

Theoretical background for groundwater flow velocity estimation.

The velocity of groundwater at which water is moving through the pore matrix of an aquifer available for flow is known as seepage velocity [46,47]. The pace at which fluid particles flow across the porous medium in a straight line from one place to another [48,49] and the apparent velocity through the porous medium is called the seepage velocity [50]. It is more realistic than Darcy flux, also known as Darcy velocity, in expressing the actual velocity of groundwater within the pores of an aquifer; Darcy flux assumes that the flow occurs throughout the soil, when in reality, the flow is limited to the pore space [51]. The seepage velocity is calculated by dividing the Darcy flux by the effective porosity, as shown in Equation 1 [51].

$$V_{seep} = \frac{v}{n_{eff}} \quad (1)$$

Where V_{seep} is the seepage velocity (m/d), v is the Darcy flux ($m^3/s/m^2$), and n_{eff} is the effective porosity of the aquifer (dimensionless). Darcy velocity is the product of the hydraulic gradient multiplied by the hydraulic conductivity of the aquifer, as in Equation (2)[52]:

$$v = -k \frac{\Delta h}{\Delta s} \quad (2)$$

where k is the hydraulic conductivity (m/s), Δh is the difference in the hydraulic head (m), and Δs is the distance (m). The hydraulic conductivity can be written in terms of transmissivity and the saturated thickness of the aquifer, as in Equation (3)[46,52]:

$$k = \frac{T}{b} \quad (3)$$

where T is the transmissivity (m^2/d) and b is the saturated thickness of the aquifer (m). Equation (3) is useful in groundwater hydraulics; most of the wells' hydraulic calculations and equations are written in terms of transmissivity rather than the hydraulic conductivity [46,52]. Combining Equations (1)–(3), the seepage velocity can be written as Equation (4):

$$V_{seep} = -\frac{T}{bn_{eff}} \frac{\Delta h}{\Delta s} \quad (4)$$

Therefore, Equation (4) was used accordingly as a model in ArcMap/GIS and as a mapping framework to calculate the seepage velocity of the aquifers.

Table S1: Water wells history, hydraulic parameters and calculated effective porosity

Sample ID	X	Y	SWL	BH Depth	Saturated thickness (b)	T(m2/day)	Specific capacity (Sc)	Initial effective porosity	Effective porosity
EAE01	337698	926445	21.39	70.3	48.91	2.45×10^1	0.87	0.03415	0.14935
EAE02	338942	923746	12.59	44.86	32.27	3.21×10^1	1.896	0.35604	0.15928
EAE03	341178	924774	53.02	76	22.98	1.37×10^3	331.26	0.91148	0.24399
EAE04	340757	924251	49.17	60.78	11.61	7.05×10^0	6.59	0.33067	0.17654
EAE07	344663	921508	24.2	43.5	19.3	3.88×10^2	534.19	0.94009	0.25381
EAE08	344821	920280	20.52	47.13	26.61	6.13×10^{-1}	0.099	0.16406	0.12481
EAE10	348666	919456	62.16	84.3	22.14	1.12×10^2	42.6	0.64057	0.20597
EAE11	350964	918909	11.17	51.45	40.28	6.24×10^{-1}	0.94	0.32279	0.15031
EAE12	353085	916542	23.41	76.7	53.29	9.33×10^{-1}	1.41	0.40014	0.15543
EAE13	349869	916553	60.08	73.66	13.58	9.50×10^{-2}	0.325	0.27182	0.13769
EAE14	349548	914882	58.08	76.88	18.8	5.33×10^3	845.547	0.99558	0.26363
EAE19	368834	915079	24.45	63.69	39.24	2.66×10^0	3.78	0.45598	0.16862
EEJ02	429740	984856	8.17	49.5	41.33	7.18×10^1	38.59	0.74581	0.20429
EEJ06	433310	996719	14.92	62.66	47.74	3.84×10^0	5.43	0.44992	0.17374

EEJ09	425021	986568	5.94	35.6	29.66	1.34×10 ¹	11.48	0.53468	0.18482
EEJ10	427230	996599	7.23	46.88	39.65	4.81×10 ²	265.49	0.98967	0.23957
EEJ16	432590	1012878	14.92	62.66	47.74	1.65×10 ⁰	3.07	0.46527	0.16575
EEJ17	437268	1005326	29.49	47.35	17.86	1.81×10 ¹	21.57	0.51993	0.19471
EEJ20	427230	993936	32.82	53.39	20.57	1.17×10 ⁰	1.72	0.29018	0.158
EME01	297887	1263242	10.32	21.75	11.43	8.35×10 ⁻¹	777	0.88655	0.26179
EME02	293507	1268379	11.02	26	14.98	1.19×10 ³	1190.48	0.99599	0.27118
EME03	295781	1255382	17.61	53.26	35.65	2.52×10 ¹	9.59	0.54584	0.1821
EME05	298208	1257600	10.05	49	38.95	1.61×10 ³	8.4	0.54579	0.18012
EME07	295075	1256183	2.42	61.34	58.92	7.35×10 ⁰	26.66	0.76629	0.19814
EME08	297599	1252650	16.37	49.02	32.65	1.61×10 ³	23.08	0.63647	0.1958
EME09	295613	1260950	6.67	51.4	44.73	1.50×10 ²	71.35	0.8406	0.21493
EME12	304882	1251109	4.96	42.5	37.54	6.37×10 ⁰	25.58	0.67533	0.19747
EME13	289477	1268665	23.06	50	26.94	2.74×10 ¹	1764.71	1.16469	0.28014
EME15	296417	1259982	11.38	50.3	38.92	2.67×10 ²	1.96	0.38614	0.15972
EME18	305841	1257066	9.01	55.4	46.39	2.35×10 ¹	25.21	0.71345	0.19723
ESD01	444972	905278	10.35	25.3	14.95	1.39×10 ²	55.83	0.6017	0.21062
ESD03	413694	971609	19.09	38.05	18.955	3.96×10 ²	163.04	0.78153	0.23011
ESD04	440487	909637	21.48	68.6	47.12	9.07×10 ⁻¹	1.52	0.38923	0.1564
ESD08	448194	904739	40.7	62	21.3	4.04×10 ⁰	2.19	0.31386	0.16119
ESD09	446896	904608	12.99	35.71	22.72	3.60×10 ¹	20.24	0.55486	0.19369
ESD10	447561	904656	23.79	51.5	27.71	1.22×10 ⁰	1.68	0.32471	0.15769
ESD11	448698	896983	20.37	42.94	22.57	6.23×10 ¹	30.91	0.60457	0.20058
ESD13	449212	913788	15.01	18.6	3.59	3.65×10 ⁰	17.36	0.26838	0.19125
ESD16	443281	909888	22.3	43.5	21.2	2.58×10 ⁰	2.46	0.32313	0.16274
ESD17	449596	928315	38.9	47	8.1	5.98×10 ¹	45.02	0.46946	0.20691
ESD19	448348	907059	52	80	28	2.63×10 ²	158.23	0.85329	0.22955
ESD20	448033	914224	41	75	34	1.72×10 ⁰	2.49	0.38988	0.1629