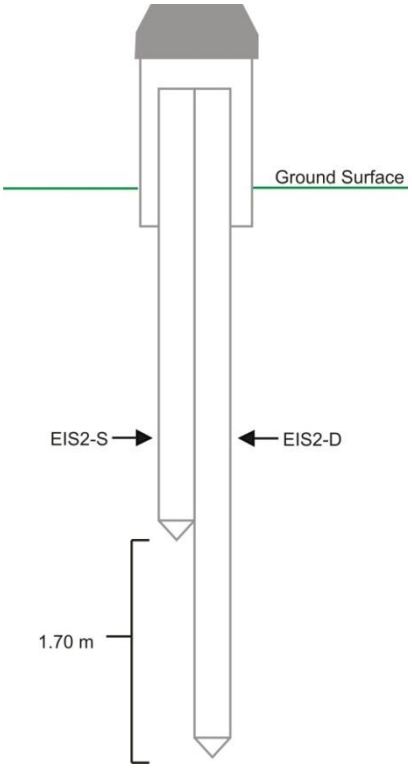
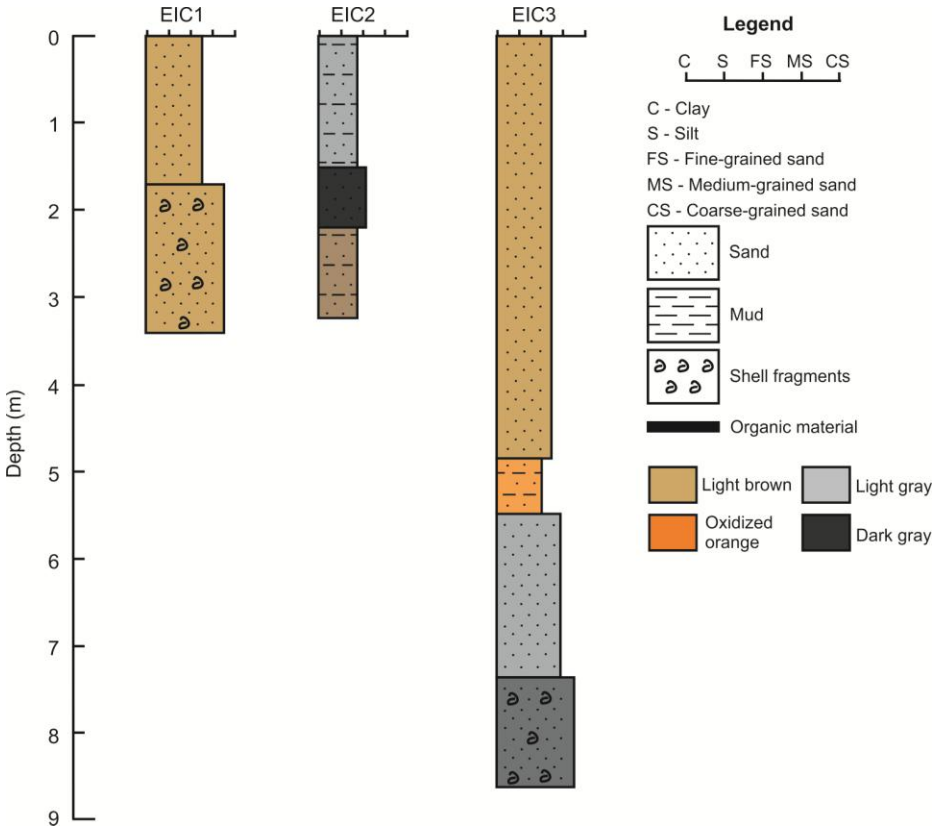
APPENDIX A: ADDITIONAL FIELD WORK



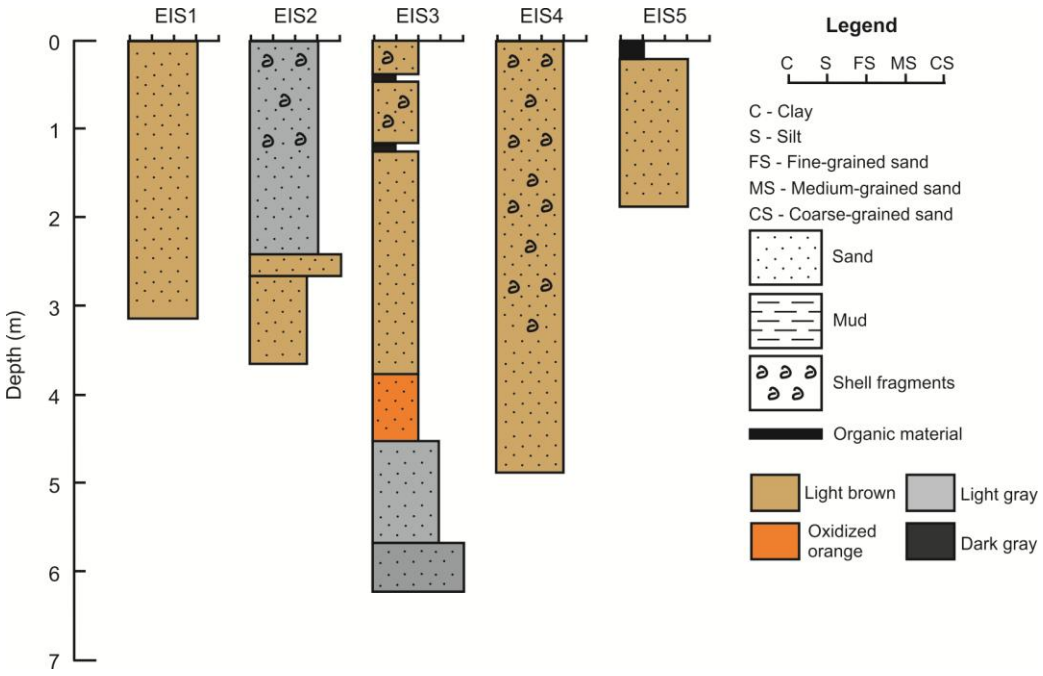
Nested piezometer design utilized on Emerald Isle.

Summary of soil descriptions from core analyses.

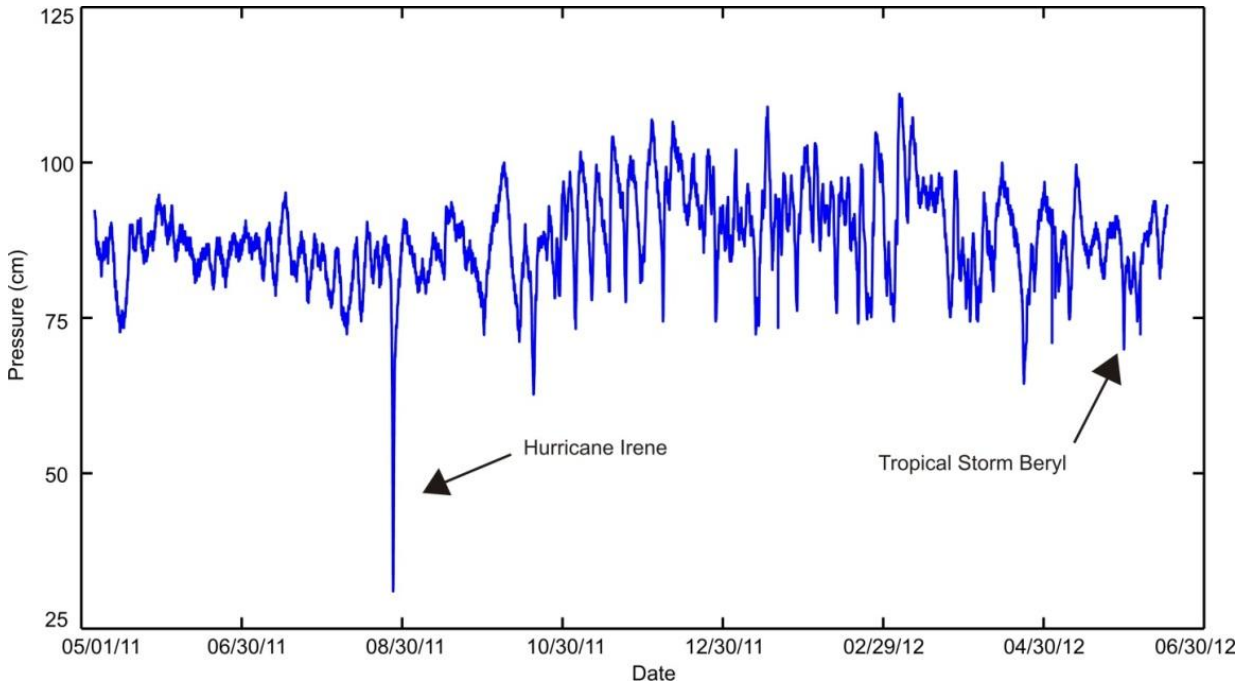
Well ID	Soil Description	Topographic Setting
EIC1	Fine sand with very little organic matter	Ridge/slope
EIC2	Fine to medium sand with very little organic matter	Swale
EIC3	Fine sand	Ridge/slope
EIN1	Medium sand	Ridge/slope
EIN2	Fine sand	Swale
EIN3	Fine to medium sand with a 3-4" organic matter horizon	Swale
EIN4	Organic matter horizon 2-3", clay horizon, medium sand	Ridge/slope
EIN5	Fine sand	Ridge/slope
EIN6	Fine to medium sand	Swale
EIS1	Medium sand	Ridge/slope
EIS2D	Fine to medium sand with a 2" organic matter horizon	Swale
EIS2S	Fine to medium sand with a 2" organic matter horizon	Swale
EIS3	Fine to medium sand with very little organic matter	Ridge/slope
EIS4	Fine to medium sand	Ridge/slope
EIS5	Medium sand with a 2" organic matter horizon	Ridge/slope



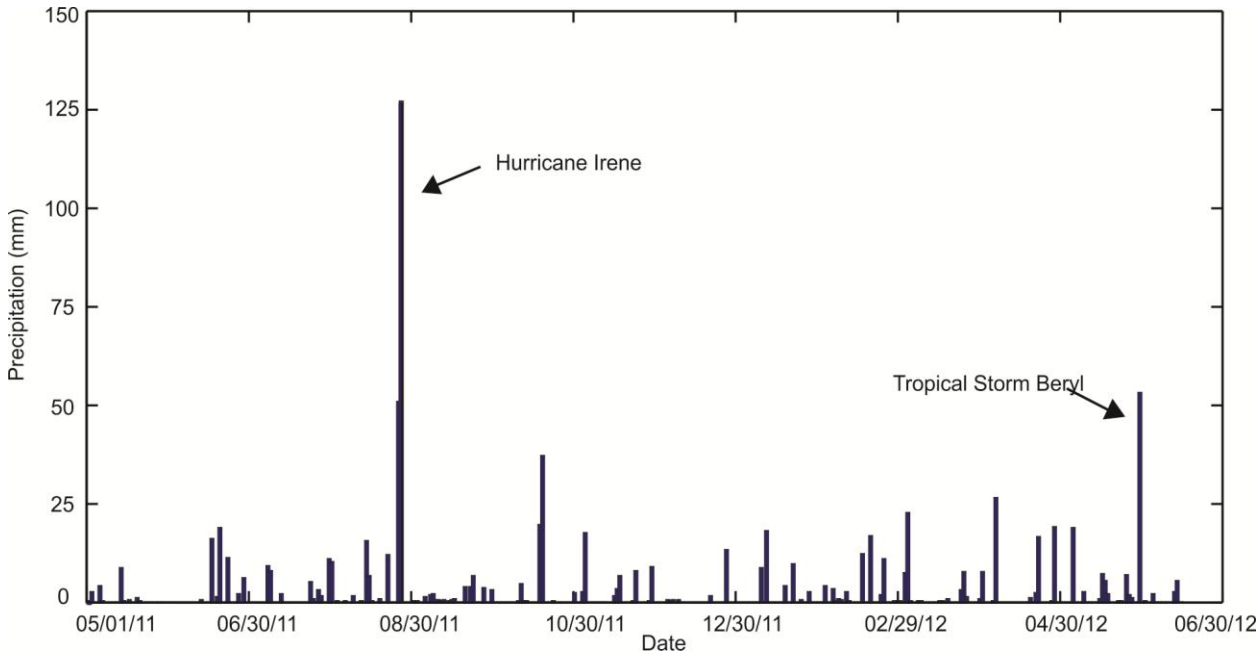
Core logs from the central transect of wells.



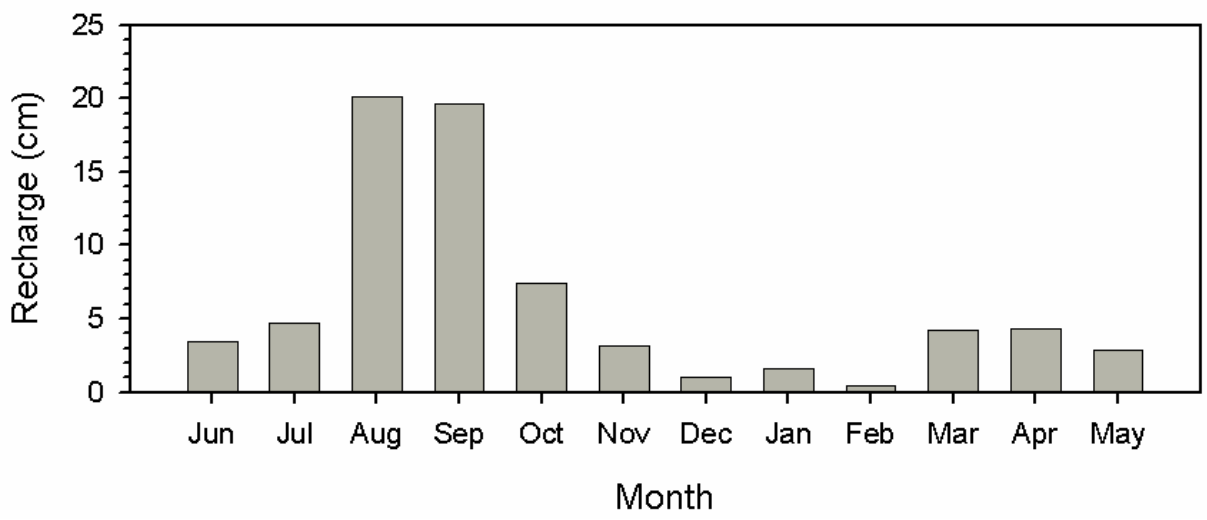
Core logs from the southern transect of wells.



Pressure data on Emerald Isle, NC during the monitoring period.

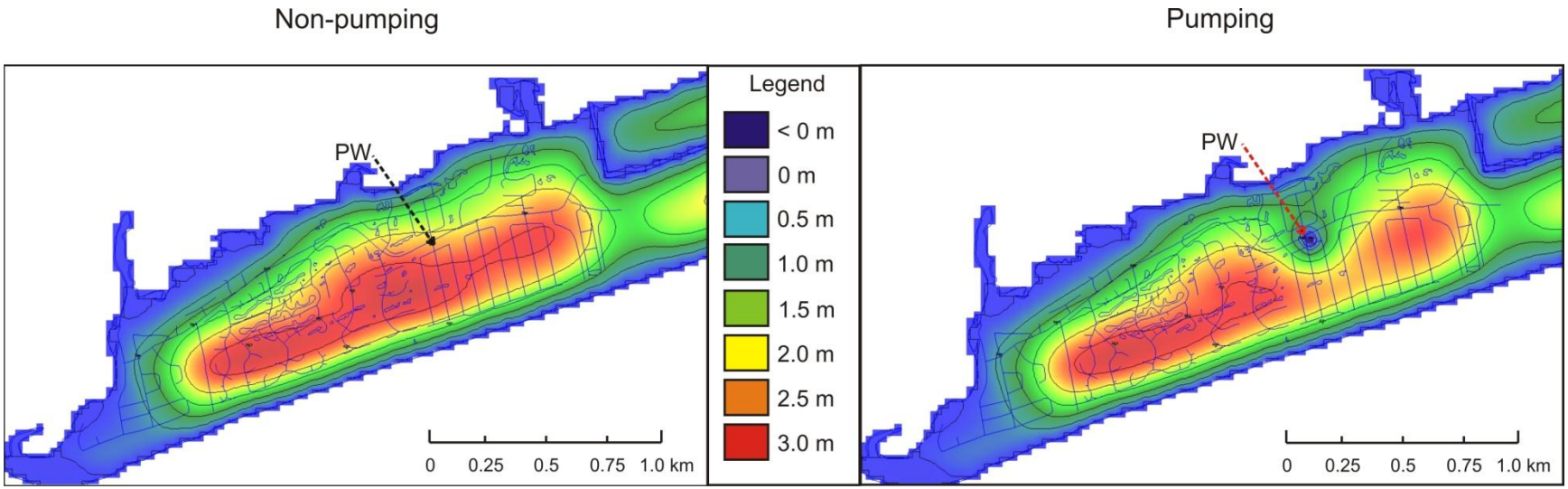


Precipitation data on Emerald Isle, NC during the monitoring period.

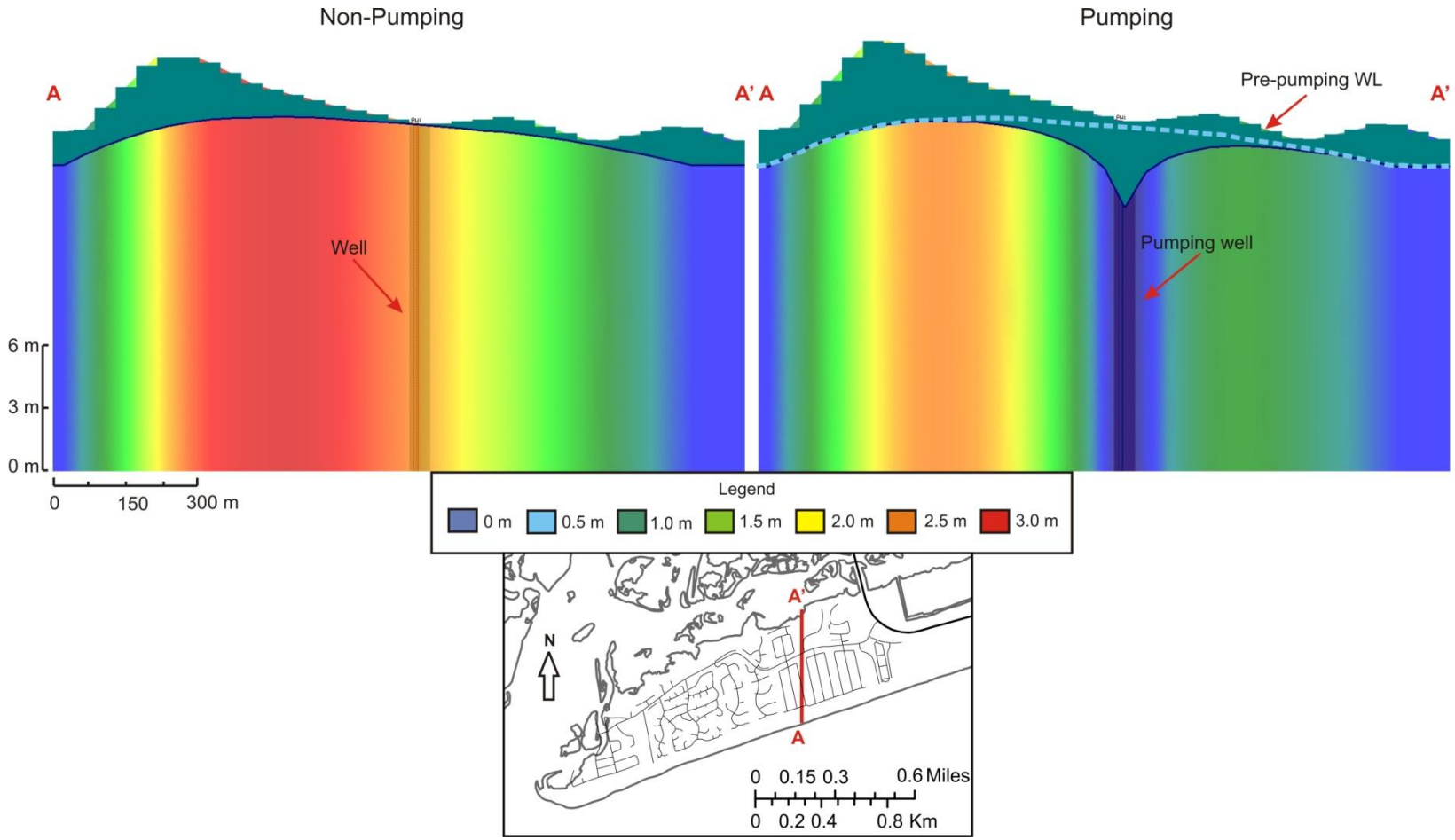


Monthly recharge estimates from June 2011 through May 2012.

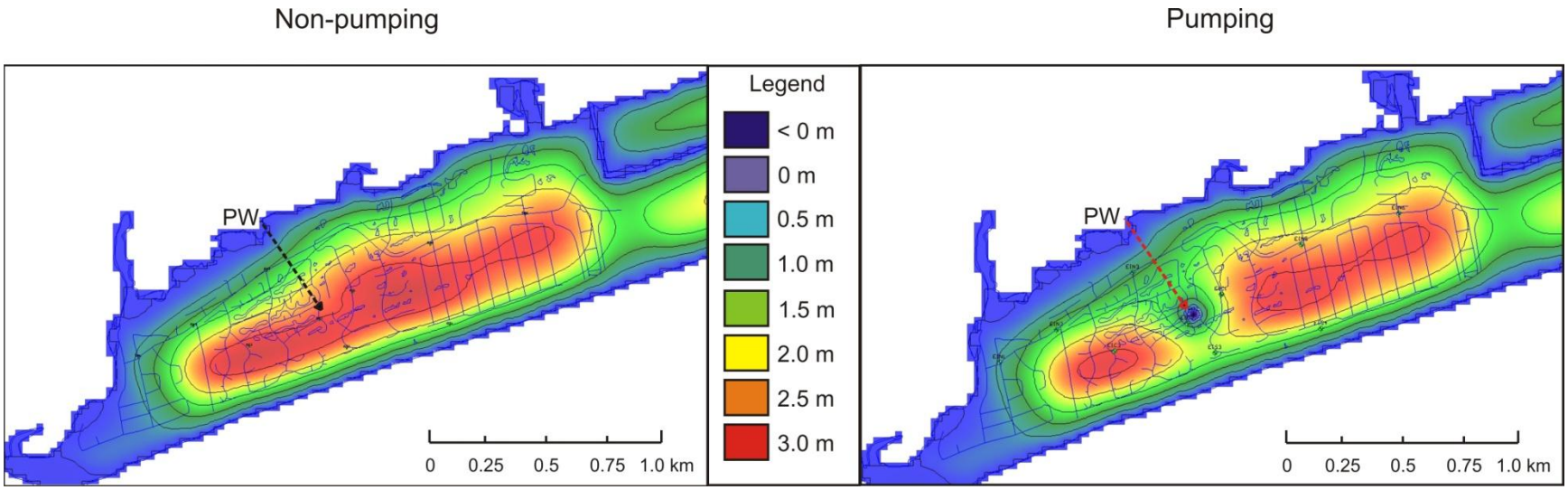
APPENDIX B: MODFLOW PUMPING SIMULATIONS



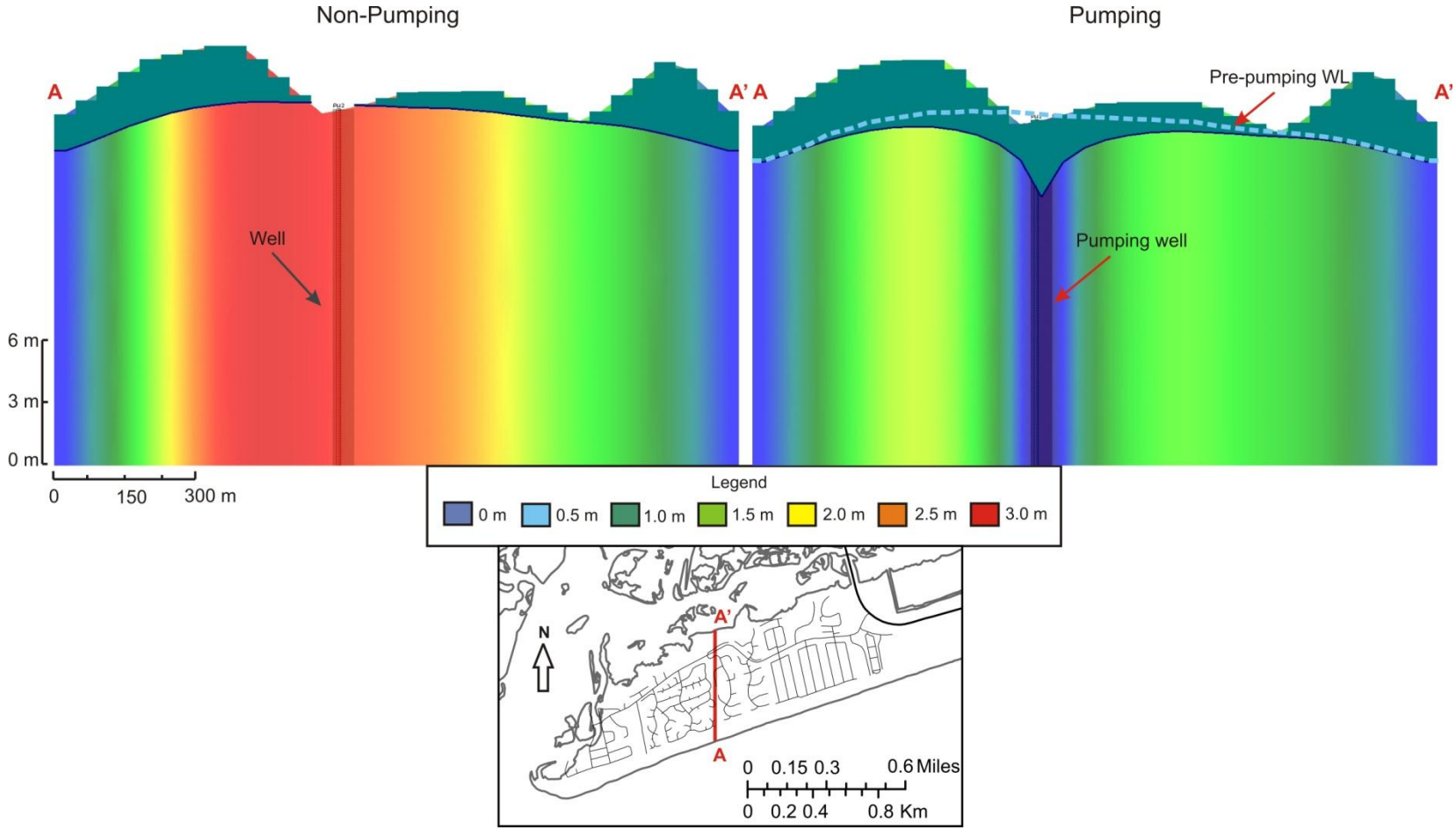
Map view simulating pumping well at location 1 (PW1). Values on the map represent the elevation of the water table. PW = pumping well.



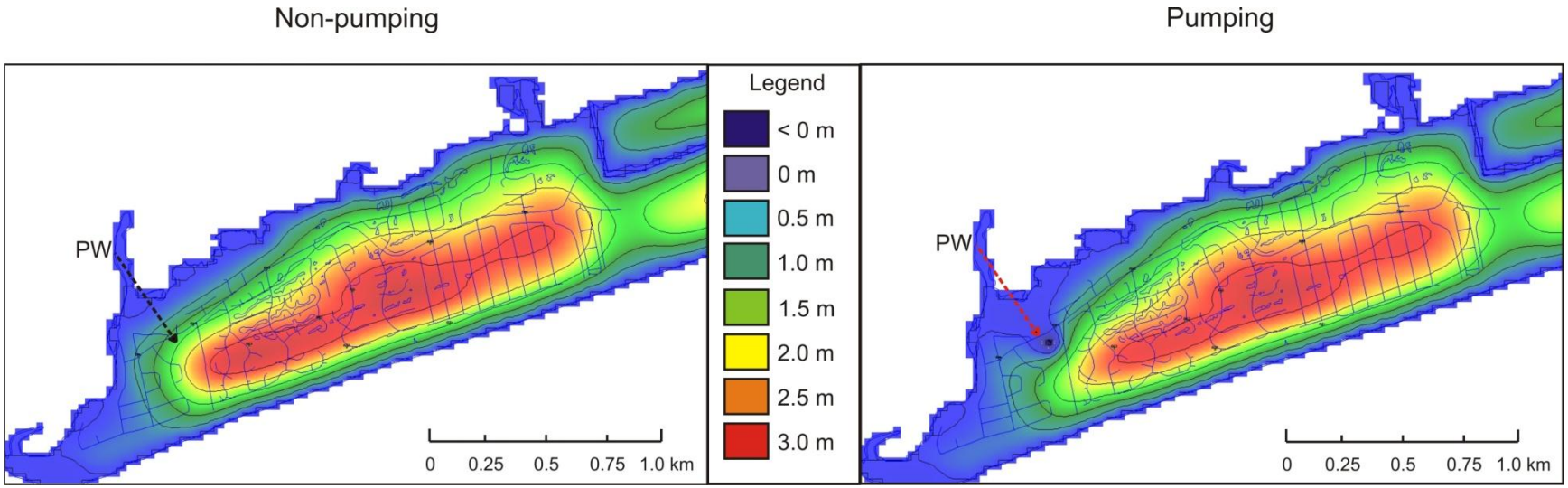
Cross-sections of transect A-A' for PW1with non-pumping and pumping scenarios' effect on the water table. Inset: Cross section location. WL = water level.



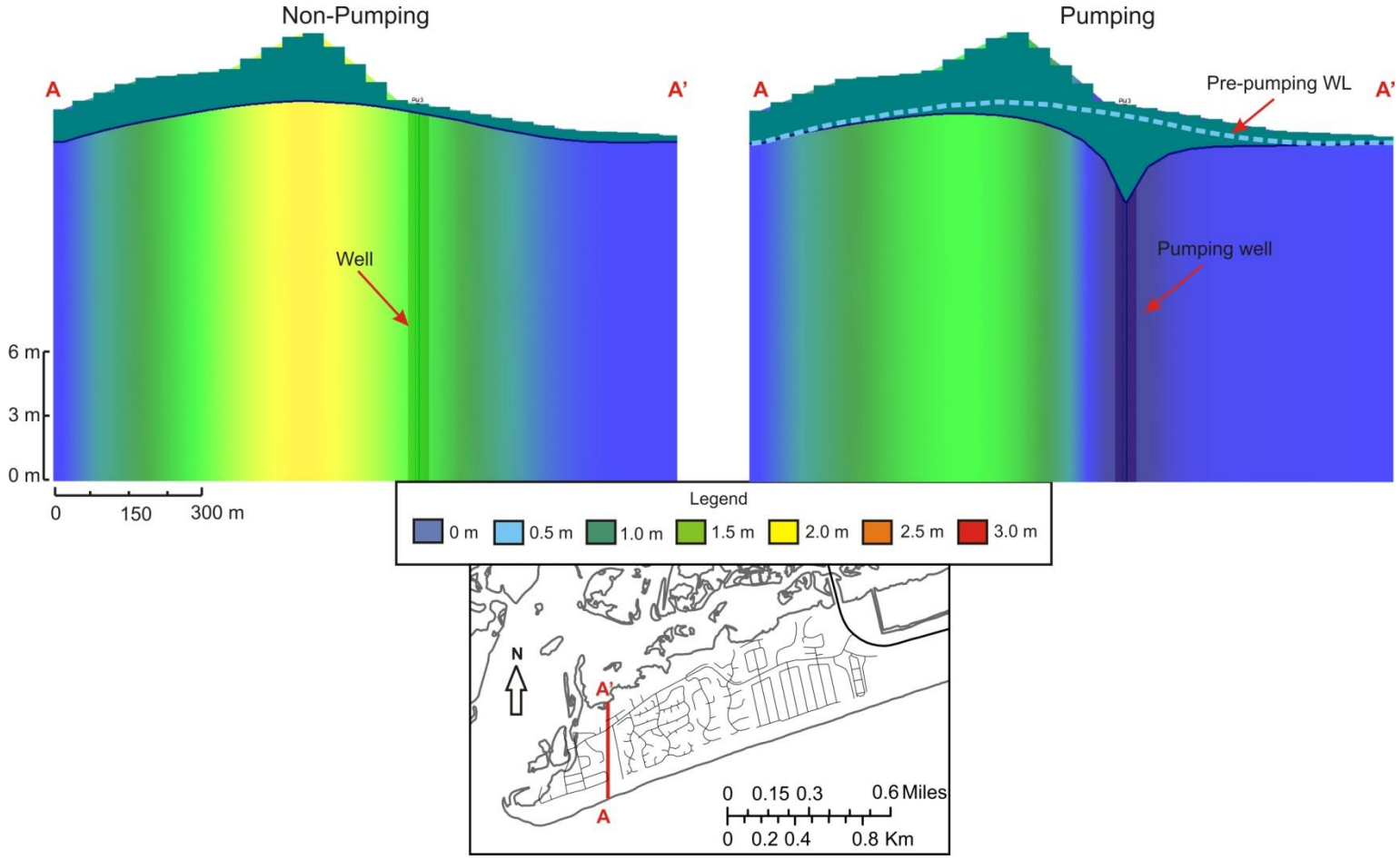
Map view simulating pumping well at location 2 (PW2). Values on the map represent the elevation of the water table. PW = Pumping well.



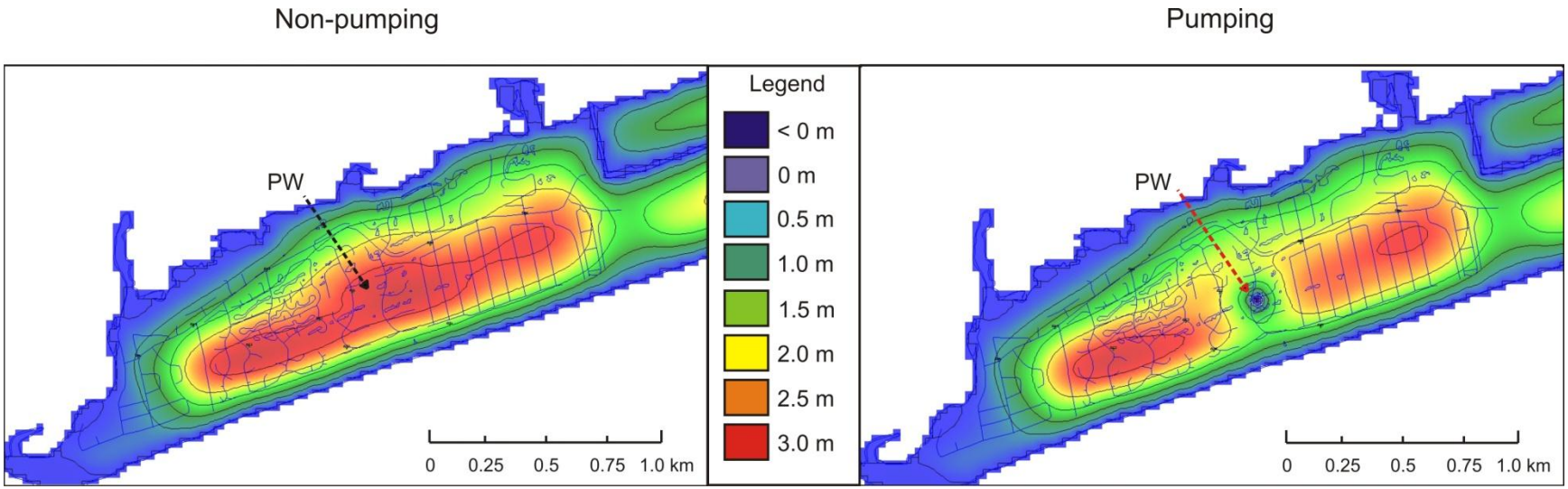
Cross-sections of transect A-A' for PW2 with non-pumping and pumping scenarios' effect on the water table. Inset: Cross section location. WL = water level.



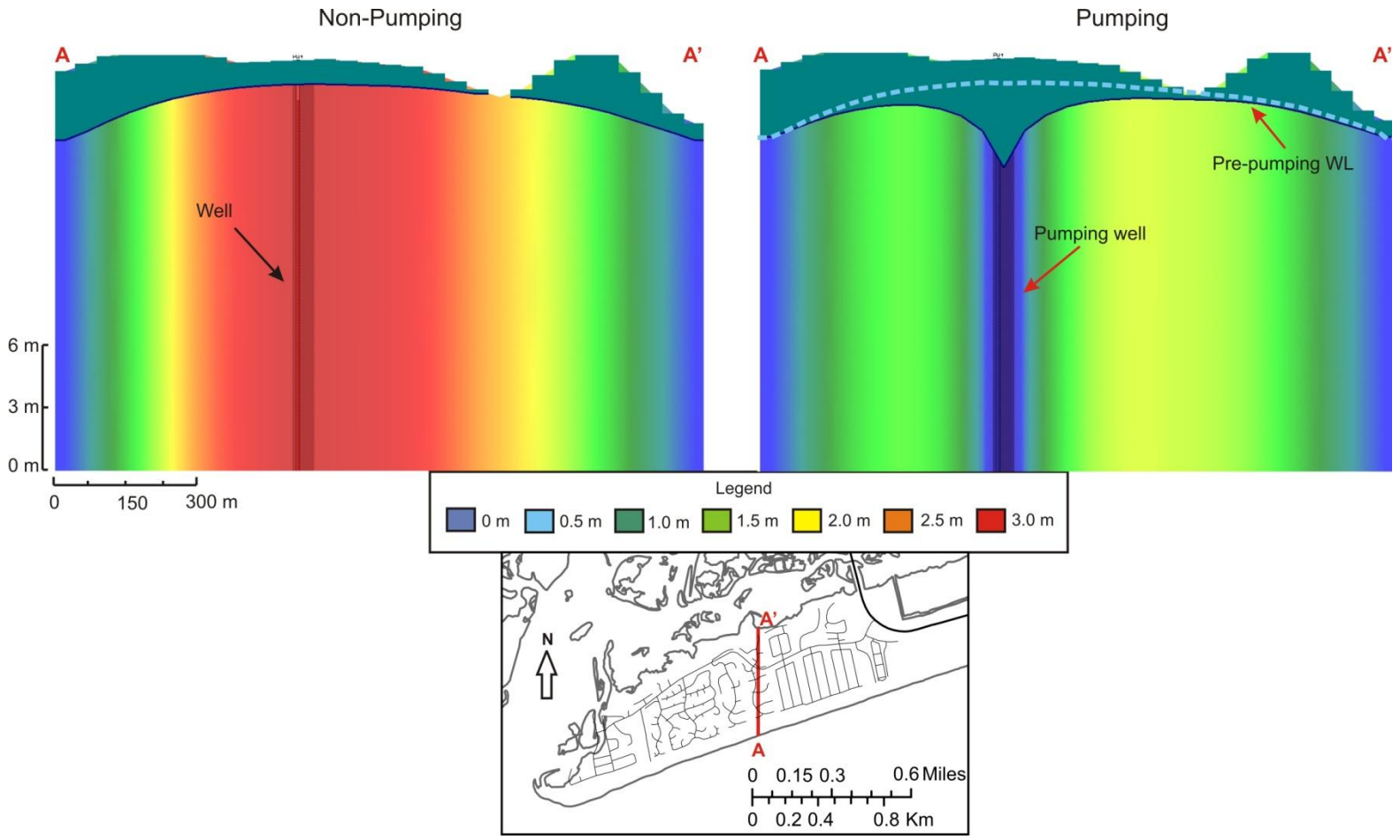
Map view simulating pumping well at location 3 (PW3). Values on the map represent the elevation of the water table. PW = pumping well.



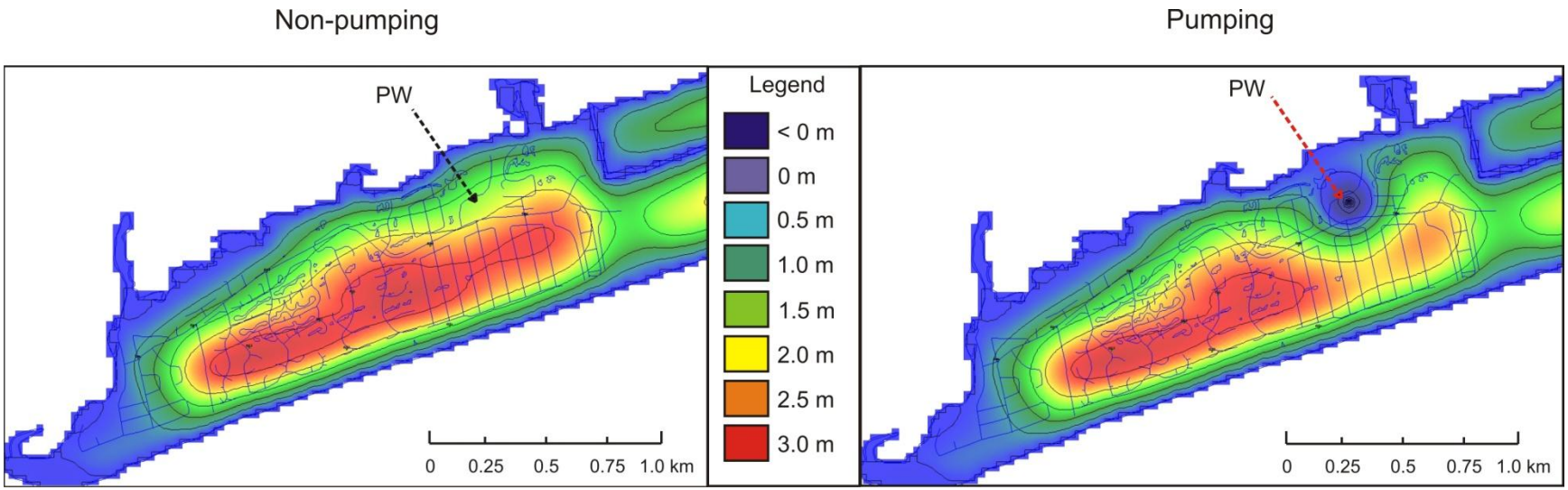
Cross-sections of transect A-A’ for PW3 with non-pumping and pumping scenarios’ effect on the water table. Inset: Cross section location. WL = water level.



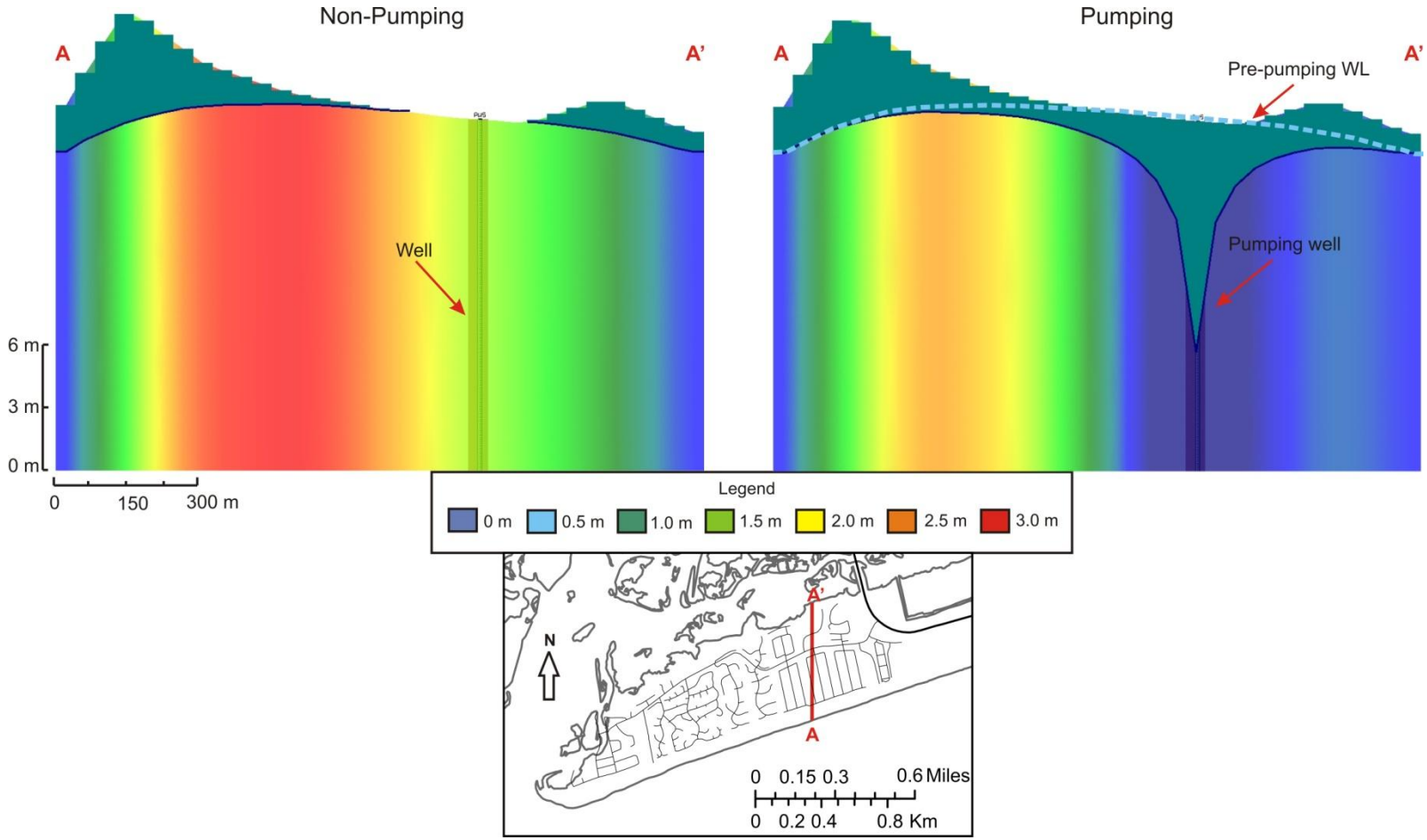
Map view simulating pumping well at location 4 (PW4). Values on the map represent the elevation of the water table. PW = pumping well.



Cross-sections of transect A-A’ for PW4 with non-pumping and pumping scenarios’ effect on the water table. Inset: Cross section location. WL = water level.



Map view simulating pumping well at location 5 (PW5). Values on the map represent the elevation of the water table. PW = pumping well.



Cross-sections of transect A-A' for PW5 with non-pumping and pumping scenarios' effect on the water table. Inset: Cross section

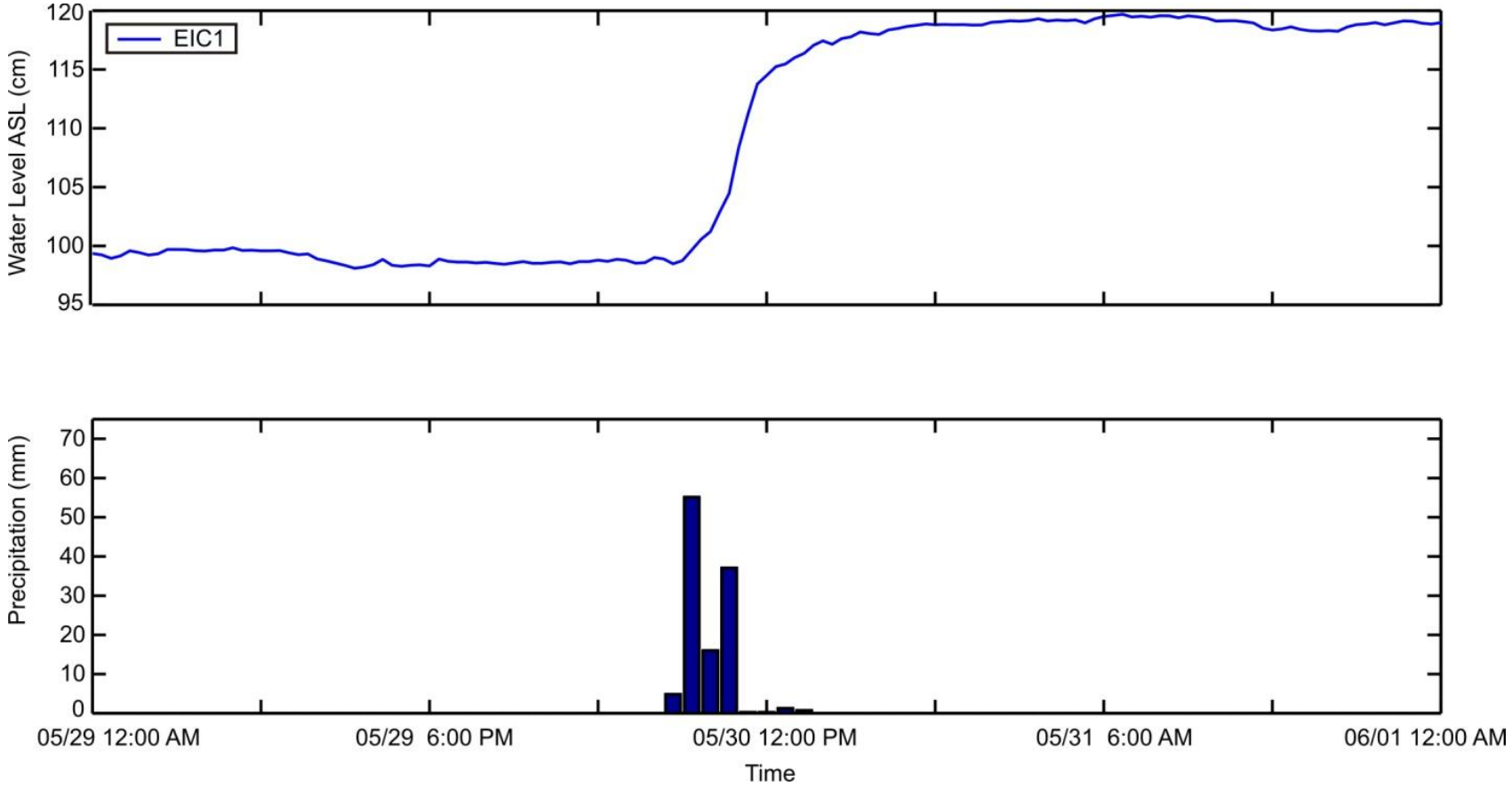
APPENDIX C: GROUNDWATER RESPONSE TIME PLOTS

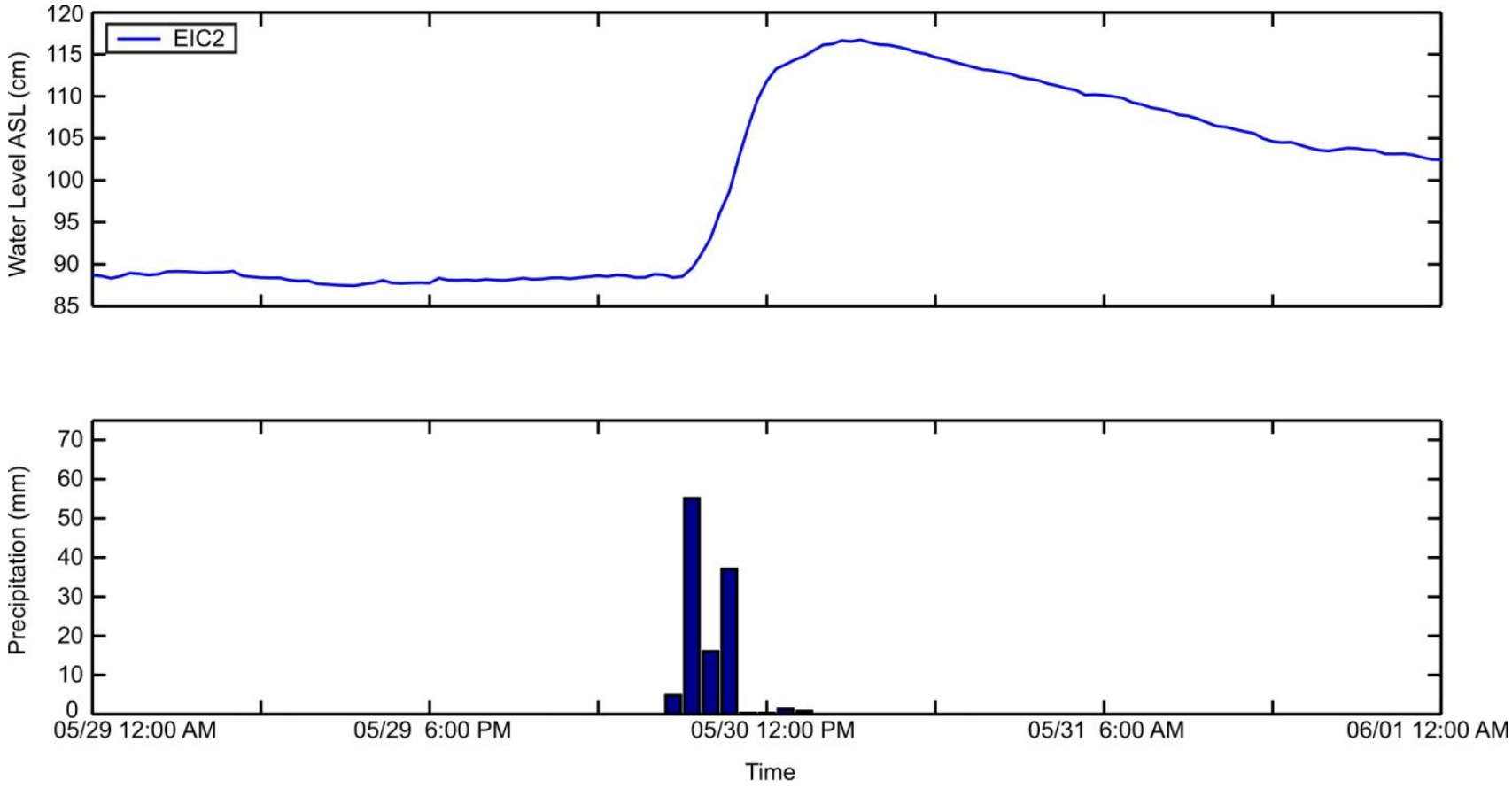
This appendix is composed of the response plots for each water level logger used in the study. These plots encompass the data from Table 6. The plots of each well are accompanied by the daily precipitation bar graph.

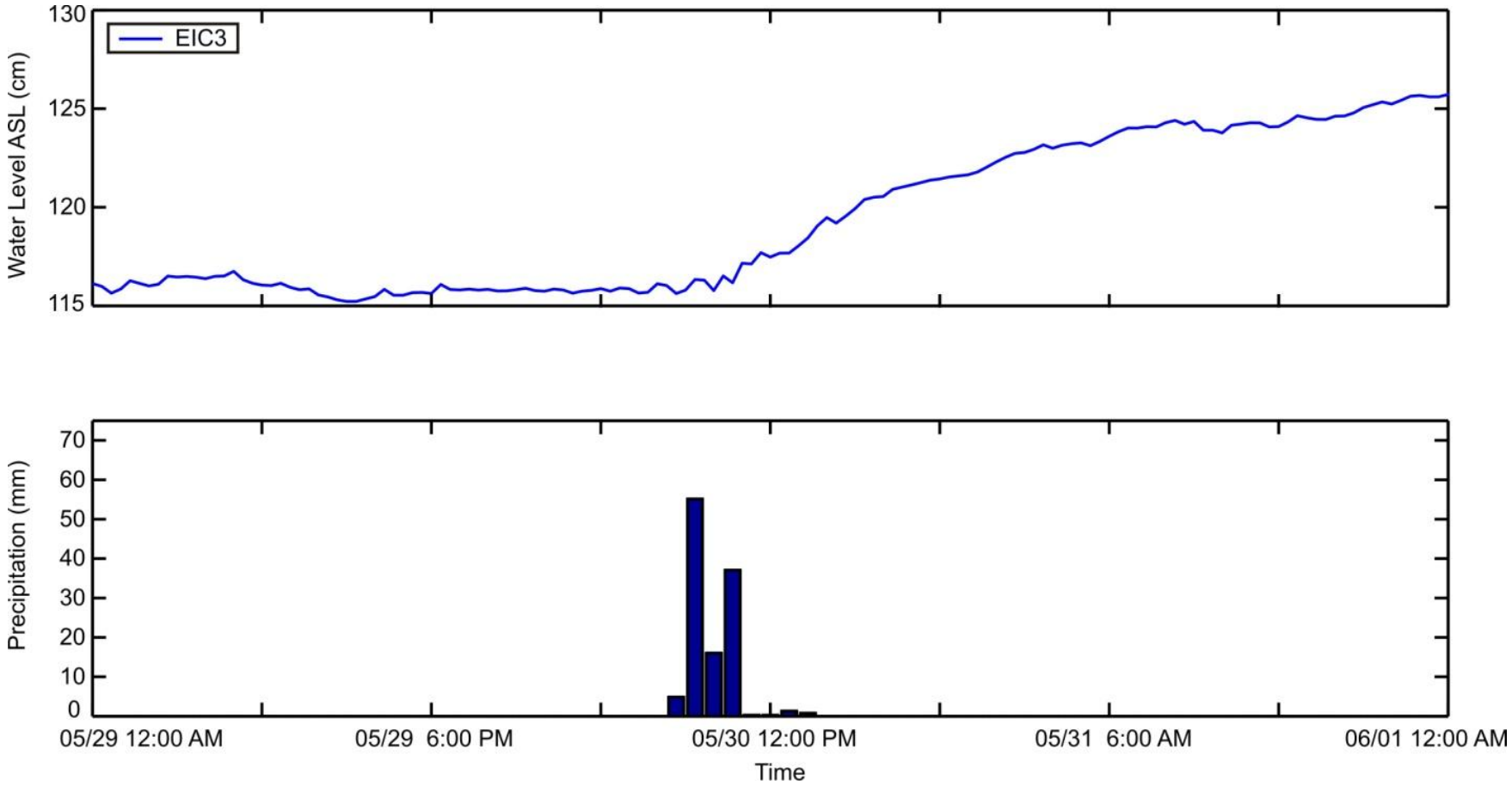
Explanation:

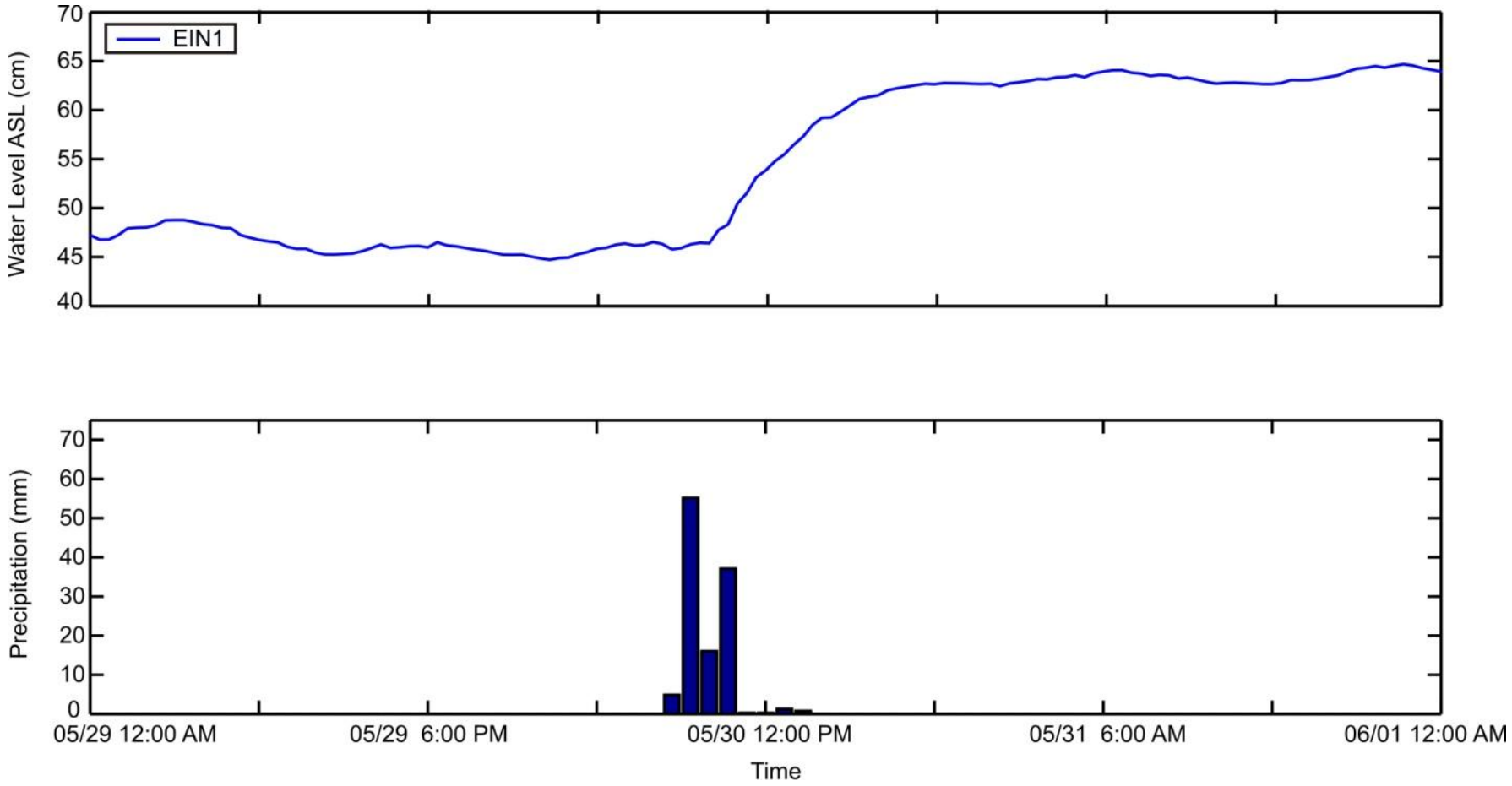
Blue Line = groundwater level

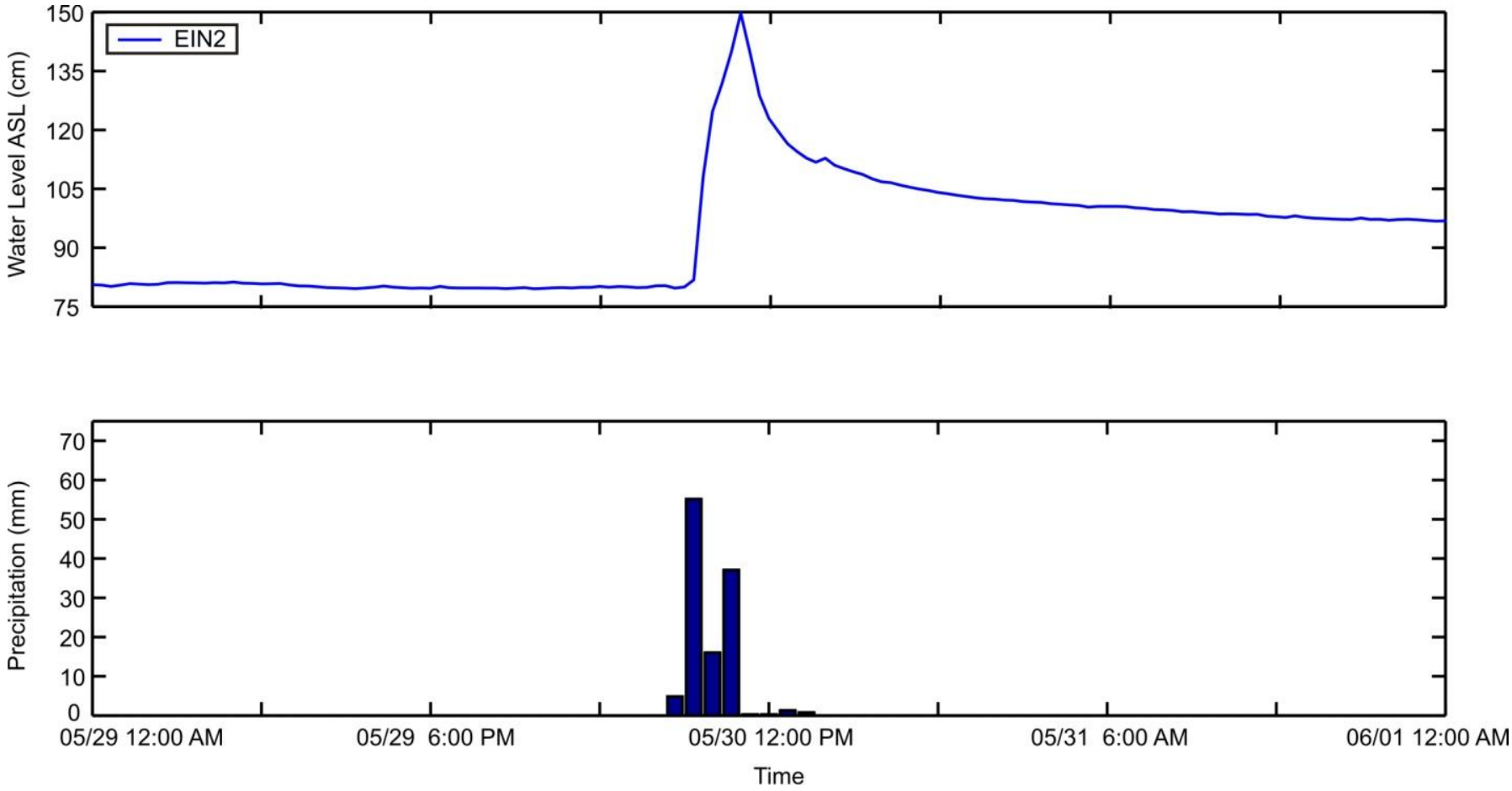
Blue Bar = daily precipitation amount

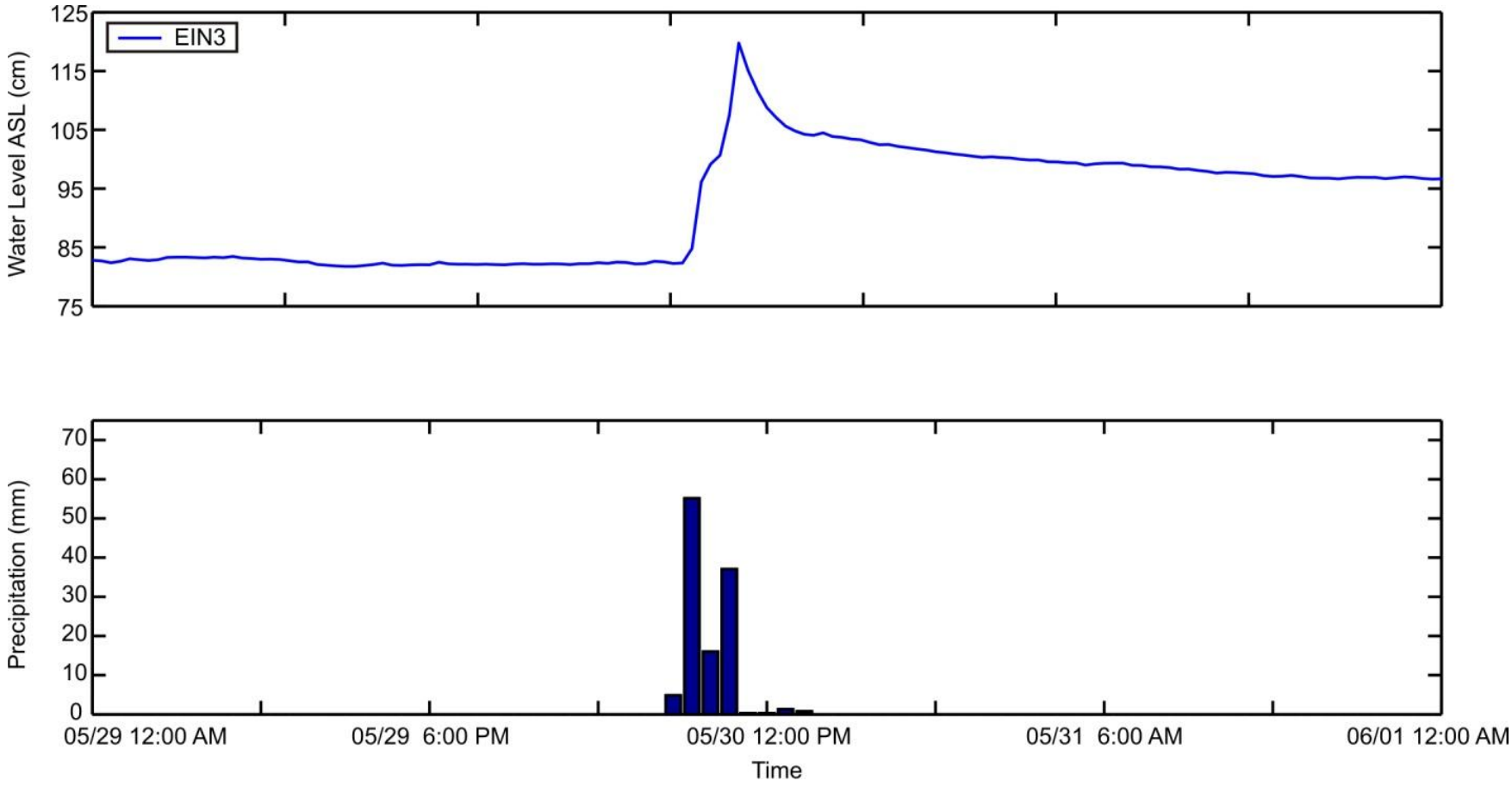

EIC1
Water Level ASL (cm)
120
115
110
105
100
95
Precipitation (mm)
70
60
50
40
30
20
10
0
05/29 12:00 AM
05/29 6:00 PM
05/30 12:00 PM
05/31 6:00 AM
06/01 12:00 AM
Time

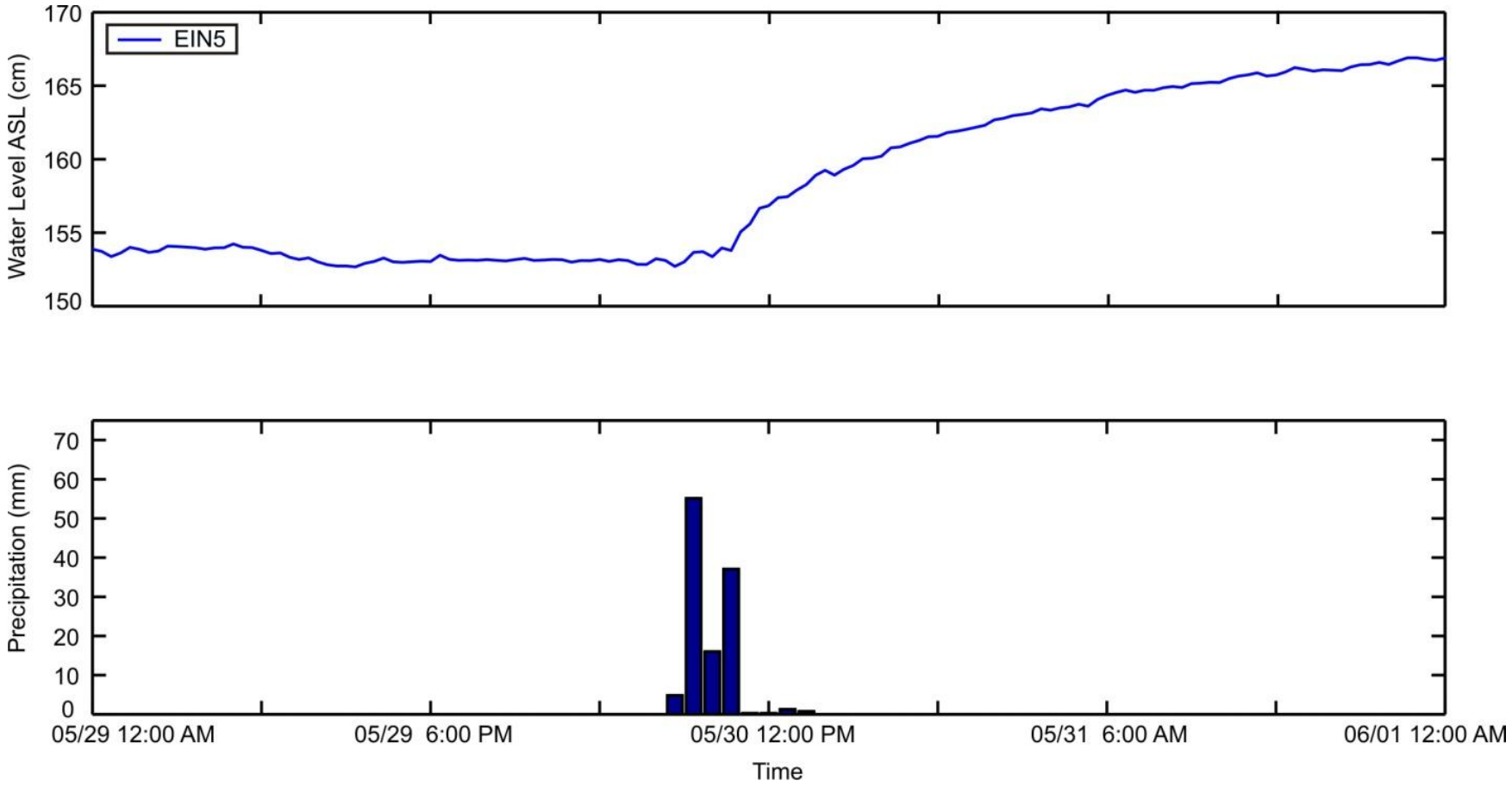

EIC2
Water Level ASL (cm)
120
115
110
105
100
95
90
85
Precipitation (mm)
70
60
50
40
30
20
10
0
05/29 12:00 AM
05/29 6:00 PM
05/30 12:00 PM
05/31 6:00 AM
06/01 12:00 AM
Time

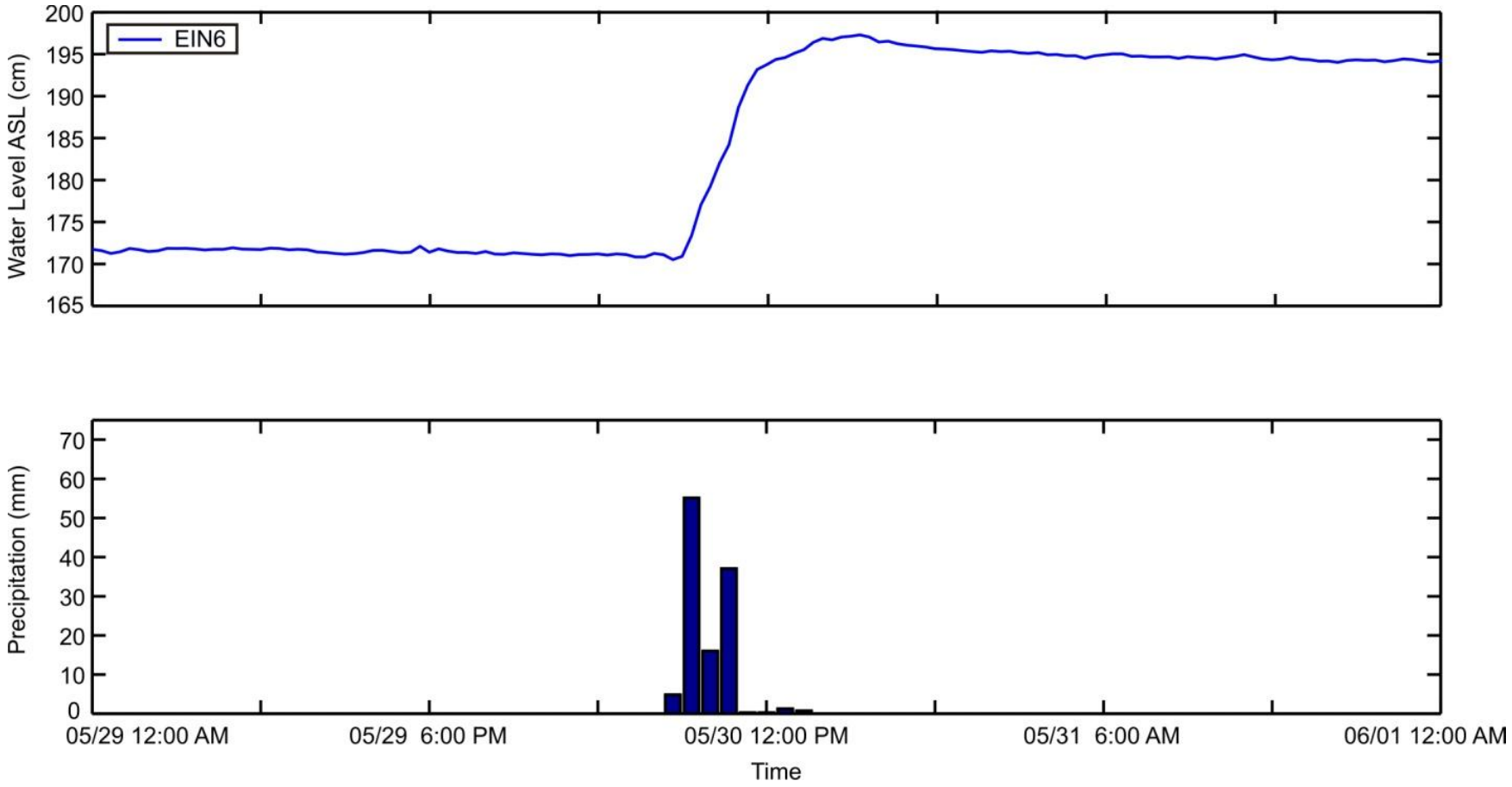

EIC3
Water Level ASL (cm)
130
125
120
115
Precipitation (mm)
70
60
50
40
30
20
10
0
05/29 12:00 AM
05/29 6:00 PM
05/30 12:00 PM
05/31 6:00 AM
06/01 12:00 AM
Time

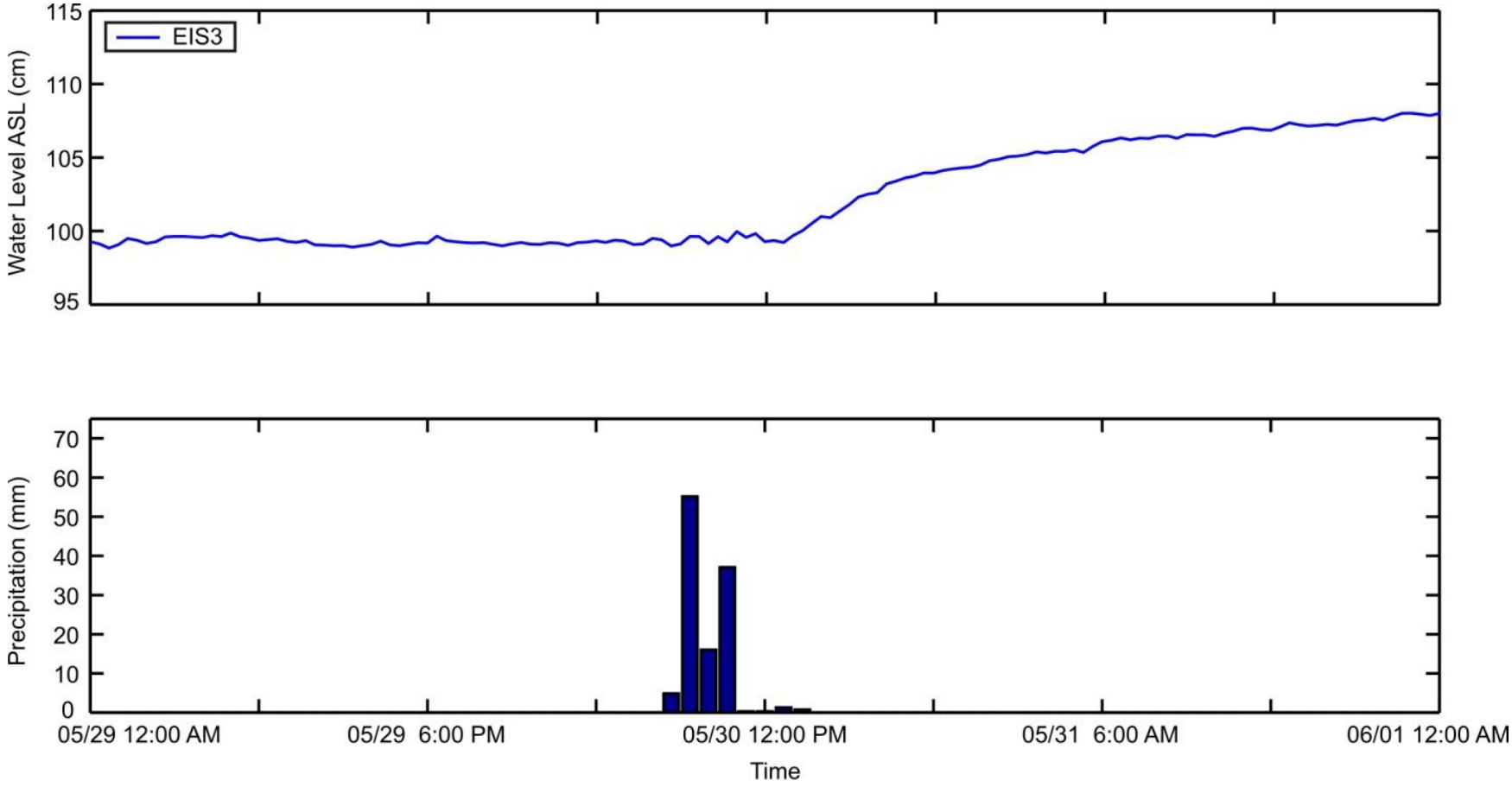

EIN1
Water Level ASL (cm)
70
65
60
55
50
45
40
Precipitation (mm)
70
60
50
40
30
20
10
0
05/29 12:00 AM
05/29 6:00 PM
05/30 12:00 PM
05/31 6:00 AM
06/01 12:00 AM
Time

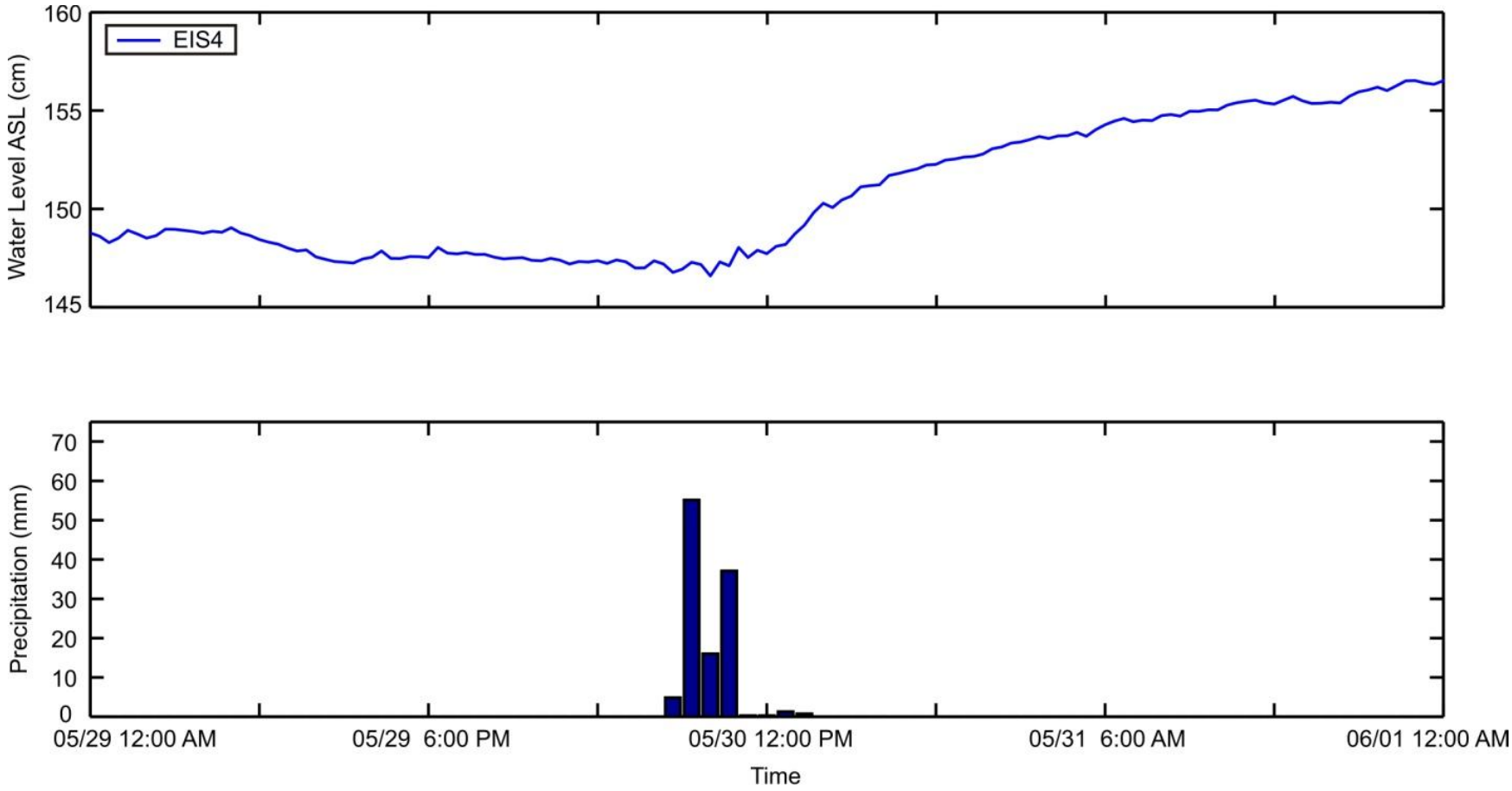

EIN2
Water Level ASL (cm)
150
135
120
105
90
75
Precipitation (mm)
70
60
50
40
30
20
10
0
05/29 12:00 AM
05/29 6:00 PM
05/30 12:00 PM
05/31 6:00 AM
06/01 12:00 AM
Time


EIN3
Water Level ASL (cm)
125
115
105
95
85
75
Precipitation (mm)
70
60
50
40
30
20
10
0
05/29 12:00 AM
05/29 6:00 PM
05/30 12:00 PM
05/31 6:00 AM
06/01 12:00 AM
Time


EIN5
Water Level ASL (cm)
170
165
160
155
150
Precipitation (mm)
70
60
50
40
30
20
10
0
05/29 12:00 AM
05/29 6:00 PM
05/30 12:00 PM
05/31 6:00 AM
06/01 12:00 AM
Time


EIN6
Water Level ASL (cm)
200
195
190
185
180
175
170
165
Precipitation (mm)
70
60
50
40
30
20
10
0
05/29 12:00 AM
05/29 6:00 PM
05/30 12:00 PM
05/31 6:00 AM
06/01 12:00 AM
Time


EIS3
Water Level ASL (cm)
115
110
105
100
95
Precipitation (mm)
70
60
50
40
30
20
10
0
05/29 12:00 AM
05/29 6:00 PM
05/30 12:00 PM
05/31 6:00 AM
06/01 12:00 AM
Time


EIS4
Water Level ASL (cm)
160
155
150
145
Precipitation (mm)
70
60
50
40
30
20
10
0
05/29 12:00 AM
05/29 6:00 PM
05/30 12:00 PM
05/31 6:00 AM
06/01 12:00 AM
Time

APPENDIX D: MODFLOW CALIBRATION PLOTS

This appendix is composed of the calibration plots for each run in the Visual MODFLOW modeling process. The data plotted are observed head values for the study period against calculated head values the model predicts.

a) Run #1 with all wells included.

b) Run #1 without wells EIC1, EIC2, and EIC3.

c) Run #2 with all wells included.

d) Run #2 without wells EIC1, EIC2, and EIC3.

e) Run #3 with all wells included.\

f) Run #3 without wells EIC1, EIC2, and EIC3.

g) Run #4 with all wells included.

h) Run #4 without wells EIC1, EIC2, and EIC3.

i) Run #5 with all wells included.

j) Run #5 without wells EIC1, EIC2, and EIC3.

k) Run #6 with all wells included.

l) Run #6 without wells EIC1, EIC2, and EIC3.

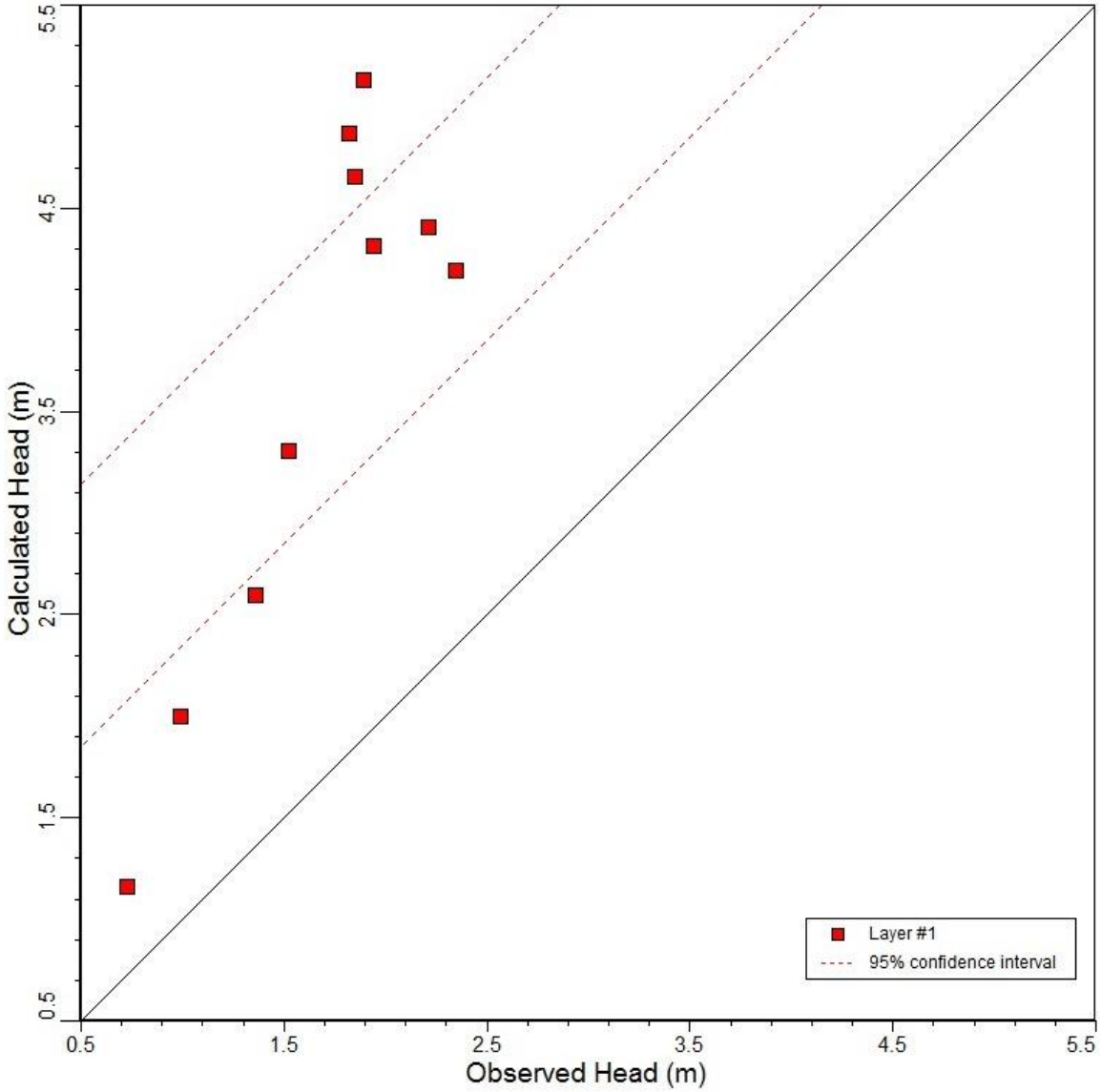
m) Run #7 with all wells included.

n) Run #7 without wells EIC1, EIC2, and EIC3.

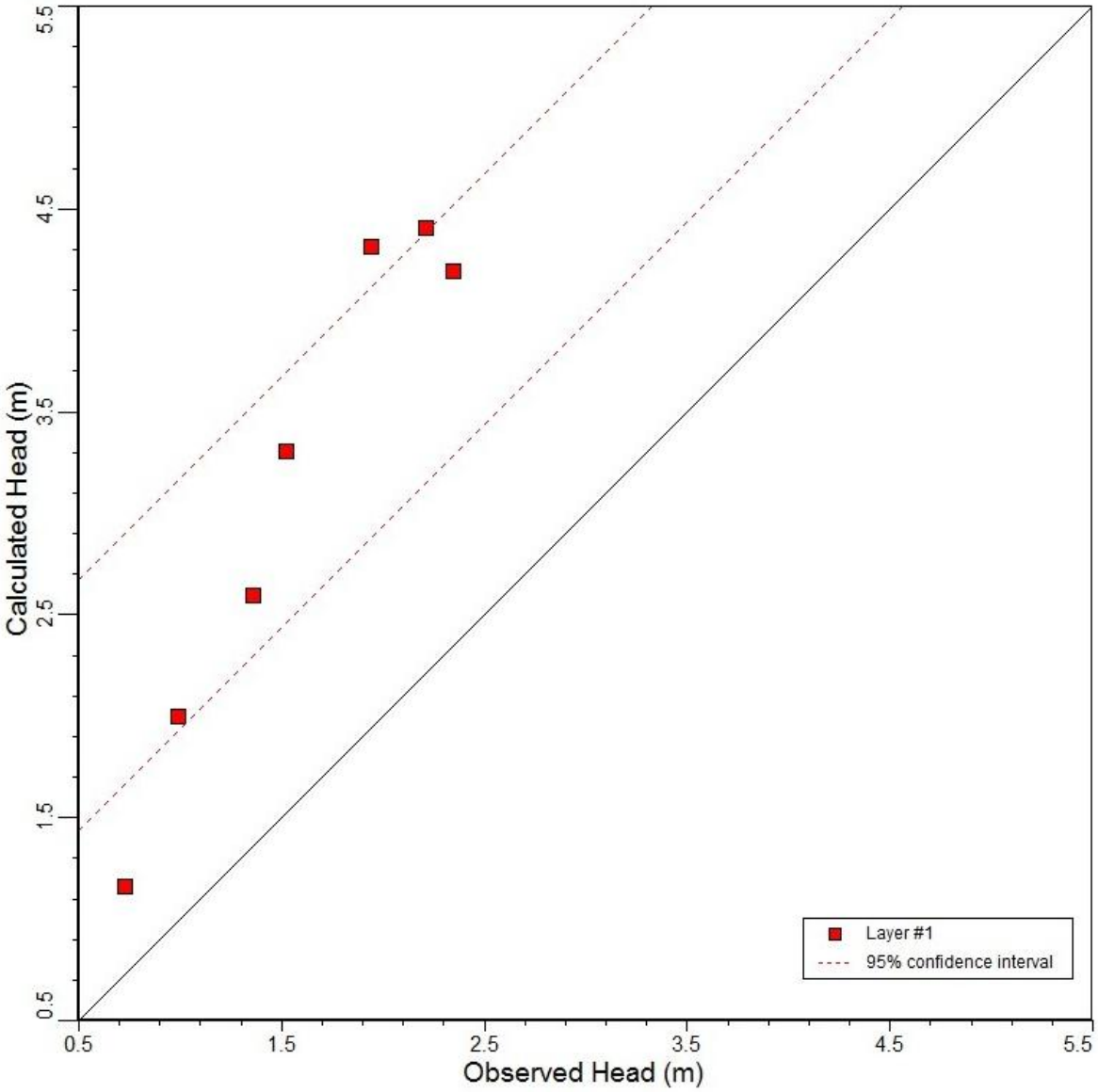
o) Run #8 with all wells included.

p) Run #8 without wells EIC1, EIC2, and EIC3.

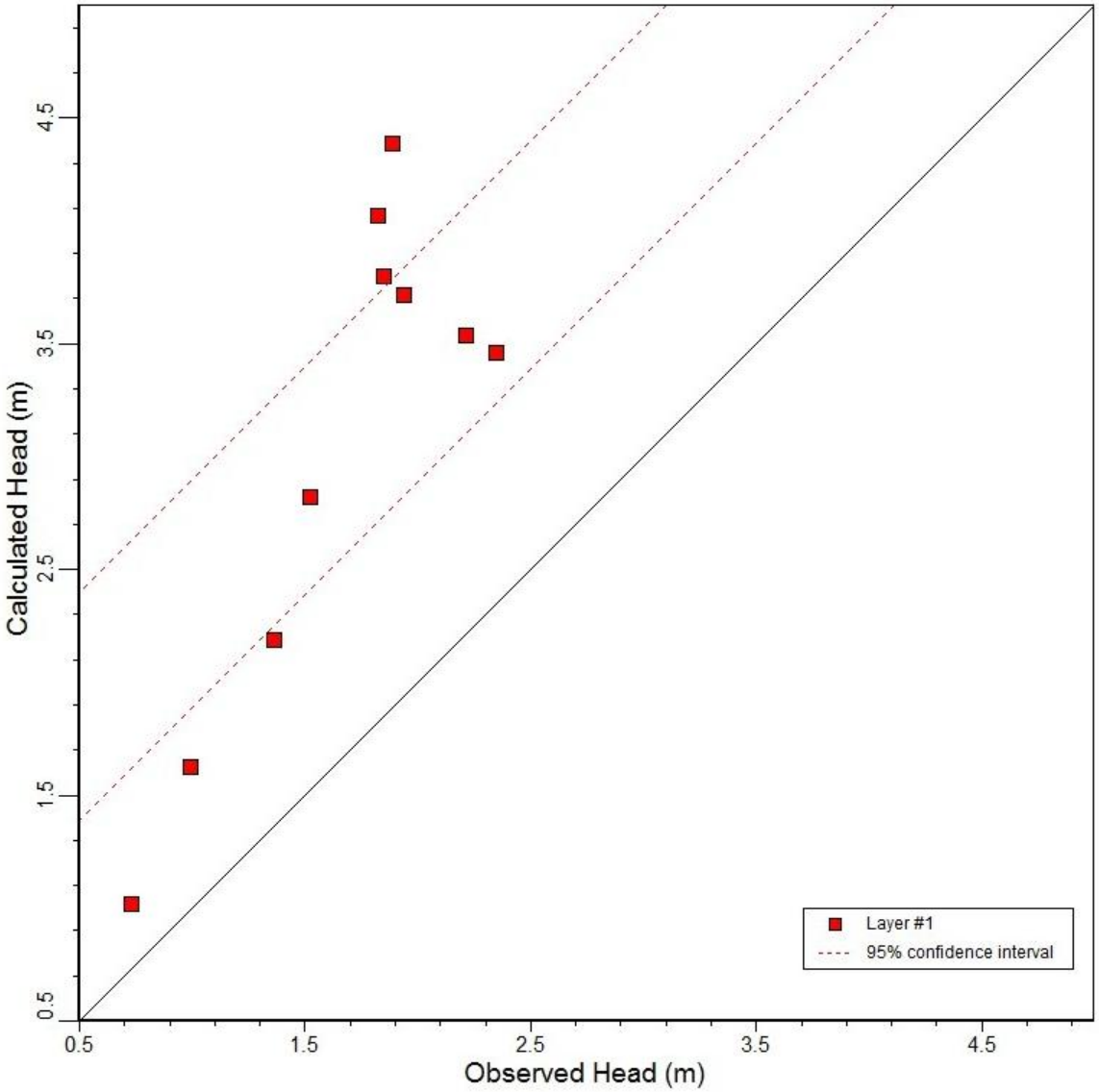
a)


Calculated Head (m)
Observed Head (m)
0.5
1.5
2.5
3.5
4.5
5.5
Layer #1
95% confidence interval

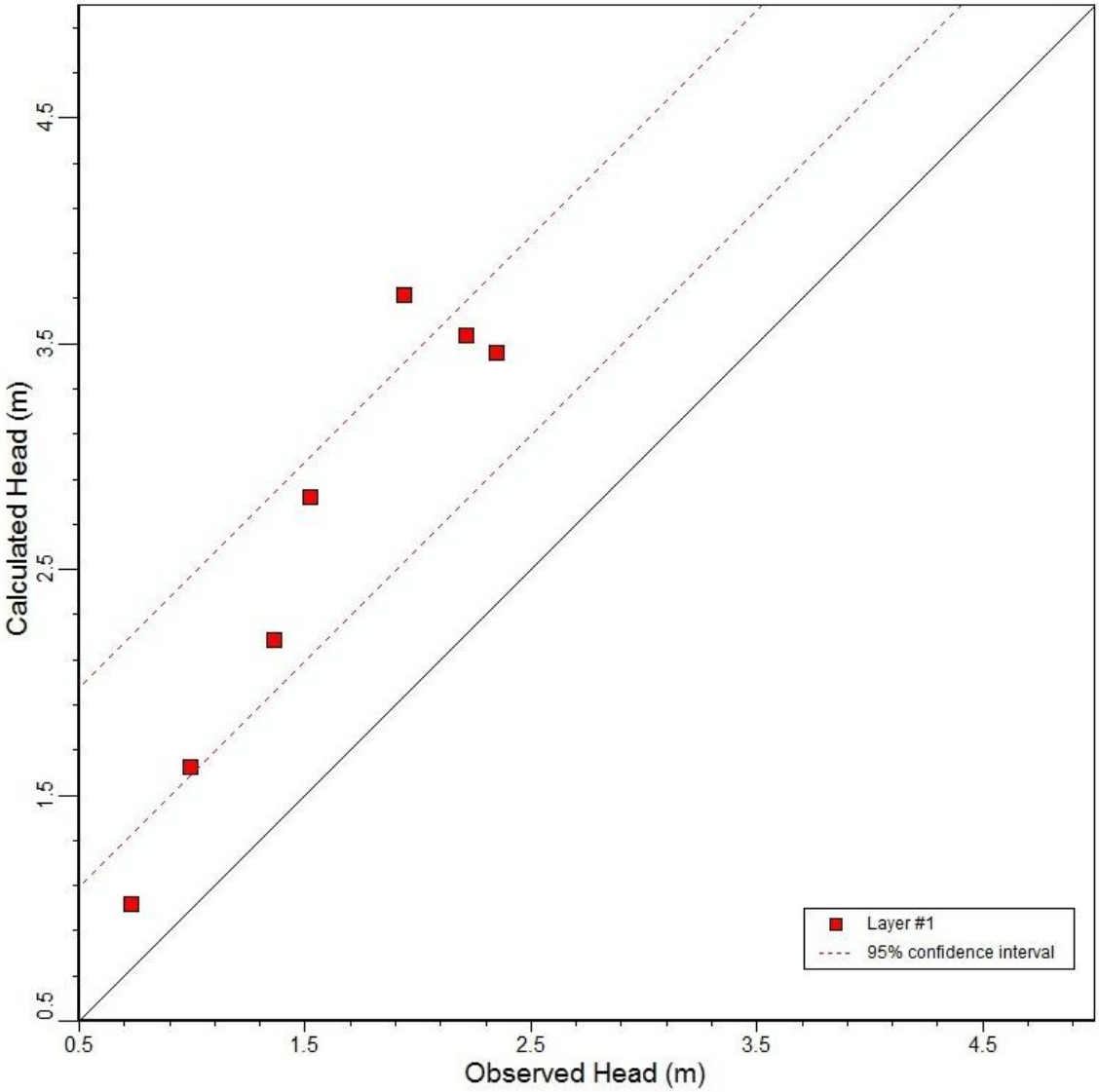
b)


Calculated Head (m)
Observed Head (m)
0.5
1.5
2.5
3.5
4.5
5.5
Layer #1
95% confidence interval

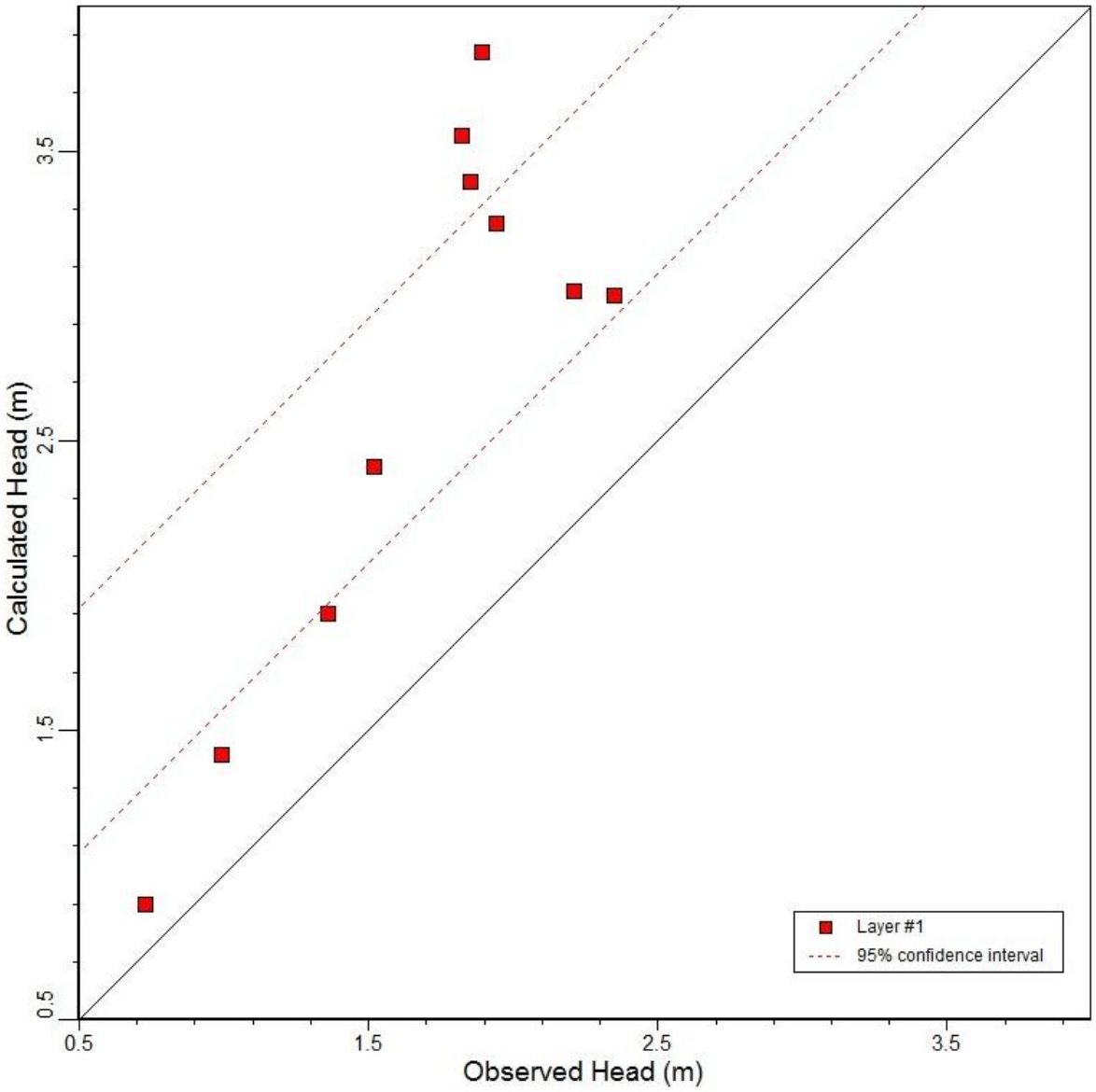
c)


Calculated Head (m)
Observed Head (m)
0.5
1.5
2.5
3.5
4.5
Layer #1
95% confidence interval

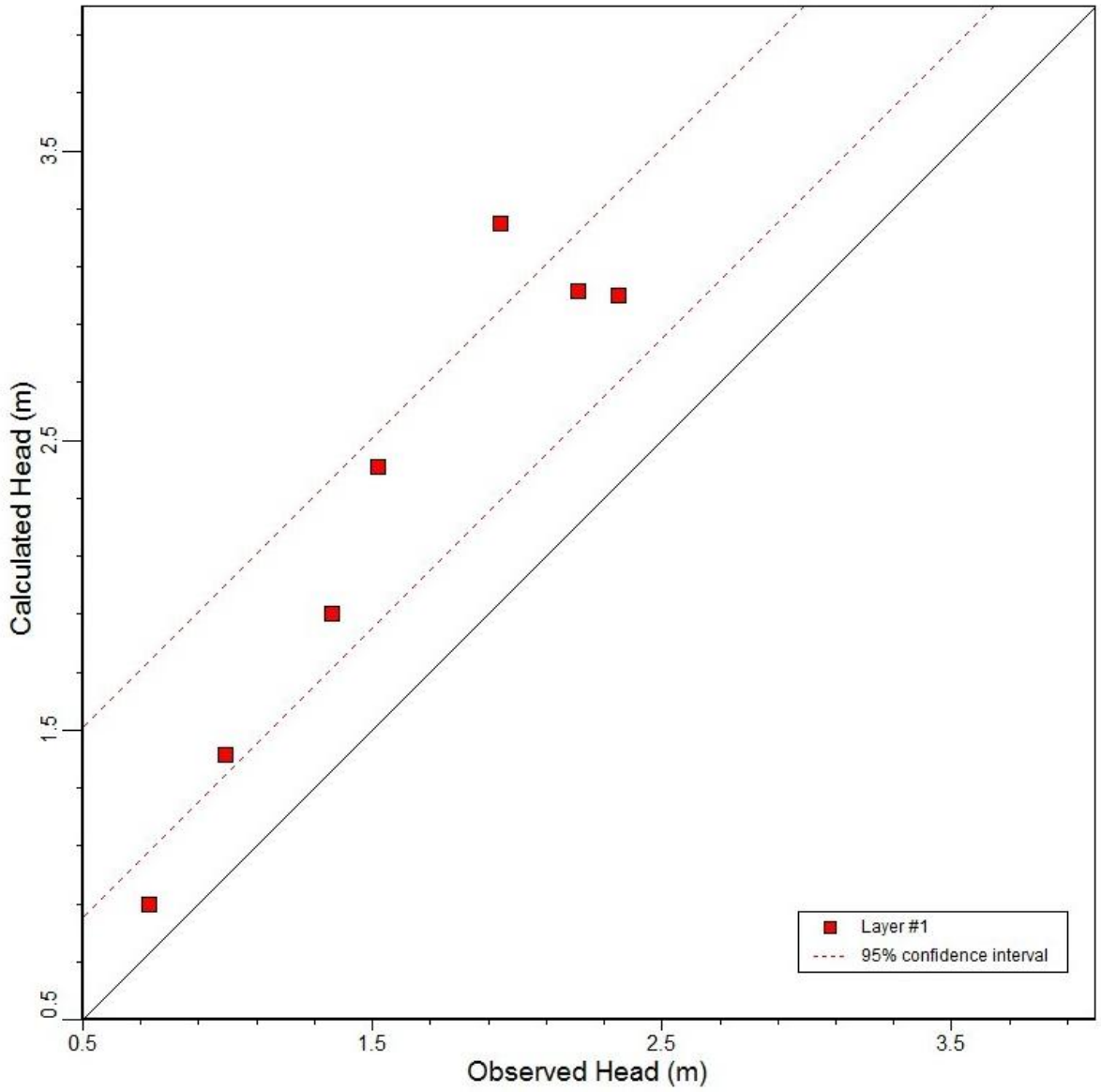
d)


Calculated Head (m)
Observed Head (m)
0.5
1.5
2.5
3.5
4.5
Layer #1
95% confidence interval

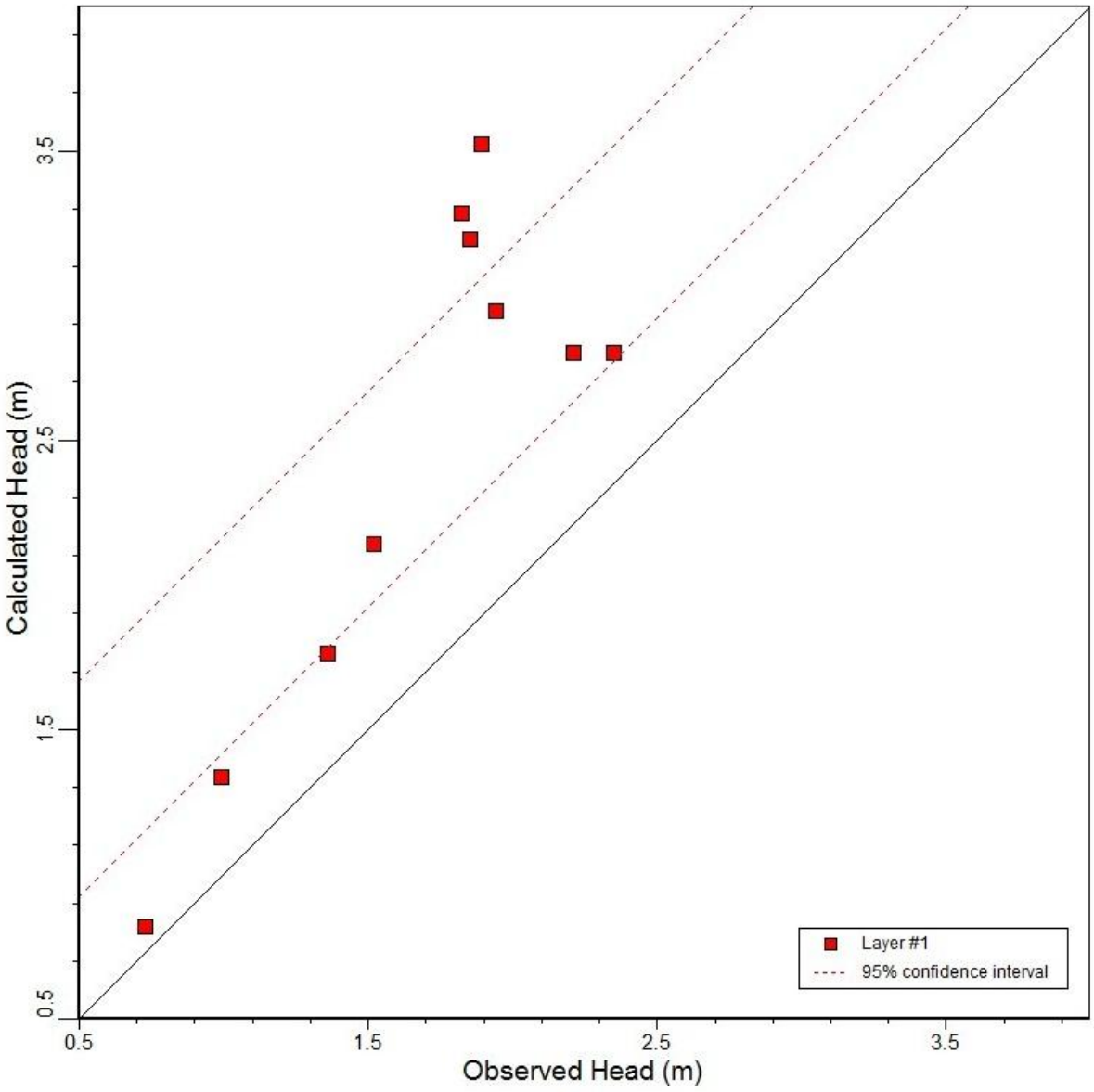
e)


Calculated Head (m)
Observed Head (m)
0.5
1.5
2.5
3.5
Layer #1
95% confidence interval

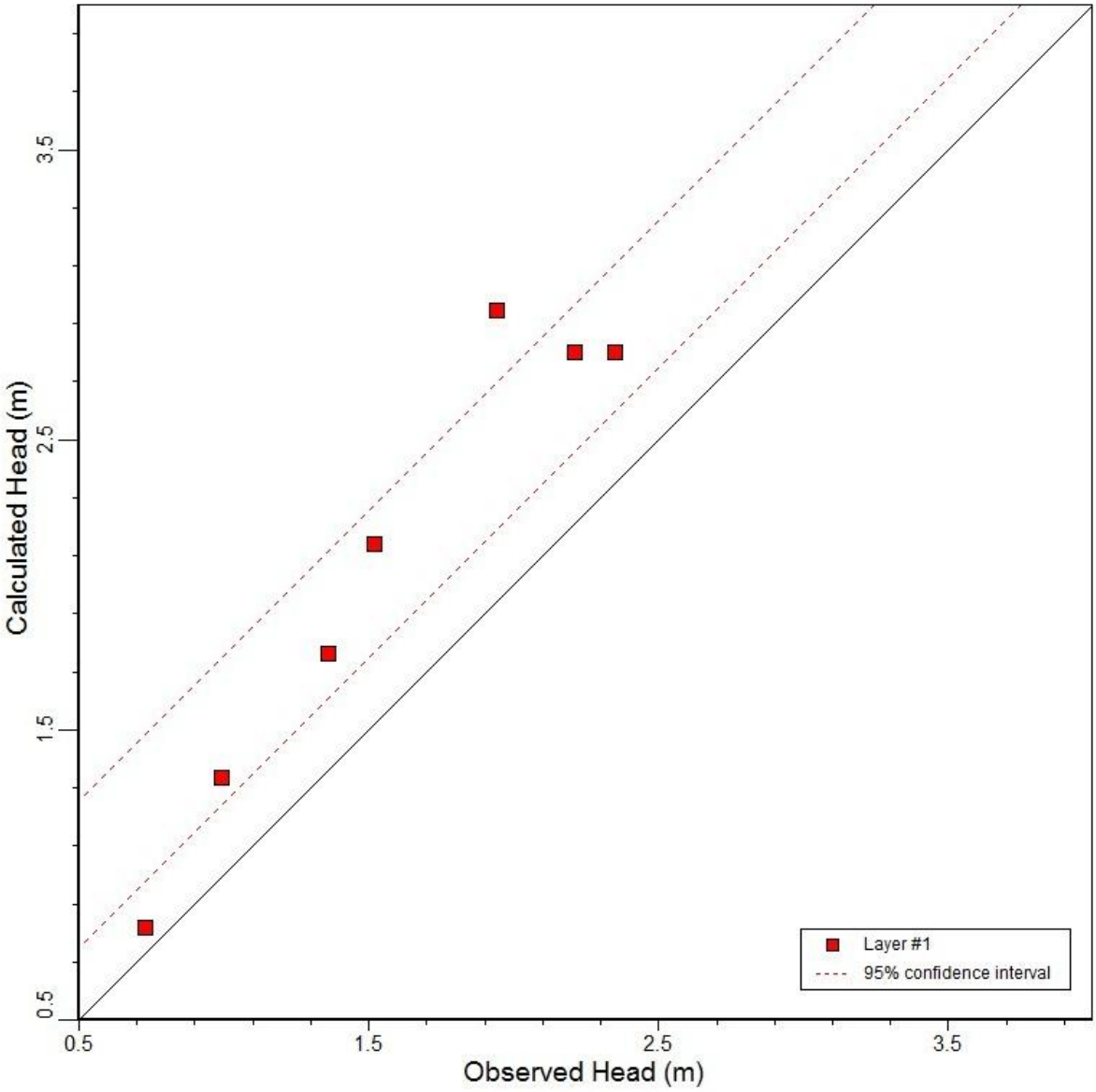
f)


Calculated Head (m)
Observed Head (m)
0.5
1.5
2.5
3.5
Layer #1
95% confidence interval

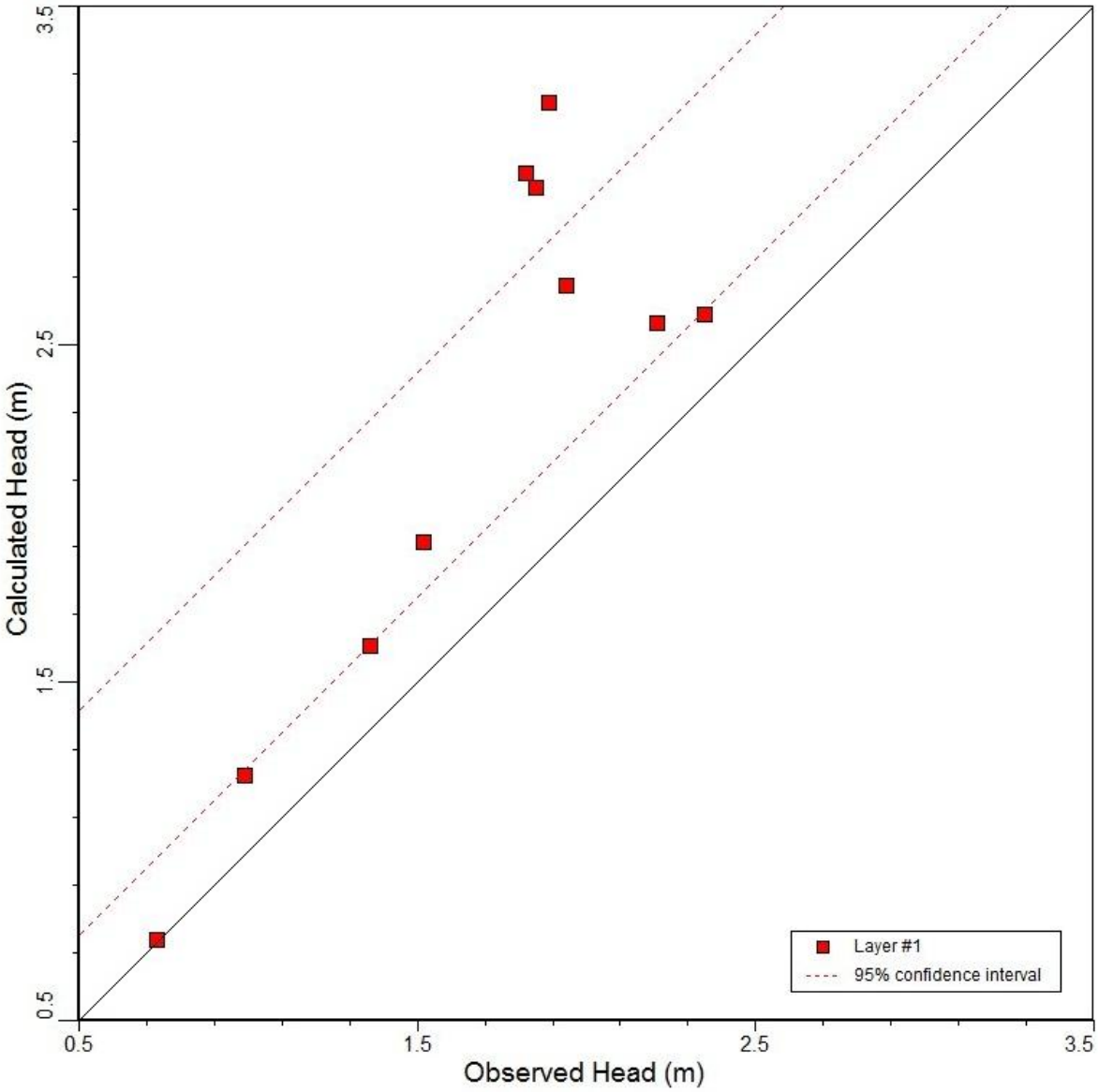
g)


Calculated Head (m)
Observed Head (m)
0.5
1.5
2.5
3.5
Layer #1
95% confidence interval

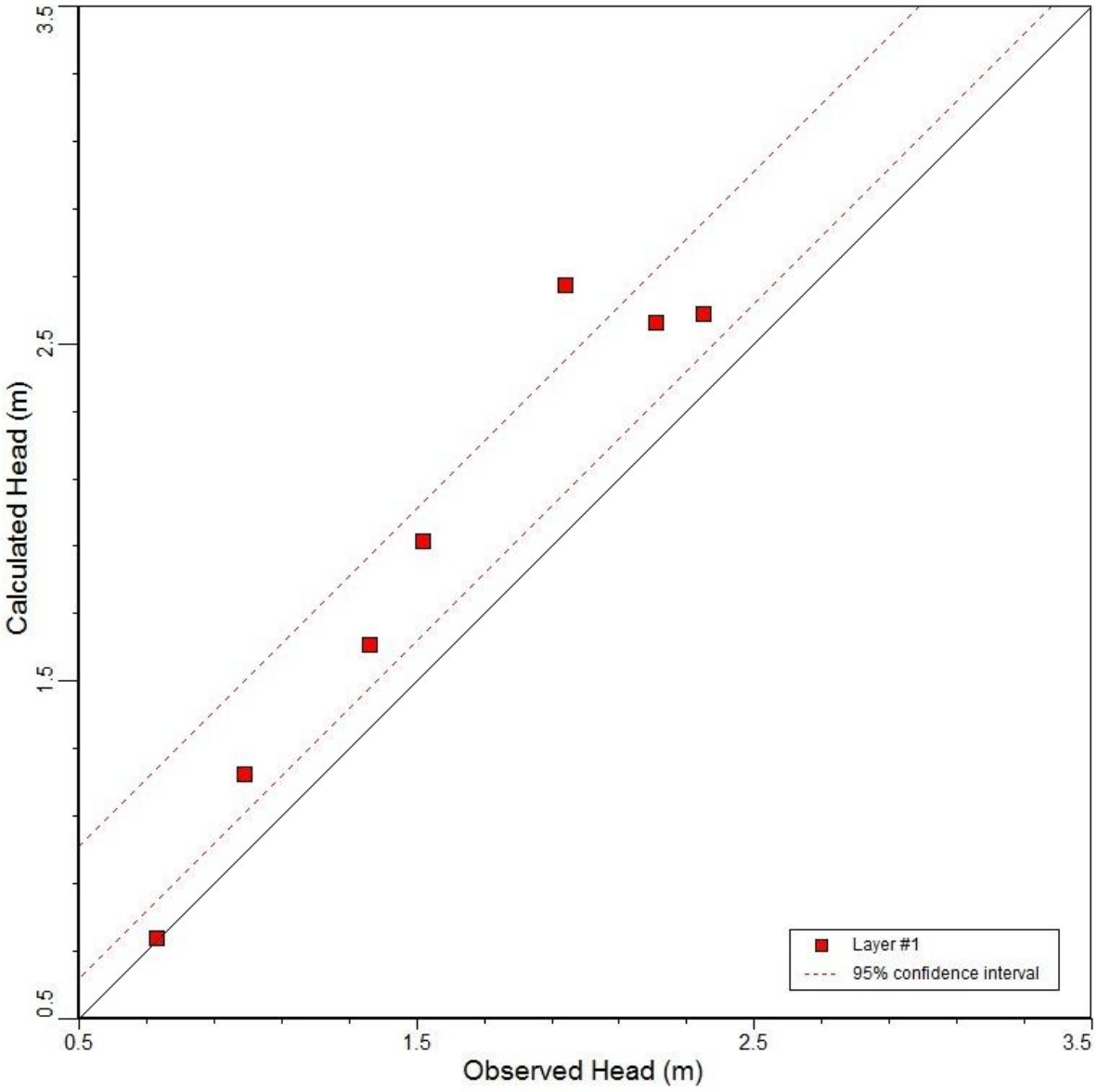
h)


Calculated Head (m)
Observed Head (m)
0.5
1.5
2.5
3.5
Layer #1
95% confidence interval

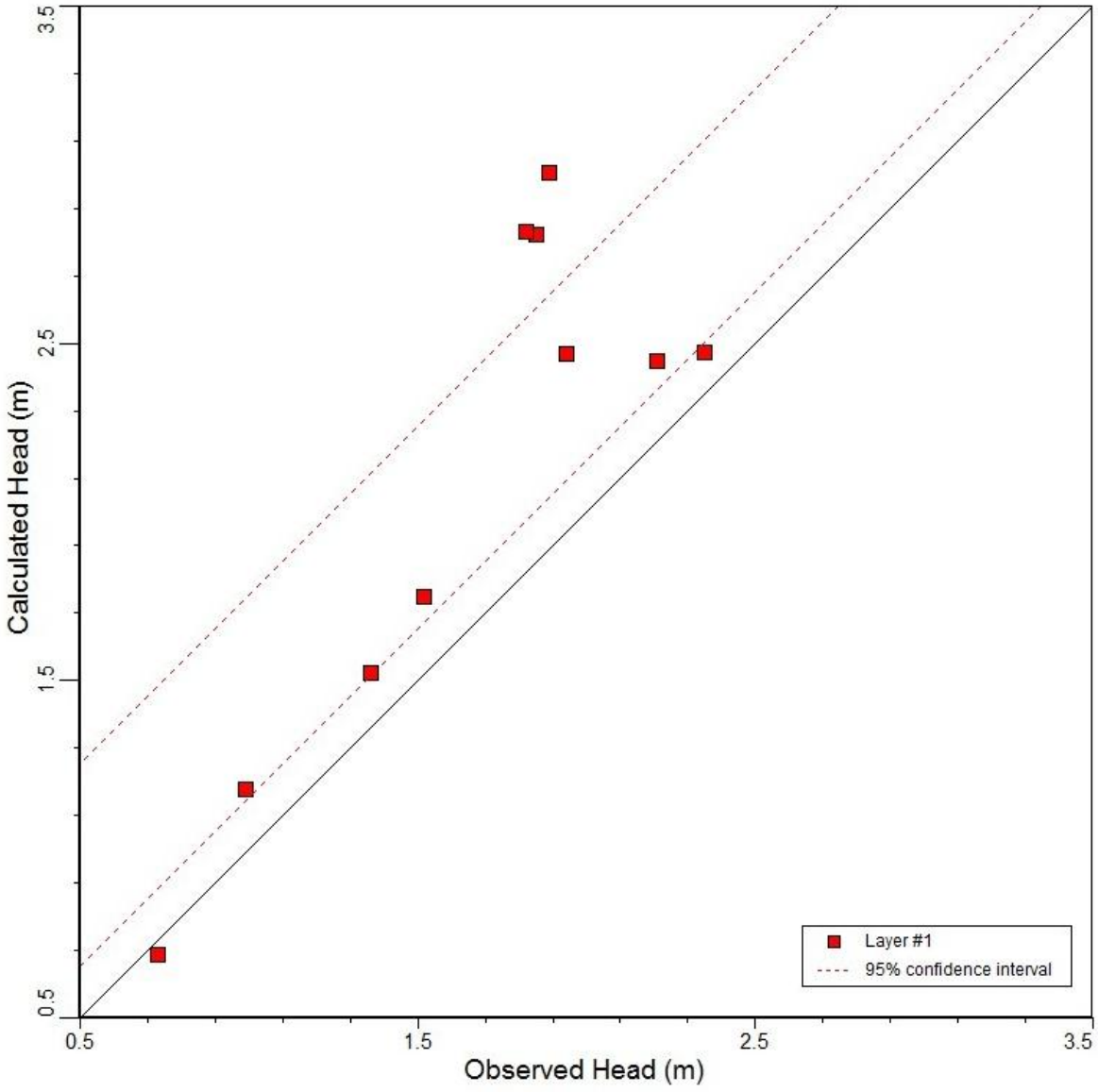
i)


Calculated Head (m)
Observed Head (m)
0.5
1.5
2.5
3.5
Layer #1
95% confidence interval

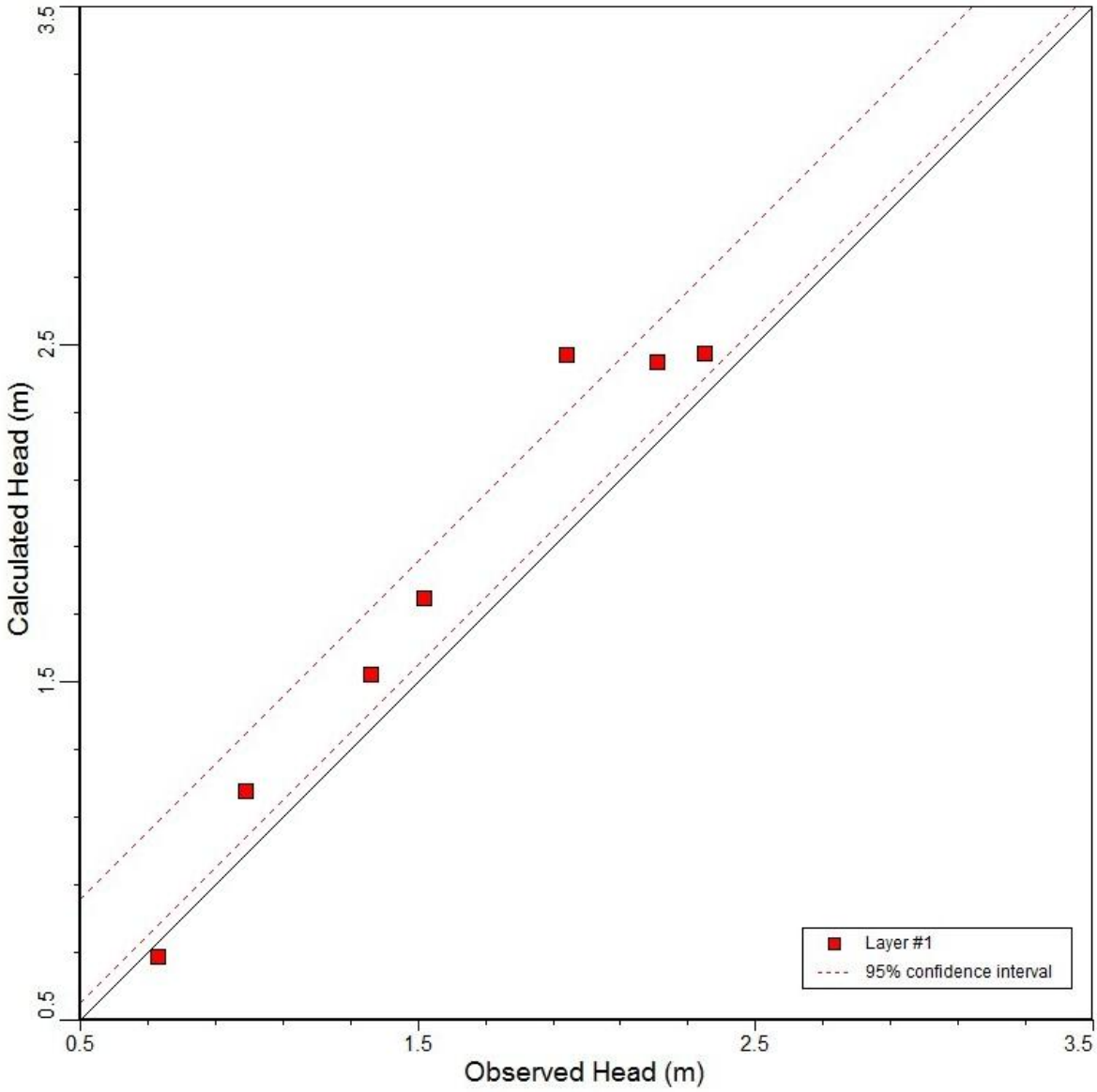
j)


Calculated Head (m)
Observed Head (m)
0.5
1.5
2.5
3.5
Layer #1
95% confidence interval

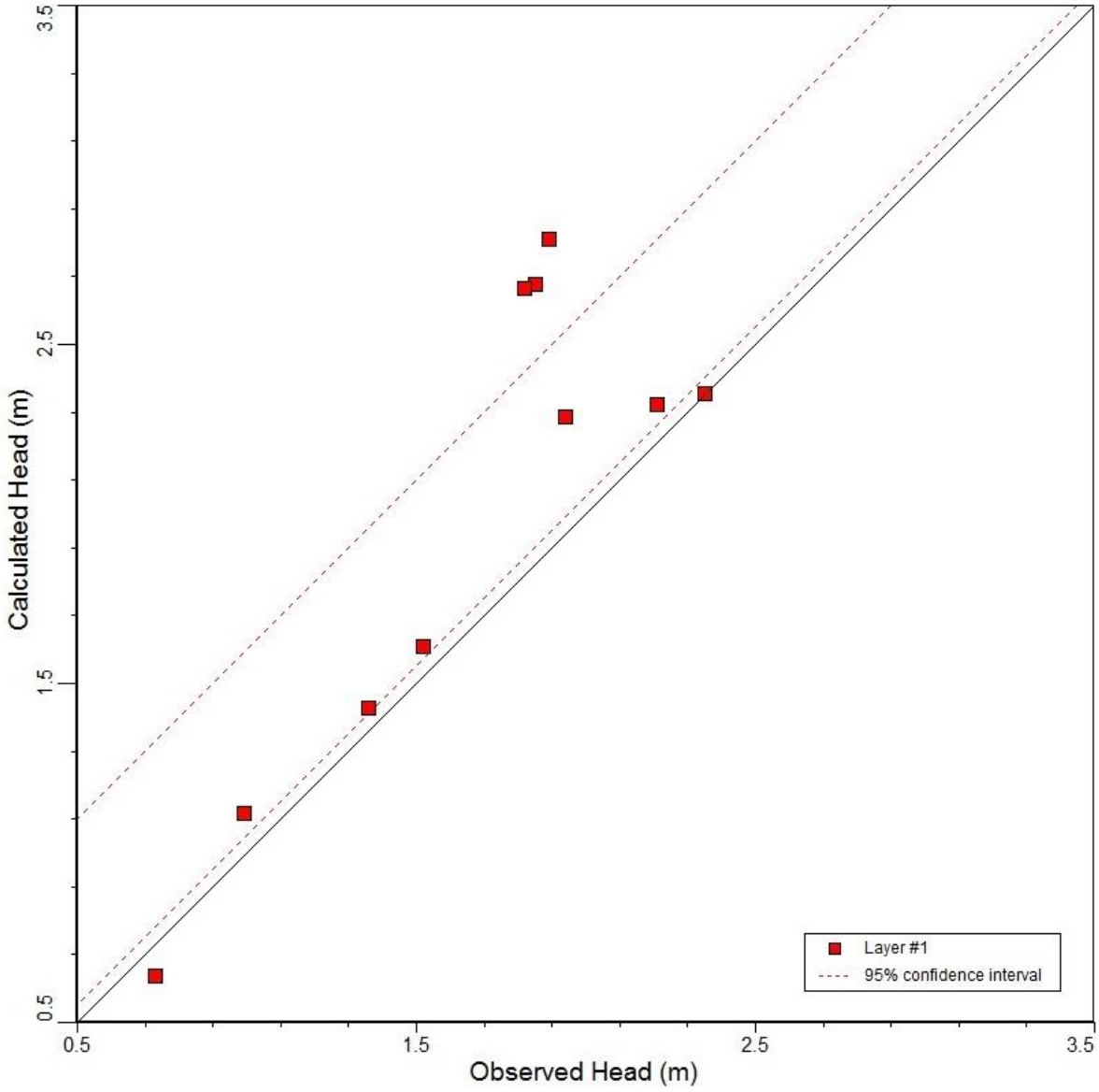
k)


Calculated Head (m)
Observed Head (m)
0.5
1.5
2.5
3.5
Layer #1
95% confidence interval

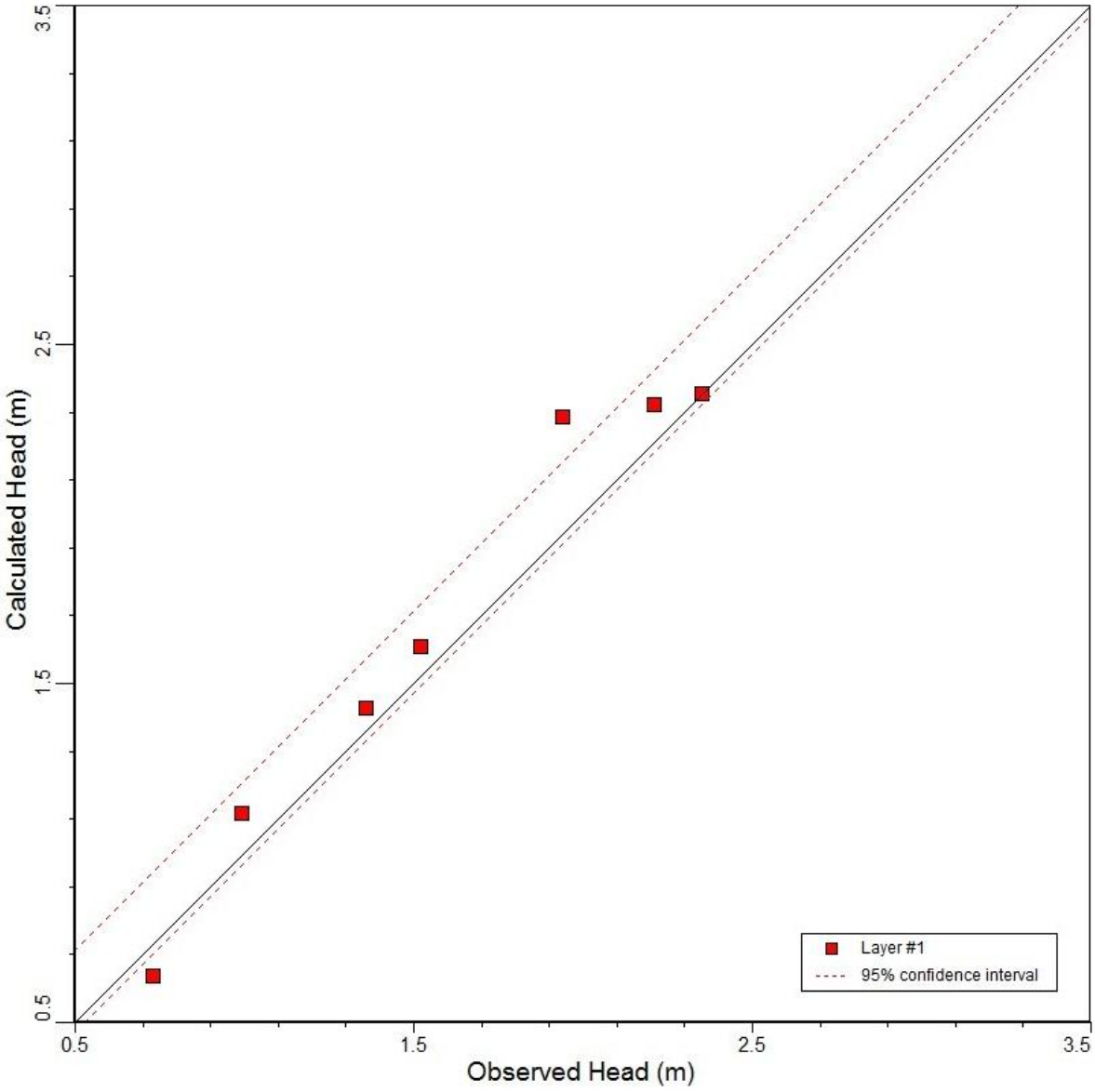
l)


Calculated Head (m)
Observed Head (m)
0.5
1.5
2.5
3.5
Layer #1
95% confidence interval

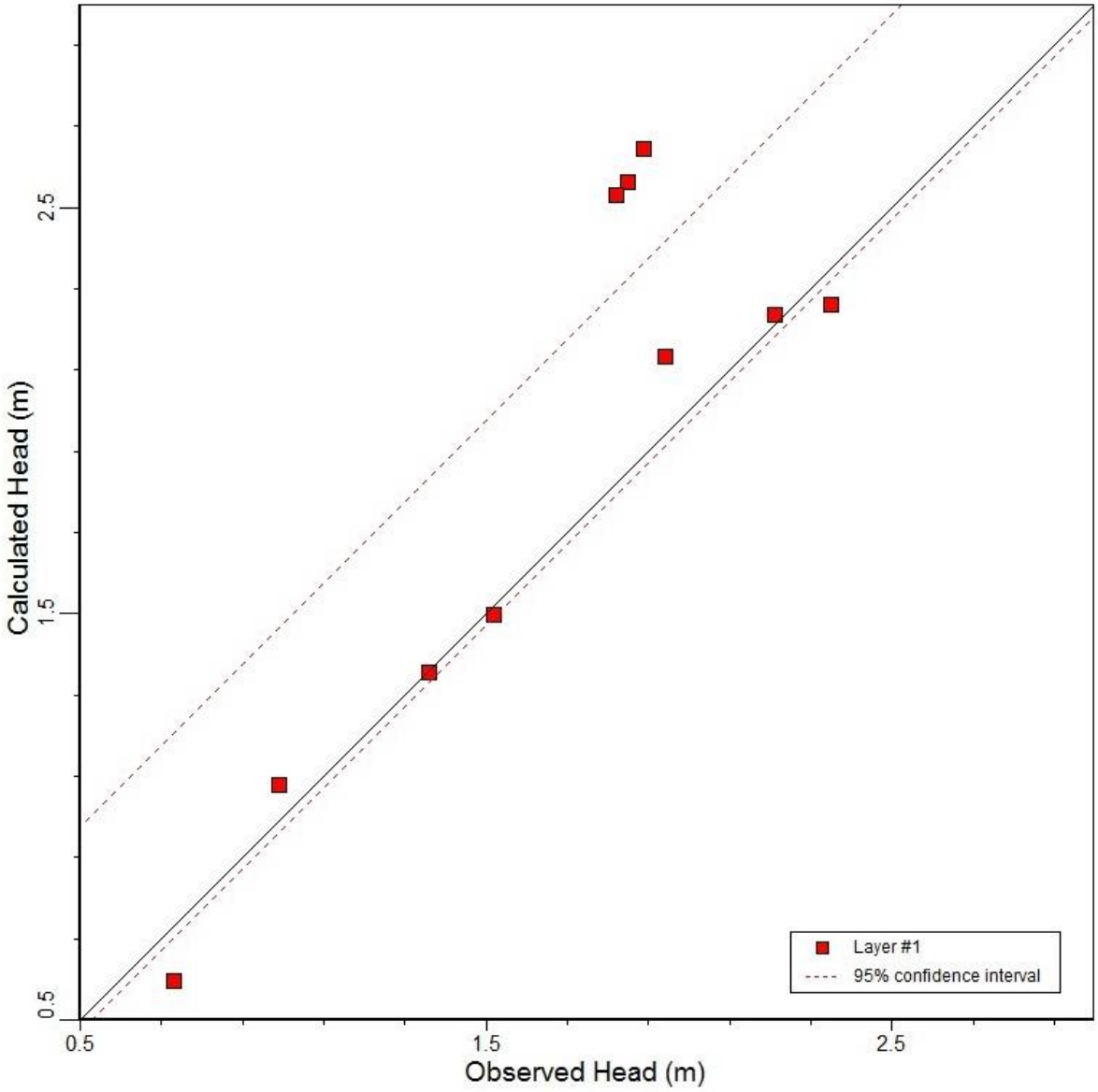
m)


Calculated Head (m)
Observed Head (m)
0.5
1.5
2.5
3.5
Layer #1
95% confidence interval

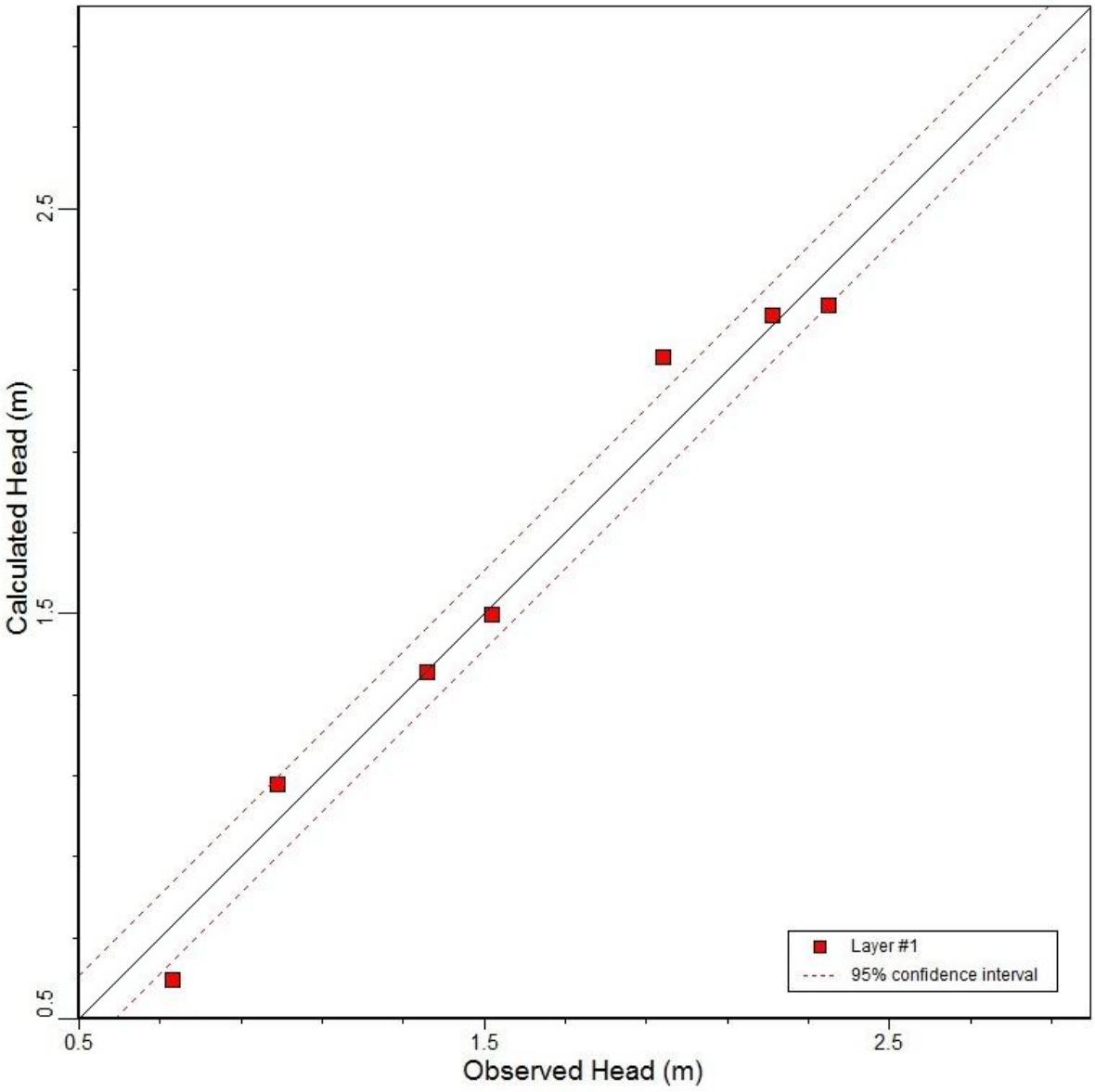
n)


Calculated Head (m)
Observed Head (m)
0.5
1.5
2.5
3.5
Layer #1
95% confidence interval

o)


Calculated Head (m)
0.5
1.5
2.5
Observed Head (m)
0.5
1.5
2.5
Layer #1
95% confidence interval

p)


Calculated Head (m)
0.5
1.5
2.5
Observed Head (m)
0.5
1.5
2.5
Layer #1
95% confidence interval

APPENDIX E: GEOPHYSICAL METHODS AND RESULTS

Subsurface Imaging

Ground penetrating radar (GPR) was used to image the subsurface of the Surficial aquifer in the study area. The GPR uses electromagnetic waves to locate subsurface interfaces. As the transmission of electromagnetic signals enter into the ground, it is reflected and detected based on the received signal from the buried target. These targets are identified as conductors, insulators (dielectric), or a combination of both (van Overmeeren, 1998). These weak signals that are received allow for the imaging of subsurface structures.

Reflected signals are more sensitive to water, so these data have the potential to show the position of the water table, as well as the underlying physiography of the structures that could affect recharge (Annan, 2005). A 200-megahertz monostatic antenna was dragged behind an all-terrain vehicle (ATV) with a survey wheel attached to it, which measured the distance travelled along the various transects (Fig. 1). At this frequency, up to 12 m of the Surficial aquifer can be imaged. Geophysical reflections were recorded every 5 m using an SIR-3000 data acquisition system.

GPR performs best in coarse-grained material, the predominant grain type within the study area (Annan, 2005). Radiowave signals are also more sensitive to the presense of water, thus the water table has the potential to be delineated (van Overmeeren, 1998). The geophysical data taken during fieldwork were digitized to determine which reflections best indicated the presence of the water table. During analysis, the primary feature sought was a continuous reflection that could cut across structural features typical of seismic logs. At some of the well sites, the water table was difficult to delineate with a high confidence level. Certain reflections were either excessively discontinuous or inconsistent with known water depths.

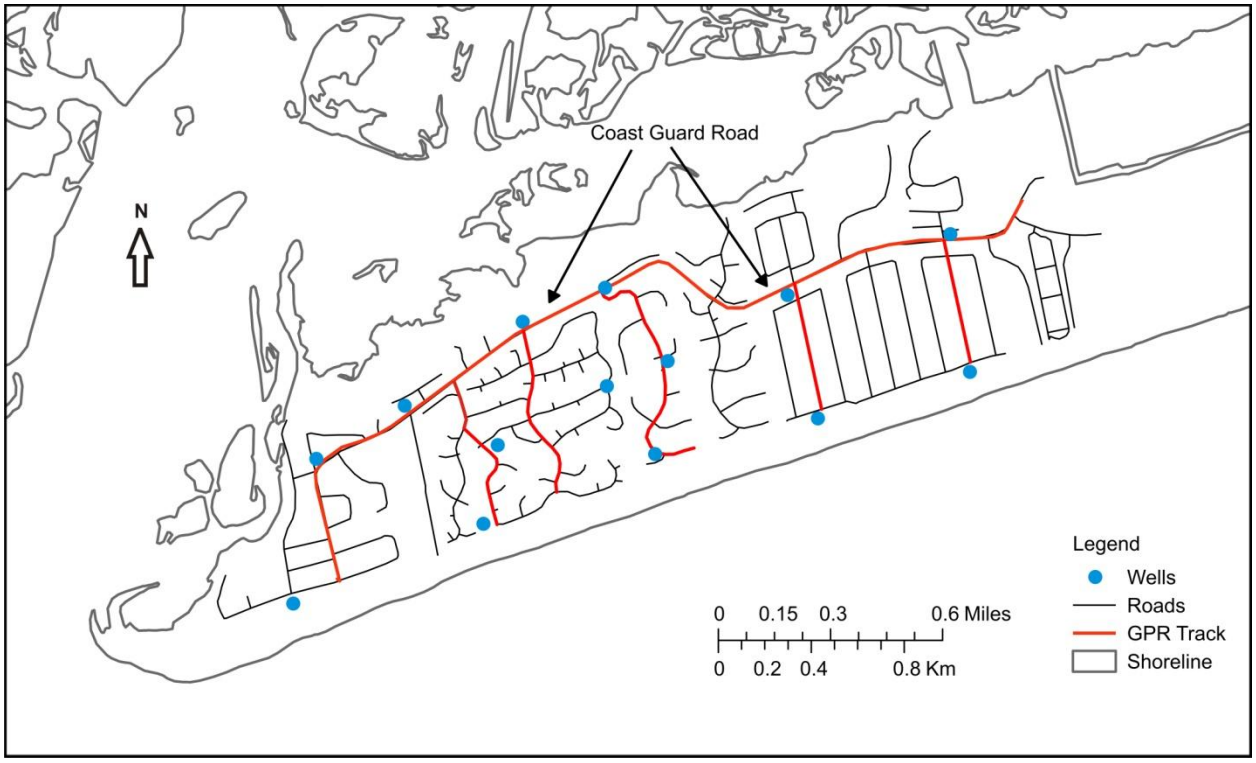


Figure 1: Map of Emerald Isle with the GPR tracks taken during fieldwork.

The raw data were processed using RADAN 6 software. Processing involved four steps: adjusting the temporal and spatial filter for ambient noise reduction, boosting the time gain to equalize wave amplitudes, spatial deconvolution for correcting radar reflectivity, and surface normalizing to compensate for the island's topography. Water level measurements were recorded at each well site during the survey. These data were used to define the reflection that best represented the water table. Once the reflection had been delineated, the water table could be tracked across longer transects.

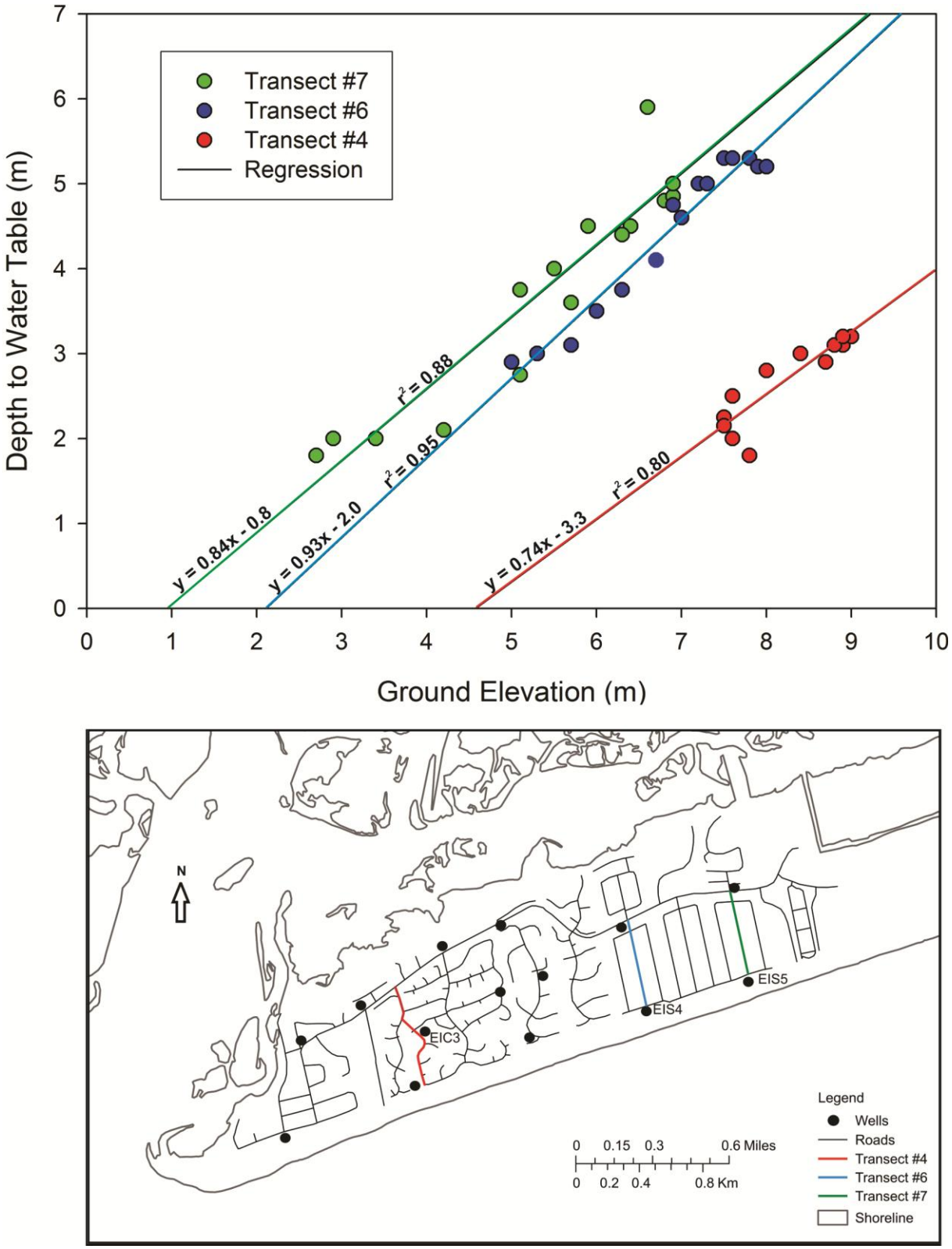


Figure 2: Depth to water table values vs. ground elevations found in the north-to-south GPR sections.

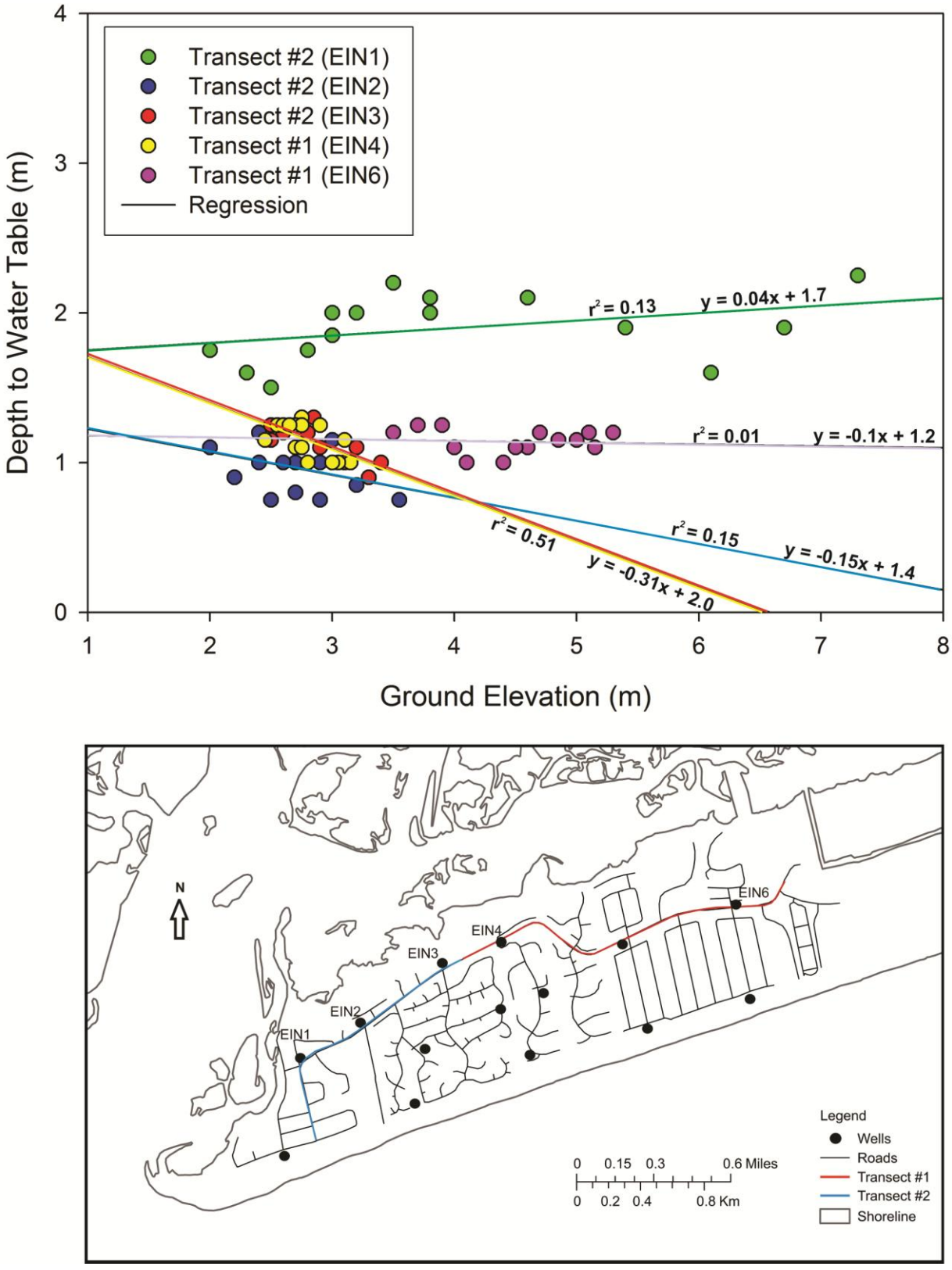


Figure 3: Depth to water table values vs. ground elevations found in the Coast Guard Road GPR section.

Geophysical Analysis

A regression analysis was used to determine the relationship between the ground elevation and the depth to the water table as measured on the day of the GPR surveys. The plots represent two distinct patterns: locations where the water table depth is positively correlated with elevation (Fig. 2), and locations where the water table depths have a low correlation to elevation (Fig. 3). Wells EIS5, EIS4, and EIC3 are all located within the southern dune field of the island whereas the wells the second survey are along Coast Guard Road. This northern transect of wells along Coast Guard Road do not experience much variance in water depth as the ground elevation changes, whereas the wells located along the transects perpindicular to the dunes have a highly positive correlation. Figure 2 is representitive of locations where the water table may be more of a subdued profile of the topography. This association is what was hypothesized for the study. However, Figure 3 shows a water table that closely mirrors the physiographic changes of the land surface. These data show that the water table is influenced by topography, but this relationship is highly variable throughout the study area.

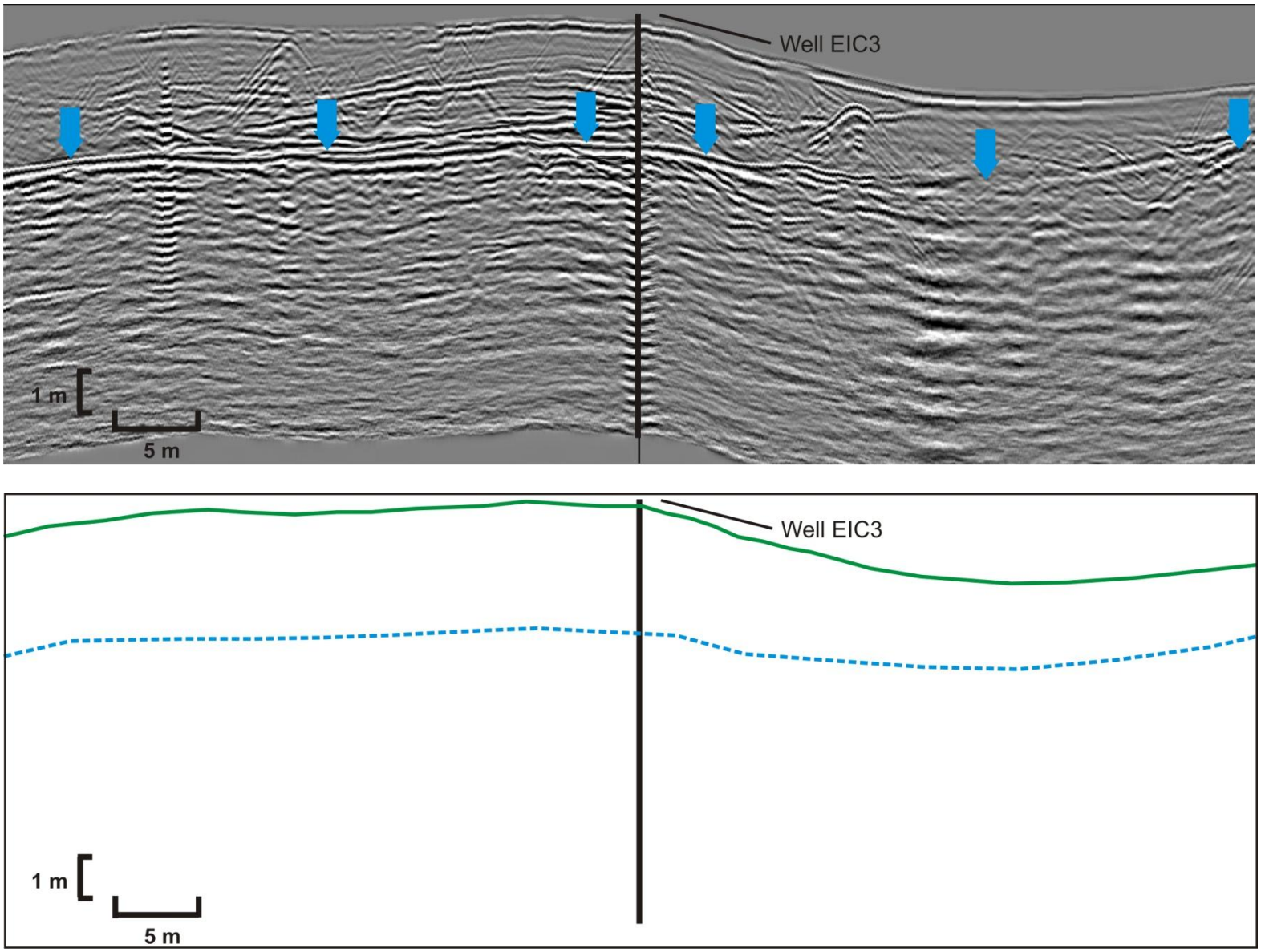
This remainder of this appendix is composed of both digitized and raw ground penetrating radar data recorded in the field. Data were analyzed using Geophysical Survey Systems Inc. RADAN 6.6 software.

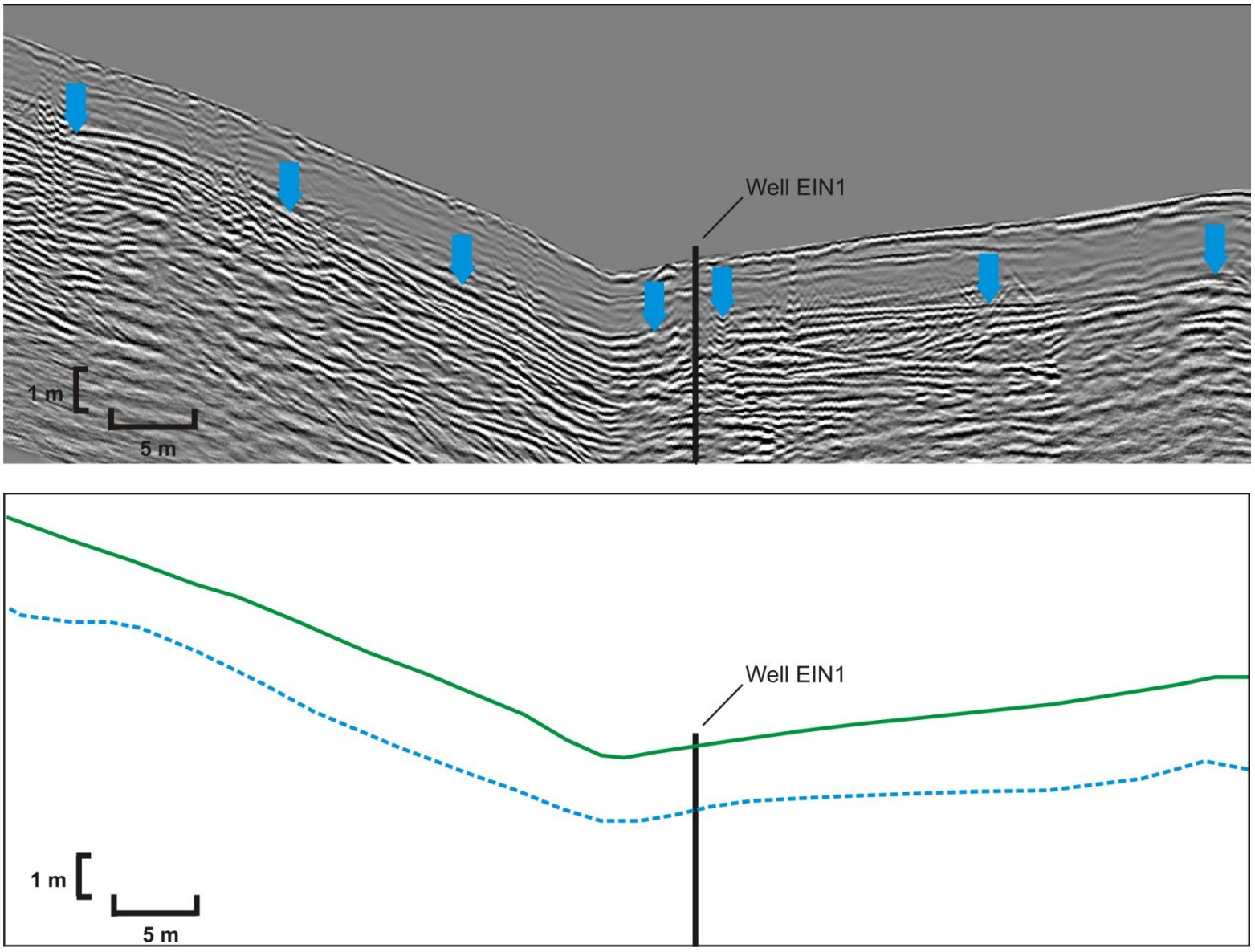
Blue arrows = reflection representing the water table

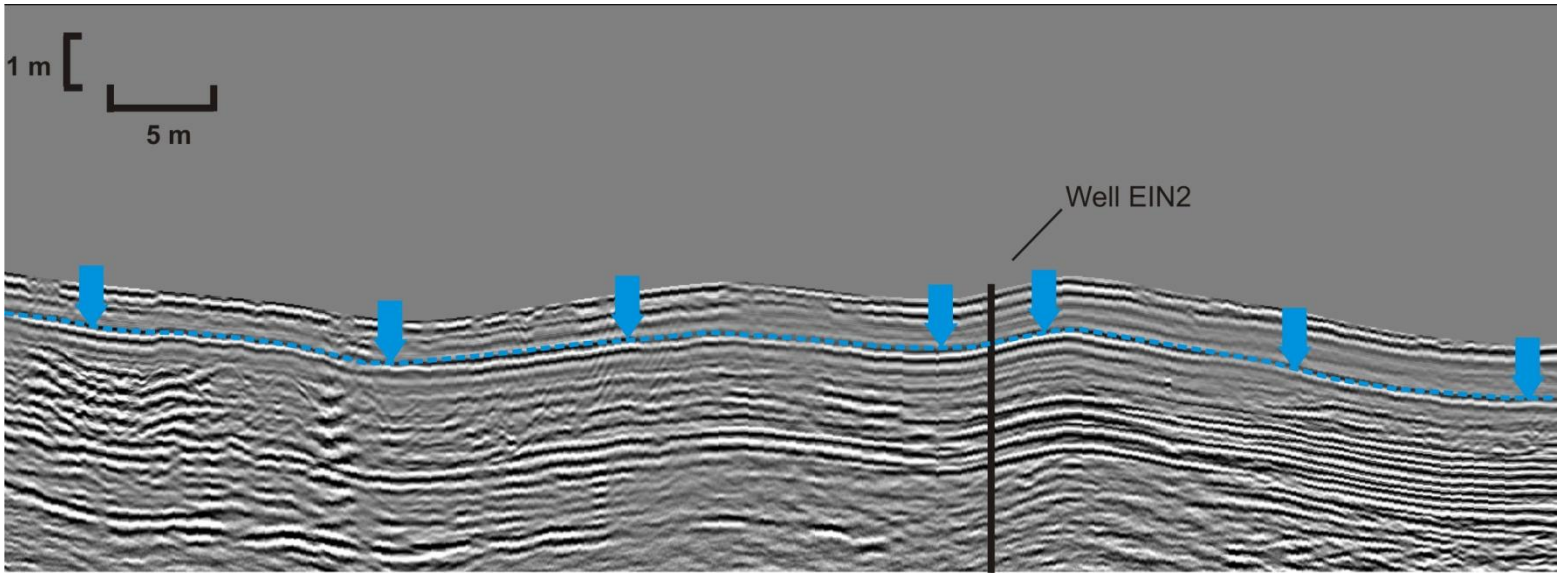
Blue dashed line = water table interpretation

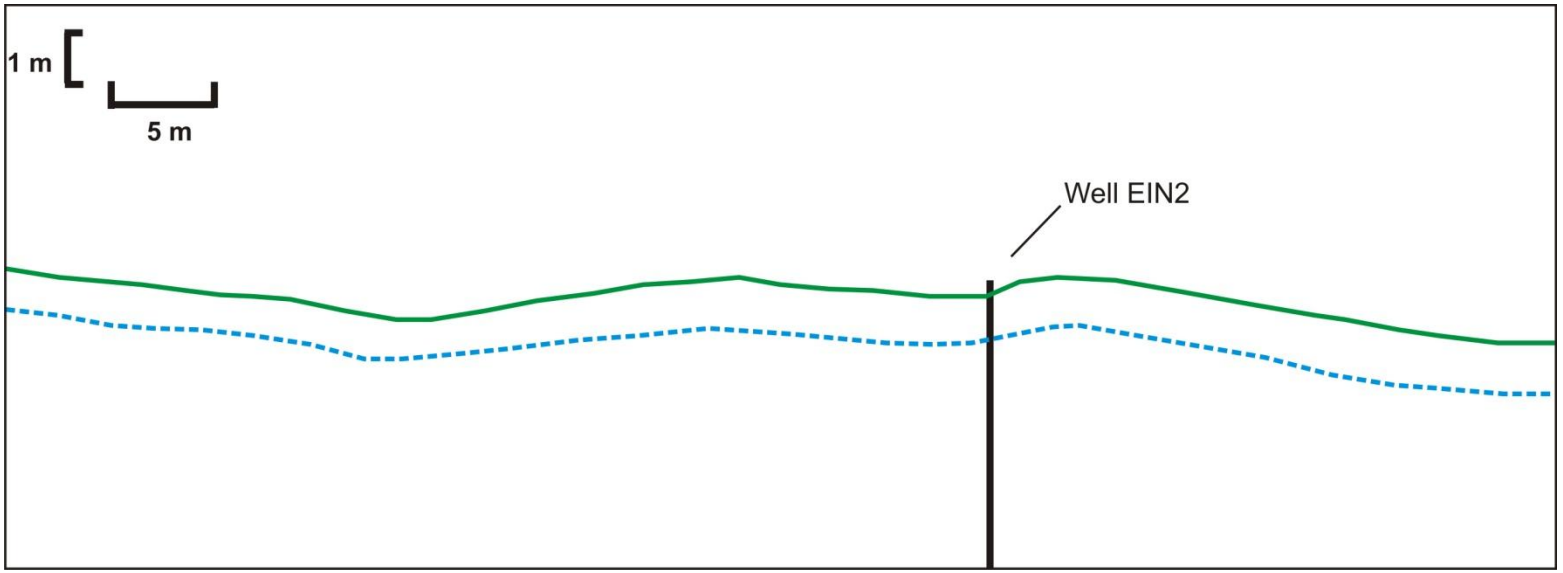
Green line = ground surface

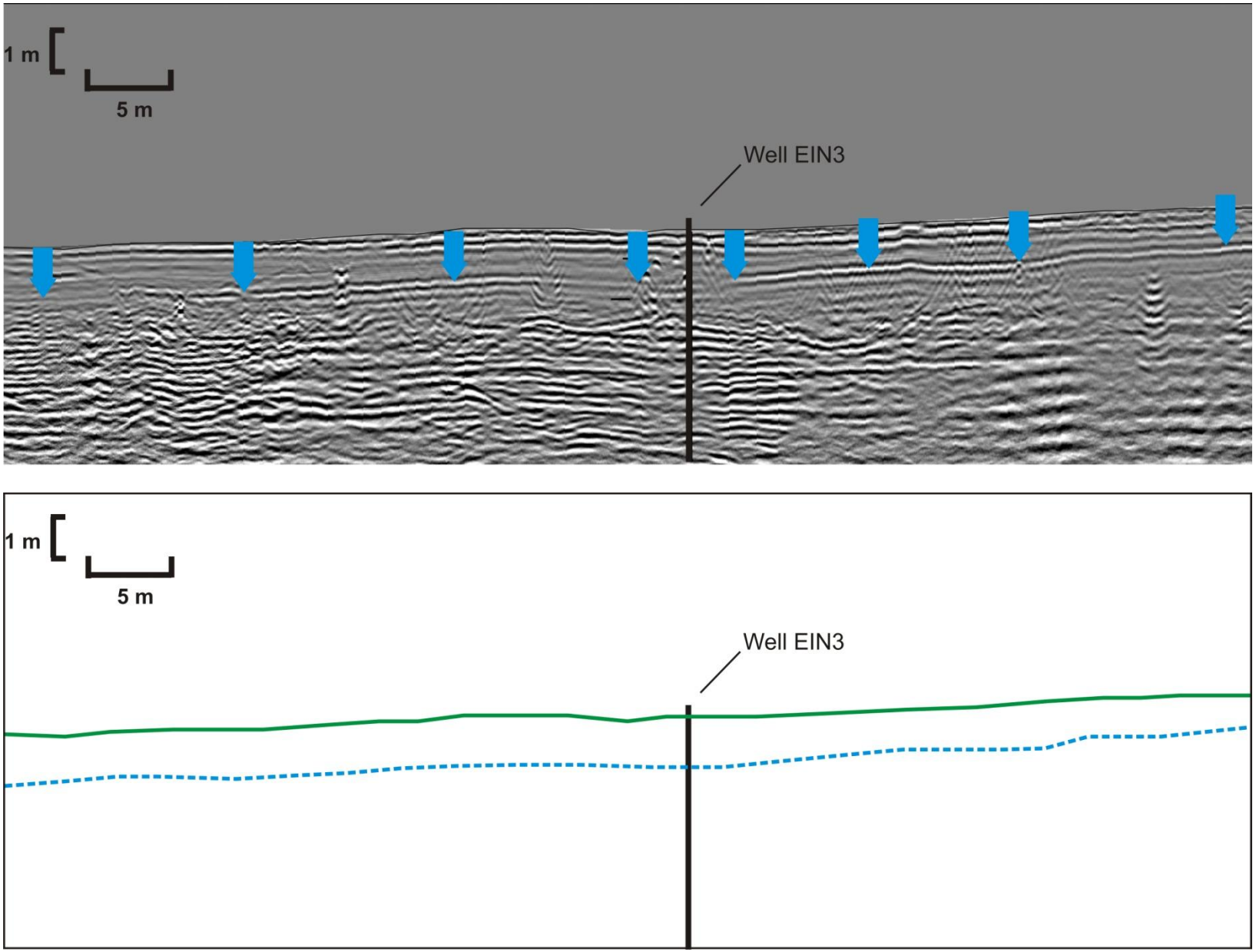
Red arrows = direction of the GPR track

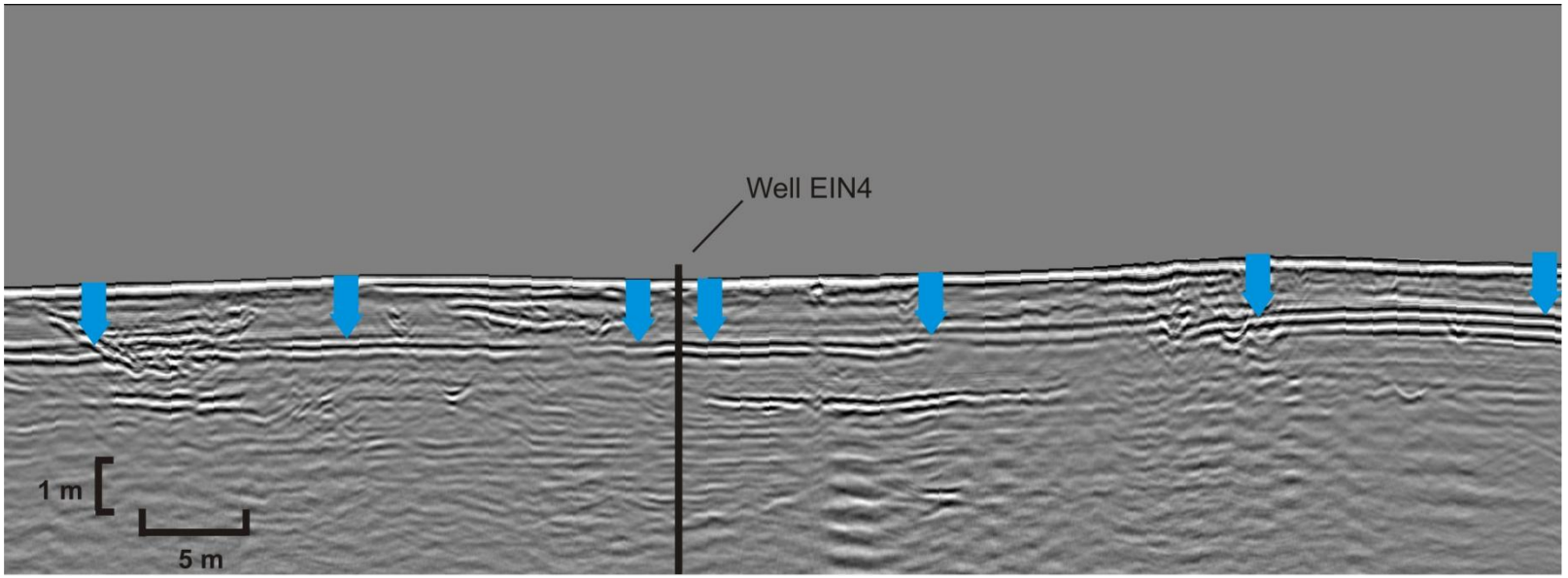

Well EIC3
1 m
5 m
Well EIC3
1 m
5 m


Well EIN1
1 m
5 m
Well EIN1
1 m
5 m


1 m
5 m
Well EIN2


1 m
5 m
Well EIN2


1 m
5 m
Well EIN3
1 m
5 m
Well EIN3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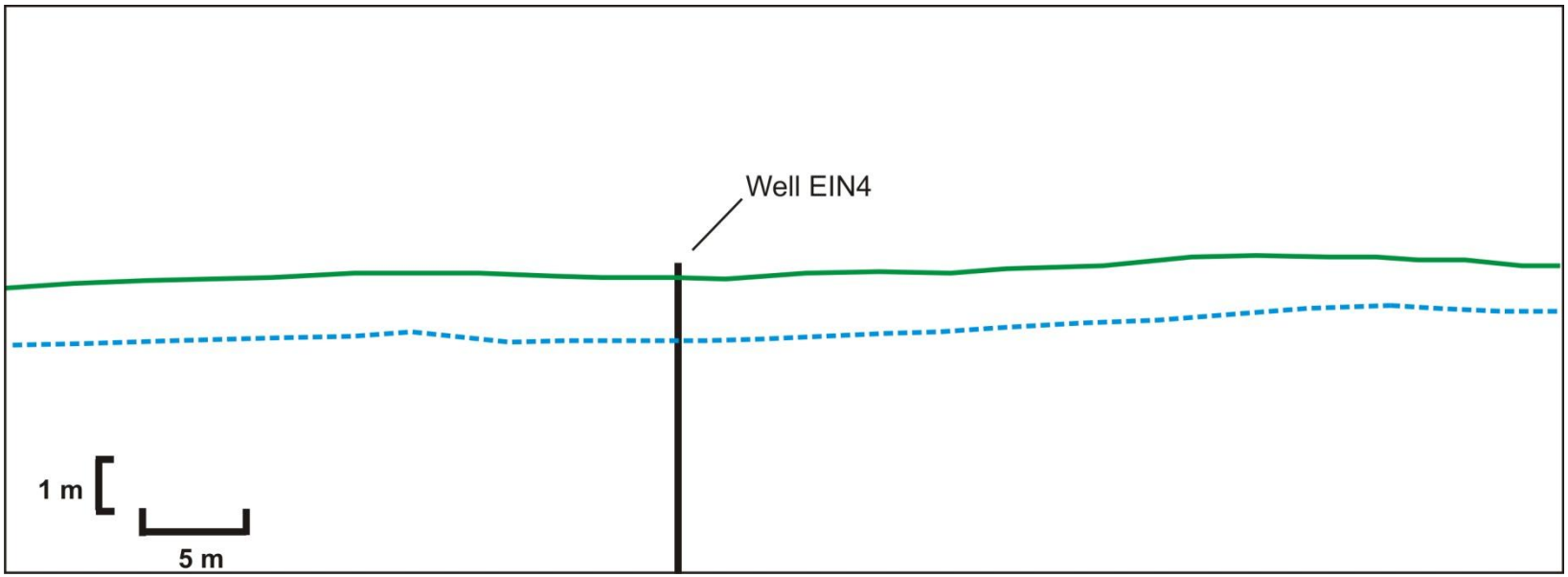
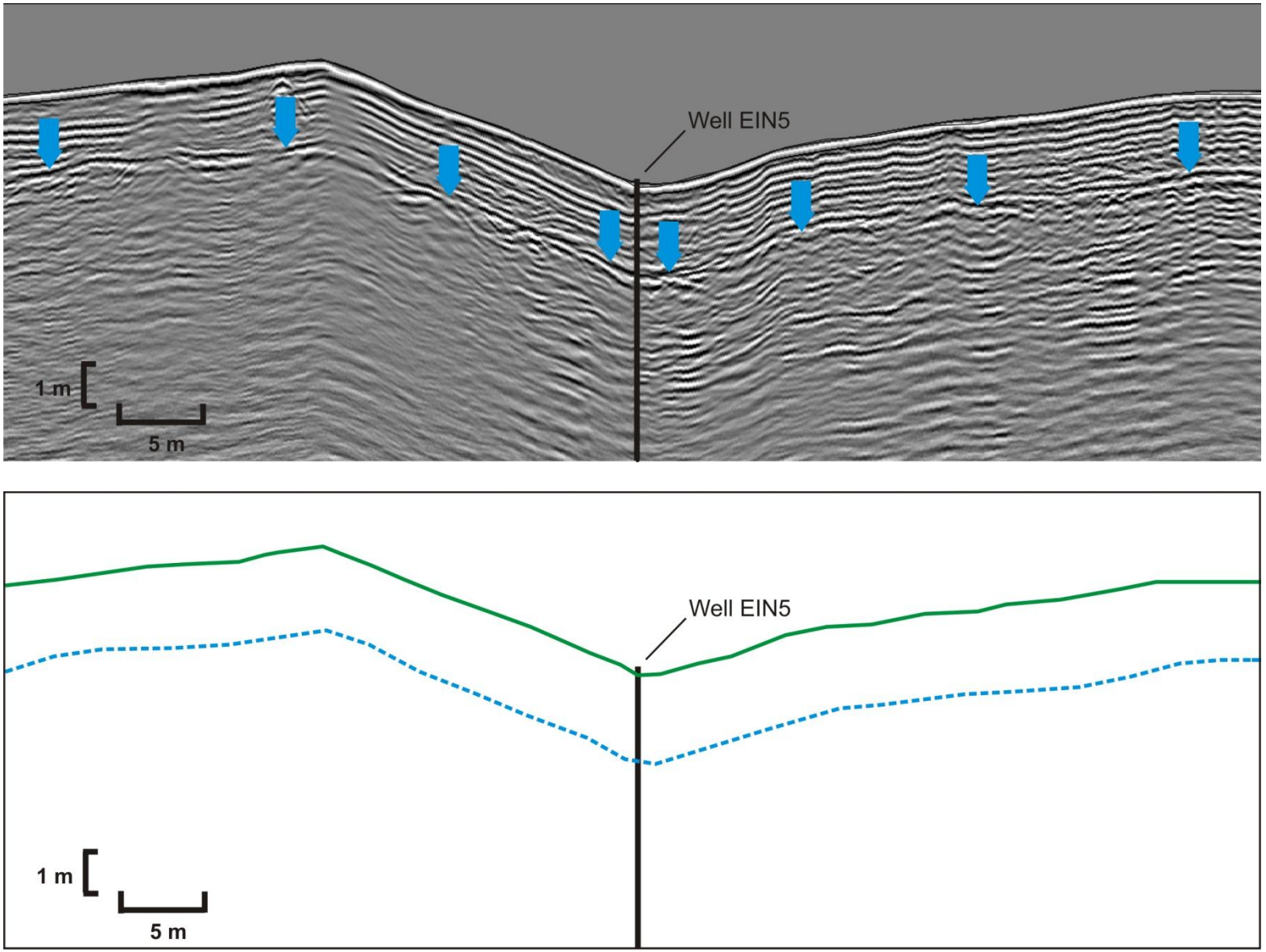
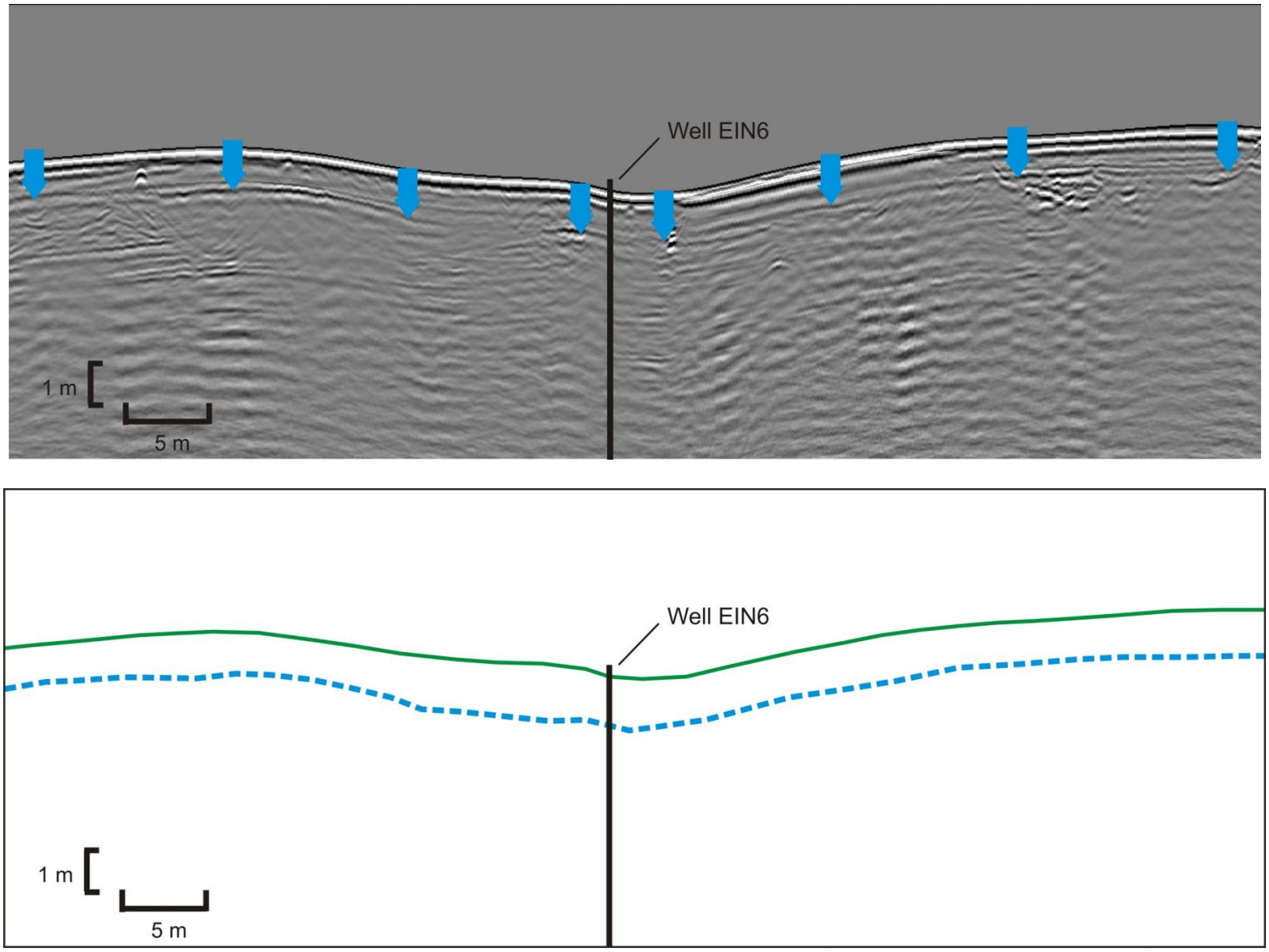
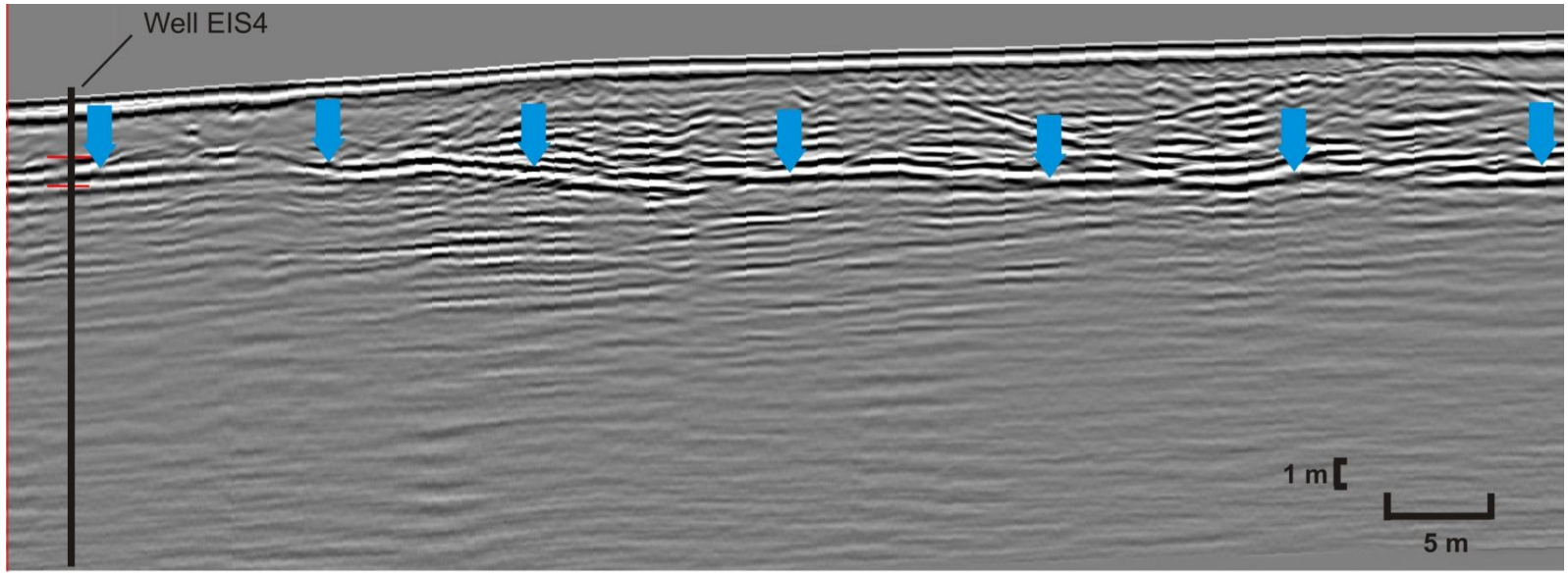
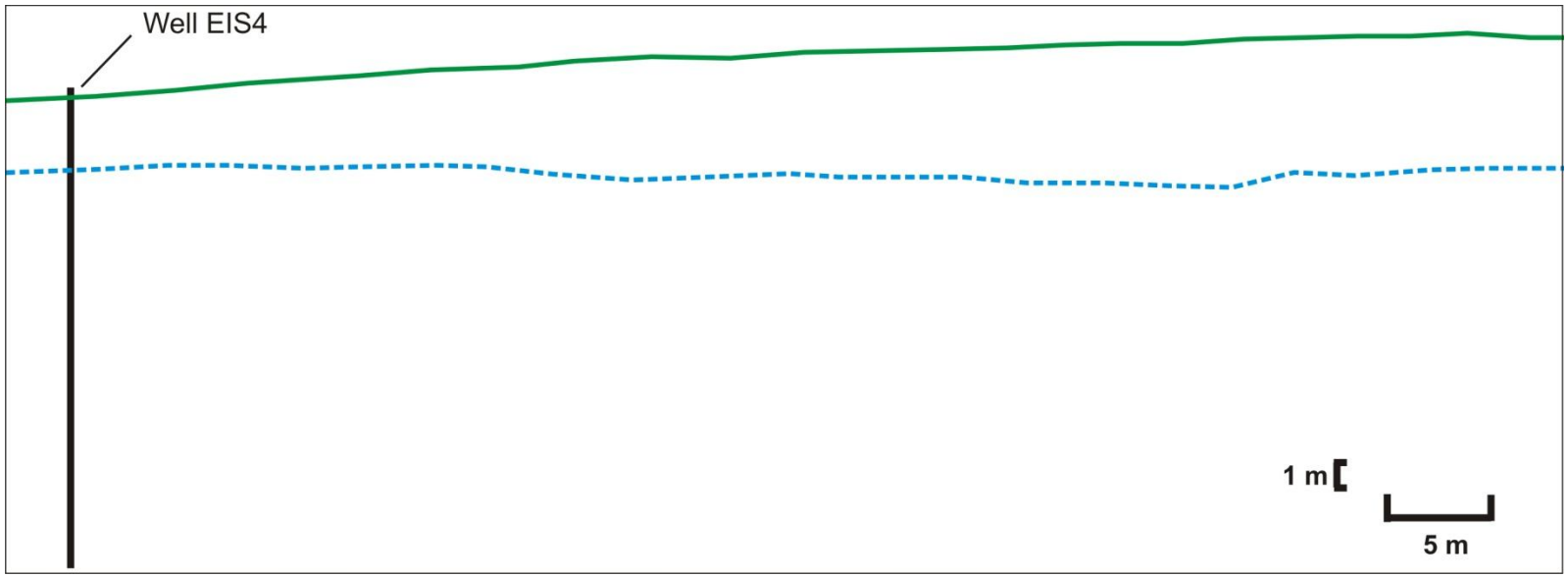
1 m
5 m

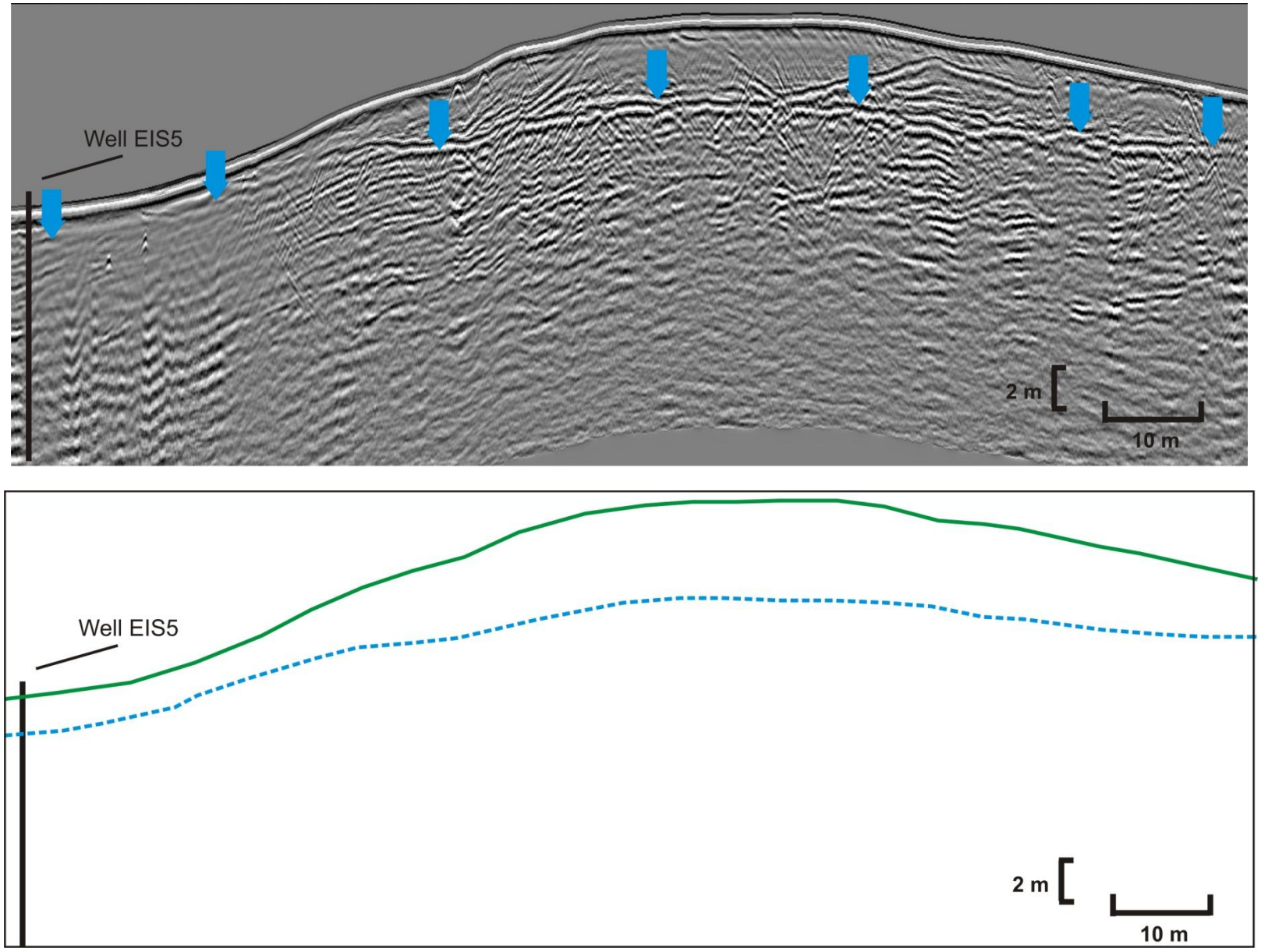

Well EIN4
1 m
5 m


Well EIN5
1 m
5 m
Well EIN5
1 m
5 m

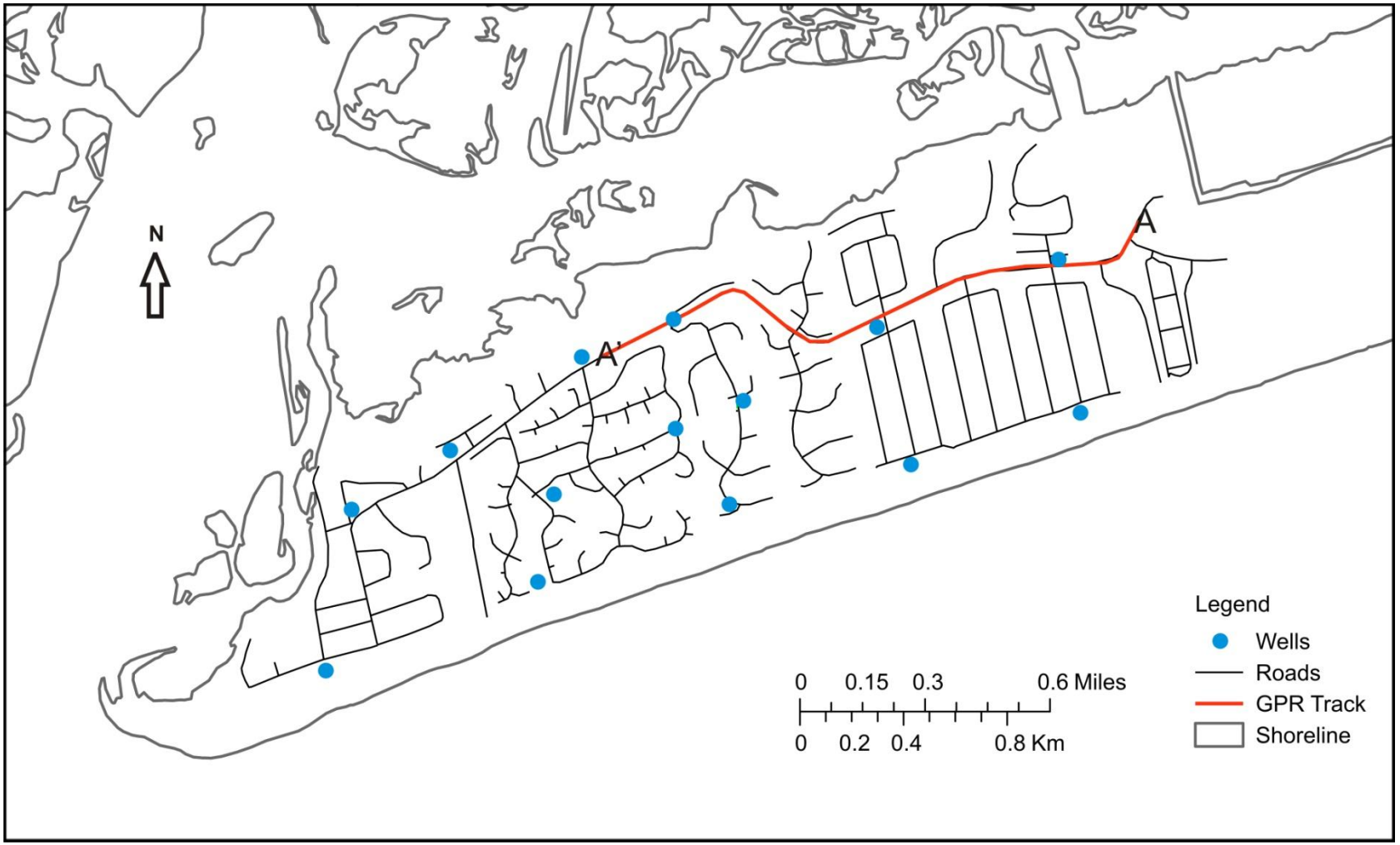

Well EIN6
1 m
5 m
Well EIN6
1 m
5 m

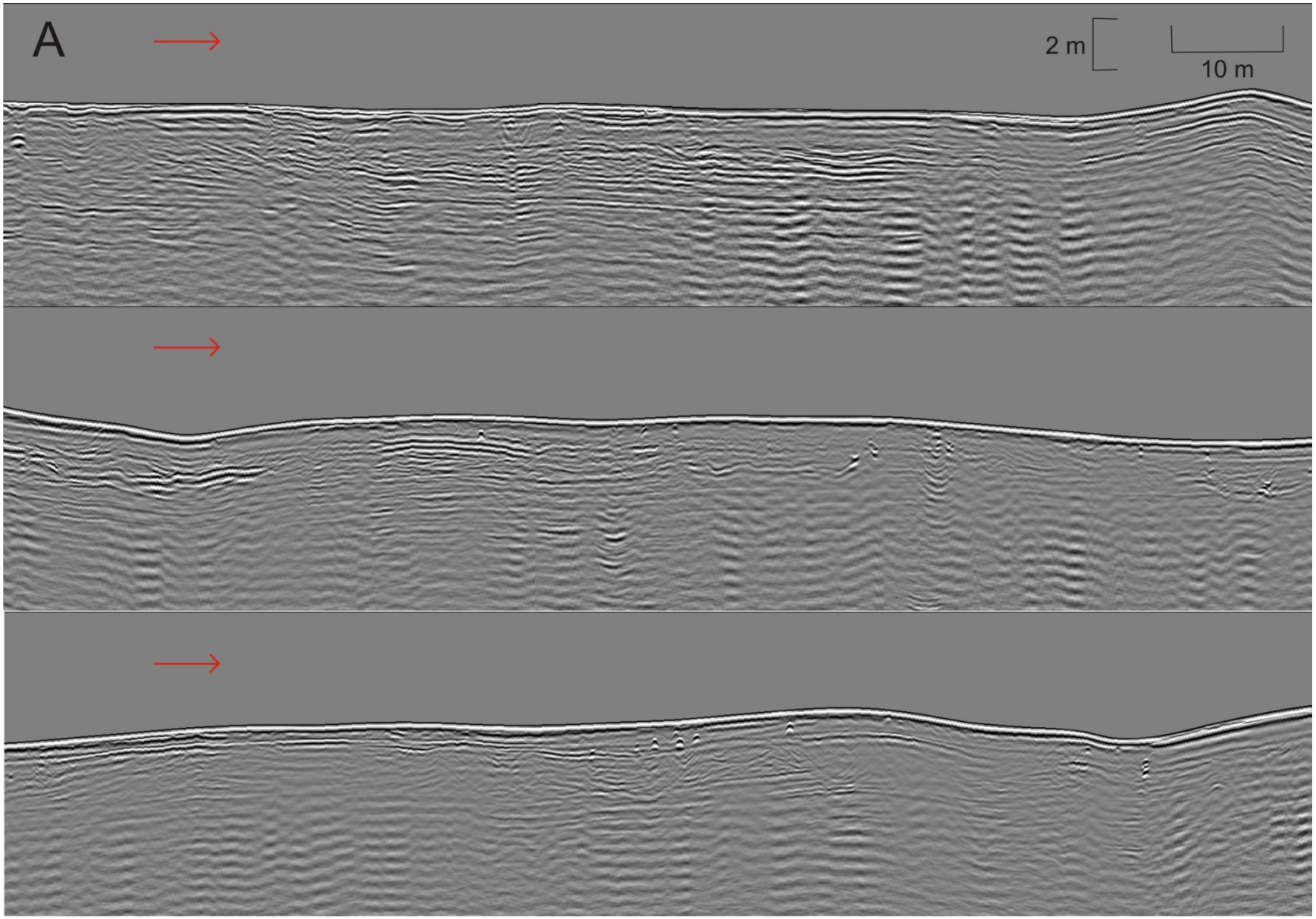

Well EIS4
1 m
5 m

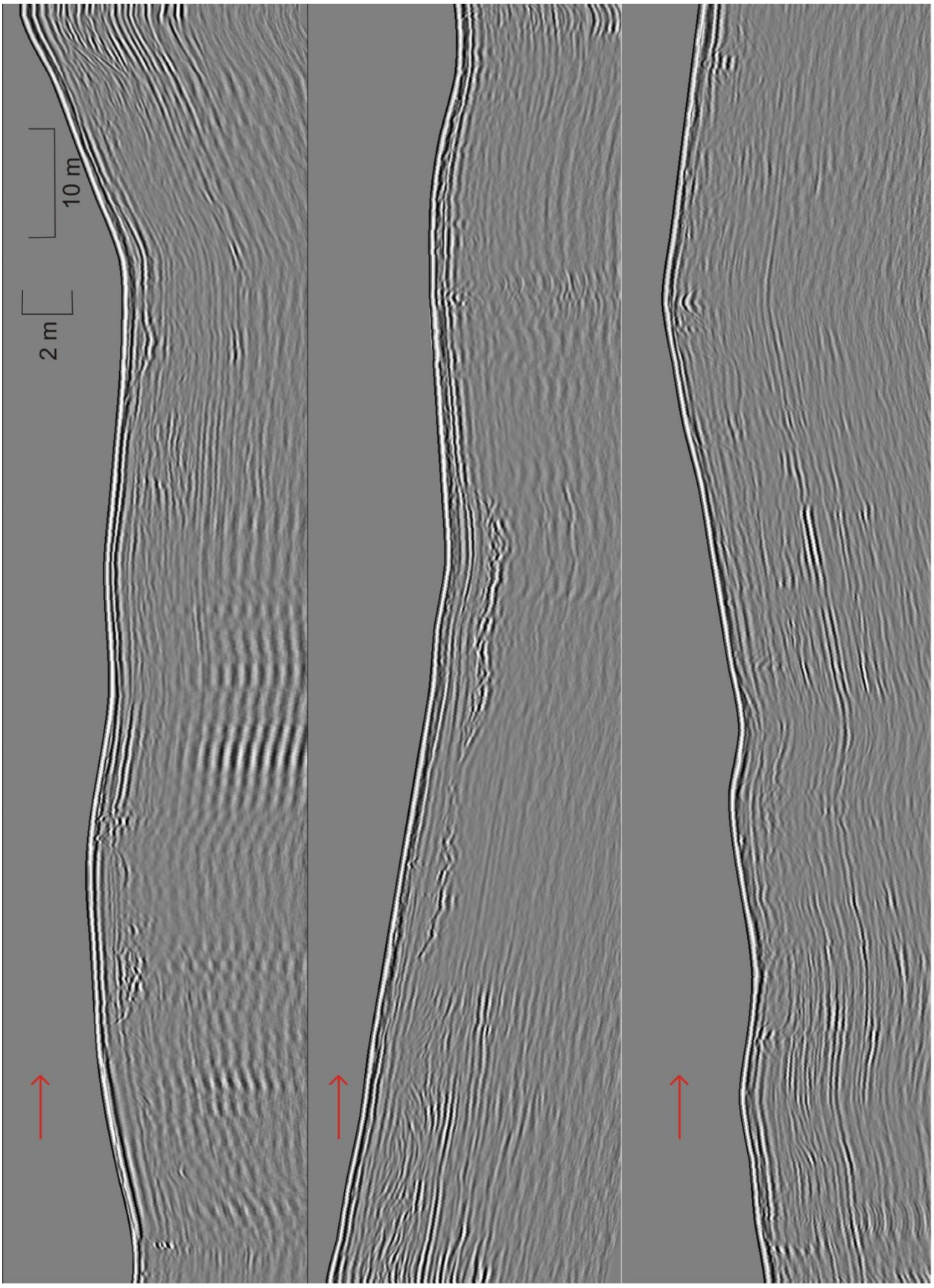

Well EIS4
1 m
5 m

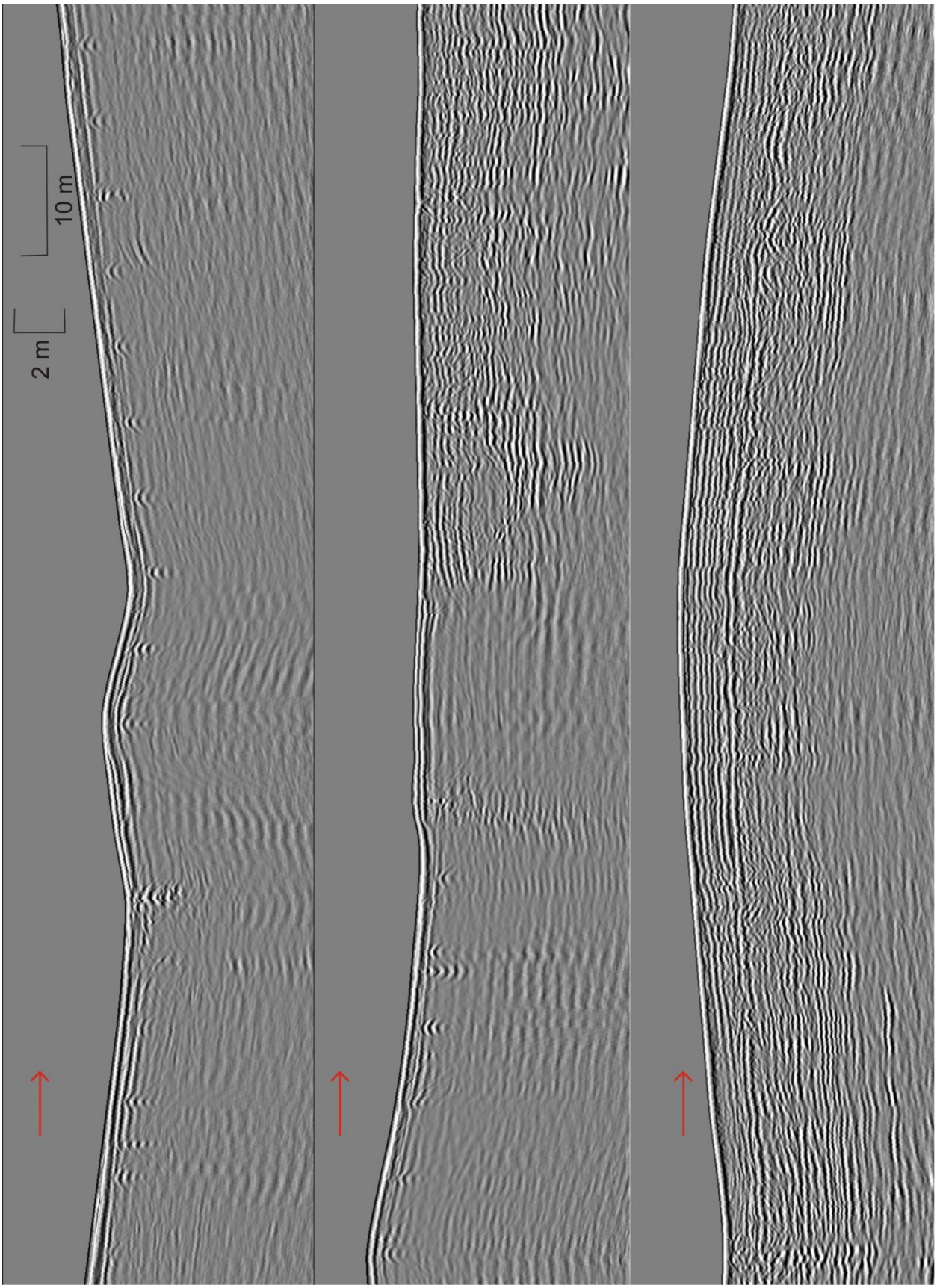

Well EIS5
2 m
10 m
Well EIS5
2 m
10 m

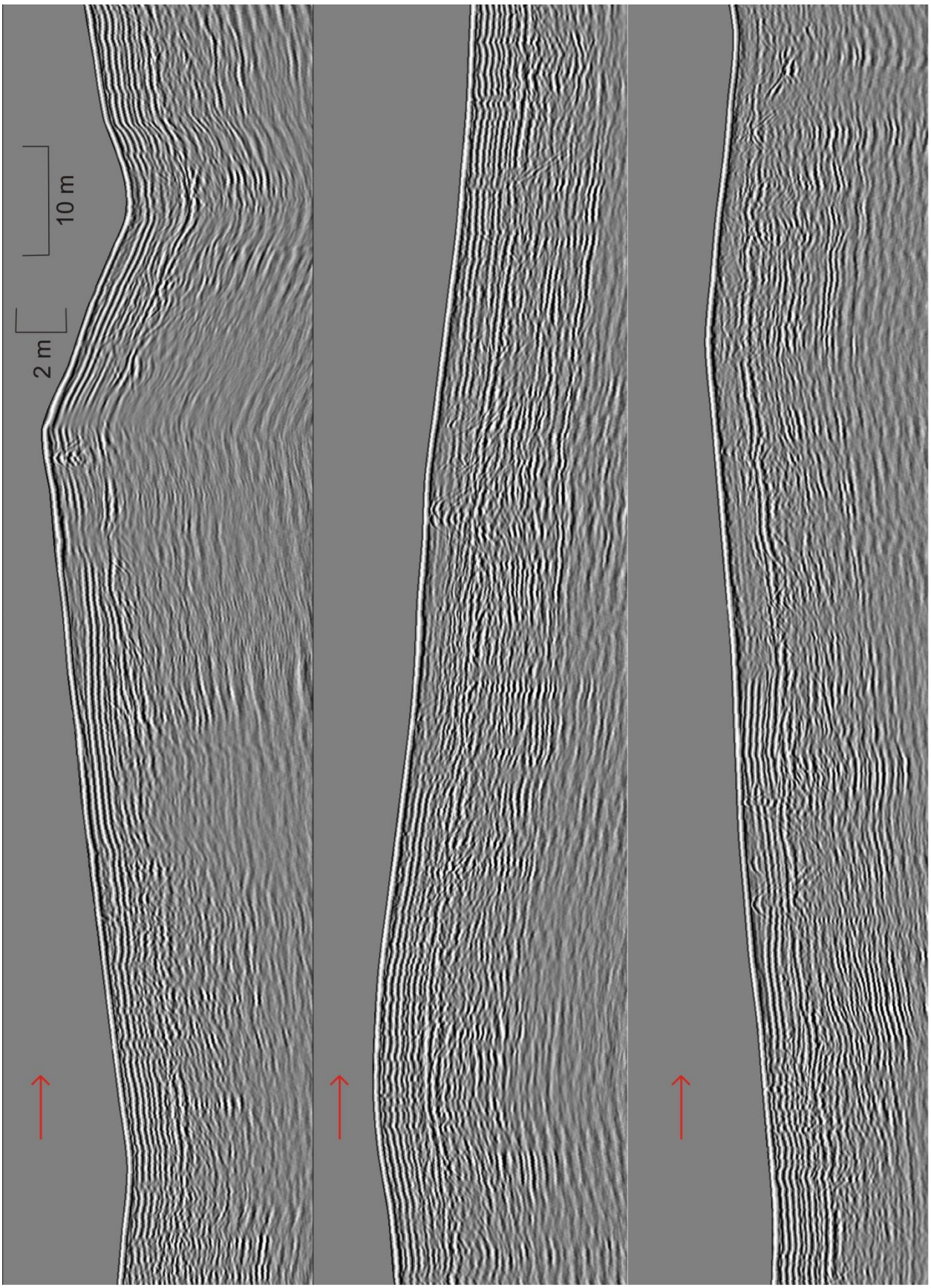
Line #1: A – A’

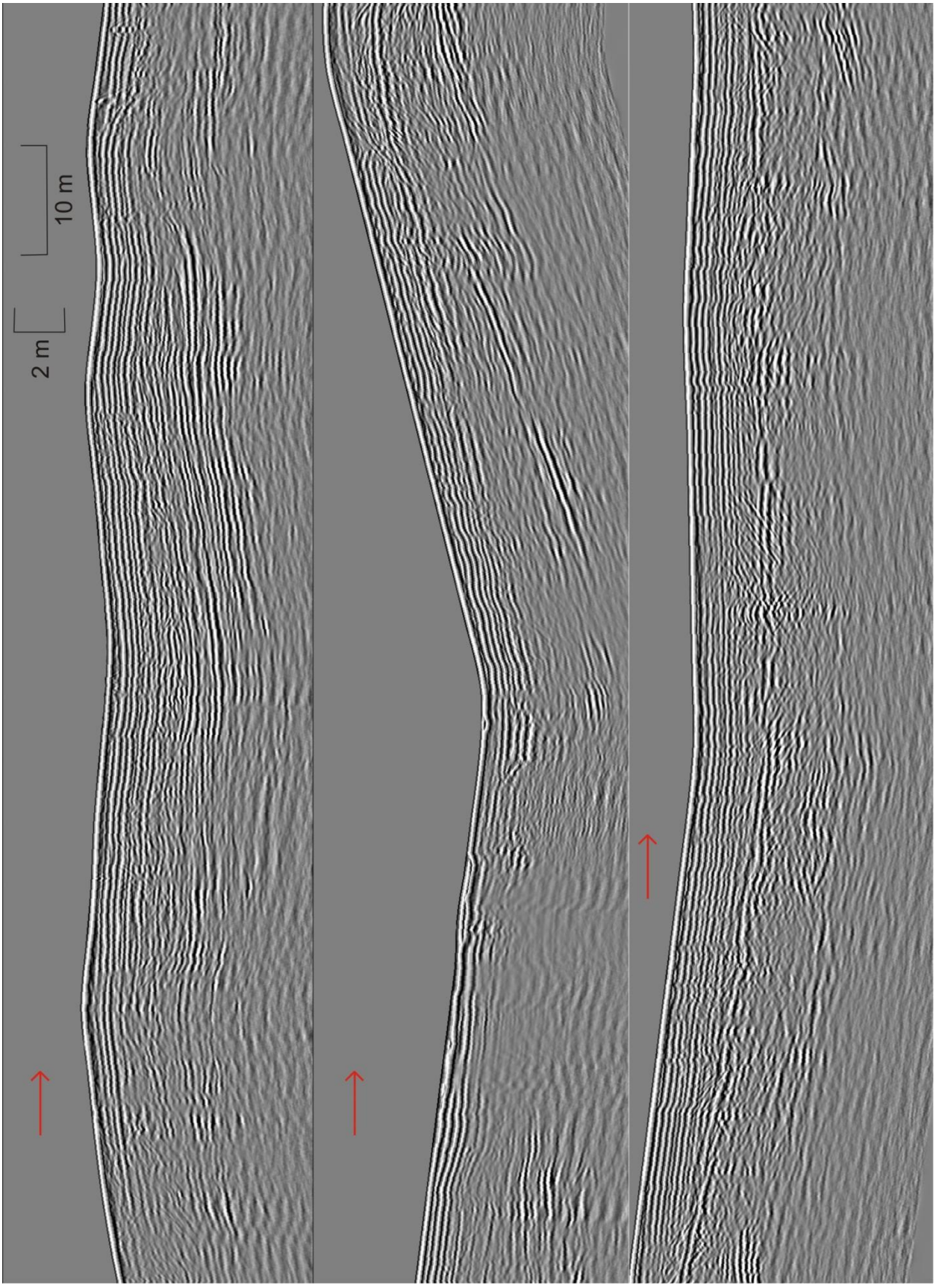

N
A
A'
0 0.15 0.3 0.6 Miles
0 0.2 0.4 0.8 Km
Legend
Wells
Roads
GPR Track
Shoreline

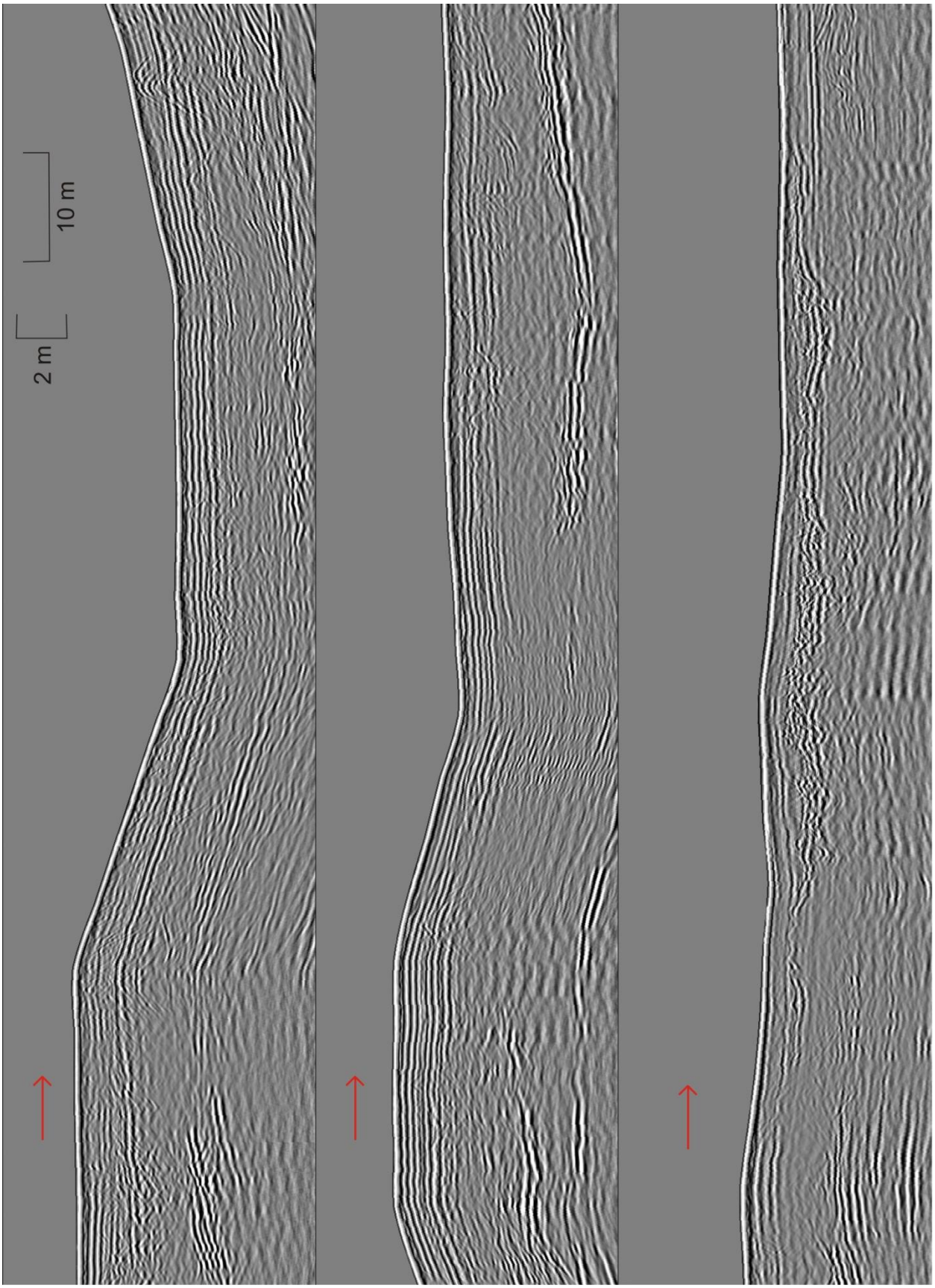

A
2 m
10 m

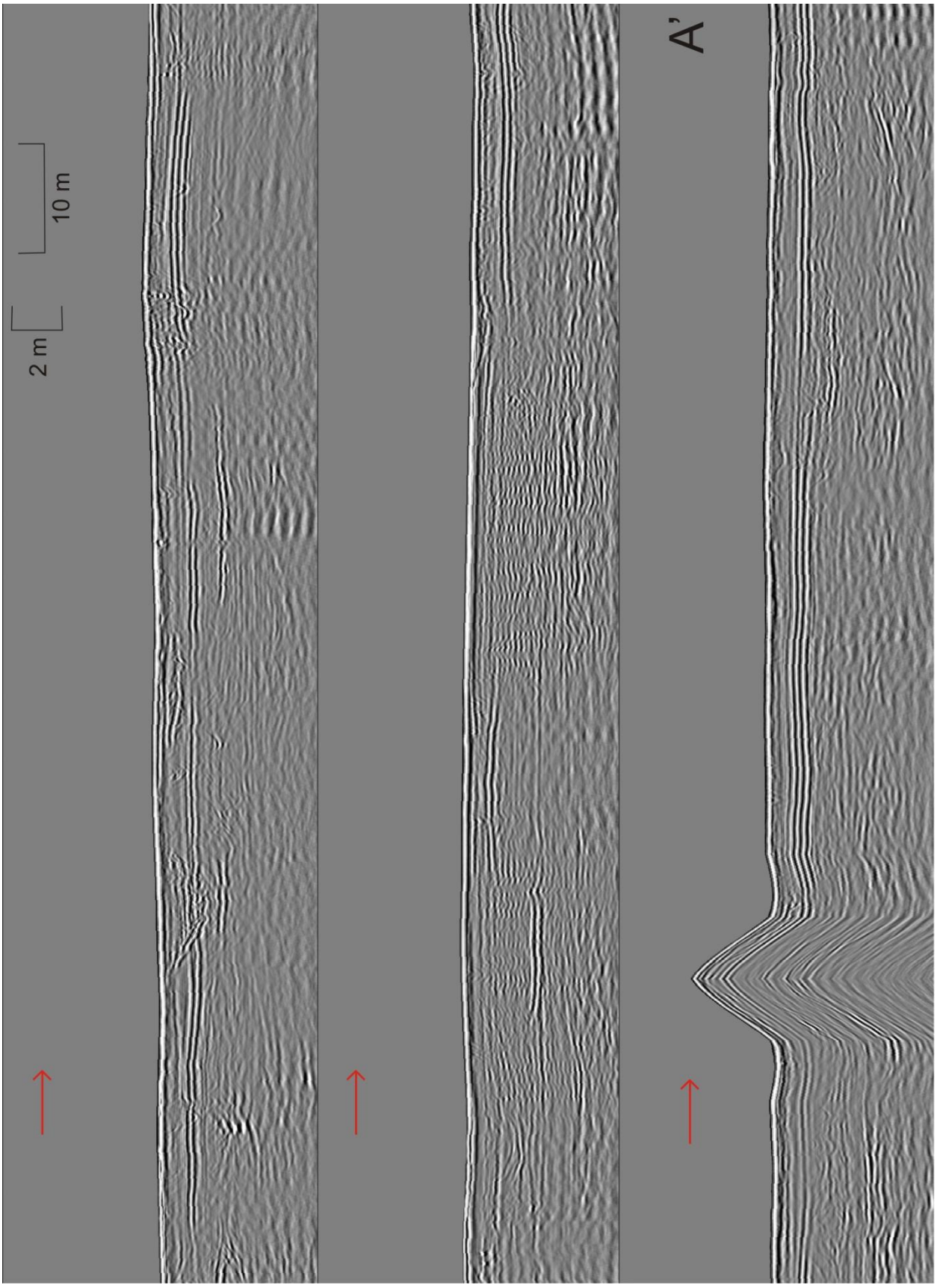

10 m
2 m


10 m
2 m

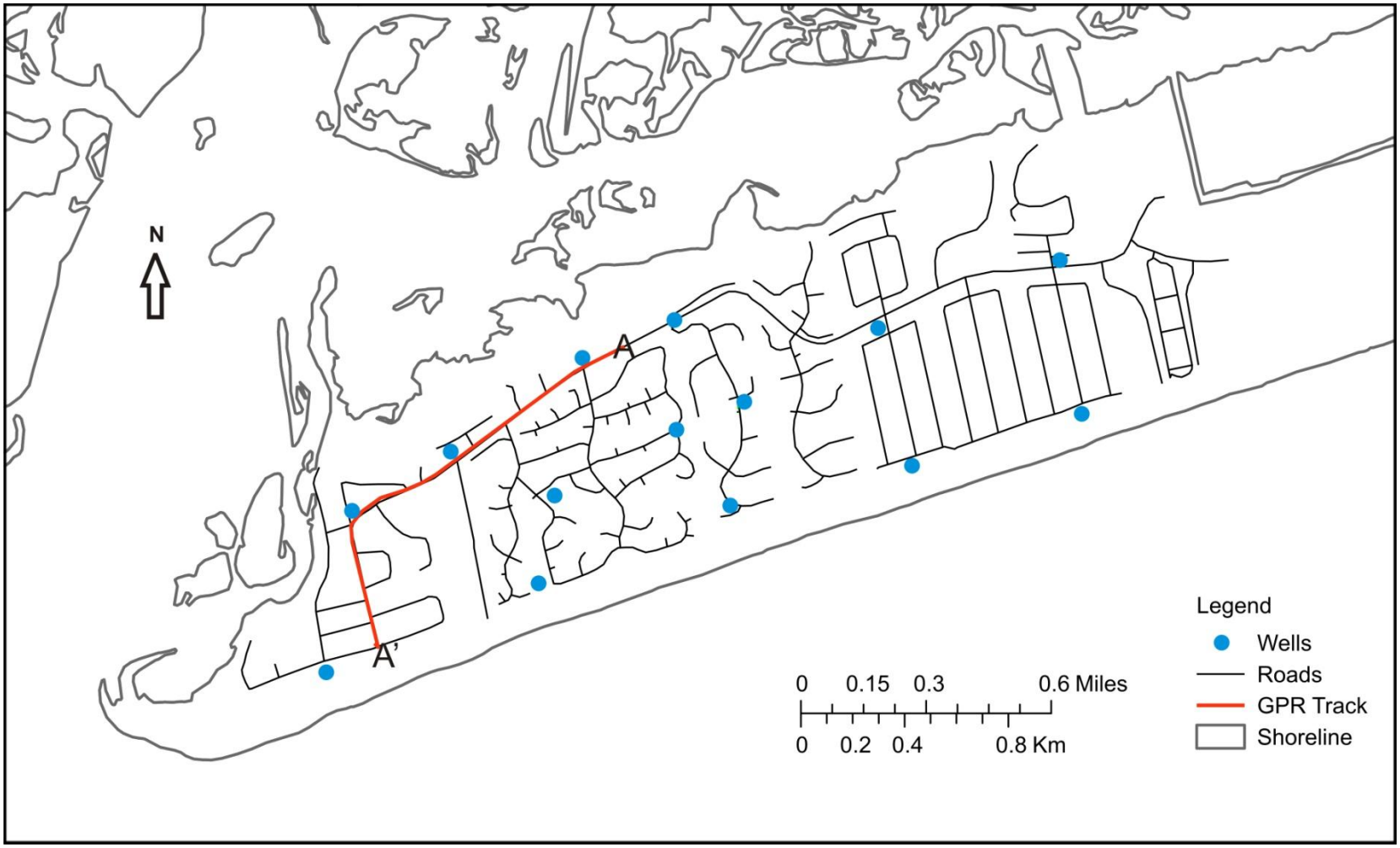

10 m
2 m

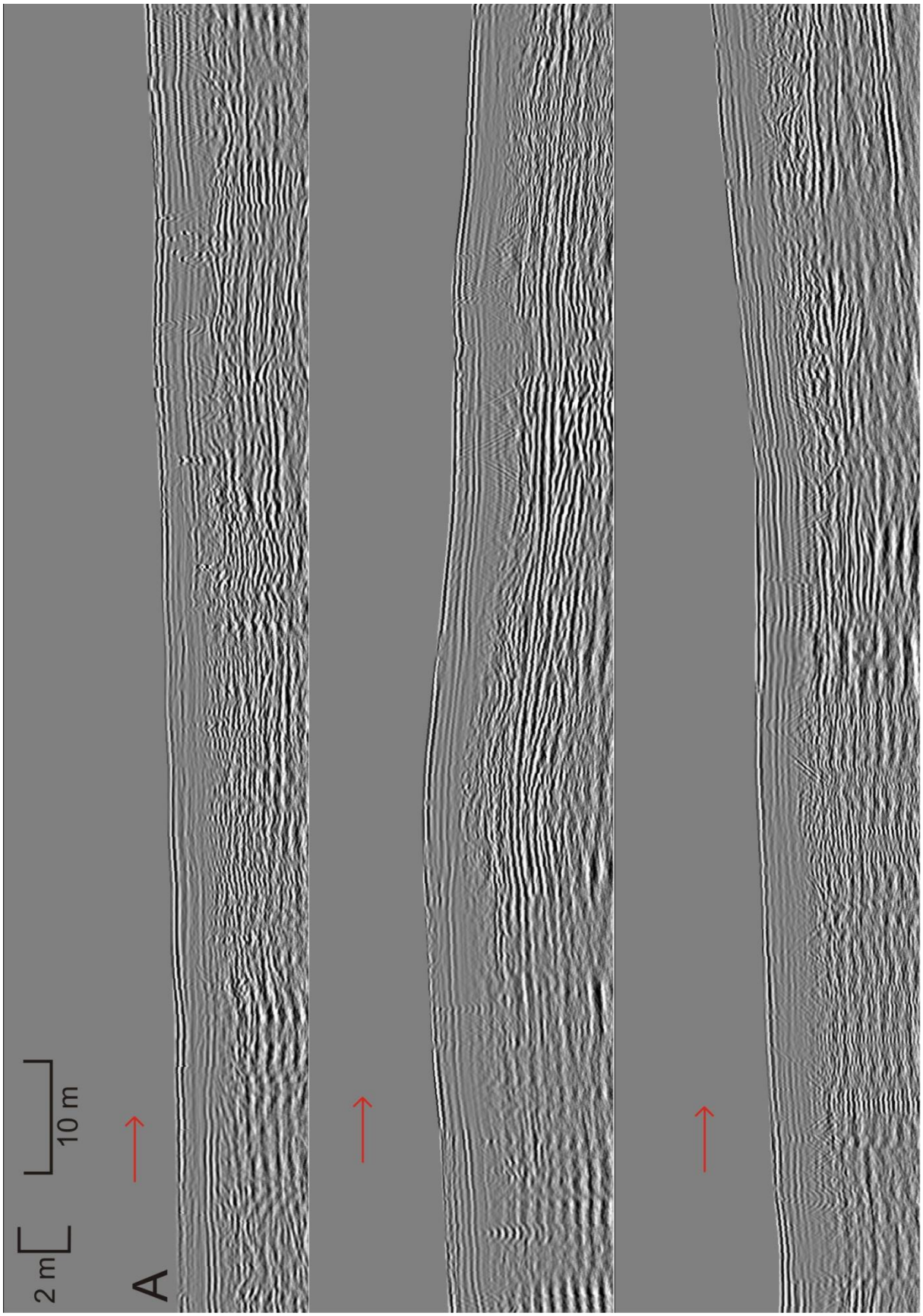

10 m
2 m

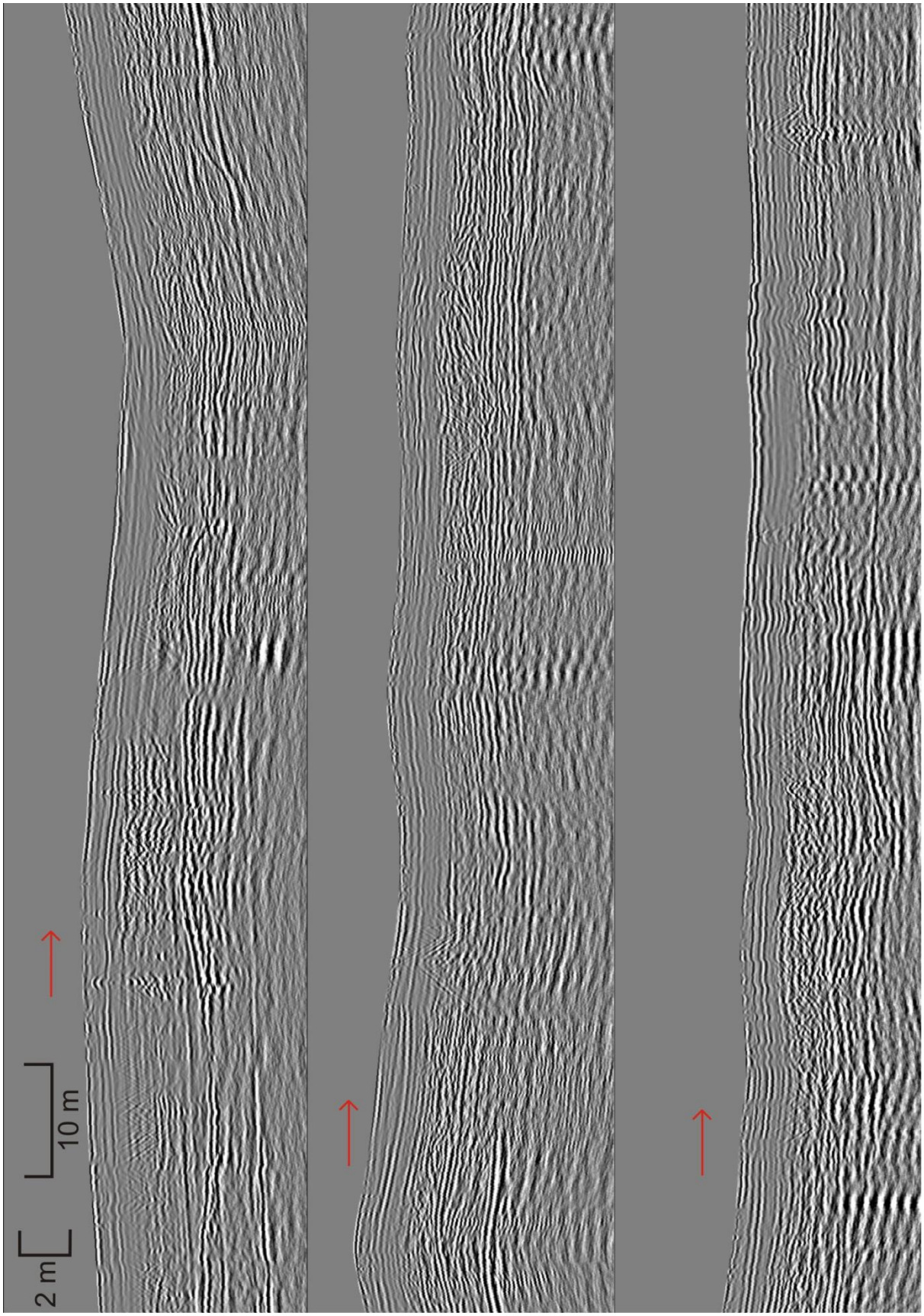

10 m
2 m

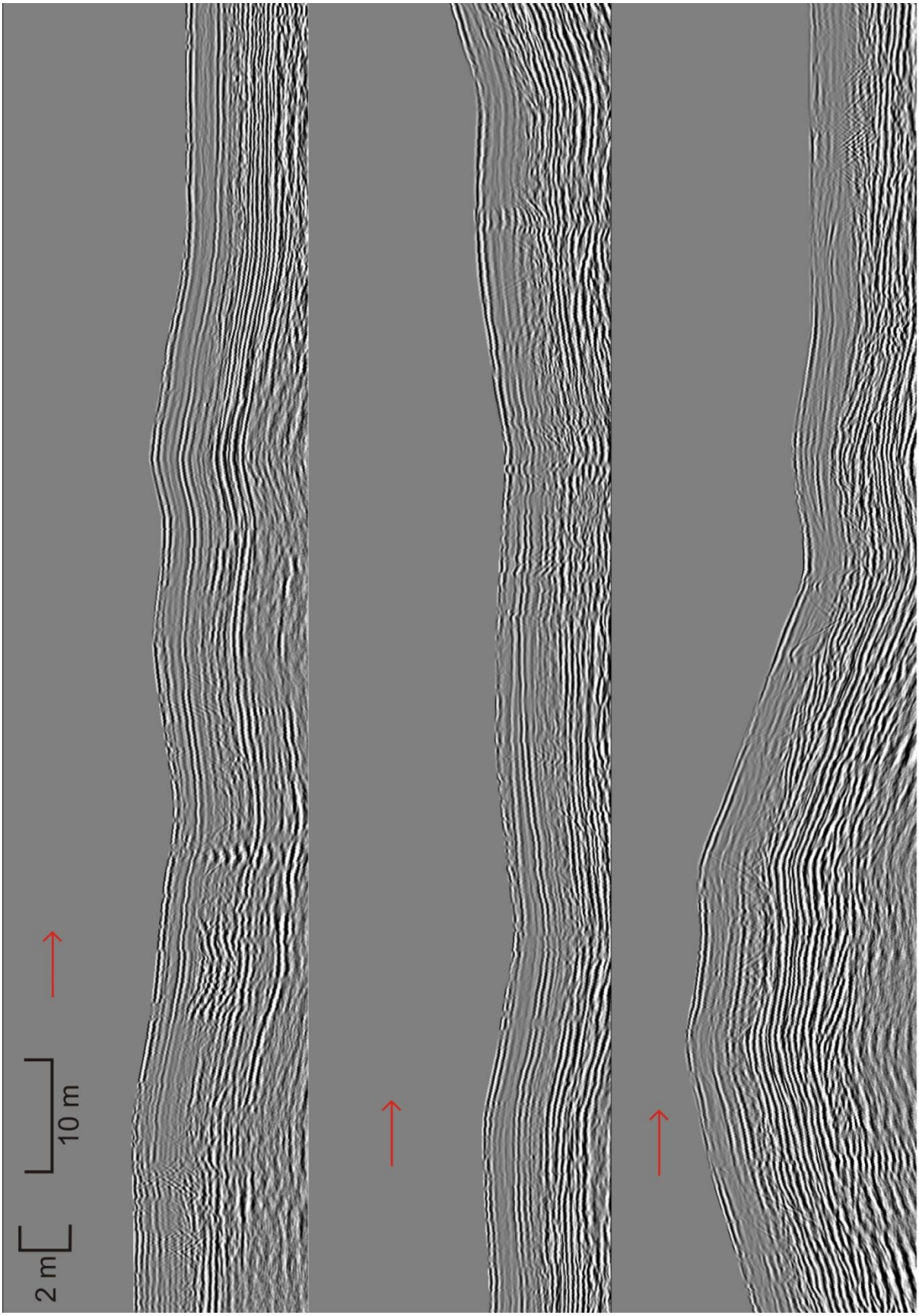

10 m
2 m
A'

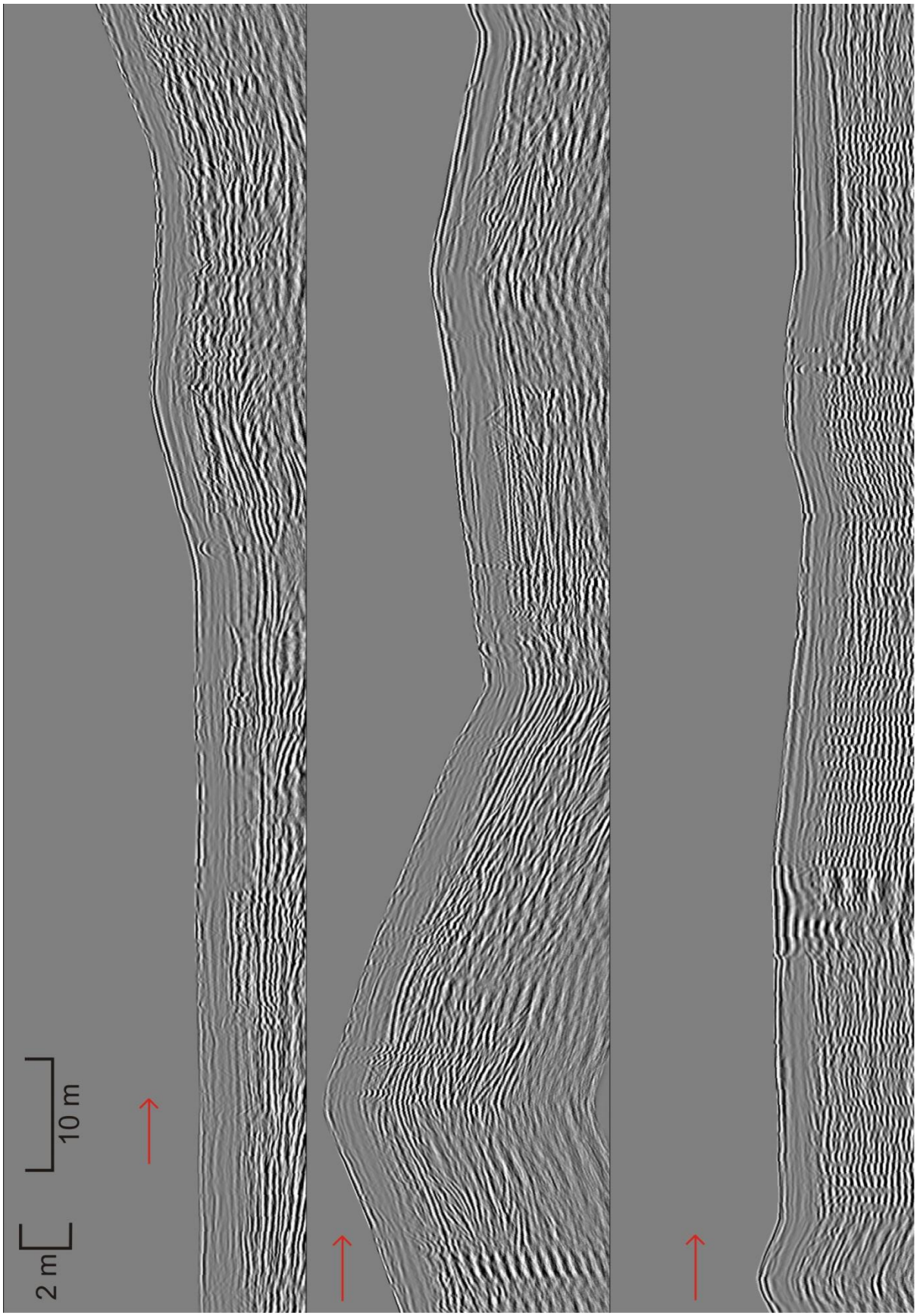
Line #2: A – A’

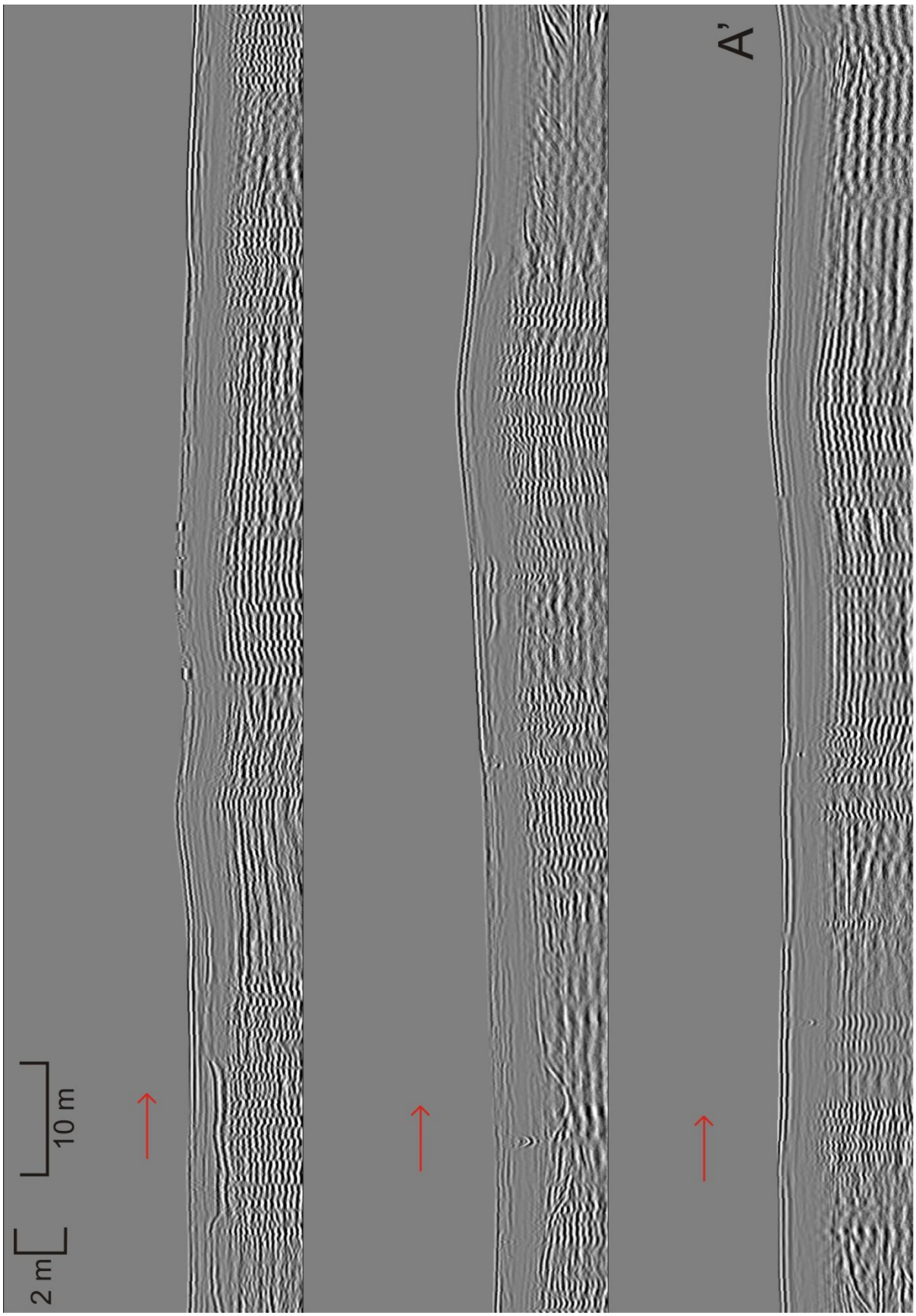

N
A
A’
0 0.15 0.3 0.6 Miles
0 0.2 0.4 0.8 Km
Legend
Wells
Roads
GPR Track
Shoreline


A
2 m
10 m

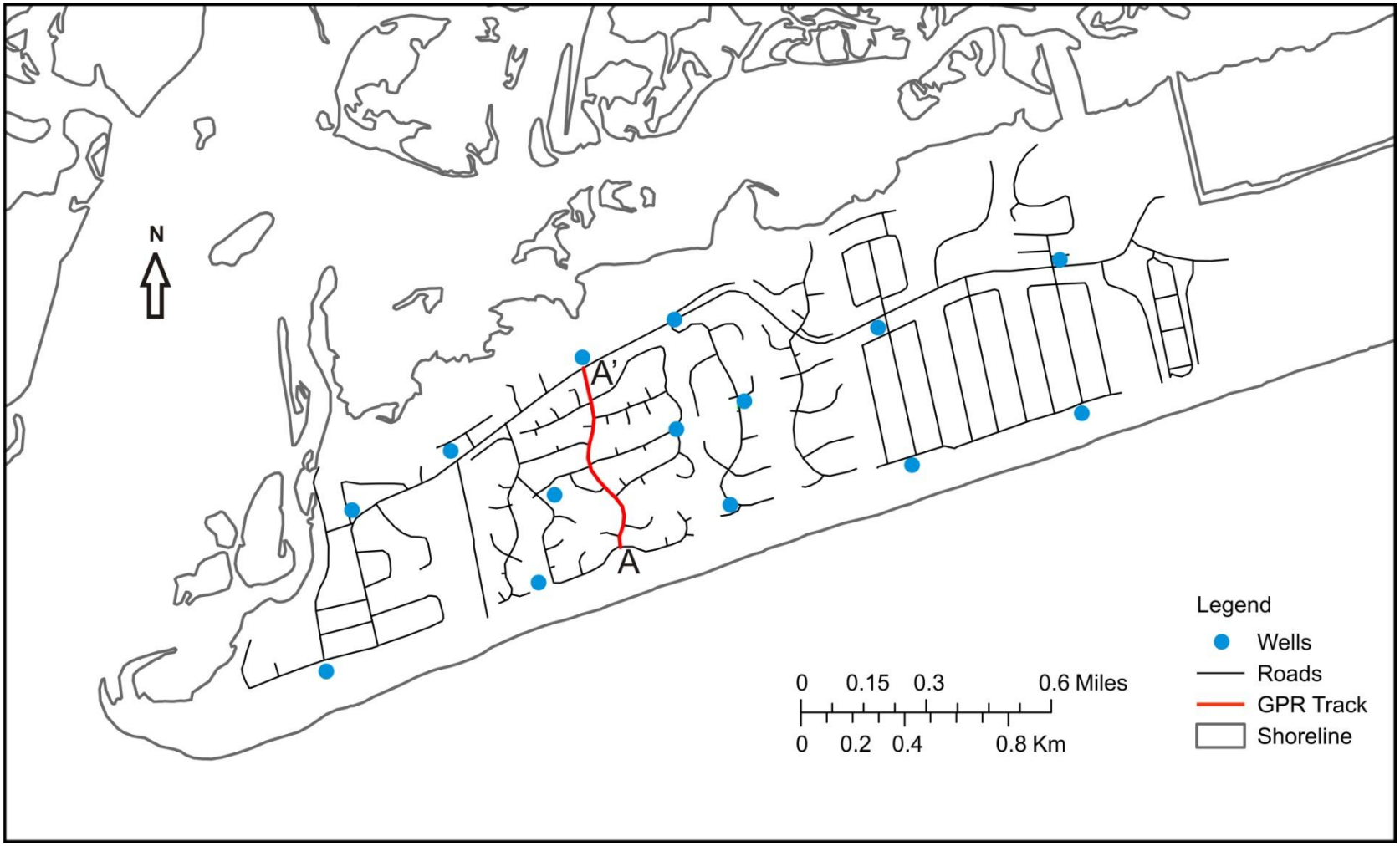

10 m
2 m

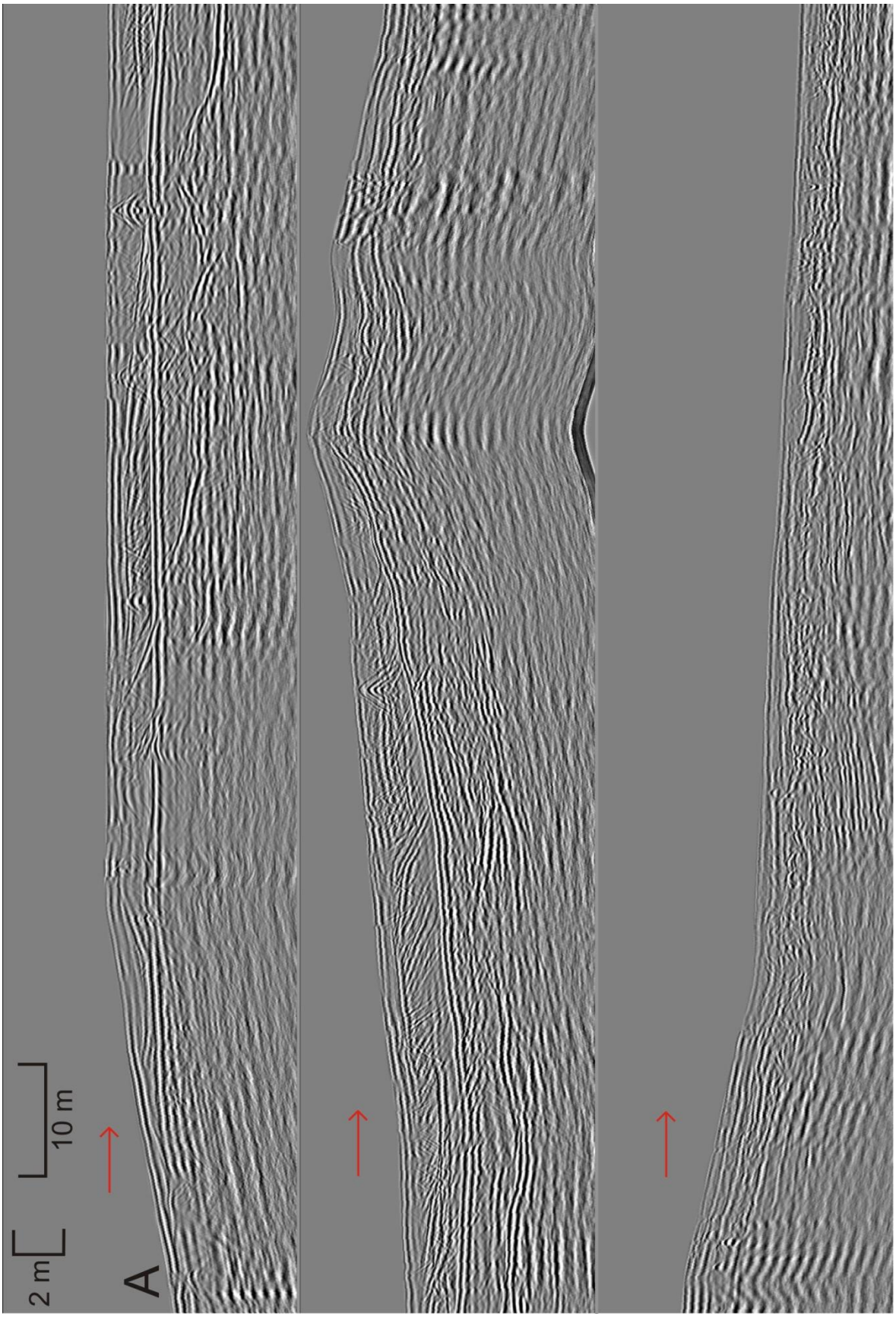

10 m
2 m

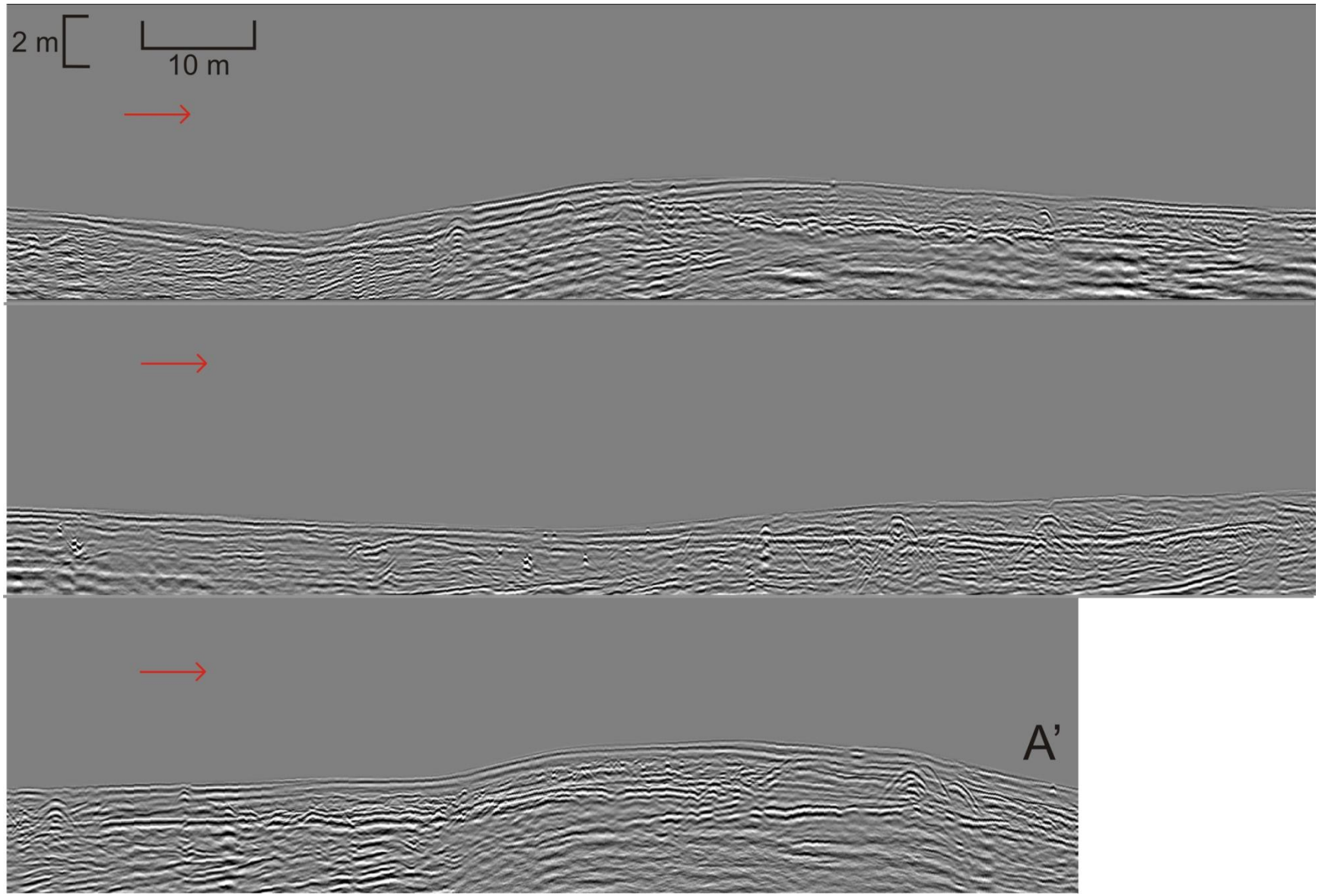

10 m
2 m


A'
10 m
2 m

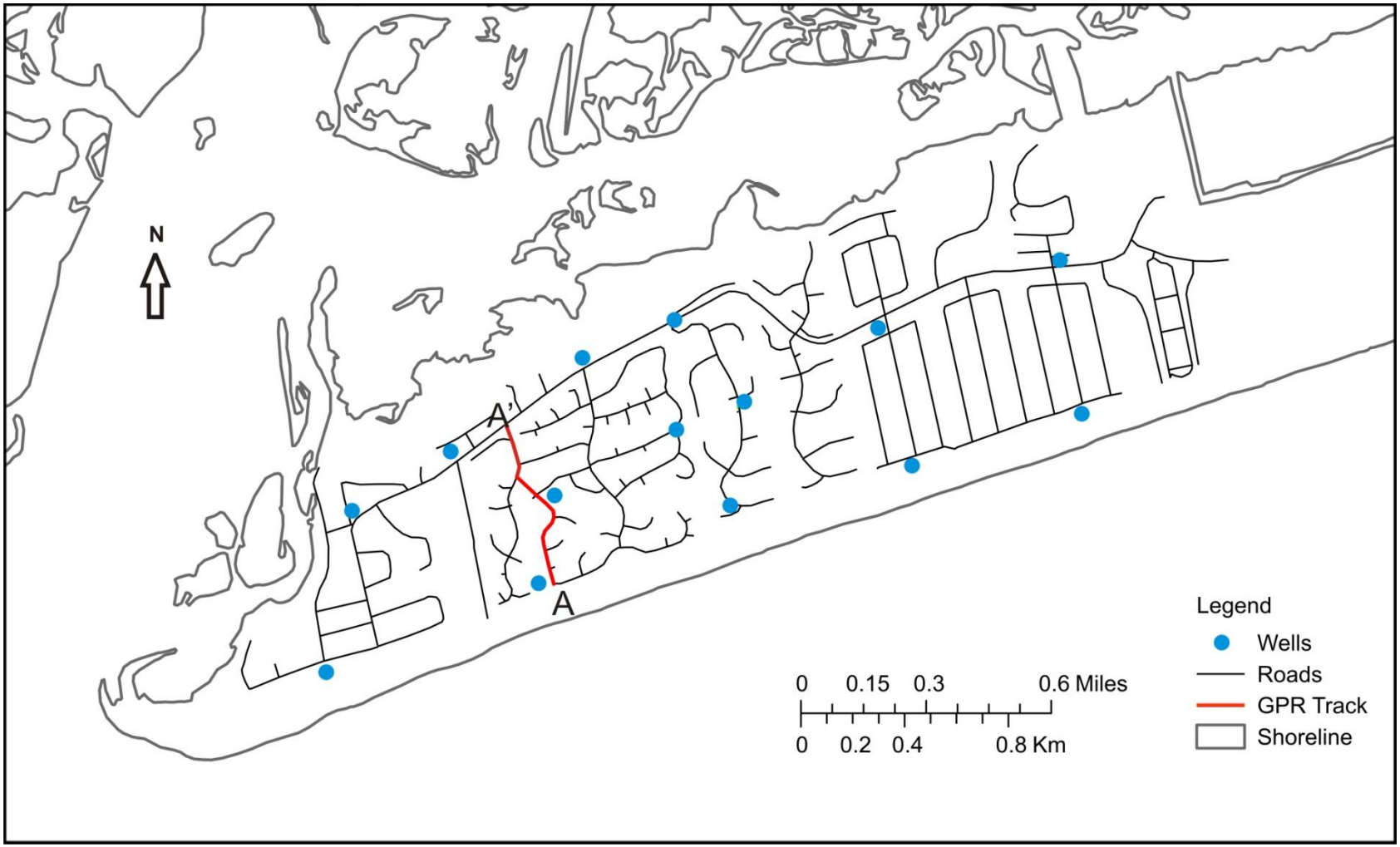
Line #3: A – A’

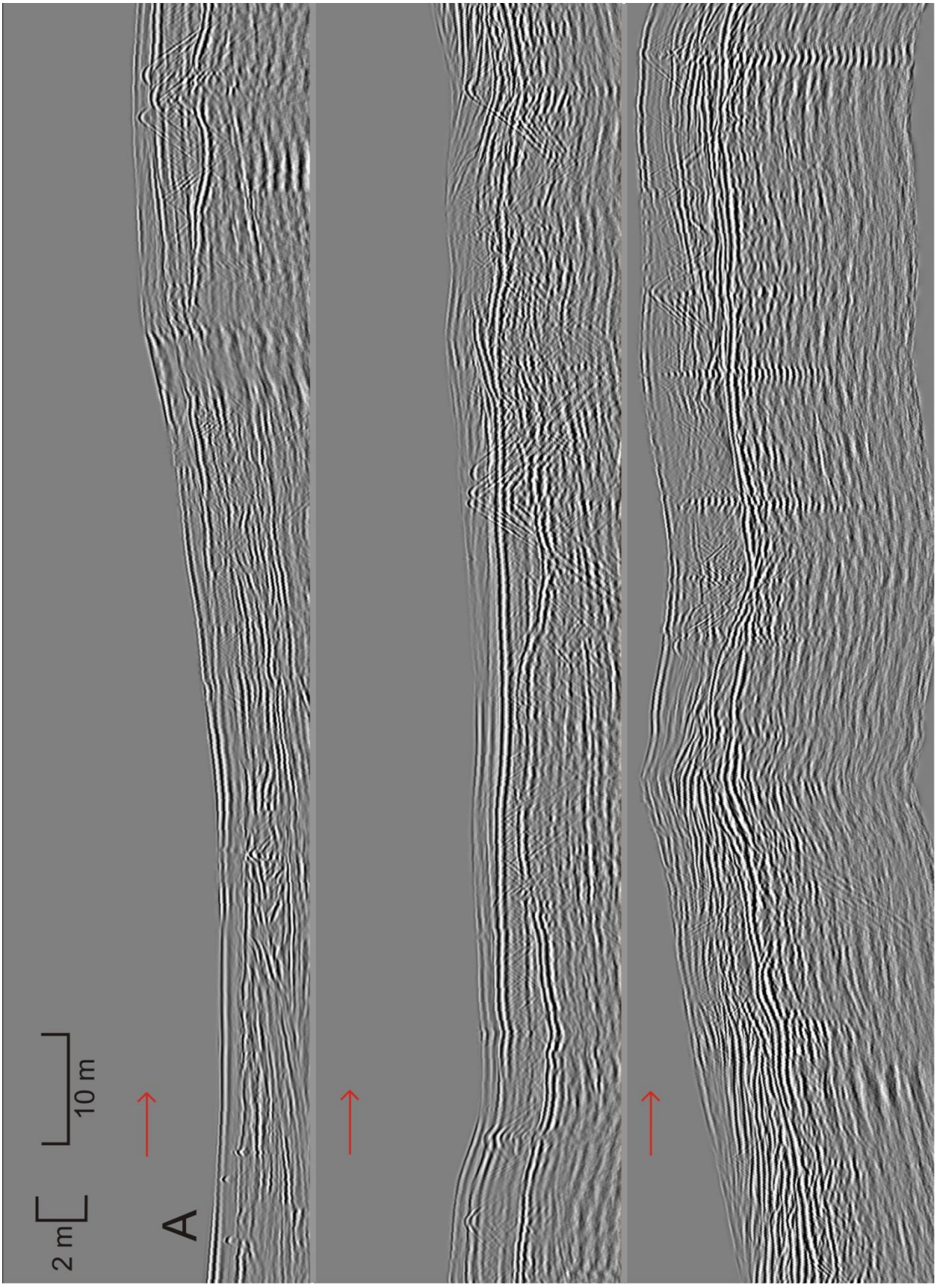

N
A’
A
0 0.15 0.3 0.6 Miles
0 0.2 0.4 0.8 Km
Legend
Wells
Roads
GPR Track
Shoreline

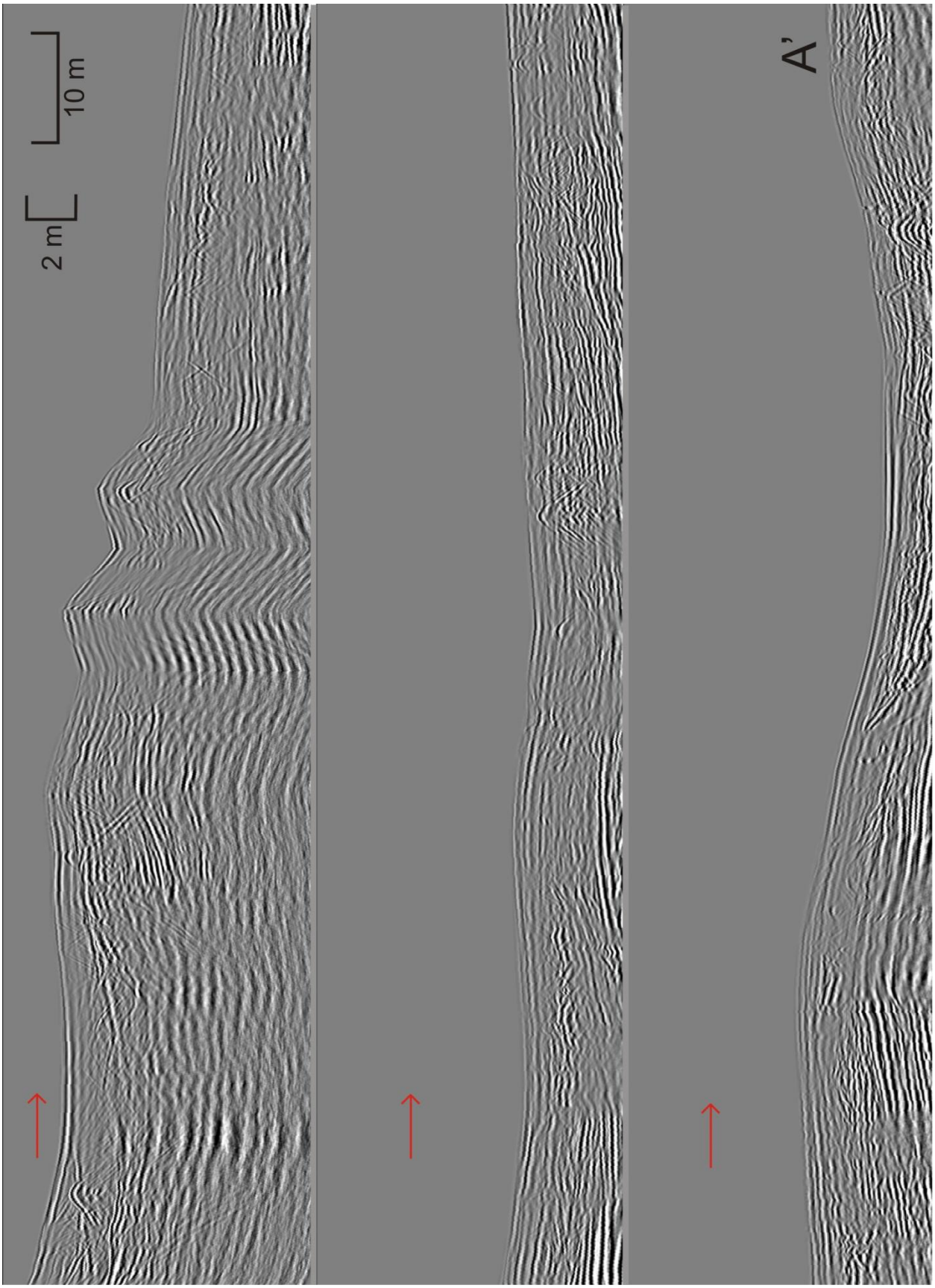

A
2 m
10 m


2 m
10 m
A’

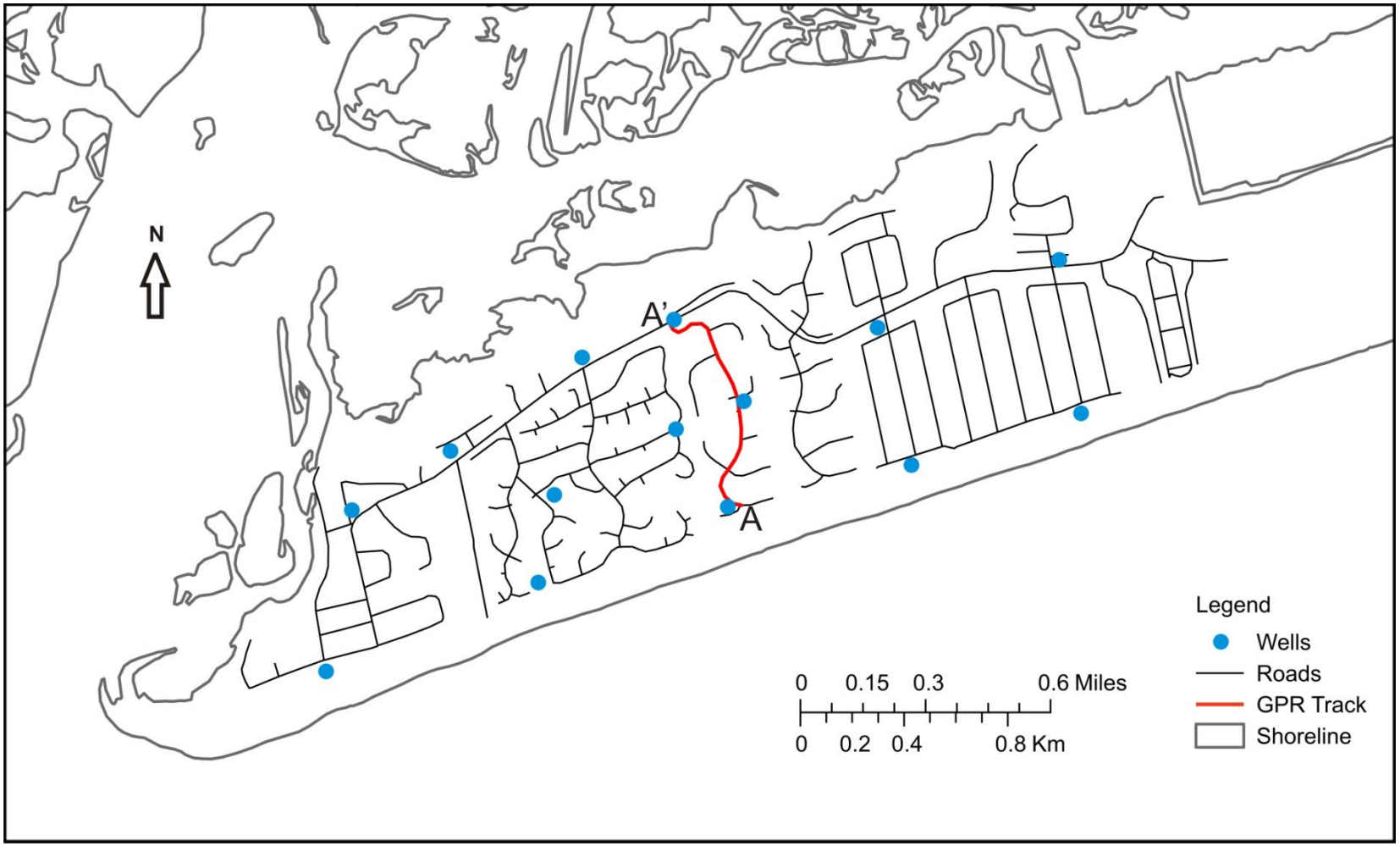
Line #4: A – A’

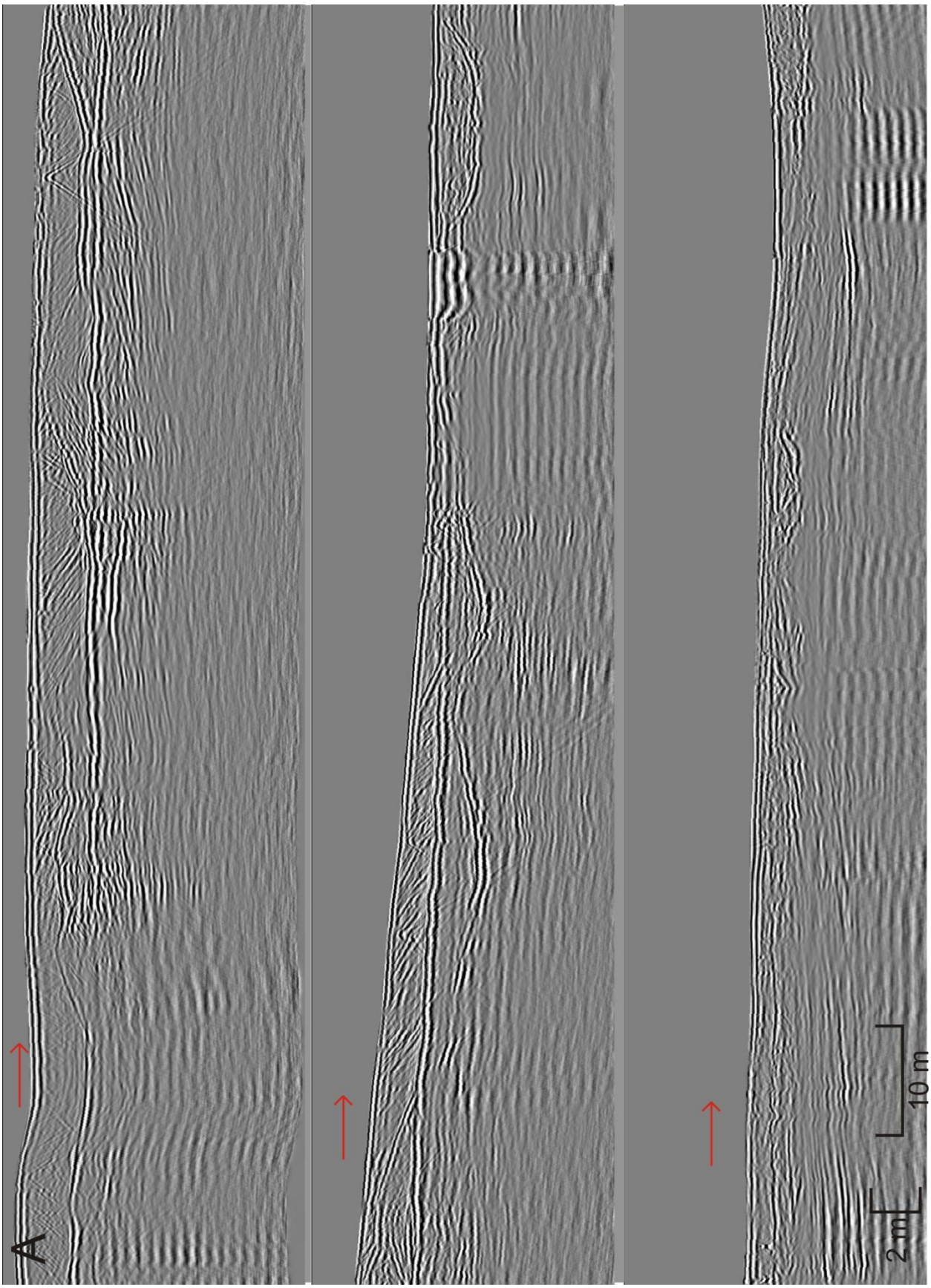

N
A’
A
0 0.15 0.3 0.6 Miles
0 0.2 0.4 0.8 Km
Legend
Wells
Roads
GPR Track
Shoreline

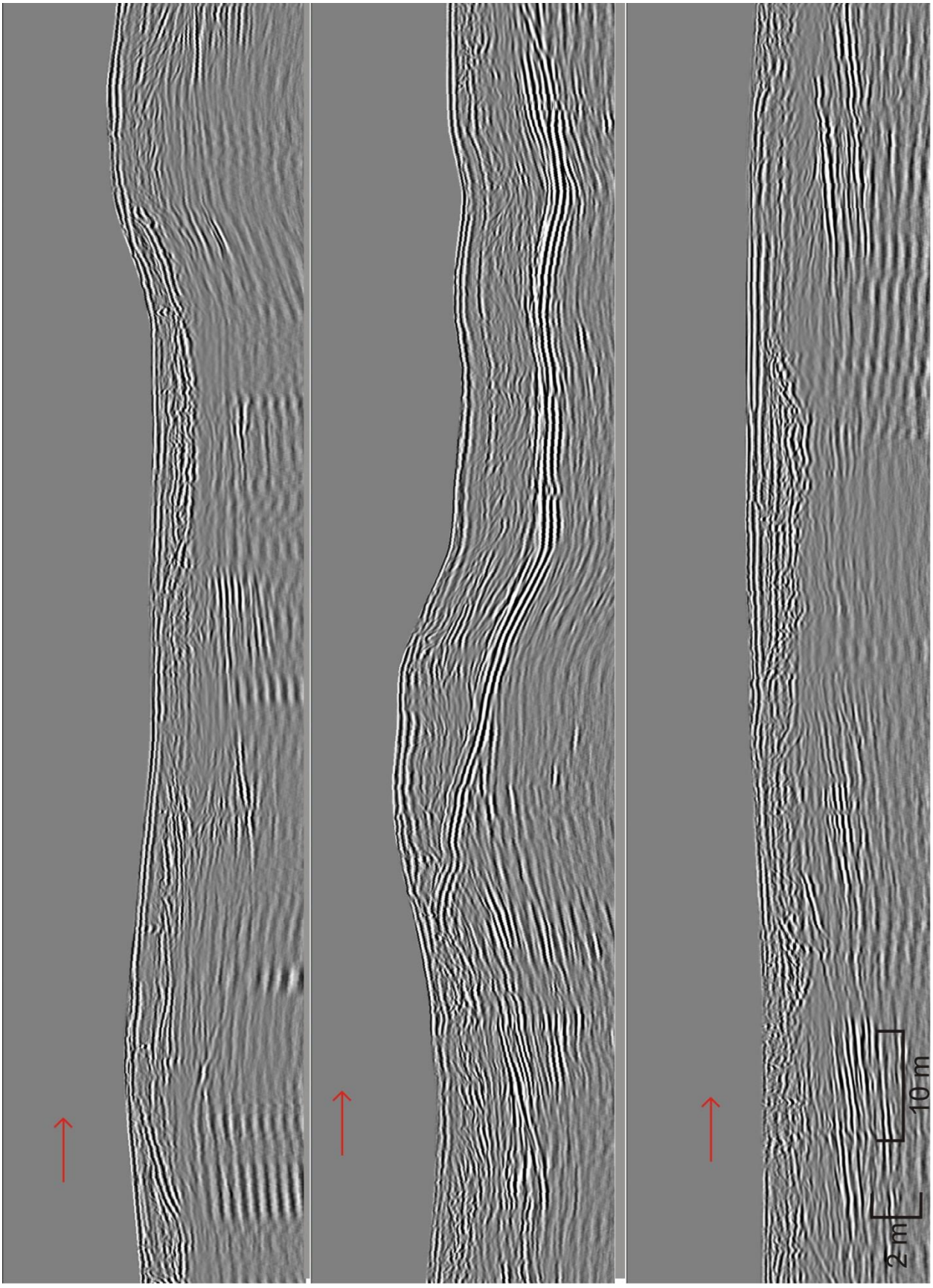

A
2 m
10 m

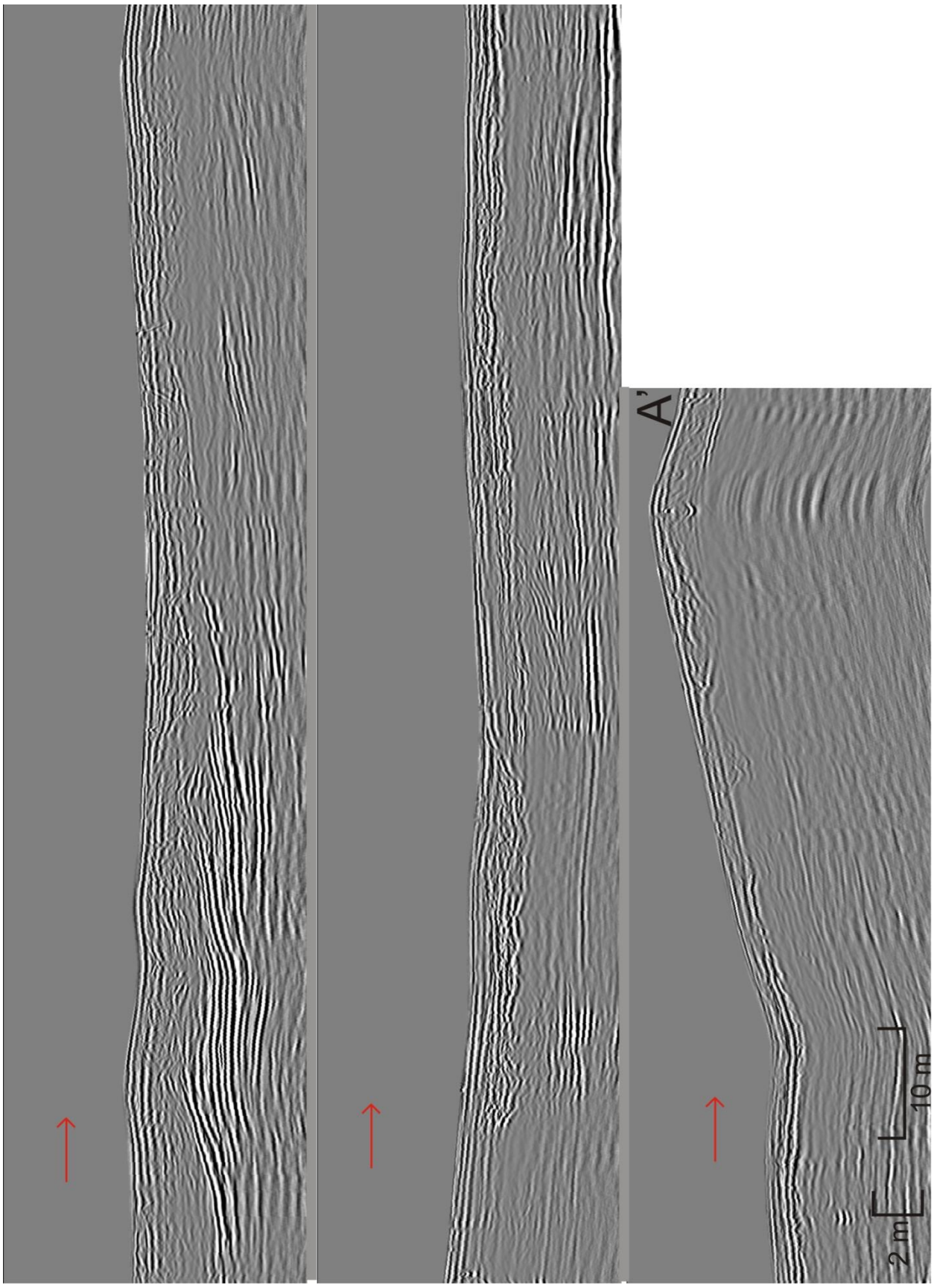

10 m
2 m
A'

Line #5: A – A’

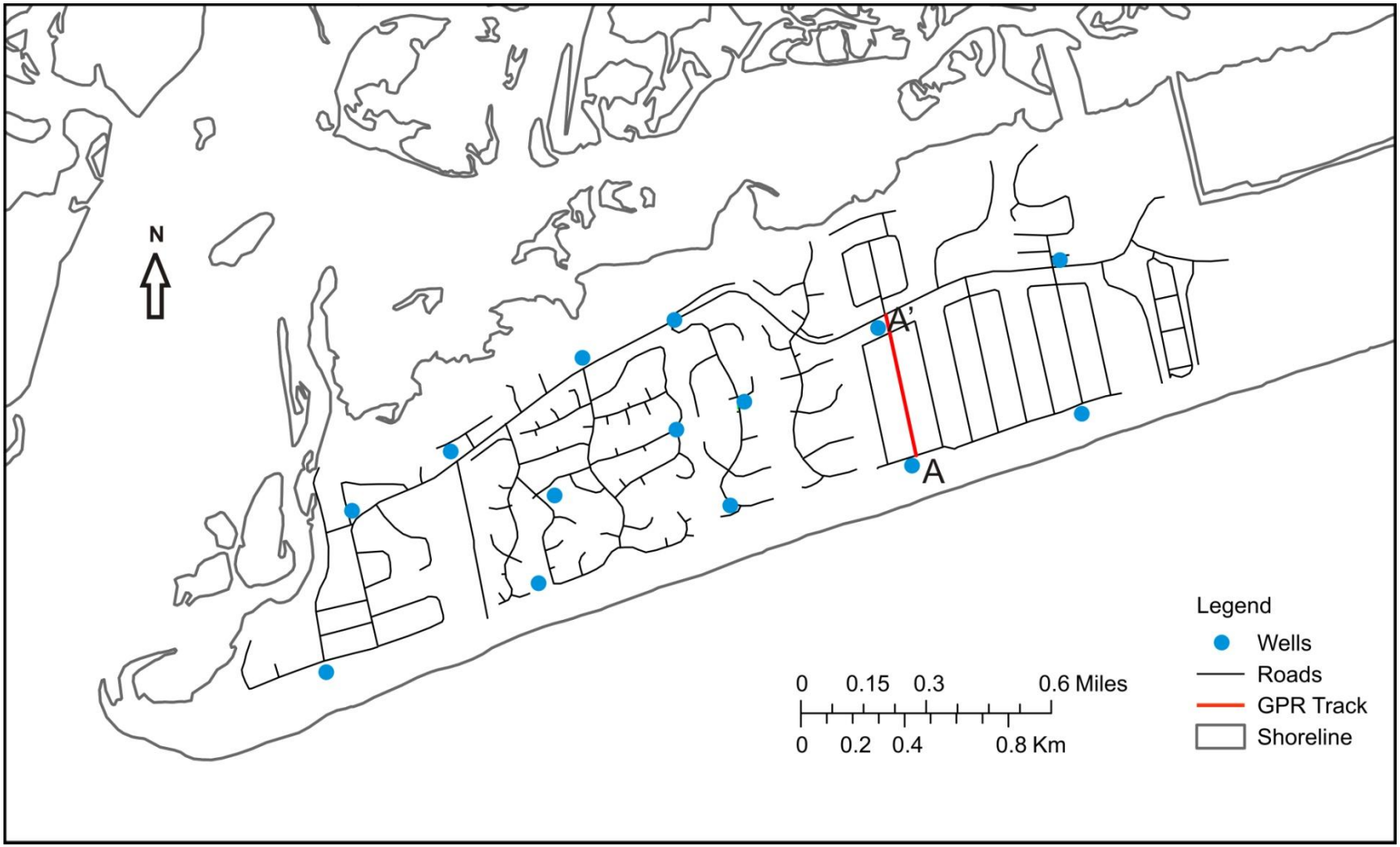

N
A’
A
Legend
Wells
Roads
GPR Track
Shoreline
0 0.15 0.3 0.6 Miles
0 0.2 0.4 0.8 Km

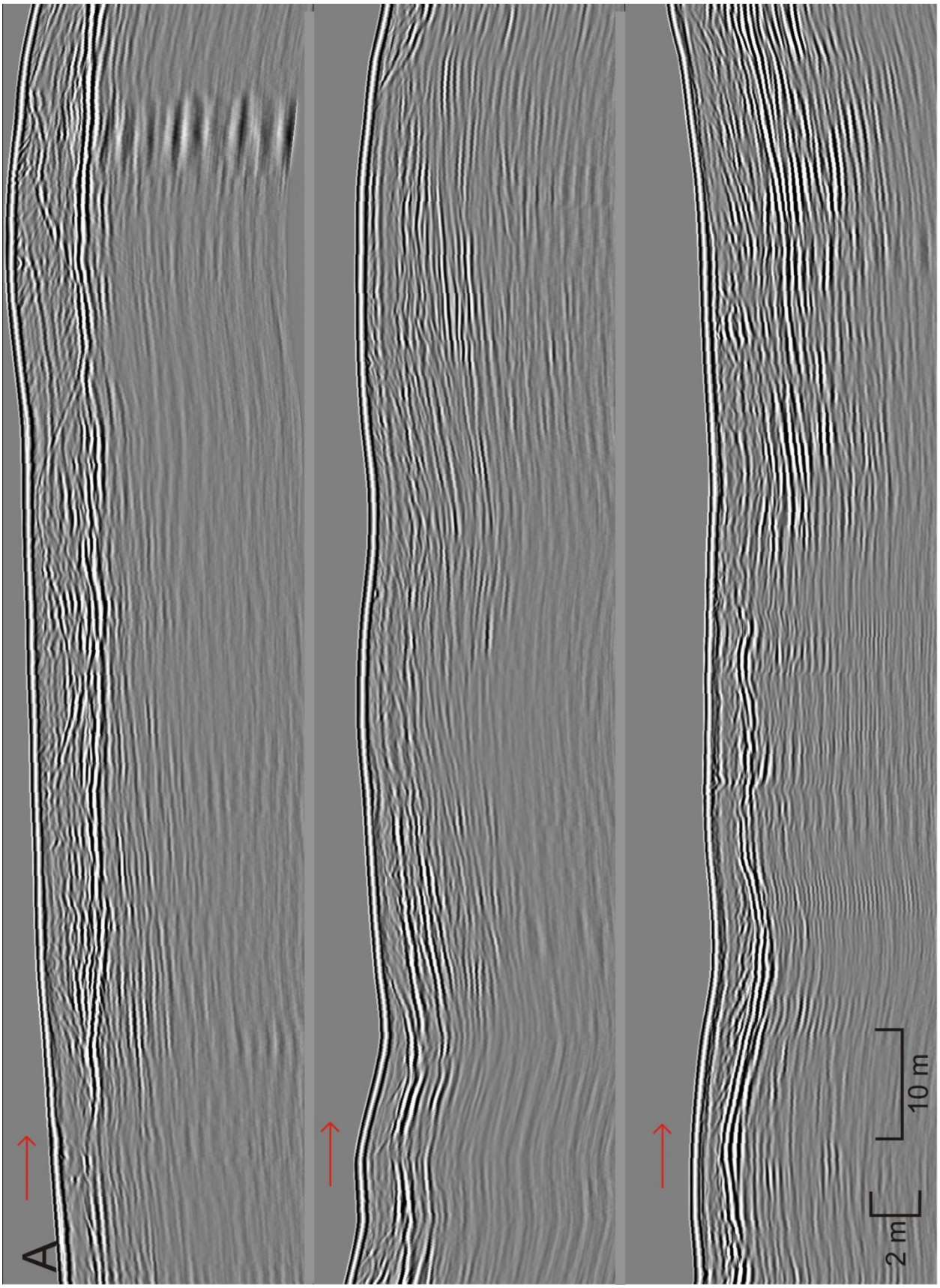

A
10 m
2 m

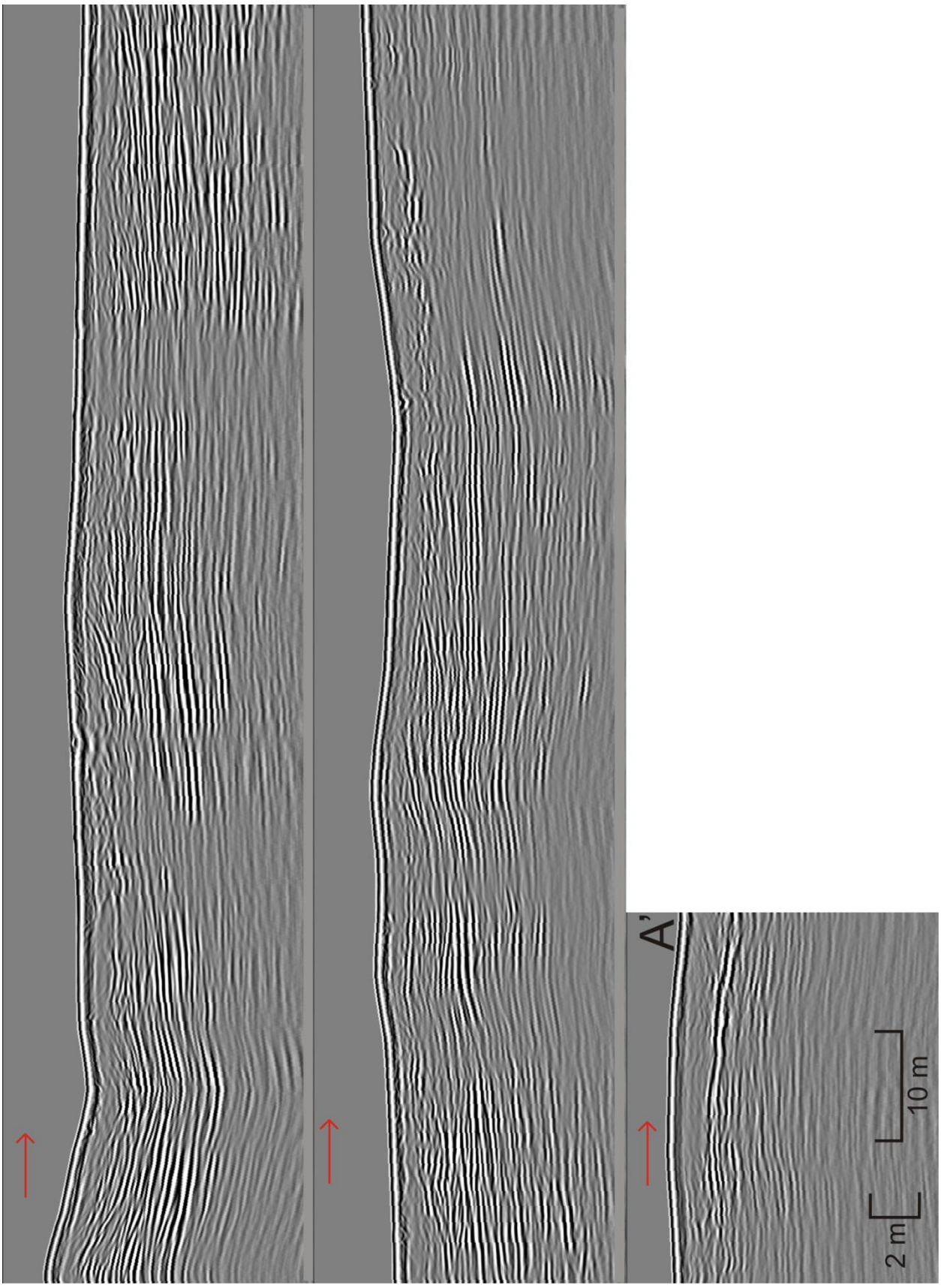

10 m
2 m


A'
2 m
10 m

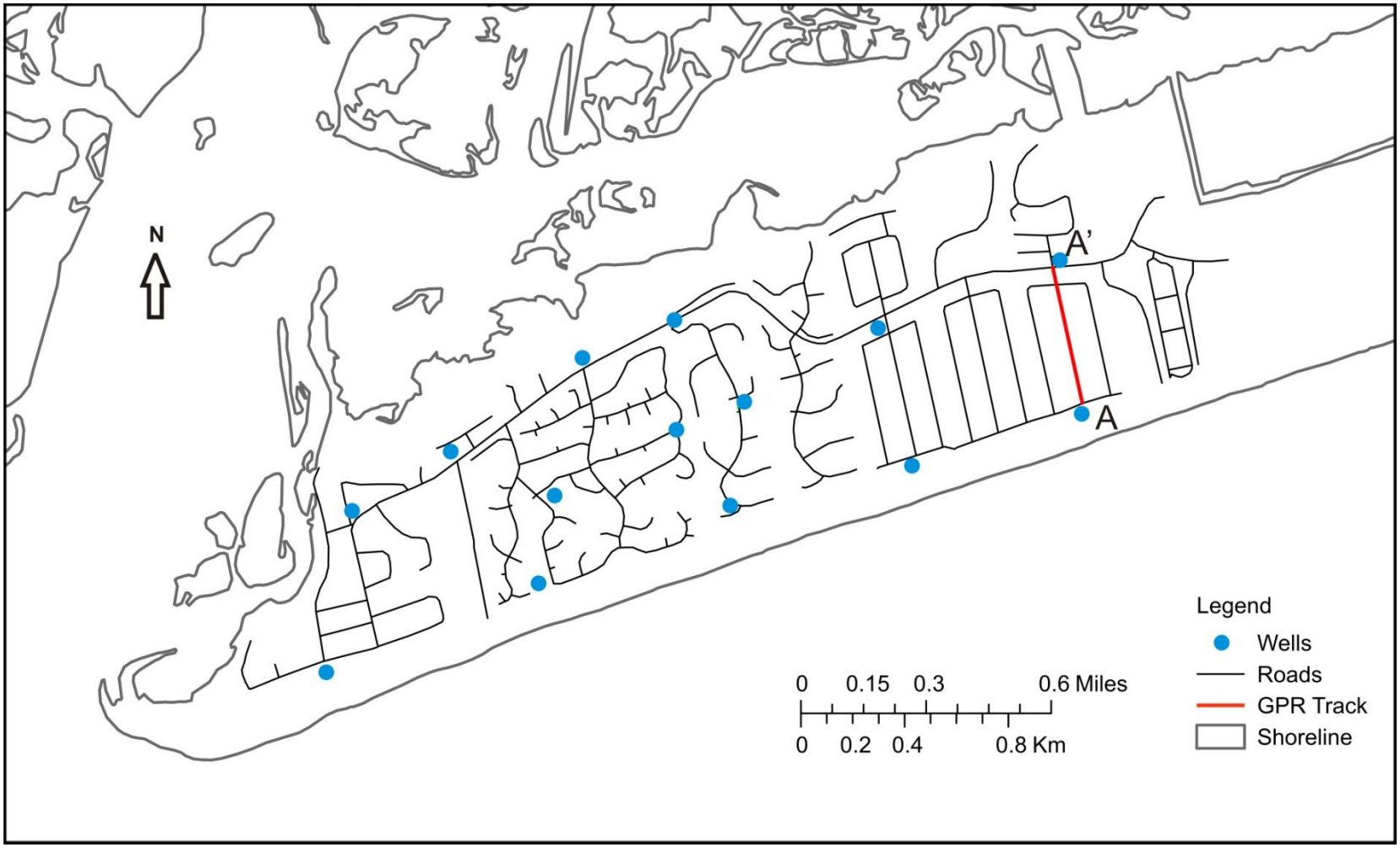
Line #6: A – A’

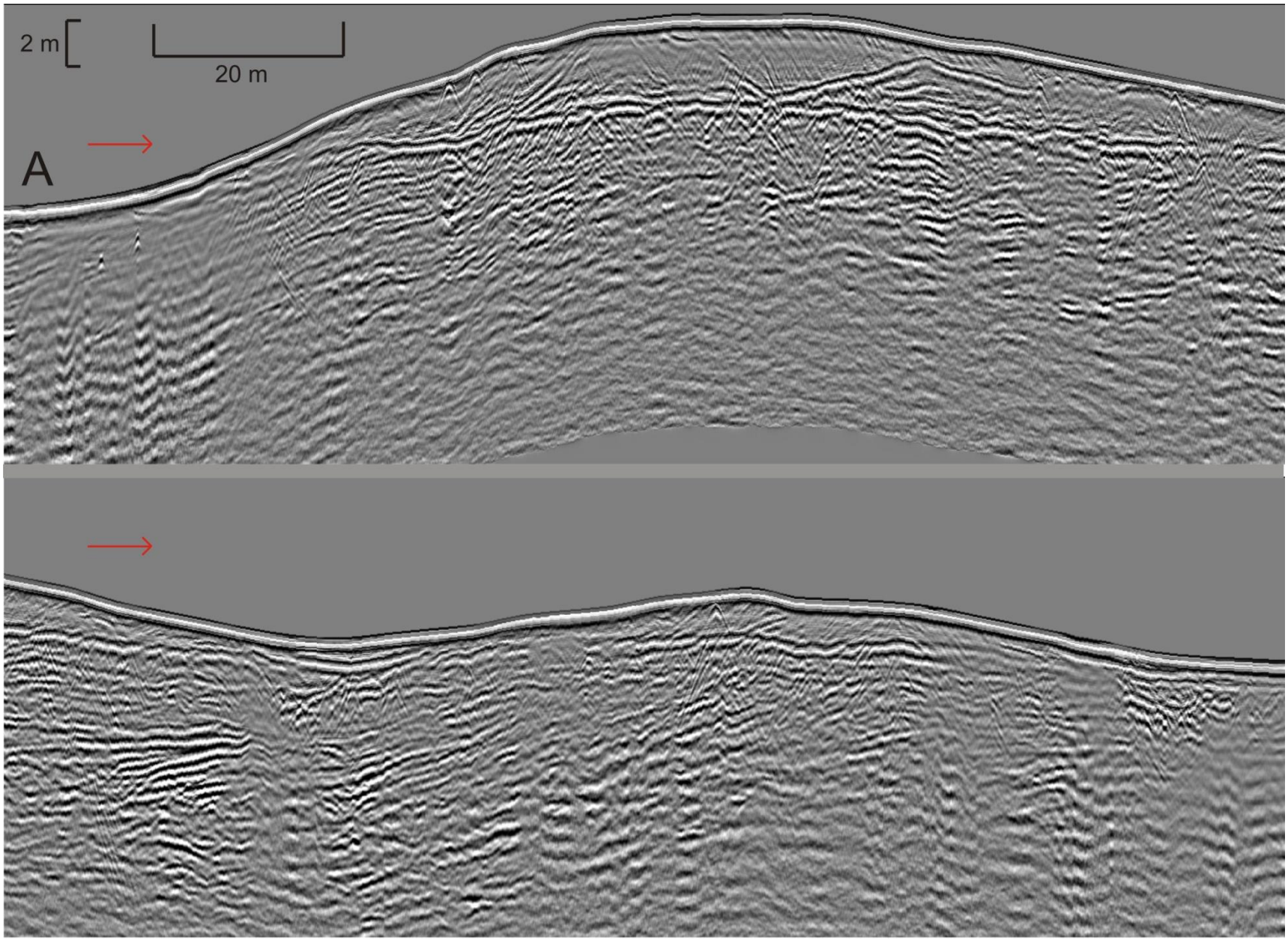

N
A’
A
0 0.15 0.3 0.6 Miles
0 0.2 0.4 0.8 Km
Legend
Wells
Roads
GPR Track
Shoreline

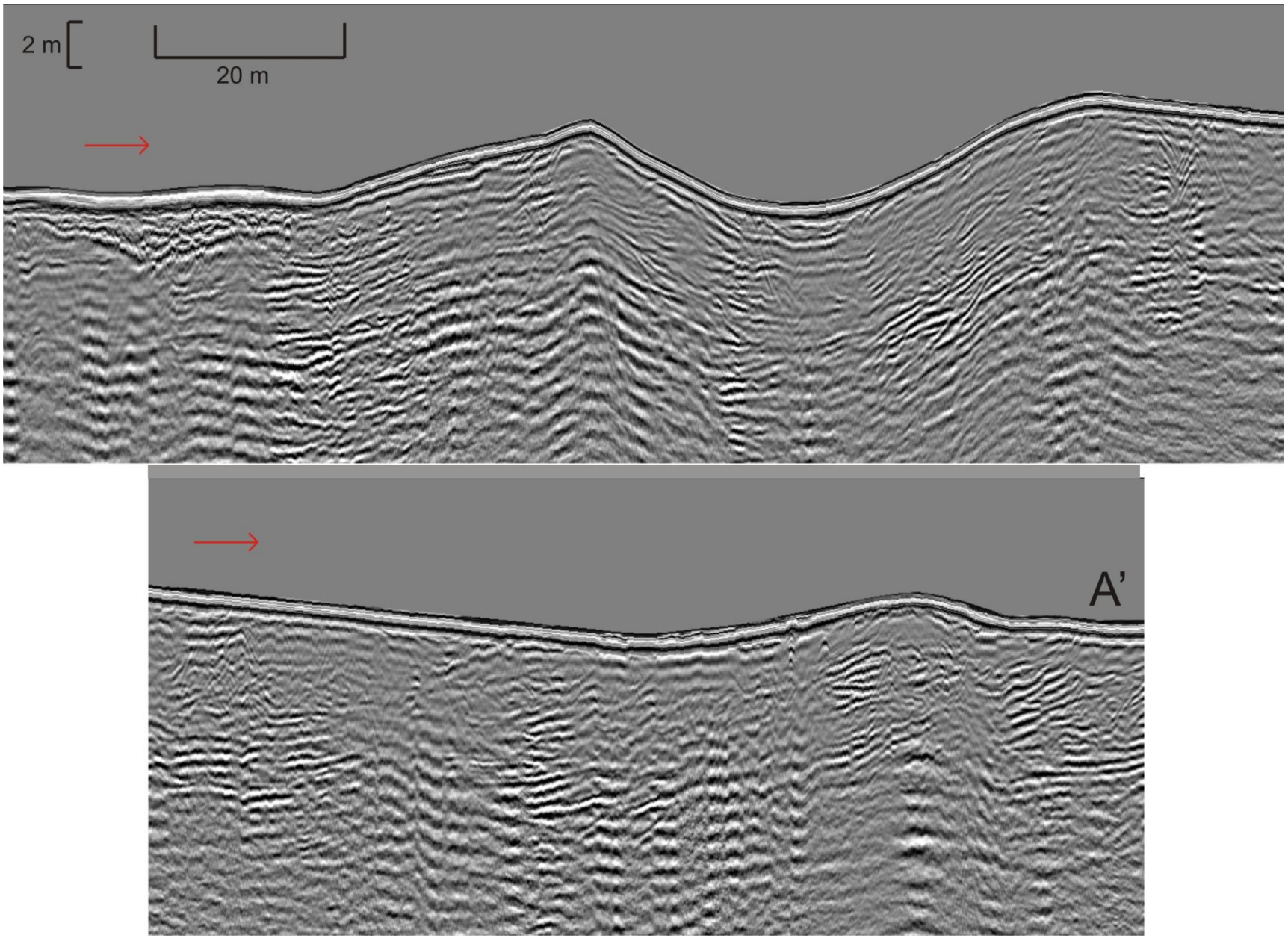

A
10 m
2 m


A'
10 m
2 m

Line #7: A – A’


N
A’
A
0 0.15 0.3 0.6 Miles
0 0.2 0.4 0.8 Km
Legend
Wells
Roads
GPR Track
Shoreline


2 m
20 m
A


2 m
20 m
A’