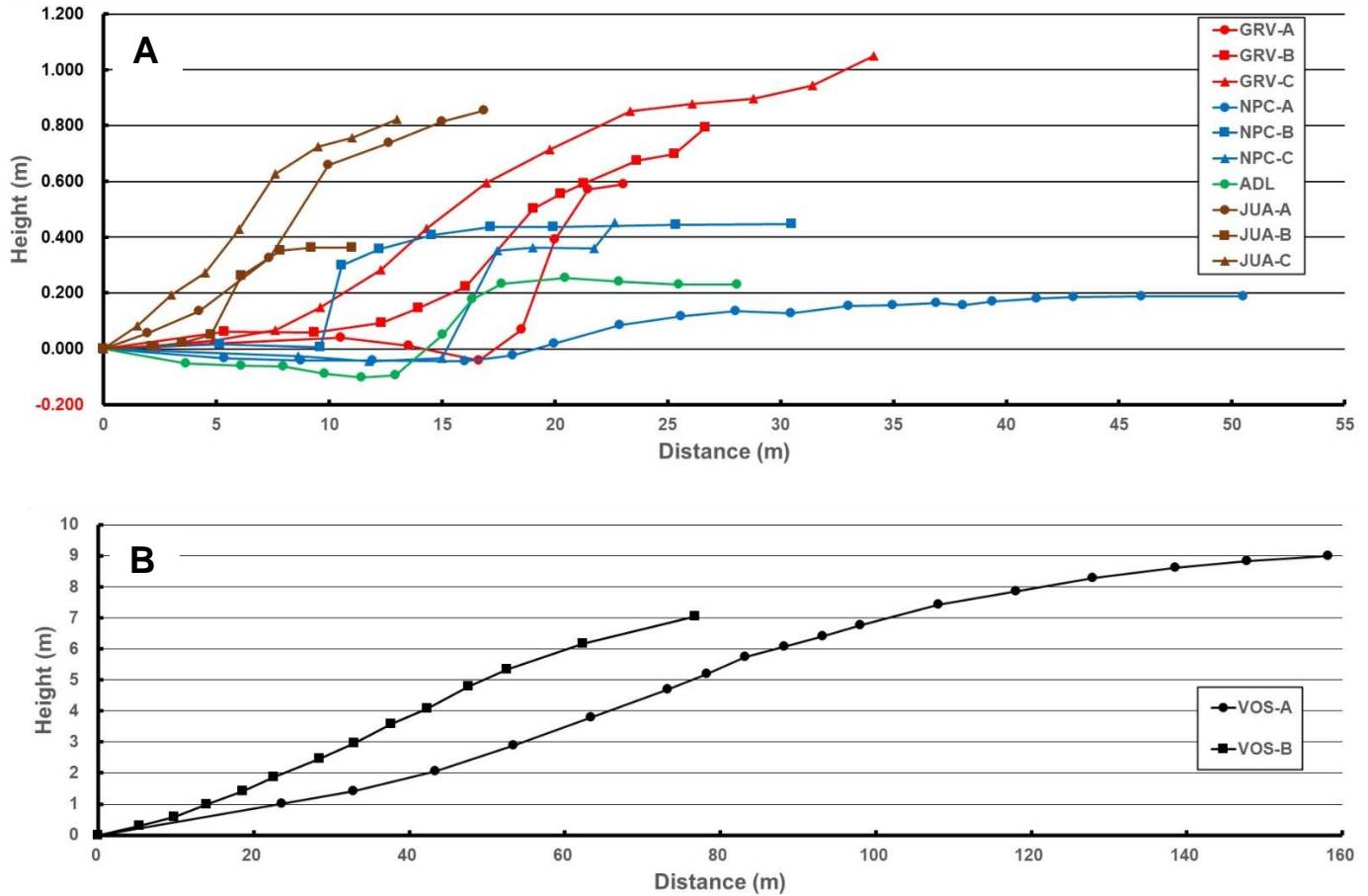


Figure S1. Profiles of fault creep scarps across which permanent benchmarks were periodically revisited for precise levelling to measure vertical height. Precise levelling surveys across the scarps were first conducted at different times. Each profile represents the line connecting the relative positions of benchmarks at time of first survey (VOS-A, GRV-A, and NPC-A, B, and C on 9-24-1999; GRV-B and C on 9-19-2005; ADL on 11-20-2005; JUA-A and B on 9-07-2012; VOS-B on 3-22-2017, and; JUA-C and B on 3-30-2019). The shorter lines (a) range in length from 11 m to 50.5 m while the longer profiles (b) are from 77 m to 158 m long.

2 Supplementary Tables

Table S1. Results of precise deformation survey for the sites retained since 1999 and for those survey lines established at later dates (i.e., GRV-B and GRV-C in 2005, ADL in 2005, JUA-A and JUA-B in 2012, JUA-C in 2019, and VOS-B in 2017).

NPC-A		NPC-B		NPC-C		GRV-A		GRV-B		GRV-C		ADL		VOS-A		VOS-B		JUA-A		JUA-B		JUA-C		
Date	Displ. (cm)	Date	Displ. (cm)	Date	Displ. (cm)	Date	Displ. (cm)	Date	Displ. (cm)	Date	Displ. (cm)	Date	Displ. (cm)	Date	Displ. (cm)	Date	Displ. (cm)	Date	Displ. (cm)	Date	Displ. (cm)	Date	Displ. (cm)	
1999.73	0.000	1999.73	0.000	1999.73	0.000	1999.73	0.000							1999.73	0.000									
1999.94	-0.167	1999.94	-0.156	1999.94	0.000	1999.94	-0.056							1999.94	0.295									
2000.23	-0.197	2000.23	-0.111	2000.23	-0.400	2000.23	0.328							2000.23	-0.012									
2000.44	-0.142	2000.44	-0.822	2000.44	-1.033	2000.44	-0.306							2000.44	-0.773									
2000.77	0.070	2000.77	-0.633	2000.77	-0.633	2000.77	-0.472							2000.77	-1.313									
2001.23	-0.315	2001.23	-0.600	2001.23	-0.633	2001.23	-0.478							2001.23	-1.718									
2001.79	-0.003	2001.79	-0.767	2001.79	-0.833	2001.79	-0.572							2001.79	-1.952									
2002.22	-0.293	2002.22	-1.289	2002.22	-1.267	2002.22	-0.711							2002.22	-3.153									
2002.84	-0.273	2002.84	-1.656	2002.84	-1.433	2002.84	-1.844							2002.84	-3.845									
2003.23	-0.407	2003.23	-1.900	2003.23	-1.933	2003.23	-2.522							2003.23	-4.840									
2003.88	-0.195	2003.88	-2.233	2003.88	-2.367	2003.88	-3.894							2003.88	-5.912									
2004.22	-0.407	2004.22	-2.767	2004.22	-3.267	2004.22	-4.867							2004.22	-7.512									
2004.84	-0.407	2004.84	-4.156	2004.84	-4.533	2004.84	-7.361							2004.84	-8.667									
2005.19	-0.268	2005.19	-4.589	2005.19	-5.333	2005.19	-9.444							2005.19	-10.209									
2005.88	-0.273	2005.88	-6.322	2005.88	-6.967	2005.88	-12.983	2005.89	0.000	2005.89	0.000	2005.89	0.000	2005.88	-11.158									
2006.06	-0.307	2006.06	-6.489	2006.06	-7.167	2006.06	-13.006	2006.06	-0.283	2006.06	-0.017	2006.06	0.617	2006.06	-11.653									
2006.47	-0.332	2006.47	-7.689	2006.47	-8.733	2006.47	-13.761	2006.47	-0.717	2006.47	-1.017	2006.47	0.817	2006.47	-13.256									
2006.89	-0.368	2006.89	-7.778	2006.89	-8.567	2006.89	-13.833	2006.89	-0.717	2006.89	-1.150	2006.89	0.367	2006.89	-12.759									
2007.54	-0.463	2007.54	-8.400	2007.54	-9.400			2007.54	-0.217	2007.54	-0.217	2007.54	-14.317											
2007.93	-0.303	2007.93	-8.244			2007.55	-16.661	2007.55	-2.950	2007.55	-4.094			2007.92	-15.076									
2008.70	-0.267	2008.70	-8.311									2007.92	-0.117	2007.92	-15.076									
2009.24	-0.452	2009.24	-8.144	2007.93	-8.767	2007.93	-17.750	2007.93	-3.833	2007.93	-4.639													
2009.66	-0.395	2009.66	-8.133	2008.70	-8.800	2008.70	-20.267	2008.70	-5.500	2008.70	-7.072	2008.70	-0.717	2008.70	-16.376									
2010.03	-0.308	2010.03	-8.156	2009.24	-8.633	2009.24	-20.933	2009.24	-6.017	2009.24	-8.094	2009.24	-1.050	2009.24	-17.528									
2010.25	-0.395	2010.25	-8.256	2009.66	-8.300	2009.66	-22.094	2009.66	-6.583	2009.66	-8.717	2009.66	-2.183	2009.66	-17.984									
2010.55	-0.492	2010.55	-8.256			2010.02	-21.950	2010.02	-6.517					2010.02	-17.895									
2011.02	-0.457	2011.02	-8.311	2010.03	-7.833					2010.03	-8.672	2010.03	-2.317											
2011.67	-0.492	2011.67	-8.000	2010.25	-8.333	2010.25	-23.072	2010.25	-6.900	2010.25	-9.794	2010.25	-2.350	2010.25	-18.640									
2012.13	-0.435	2012.13	-8.000	2010.55	-8.367	2010.55	-23.328	2010.55	-7.550	2010.55	-10.272	2010.55	-2.117	2010.55	-19.173									
				2011.02	-8.100	2011.02	-23.328	2011.02	-7.533	2011.02	-10.361	2011.02	-2.317	2011.02	-19.990									
2012.89	0.002	2012.89	-7.733	2011.67	-7.300	2011.67	-23.306	2011.67	-7.400	2011.67	-10.161	2011.67	-2.783	2011.67	-21.212									
2013.24	-0.512	2013.24	-7.889	2012.13	-7.000																			
2013.67	0.015	2013.67	-7.644			2012.14	-23.178	2012.14	-7.317	2012.14	-10.194	2012.14	-2.783	2012.14	-21.278									
2014.03	-0.297	2014.03	-7.733					2012.68	-7.100	2012.68	-9.894	2012.68	-2.417	2012.68	-22.017									
2014.23	-0.395	2014.23	-7.833																2012.69	0.000	2012.69	0.000		
2014.67	-0.407	2014.67	-7.656			2012.89	-23.078	2012.89	-6.783															
2015.23	-0.487	2015.23	-7.744							2012.90	-9.950	2012.90	-2.583	2012.90	-22.051			2012.90	-0.083	2012.90	-0.178			
2015.69	-0.347	2015.69	-7.880	2013.24	-6.700	2013.24	-22.900	2013.24	-6.833	2013.24	-9.772	2013.24	-2.450	2013.24	-22.356			2013.24	-0.667	2013.24	-0.433			
2016.22	-0.487	2016.22	-7.757	2013.68	-6.167	2013.68	-22.967	2013.68	-6.750	2013.68	-9.794	2013.68	-2.750	2013.68	-22.590			2013.68	-1.150	2013.68	-0.822			
2016.63	-0.415	2016.63	-7.796	2014.03	-6.000	2014.03	-22.661	2014.03	-6.967	2014.03	-9.750	2014.03	-2.683	2014.03	-22.862			2014.03	-1.383	2014.03	-0.911			
				2014.23	-6.467	2014.23	-22.574	2014.23	-6.883	2014.23	-9.950													
2017.22	-0.282	2017.22	-7.812									2014.24	-2.583	2014.24	-23.251			2014.24	-2.183	2014.24	-1.189			
2017.72	-0.383	2017.71	-7.762	2014.67	-5.867	2014.67	-22.485	2014.67	-7.062	2014.67	-9.939	2014.67	-2.558	2014.67	-24.778			2014.67	-3.100	2014.67	-2.022			
2018.23	-0.531	2018.23	-7.883	2015.23	-5.973									2015.23	-26.096			2015.23	-5.263	2015.23	-2.849			
2018.69	-0.389	2018.70	-7.853					2015.24	-6.987	2015.24	-10.003	2015.24	-2.443											
				2015.69	-6.083			2015.69	-6.843	2015.69	-10.016	2015.69	-2.087	2015.69	-28.534			2015.69	-8.132	2015.69	-4.596			
				2016.22	-6.202			2016.22	-7.088	2016.22	-10.219	2016.22	-2.760	2016.22	-30.711									
						2016.22	-7.125												2016.23	-10.677	2016.23	-6.218		
				2016.63	-5.897							2016.64	-9.901	2016.64	-33.084			2016.64	-13.353	2016.64	-8.109			
												2016.64	-34.105											
				2017.22	-6.050			2017.22	-6.847	2017.22	-10.291	2017.22	-2.843	2017.22	-35.166									
																		2017.23	0	2017.23	-15.640	2017.23	-9.924	
				2017.71	-5.460			2017.71	-7.255	2017.71	-10.197	2017.71	-2.090	2017.71	-36.600			2017.71	-1.03	2017.71	-17.385	2017.71	-11.788	
				2018.23	-5.953			2018.23	-7.123	2018.23	-10.249			2018.23	-37.924			2018.23	-2.669					
												2018.24	-2.080					2018.24	-19.172	2018.24	-13.011			
				2018.70	-5.507			2018.70	-7.273	2018.70	-10.071	2018.70	-2.310	2018.70	-39.566			2018.70	-21.103	2018.70	-14.201			
								2019.24	-7.133	2019.24	-10.139													
												2019.25	-2.640	2019.25	-41.327			2019.25	-5.346	2019.25	-22.862	2019.25	-15.410	
								2019.70	-7.130	2019.70	-10.054	2019.70	-2.300	2019.70	-42.703			2019.70	-6.224	2019.70	-24.048	2019.70	-16.298	
																					2019.70	-16.298	2019.70	-1.237

Table S2. Summary of annual groundwater extraction from 1977 to August 2019.

Year	Cumulative Annual Groundwater Extraction (lps)																
	Buffer Zones Around Sites																
	NPC				GRV				ADL				JUA-VOS				
	2	3	4	5	2	3	4	5	2	3	4	5	2	3	4	5	
1977	29.5	50	60.5	143.4				13	33.15					38	106	106	106
1978	32	52.5	63	149.8				22	43.15	14.35	14.35	52.25	52.25	75.9	187.15	191.15	196.15
1979	49.47	72.77	233.34	544	67	208.11	262.22	297.48	35.25	32.35	55.75	93.65					199.65
1980	58.26	99.06	282.83	606.19	79.62	220.73	274.84	330.4		43.25	94.66	141.26	100.5	216.75	220.75	234.64	
1981	65.4	110.2	304.47	641.43	86.62	227.73	281.84	344.44	43.25		111.66	171.16	108.5	238.75	246.25	265.34	
1982	74.6	127.8	329.17	675.45		243.1	301.01	388.96	70.55	84.05	154.4	215.83	116.5	264.25	275.55	306.14	
1983	88.7	154.9	363.27	712.97		246.1	304.01	396.96		156.35	162.4	223.83		280.25	291.55	330.14	
1984		157.9	398.87	758.58	91.42	257.21	323.82	445.27	121.85	159.59	236.74	301.24	145.6	327.85	360.85	399.44	
1985	102.85	174.21	415.48	775.19		260.21	326.82	452.37		162.59	239.74	304.24			363.15	426.74	
1986		184.41	428.18	789.21	92.07	260.86	327.47	463.22			240.39	304.89					
1987	106.85	188.41	432.18	793.21	95.14	263.93	330.54	466.29				308.46					
1988		216.41	460.18	821.21						173.36	251.16	319.23	156.37	338.62	373.92	437.51	
1989	107.25	235.74	480.16	885.54	124.14	294.73	361.34	497.09		179.16	273.76	343.63	178.97	361.22	396.52	460.11	
1990	111.53	247.62	492.04	948.98	140.74	323.63	388.64	530.27	122.09	211.8	322.24	393.75		385.72	421.26	493.23	
1991		252.56	512.24	983.48			388.86	535.14									
1992	118.77	266.99	533.25	1005.7	150.71	333.6	398.83	545.11			338.54	420.21	195.43	412.18	447.72	519.69	
1993			533.41	1008.8	162.43	350.67	415.9	562.18		251.8	348.54	447.28	205.43	422.18	457.72	529.69	
1994		267.39	536.37	1016.4		353.19	427.46	601.54	152.4	258.11	390.41	489.15		428.49	488.03	566	
1995	154.45	304.06	576.25	1058.5	169.63	376.41	570.68	864.87	390.28	509.05	641.35	752.25	207.43	508.37	735.9	817.65	
1996	154.47	304.37	579.66	1062.2	171.26	380.89	585.81	880.11	400.28	519.05	654.65	766.88	210.73	511.67	751.7	833.45	
1997	164.64	317.11	592.4	1078.7	171.56	384.54	621.83	929.82	458.62	577.39	726.23	863.15	243.01	554.84	850.87	932.62	
1998	166.79	319.26	595.84	1083.1							757.31	910.05	289.61	601.44	901.94	983.69	
1999	169.03	327.69	608.51	1097.8	176.82	392.2	635.2	944.03		582.03	786.54	942.74	300.92	617.85	918.79	1000.5	
2000			612.08	1105	181.7	396.96	645.72	954.55	460.81	585.48	789.37	985.21		647.85	958.28	1055.7	
2001	178.43	338.35	622.74	1116.6		397.09	647.11	956.57	462.36	587.04	791.16	997.21	301.89	658.86	970.15	1067.6	
2002		339.35	624.24	1119.2				976.89	462.68	587.35	792.73	1020.8		662.46	982.08	1079.5	
2003								1001.2	479.75	611.3	810.55	1045.9		663.21	999.9	1097.3	
2004					181.81		656.11	1019	488.75	621.66	824.77	1068.9	303.25	664.58	1010.3	1118.4	
2005	183.35	344.27	637.39	1139.2	202.07	420.61	680.13	1057.3	491.62	644.69	852.3	1123.2	323.41	689.61	1036.2	1169.6	
2006	203.57	366.85	677.7	1179.5			691.17	1072.7	492.85	655.39	863.54	1134.5	338.41	704.61	1052.4	1186.8	
2007	220.75	373.68	673.26	1131.7		436.38	710.87	1116.2	497.51	672.92	890.53	1161.6			1068.3	1207.6	
2008																	
2009	235.64	388.57	688.81	1126.2			711.53	1121.8		672.8	879.16	1156.5	284.61	655.86	1019.2	1145.5	
2010	238.79	391.72	691.96	1129.4					487.58	663.49	875.07	1152.4		646.55	1016.4	1142.7	
2011							711.19	1097.4	461.9	643.47	854.8	1137.6	291.86	650.09	1008.3	1139.3	
2012										653.65	864.99	1147.7	302.36	660.27	1018.5	1149.4	
2013							784.07	1170	576.66	766.22	972.56	1215.6			1130.6	1269	
2014										776.73	983.07	1226.1	307.87	681.29	1156.6	1238.2	
2015																	
2016																	
2017												1191.3		605.64	1077.7	1235.2	
2018									576.9	776.97	936.41	1182.5		596.88	1081.6	1256.9	
2019	215.11	358.37	665.31	1076.3	162.38	394.19	773.49	1157.6	566.37	755.5	909.94	1145.7	248.97	571.68	1050.3	1188.1	

Data Source: National Water Resources Board, Department of Environment and Natural Resources, Republic of the Philippines

Note: Cumulative groundwater extraction values at any given year for each buffer zone are estimated by subtracting values from wells whose permits were cancelled at the time indicated.

Table S3. Post-2004 number and capacity of wells for each city/municipality as of August 2019

City	Number of Wells						Water Discharge of Wells (lps)					
	<i>I</i>	<i>C</i>	<i>Irr.</i>	<i>D</i>	<i>M</i>	<i>Tot</i>	<i>I</i>	<i>C</i>	<i>Irr.</i>	<i>D</i>	<i>M</i>	<i>Tot</i>
Muntinlupa	5	8			12	25 ^a	37.88	9.26			80.21	127.35 ^a
Biñan	10	9	1	2	20	42 ^b	194.73	2.352	10.5	33.96	181.87	423.412 ^b
San Pedro	11	2			21	34 ^c	131.263	1.543			76.75	209.556 ^c
Carmona	2	6				12 ^d	14.87	2.398			14.93	32.198 ^d
GMA		1	1		4	6 ^e		1.26	12.62		37.51	51.390 ^e
Dasmariñas		1		2	16	19		1.5		15.89	169.413	186.803
Taguig	1	3				4	2.36	12				14.36
Parañaque	4	1			13	18	2.85	0.87			41.24	44.96
Las Piñas		1		4	23	28		0.058		16	109.936	125.994
Bacoor		9			36	45 ^f		26.69			192.606	219.296 ^f
Imus	5					59 ^g	31.05				332.803	363.853 ^g

I – Commercial; C - Commercial (incl. hospitals, supermarkets, etc.); Irr. – Irrigation; D – Domestic; M – Municipal

^a 2 cancelled as of Aug. 6, 2012 with combined capacity of 12.26

^b 7 cancelled as of Oct. 24, 2018 with combined capacity of 52.654; another one cancelled on Jan 13, 2012 with a capacity of 0.05

^c 2 cancelled as of Oct. 24, 2018 with combined capacity of 0.523; 1 cancelled as of March 10, 2015 with a capacity of 3.790; 1 cancelled as of April 29, 2019 with a capacity of 4.47

^d 1 cancelled as of Oct. 24, 2018 with a capacity of 0.2030

^e 1 cancelled as of June 28, 2012 with a capacity of 5.0

^f 3 cancelled as of Oct. 24, 2018 with a combined capacity of 11.5; 1 cancelled as of Feb. 18, 2014

^g 1 cancelled as of Oct. 24, 2018 with a capacity of 4.920; 1 cancelled as of March 11, 2014 with a capacity of 0.650; 1 cancelled as of Jan. 4, 2012 with a capacity of 2.78; 5 increased combined capacity to 49.19 as of June 3, 2014 (original capacity unknown)