

SUPPLEMENTARY MATERIAL

Formulation of the relationship between temperature and groundwater conductivity in varying geological conditions

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Table S1. Observation locations and groundwater temperature (T) and electrical conductivity (EC) in sampled locations

Code	Group	Area	Location identifier	Spring/well	Type	T (°C)	EC ($\mu\text{S}\cdot\text{cm}^{-1}$)
A	geothermal	Ungaran	A1	Nglimut	hot	40.40	1,669.20
			A2	Gedongsongo-1	hot	73.49	1,515.80
			A3	Gedongsongo-2	cold	25.99	2,745.00
			A4	Gedongsongo-3	hot	40.61	473.10
			A5	Sidomukti	cold	22.23	135.80
			A6	Diwak	warm	38.24	22,620.00
			A7	Kaliulo	warm	37.35	19,375.00
			A8	Sendang Kramat	warm	32.47	1,378.70
B	karst	Gunungsewu	B1	Dendengwelut	normal	26.64	116.73
			B2	Towet	normal	26.59	135.91
			B3	Suci	normal	26.51	50.28
			B4	Winong	normal	26.13	128.73
			B5	Boromo	normal	26.20	130.34
			B6	Namberan	normal	27.18	132.92
			B7	Gadel	normal	26.51	50.31
			B8	Komplet	normal	26.98	470.35
			B9	Dondong	normal	27.95	133.72
			B10	Luweng Lor	normal	26.50	146.00
C	alluvial	South Coast	C1	Godekan	normal	28.23	390.50
			C2	Bugen	normal	27.78	761.60
			C3	Caben	normal	28.22	764.50
			C4	Beji	normal	29.17	463.60

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Code	Group	Area	Location identifier	Spring/well	Type	T (°C)	EC ($\mu S \cdot cm^{-1}$)
C	alluvial	South Coast	C5	Kaputren	normal	28.56	989.90
			C6	Parangtritis Beach	normal	28.21	423.40
			C7	Depok	normal	29.95	660.40
			C8	Parangtritis Beach	normal	29.38	665.90
			C9	Parangtritis Beach	normal	30.35	1,106.10
			C10	Cemoro Beach	normal	25.12	410.40
			C11	Parangwedang	warm	36.06	13,945.00
D	volcanic	Merapi	D1	Tuk	cold	24.57	233.50
			D2	Arjuna	cold	25.14	251.10
			D3	Pakem	cold	25.72	269.70
			D4	Dono Warha	cold	25.94	199.97
			D5	Sempu	cold	25.51	210.20
			D6	Mringin	cold	24.59	144.80
			D7	Ngepring	cold	22.80	181.17
			D8	Kaligayam	cold	23.30	151.51
			D9	Pajangan	normal	26.36	505.90
E	geothermal	Guci	E1	Guci	hot	34.19	798.50
			E2	Pancuran 5	hot	29.63	788.17
			E3	Paguyangan	hot	72.85	1,852.60
			E4	Geyong Cave	hot	40.52	850.20
			E5	Pancuran 7	hot	46.06	1,048.30

Source: own study.

Table S2. Temperature (T) and electrical conductivity (EC) values from testing results in the Balai Teknik Kesehatan Lingkungan dan Pengendalian Penyakit (BTKLPP) laboratory

No	Geology	Spring/well identifier	T (°C)	EC ($\mu S \cdot cm^{-1}$)
1	Ungaran geothermal	A1	24.6	2,104
2		A2	24.6	1,103
3		A5	24.6	147
4		A6	24.7	2,369
5		A7	24.7	20,670
6		A8	24.7	1,465
7	Gunungsewu	B2	25.0	145
8		B3	24.8	95
9		B4	24.8	136
10	Alluvial	C5	24.5	399
11		C6	24.8	1,031

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No	Geology	Spring/well identifier	T (°C)	EC ($\mu\text{S}\cdot\text{cm}^{-1}$)
12	Alluvial	C7	24.7	686
13		C11	24.3	19,940
14	Merapi volcanic	D1	25.0	240
15		D4	24.7	201
16	Guci geothermal	E1	24.6	638
17		E2	24.7	593
18		E3	24.7	1,238
19		E4	24.7	754
20		E5	24.7	932

Source: own study.

Table S3. Dependence of electrical conductivity (EC) on temperature (T)

No.	Spring/well identifier	Formula EC (σ)	R^2
1	A1	$\sigma = 0.2408T^2 - 12.215T + 1717.1$	0.9588
2	A2	$\sigma = 0.2117T^2 - 12.934T + 1833$	0.9276
3	A5	$\sigma = 0.0266T^2 - 1.2609T + 169.29$	0.9335
4	A6	$\sigma = 0.446T^2 - 26.497T + 2501.7$	0.9800
5	A8	$\sigma = 0.2712T^2 - 15.411T + 1669.9$	0.9374
6	B2	$\sigma = 0.0158T^2 - 0.3371T + 169.07$	0.9374
7	B3	$\sigma = 0.0118T^2 - 0.4588T + 113.86$	0.8776
8	B4	$\sigma = 0.0533T^2 - 3.2812T + 251.64$	0.9586
9	C5	$\sigma = 0.1988T^2 - 11.827T + 1240.5$	0.9870
10	C6	$\sigma = 0.1815T^2 - 12.303T + 1033.1$	0.9763
11	C7	$\sigma = 0.1306T^2 - 9.5128T + 784.38$	0.9770
12	D1	$\sigma = 0.0607T^2 - 3.2818T + 379.11$	0.9826
13	D4	$\sigma = 0.0384T^2 - 1.9762T + 250.98$	0.9753
14	E1	$\sigma = 0.1179T^2 - 6.6956T + 816.78$	0.9825
15	E2	$\sigma = 0.1797T^2 - 11.476T + 928.26$	0.9065
16	E3	$\sigma = 0.296T^2 - 18.72T + 1676.2$	0.9853
17	E4	$\sigma = 0.1394T^2 - 7.7132T + 921.44$	0.9917
18	E5	$\sigma = 0.1935T^2 - 11.883T + 1224.8$	0.9748
Average			0.9583

Source: own study.

Table S4. The coefficients (A , B , and C) for the relationship formula of temperature (T) and electrical conductivity (EC) in various springs

Spring/well identifier	A	B	C
A1	0.2408	12.215	1,717.1
A2	0.2117	12.934	1,833
A5	0.0266	1.2609	169.29
A6	0.4400	26.497	2,501.7
A8	0.2712	15.411	1,669.9
B2	0.0158	0.3371	169.07
B3	0.0118	0.4588	113.86
B4	0.0533	3.2812	251.64
C5	0.1988	11.827	1,240.5
C6	0.1815	12.303	1,033.1
C7	0.1306	9.5128	784.38
D1	0.0607	3.2818	379.11
D4	0.0384	1.9762	250.98
E1	0.1179	6.6956	816.78
E2	0.1797	11.47	928.26
E3	0.2960	18.72	1,676.2
E4	0.1394	7.7132	921.44
E5	0.1935	11.883	1,224.8

Source: own study.

Table S5. Actual temperature values in the field (T_F) and validated EC values at field temperatures

Spring/well identifier	T_F	σ_F	σ_{FV}
A1	40.40	1,669.20	1,887.4714
A2	73.49	1,515.80	1,755.8575
A5	22.23	135.80	154.40519
A6	38.24	2,262.00	2,258.5338
A8	32.47	1,378.70	1,455.4312
B2	26.59	135.91	158.5188
B3	26.51	50.28	102.6204
B4	26.13	128.73	168.77032
C5	28.56	989.90	1,064.8768
C6	28.21	423.40	926.16313
C7	29.95	660.40	645.07437
D1	24.57	233.50	287.6186
D4	25.94	199.97	213.25844
E1	34.19	798.50	682.96906

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Spring/well identifier	T_F	σ_F	σ_{FV}
E2	29.63	788.17	665.37707
E3	72.85	1,852.60	1,805.1549
E4	40.52	850.20	806.79262
E5	46.06	1,048.30	1,029.3127

Source: own study.

Table S6. Summary of coefficients in the temperature and electrical conductivity relationship formula for each geological group

Group	Sample	Sub group coefficient			General coefficient		
		A	B	C	A	B	C
Geothermal	A1, A2, A6, A8	0.21–0.44	12.21–26.50	1,669.9–2,501.7	0.12–0.44	6.70–26.50	816.78–2,501.7
	E1–E5	0.12–0.30	6.70–18.72	816.78–1,676.2			
Karst	B2–B4	0.01–0.05	3.28–3.45	113.86–251.64	0.01–0.05	3.28–3.45	113.86–251.64
Volcanic	A5	0.03	1.26	169.29	0.03–0.06	1.26–3.28	169.29–250.98
	D1, D4	0.04–0.06	1.98–3.28	379.11–250.98			
Alluvial	C5–C7	0.13–0.2	1.28–9.51	784.38–1,240.5	0.13–0.20	1.28–9.51	1.28–9.51

Source: own study.

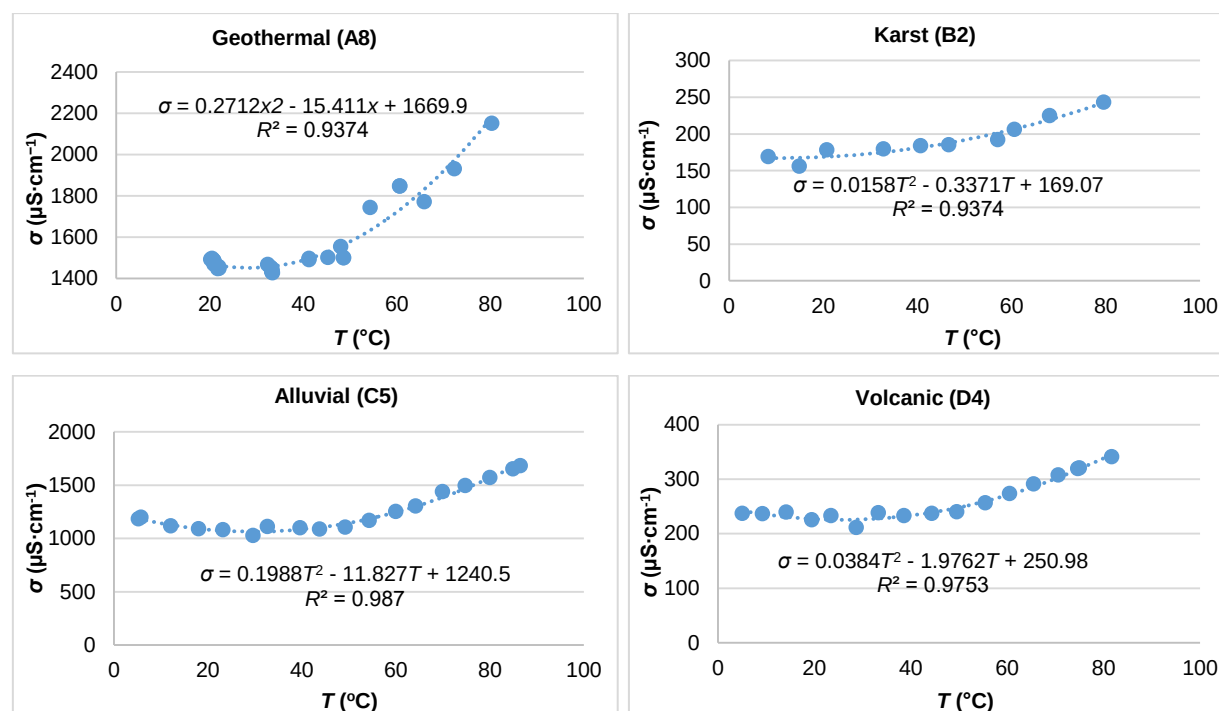


Fig. S1. Example of temperature (T) and electrical conductivity (EC) relationships representing four geological groups; source: own study

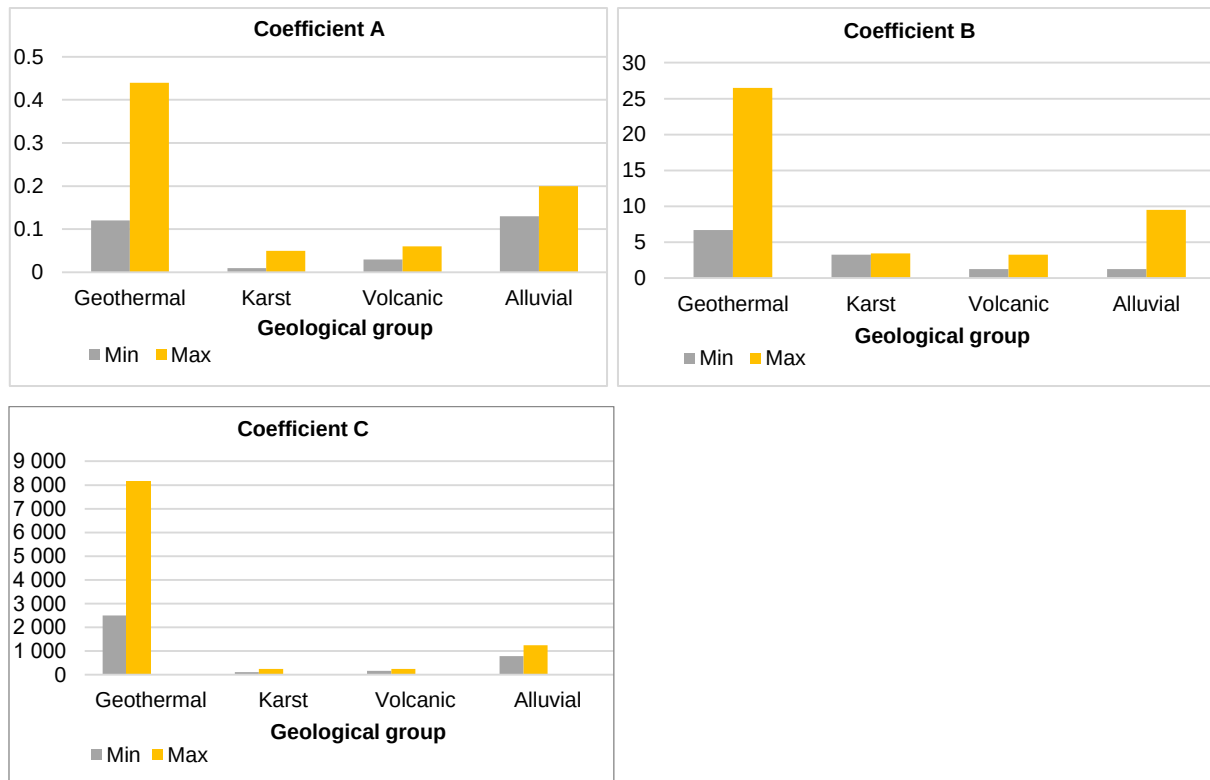


Fig. S2. Significant differences in coefficients *A*, *B*, and *C* across geological groups; source: own study