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Sources and fate of nitrate in groundwater at agricultural operations overlying glacial sediments

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Supplementary Material

Measured hydraulic heads and gradients

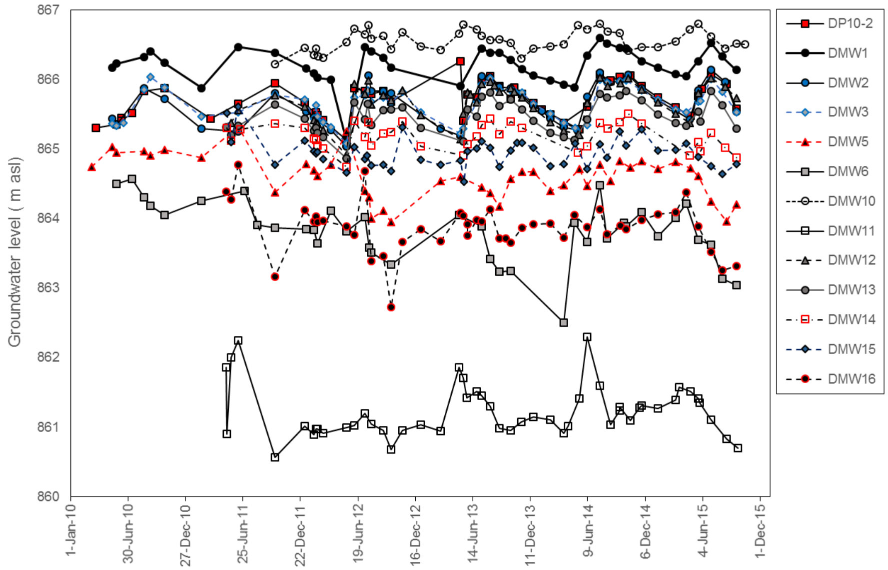

Figure S1. Time series of hydraulic heads measured in water table monitoring wells at CFO1

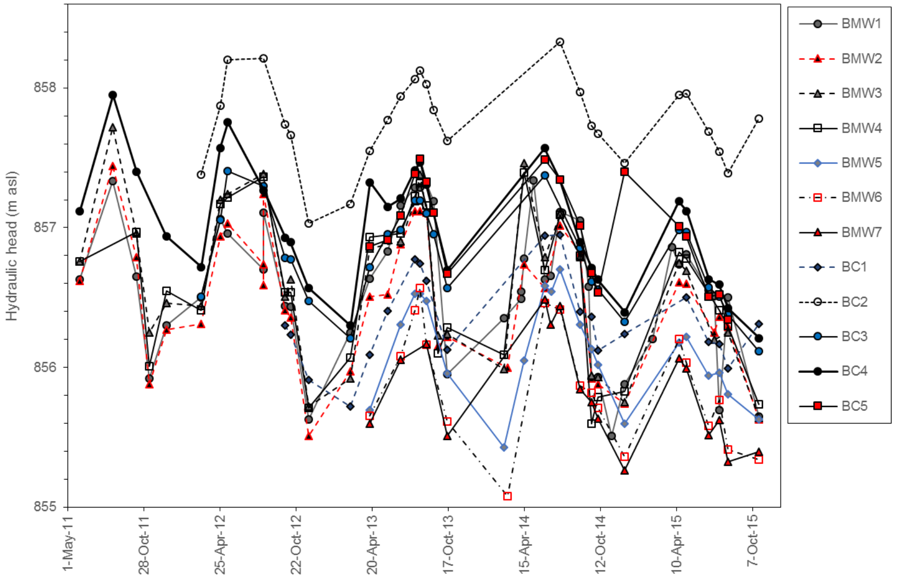

Figure S2. Time series of hydraulic heads measured in water table monitoring wells at CFO4

Table S1. Horizontal hydraulic gradients at CFO1 at the water table.

Well IDs	Horizontal hydraulic gradient
DMW1 and DP10-2	4.63×10^{-3}
DMW2 and DMW-16	6.06×10^{-3}
DP10-2 and DMW5	4.39×10^{-3}
DP10-2 and DMW11	9.74×10^{-3}
DMW10 and DMW11	1.38×10^{-2}

Table S2. Mean vertical gradients between nested water table wells and piezometers at CFO1

Well IDs	Vertical hydraulic gradient
DMW10 and DP11-10b	3.34×10^{-3}
DMW11 and DP11-11b	-2.79×10^{-2}
DMW12 and DP11-12b	2.20×10^{-3}
DMW13 and DP11-13b	1.36×10^{-2}
DMW14 and DP11-14b	1.80×10^{-3}
DMW15 and DP11-15b	3.37×10^{-2}
DMW16 and DP11-16b	2.86×10^{-2}
DP10-2 and DP10-1	1.78×10^{-1}

Table S3. Horizontal hydraulic gradients at CFO4 at the water table.

Well IDs	Horizontal hydraulic gradient
BC2 and BMW2	3.94×10^{-3}
BMW2 and BMW7	4.32×10^{-3}
BC2 and BMW7	3.79×10^{-3}

Table S4. Mean vertical hydraulic gradients in nested water table wells and piezometers at CFO4

Well IDs	Vertical hydraulic gradient
BMW2 and BM10-15e	4.61×10^{-2}
BMW4 and BP10-15w	4.22×10^{-2}
BMW5 and BP5-15	4.46×10^{-2}
BMW6 and BP6-15	4.16×10^{-2}

Measured hydrochemistry data

Table S5. Measured concentrations of chloride (Cl^-), bicarbonate (HCO_3^-), dissolved organic carbon (DOC), total nitrogen (TN), NH_3-N, NO_3-N, NO_2-N, and total organic nitrogen (TON) in groundwater wells and water filtered from the EMS and catch basin at CFO1 (mean ± standard deviation).

Sample ID	Cl^- (mg L^{-1})	HCO_3^- (mg L^{-1})	DOC (mg L^{-1})	NH_3-N (mg L^{-1})	NO_3-N* (mg L^{-1})	NO_2-N (mg L^{-1})	TON (mg L^{-1})	TN (mg L^{-1})
EMS filtrate	552 ± 63 (n=10)	2575 ± 457 (n=10)	1377 ± 948 (n=10)	512 ± 181 (n=10)	0.31 ± 0.12 (n=10)	-	834 ± 408 (n=7)	1444 ± 364 (n=7)
Catch basin filtrate	592 ± 309 (n=9)	833 ± 615 (n=9)	576 ± 362 (n=9)	4.5 ± 2.1 (n=9)	<0.1 (n=9)	-	1023 ± 433 (n=6)	1027 ± 433 (n=6)
DMW1	50 ± 40 (n=18)	453 ± 82 (n=18)	6.4 ± 1.4 (n=4)	<0.1 (n=18)	6.5 ± 3.6 (n=18)	<0.1 (n=18)	0.6 ± 0.2 (n=18)	7.2 ± 3.8 (n=18)
DMW2	404 ± 186 (n=20)	339 ± 61 (n=20)	3.5 ± 0.5 (n=5)	0.1 ± 0 (n=20)	1.2 ± 1.3 (n=20)	<0.1 (n=20)	2.9 ± 0.2 (n=17)	3.2 ± 0.2 (n=17)
DMW3	871 ± 146 (n=22)	4362 ± 476 (n=22)	282.1 ± 30 (n=5)	373.4 ± 79.4 (n=22)	1.1 ± 2.7 (n=22)	2.7 ± 8.3 (n=22)	1.4 ± 0.7 (n=16)	20.2 ± 3.2 (n=16)
DMW4	50 ± 24 (n=21)	448 ± 57 (n=21)	4.5 ± 0.8 (n=5)	0.2 ± 0.7 (n=21)	0.1 ± 0.2 (n=21)	<0.1 (n=21)	0.3 ± 0.1 (n=16)	3.2 ± 0.5 (n=16)
DMW5	35 ± 11 (n=22)	534 ± 30 (n=22)	6.6 ± 1.0 (n=5)	0.1 ± 0.1 (n=22)	1.0 ± 0.5 (n=22)	<0.1 (n=22)	0.9 ± 0.7 (n=16)	21.2 ± 9.0 (n=16)
DMW6	394 ± 25 (n=21)	778 ± 67 (n=21)	25.8 ± 5.4 (n=5)	4.0 ± 1.0 (n=21)	0.2 ± 0.2 (n=21)	<0.1 (n=21)	<0.1 (n=15)	0.4 ± 0.2 (n=15)
DMW10	234 ± 7 (n=17)	712 ± 15 (n=17)	58.5 ± 1.0 (n=5)	0.2 ± 0.1 (n=17)	0.1 ± 0.2 (n=17)	0.1 ± 0 (n=17)	<0.1 (n=16)	<0.3 (n=16)
DMW11	437 ± 121 (n=16)	771 ± 38 (n=16)	18.0 ± 1.7 (n=5)	0.3 ± 0.2 (n=16)	18.5 ± 2.7 (n=16)	0.1 ± 0.3 (n=16)	0.3 ± 0.1 (n=16)	0.5 ± 0.2 (n=16)
DMW12	75 ± 11 (n=16)	405 ± 24 (n=16)	3.9 ± 0.6 (n=5)	0.1 ± 0.1 (n=16)	2.8 ± 0.5 (n=16)	0.1 ± 0 (n=16)	0.4 ± 0.6 (n=20)	1.7 ± 1.6 (n=20)
DMW13	70 ± 19 (n=16)	767 ± 119 (n=16)	7.7 ± 1.7 (n=5)	0.9 ± 1.0 (n=16)	19.2 ± 8.7 (n=16)	0.2 ± 0.2 (n=16)	50.6 ± 17.2 (n=22)	427.8 ± 69.2 (n=22)
DMW14	7 ± 5 (n=15)	445 ± 66 (n=15)	3.7 ± 0.6 (n=5)	0.3 ± 0.1 (n=15)	<0.1 (n=15)	<0.1 (n=15)	0.3 ± 0.6 (n=21)	0.6 ± 1.5 (n=21)
DMW15	14 ± 1 (n=16)	670 ± 32 (n=16)	3.8 ± 0.9 (n=5)	0.1 ± 0 (n=16)	<0.1 (n=16)	<0.1 (n=16)	0.3 ± 0.1 (n=22)	1.5 ± 0.4 (n=22)
DMW16	65 ± 7 (n=16)	604 ± 18 (n=16)	7.3 ± 0.5 (n=5)	<0.1 (n=16)	0.1 ± 0.1 (n=16)	<0.1 (n=16)	2.6 ± 0.8 (n=21)	6.9 ± 0.9 (n=21)
DP10-1	<5 (n=23)	467 ± 19 (n=23)	3.7 ± 0.5 (n=5)	0.7 ± 0.1 (n=23)	<0.1 (n=23)	<0.1 (n=23)	0.3 ± 0.5 (n=23)	1.2 ± 0.5 (n=23)
DP10-2	68 ± 16 (n=22)	701 ± 36 (n=22)	6.3 ± 1.1 (n=5)	1.2 ± 0.9 (n=22)	12.6 ± 4.5 (n=22)	0.1 ± 0.1 (n=22)	0.9 ± 0.5 (n=22)	14.8 ± 4.2 (n=22)
DP11-10b	22 ± 14 (n=17)	689 ± 102 (n=17)	30.3 ± 24.9 (n=5)	0.5 ± 0.1 (n=17)	0.5 ± 1.7 (n=17)	<0.1 (n=17)	0.2 ± 0.2 (n=17)	1.3 ± 1.6 (n=17)
DP11-11b	16 ± 3 (n=16)	604 ± 67 (n=16)	8.9 ± 2.2 (n=5)	1.2 ± 0 (n=16)	<0.1 (n=16)	<0.1 (n=16)	<0.1 (n=16)	1.4 ± 0.1 (n=16)
DP11-12b	98 ± 20 (n=15)	492 ± 23 (n=15)	6.5 ± 0.6 (n=5)	0.1 ± 0.1 (n=15)	1.4 ± 1.3 (n=15)	<0.1 (n=15)	0.4 ± 0.1 (n=15)	1.9 ± 1.3 (n=15)
DP11-13b	15 ± 3 (n=16)	436 ± 26 (n=16)	11.7 ± 4.2 (n=5)	0.7 ± 0 (n=16)	<0.1 (n=16)	<0.1 (n=16)	0.2 ± 0.1 (n=16)	1.0 ± 0.1 (n=16)
DP11-14b	6 ± 3 (n=16)	461 ± 47 (n=16)	7.3 ± 1.1 (n=5)	0.9 ± 0.1 (n=16)	<0.1 (n=16)	<0.1 (n=16)	<0.1 (n=16)	1.1 ± 0.1 (n=16)
DP11-15b	6 ± 2 (n=17)	442 ± 91 (n=17)	6.4 ± 2.6 (n=6)	0.7 ± 0.1 (n=17)	<0.1 (n=17)	<0.1 (n=17)	<0.1 (n=17)	0.9 ± 0.2 (n=17)
DP11-16b	33 ± 3 (n=17)	531 ± 55 (n=17)	9.0 ± 8.4 (n=5)	0.8 ± 0.1 (n=17)	<0.1 (n=17)	<0.1 (n=17)	<0.1 (n=17)	1.0 ± 0.1 (n=17)

***For EMS filtrate and catch basin filtrate, these values are NO_3-N + NO_2-N**

Table S6. Measured concentrations of chloride (Cl^-), bicarbonate (HCO_3^-), dissolved organic carbon (DOC), total nitrogen (TN), NH_3-N, NO_3-N, NO_2-N, and total organic nitrogen (TON) in groundwater wells and water filtered from the EMS at CFO4 (mean ± standard deviation).

Sample ID	Cl^- (mg L^{-1})	HCO_3^- (mg L^{-1})	DOC (mg L^{-1})	NH_3-N (mg L^{-1})	NO_3-N* (mg L^{-1})	NO_2-N (mg L^{-1})	TON (mg L^{-1})	TN (mg L^{-1})
EMS filtrate	806 ± 17 (n=3)	2353 ± 89 (n=3)	3367 ± 115 (n=3)	736 ± 12 (n=3)	0.27 ± 0.02 (n=3)	-	407 ± 118 (n=3)	1143 ± 127 (n=3)
BC1	<10 (n=11)	494 ± 13 (n=11)	5.0 ± 0.8 (n=4)	<0.1 (n=11)	<0.1 (n=11)	<0.1 (n=11)	<0.1 (n=11)	<0.3 (n=11)
BC2	6 ± 3 (n=12)	516 ± 33 (n=12)	6.0 ± 3.0 (n=4)	<0.1 (n=12)	1.1 ± 2.7 (n=12)	<0.1 (n=12)	0.2 ± 0.2 (n=12)	1.4 ± 2.8 (n=12)
BC3	<5 (n=13)	504 ± 21 (n=13)	6.9 ± 2.9 (n=4)	<0.1 (n=13)	0.1 ± 0.1 (n=13)	<0.1 (n=13)	0.1 ± 0.1 (n=13)	<0.3 (n=13)
BC4	58 ± 64 (n=24)	576 ± 110 (n=24)	9.2 ± 3.5 (n=9)	<0.1 (n=24)	8.8 ± 13.2 (n=24)	<0.1 (n=24)	0.7 ± 0.8 (n=24)	9.6 ± 14.0 (n=24)
BC5	26 ± 6 (n=8)	498 ± 51 (n=8)	6.8 ± 3.1 (n=3)	<0.1 (n=8)	5.7 ± 1.5 (n=8)	<0.1 (n=8)	0.6 ± 0.4 (n=8)	6.3 ± 1.5 (n=8)
BMW1	305 ± 251 (n=28)	926 ± 190 (n=28)	21.5 ± 12.4 (n=11)	<0.1 (n=28)	2.2 ± 2.5 (n=28)	<0.1 (n=28)	1.1 ± 0.9 (n=28)	3.3 ± 3.2 (n=28)
BMW2	502 ± 97 (n=22)	1186 ± 87 (n=22)	20.2 ± 4.9 (n=9)	<0.1 (n=22)	6.0 ± 7.4 (n=22)	0.1 ± 0.1 (n=22)	1.6 ± 0.4 (n=22)	7.8 ± 7.6 (n=22)
BMW3	182 ± 81 (n=25)	881 ± 146 (n=25)	15.6 ± 3.3 (n=9)	<0.1 (n=25)	17.4 ± 10.3 (n=25)	0.1 ± 0.1 (n=25)	1.6 ± 0.8 (n=25)	19.1 ± 10.8 (n=25)
BMW4	188 ± 74 (n=24)	666 ± 55 (n=24)	12.0 ± 3.3 (n=11)	<0.1 (n=24)	33.6 ± 21.1 (n=24)	0.2 ± 0.3 (n=24)	2.5 ± 2.9 (n=24)	36.3 ± 21.9 (n=24)
BMW5	106 ± 23 (n=8)	975 ± 163 (n=8)	8.6 ± 1.3 (n=3)	<0.1 (n=8)	6.5 ± 4.8 (n=8)	0.1 ± 0 (n=8)	0.7 ± 0.3 (n=8)	7.3 ± 4.9 (n=8)
BMW6	156 ± 18 (n=8)	538 ± 27 (n=8)	6.9 ± 1.7 (n=3)	<0.1 (n=8)	0.4 ± 0.2 (n=8)	0.1 ± 0 (n=8)	0.5 ± 0.1 (n=8)	1.0 ± 0.2 (n=8)
BMW7	127 ± 15 (n=8)	699 ± 65 (n=8)	8.1 ± 2.8 (n=3)	<0.1 (n=8)	9.2 ± 3.0 (n=8)	0.1 ± 0 (n=8)	0.7 ± 0.4 (n=8)	10.0 ± 3.2 (n=8)
BP10-15e	7 ± 4 (n=19)	493 ± 33 (n=19)	3.4 ± 0.4 (n=7)	0.1 ± 0.1 (n=19)	0.1 ± 0.1 (n=19)	<0.1 (n=19)	<0.1 (n=19)	0.4 ± 0.2 (n=19)
BP10-15w	<5 (n=17)	507 ± 11 (n=17)	3.5 ± 0.6 (n=4)	<0.2 (n=17)	0.3 ± 1.0 (n=17)	<0.1 (n=17)	<0.1 (n=17)	0.6 ± 1.1 (n=17)
BP5-15	<5 (n=8)	509 ± 12 (n=8)	5.0 ± 1.1 (n=3)	<0.1 (n=8)	<0.1 (n=8)	<0.1 (n=8)	<0.1 (n=8)	<0.3 (n=8)
BP6-15	<5 (n=7)	487 ± 7 (n=7)	3.3 ± 1.1 (n=3)	<0.2 (n=7)	<0.1 (n=7)	<0.1 (n=7)	<0.1 (n=7)	<0.3 (n=7)

***For EMS filtrate, this value is NO_3-N + NO_2-N**

Table S7. Hydrochemistry of water from continuous core samples

Core ID	Depth (m BG)	Lithology	Cl- (mg L^{-1})	NH_3-N (mg L^{-1})	NO_3-N (mg L^{-1})	NO_2-N (mg L^{-1})	NO_3-N/Cl-
DC15-20	2	Sand	76.4	4.27	0.64	4.99	0.008
	3	Sand	47.2	2.02	2.42	3.75	0.051
	4	Sand	22.3	2.45	1.76	0.12	0.079
	5	Sand	21.0	1.88	0.96	0.07	0.046
	6	Sand	28.2	2.12	1.16	0.14	0.041
	7	Sand	27.2	2.19	0.89	0.33	0.033
	8	Sand	28.5	2.85	14.39	0.32	0.505
	9	Sand	12.9	1.29	0.68	1.39	0.053
	10	Sand	35.7	1.95	2.05	0.81	0.057
	10.5	Sand	33.0	0.00	4.10	0.00	0.124
	11	Sand	64.1	2.17	1.38	1.23	0.022
	12	Sand	112.4	2.17	2.12	0.03	0.019
	13	Sand	119.8	1.70	2.77	0.30	0.023
	14	Sand	75.6	1.06	0.85	2.20	0.011
	15	Sand	56.3	2.30	2.04	0.00	0.036
DC15-21	2	Sand	147.6	1.37	0.14	1.83	0.001
	2.5	Sand	23.7	0.82	0.90	0.29	0.038
	3.5	Sand	18.0	1.29	3.72	1.78	0.207
	4.5	Sand	20.5	1.91	4.74	0.26	0.232
	5	Sand	29.7	1.24	3.59	0.00	0.121
	6	Sand	22.8	2.00	0.95	0.04	0.042
	7	Sand	33.6	2.98	1.93	0.25	0.058
	8	Sand	24.4	1.67	4.07	0.16	0.167
	9	Sand	25.6	3.26	3.65	0.08	0.142
	10	Sand	21.5	0.82	1.28	0.21	0.060
DC15-22	2	Sand	72.9	1.19	13.44	0.00	0.184
	2.5	Clay	72.8	0.84	17.52	3.73	0.241
	3	Sand	79.8	0.76	16.66	0.12	0.209
	4	Sand	109.8	1.94	22.88	1.28	0.208
	5	Sand	60.8	2.59	12.82	2.17	0.211
	6.5	Sand	99.2	3.20	4.68	4.04	0.047
	7	Sand	88.4	2.40	9.90	0.00	0.112
	7	Sand	95.0	0.00	6.08	2.80	0.064
	8	Sand	75.8	1.92	12.89	0.00	0.170
	9.5	Sandy clay	157.7	1.54	39.50	2.04	0.251
	10	Sandy clay	73.0	1.55	10.99	0.29	0.151
	11	Sand	107.7	3.32	12.10	0.82	0.112
	12	Sand	91.4	1.14	15.60	1.45	0.171
DC15-23	2	Clay	70.0	0.94	66.40	1.35	0.948
	3	Clay	122.2	0.76	9.48	1.87	0.078
	4	Clay	48.8	5.87	8.90	0.86	0.182
	5	Clay	56.1	4.62	10.53	0.63	0.188
	6	Sand	98.2	8.59	7.05	1.87	0.072
	6.5	Sand	61.2	1.86	9.76	2.93	0.160
	7	Sand	84.9	1.57	10.17	0.25	0.120
	7.5	Sand	57.5	2.60	10.51	0.06	0.183
	8	Sand	67.8	2.24	9.88	1.13	0.146
	8.5	Clay	106.1	9.82	7.47	0.31	0.070
	9	Sand	85.5	11.70	12.69	0.92	0.148
	9.5	Sand	72.4	9.75	17.27	1.85	0.238
	11	Sand	82.6	9.20	21.05	0.07	0.255
	11.5	Sand	68.5	2.99	20.88	1.02	0.305
	12	Clay	87.9	0.69	1.52	2.06	0.017
	13	Clay	22.9	5.07	1.01	0.00	0.044
	14	Clay	17.9	1.80	1.16	0.34	0.065
	15	Clay	12.6	1.47	1.01	0.32	0.080

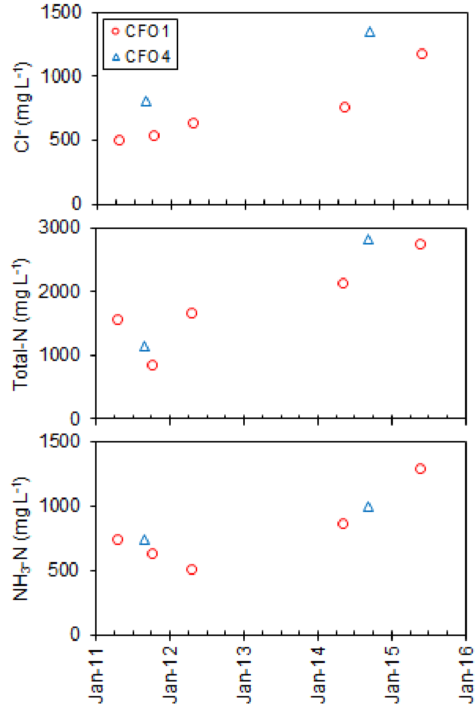

Figure S3. Concentrations of Cl^-, total-N, and NH_3-N in water filtered from the EMS slurry at CFO1 and CFO4.

Stable isotopes of water and nitrate

Samples for the stable isotopes of water (δ^2H and $\delta^{18}O_{H2O}$) were collected from wells at CFO1 quarterly between February 2011 and August 2013. Samples for stable isotopes of water were collected from wells at CFO4 on 16 October 2013. Wells were purged prior to sample collection (1–3 casing volumes) in 20 mL HDPE bottles. Core samples for analysis of stable isotopes of water were stored in Ziploc™ bags and kept cool until analysis.
Stable isotopes of water (δ^2H and $\delta^{18}O_{H2O}$) in groundwater samples from wells and pore water squeezed from continuous core were analyzed using a Los Gatos LGR model 908-0008 liquid water isotope analyzer (off-axis integrated cavity output spectroscopy) (Lis et al., 2008). The accuracy of this method is ± 0.8‰ for δ^2H and ± 0.1‰ for $\delta^{18}O_{H2O}$. Pore water from continuous core collected in 2015 was analyzed for δ^2H and $\delta^{18}O_{H2O}$ using the vapour equilibration method (Wassenaar et al. (2008). The Ziploc bag containing the core sample was filled with dry air to equilibrate with the pore water vapour for 3 days at room temperature. The isotopic values of this equilibrated vapour was then analyzed using a Picarro L1102-*i* water isotope analyzer. The precision of this analysis is ±2.0‰ for δ^2H and ±4.0‰ for $\delta^{18}O_{H2O}$. Stable isotopic values of ground water were predominantly close to Calgary meteoric water line (Peng et al., 2004) with δ^2H_{H2O} ranging from -175.9 to 117.2‰ and $\delta^{18}O_{H2O}$ ranging from -22.5 to -12.9‰.

Table S8. Stable isotope values of water and nitrate at CFO1

Site	Well ID*	$\delta^{18}O_{H2O}$	$\delta^{2}H_{H2O}$	$\delta^{18}O_{NO3}$	$\delta^{15}N_{NO3}$
CFO1†	DMW1	-16.7 ± 1.3 (n=4)	-136.2 ± 10.3 (n=4)	-0.5 ± (n=1)	12.6 ± (n=1)
	DMW2	-15.5 ± 0.6 (n=7)	-126.9 ± 4.4 (n=7)	6.0 ± 2.0 (n=2)	20.6 ± 0.3 (n=2)
	DMW3	-13.8 ± 0.5 (n=9)	-118.2 ± 0.8 (n=9)	-1.2 (n=1)	7.8 (n=1)
	DMW4	-14.2 ± 0.4 (n=7)	-119.9 ± 0.9 (n=7)	-	-
	DMW5	-14.9 ± 0.5 (n=7)	-124.1 ± 1.8 (n=7)	19.7 ± 0.1 (n=2)	61.3 ± 0.1 (n=2)
	DMW6	-15.2 ± 0.2 (n=7)	-126.8 ± 0.9 (n=7)	-	-
	DMW10	-17.8 ± 0.2 (n=8)	-143.6 ± 0.9 (n=8)	-	-
	DMW11	-16.6 ± 0.2 (n=7)	-134.6 ± 1.1 (n=7)	10.6 ± 0.4 (n=2)	33.2 ± 0.1 (n=2)
	DMW12	-15.7 ± 0.3 (n=7)	-127.7 ± 0.5 (n=7)	13.0 ± 1.9 (n=2)	28.4 ± 2.1 (n=2)
	DMW13	-16.1 ± 0.6 (n=7)	-127.7 ± 3.4 (n=7)	5.8 ± 1.4 (n=2)	23.0 ± 0.1 (n=2)
	DMW14	-14.5 ± 0.6 (n=7)	-121.7 ± 2.4 (n=7)	-	-
	DMW15	-15.0 ± 0.2 (n=8)	-125.5 ± 1.1 (n=8)	-	-
	DMW16	-15.4 ± 0.3 (n=7)	-128.5 ± 1.2 (n=7)	-	-
	DP10-1	-18.0 ± 0.7 (n=9)	-145.8 ± 2.4 (n=9)	11.5 (n=1)	1.6 ± (n=1)
	DP10-2	-16.8 ± 0.3 (n=9)	-131.8 ± 2.6 (n=9)	3.6 ± 1.8 (n=2)	22.0 ± 3.2 (n=2)
	DP11-10b	-19.1 ± 0.3 (n=8)	-152.9 ± 0.7 (n=8)	-	-
	DP11-11b	-21.6 ± 0.3 (n=7)	-171.0 ± 0.8 (n=7)	-	-
	DP11-12b	-15.4 ± 0.5 (n=7)	-126.0 ± 1.3 (n=7)	18.8 ± 2.5 (n=2)	39.7 ± 5.4 (n=2)
	DP11-13b	-18.3 ± 0.2 (n=7)	-146.7 ± 1.2 (n=7)	-	-
	DP11-14b	-21.1 ± 0.4 (n=9)	-165.7 ± 2.2 (n=9)	-	-
	DP11-15b	-22.2 ± 0.3 (n=8)	-174.0 ± 1.0 (n=8)	-	-
	DP11-16b	-20.8 ± 0.4 (n=7)	-163.6 ± 0.7 (n=7)	-	-
	EMS filtrate			13.1 ± 6.5 (n=4)	2.6 ± 2.1 (n=4)
	DP11-13_4m			9.8	30.3
	DP11-13_5m			10.8	31.0
	DP11-13_6m			5.2	24.5
	DP11-13_7m			10.2	31.6
	DP11-13 _8m			14.0	36.4
	DP11-13_9m			9.9	29.6
	C15-20_3m	-116.0	-12.8	9.7	-0.9
	C15-20_8m	-117.2	-13.9	-1.2	-5.2
	C15-20_13m	-118.4	-13.8	16.0	1.3
	C15-21_2m	-116.1	-13.5	3.6	23.3
	C15-21_8m	-113.0	-12.8	-4.9	6.2
	C15-22_2m	-130.0	-16.1	4.7	22.2
	C15-22_4m	-128.3	-15.2	2.8	21.6
	C15-22_5m	-134.3	-16.8	3.9	15.7
	C15-22_6.5m	-134.0	-16.4	16.8	30.8
	C15-22_8m	-135.3	-17.5	5.6	21.1
	C15-22_10m	-132.6	-16.9	7.4	26.1
	C15-22_12m	-133.2	-17.0	3.3	18.5
	C15-23_2m	-134.7	-16.8	1.7	22.1
	C15-23_5m	-137.6	-17.8	5.9	15.6
	C15-23_7m	-132.5	-16.2	4.6	14.8
	C15-23_8m	-132.3	-16.6	1.46	14.3
	C15-23_9m	-132.7	-16.3	4.9	16.7
	C15-23_11m	-131.8	-15.9	1.3	13.7
	C15-23_13m	-139.4	-16.2	15.7	15.6

† For all continuous core samples n=1. *central depth of core samples, x, indicated as SampleID_xm

Table S9. Stable isotope values of water and nitrate at CFO4

Site	Well ID	$\delta^{18}O_{H2O}$	$\delta^{2}H_{H2O}$	$\delta^{18}O_{NO3}$	$\delta^{15}N_{NO3}$
CFO4†	BC1	-16.7	-142.3	29.5	0.3
	BC2	-18.6	-138.6	15.8	9.4
	BC3	-17.5	-144.6	31.6	5.0
	BC4	-18.5	-148.8	1.6	30.6
	BC5	-18.5	-137.6	-1.9	12.6
	BMW1	-17.6	-144.1	-	-
	BMW2	-17.4	-136.5	8.3	41.6
	BMW3	-	-	2.1	22.8
	BMW4	-18.0	-145.6	-0.3	22.2
	BMW5	-18.0	-137.5	6.5	28.9
	BMW6	-18.9	-152.4	22.1	70.5
	BMW7	-	-	5.9	34.0
	BP10-15e	-18.1	-146.5	18.3	16.4
	BP10-15w	-	-	18.9	-1.3
	BP5-15	-17.7	-137.3	-	-
	BP6-15	-17.9	-145.1	-	-

† For all samples at CFO4 n=1.

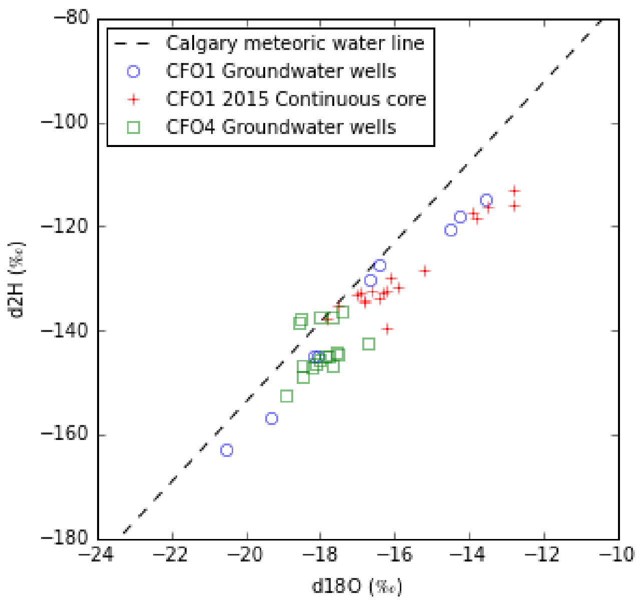

Figure S4. Cross-plot of stable isotopic values of groundwater wells at CFO1 and CFO4 and continuous core samples collected at CFO1 during 2015, relative to the Calgary meteoric water line ($\delta^{2}H = 7.68\ \delta^{18}O_{H2O} - 0.21$).

Table S10 Constraining values and results of mixing model calculations

Sample ID	Cl	NO_3-N	f_d	NO_3-N_i/Cl_i	Cl_i (mg L^{-1})		NO_3-N_i (mg L^{-1})		f_m	
	(mg L^{-1})	(mg L^{-1})	(mean ± stdev)	(mean ± stdev)	min	max	min	max	min	max
CFO1										
DMW11	436.1	17.1	0.17 ± 0.07	0.23 ± 0.10	436	667	98	150	0.65	1
DMW12	78.0	2.6	0.23 ± 0.10	0.14 ± 0.06	78	1047	11	150	0.07	1
DMW13	56.7	23.7	0.56 ± 0.22	0.75 ± 0.29	57	189	42	141	0.30	1
DP10-2	74.5	11.8	0.52 ± 0.22	0.30 ± 0.13	74	277	23	84	0.27	1
DP11-12b	95.7	0.6	0.15 ± 0.08	0.04 ± 0.02	96	1300	4.2	90	0.07	1
DC15-22_10m	73.0	11.0	0.47 ± 0.21	0.32 ± 0.14	73	289	23	93	0.25	1
DP11-13_4.3m	28.5	7.0	0.30 ± 0.15	0.82 ± 0.41	29	184	23	150	0.15	1
DP11-13_5.2m	25.0	7.8	0.34 ± 0.13	0.91 ± 0.35	25	160	23	146	0.16	1
DP11-13_7m	72.3	12.0	0.27 ± 0.13	0.62 ± 0.30	72	244	45	150	0.30	1
DP11-13 _7.9m	70.8	9.1	0.17 ± 0.09	0.76 ± 0.40	71	199	54	150	0.36	1
DP11-13_8.8m	81.7	11.0	0.32 ± 0.15	0.89 ± 0.42	82	323	39	150	0.25	1
CFO4										
BC4	163.1	35.1	0.37 ± 0.13	0.58 ± 0.20	163	258	95	150	0.63	1
BMW2	595.6	16.5	0.13 ± 0.06	0.21 ± 0.10	596	707	127	150	0.84	1
BMW5	131.2	12.9	0.34 ± 0.16	0.29 ± 0.14	131	520	38	150	0.25	1
BMW6	156.0	0.4	0.01 ± 0.01	0.26 ± 0.26	156	1300	0.4	150	0.12	1
BMW7	134.7	11.6	0.21 ± 0.11	0.41 ± 0.22	135	365	55	150	0.37	1

References

Lis, G., Wassenaar, L. I., and Hendry, M. J.: High-precision laser spectroscopy D/H and $^{18}O/^{16}O$ measurements of microliter natural water samples, Anal. Chem., 80, 287-293, 10.1021/ac701716q, 2008.

Peng, H., Mayer, B., Harris, S., and Roy Krouse, H.: A 10-yr record of stable isotope ratios of hydrogen and oxygen in precipitation at Calgary, Alberta, Canada, Tellus B, 56, 147-159, 2004.

Wassenaar, L. I., Hendry, M. J., Chostner, V. L., and Lis, G. P.: High resolution pore water δ^2H and $\delta^{18}O$ measurements by H_2O(liquid)−H_2O(vapor) equilibration laser spectroscopy, Environ. Sci. Technol., 42, 9262-9267, 10.1021/es802065s, 2008.