The effect of Voxel Size on IP Inversions

ExploreGeo Technical Note 8

ExploreGeo Pty Ltd

Explanation

This technical note will examine the effect of varying the inversion mesh size of three induced polarisation datasets for one particular forward model. Each dataset used a different electrode array. The three arrays used were;

- 100 x 200m Offset dipole-dipole
- 100 x 200m staggered Offset Pole-dipole
- 100 x 200m Co-linear dipole-dipole

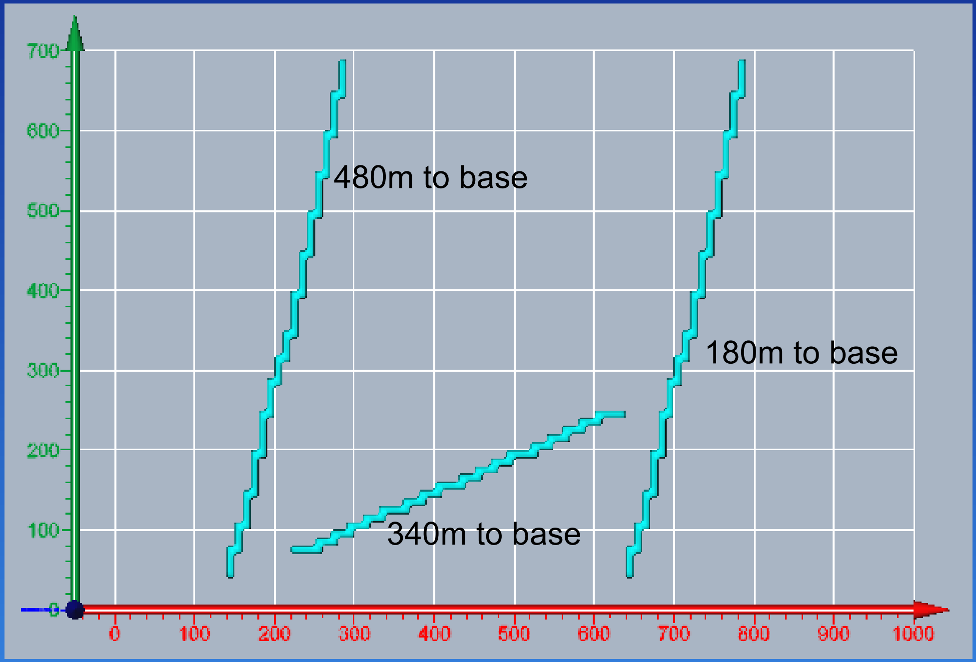
For each dataset, the only variable changed was the inversion mesh size. Four mesh sizes were used:

- 50m x 200m
- 50m x 100m
- 50m x 50m
- 25m x 25m

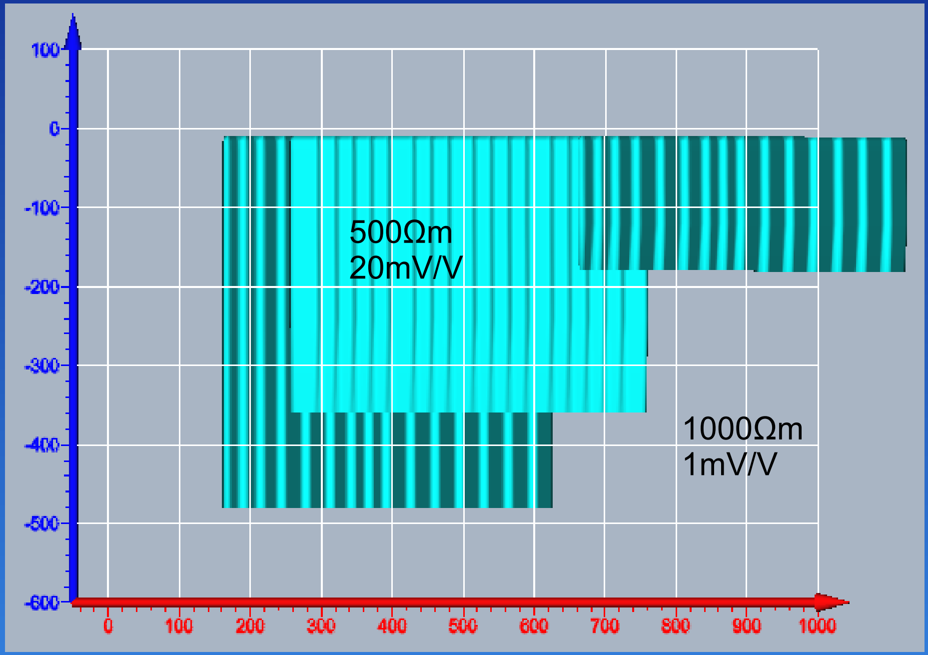
Details of the forward model, arrays, and mesh are outlined on the following slides.

Forward model details

The model contains three mineralised bodies all 10m wide. The tops of all three bodies are at 10m below the ground surface, but vary in depth to their bases. All three bodies have the same resistivity and chargeability.

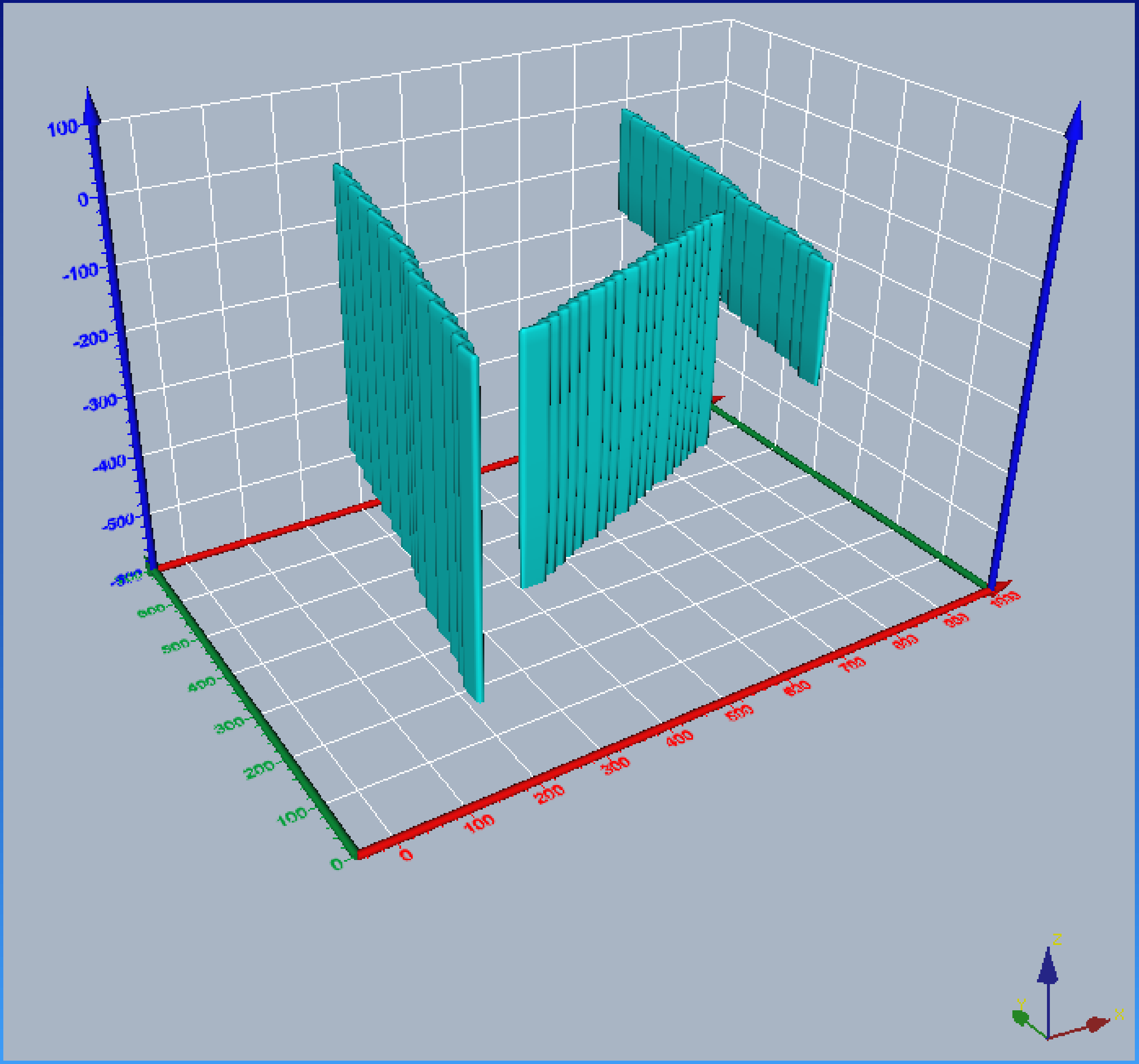


Plan view of model



Front view of model

Forward model details



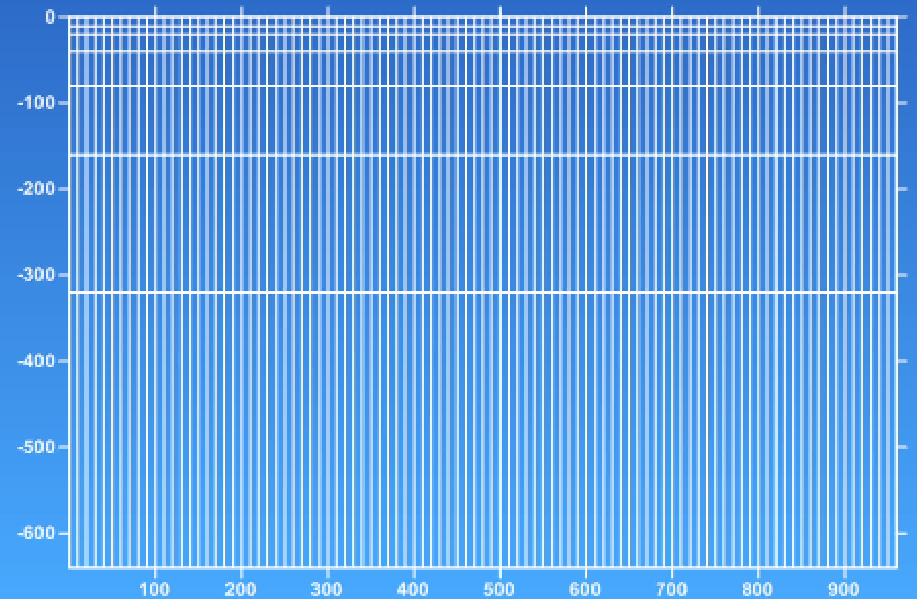
3D view of model

Forward modelling details

Forward modelling was undertaken using Geotomo’s Res3Dmodx64 program which is a finite difference and finite element routine developed by Meng Heng Loke.

The mesh consisted of 10m x 10m voxels over a 960m x 740m area with 7 layers, increasing in thickness from 10m to 320m to give a maximum depth of 640m. All electrodes (current and potential) were included in the mesh. The mesh size was 96 x 74 x 7.

An extended mesh was created for use with the Offset Pole-dipole array which had a size of 96 x 1470 x 7.



Forward modelling details

Noise was added to the calculated chargeability and resistivity values after their export from Res3Dmod. This was done by back calculating the primary voltage from the modelled apparent resistivity, assuming a transmitter current of 20A. Although 20A is a relatively high current and unachievable for many commercial IP transmitters, it is commonly achieved by leading contractors using their own hardware. A random number of between +/- 5% was added to the calculated primary voltage as below.

If $V_p > 0.1$ mV

$$V_{p(noise)} = V_p + RN*V_p*0.1$$

If $V_p \leq 0.1$ mV

$$V_{p(noise)} = V_p + RN*0.1$$

RN = Random number between -0.5 and +0.5

Forward modelling details

The apparent resistivity was then recomputed using the noise added primary voltage, and noise was added to the chargeability in the same proportion as the apparent resistivity.

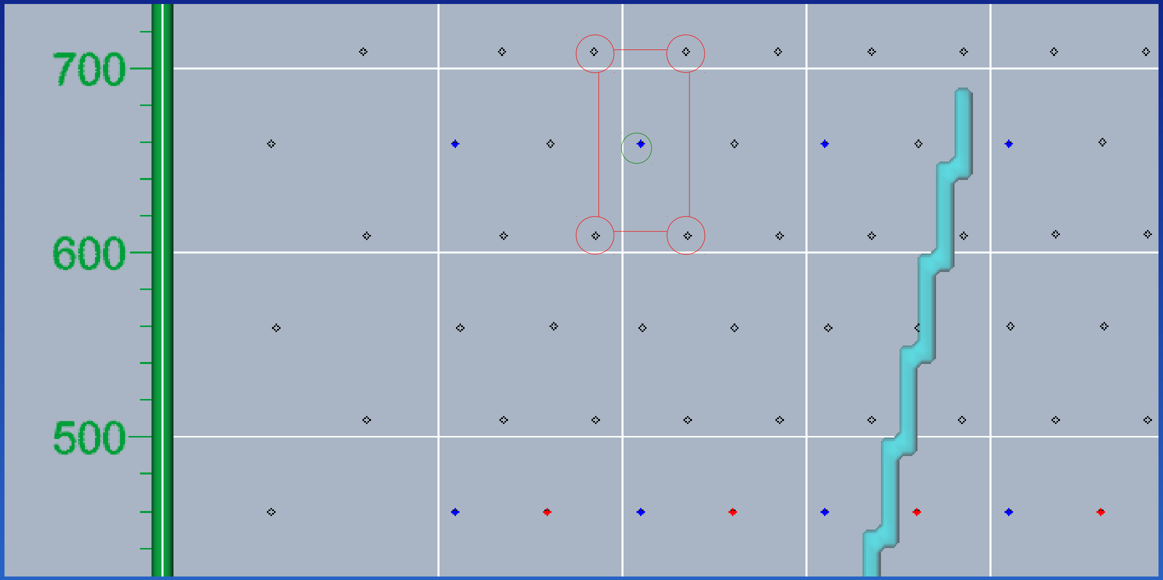
The data were then clipped to remove any readings with a primary voltage of less than 0.1 mV in order to try and mimic real receiver noise thresholds.

Inversion details

All arrays were inverted using Res3Dinvx64. The results were loaded into a 3D display package and are displayed here as sections and plans of resistivity and chargeability overlain on the true model.

Pictures of the inversion mesh - explanation

The inversion mesh voxel corners and centre points are shown as diamonds.



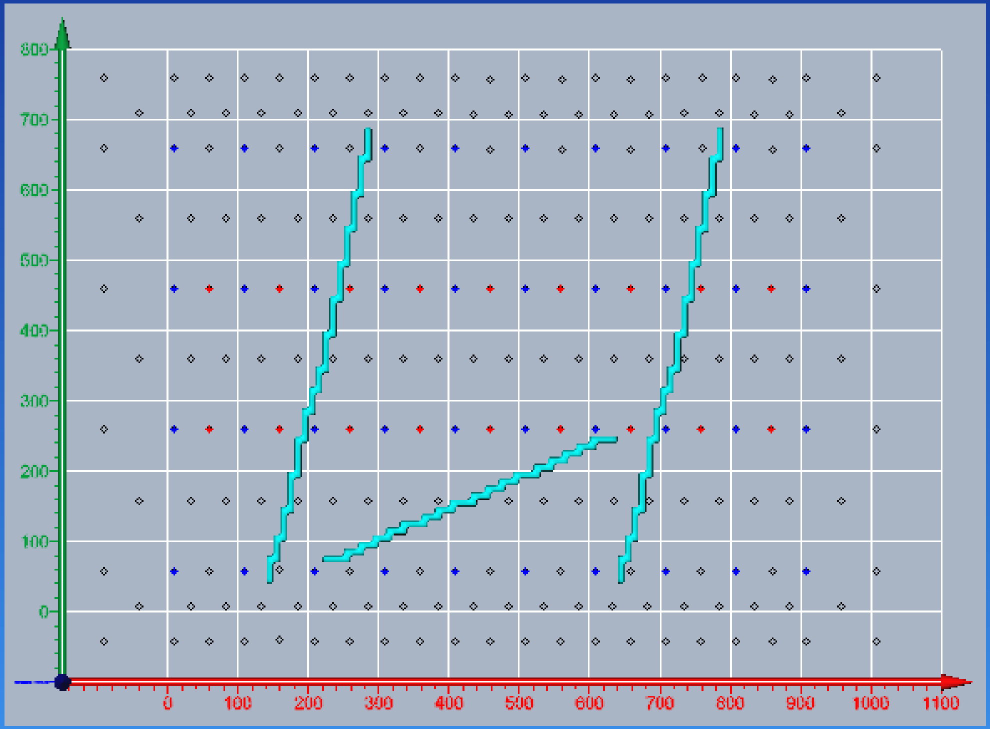
Close-up of inversion mesh data points

The data points within the red circles represent the four corners of the voxel, and the data point within the green circle represents the centre of the voxel. The red lines outline a single voxel, in this case 50m x 100m.

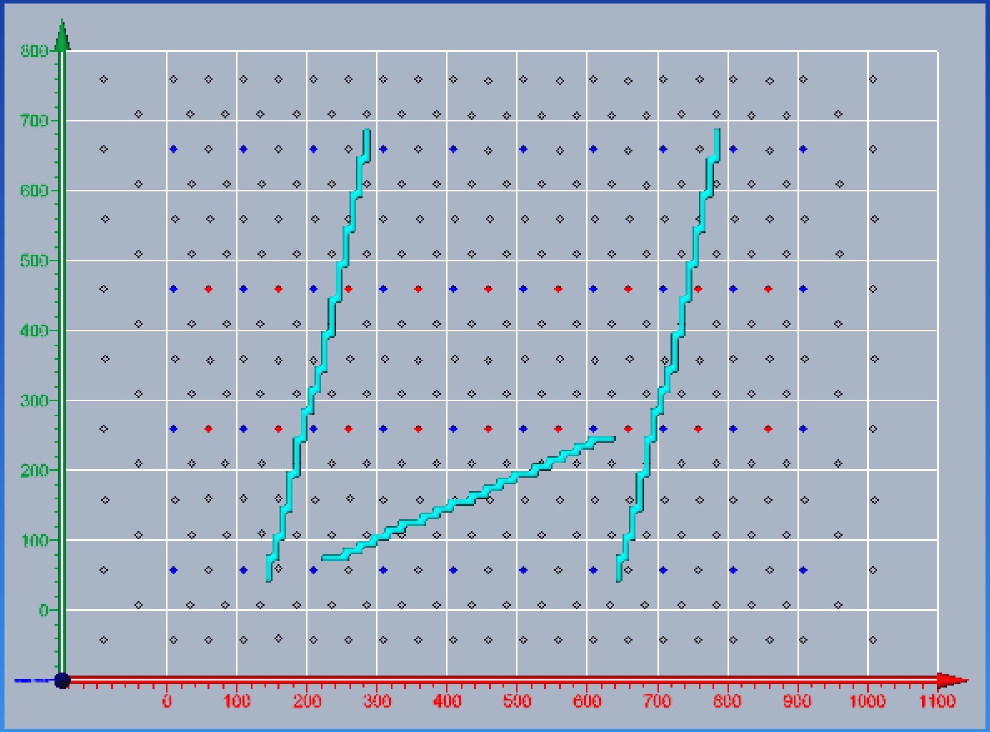
The output from Res3Dinv includes the centres and interpolated corner values for each voxel.

View of inversion mesh points – Offset dipole-dipole

The following slides show a plan view of the inversion mesh voxel data points for each electrode array and mesh size. These are overlain by the electrode locations for the particular array. Red points represent the transmitter electrodes, and blue points represent the receiver electrodes.

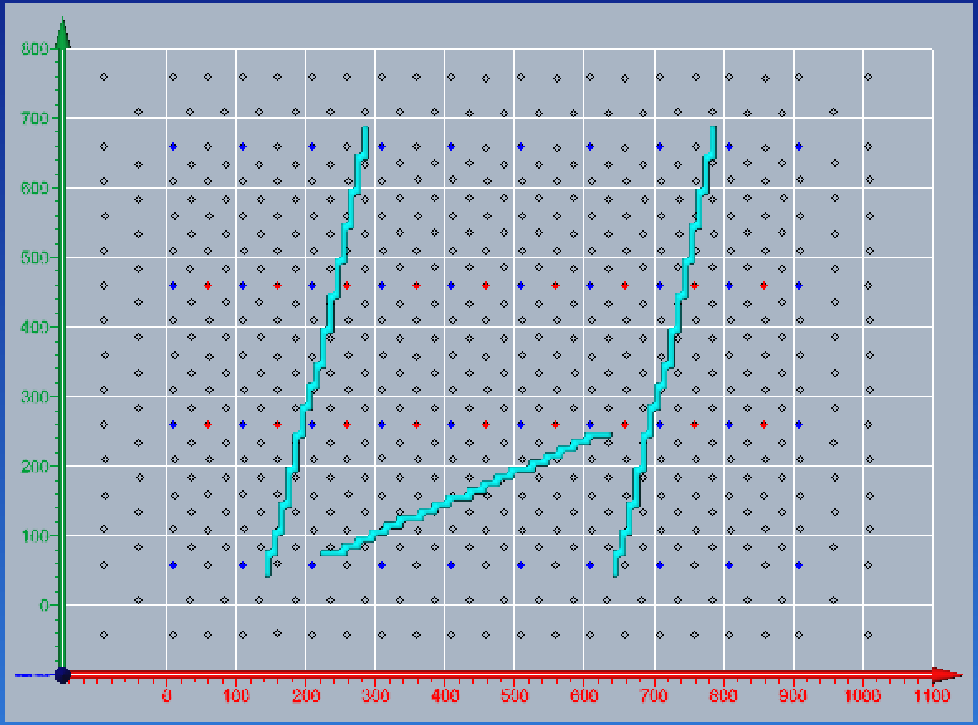


50m x 200m

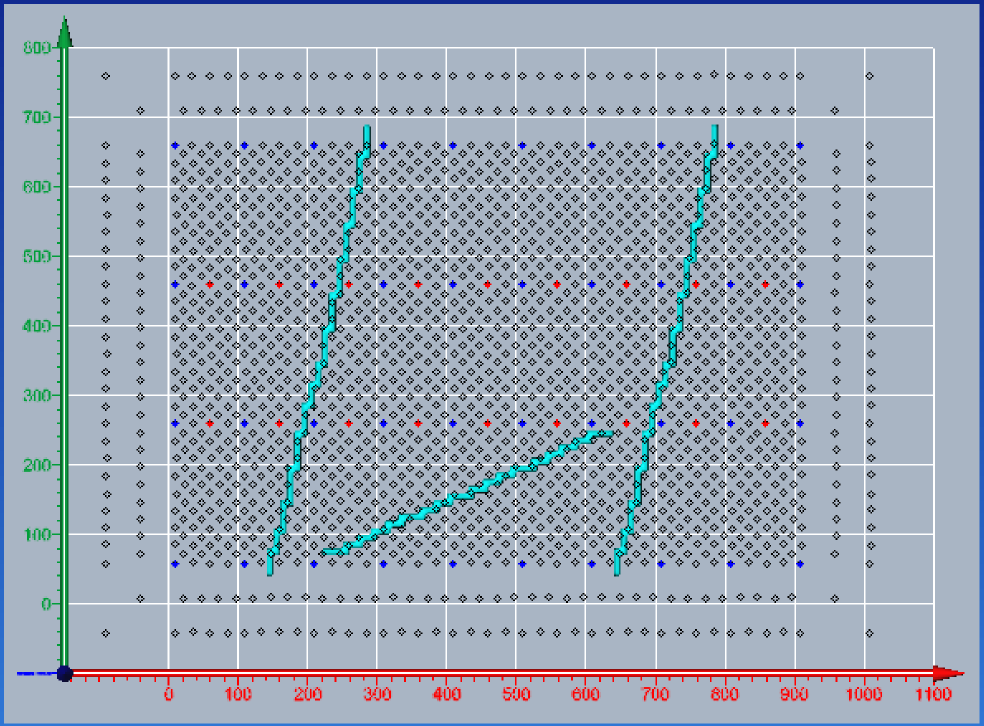


50m x 100m

View of inversion mesh points – Offset dipole-dipole

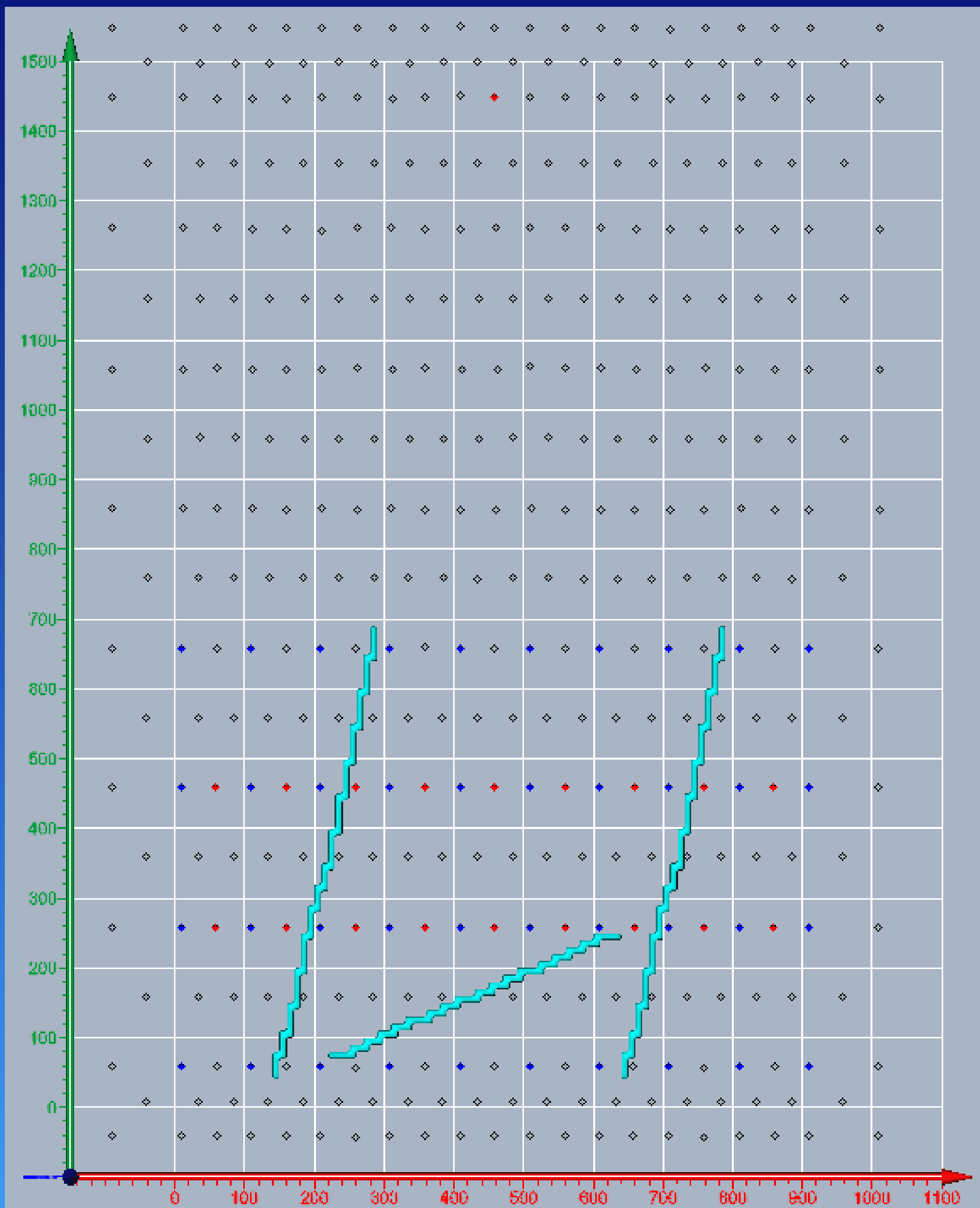


50m x 50m

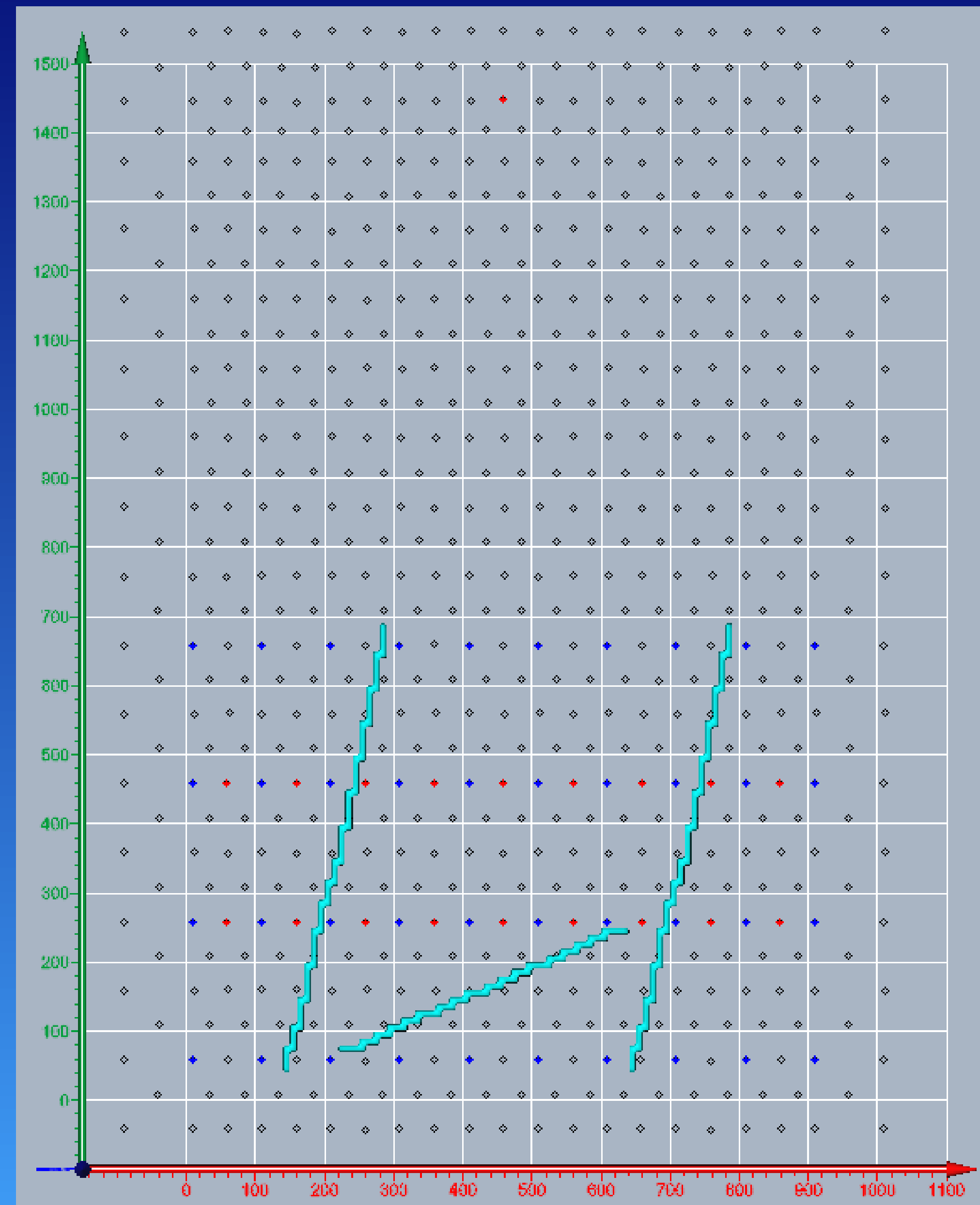


25m x 25m

View of inversion mesh points – Offset Pole-dipole

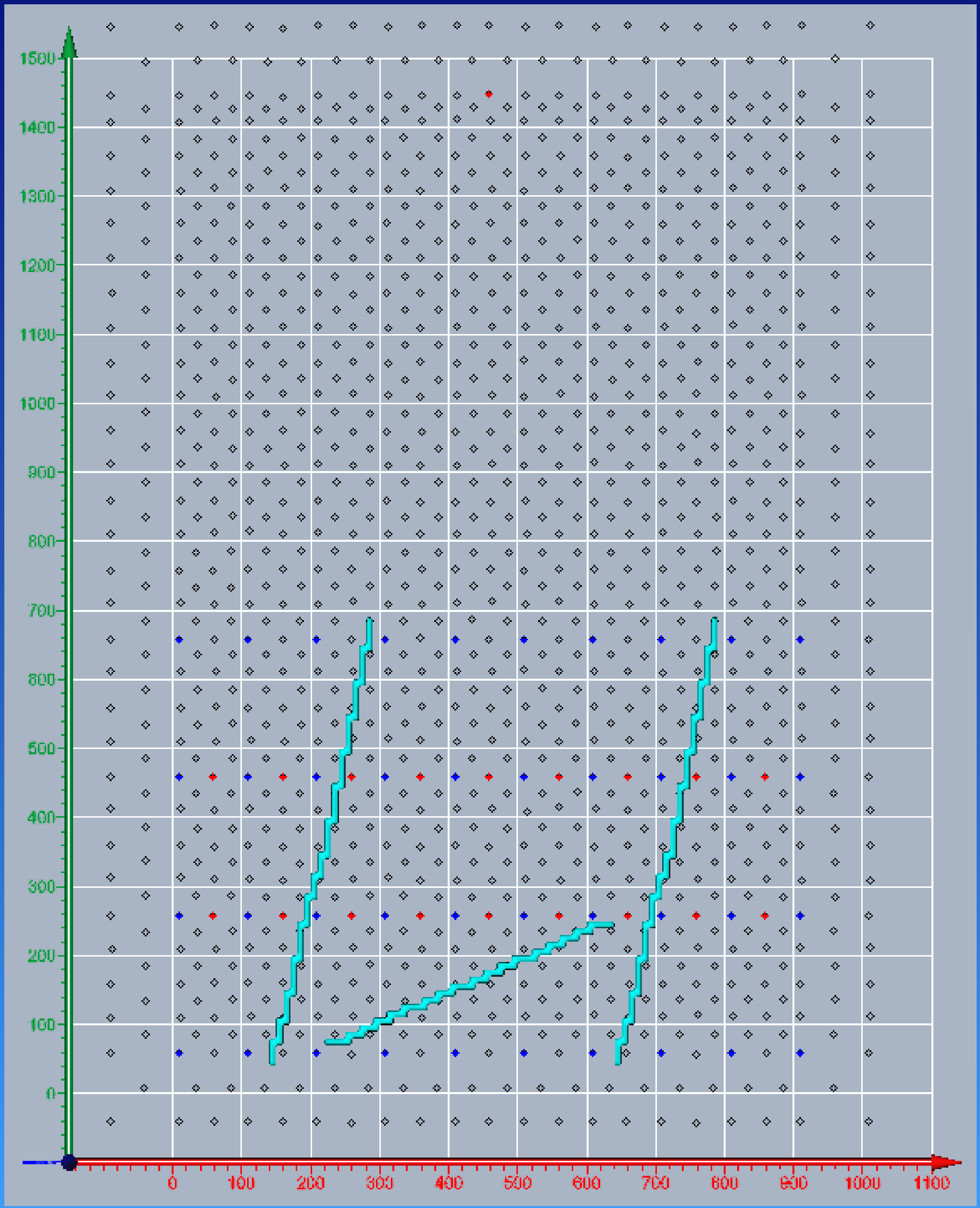


50m x 200m

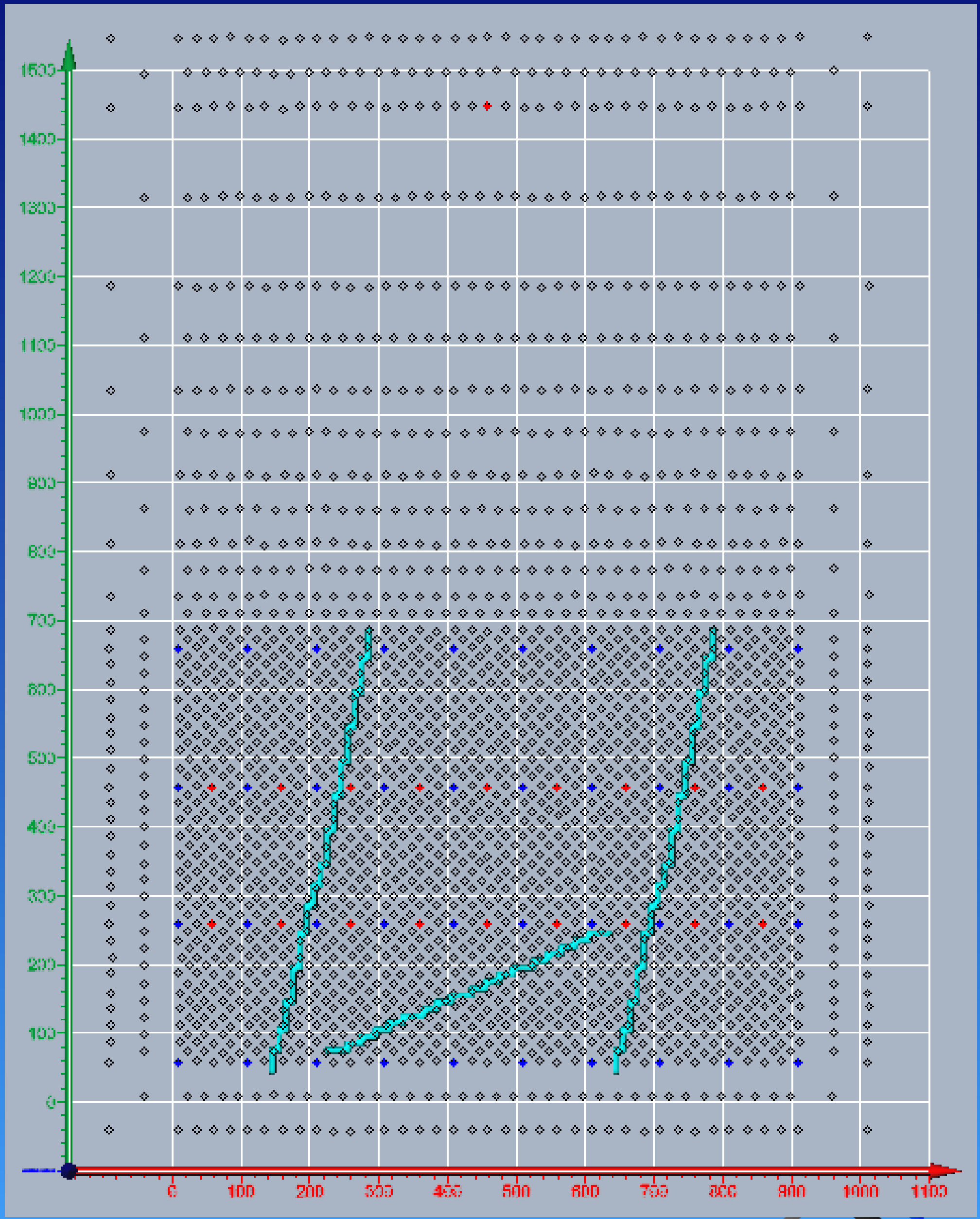


50m x 100m

View of inversion mesh points – Offset Pole-dipole

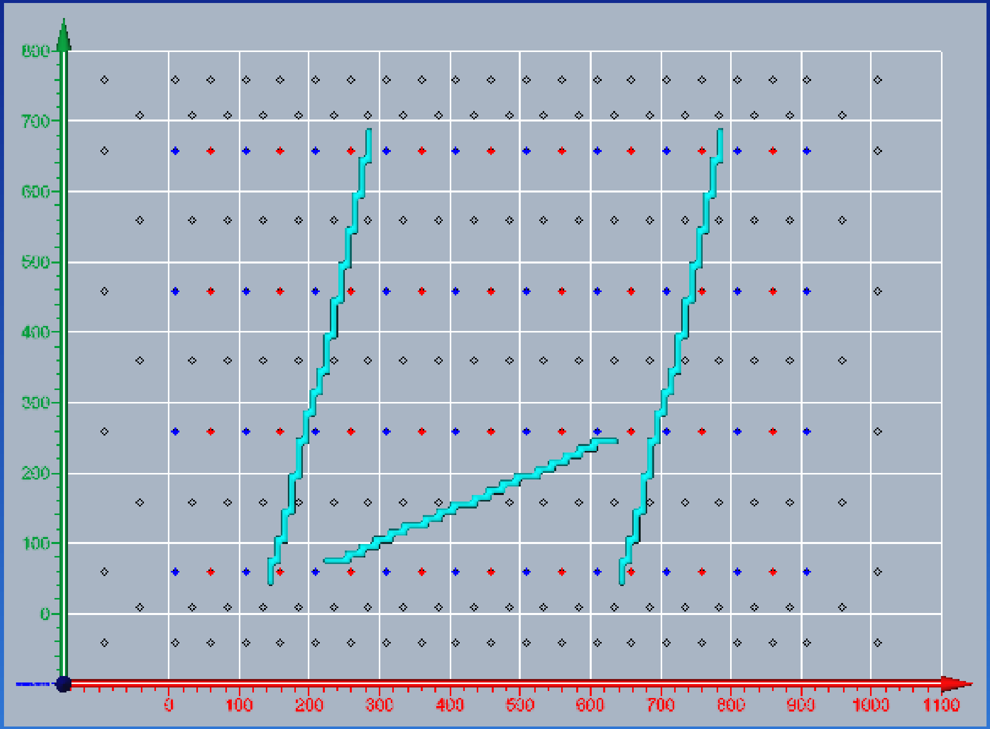


50m x 50m

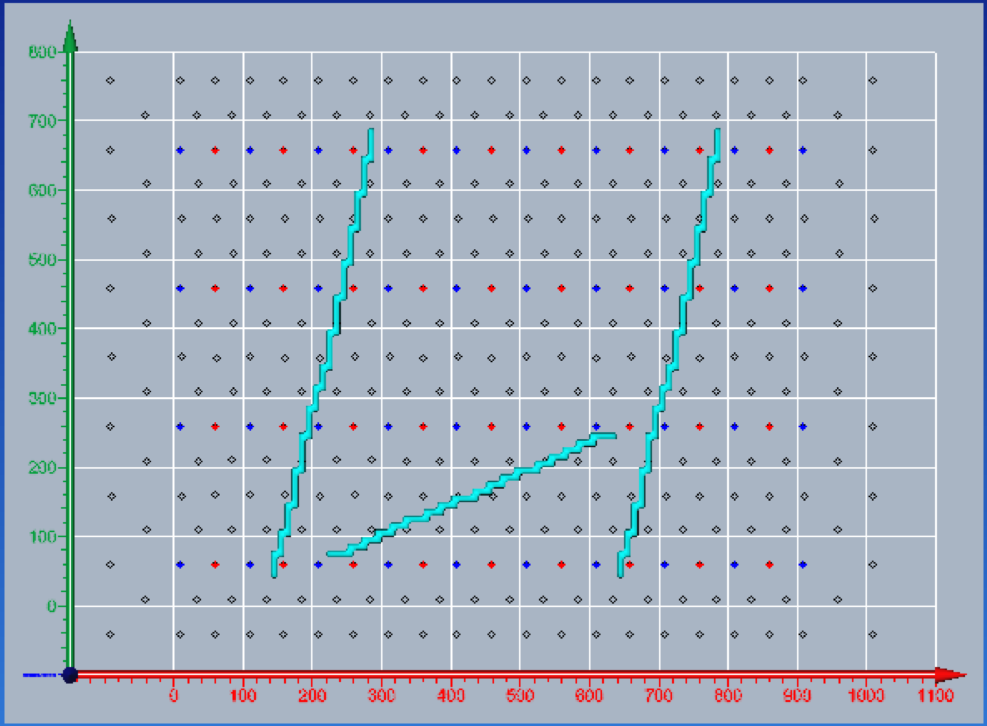


25m x 25m

View of inversion mesh points – Co-linear dipole-dipole

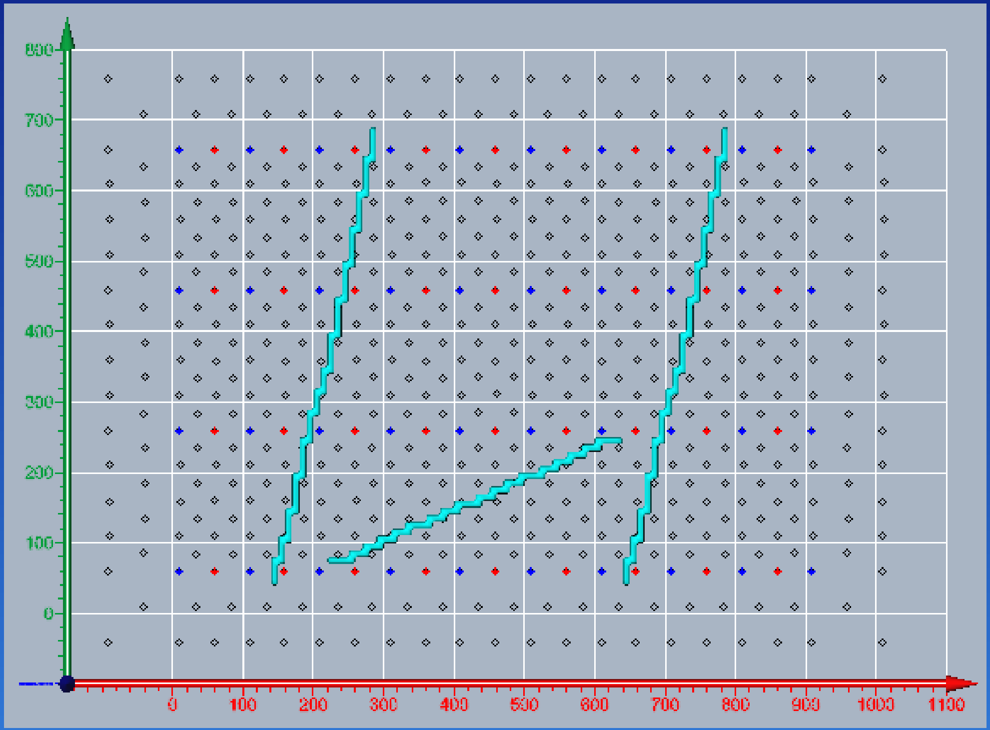


50m x 200m

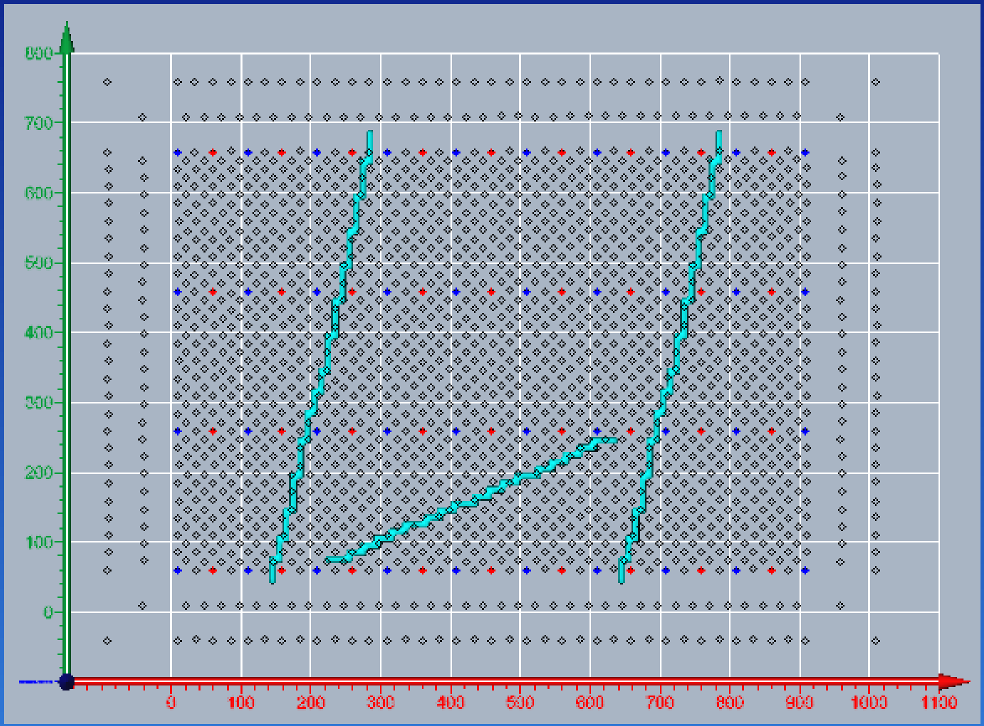


50m x 100m

View of inversion mesh points – Co-linear dipole-dipole



50m x 50m



25m x 25m

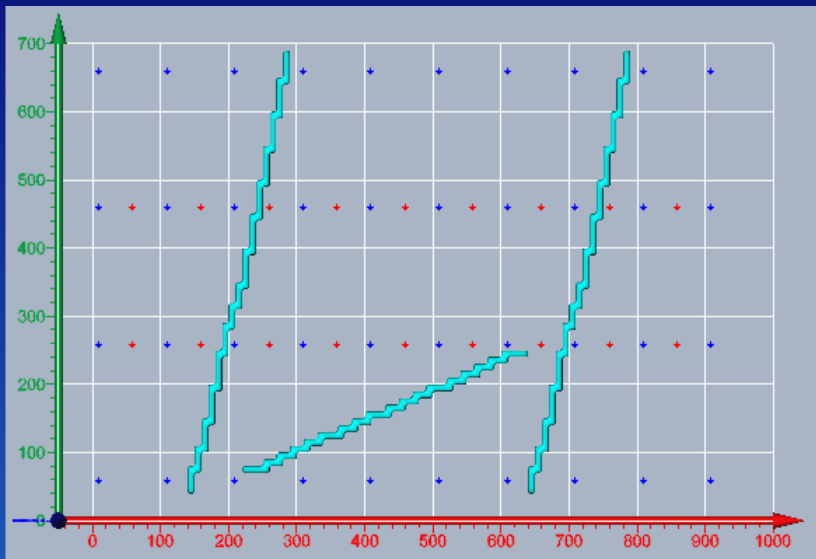
Electrode array details

All arrays used 100m electrode spacing for both receiver (blue) and transmitter (red) dipoles.

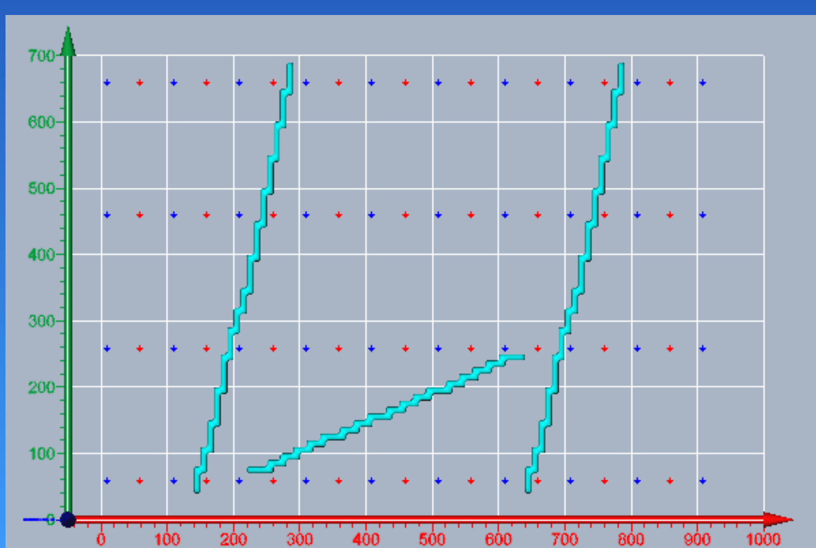
The line spacing was 200m. Potentials were only read on EW dipoles.

The Offset Pole-Dipole array was modelled with a pole electrode at coordinates 460, 1450 (as shown on next slide).

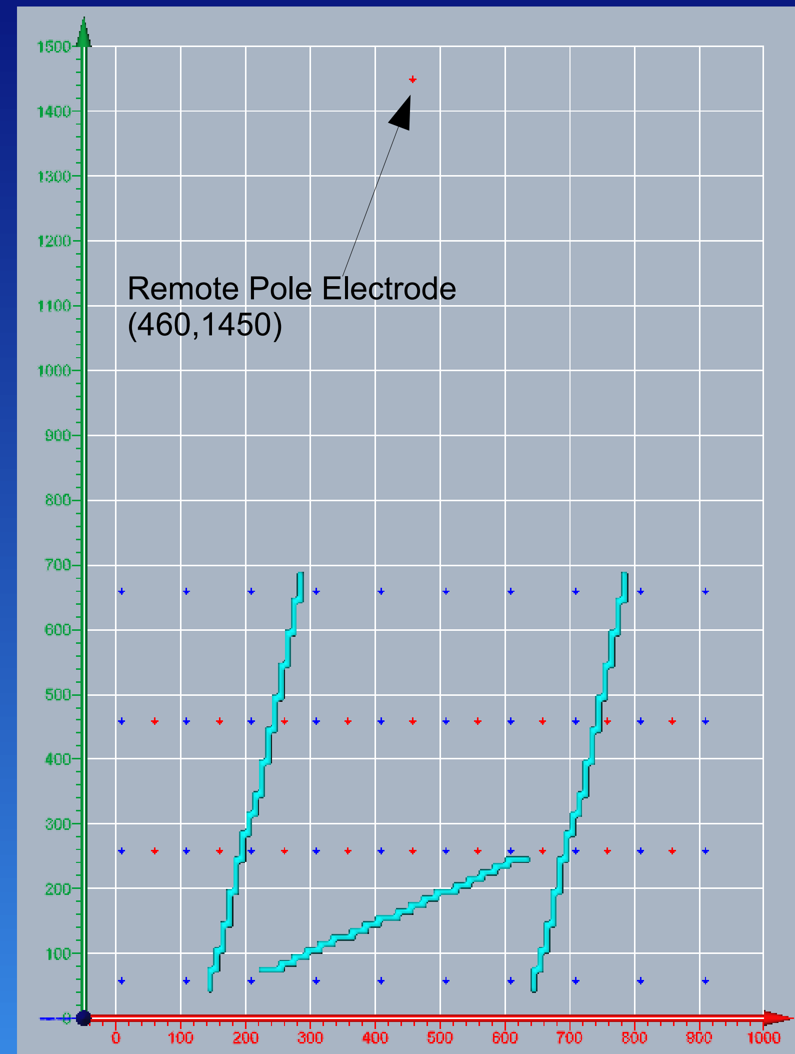
Electrode array details



Offset dipole-dipole array



Co-linear dipole-dipole array



Offset Pole-dipole array

Figure details

All chargeability sections and contours use a linear colour scale with a contour interval of 0.5 mV/V.

The plan view contours are shown for a slice 50m below the ground surface.

	x cell size	y cell size	z cell size	x search radius	y search radius	z search radius
50m x 200m mesh	20	35	20	50	100	100
50m x 100m mesh	20	18	20	50	75	100
50m x 50m mesh	20	9	20	50	50	100
25m x 25m mesh	10	9	20	50	50	100

All chargeability isosurfaces are shown at 2.5 mV/V.

Chargeable bodies are represented in cyan.

Electrodes are represented by arrows:

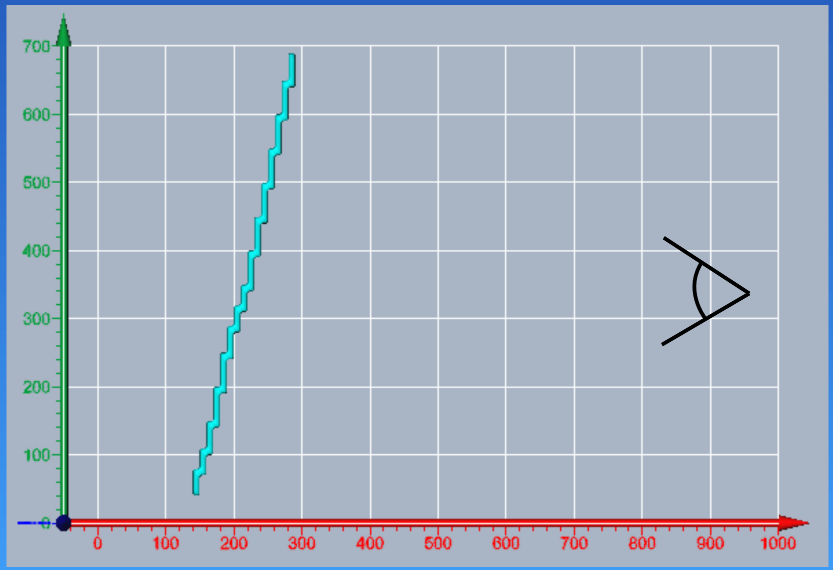
- Red for transmitters.
- Blue for receivers.

Figure details

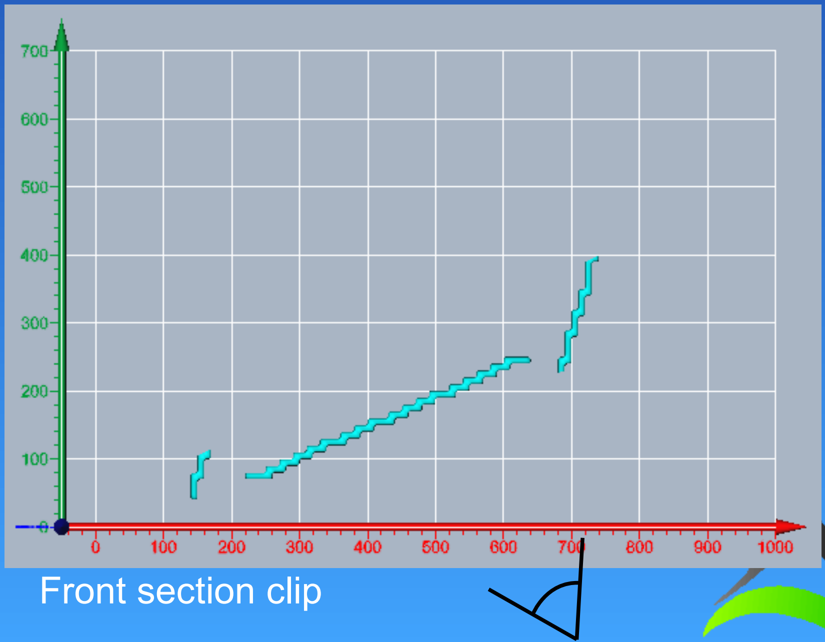
For each array and mesh combination, five figures will be shown:

- Plan view with contours
- Section viewed from the right with contours
- Section viewed from the front with contours
- Plan view with isosurface
- 3d view with isosurface

The models have been clipped for clarity in the side and front view section images as shown below. The viewing position is denoted by:



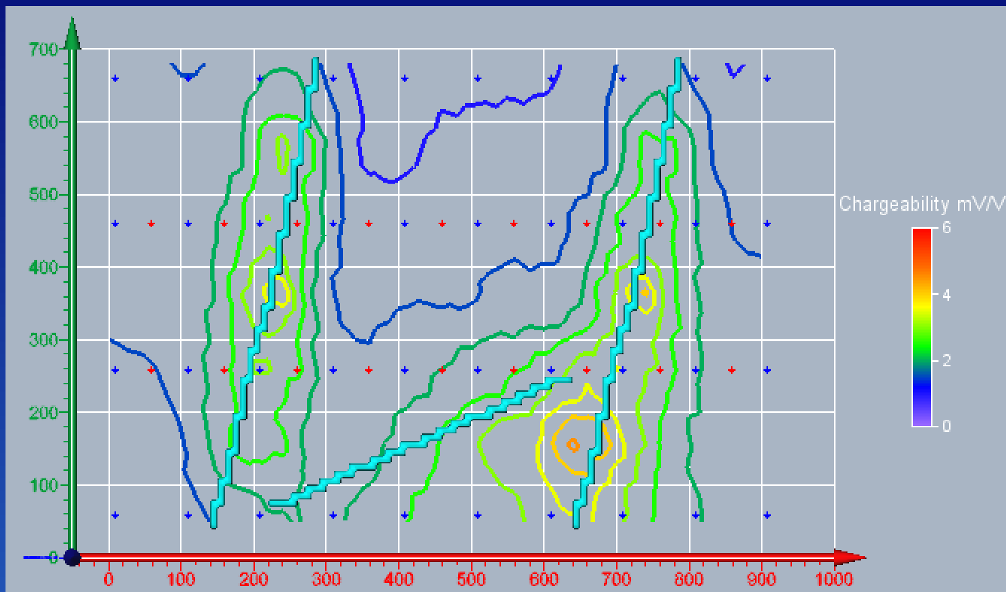
Side section clip



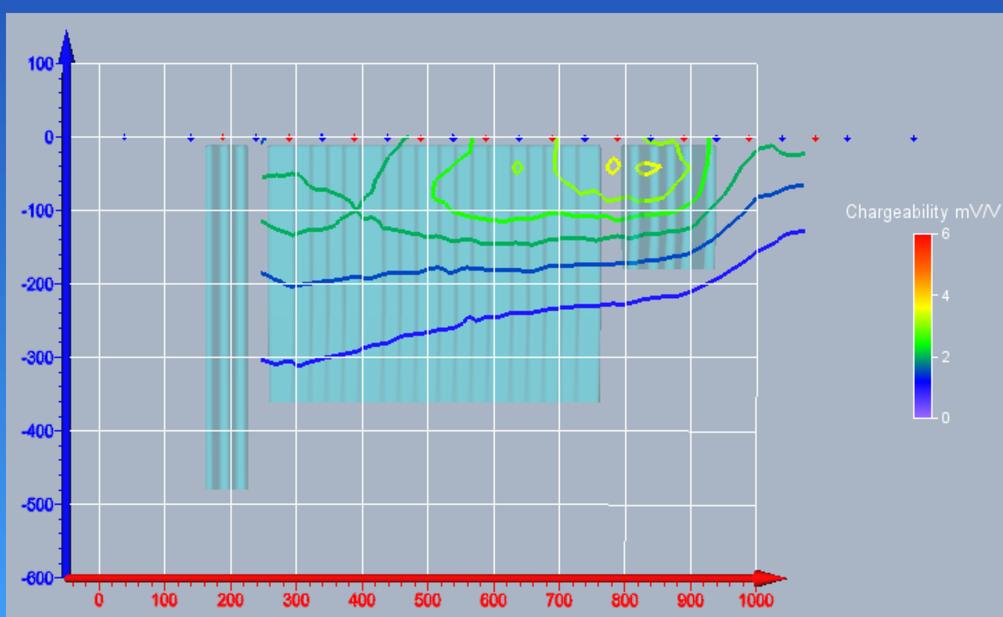
Front section clip

Offset dipole-dipole array

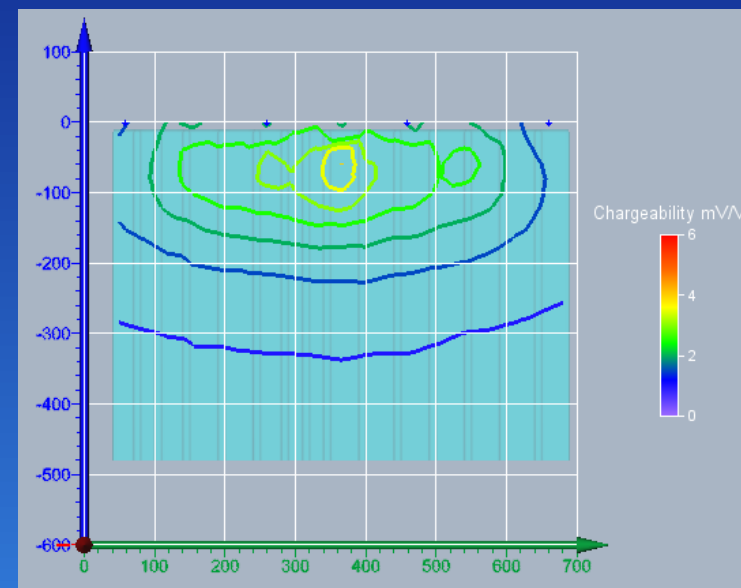
Offset dipole-dipole - 50m x 200m mesh



Plan view

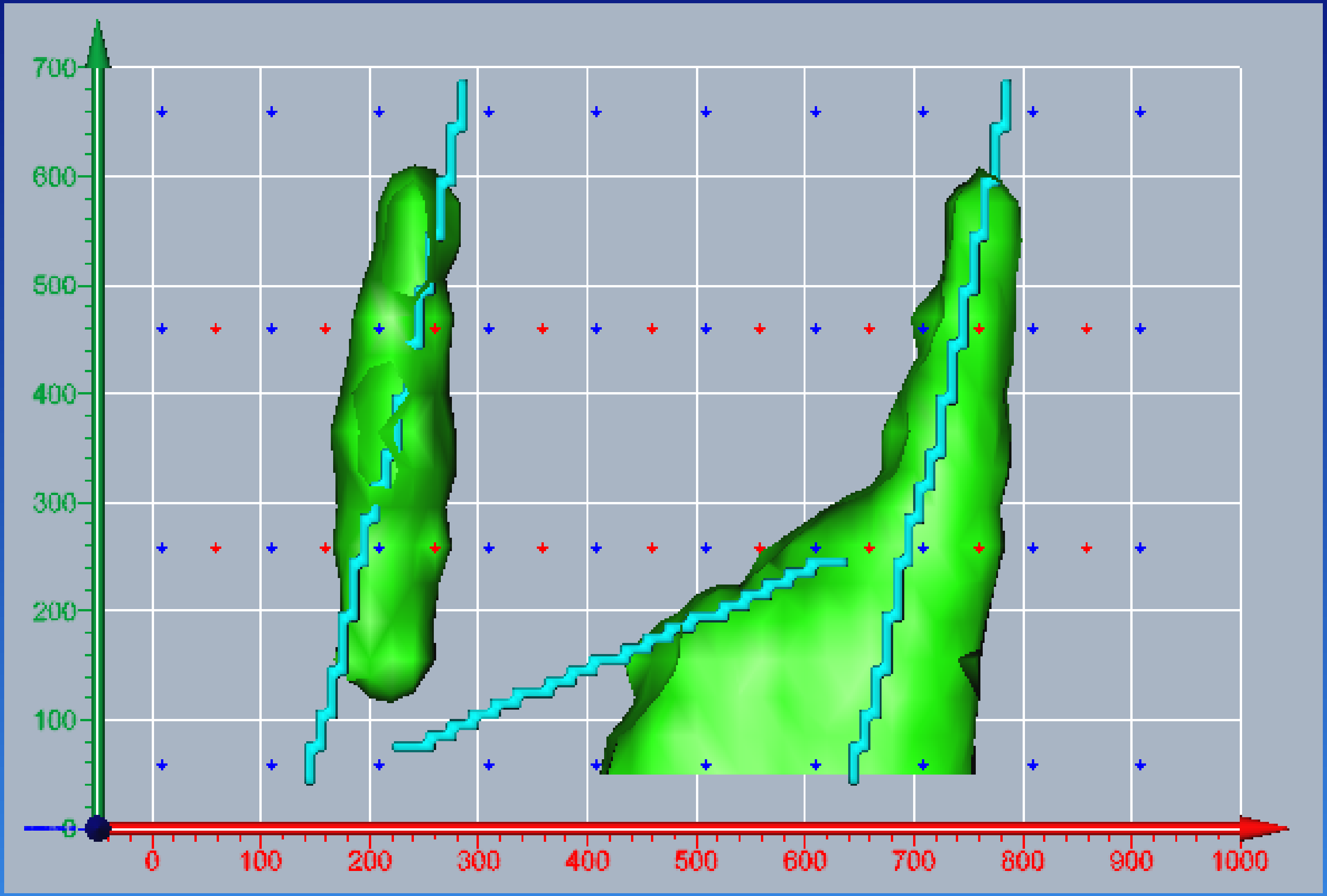


Front section



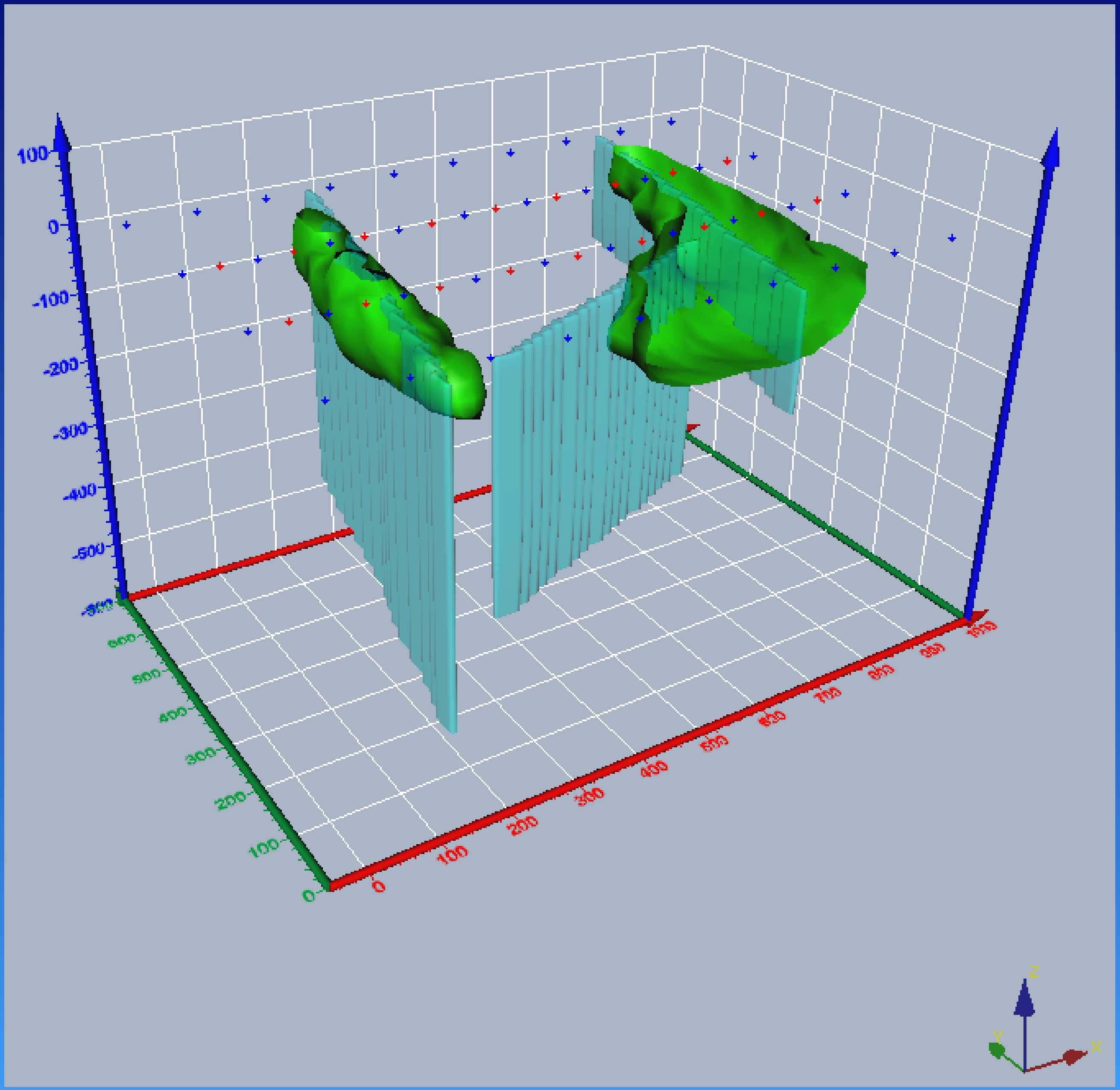
Side section

Offset dipole-dipole - 50m x 200m mesh



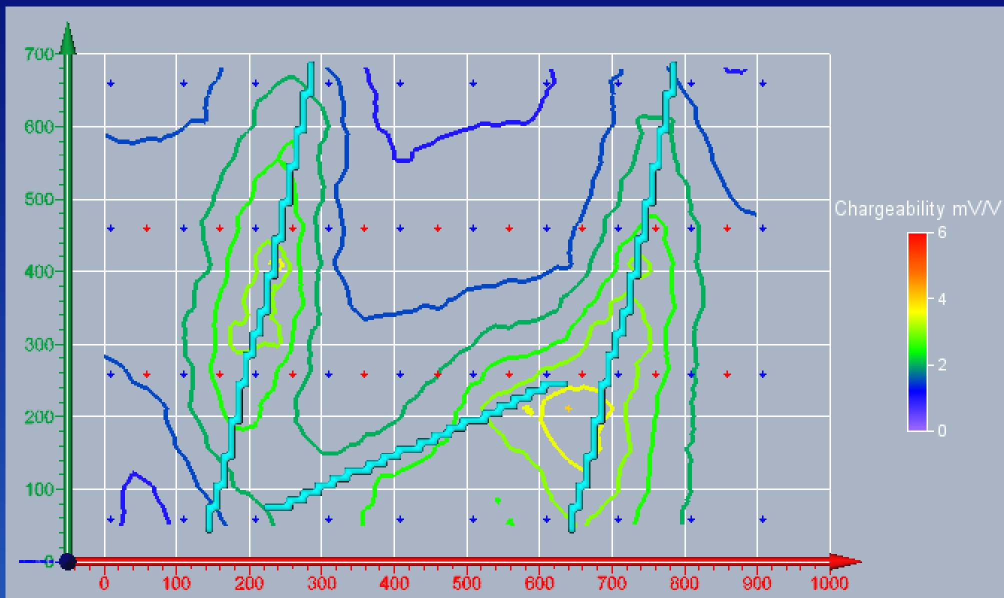
Plan view with 2.5 mV/V isosurface

Offset dipole-dipole - 50m x 200m mesh

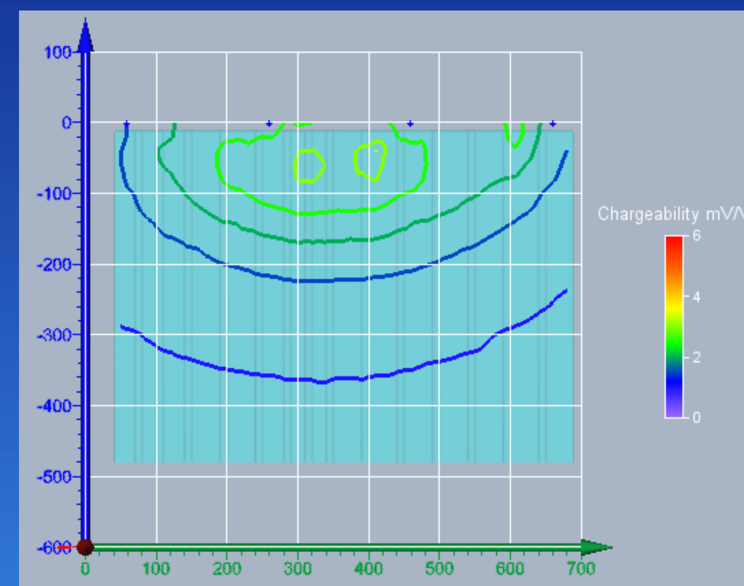


3D view with 2.5 mV/V isosurface

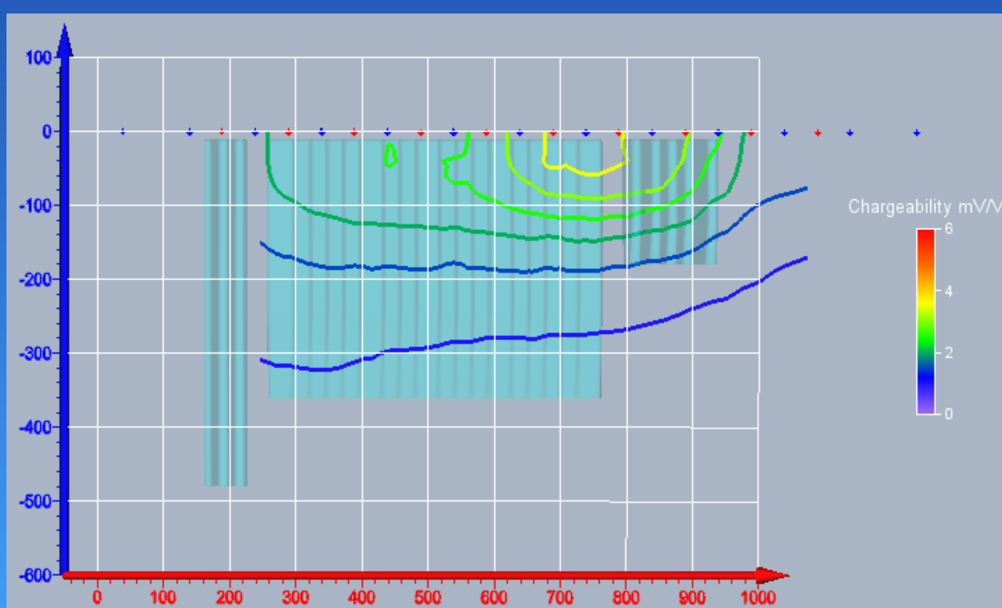
Offset dipole-dipole - 50m x 100m mesh



Plan view

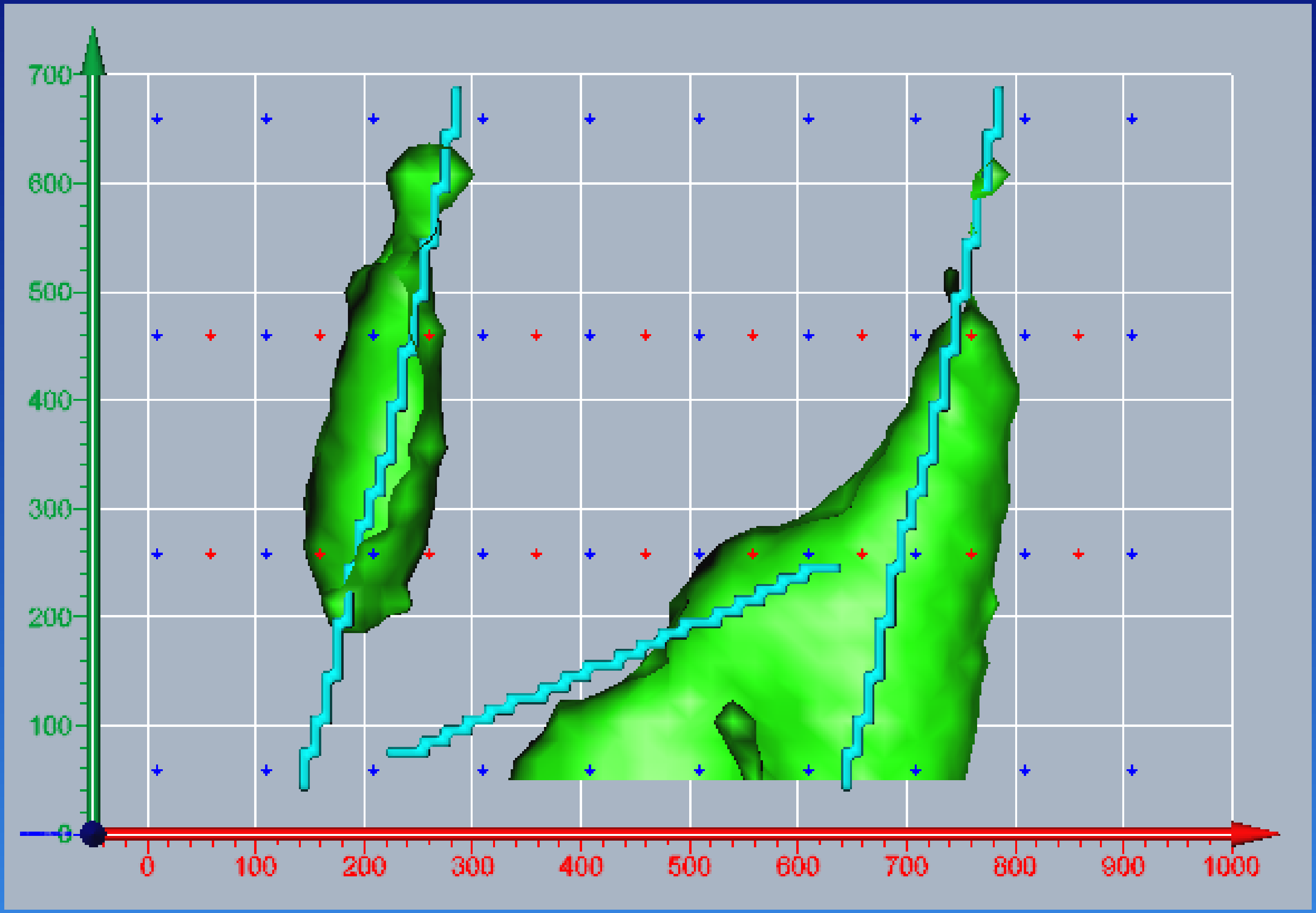


Side section



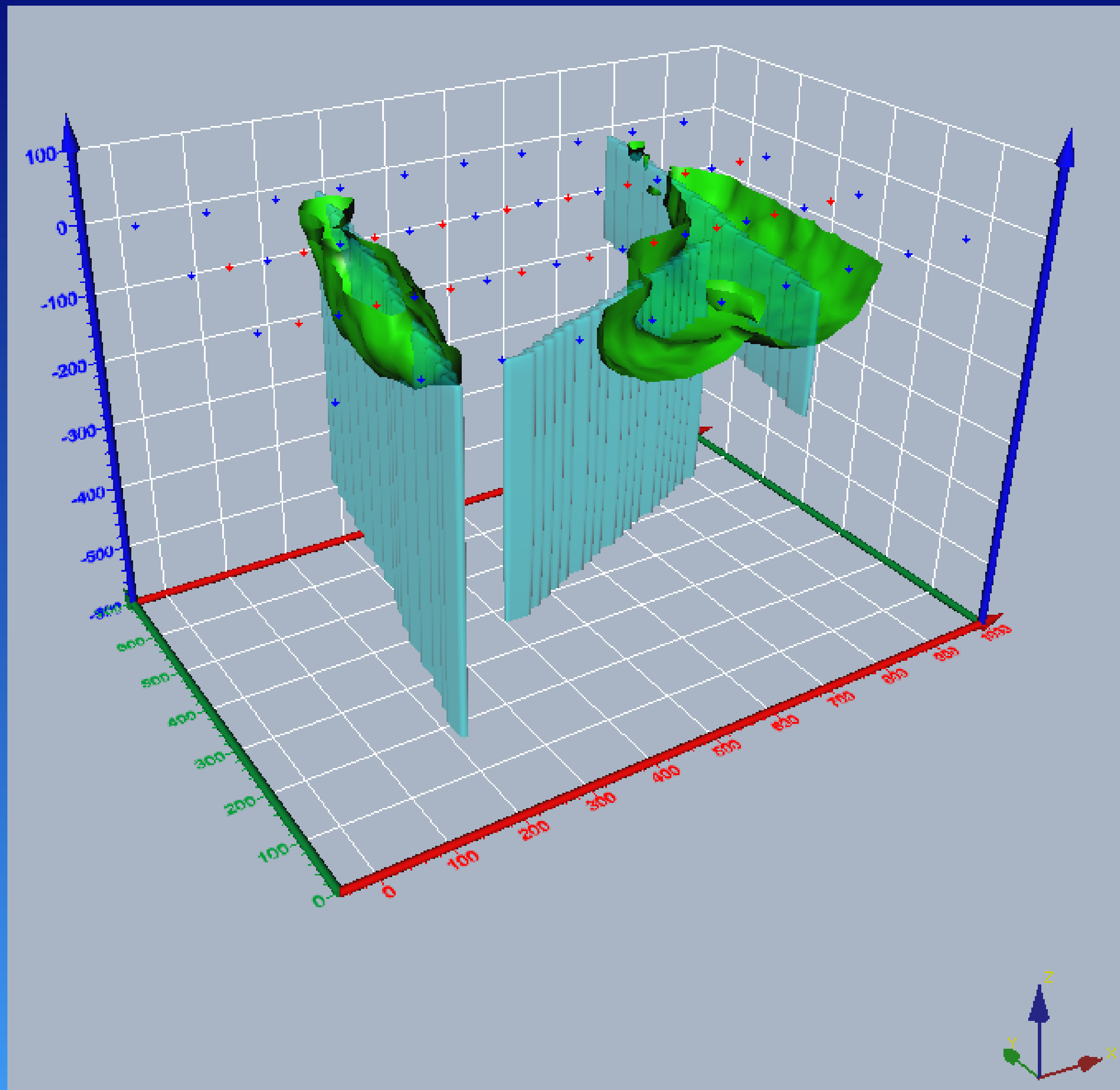
Front section

Offset dipole-dipole - 50m x 100m mesh



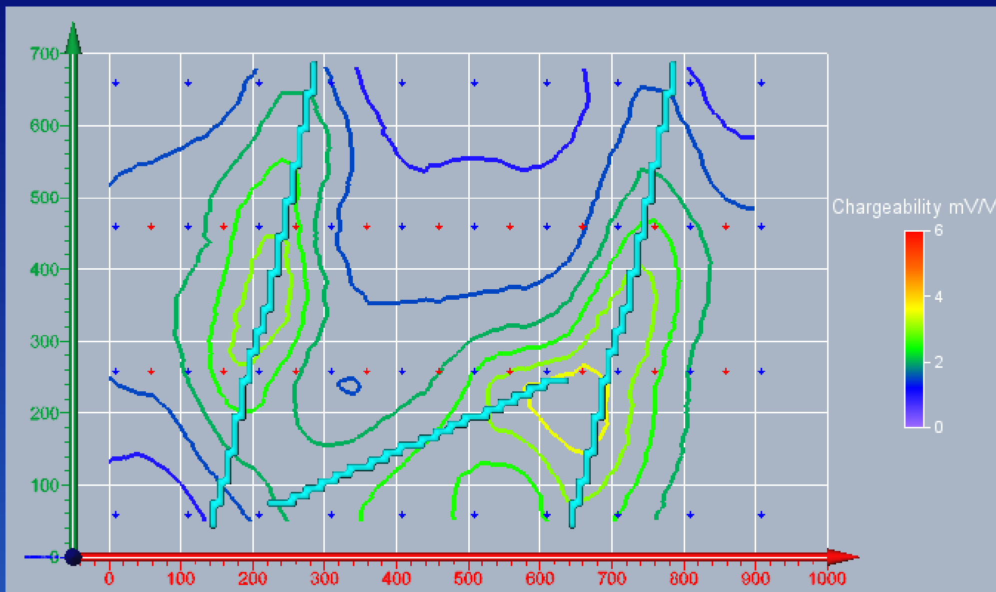
Plan view with 2.5 mV/V isosurface

Offset dipole-dipole - 50m x 100m mesh

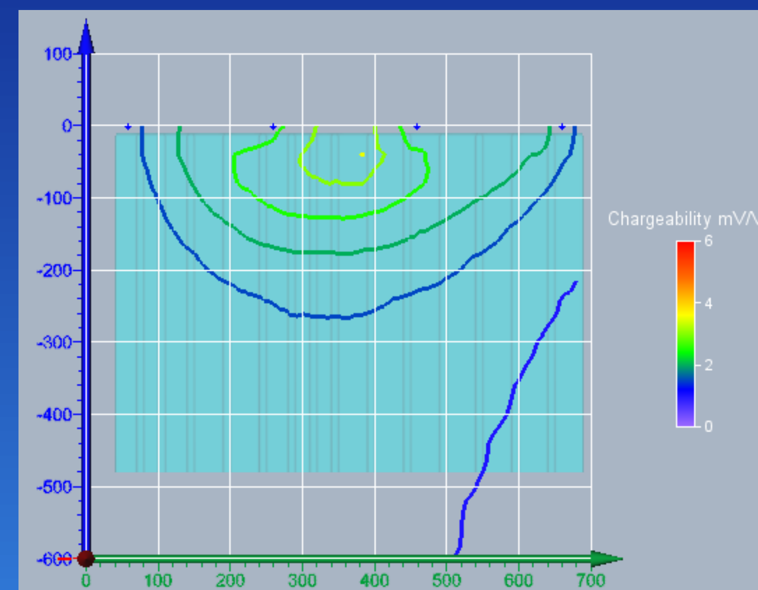


3D view with 2.5 mV/V isosurface

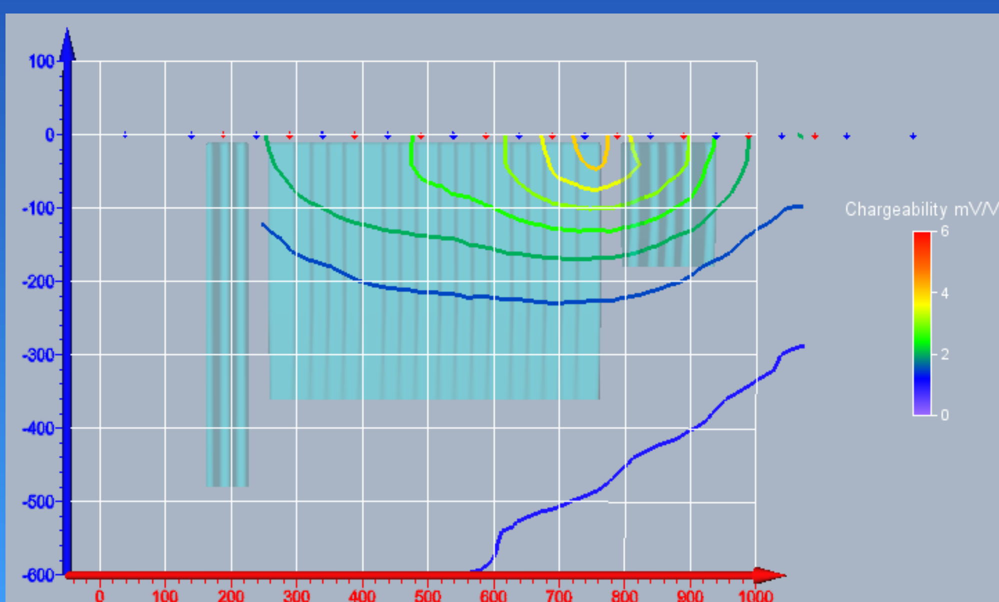
Offset dipole-dipole - 50m x 50m mesh



Plan view

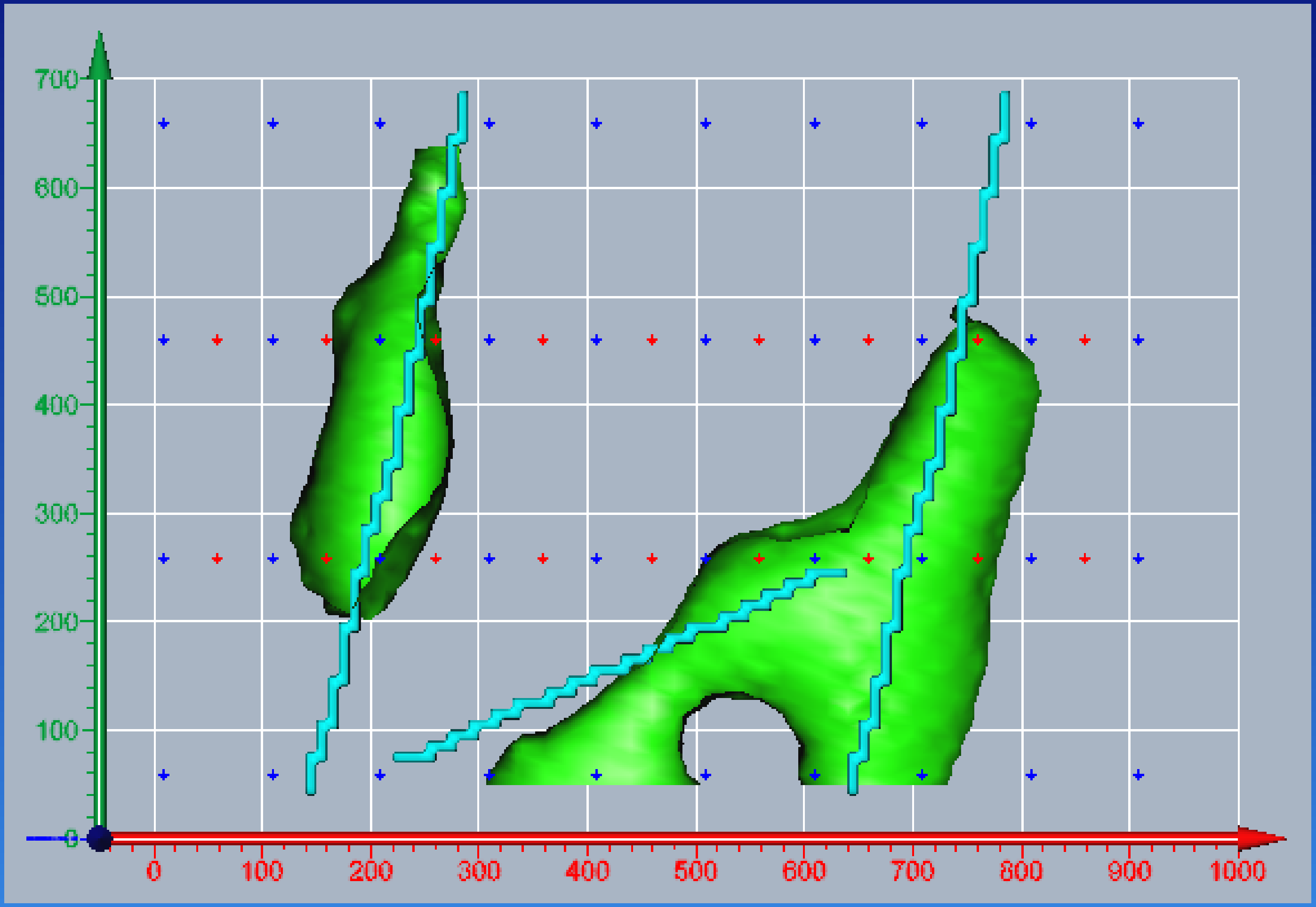


Side section



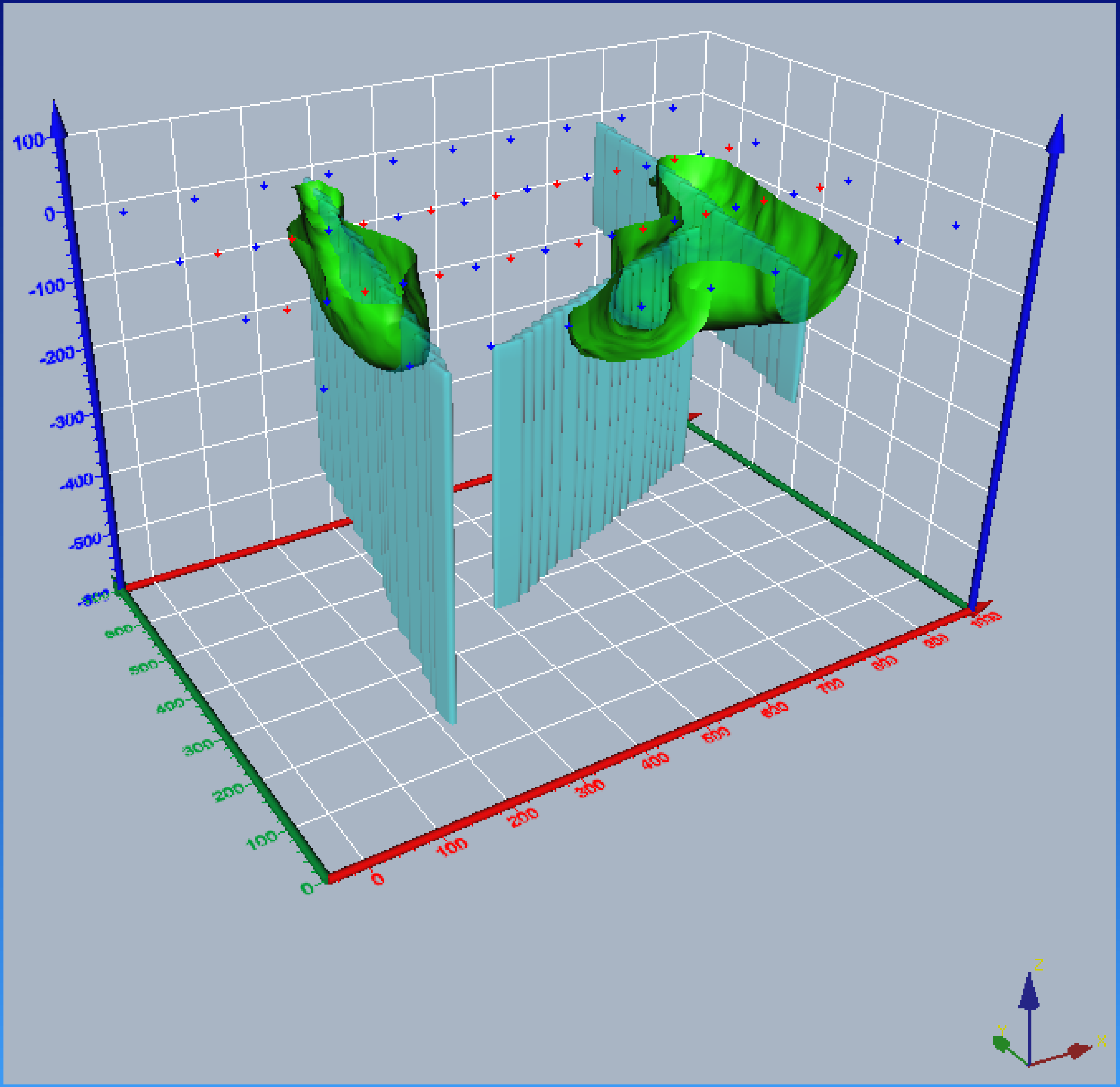
Front section

Offset dipole-dipole - 50m x 50m mesh



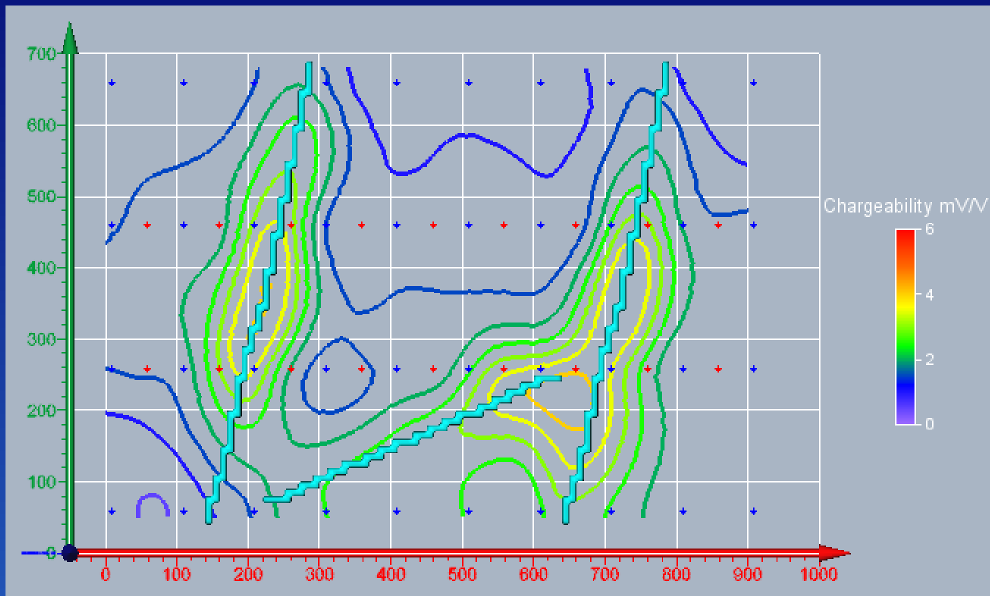
Plan view with 2.5 mV/V isosurface

Offset dipole-dipole - 50m x 50m mesh

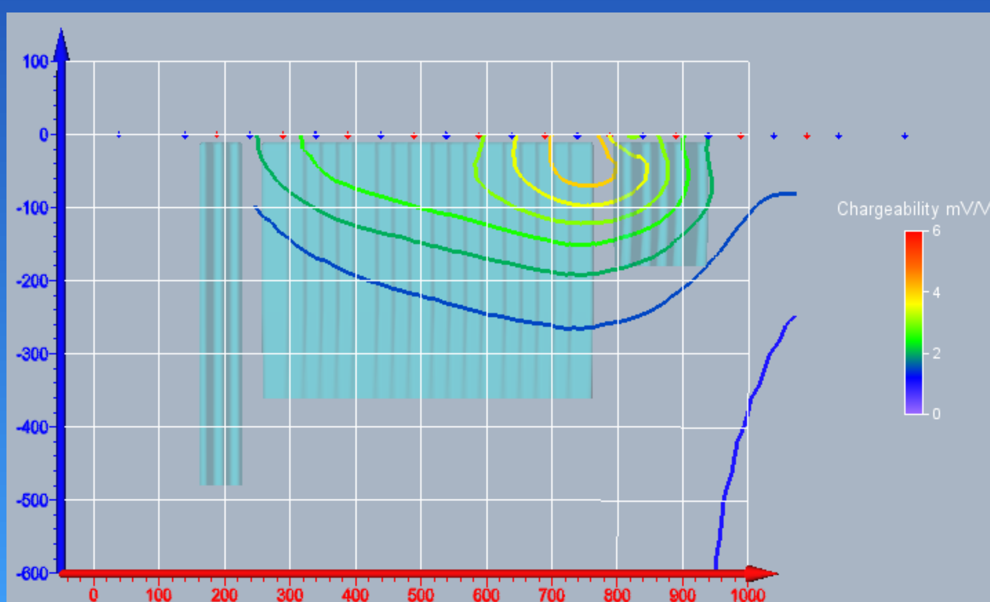


3D view with 2.5 mV/V isosurface

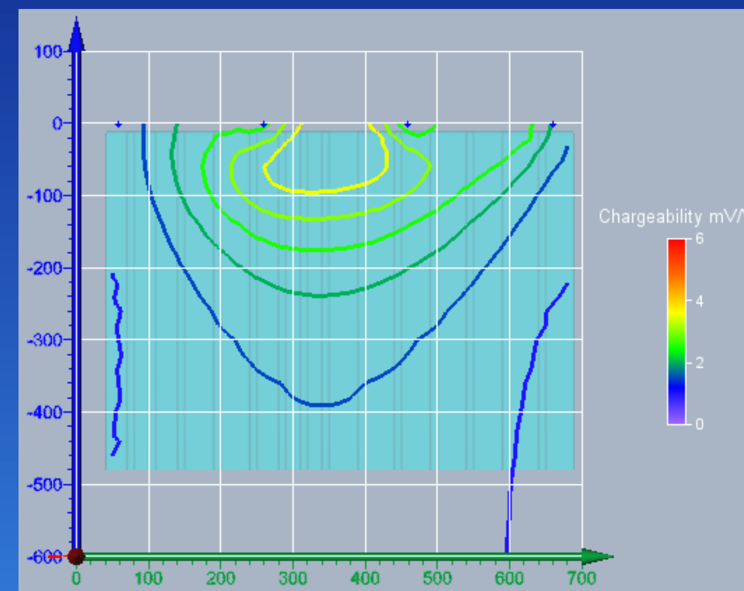
Offset dipole-dipole - 25m x 25m mesh



Plan view

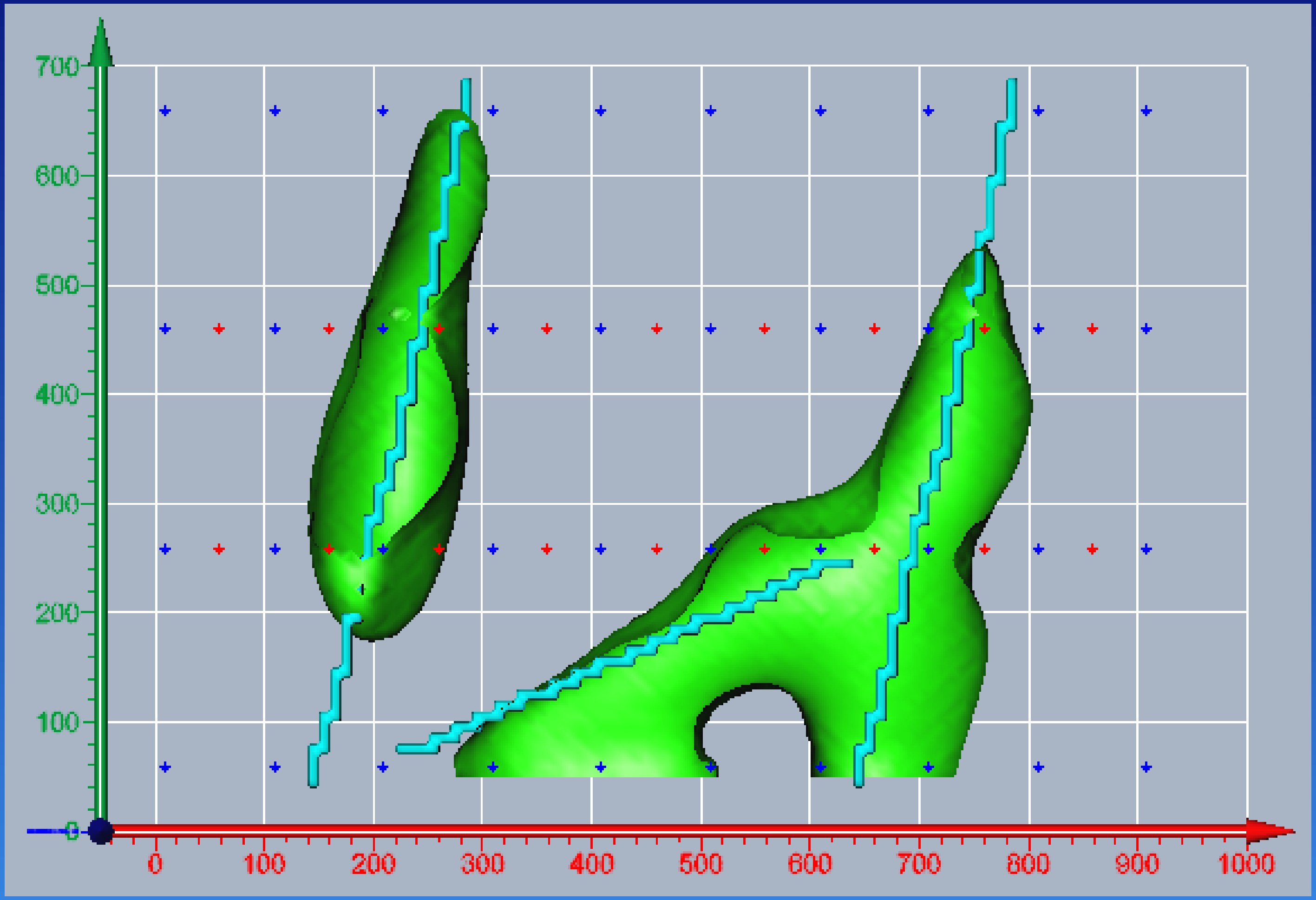


Front section



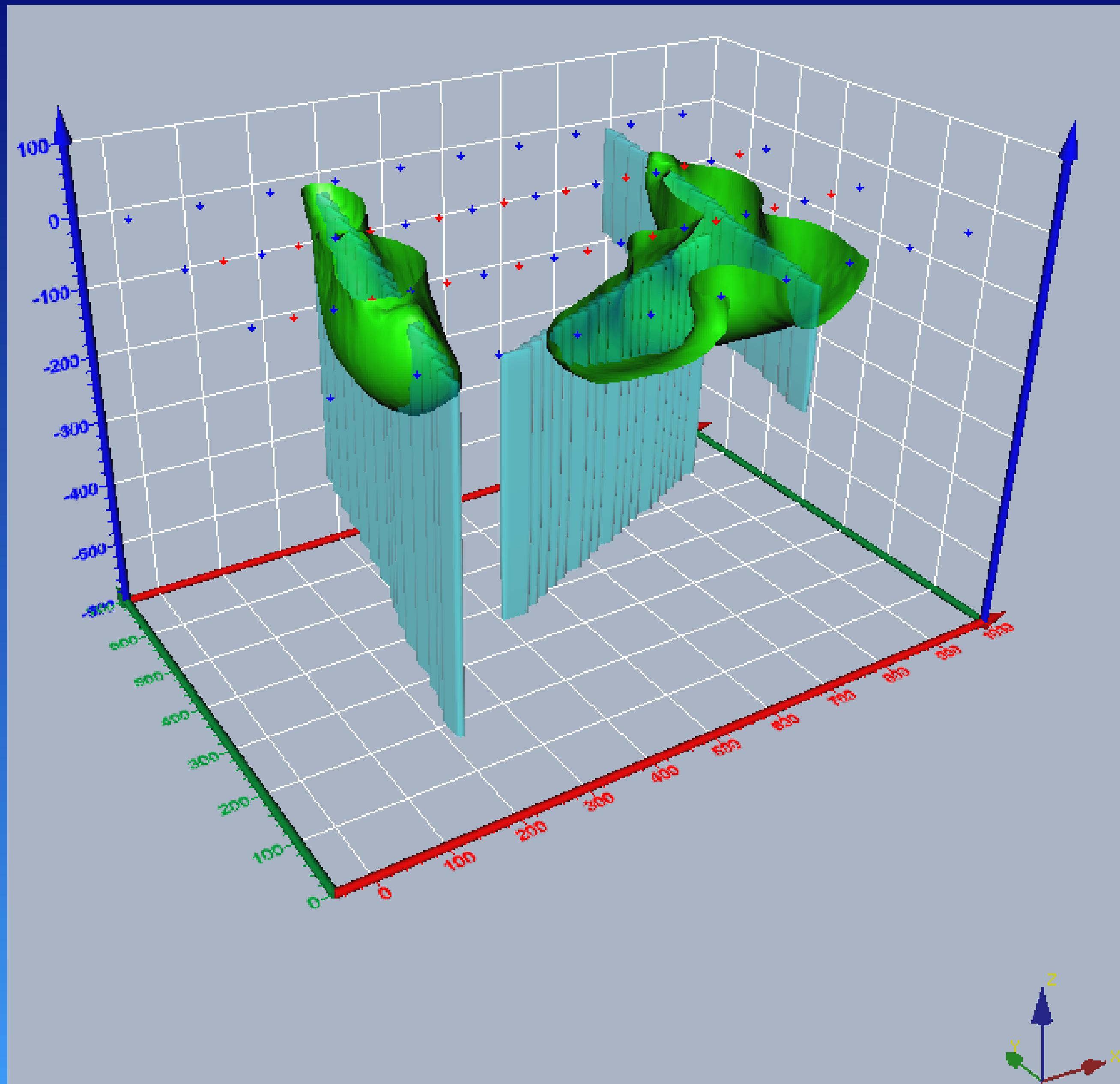
Side section

Offset dipole-dipole - 25m x 25m mesh



Plan view with 2.5 mV/V isosurface

Offset dipole-dipole - 25m x 25m mesh



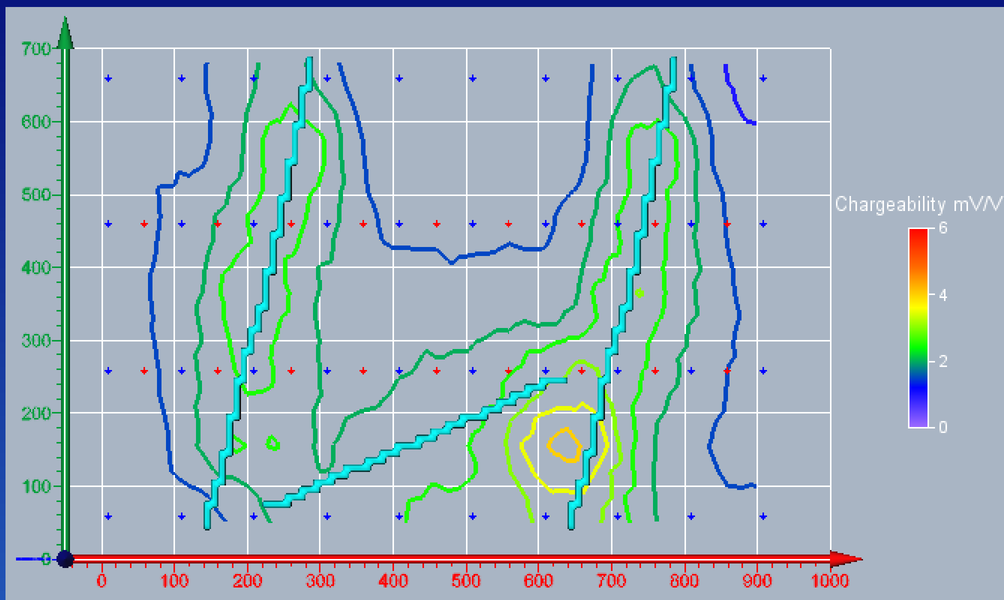
3D view with 2.5 mV/V isosurface

Offset dipole-dipole - Observations

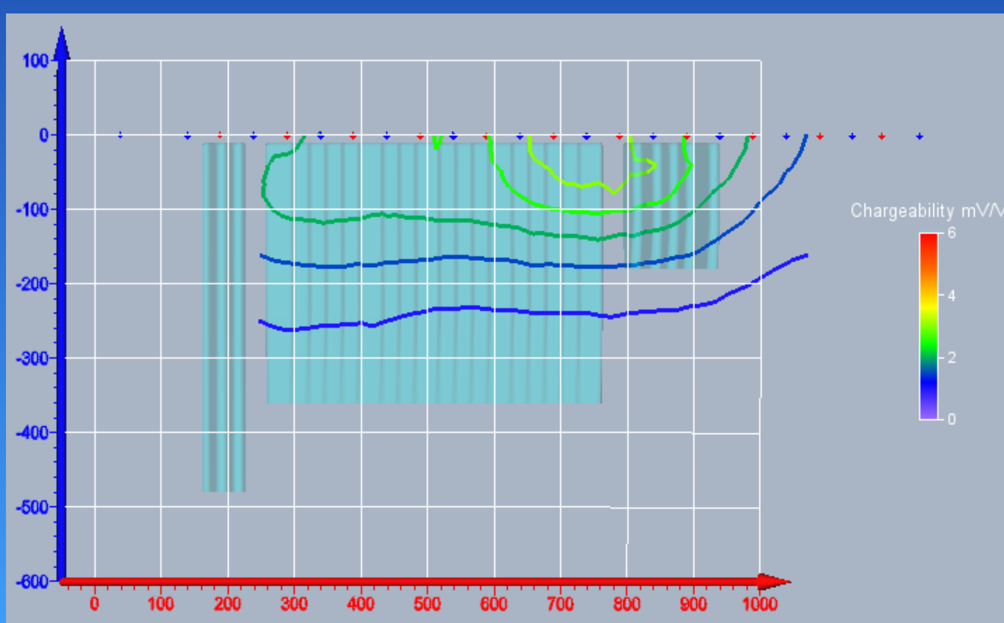
- As the voxel size decreases, the central and right most bodies become more clearly resolved as does the strike of the left most body.
- Likewise the maximum anomaly moves closer to the projected intersection point between the left and central bodies.
- At the coarsest voxel size the strike of the left most most body was not resolved
- The thin bodies are not resolved well beyond 200m (2 dipoles) depth

Offset Pole-dipole array

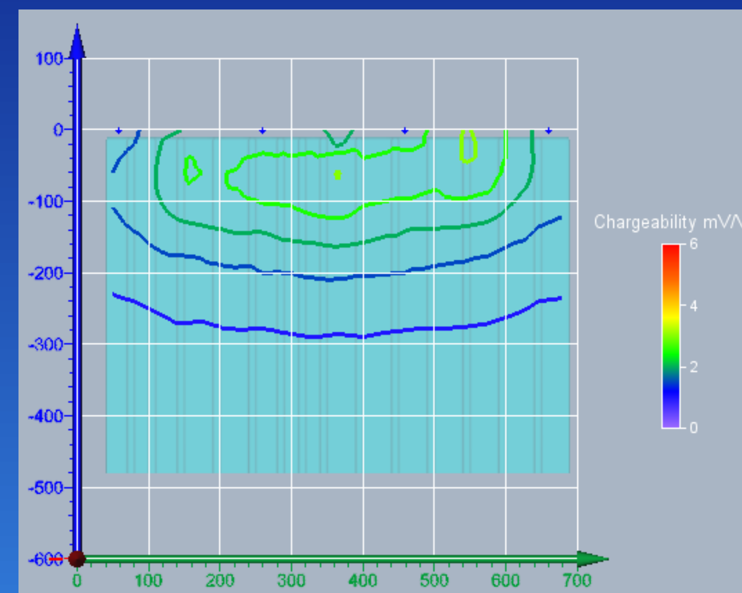
Offset Pole-dipole - 50m x 200m mesh



Plan view

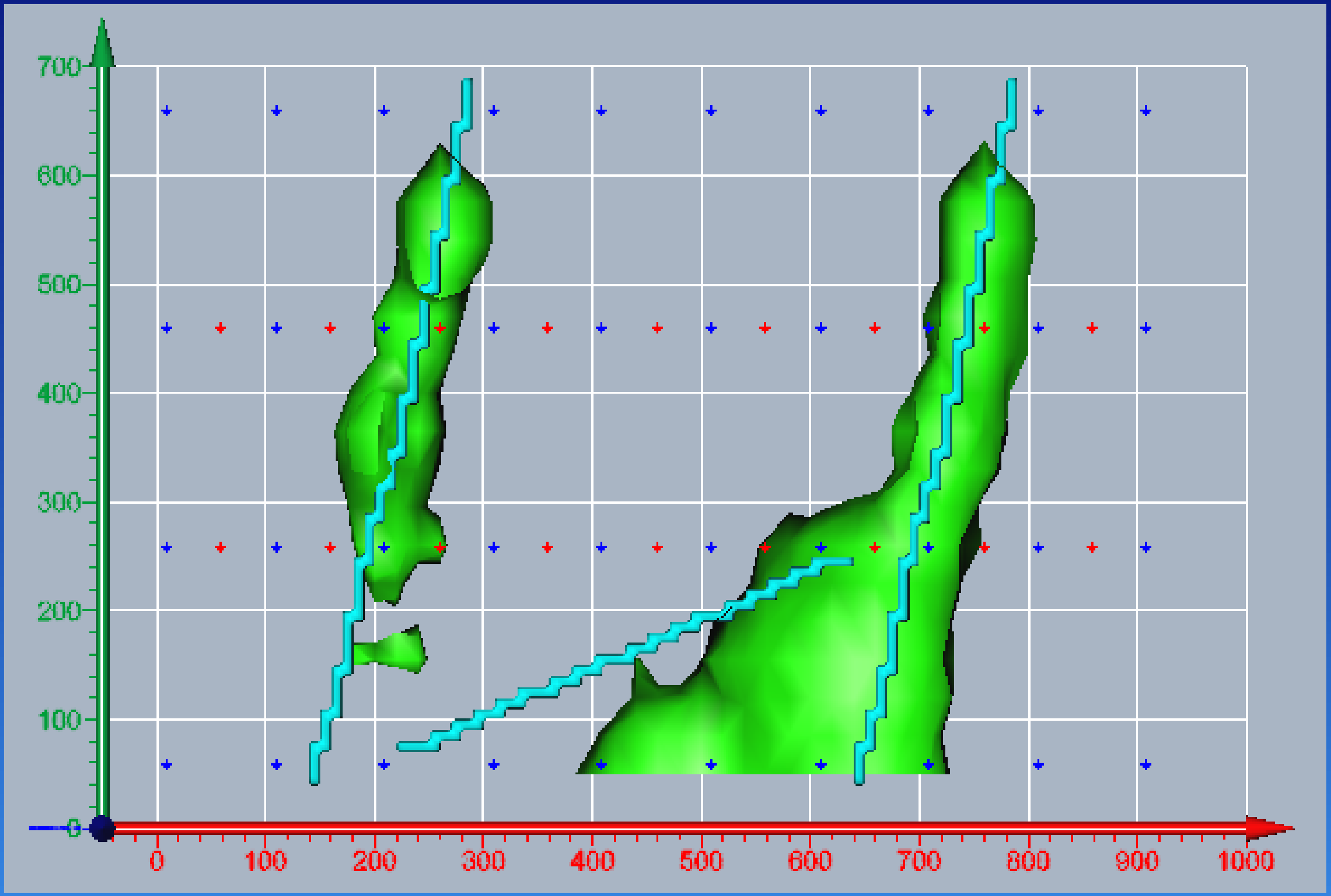


Front section



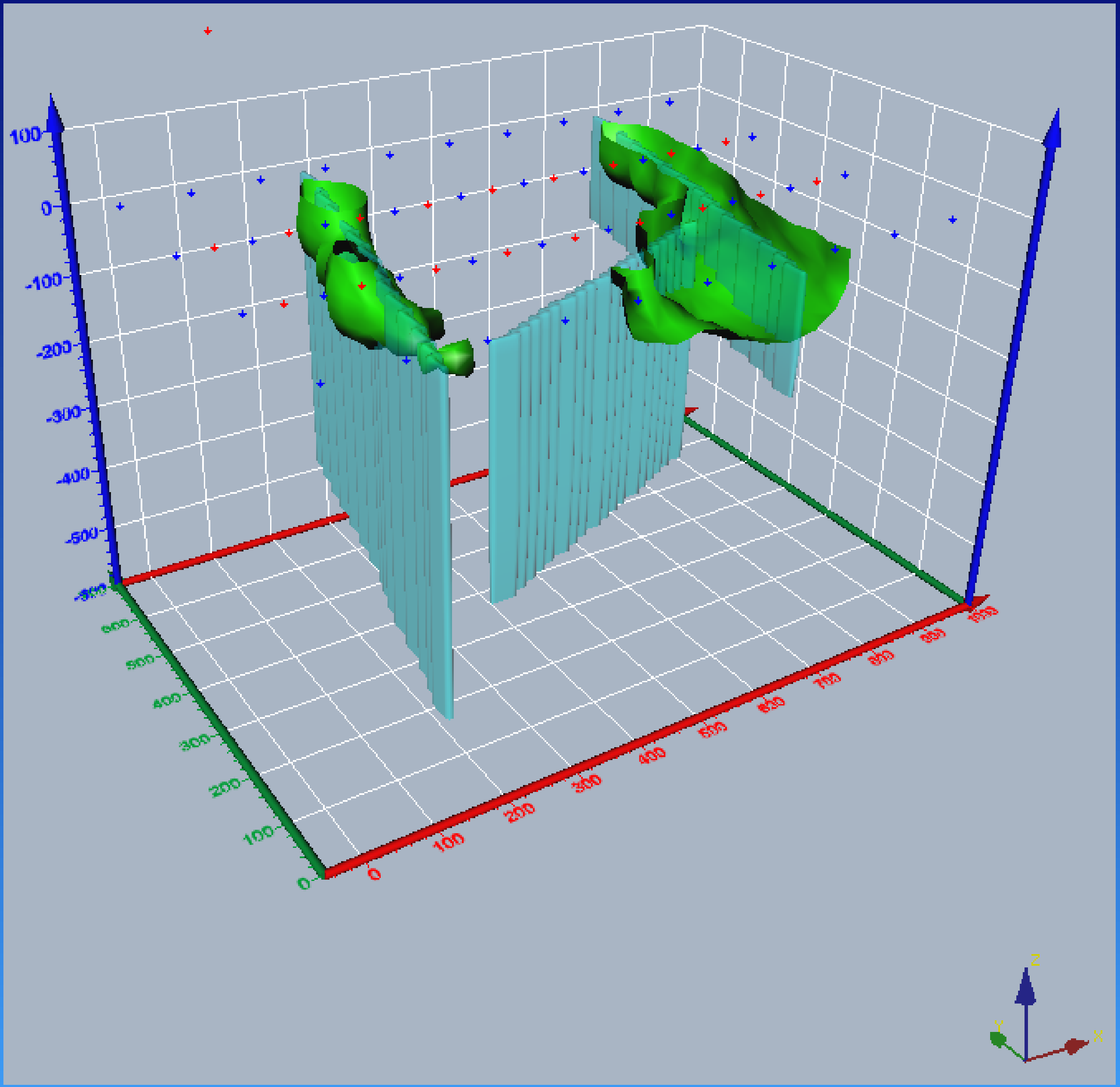
Side section

Pole-dipole - 50m x 200m mesh



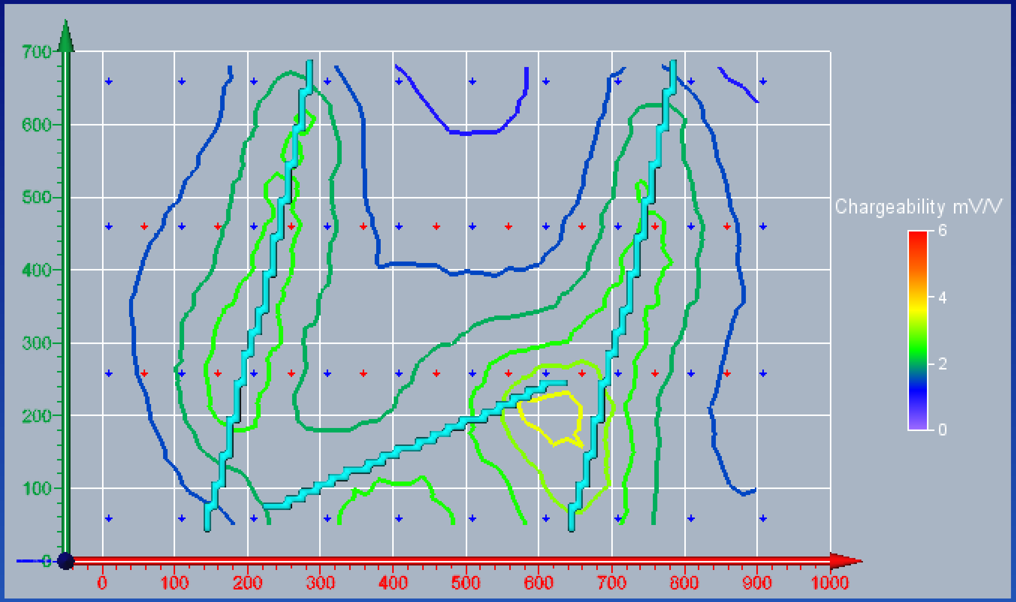
Plan view with 2.5 mV/V isosurface

Pole-dipole - 50m x 200m mesh

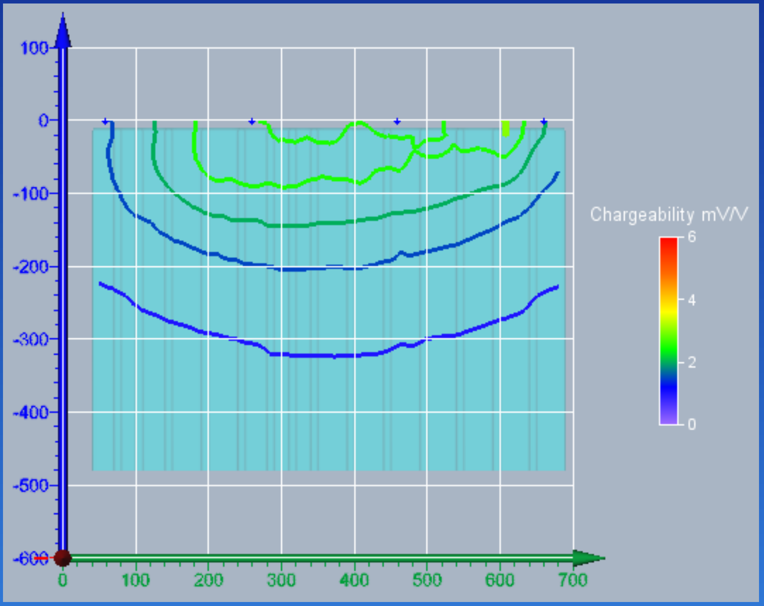


3D view with 2.5 mV/V isosurface

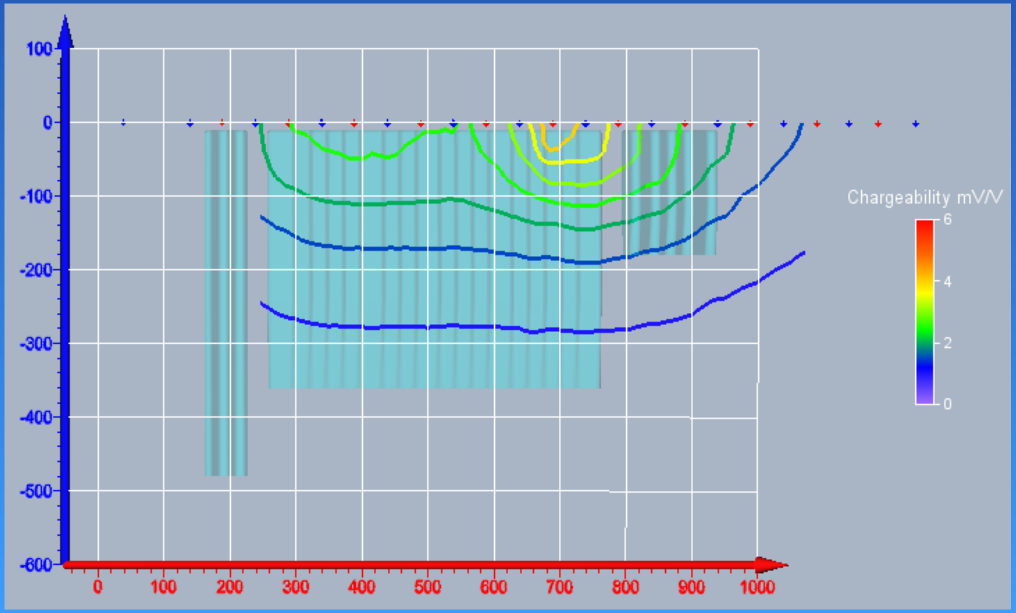
Pole-dipole - 50m x 100m mesh



Plan view

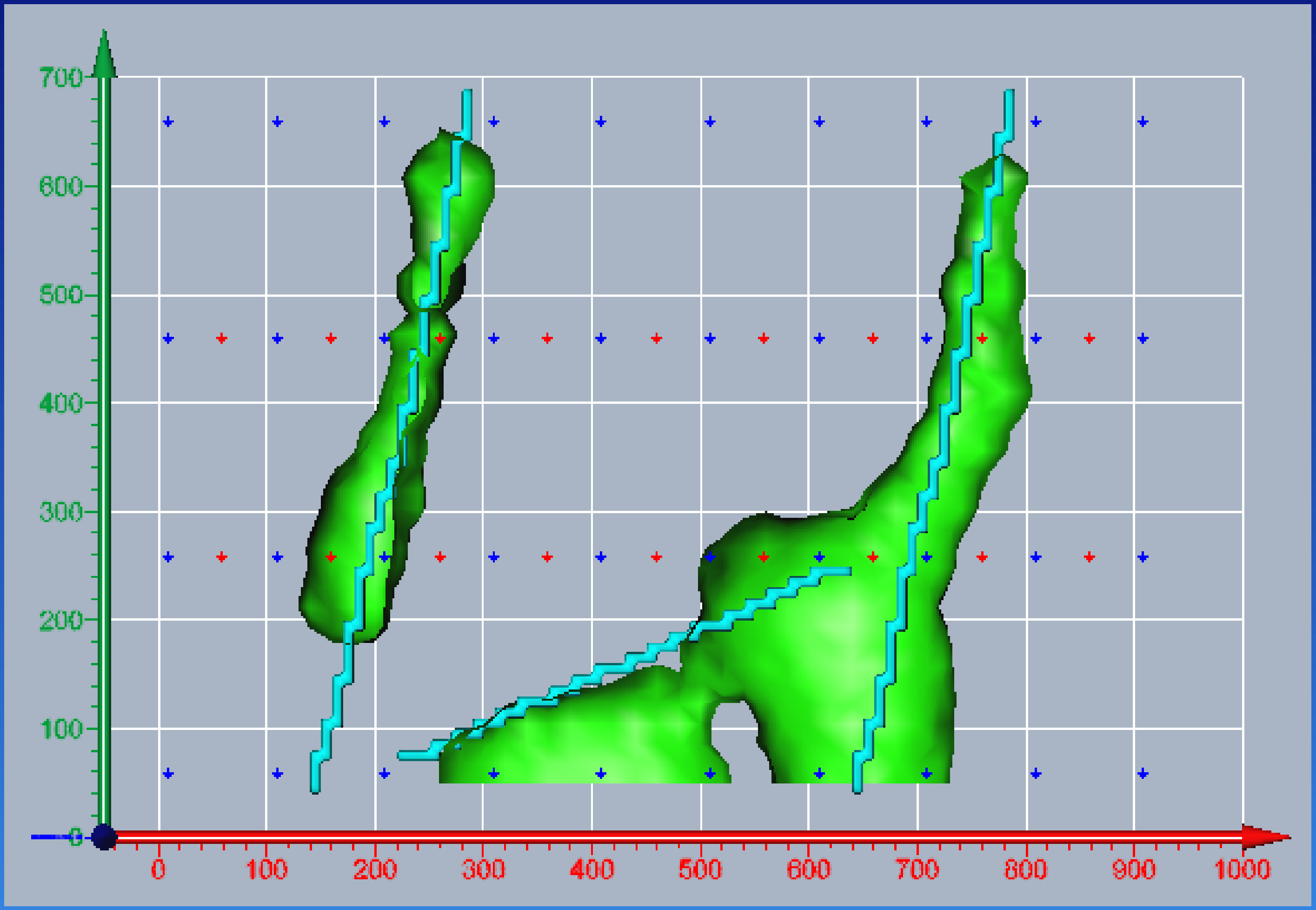


Side section



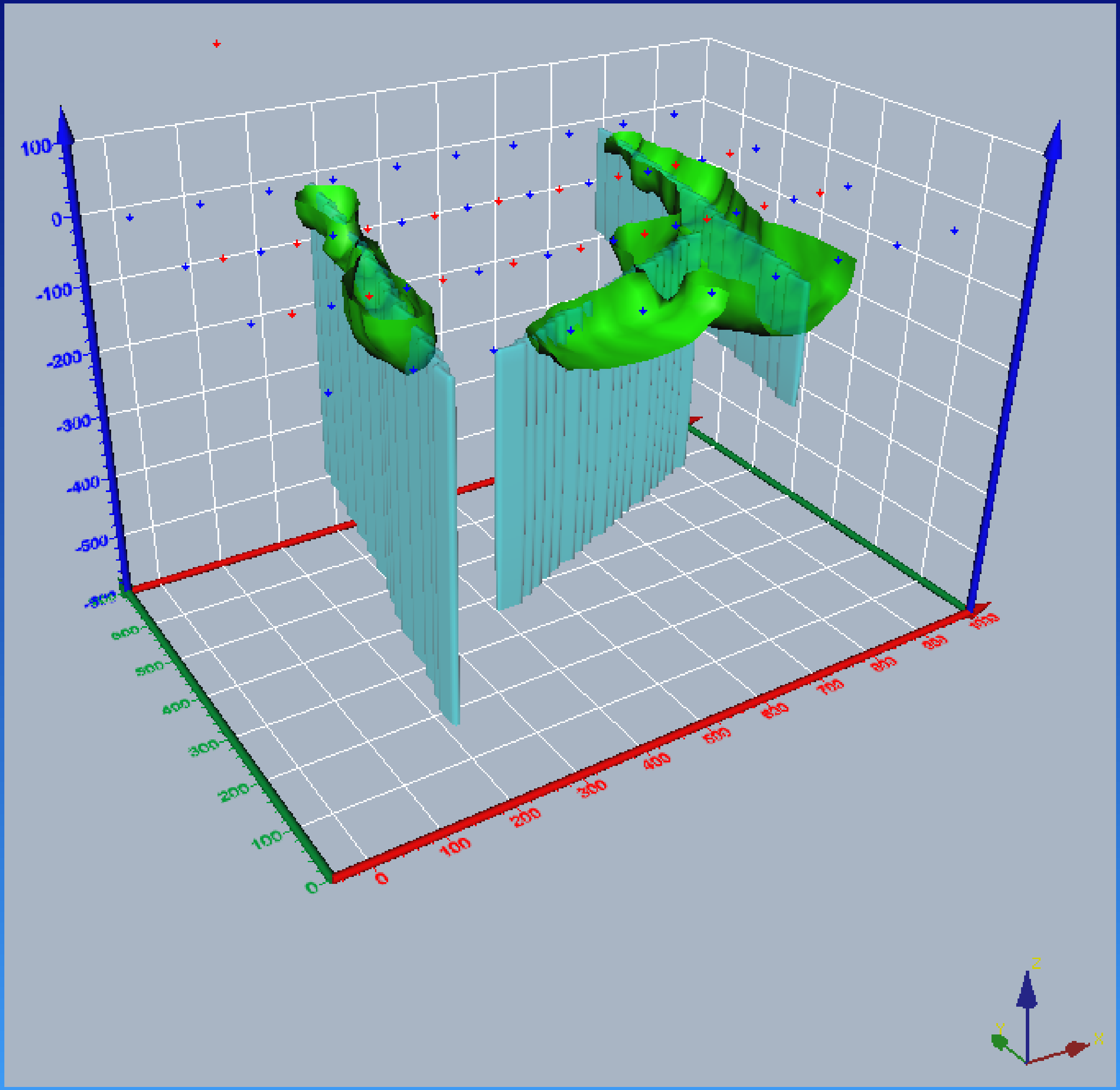
Front section

Offset Pole-dipole - 50m x 100m mesh



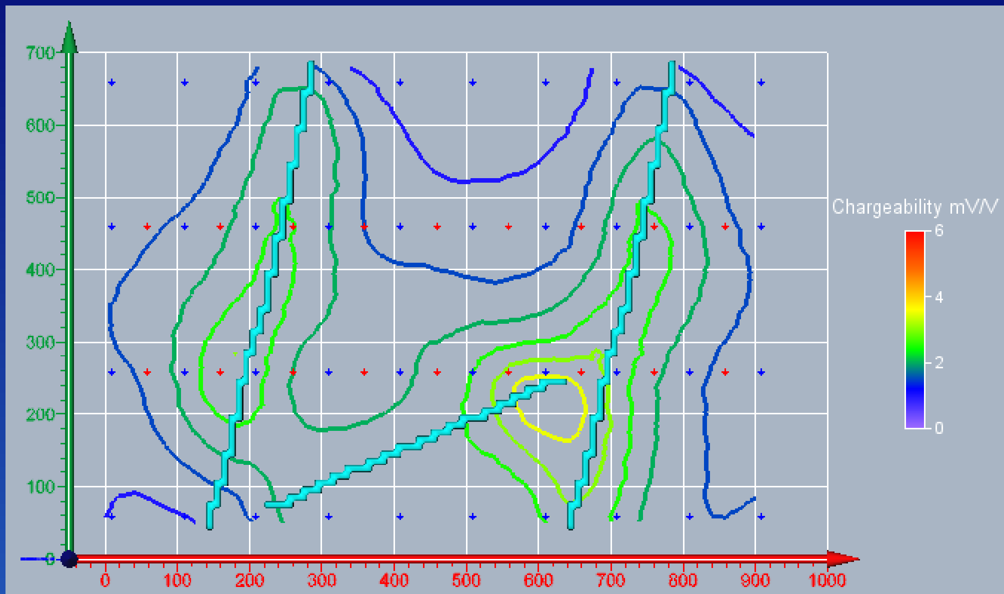
Plan view with 2.5 mV/V isosurface

Offset Pole-dipole - 50m x 100m mesh

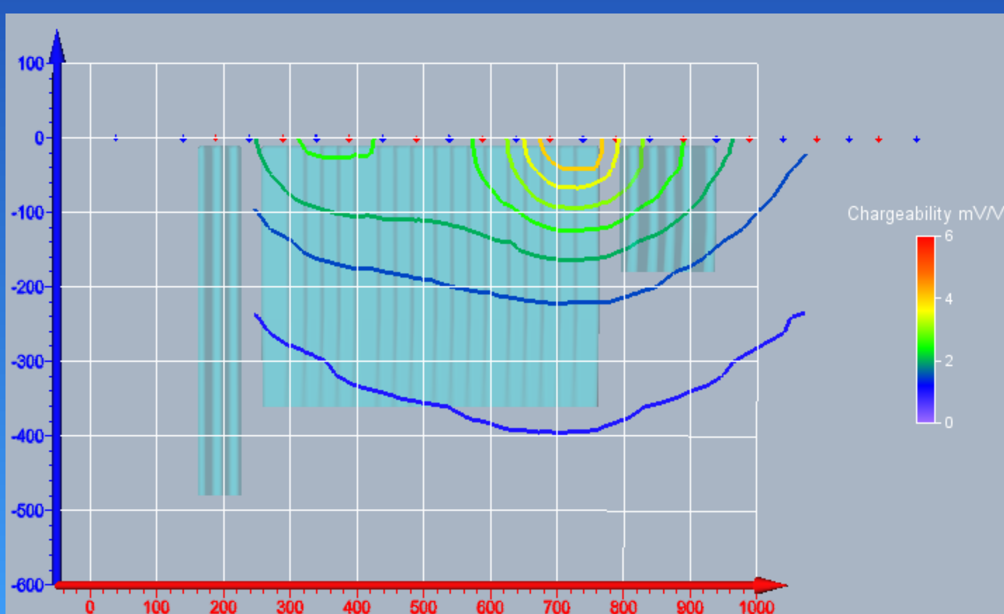


3D view with 2.5 mV/V isosurface

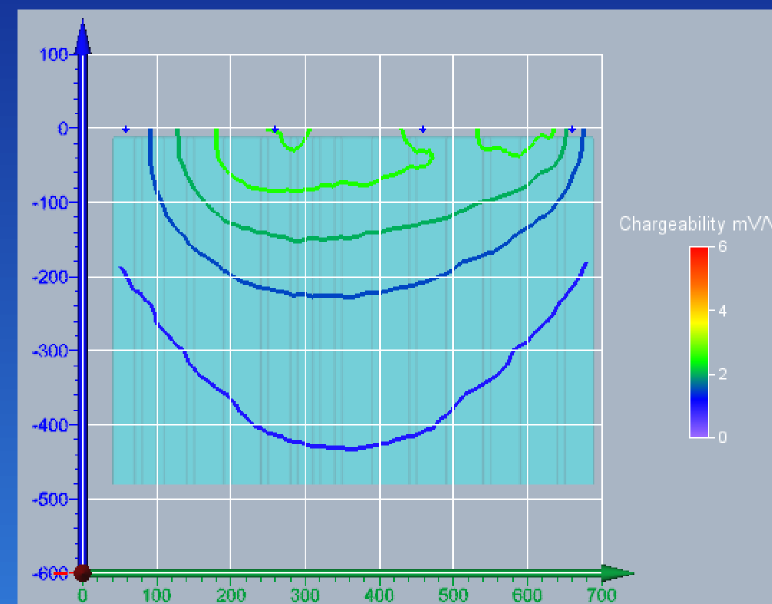
Offset Pole-dipole - 50m x 50m mesh



Plan view

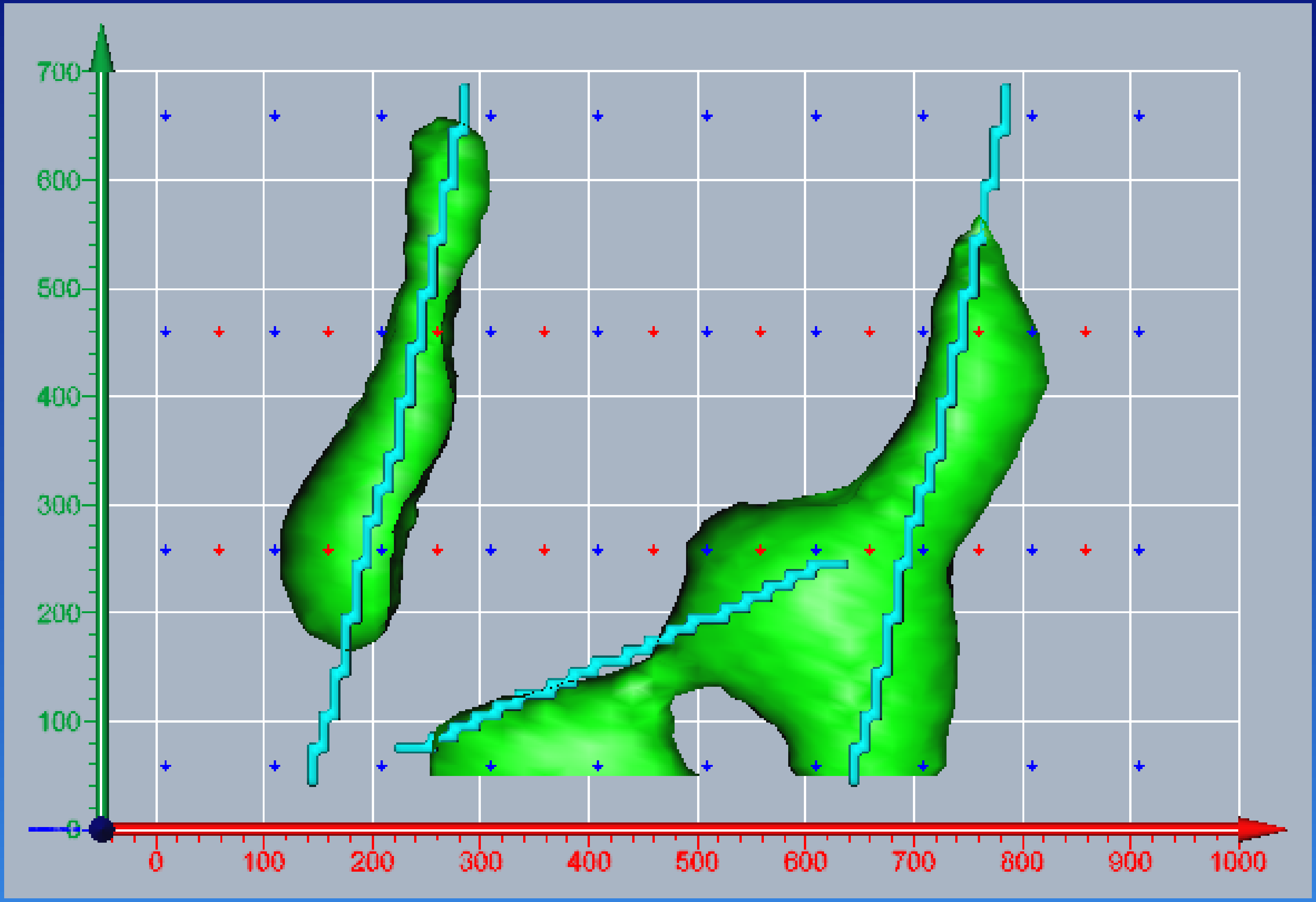


Front section



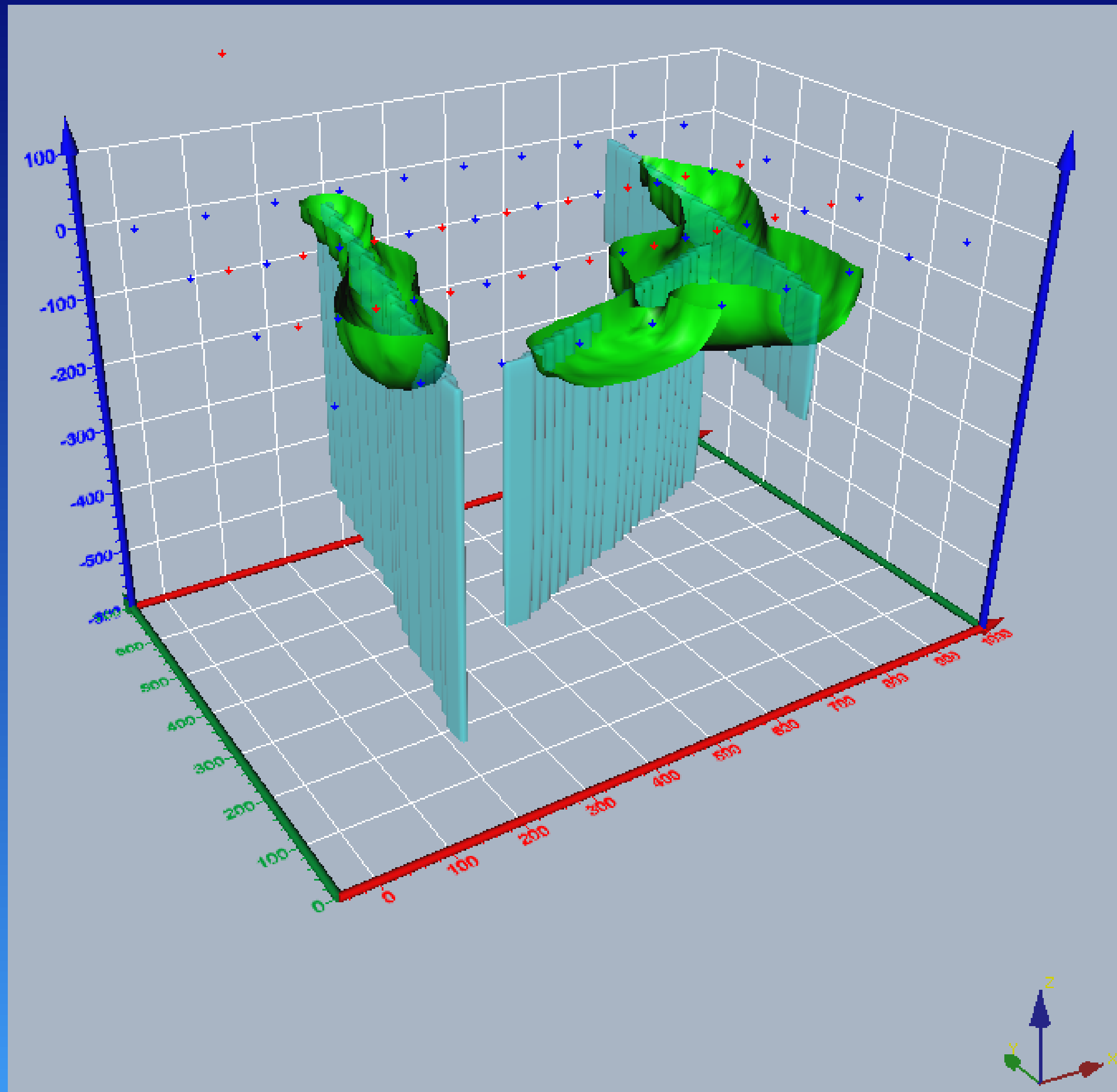
Side section

Offset Pole-dipole - 50m x 50m mesh



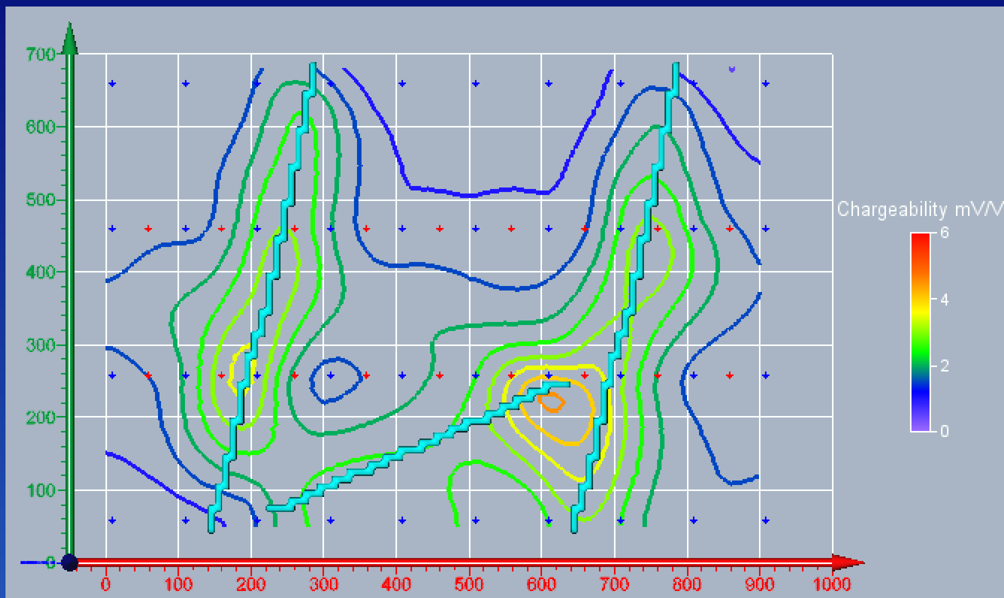
Plan view with 2.5 mV/V isosurface

Offset Pole-dipole - 50m x 50m mesh

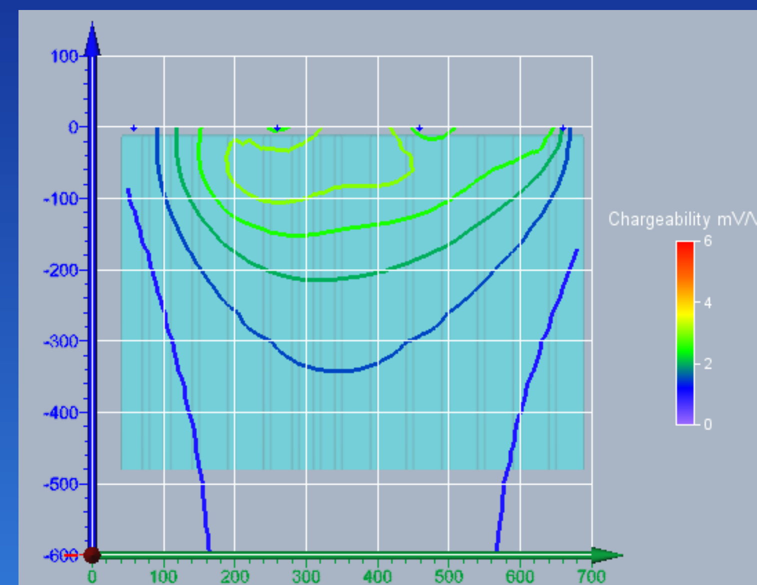


3D view with 2.5 mV/V isosurface

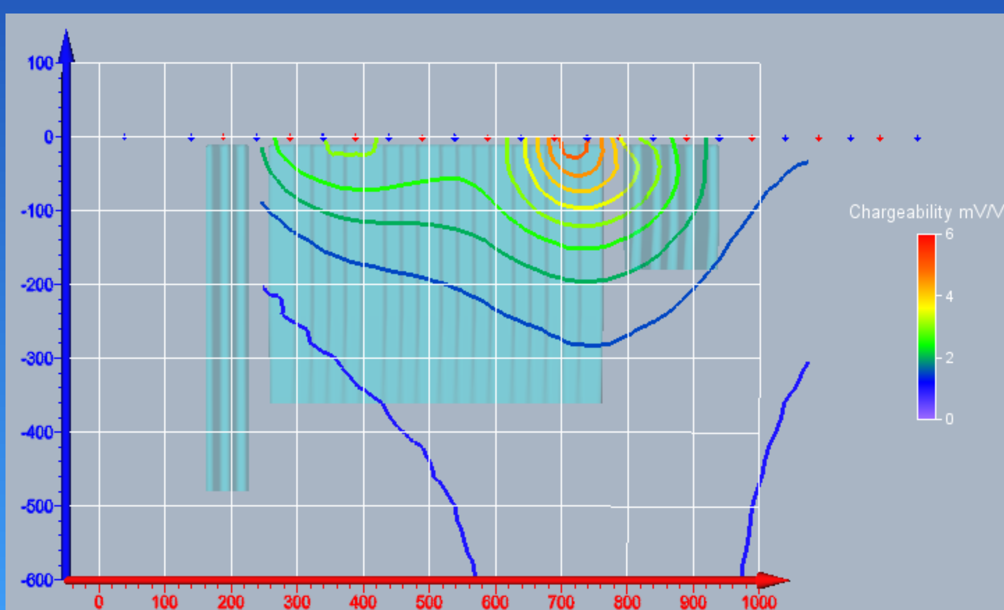
Offset Pole-dipole - 25m x 25m mesh



Plan view

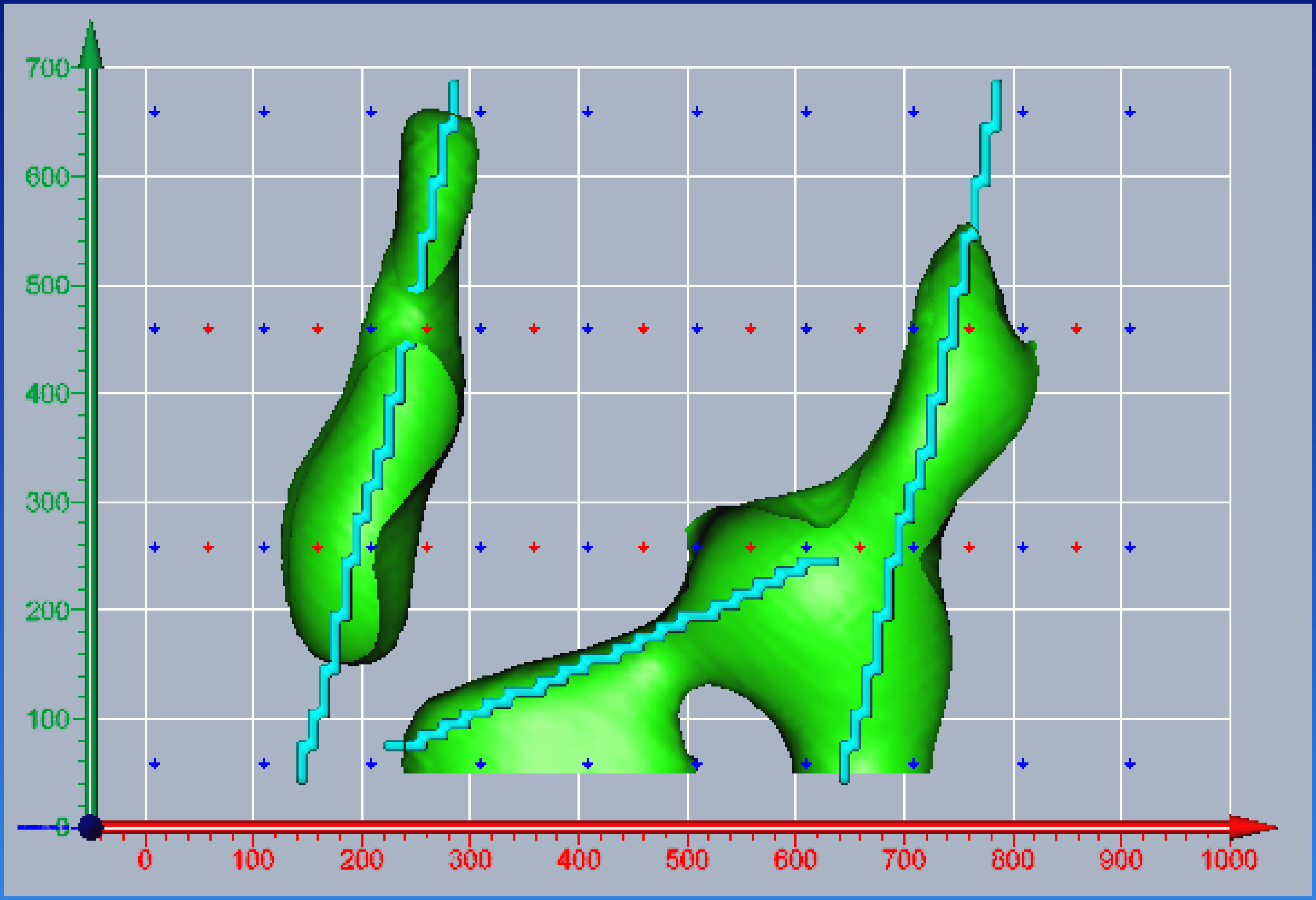


Side section



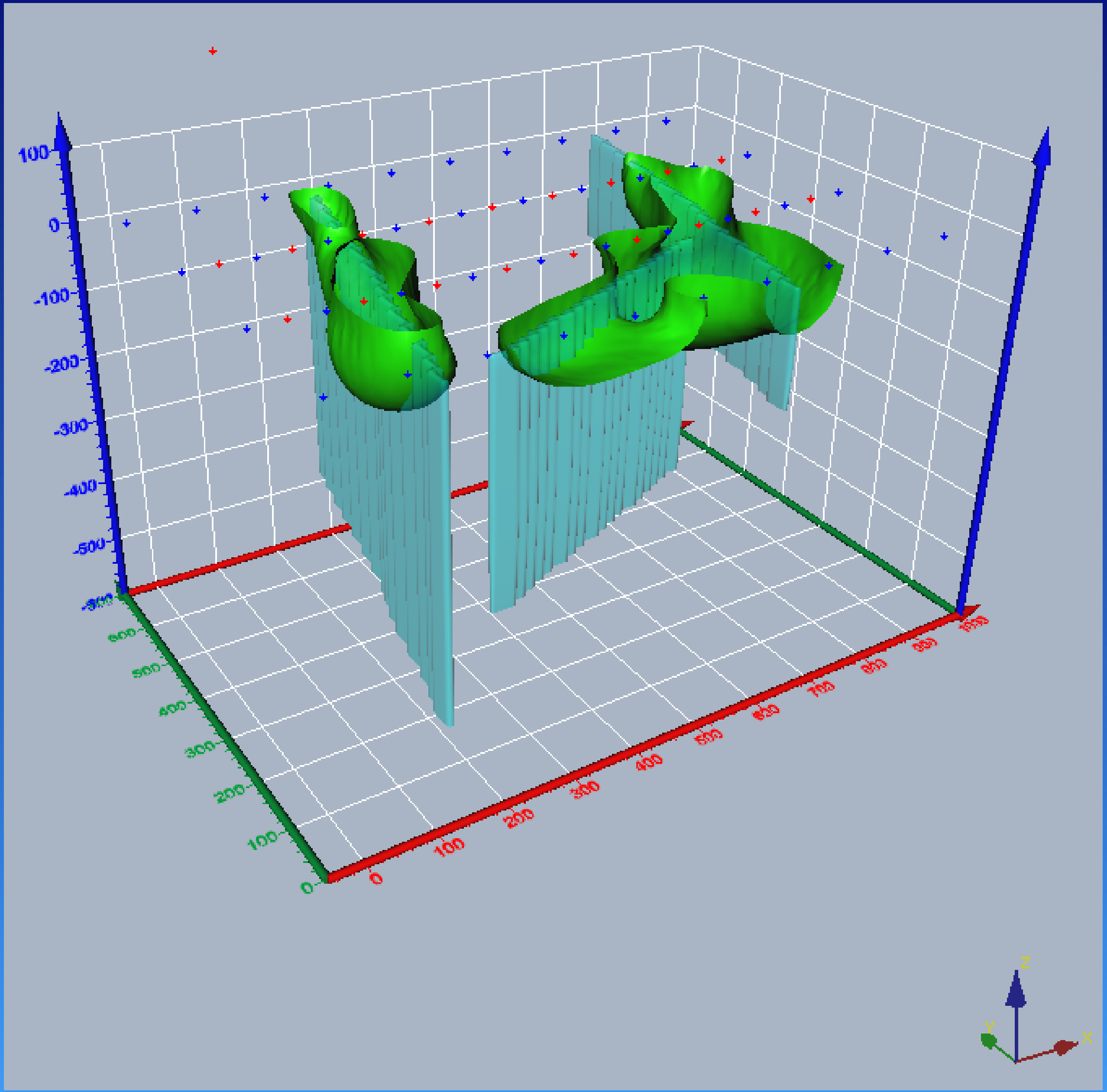
Front section

Offset Pole-dipole - 25m x 25m mesh



Plan view with 2.5 mV/V isosurface

Offset Pole-dipole - 25m x 25m mesh



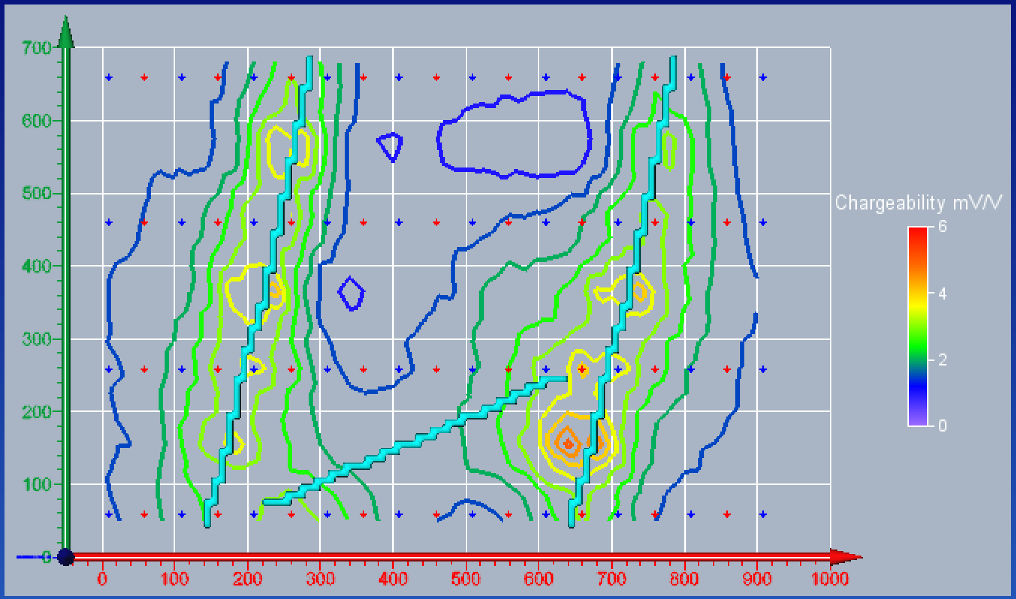
3D view with 2.5 mV/V isosurface

Offset Pole-dipole - Observations

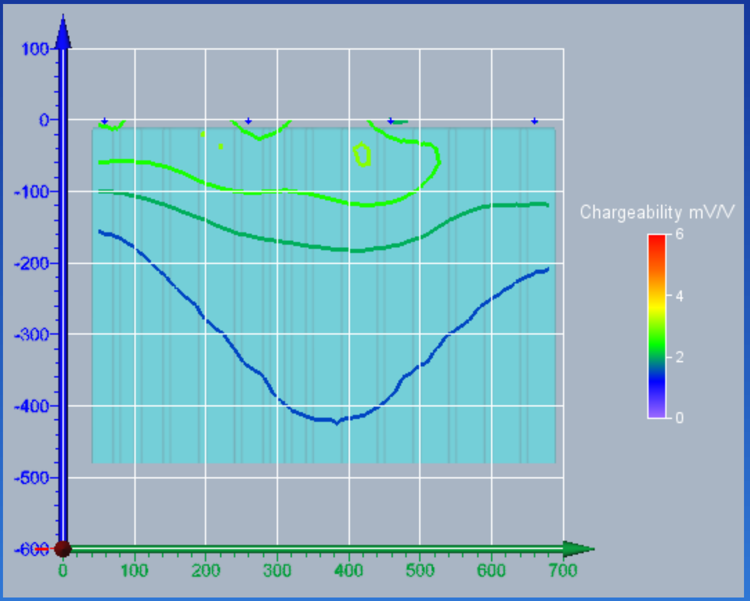
- As the voxel size decreases, the central and right hand bodies become more clearly resolved.
- The pole-dipole array has done a slightly better job of resolving the bodies, in plan, than the offset dipole-dipole array, particularly at coarser mesh sizes.
- In these examples the pole-dipole array shows a greater contrast in chargeability over the bodies, at shallow depths but does not appear to be extending the bodies to the same depth as the offset dipole-dipole

Co-linear dipole-dipole array

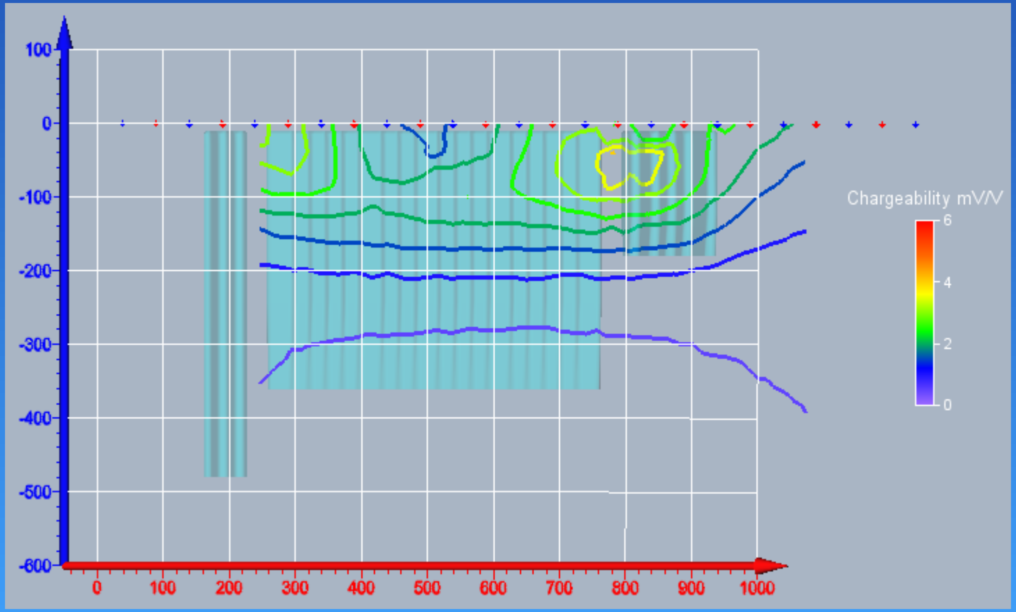
Co-linear dipole-dipole - 50m x 200m mesh



Plan view

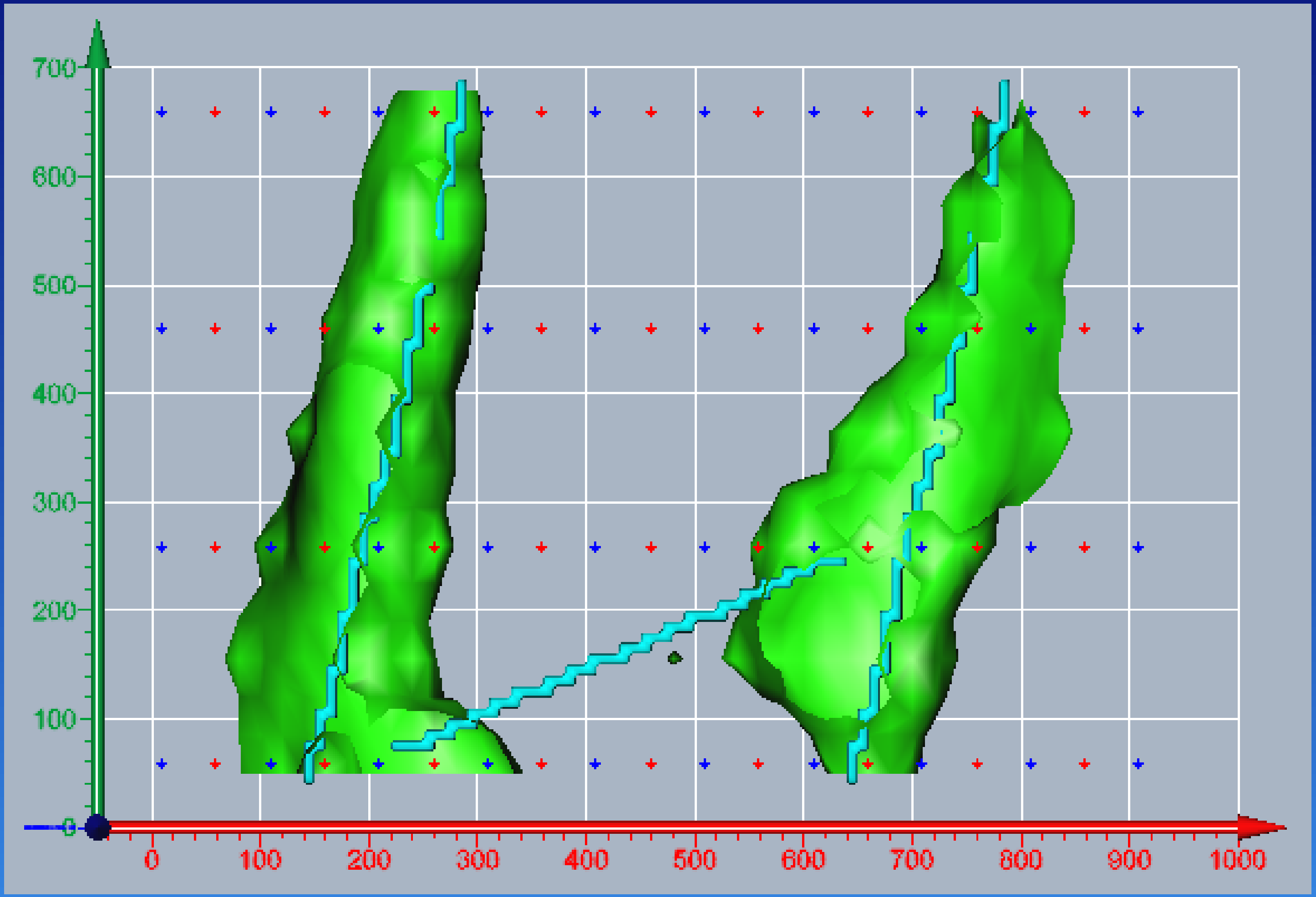


Side section



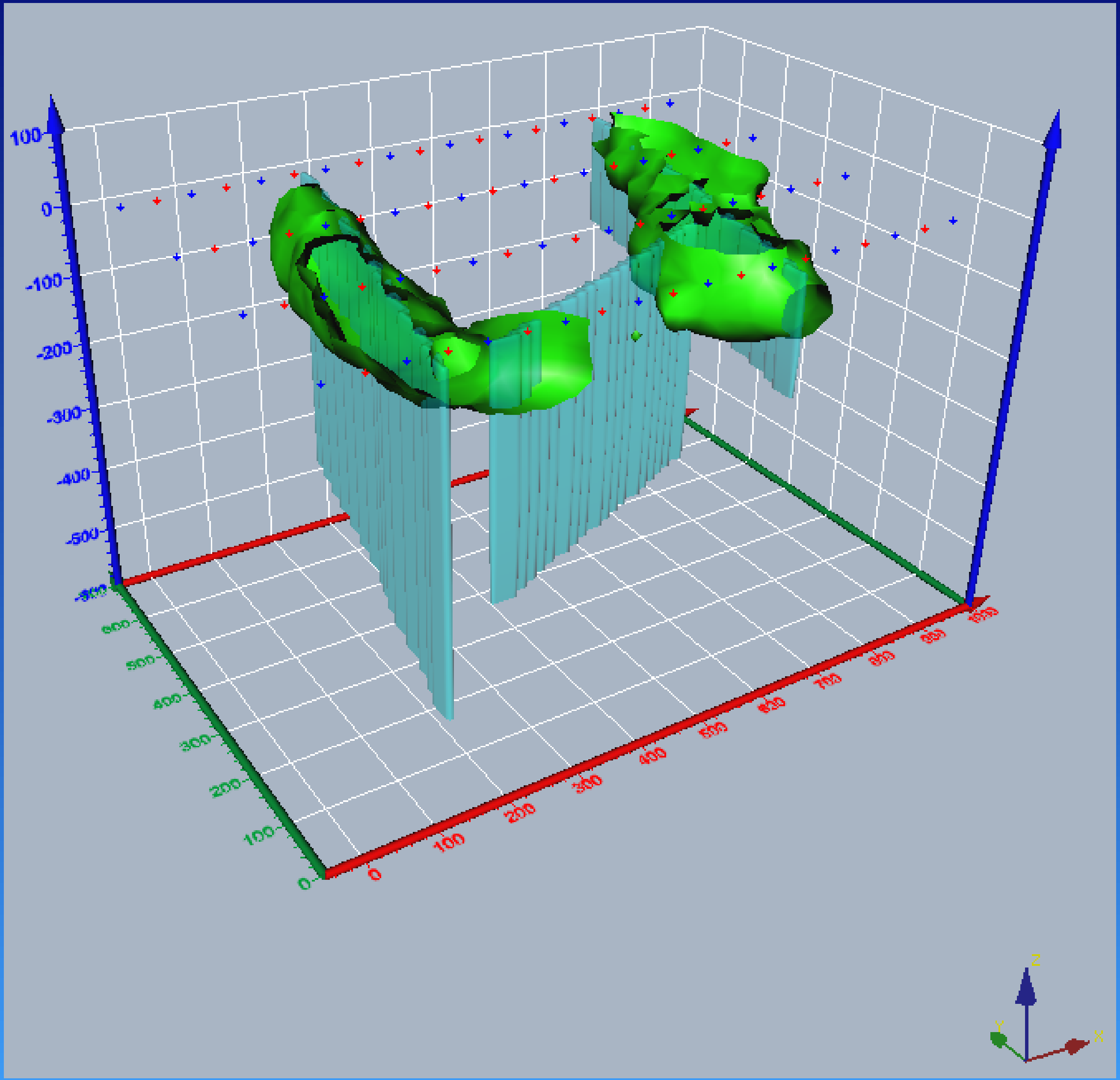
Front section

Co-linear dipole-dipole - 50m x 200m mesh



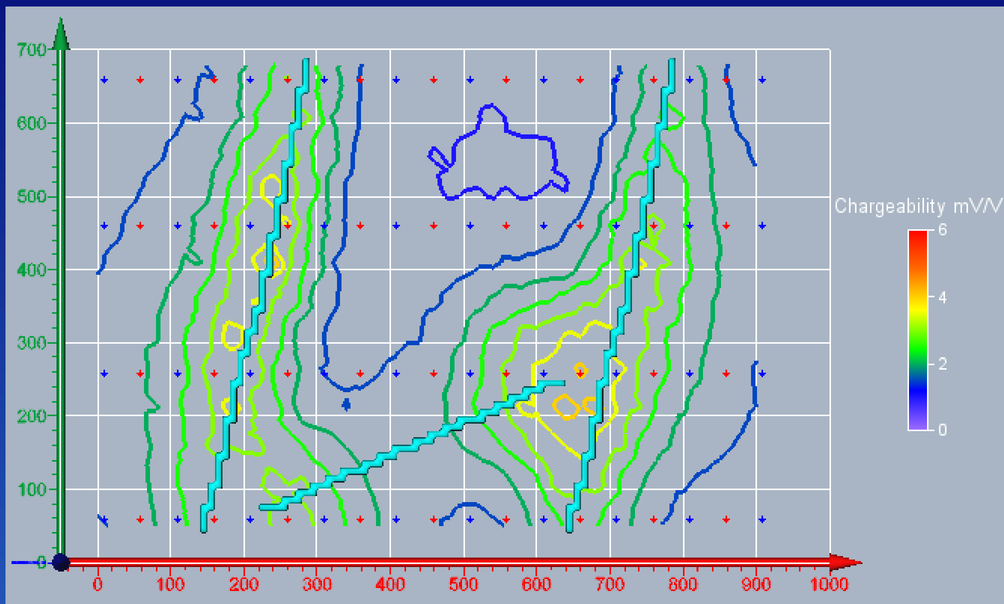
Plan view with 2.5 mV/V isosurface

Co-linear dipole-dipole - 50m x 200m mesh

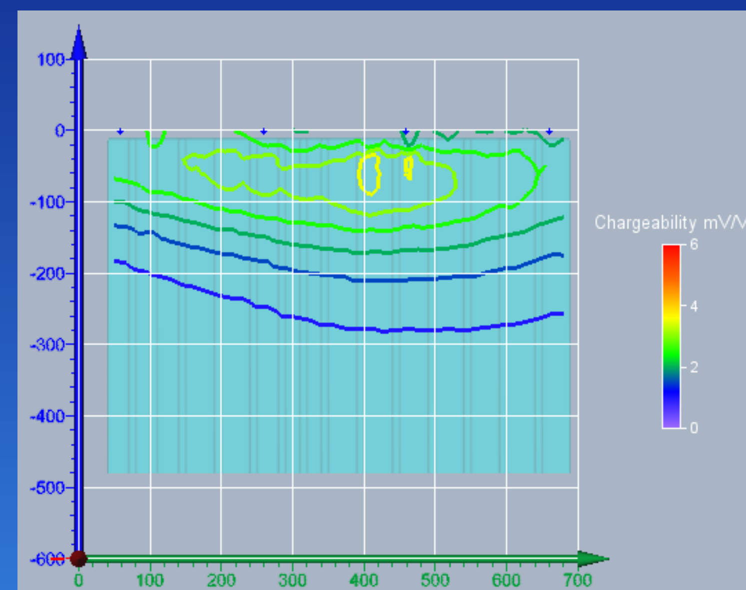


3D view with 2.5 mV/V isosurface

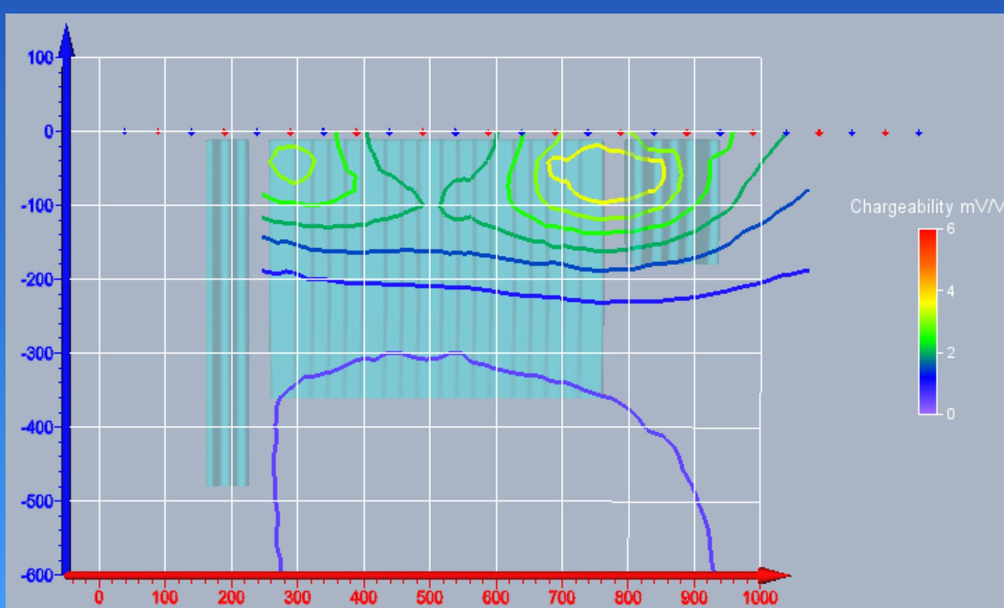
Co-linear dipole-dipole - 50m x 100m mesh



Plan view

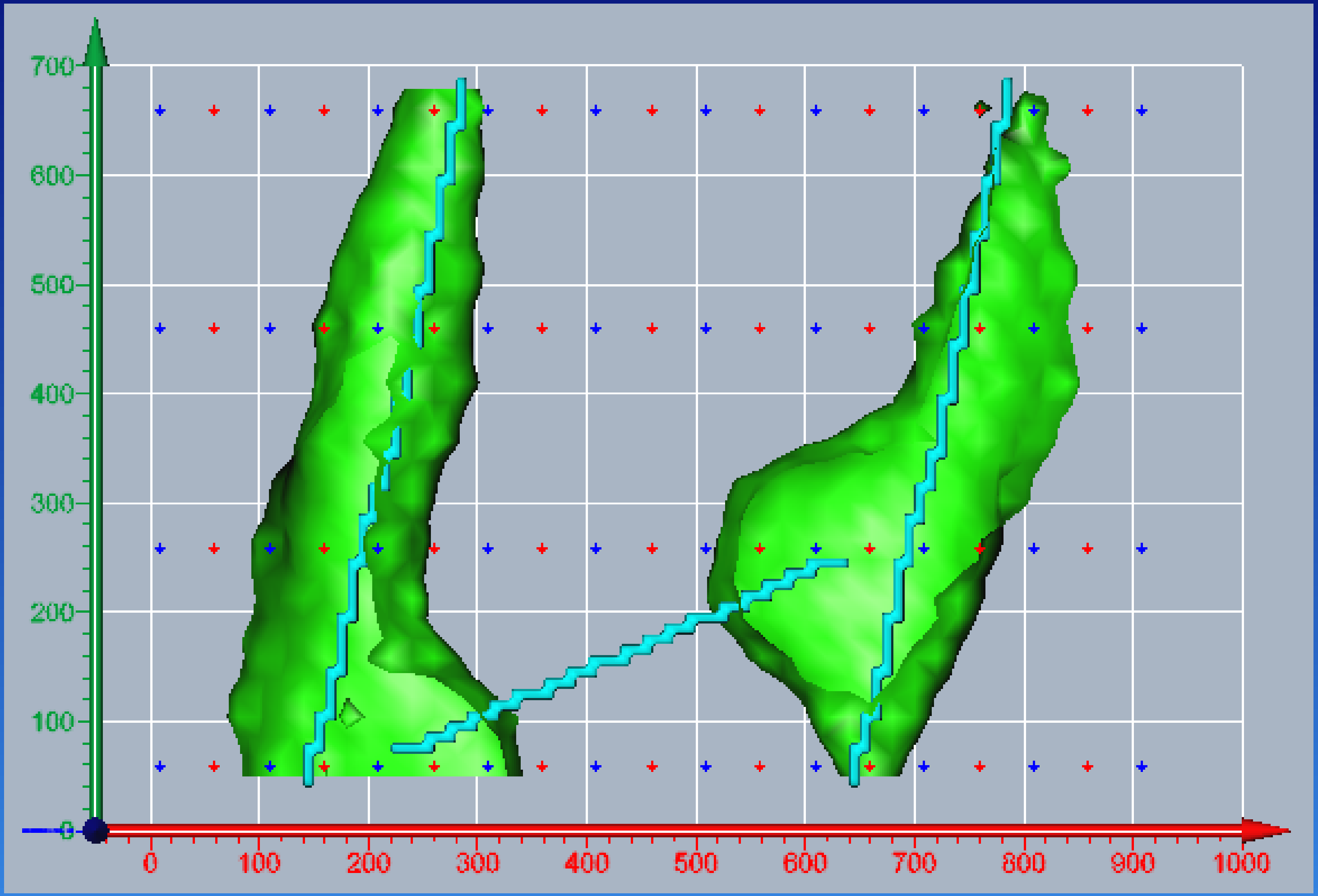


Side section



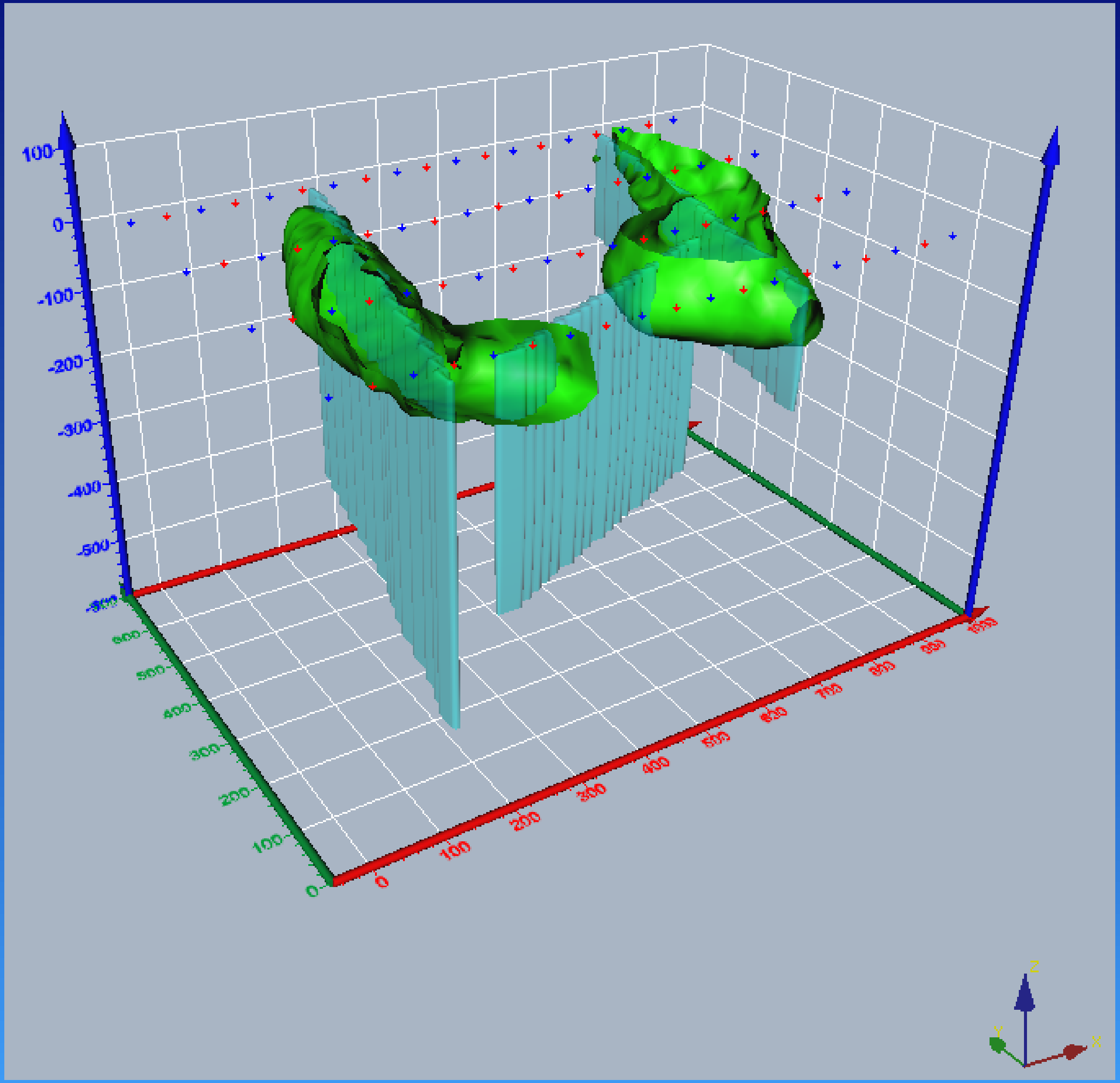
Front section

Co-linear dipole-dipole - 50m x 100m mesh



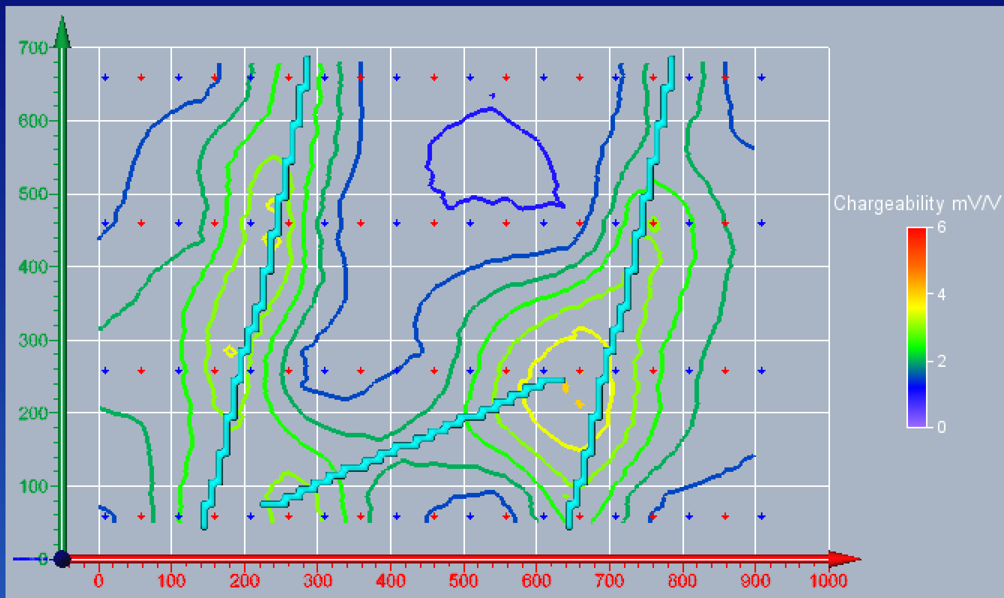
Plan view with 2.5 mV/V isosurface

Co-linear dipole-dipole - 50m x 100m mesh

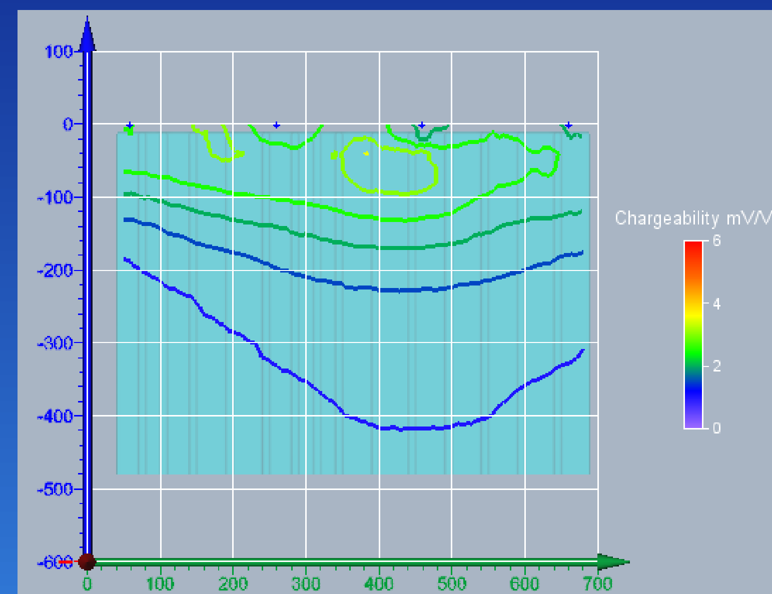


3D view with 2.5 mV/V isosurface

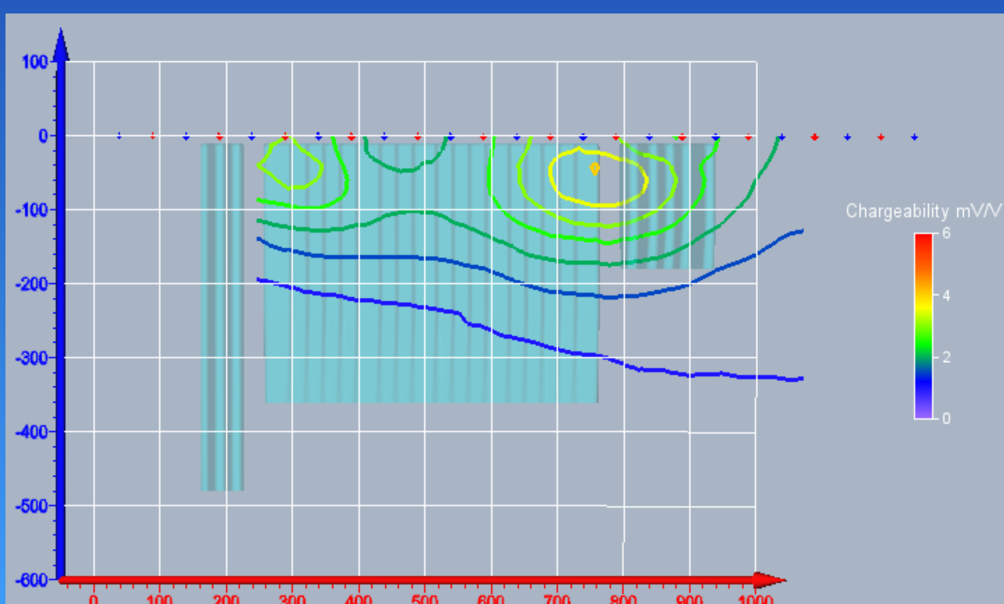
Co-linear dipole-dipole - 50m x 50m mesh



Plan view

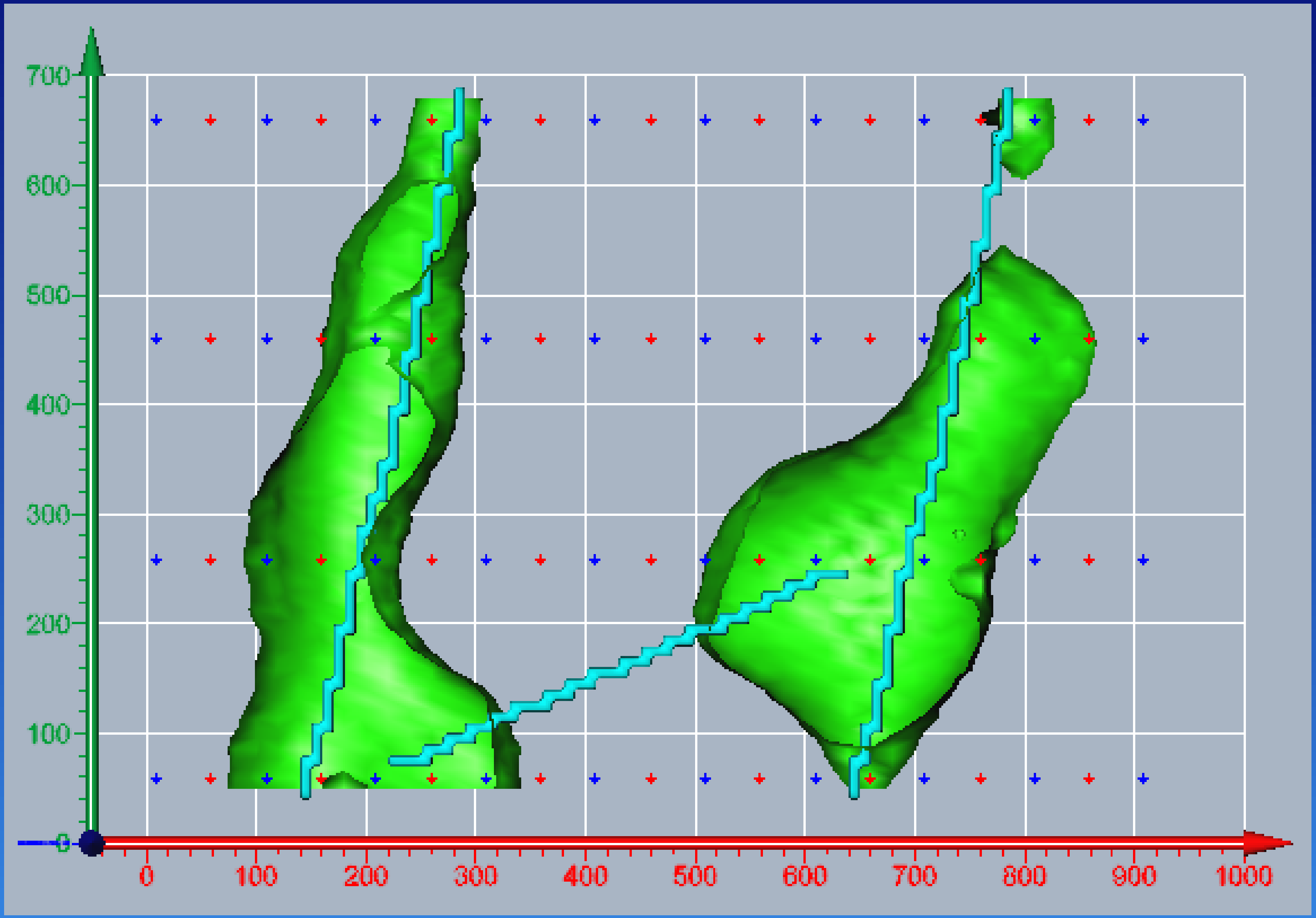


Side section



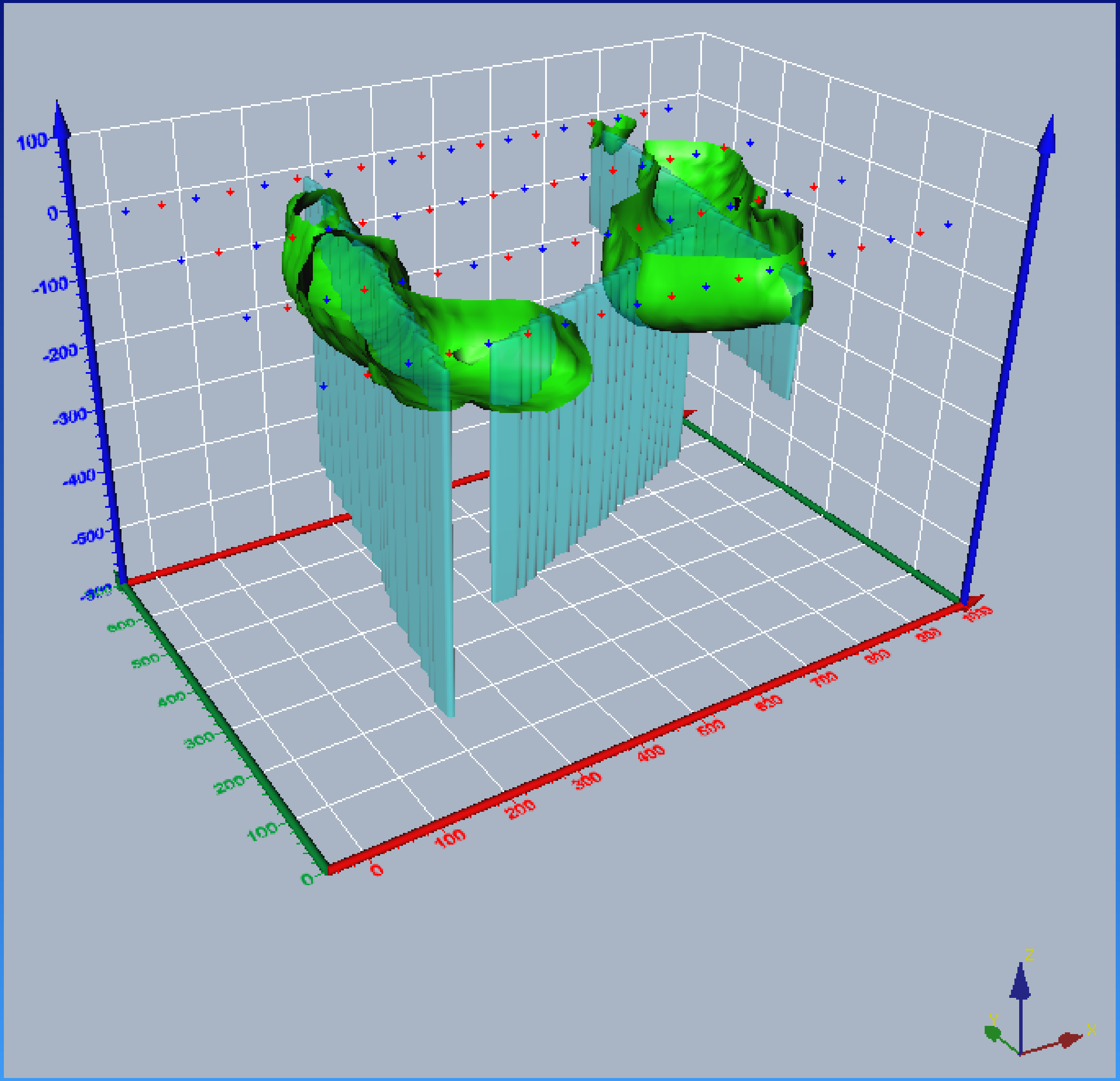
Front section

Co-linear dipole-dipole - 50m x 50m mesh



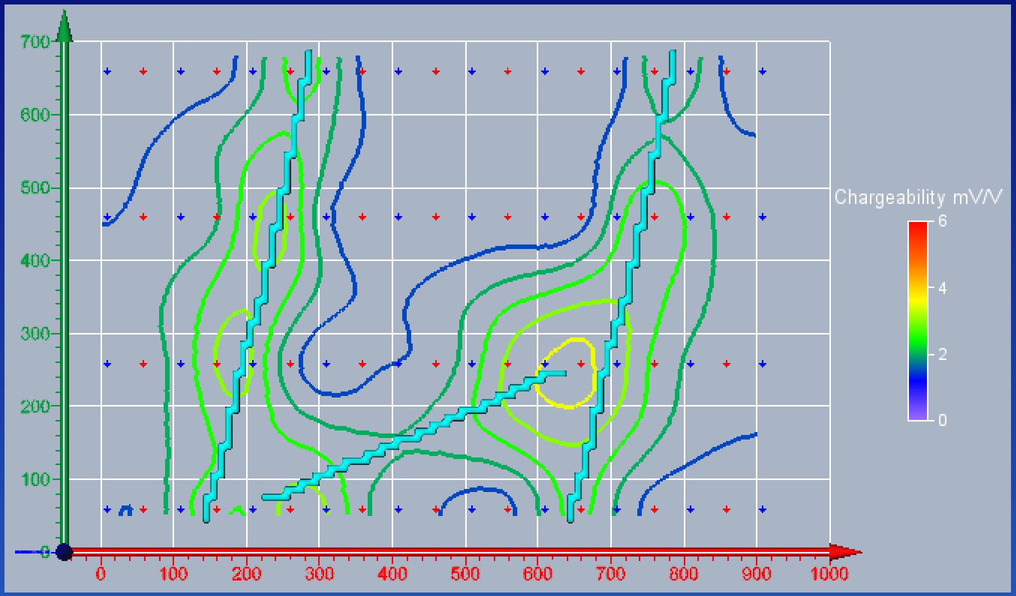
Plan view with 2.5 mV/V isosurface

Co-linear dipole-dipole - 50m x 50m mesh

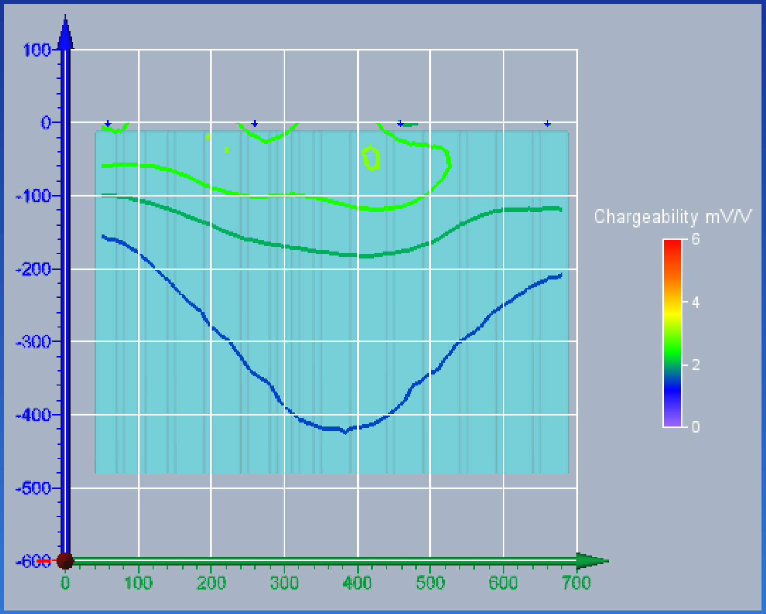


3D view with 2.5 mV/V isosurface

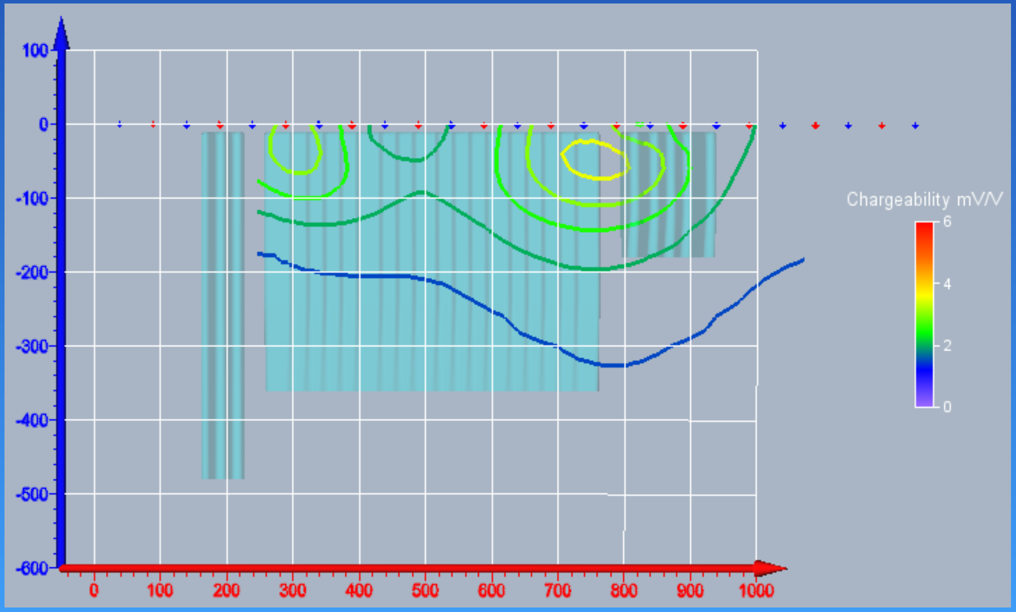
Co-linear dipole-dipole - 25m x 25m mesh



Plan view

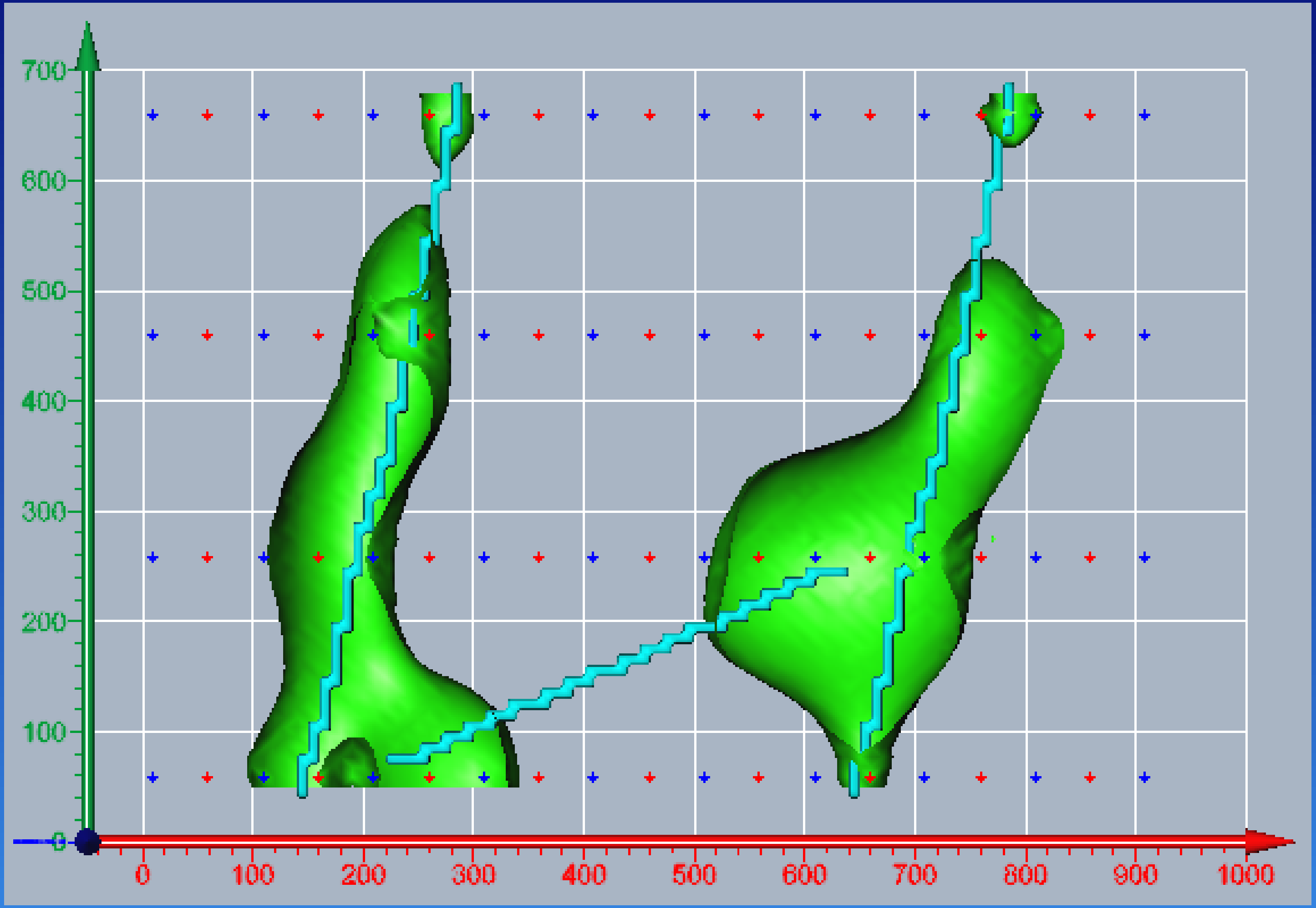


Side section



Front section

Co-linear dipole-dipole - 25m x 25m mesh



Plan view with 2.5 mV/V isosurface

Co-linear dipole-dipole - Observations

- Unlike the two offset arrays this array had current electrodes on the two outer lines and thus had 50m spaced electrodes on those lines. As a result it has done a better job of resolving the two bodies which are near perpendicular to the lines.
- Because the potential was only measured on the current injection line it has done a poor job of resolving the central body which lies between lines.
- As with the previous two arrays, resolution improved with decreasing mesh size.
- Although there is not a lot in it, the two dipole-dipole arrays appear to extend the bodies to greater depths than the offset pole-dipole array. However, none of the arrays resolve these narrow bodies to their true depths.

Conclusions

- All three arrays show that as the inversion mesh size decreases, resolution increases. As expected, this improvement is greatest for bodies lying between the lines.
- The 2D co-linear array was unable to resolve the central body lying between its survey lines.
- The offset pole-dipole array had better plan view resolution than the offset dipole-dipole array, at coarse mesh sizes.
- None of the arrays resolved the base of the bodies, however this is not unexpected when the body has a width of 1/10th of the dipole size.