A Transient Electromagnetic investigation of Malkiel, Geurie, South of Dubbo

March 2013

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phone 0418 964097
for Demonstation and P&L Chaseling, March 2013

GROUNDWATER IMAGING

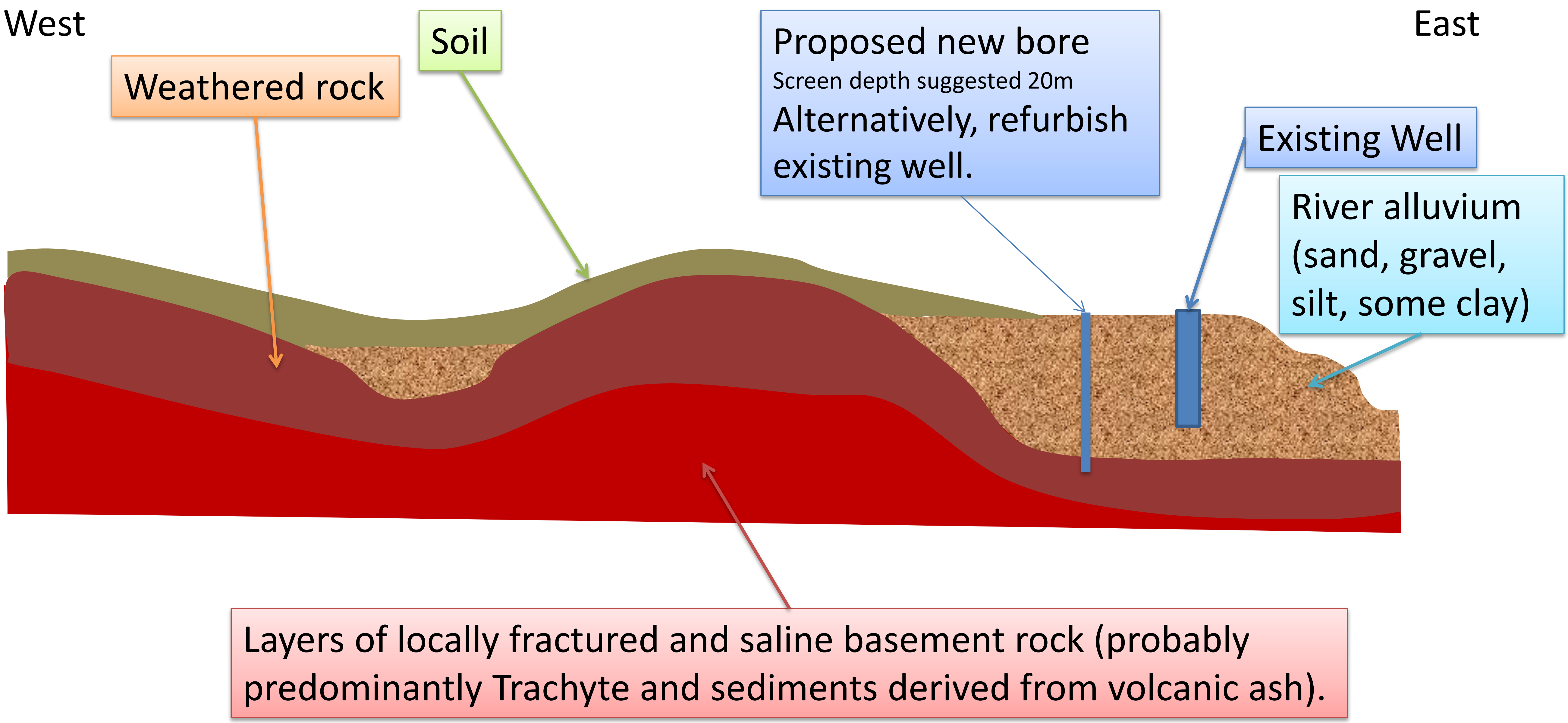
Malkiel Survey Summary

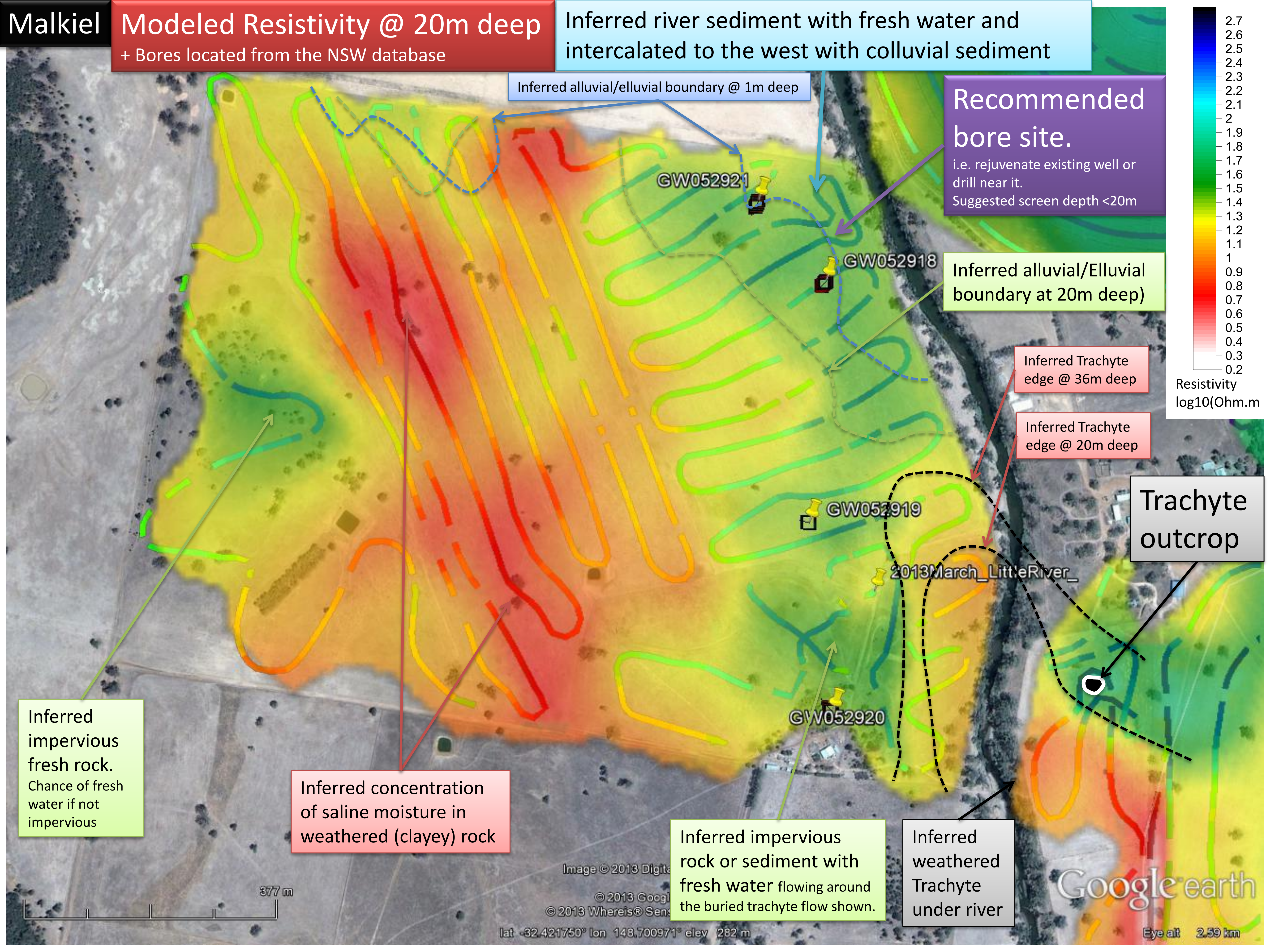
- Malkiel of P&L Chaseling was surveyed using a Transient Electromagnetic Imaging System (AgTEM3) to indicate resistivity at depths from the surface to 80m deep. Resistivity increases as strata salinity, porosity and/or clay content decreases. The primary aim was to identify and scope the potential of bore sites for irrigation.
- It is thought that the property is largely if not completely underlain by Saline weathered, once consolidated Triassic sedimentary rock and volcanic rock (flows?). These flows have a weathering profile that is clayey – described typically as green clay in the bottom of many drill holes on Terra Bella to the east. This profile, which marks the base of the alluvium, would restrict downward water flow and forms a low resistivity layer that can be imaged using geophysics where it is present. Aquifers within or beneath the flows may exist but their transmissivity and water storage capacity is probably much poorer than alluvial aquifers above the lava flows.
- One alluvial aquifer target – on the NE fringe of the property – is proposed for water extraction. It already has a well within it which perhaps could be deepened and refurbished. Alternatively another hole could be drilled up to 100m further west from the well.

2013 Survey - Malkiel

- Interpretation of the Malkiel dataset suggests that the property is underlain predominantly by shallow consolidated basement rock. Given the proximity of trachyte plugs, it is thought that it is underlain largely by trachyte larva flows and other associated sediments now likely to have become silicified and weathered (generating some groundwater salinity). These rocks, especially where fractured, are thought to be potential sources of stock water with flows and supply being dependent on fracture networks and their upward continuation into areas that collect and capture rainfall so that recharge may occur. Sloping layers are evident within the basement rock suggesting layering of strata that weather differently. Perhaps resistive layers are bases of silicified sandstones and trachyte flows while low resistivity layers are weathered tops of flows. Perhaps some deeper low resistivity layers are permeable ash flows or volcanic source sediments now containing saline or brackish water. Interpretation of these layers is complicated by zones of faults and fractures that also affect groundwater flow and thus ground resistivity. Exploratory drilling may target various features in these deeper strata, but, given that they are as yet only geophysically explored, no further recommendation is given at this stage. The situation is very different in the northeast margin of the property.
- The northeastern margin of the property has shallow alluvium and the TEM data suggests that this extends into the property only about 250 metres before pinching out against the weathered basement rock. The depth extent of this alluvium associated with a prior course of one or both of the nearby rivers is thought to be around 20m given that ground conductivity increases beneath that depth. Comparison of the 20m depth slice data on NE Malkiel and west Terra Bella suggests that sediment intersected by bores on Terra Bella is deeper and coarser (more permeable) than on NE Malkiel.
- It is recommended that options of refurbishing the existing large diameter well, or, of drilling and developing another bore in the close vicinity of the well be investigated. Test holes in the vicinity of the well could be rationally sited up to 100 metres west of the existing well as a high resistivity layer, suggesting alluvium containing coarse permeable sediment and fresh water, extends that far further west as marked on the 20m Malkiel depth slice. It is suggested that clayey colluvium has onlapped this river alluvium as suggested in the schematic cross section.
- It may be observed on the Malkiel 20m depth slice that the high resistivity extends up under the hill upon which the house is situated. This extension may simply be the result of abutment of the course alluvium against hard un-weathered rock. Alternatively it may represent a pathway of fresh groundwater flow (possibly Triassic Silicified conglomerate) around the low resistivity feature (assumed weathered trachyte flow) identified in the southeast corner of the property and inferred to extend under the river to trachyte outcrop on TerraBella. Inferring that the low resistivity feature extends under the Little River, it is suggested that upstream alluvial groundwater associated with the Little River is trapped by a lava flow here. This interpretation has implications on the connectivity of good groundwater supplies on the property south of Terra Bella to the Macquarie River alluvium – i.e. that such supply is sourced from the Little River alluvium and catchment upstream of this choke alone.

Malkiel – interpreted cross section – NW corner to NE corner.





Malkiel
Modeled Resistivity @ 20m deep
+ Bores located from the NSW database
Inferred river sediment with fresh water and intercalated to the west with colluvial sediment
Inferred alluvial/elluvial boundary @ 1m deep
Recommended bore site.
i.e. rejuvenate existing well or drill near it.
Suggested screen depth <20m
GW052921
GW052918
Inferred alluvial/Elluvial boundary at 20m deep)
Inferred Trachyte edge @ 36m deep
Inferred Trachyte edge @ 20m deep
GW052919
2013March_LittleRiver_
Trachyte outcrop
GW052920
Inferred impervious fresh rock.
Chance of fresh water if not impervious
Inferred concentration of saline moisture in weathered (clayey) rock
Inferred impervious rock or sediment with fresh water flowing around the buried trachyte flow shown.
Inferred weathered Trachyte under river
Resistivity log10(Ohm.m
2.7
2.6
2.5
2.4
2.3
2.2
2.1
2
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
377 m
lat -32.421750° lon 148.700971° elev 282 m
Eye alt 2.59 km
Google earth

Contents

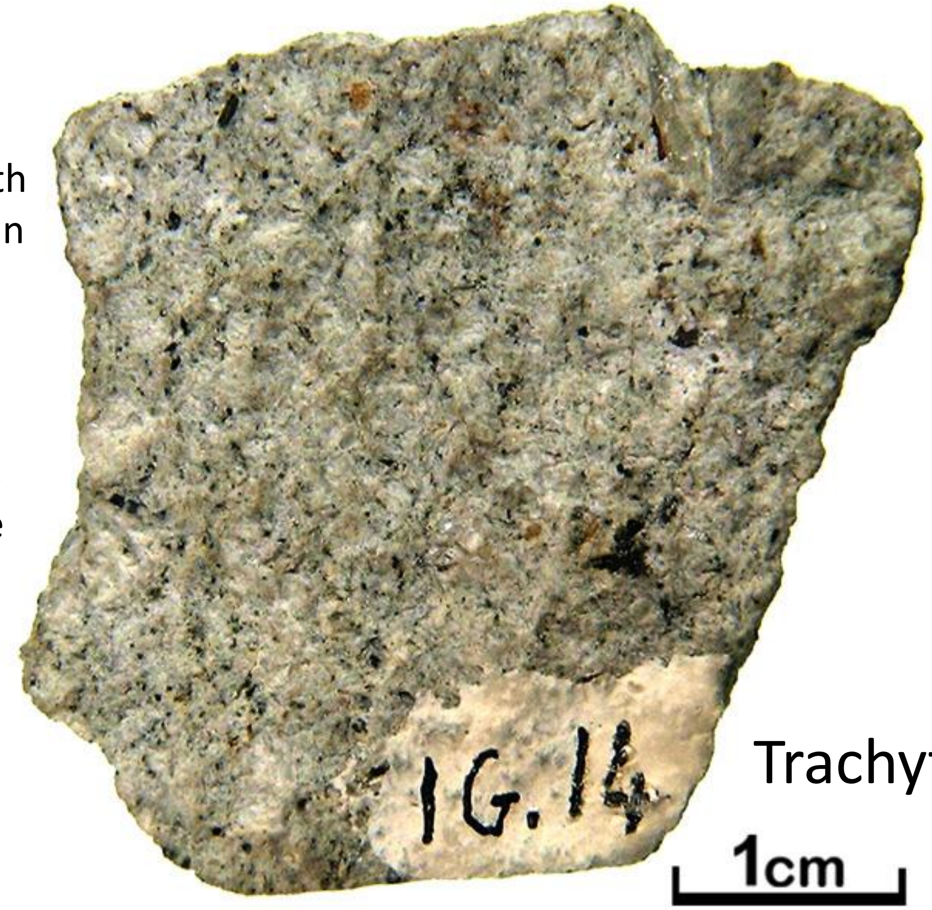
Introduction

- METHOD : Transient electromagnetic survey, on the property Malkiel of P&L Chaseling, south of Dubbo, was conducted using TerraTEM and a trailer mounted loop system in February 2013.
- AIM: To identify and scope the potential of bore sites for irrigation
- SURVEY PARAMETERS : Detailed mapping, was conducted at a nominal line spacing of 50m was adopted, while reconnaissance was conducted at 100m spacing or more depending on the scale of geological features under investigation. Data was provided at about 10m increments along line. Survey depth of investigation was from 1m to 80m divided into 10 separate layers. Near the surface, the system footprint is small, so it can be used close to metal infrastructure, while at 80m deep the footprint is thought to be over 80m across.
- DIGITAL DATA : For detailed understanding of the data, access all data and bore records from the supplied Google Earth files (_report/*.kmz on the report DVD) simply by opening the files in Google Earth or similar viewers. These are small files that are readily emailed. Positioning of potential new drill holes should involve location, within Google Earth, using the cursor co-ordinates displayed at the bottom of the screen. This method will be more accurate than measurement off the paper or raster maps supplied. Data may also be supplied in an ESRI ArcMap version 10 MXD file and component shapefiles and image files.
- DIGITAL BORE LITHOLOGIES : Lithologies and some water levels in existing bores are displayed in the Google Earth files – click on them to bring up particulars. Be aware that they are simply reproduction of government water bore drillers log records which contain positioning and other errors – treat them all with reservation. If better information is acquired they can be adjusted accordingly.
- GEOLOGY: Sand, gravel and clay alluvium of the Macquarie River overlies basement rock principally composed of Trachyte. This volcanic rock forms sills, flows, plugs and tuff. A fine grained unclassified volcanic rock composes a small hill on the south of the central part of the farm and is likely to extend as a lava flow under part or much of the property. Of importance to this survey is the observation that these rocks weather to form a green (chloritic) clayey profile. As a saturated clay this layer would be of low resistivity and form a good marker horizon for the bottom of alluvial cover.

Descriptions of the lava flow rock types underlying Malkiel

Beneath Malkiel, basement rock is mapped as Triassic Napperby Formation (Siltstone thinly interbedded with fine to medium grained lithic-quartz sandstone, minor conglomerate) Beneath Terra Bella to the east, basement rock is thought to be predominantly Trachyte but a small hill in the property south centre appears to be basalt. The Trachyte is described as the Googodery Trachyte (Jurassic-Triassic) http://www.littleriver-landcare.org.au/publications ; http://dbforms.ga.gov.au/pls/www/geodx.strat_units.sch_full?wher=stratno=32590

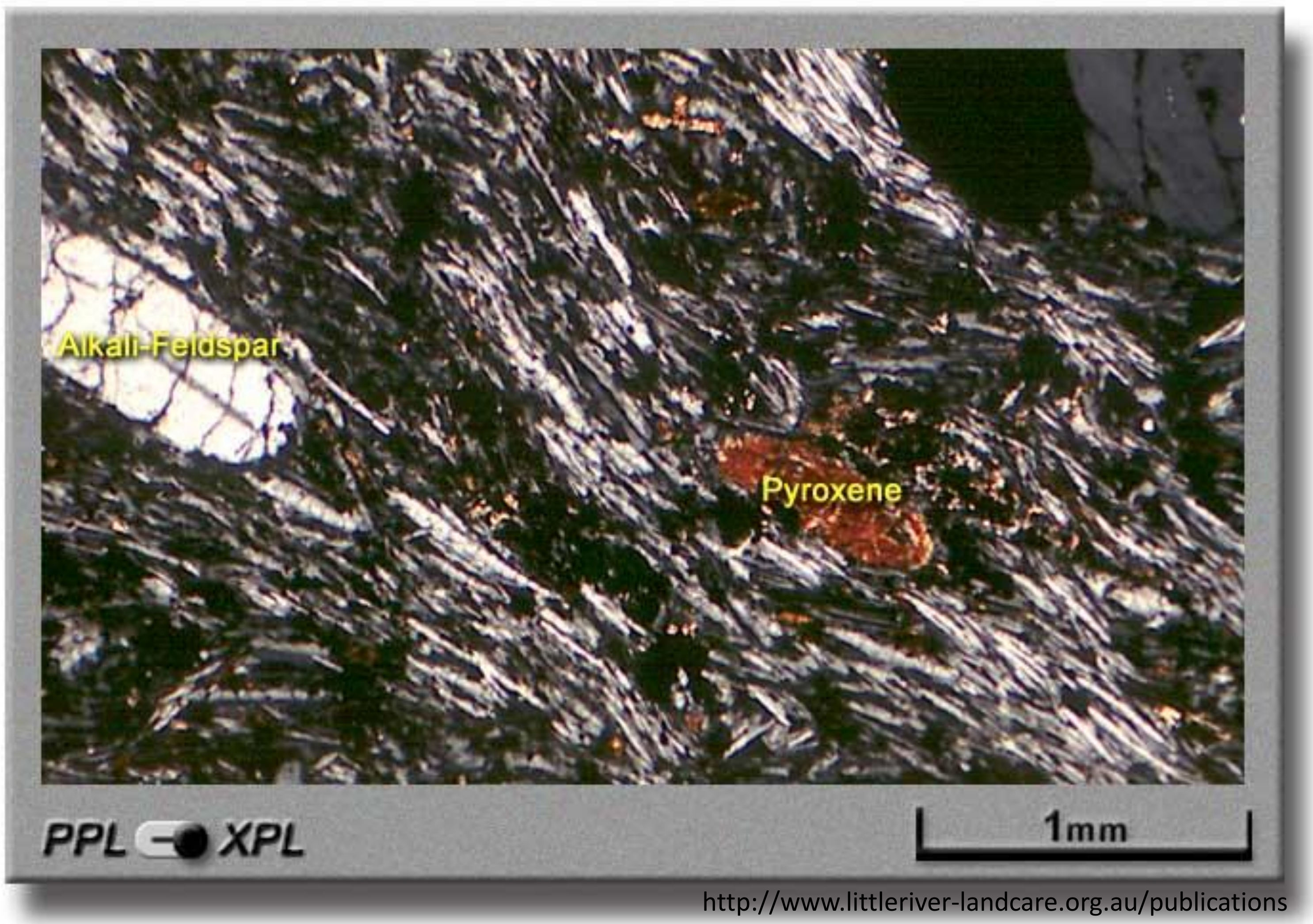
It contains much Augite (A pyroxene – see photomicrograph) which is green and exists both as phenochrysts (large crystals) and as part of the rock groundmass. Upon weathering, it converts to a green clay (Chlorite) which results in the green clayey weathering profile observed in cable tool drill holes at the property.



Trachyte

http://www.soes.soton.ac.uk/resources/collection/minerals/sections/09-Trachyte.html

Trachyte photomicrograph

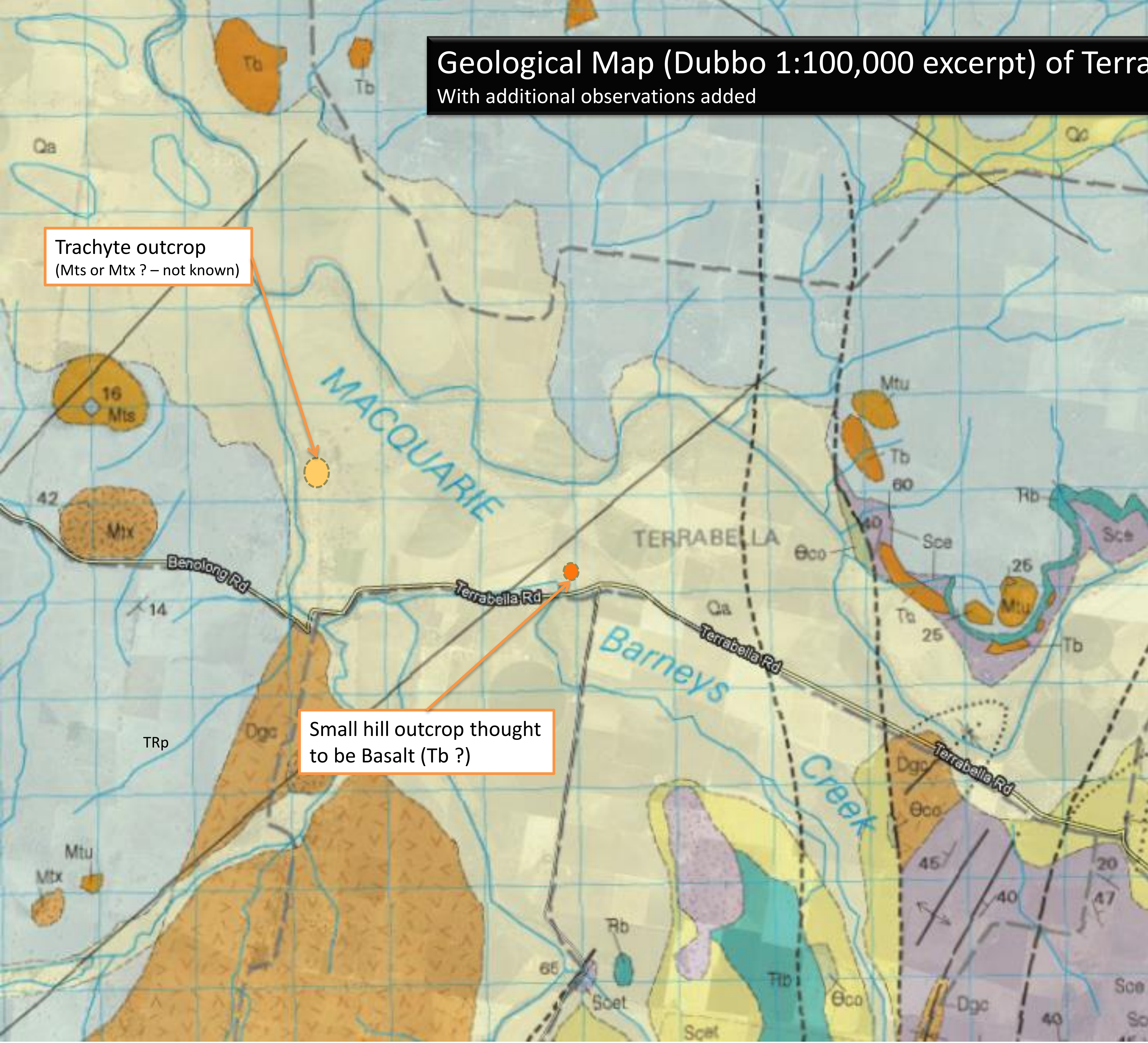


http://www.littleriver-landcare.org.au/publications

Basalt

Geological Map (Dubbo 1:100,000 excerpt) of Terra Bella & Malkiel

With additional observations added



Description of Geological Units on the Terra Bella Property

CAINOZOIC UNITS

Cainozoic	Quaternary	Qa		Alluvial silt, clay and sand, variable humic content, sporadic pebble- to cobble- sized unconsolidated conglomeratic lenses
Cainozoic	Quaternary	Qc		Colluvial polymictic gravel, sand, silt and clay; may include some eluvial in situ regolith deposits
Cainozoic		Cza	Cainozoic undifferentiated	Unconsolidated quartz and quartz-lithic gravel, sand, silt and clay
Cainozoic	Tertiary	Tb		Tholeiite, alkali basalt, basanite, nephelinite, limburgite, trachyte, rare obsidian
Cainozoic	Tertiary	Tg		Sub-basaltic and/or high level quartz or polymictic gravels and sands, granitic lag, basaltic talus
Cainozoic	Tertiary	Ti		Beige coarse-grained silcrete with angular clasts of quartz and minor lithic clasts

SURAT BASIN (of the GREAT AUSTRALIAN BASIN)

Mesozoic	Jurassic	Jp	Pilliga Sandstone	Massive to cross-bedded coarse pebbly lithic-quartz sandstone, minor fine grained sandstone and siltstone
Mesozoic	Jurassic	Ju	Purlawaugh Formation	Ferruginised red siltstone, carbonaceous mudstone, fine to medium grained lithic quartz sandstone, ironstone, minor coal

MESOZOIC IGNEOUS ROCKS

Mesozoic		Mtu		Trachyte, syenite, tuff, minor rhyolite, minor phonolite, minor obsidian
Mesozoic		Mtk		Trachyte, quartz trachyte, minor phonolite, minor rhyolite - geophysics indicates that the body has elevated K, and low in Th and U; flows, tuffs, and intrusive plugs and necks
Mesozoic		Mtt		Trachyte, quartz trachyte, rhyolite - geophysics indicates that the body has elevated U and Th, and moderate K; predominantly intrusive plugs and necks
Mesozoic		Mtx		Trachyte, quartz trachyte and analcite trachyte - geophysics indicates that the body is rich in K, Th and U; occurs predominantly as intrusive plugs and necks
Mesozoic		Mts		Syenite, microsyenite, nepheline microsyenite, phonolite, trachyte

GUNNEDAH BASIN

UNGROUPED FORMATIONS

Mesozoic	Triassic	TRp	Napperby Formation	Siltstone thinly interbedded with fine- to medium-grained lithic-quartz sandstone, minor conglomerate; bioturbation and burrows common
Mesozoic	Triassic	TRb	Boulderwood Formation	Thick-bedded lithic-quartz conglomerate, coarse pebbly lithic-quartz sandstone, and siltstone
	Permian	Pd	Dunedoo Formation	Pebbly quartz-lithic sandstone to conglomerate, breccia, white claystone, thin coal seams

CATOMBAL GROUP

CANANGLE SUBGROUP

Dtcu	Curra Creek Conglomerate	Red-purple conglomerate, minor interbedded red-purple sandstone and siltstone

BLACK ROCK SUBGROUP

Dtb	Undifferentiated	Massive to bedded quartz and lithic sandstone, hematitic shale, conglomerate

DEVONIAN INTRUSIONS

Dmd		Dolerite, diorite, gabbro sills and stocks
Dmm		Mela-monzodiorite, quartz monzodiorite intrusive sills and stocks

DEVONIAN INTRUSIONS

Devonian	Dmd		Dolerite, diorite, gabbro sills and stocks
Devonian	Dmm		Mela-monzodiorite, quartz monzodiorite intrusive sills and stocks

YEOVAL BATHOLITH

Devonian	Dbg	Mudgingar Granite	Medium- to coarse-grained pink granite
Devonian	Dog	Yennora Granite	Pink to red fine- to medium-grained hornblende biotite granite

YEOVAL COMPLEX

Devonian	Dyg		Pink microgranite, biotite-ferrohastingsite granite, red biotite microgranite

HYANDRA CREEK GROUP

Devonian	Drg	Glenlee Rhyolite	Porphyritic rhyolite, green rhyolite
Devonian	Drd	Dunoon Dacite	Dacite, rhyolite
Devonian	Dre	Ellersley Formation	Trachylatite
Devonian	Drp	Peachvale Rhyolite	Rhyolite breccia, rhyolite, minor trachylatite, minor lithic sandstone

GREGRA GROUP

Devonian	Dgg	Garra Formation	Well-bedded, fossiliferous limestone; calcareous sandstone, siltstone, breccia; shale; minor tuffaceous sandstone
Devonian	Dgc	Cuga Burga Volcanics	Latitic, crystal-lithic sandstone, breccia, siltstone, tuff; latite and lesser andesite, basalt; minor allochthonous limestone, quartzose sandstone

TOONGI GROUP

Palaeozoic	Siluro-Devonian	S-Do	Undifferentiated	Sandstone, shale, siltstone, chert, rhyolite, tuff
Palaeozoic	Siluro-Devonian	S-Dol	Glengeera Formation	Quartz sandstone, quartzofeldspathic sandstone, lithic sandstone, siltstone and shale, limestone
Palaeozoic	Siluro-Devonian	S-Dom	Trealmont Quartzite	Quartzose sandstone, lithic quartzose sandstone, quartzite
Palaeozoic	Siluro-Devonian	S-Dod	Dowd Formation	Shale, siltstone, fine-grained sandstone, lithic sandstone, rhyolite, calcarenite
Palaeozoic	Siluro-Devonian	S-Doy	Whychetella Formation	Mudstone
Palaeozoic	Siluro-Devonian	S-Dor	Wirrabilla Formation	Lithic sandstone, minor conglomerate, hornfels
Palaeozoic	Siluro-Devonian	S-Dot	Toongi Hall Tuff	Fine and coarse cherty tuff, tuffaceous siltstone, rhyolitic tuff, lithic quartz sandstone
Palaeozoic	Siluro-Devonian	S-Dow	Whylandra Formation	Lithic sandstone, volcaniclastic sandstone, siltstone, tuffaceous siltstone
Palaeozoic	Siluro-Devonian	S-Doe	Belowrie Formation	Shale, minor basic tuff and lava, phyllite
Palaeozoic	Siluro-Devonian	S-Dog	Wambangalong Formation	Quartzose sandstone, siltstone, shale, phyllite

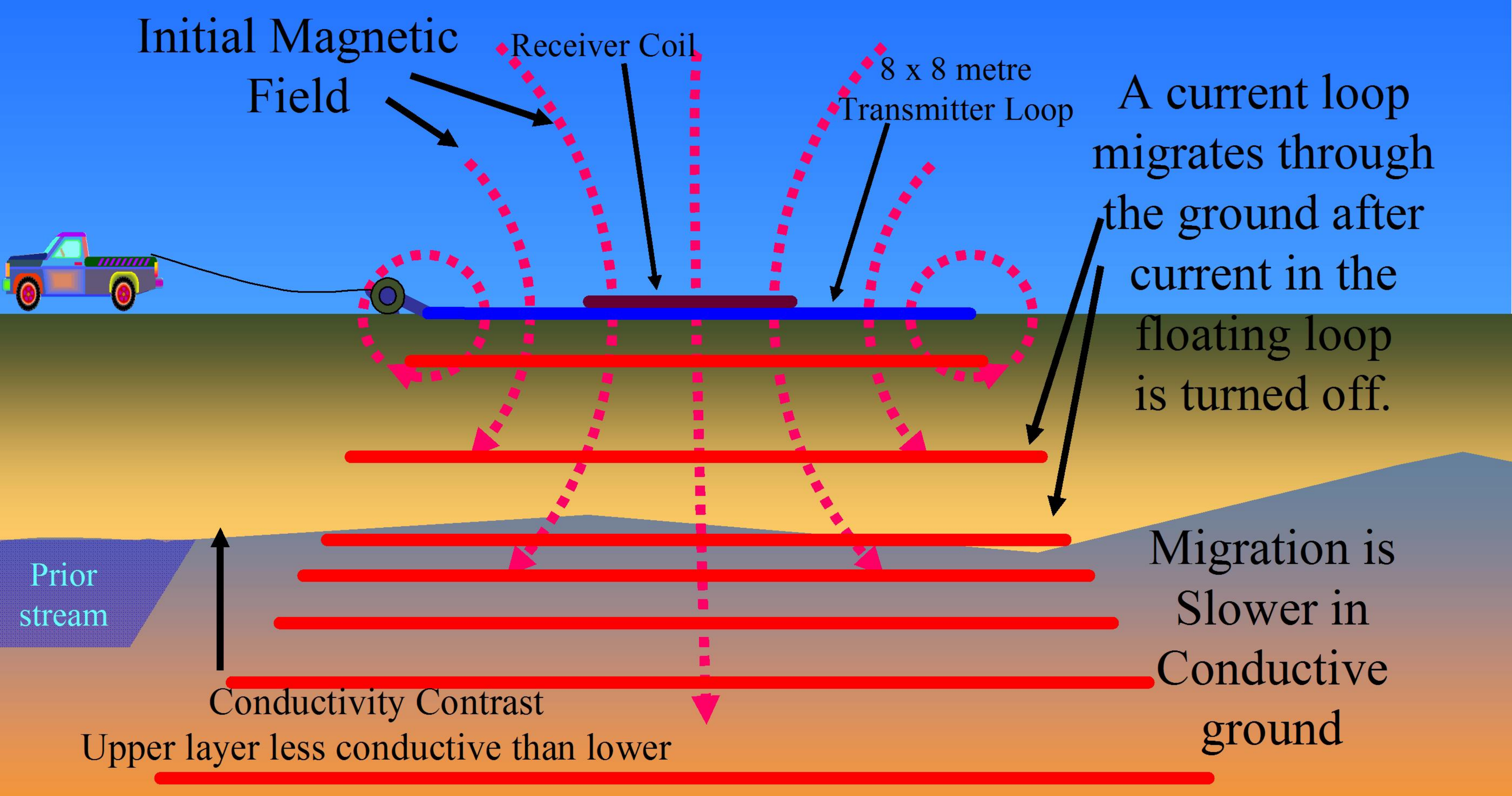
CUDAL GROUP

Palaeozoic	Soe	Hanover Formation	Massive to laminated, buff to grey to green to purple, quartzose micaceous shale, siltstone, fine-grained sandstone; rhyolitic tuff, tuffaceous sandstone; minor latitic sandstone and breccia
Palaeozoic	Soev		Weakly feldspar-phyric rhyolite

Geophysical Methods Introduction

- A quick and comprehensive way of looking at a shallow (0 to 200m deep) groundwater resource is to image it with towed transient electromagnetic devices. The resultant EC image will reveal, in a blurred manner, the proportion of ions in solution in the groundwater and rock at various depth – usually this means that dry ground, good aquifers and fresh basement rock show as electrically resistive and contrast with clays and saline aquifers that show as electrically conductive. Determining exactly what each feature represents is then a matter of interpretation which is usually solved by comparison with borehole logs and a bit of logic (eg. basement rock will be at the base, an unsaturated zone will be at the top and prior river channels will be shaped concave-up).
- A schematic of a towed transient electromagnetic survey system is provided on the next slide. Electrical current is pulsed through a large transmitter loop and each pulse induces a ‘smoke ring’ of current in the ground below as it turns on and off. As the ‘smoke ring’ dissipates out into the ground its magnetic field decays and it is the decay of this magnetic field, along with the decay of the magnetic field resulting from the transmitter loop, that is detected by various receiver loops. The decay is abated by conductive layers and enhanced by resistive layers in the substrate.
- The system used on this job, photographed on the title page, had a 2 turn 6.5 x 5m transmitter loop with 3 receiver coils – one centrally located in the transmitter loop, one 12m behind the transmitter loop, and a small one mounted right on the transmitter loop wires. The system was operated using a Monash Geoscope TerraTEM with an accelerated transmitter (to see shallower features), the continuous acquisition option, a Trimble AgGPS114 receiving Omnistar DGPS corrections and several truck batteries for power supply. The system was towed by a Landrover Defender separated from the equipment by a 7m fibreglass boom and rope assembly.
- Processing of this data involves numerous steps presented in a separate text document. The main steps are removal of movement noise, primary field stripping, cleaning of the data (removal of data mainly affected by metallic objects etc.), spatial smoothing, modeling to transform the voltage versus time data to smoothness constrained layers of resistivity versus depth, more data cleaning, gridding and presentation. The principle step is the transformation (matrix inversion) which is carried out using the Aarhus Hydrogeophysics Group algorithm EM1DInv.

Towed Transient Electromagnetic System



Why use Electrical Resistivity for Investigation of Groundwater

- reveal spatial details not observable by any more economically viable means
- Resistivity responds clearly and conclusively to recharge pathways

RESISTIVITY is the INVERSE of ELECTRICAL CONDUCTIVITY commonly used as a measure of water salinity. This is not to be confused with HYDRAULIC CONDUCTIVITY.

HIGH RESISTIVITY

- Lack of Clays
- Low Saturation
- Fresh pore water
- Impervious fresh rock

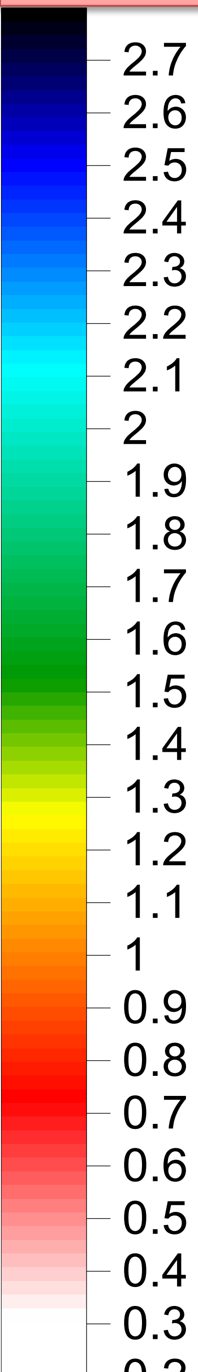
LOW RESISTIVITY

- Clays
- High Saturation
- Saline pore water
- Weathered rock

Results and Interpretation

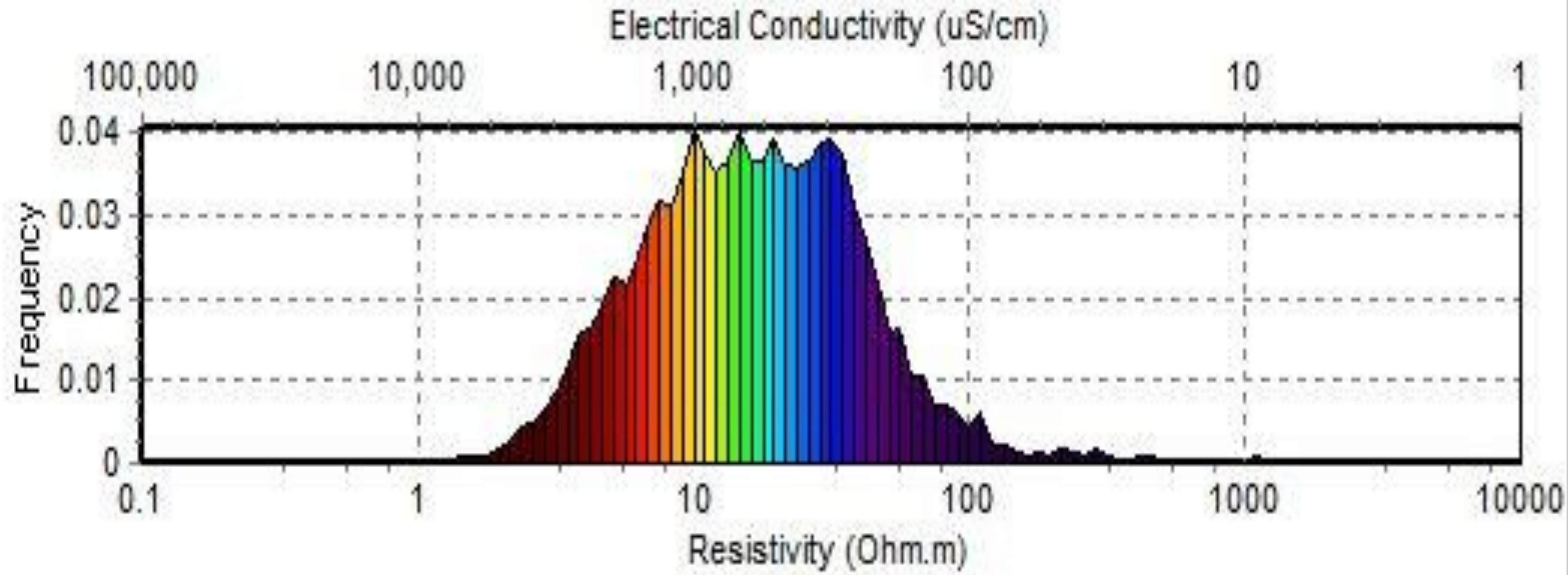
Resistivity colour scales used in this presentation

Depth Slices



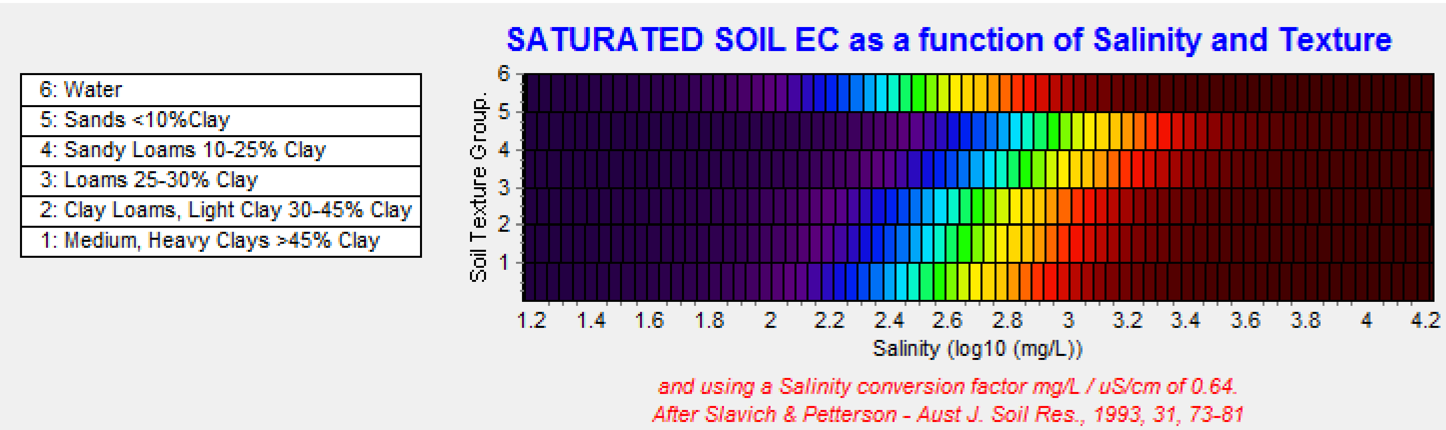
Resistivity (log10(Ohm.m))

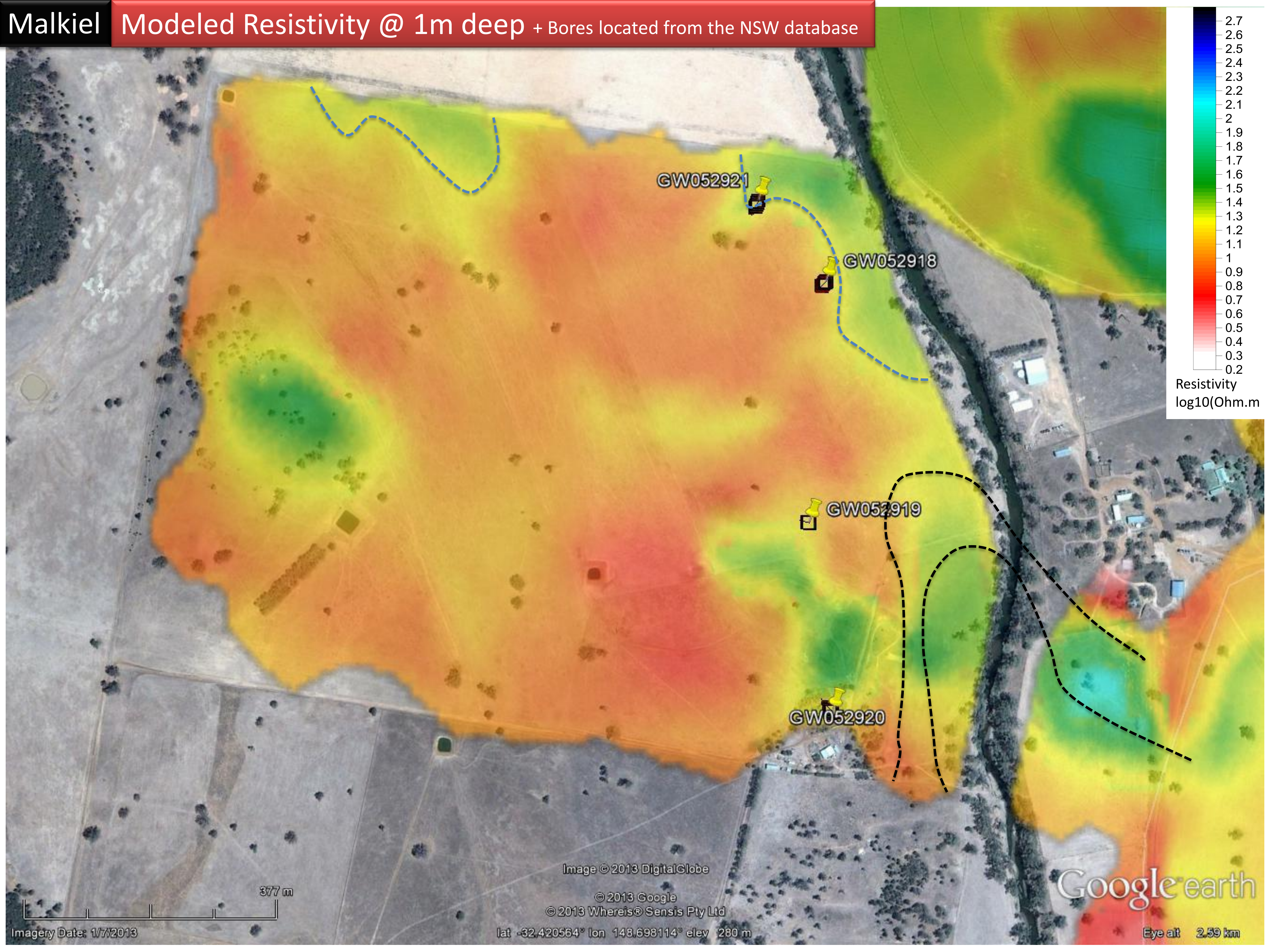
Resistivity Curtain Diagrams



Observe that resistivities encountered span three orders of magnitude. The very high resistivities are somewhat artificially high due to the limitations of system response removal that presently exist with the system used.

Using empirical conversion factors, the figure to the right indicates that, within saturated unconsolidated sediment, sediment type alone may account for about half an order of magnitude of change in resistivity, the remainder being due to groundwater salinity.





Malkiel
Modeled Resistivity @ 1m deep + Bores located from the NSW database
GW052921
GW052918
GW052919
GW052920
2.7
2.6
2.5
2.4
2.3
2.2
2.1
2
1.9
1.8
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1.6
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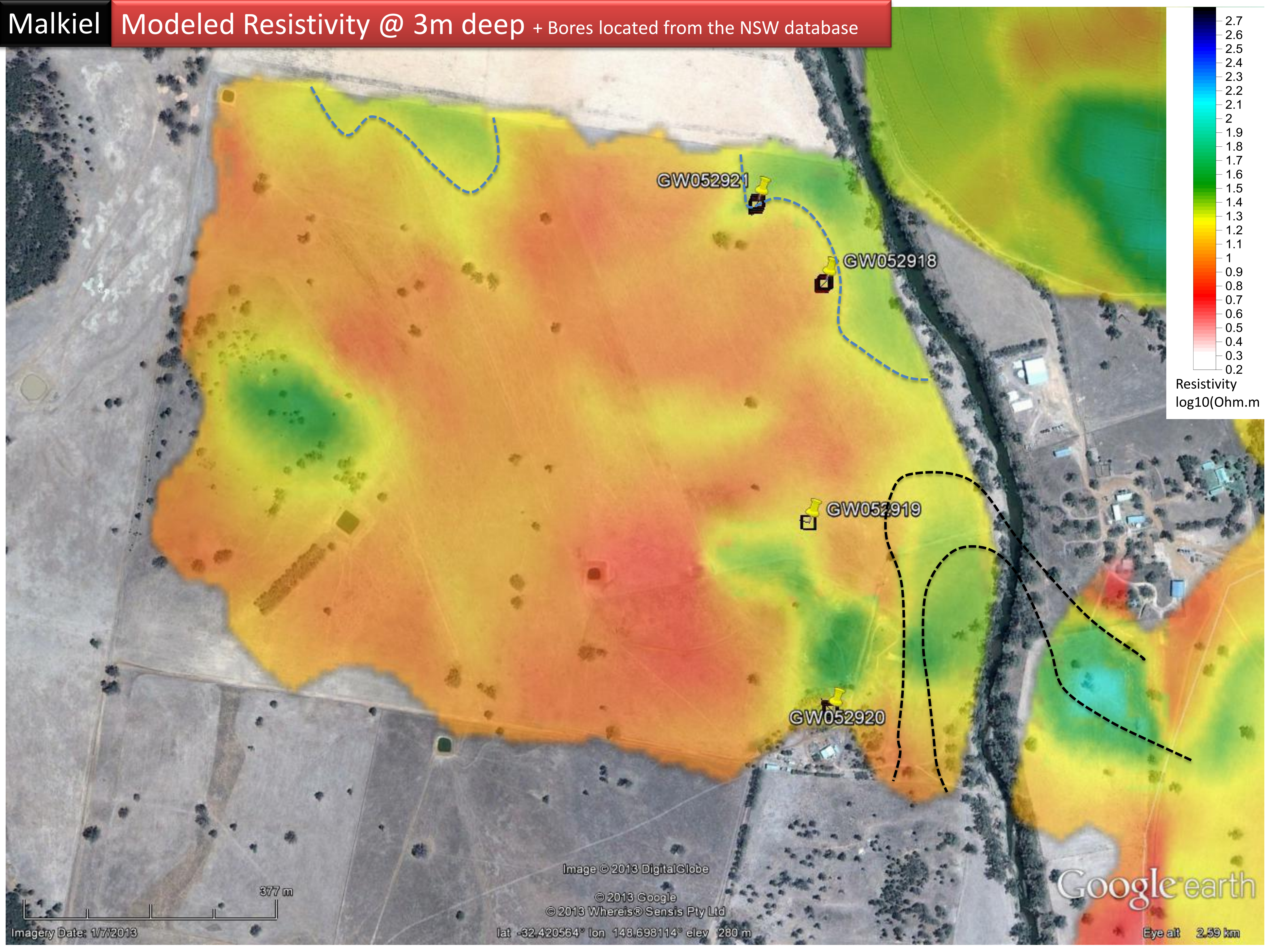
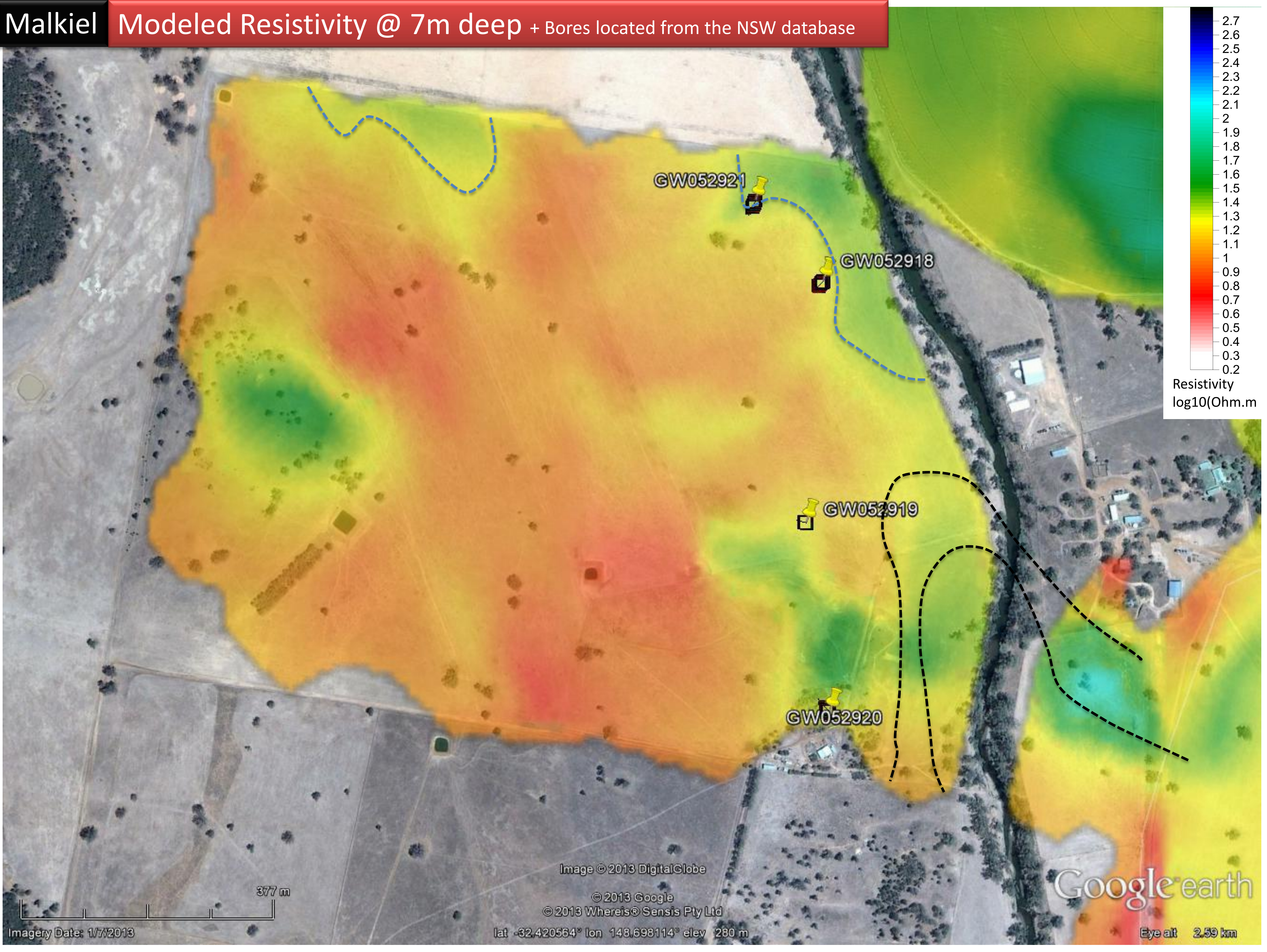
Resistivity
log10(Ohm.m
Image © 2013 DigitalGlobe
© 2013 Google
© 2013 Whereis® Sensis Pty Ltd
377 m
Imagery Date: 1/7/2013
lat -32.420564° lon 148.698114° elev 280 m
Eye alt 2.59 km
Google earth

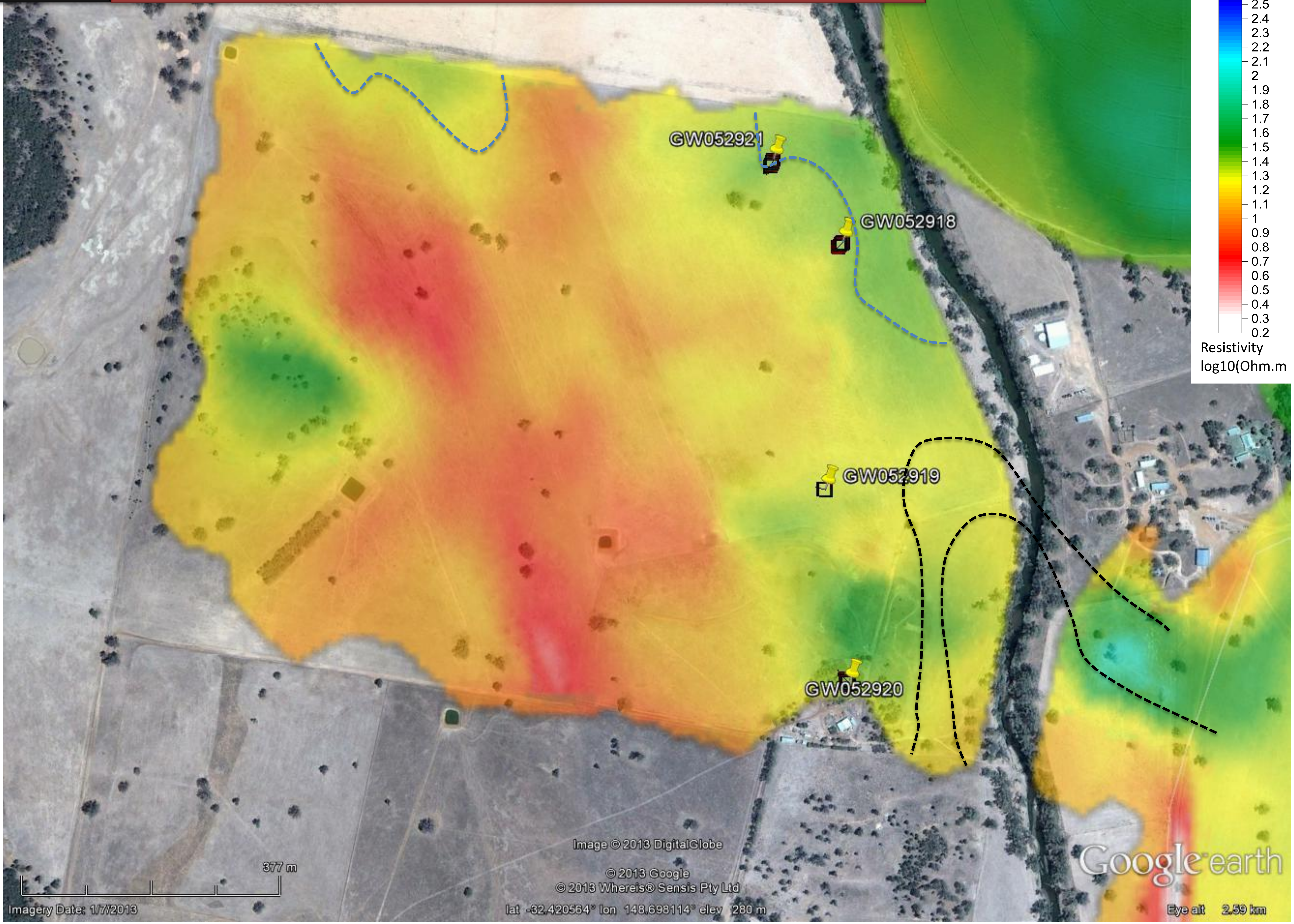
Malkiel Modeled Resistivity @ 3m deep + Bores located from the NSW database

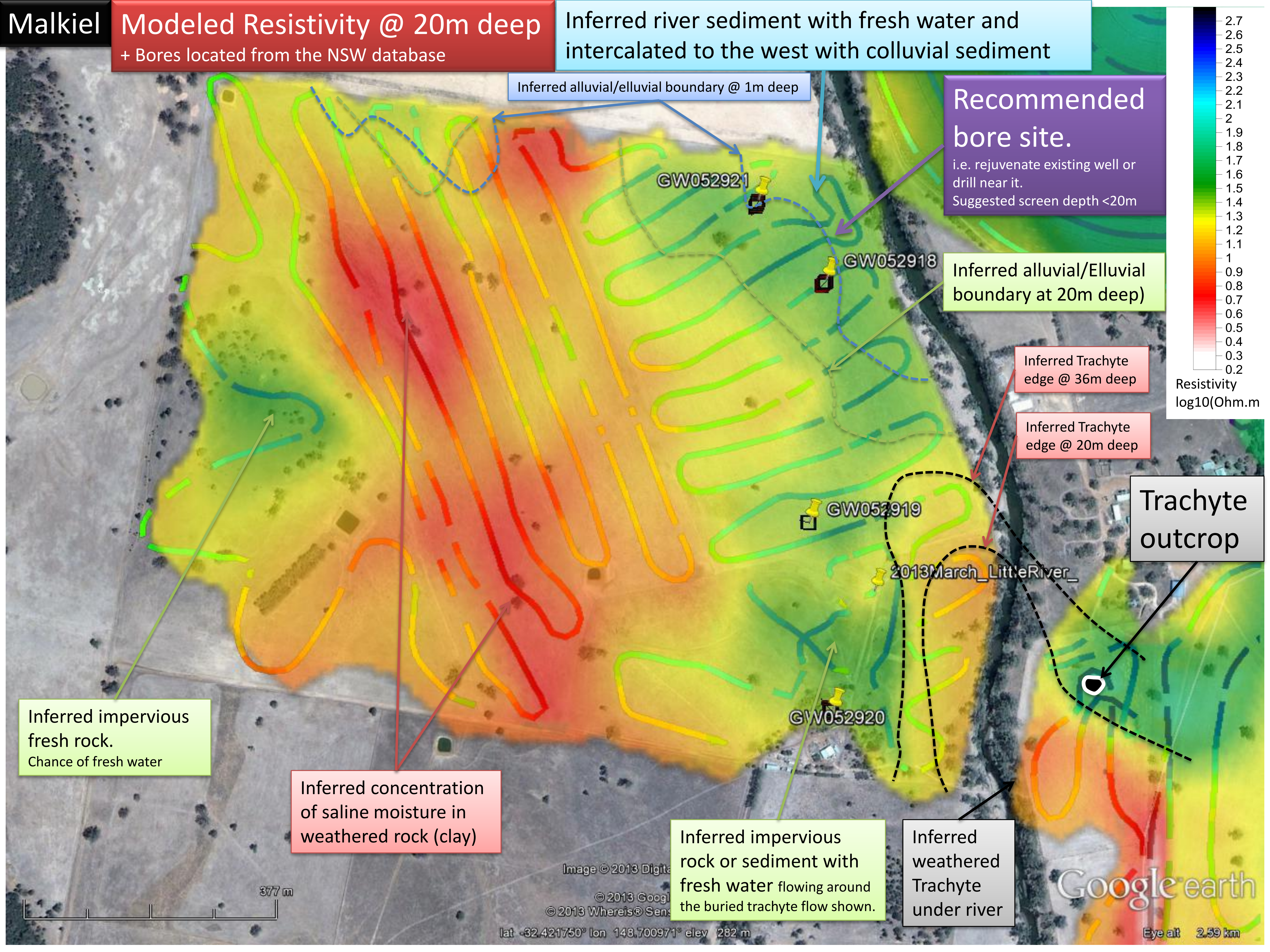


Malkiel Modeled Resistivity @ 7m deep + Bores located from the NSW database



Malkiel Modeled Resistivity @ 12m deep + Bores located from the NSW database





Malkiel
Modeled Resistivity @ 20m deep
+ Bores located from the NSW database
Inferred river sediment with fresh water and intercalated to the west with colluvial sediment
Inferred alluvial/elluvial boundary @ 1m deep
Recommended bore site.
i.e. rejuvenate existing well or drill near it.
Suggested screen depth <20m
GW052921
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Inferred alluvial/Elluvial boundary at 20m deep)
Inferred Trachyte edge @ 36m deep
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0.6
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0.3
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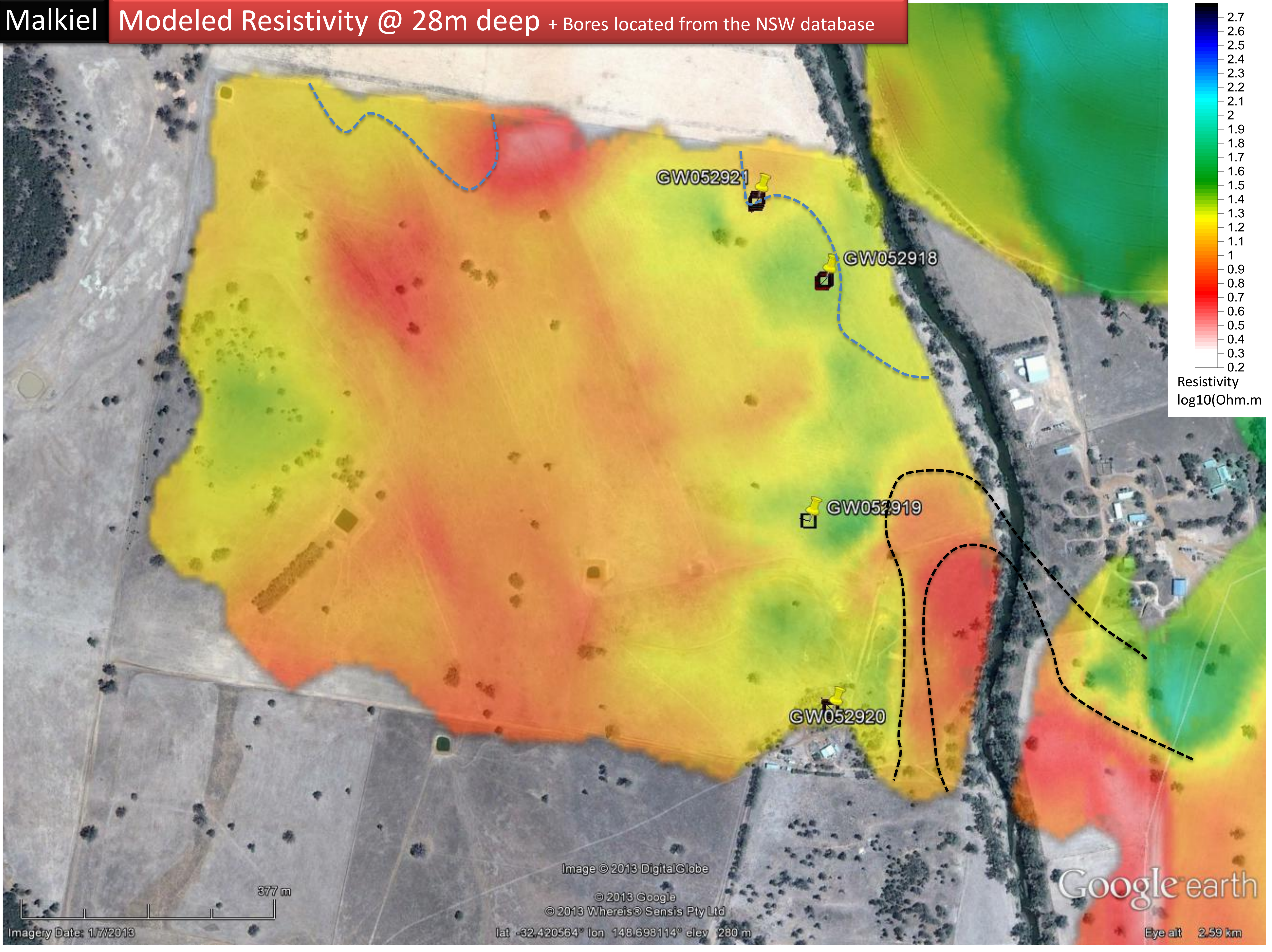
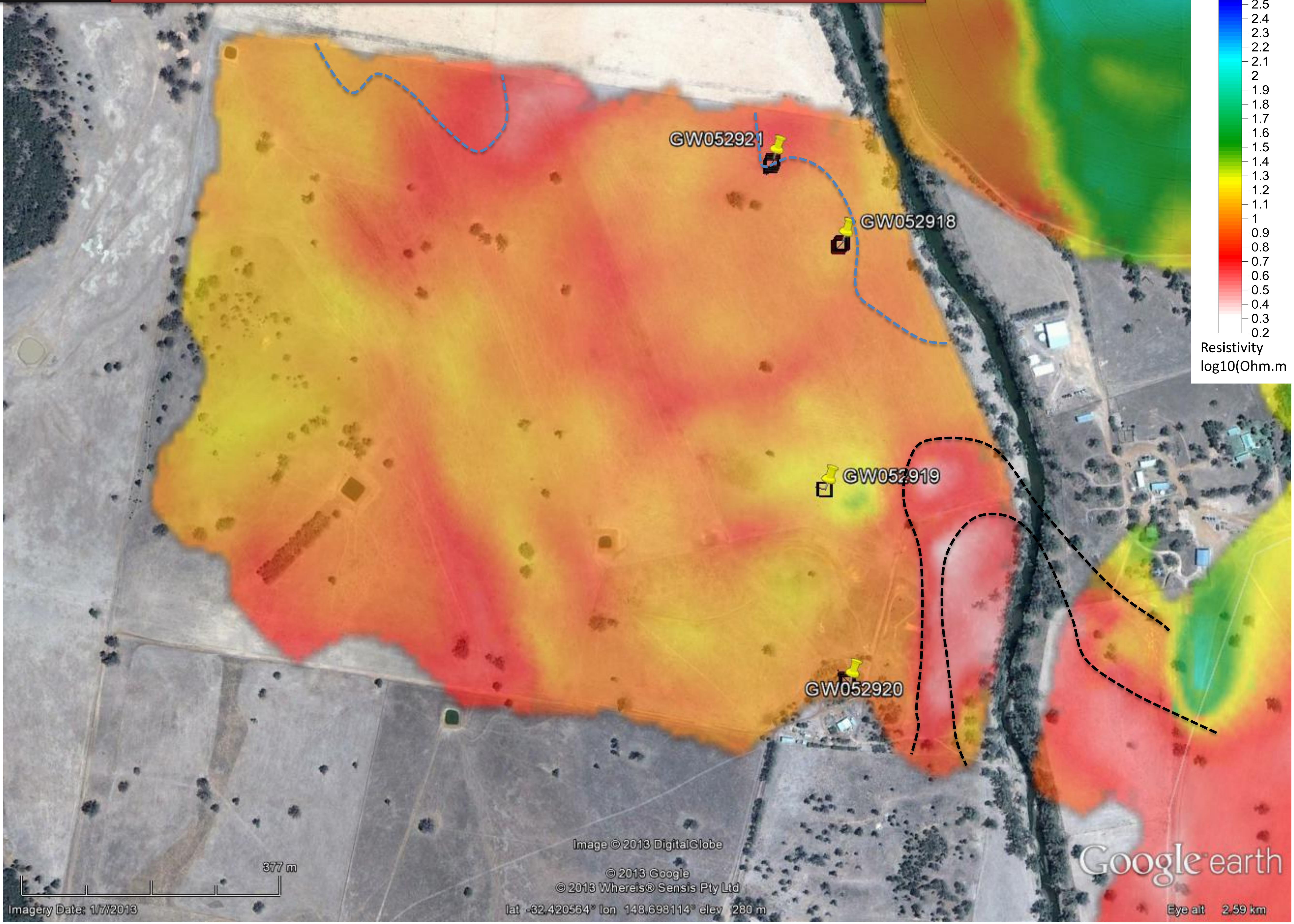
Resistivity
log10(Ohm.m
377 m
Image © 2013 Digita
© 2013 Googl
© 2013 Whereis® Sens
lat -32.421750° lon 148.700971° elev 282 m
Google earth
Eye alt 2.59 km

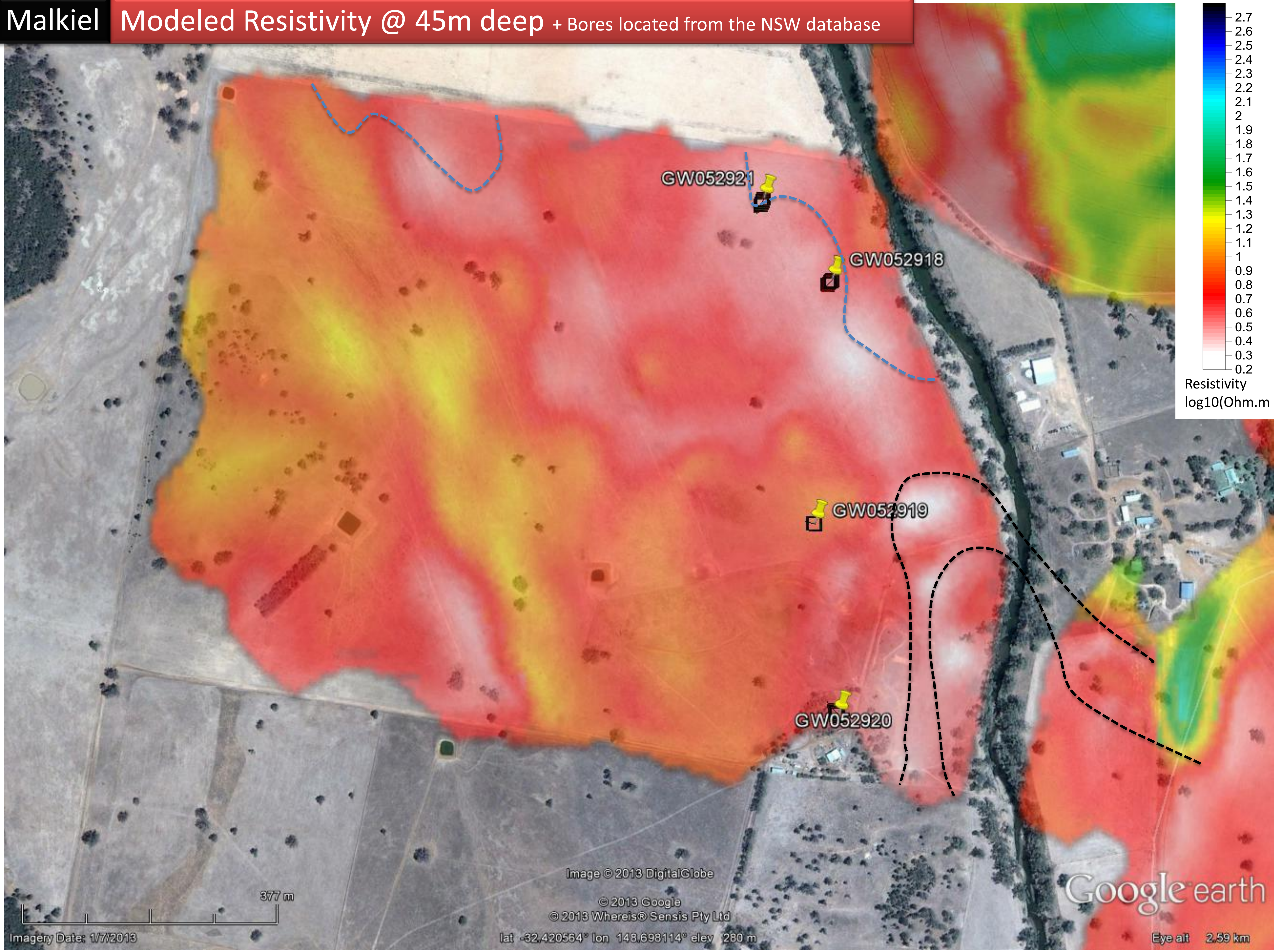
Malkiel Modeled Resistivity @ 28m deep + Bores located from the NSW database



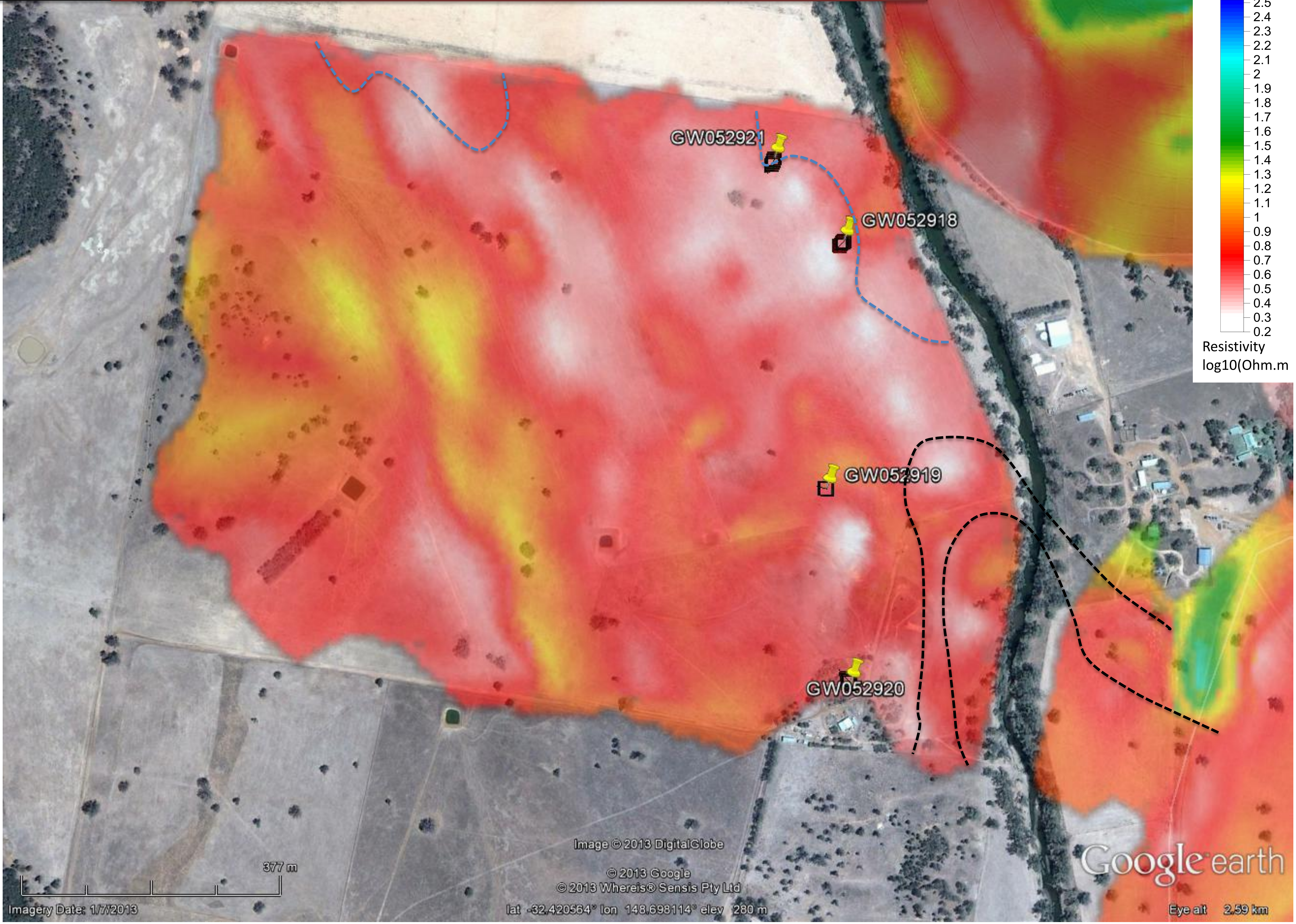
Malkiel Modeled Resistivity @ 36m deep + Bores located from the NSW database



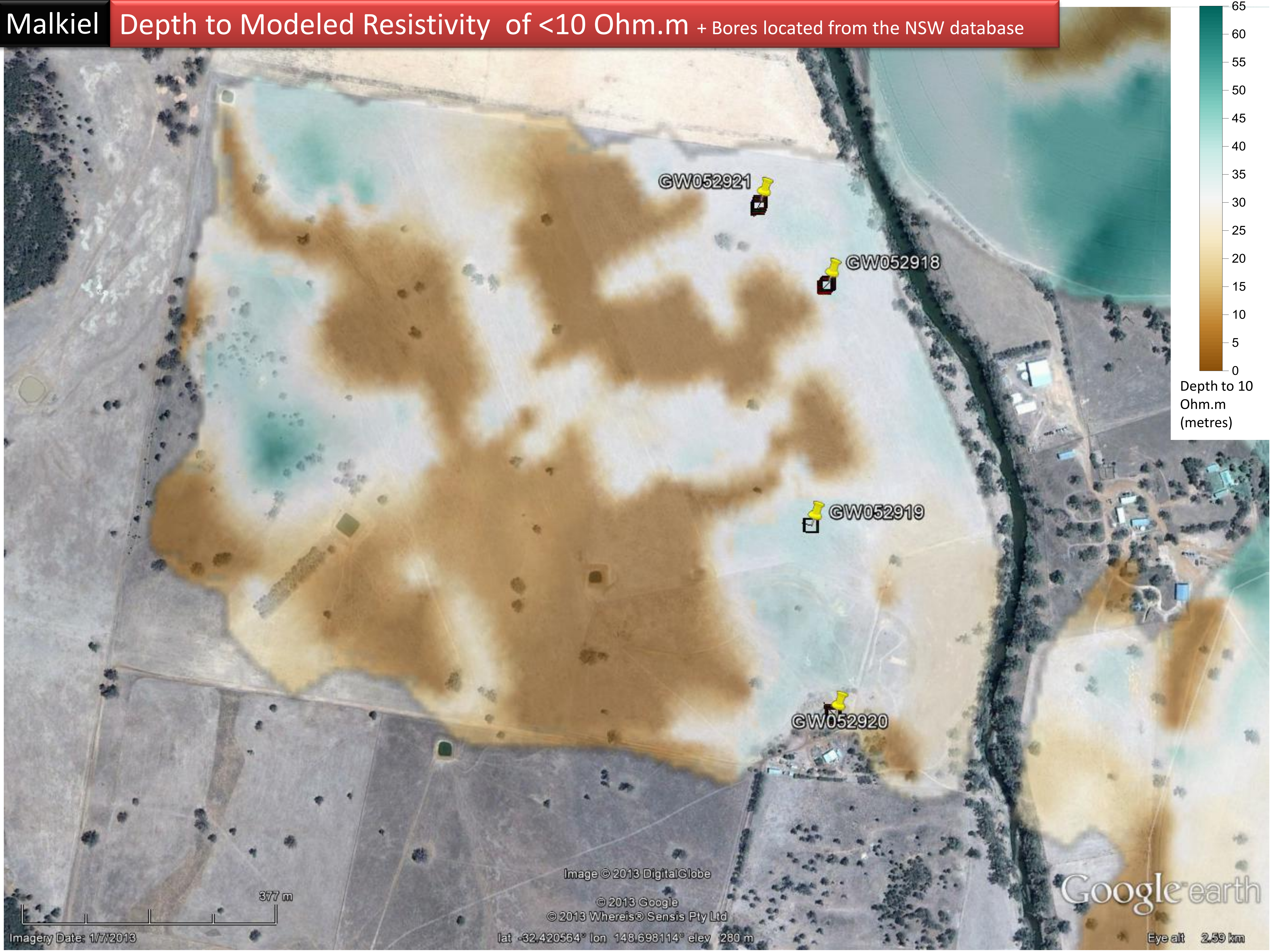
Malkiel Modeled Resistivity @ 45m deep + Bores located from the NSW database



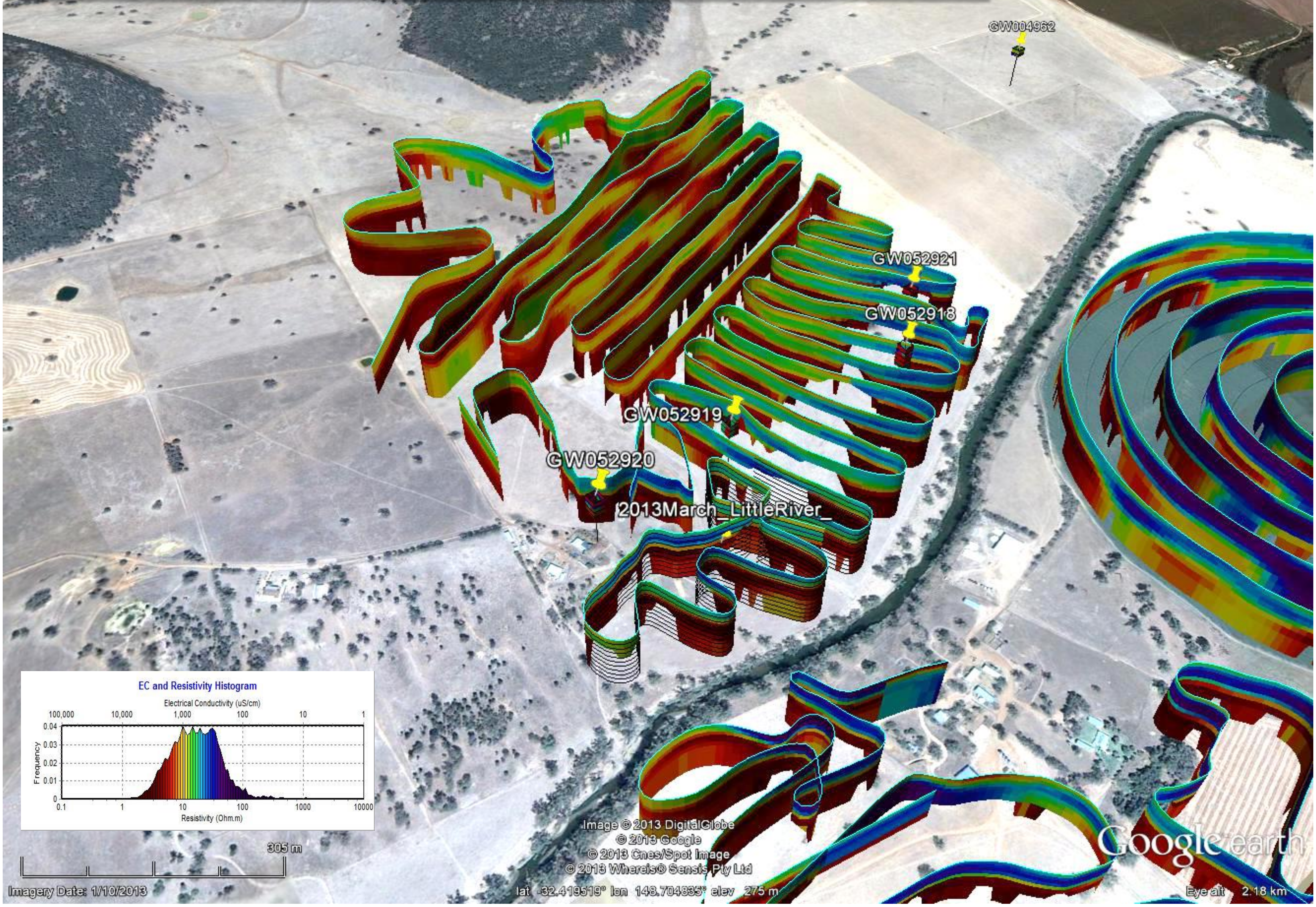
Malkiel Modeled Resistivity @ 58m deep + Bores located from the NSW database



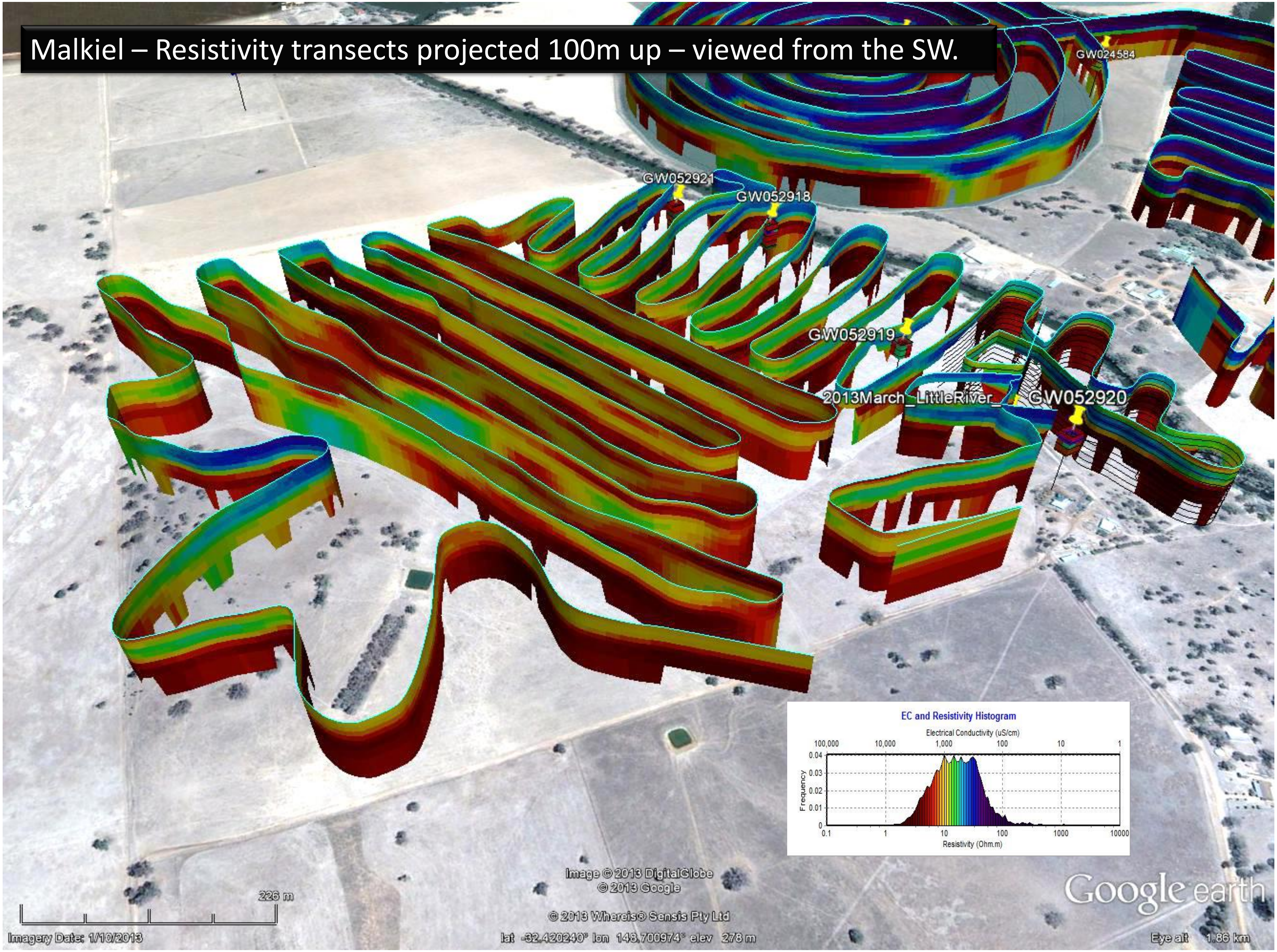
Malkiel Depth to Modeled Resistivity of <10 Ohm.m + Bores located from the NSW database



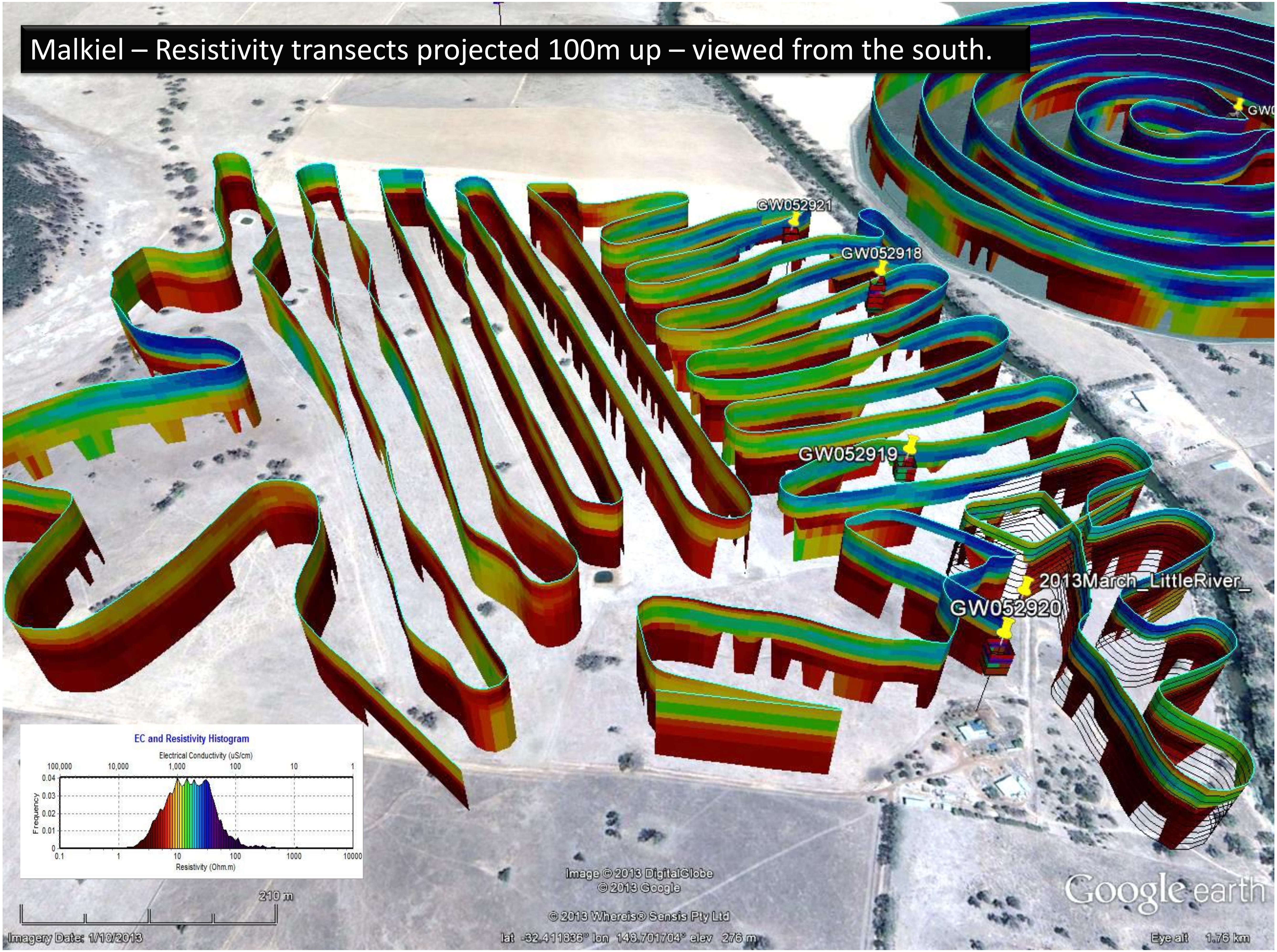
Malkiel – Resistivity transects projected 100m up – viewed from the SE.



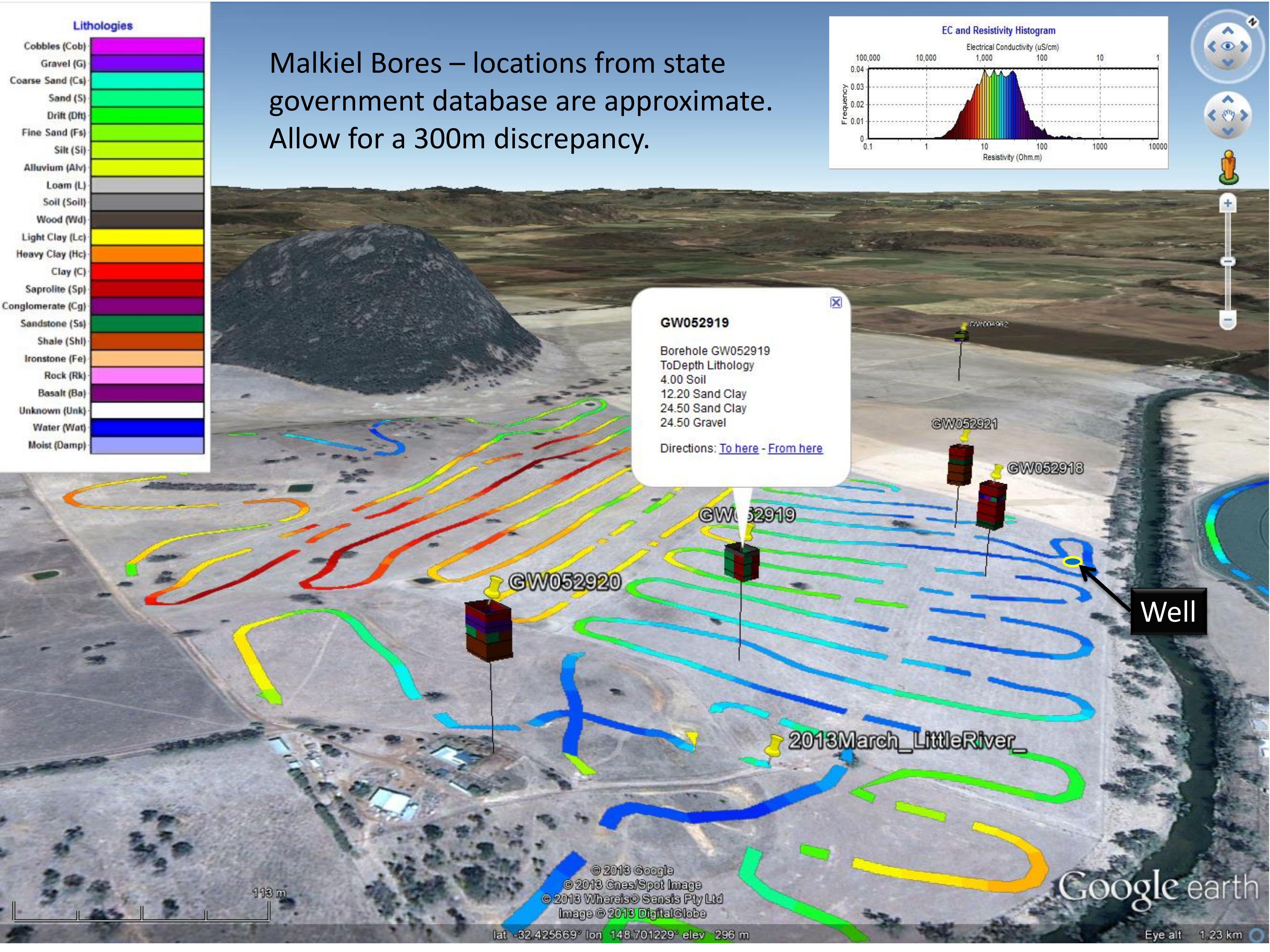
Malkiel – Resistivity transects projected 100m up – viewed from the SW.



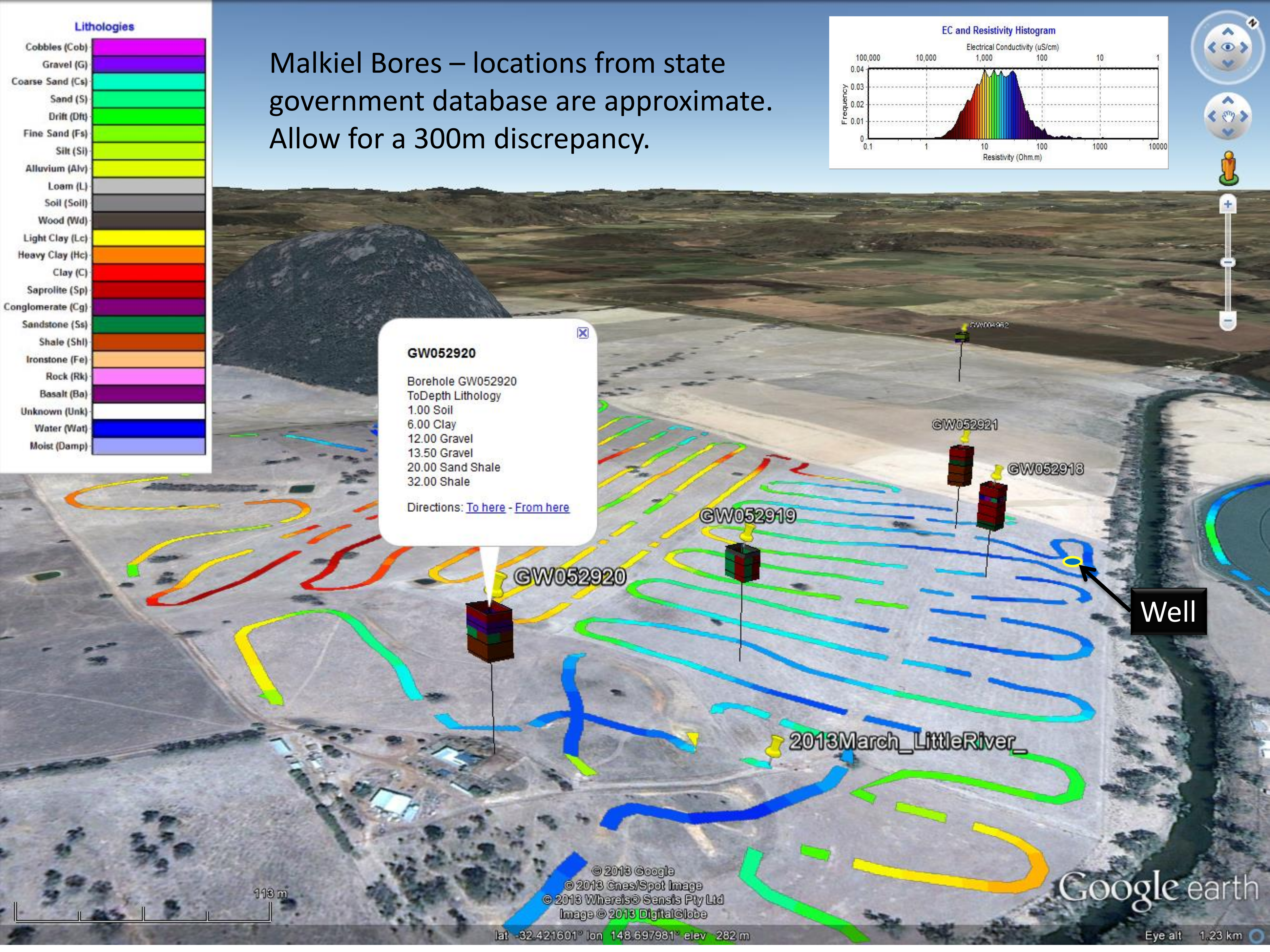
Malkiel – Resistivity transects projected 100m up – viewed from the south.

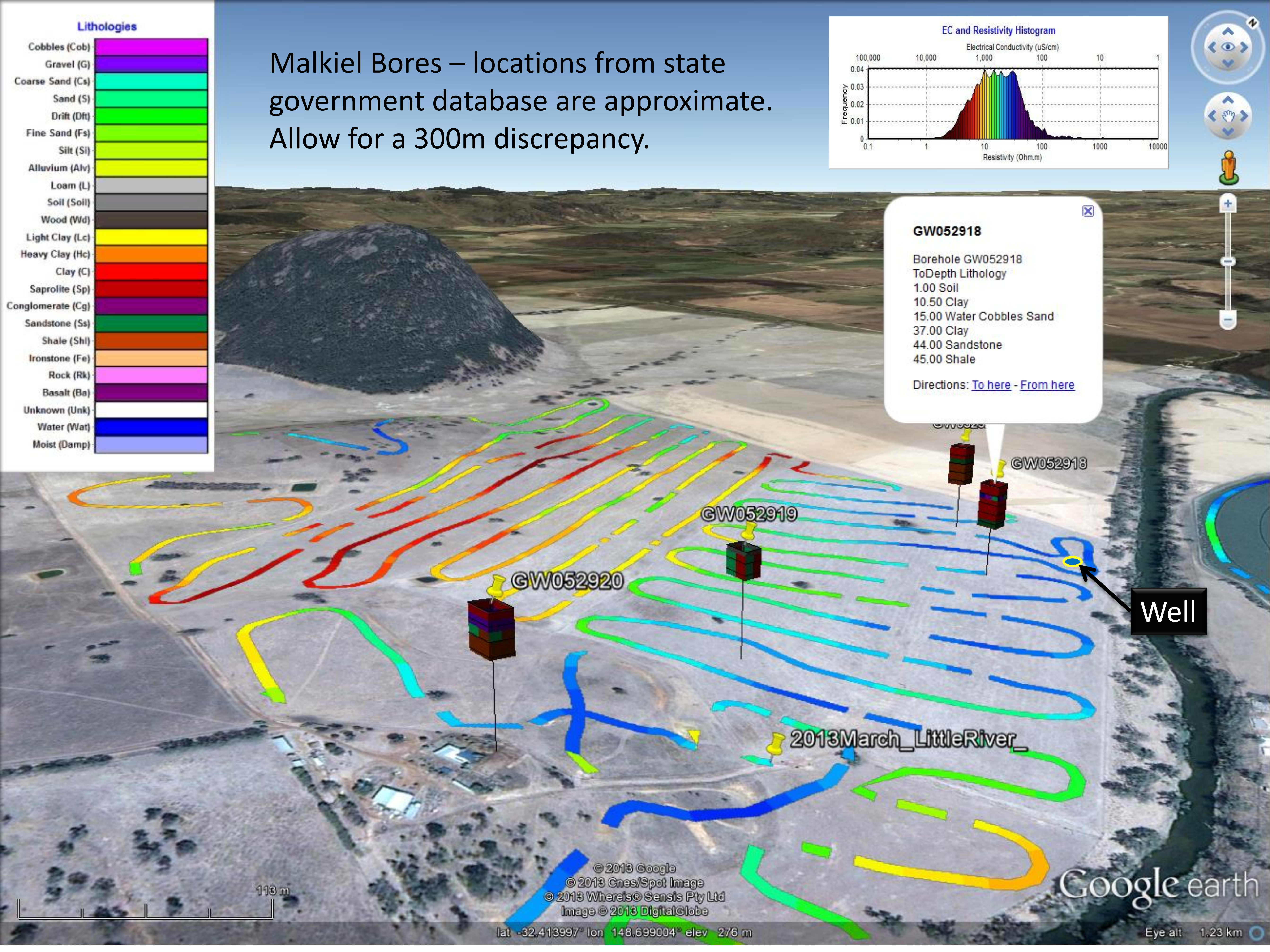


Malkiel Bores – locations from state government database are approximate. Allow for a 300m discrepancy.



Malkiel Bores – locations from state government database are approximate. Allow for a 300m discrepancy.





Malkiel Bores – locations from state government database are approximate. Allow for a 300m discrepancy.
Lithologies
Cobbles (Cob)
Gravel (G)
Coarse Sand (Cs)
Sand (S)
Drift (Dft)
Fine Sand (Fs)
Silt (Si)
Alluvium (Alv)
Loam (L)
Soil (Soil)
Wood (Wd)
Light Clay (Lc)
Heavy Clay (Hc)
Clay (C)
Saprolite (Sp)
Conglomerate (Cg)
Sandstone (Ss)
Shale (Shl)
Ironstone (Fe)
Rock (Rk)
Basalt (Ba)
Unknown (Unk)
Water (Wat)
Moist (Damp)
EC and Resistivity Histogram
Electrical Conductivity (uS/cm)
100,000 10,000 1,000 100 10 1
Frequency
0.04 0.03 0.02 0.01 0
0.1 1 10 100 1000 10000
Resistivity (Ohm.m)
GW052918
Borehole GW052918
ToDepth Lithology
1.00 Soil
10.50 Clay
15.00 Water Cobbles Sand
37.00 Clay
44.00 Sandstone
45.00 Shale
Directions: To here - From here
GW052918
GW052919
GW052920
2013March_LittleRiver_
Well
113 m
© 2013 Google
© 2013 Cnes/Spot Image
© 2013 Whereis® Sensis Pty Ltd
Image © 2013 DigitalGlobe
Google earth
lat -32.413997° lon 148.699004° elev 276 m
Eye alt 1.23 km

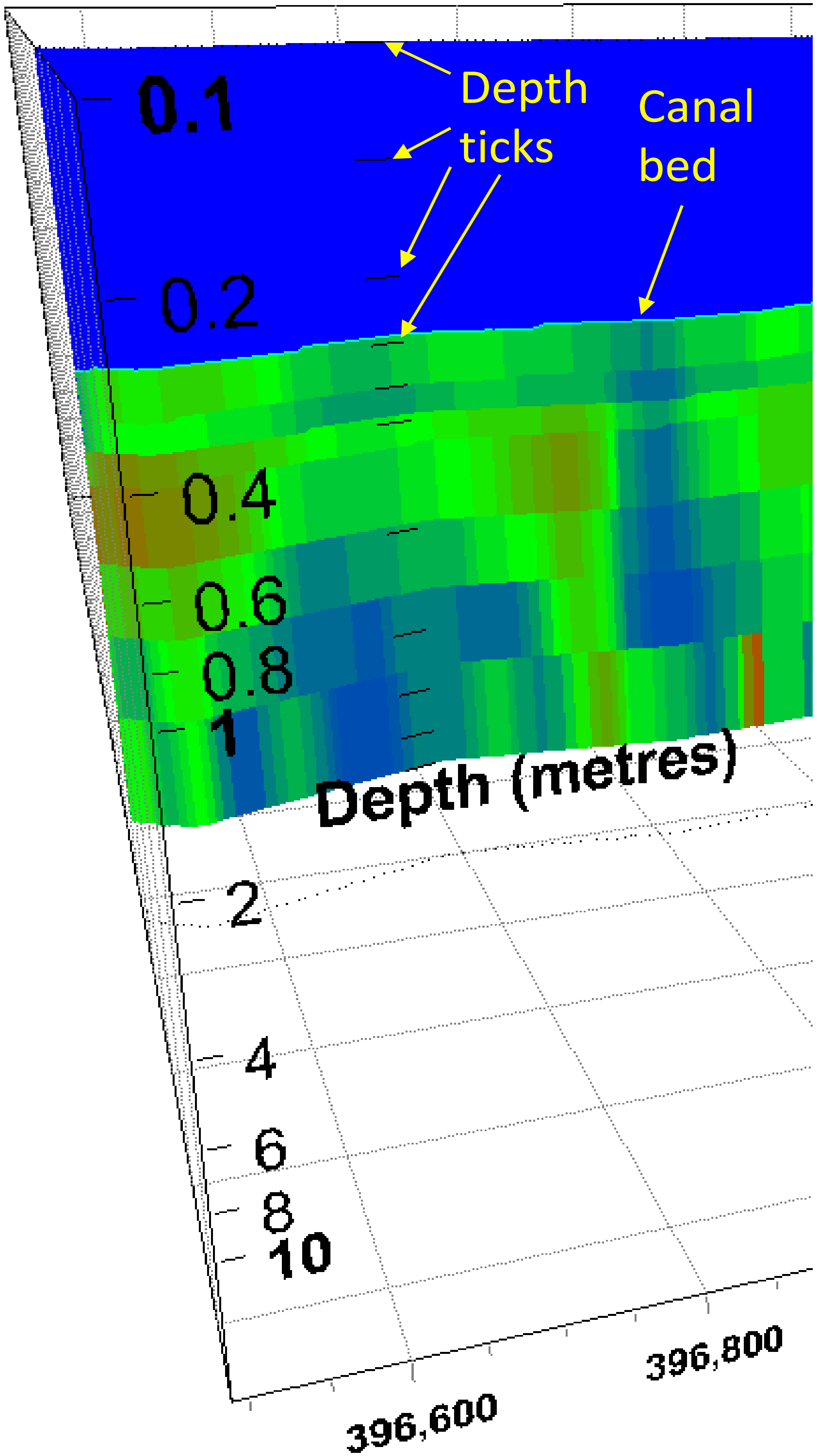
Conclusions

Malkiel consists of permeable alluvium, in the NE, overlying Triassic sedimentary rock and volcanic flows. It is not know whether there is additional porous sediment, that may function as aquifers within the Triassic strata, however, fracture zones within such strata probably host water. The NE alluvium is permeable and contains relatively good quality water while the Triassic sediments, overall, have lower resistivity suggesting that they host mainly saline or brackish water. There is a low resistivity weathered horizon on top of a possible volcanic flows in the SE. High resistivities near the surface are probably alluvial silts, sands, gravels, and cobbles while high resistivities deeper down represent the same or resistive hard rock. Lava flows have probably followed prior river courses, blocking and damming the river resulting in complicated palaeochannel remnants and aquifer connectivity. In the SE corner of Malkiel the geophysical data suggests presence of one such flow. A resistive feature in the hill just to the west may be a Triassic or more recent gravel channel beside the inferred flow.

Drilling sited in the more resistive alluvium in the NE of the farm is recommended but with suggested screen depth of only 20m. There is already a well there and an alternative strategy for consideration is to refurbish and deepen the well.

Appendices

- Identifying depths on ribbon images
- Towed Transient Electromagnetic schematic
- TEM platform configuration schematics
- TerraTEM specifications
- Processing sequence
- Results – Digital Products
- Production Report
- References



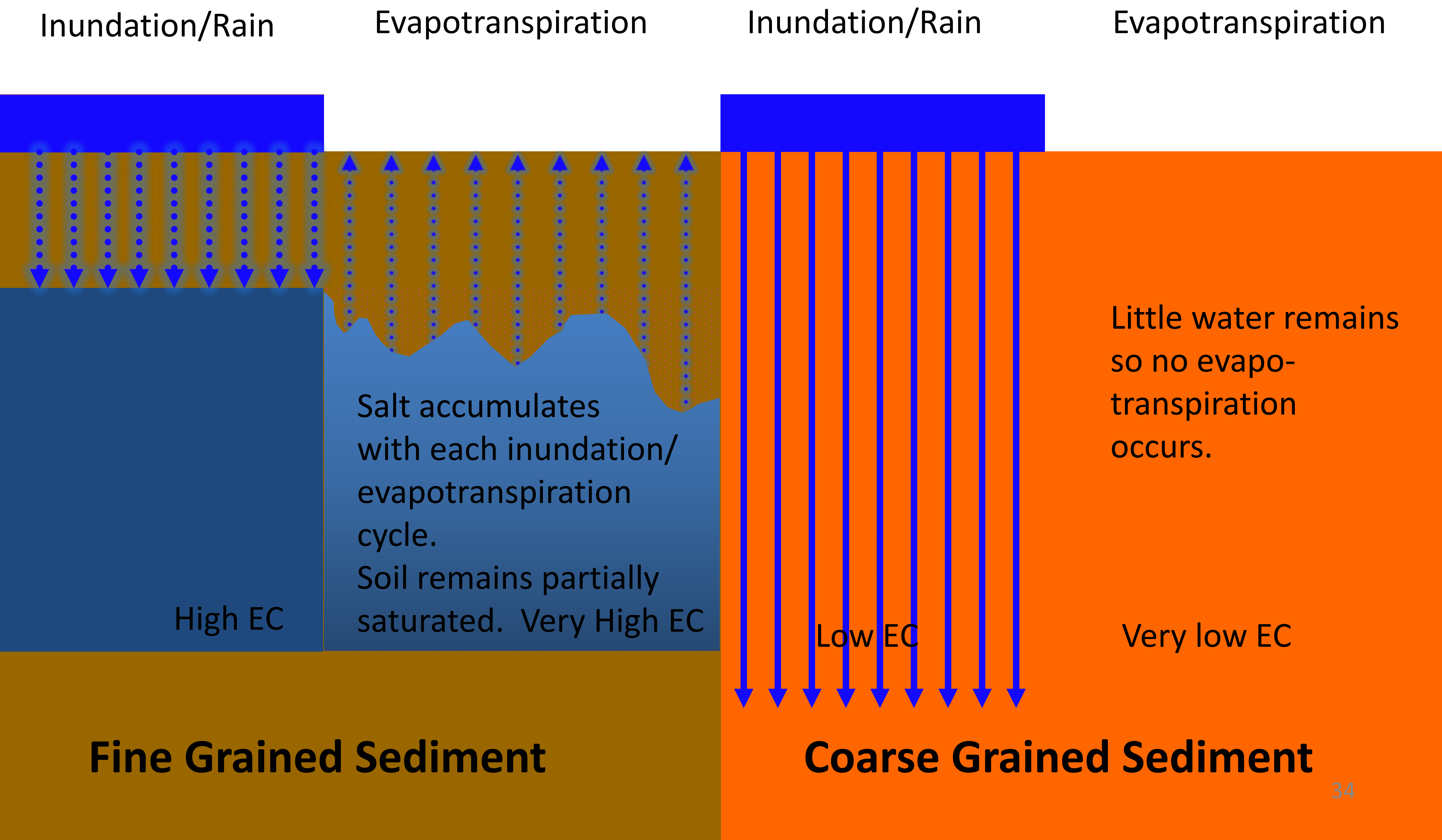
Identifying depths on ribbons

All the 3D imagery has the log or linear depth scales. It is labelled on the south-west corner of the 3D viewing space (as shown). Notice the increments are logarithmic. Logarithmic depth plotting is used so that deep data can be examined at the same time as detailed shallow (near canal bed) data. The geophysical data loses resolution with increasing depth and so this type of depth scale presents all the data in a way that is easy to see.

Look on the ribbon behind the depth scale and you will see a column of black ticks. These correspond to the ticks on the annotated depth scale. Notice that they bunch up at 1m. Black dots mark the projection of the ribbon onto the base plane of the viewing space which is 20 m below the surface.

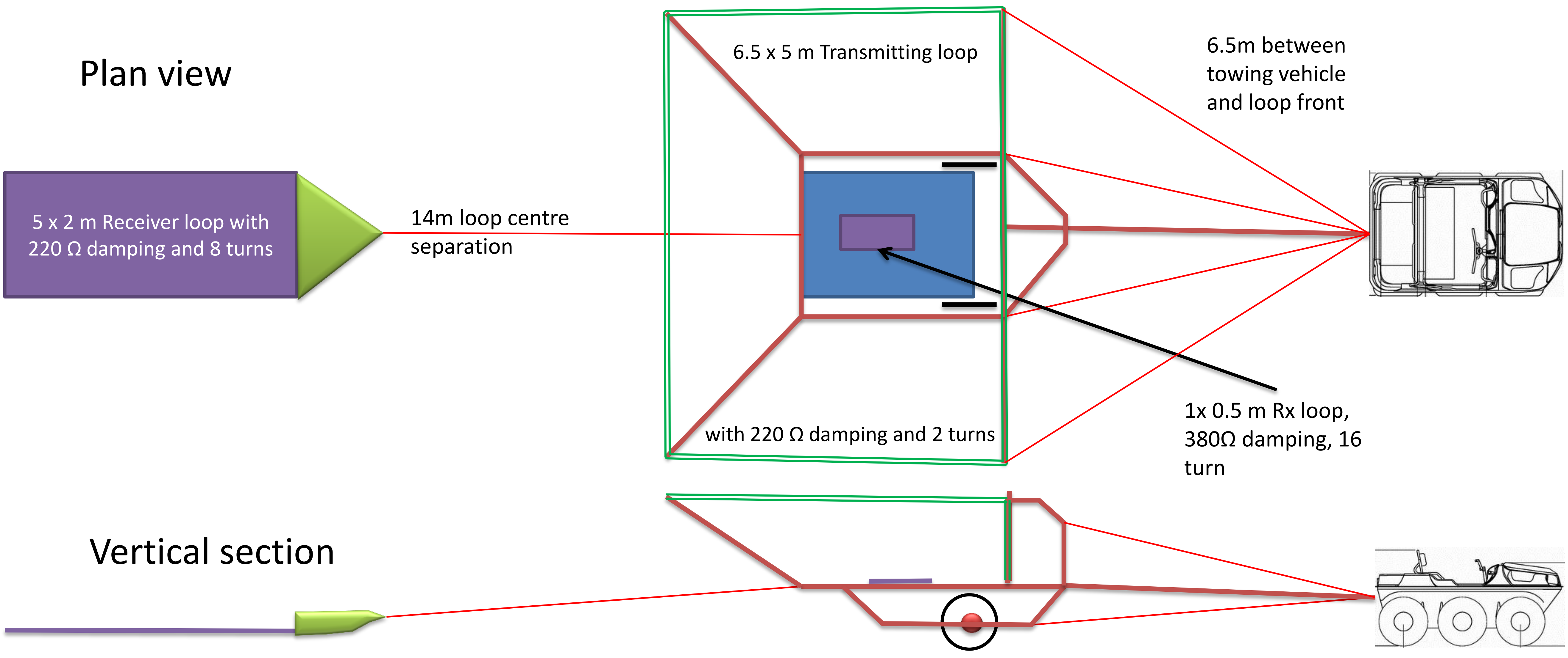
The canal bed is marked with an aqua line.

Seepage, EC and soil texture in a recharge dominated environment.



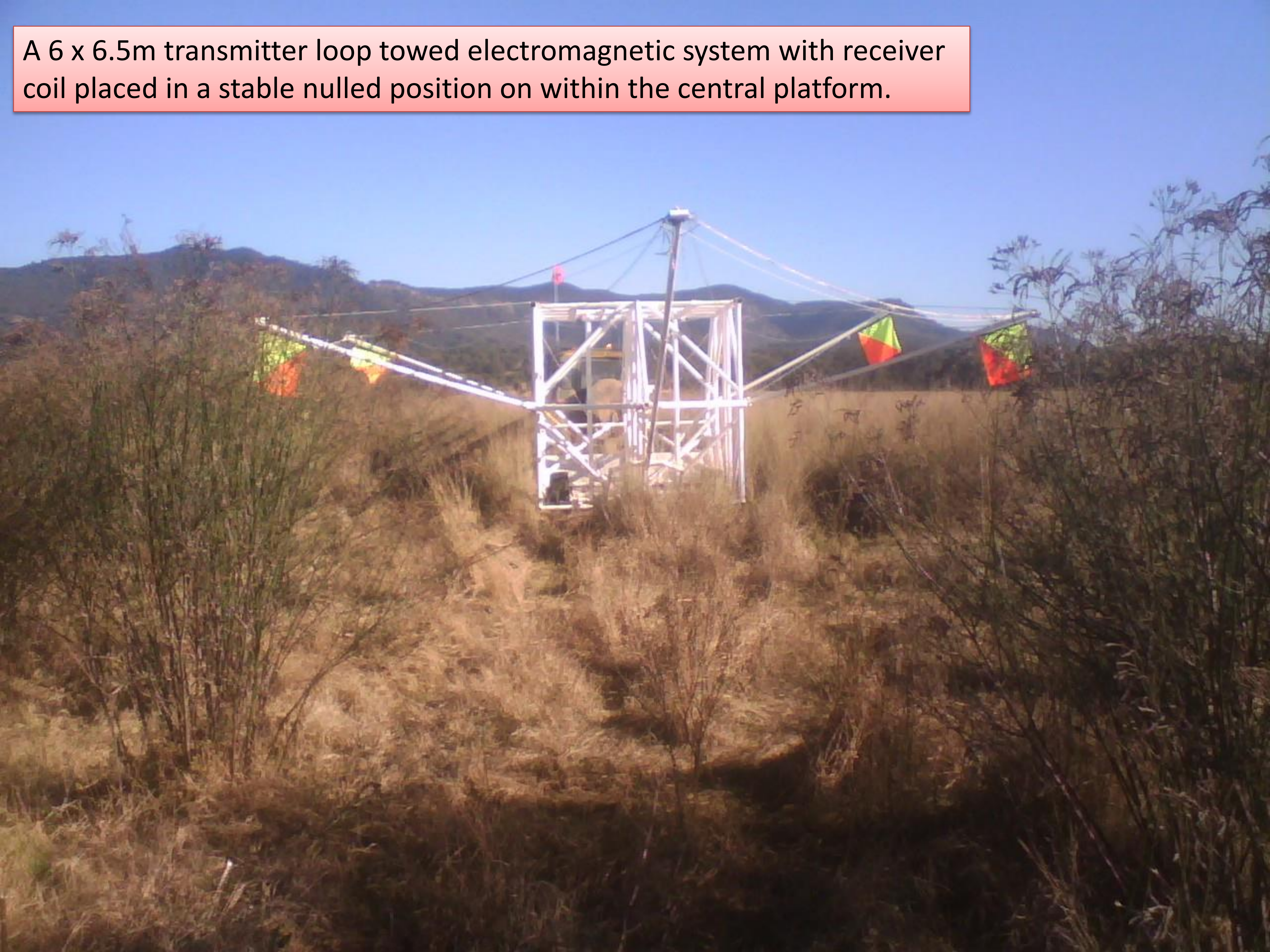
Transient EM equipment configuration

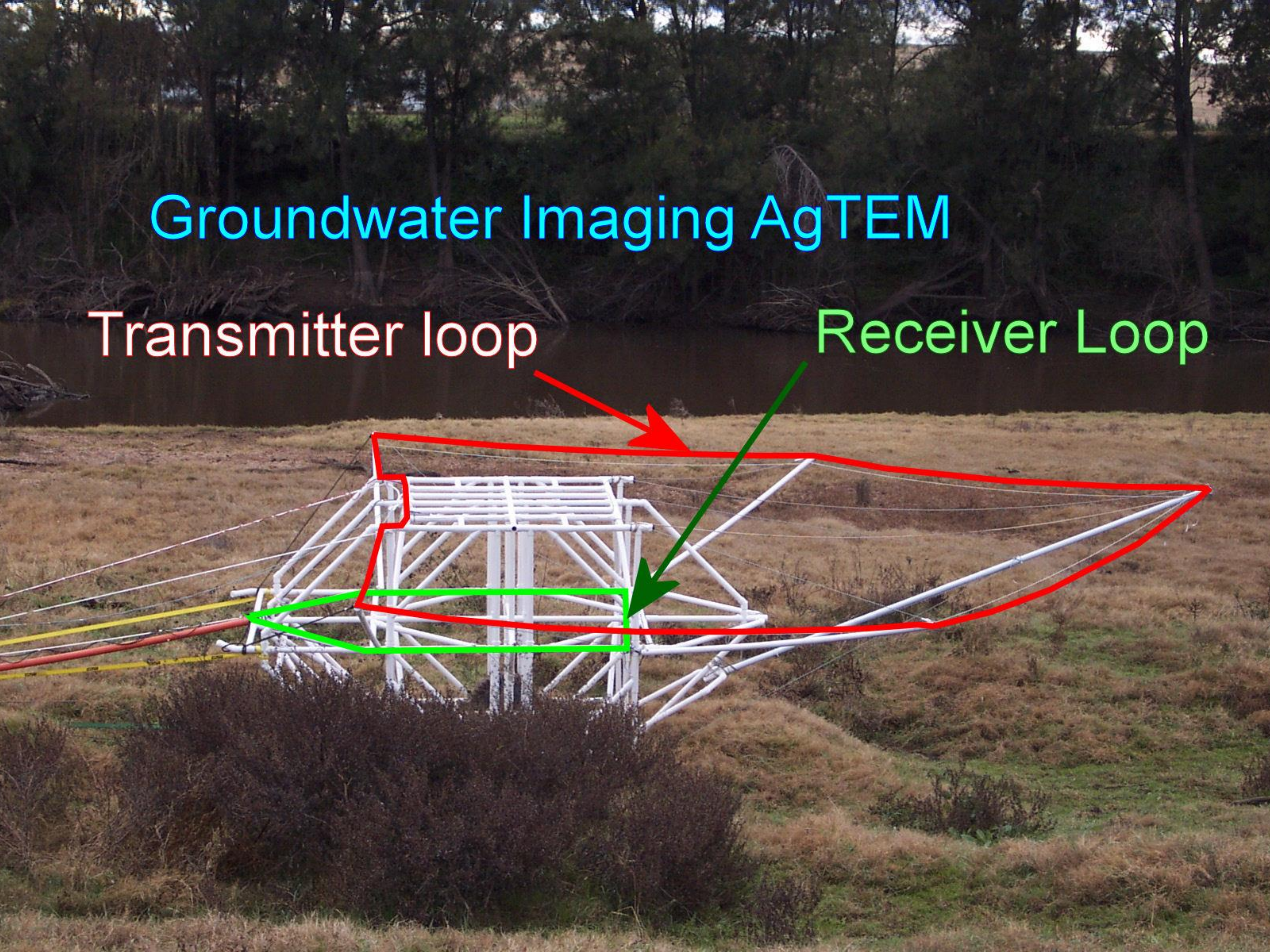
6.5 x 5 m transmitting loop towed TEM system



Transmitter loop suspension arms are attached elastically to prevent attrition upon impact with trees. Arms may be raised from the towing vehicle and fold inwards for obstacle avoidance and for compact transport when not surveying. The trailer draw-bar is detached for between-job transport. The trailer is lightweight and can be lifted by one person. Attrition is also avoided by addition of a breakaway pin.

A 6 x 6.5m transmitter loop towed electromagnetic system with receiver coil placed in a stable nulled position on within the central platform.



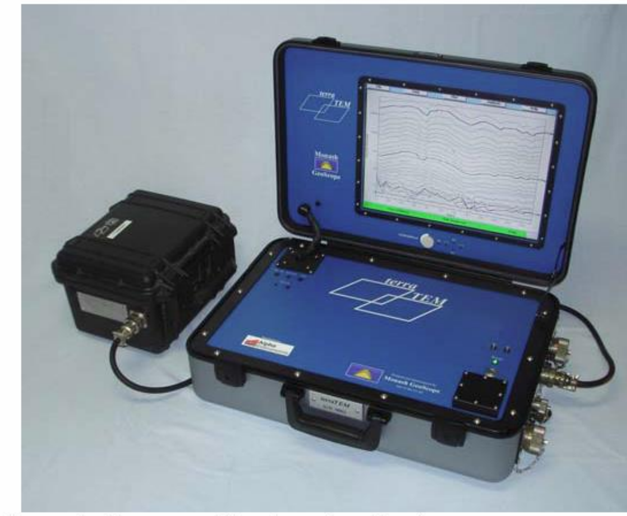

Groundwater Imaging AgTEM
Transmitter loop
Receiver Loop

Transient EM equipment specifications

Alpha Geo Instruments

terraTEM
Time-Domain EM Surveying System

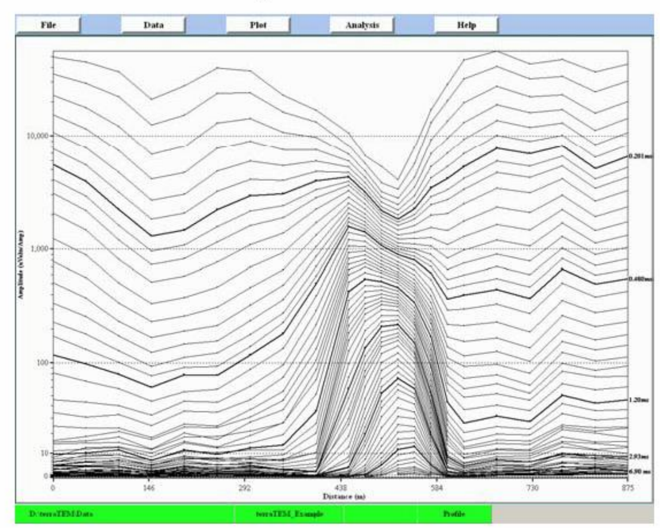
terraTEM Features



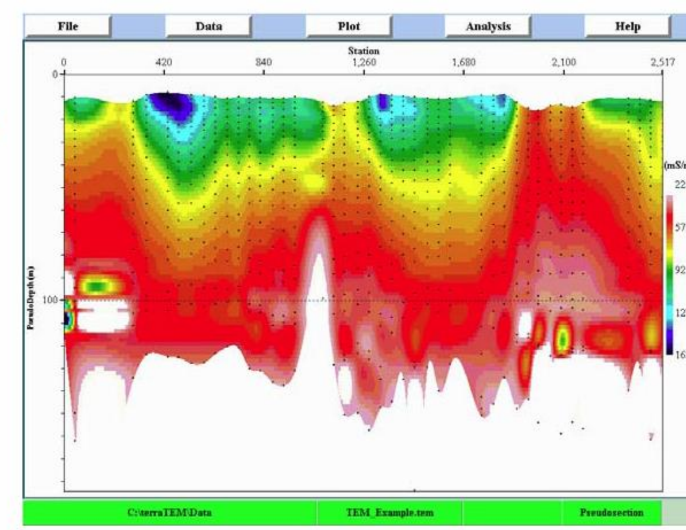
- Transmitter and receiver in one unit
- Single or 3 channel receiver with 10 amp. transmitter
- High speed sampling at 500 kHz for superior near surface resolution
- Easy to use touch screen with auto set-up and smart menus
- Large 15" LCD display for data visualisation
- Fast and easy data transfer via USB port
- Integrated 12 channel GPS system for seamless station positioning (option)
- Integrated PC for data visualisation, data processing, and interpretation in field using built-in software
- Rugged construction with external 24 V battery power pack and charger
- Several optional extras to broaden capability
- Designed and built in Australia

Screen Dumps

The following are a number of screen views from the **terraTEM** system.



Full control of all aspects of data display, post-survey filtering, and decay curve analysis



Multiple display formats, including gridding and raster images (options)

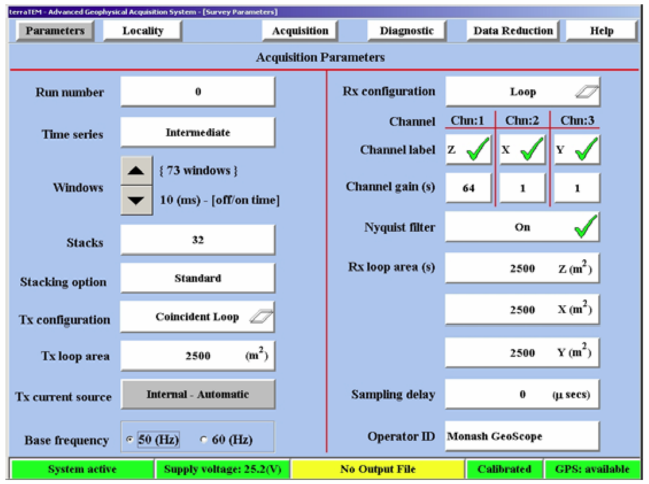
The **terraTEM** is designed, developed and manufactured by **Monash GeoScope**

Monash GeoScope

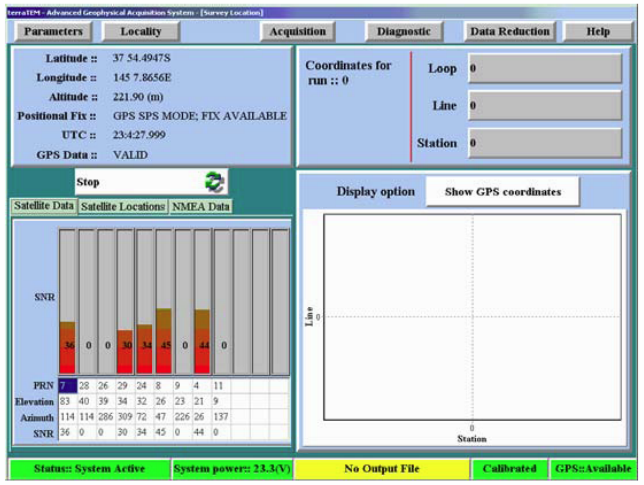
Applications

The **terraTEM** can be used for various applications including the following:

- Mineral exploration
- Near surface including geo-technical and engineering investigations
- Groundwater and salinity studies
- Environmental surveys



Easy access to all parameters, multiple binning and stacking options; smart menu system.



Internal GPS, for positional accuracy (option)

General Specifications

	terraTEM	Options
Transmitter Output	10 Amps. (max.)	**Enhanced Transmitter**
Receivers	1 Channel	**3 Channels (simultaneous)**
High Resolution Sampling Rates	500 kHz	-
User Selectable Multiple Time Gates	-	**Option**
Data Visualisation and Processing in field	Standard Software	**Enhanced Software**
Storage Device – 1 GB Flash Disk	Standard	-
GPS Receiver – 12 channel	-	**Option**
Communications – Port for Data Transfer	USB and RS-232 Standard	-
External Synchronisation	-	**Option**
Continuous Recording (with external GPS Interface)	-	**Option**
Extra Stacking Options and Gain Functions	**10 Selectable Gain Settings from 1 to 8,000**	**Auto Gain**
Vectem 3 Interface Module (for down-hole surveying)	-	**Option**
Interface Options (third party devices)	-	**Option**
Dimensions: Console: 530 x 350 x 160 mm. 13 kg. Battery Box: 280 x 250 x 180 mm. 12 kg.		
Operating Temperature: -10 to 40 degrees C.		

Further Information

For further information regarding this product, either technical or sales, please contact:

Alpha Geo Instruments

Unit 1, 43 Stanley Street, Peakhurst. N.S.W. 2210. Australia
Phone +61 (0) 2 9584 7555 **Fax** +61 (0) 2 9584 7599
e-mail info@alpha-geo.com **website** www.alpha-geo.com

Your Distributor:

terraTEM
Technical Specifications

Transmitter

Output	10 Amp. (max.)
On/Off Period	Adjustable 10 ms (50 Hz) or 8.33 ms (60 Hz) increments

Receiver

Sampling	500 kHz per channel, fixed
Inputs	+/- 40 V maximum continuous voltage.
Gain	User selectable fixed gains Other Gains Optional
Resolution	Maximum 28 bits, effective
Functions Measured	Tx/Rx loop resistance, Tx current, Tx turn-off time, battery voltage, automatic gain/offset calibration, transient response

Console

Display	LCD TFT, 15 inch
Touch Screen	Splashproof
Storage	1 GB flash RAM

External Interfaces

Communications	USB and Serial port for data transfer

Equipment Supplied

- Console
- Loop connectors
- Battery Pack (24 volts), complete with connector cable (overseas batteries not included)
- Battery charger
- USB flash disk (for data transfer)
- Operations manual

Sensor Attachments Available

Surface Receiver	RVR-1 or cable loop
Downhole	Vectem 3 or equivalent

Physical

Housing	Aluminium "Zero" case
Console: Weight	13 kgs.
Dimensions	530 x 350 x 160 mm.
Battery Pack: Weight	12 kgs.
Dimensions	280 x 250 x 180 mm.
Operating Temperature	-10 to 40 degrees C.

Options

GPS Receiver	12 channel receiver
Multi-channel Receiver	3 channel simultaneous A/D
External Transmitter Interface	External synchronisation option (for use with TEMTX-32, Zonge high powered transmitters)
Vectem 3 Interface	Internal interface module
Continuous Recording	Continuous recording of unit with external GPS interface using NMEA standard
Software Packages	Extra Stacking Options, Sferics Rejection and Gains, Spectral Analysis and Digital Signal Processing User-defined time series

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e-mail info@alpha-geo.com **website** www.alpha-geo.com

Your Distributor:

Towed platform TEM Method Description

- ***Towed platform TEM Method Description***
- Towed platform specifications are given on prior slides.
- Towed transient electromagnetic arrays have been applied by Sørensen, et. al.(2000), and the author (Allen, 2007) however the full potential of the technique is far from being realised. Other options for fast TEM data acquisition have been described by Harris et. al. (2006) and Hatch et. al. (2007).
-
- Key features of practical towed TEM devices are:
- They must facilitate towing of sufficiently large area transmitter loops and one or more receiver loops upon largely non-metallic structure;
- They must be robust enough to withstand field use;
- They must be capable of passing through farm gates and between other common obstructions without undue delay;
- They should be designed in such a way that they can isolate and minimise effects of incomplete transmitter turn off, loop self and mutual inductance, super-paramagnetic near-surface minerals and chargeable near-surface minerals;
- The transmitters need to be able to cleanly transmit high currents. Dual moment operation is beneficial;
- They must be readily road transportable and GPS equipped.
-
- Figure 4 presents a platform with the transmitter and receiver loops placed on dragged sheets, the sides of which can be raised when passing through gates. The main sheet is 2mm thick polyethylene which is heavy enough to prevent lifting by all but strong wind and rigid enough not to catch on stumps, barbed wire, and other obstacles. Practical size of the sheet is limited by the combination of the necessity of weight per unit area needed to prevent lifting by wind, and total weight which needs to be low enough to permit man-handling. The sheet is very useful for permitting precise layout of primary field nulling coils when using central loop receiver loops, and for spacing multi-turn transmitter loops so as to reduce self-capacitance and, to a lesser extent, self-inductance. It is difficult to increase the number of transmitter loop turns without compromising turn-off ramp integrity. This is a problem well understood by designers of airborne TEM systems.
-
- Receiver coil movement through the earth's magnetic field produces noise. When the coil is on a mat, it generally does not suffer from movement at frequencies above the sampling frequency as there are no taut elastic components that can resonate. Noise lower than the sampling frequency can be removed in post-processing of appropriately stacked data using techniques common to airborne TEM survey (eg. Noteboom, 2007).

Processing – introductory notes

One of the big advantages of a towed system is that it has a small near surface footprint that can isolate and avoid most problematic cultural effects. Further, it can be manoeuvred in order to test the effect of culture. In this way, processing, in effect, really starts during acquisition. Cultural effects need to be identified and this is done by repeatedly driving close to them and noting their response. Once problematic culture is identified, it is either avoided or its location is noted for later removal of affected data. The TerraTEM continuously displays decays of incoming data, and for quality control and verification of system response, these are continuously monitored while driving.

Data from all the relevant devices was merged together using interpolation and extrapolation where necessary. Position data was written in WGS84 UTM(MGA94 equivalent at the accuracy of the DGPS that will be used). Data is in tabular format in dBase files suitable for importing into ArcGIS and Google Earth products as specified in *Allen, D.A., 2005, Towards creation of a national multi-depth electrical conductivity database. Australian Society of Exploration Geophysicists, Preview, August, Issue No. 117.*

The Gridding was conducted as follows:

- Depth slice data was all log transformed;
- A proximity filter averaged points closer than 20m apart;
- An exclusion filter removed null records caused by depth slicing beneath cutoff depths;
- Natural neighbour gridding was performed with a cell size of 20m;
- The grid was blanked to remove most overshoots occurring around grid extremities in the absence of data;
- Gridding was imaged with valid and non-valid colour coded points registering data locations posted on the image so that viewers can determine what are real geological features and what are simply gridding artefacts. Non-valid points are important for showing where data cutoff above slicing depth as soundings penetrate much deeper depth when modelling resistive features – the result being that gridded data will be excessively resistive at depths below conductive feature cut out depths.

Data was then interpreted.

Processing Sequence

Define System Geometry

–

1. Quality control and data parsing during acquisition
    1. At the beginning of each day, select a reference sounding and plot it along with all incoming data.
    2. Watch all incoming data constantly making comparison with the reference sounding.
    3. Cancel acquisition or note problems as noise sources, metal artefacts, or equipment malfunctions are encountered. Alter course across ground to both more clearly define noise and artefacts and to subsequently avoid them.
    4. Each night, convert BIN file into TEM and TXT files and back them up.
    5. Each night, display selected channels of the data in plan view to appraise layout of geological features and any present geophysical artefacts.
2. Acquire system response from data obtained (stacked then averaged) in a very resistive area.
3. Determine EM1DInv inversion software initial model, constrains and control parameters.
4. –
5. Operations performed on TEM files
    1. Basetrend removal (optional – only possible on moderately to highly resistive areas). This removes movement noise from the receiver coil moving through the magnetic field of the earth slowly. Large mat receiver loops do not create much movement noise.
    2. Adjust magnitude according to primary field response (optional).
    3. Reject records with low primary field response as they are clearly suffering from equipment malfunction (eg. Receiver loop blown over by wind) (optional).
6. Convert TEM file into a relational voltage database (*Volt.DBF, *XVolt.DBF,*YVolt.DBF)
7. Normalize data using average magnitude of log10(data) from a small receiver placed directly on the transmitter loop wires (*YVolt.DBF) (This is optional as the data is already normalized according to current monitored (every 100 soundings in 2010)).
8. Remove system response, taking magnitude of transmitted data (proportional to *YVolts.DBF) into account for every sounding.
9. –
10. Display voltage data, in map view, coloured to represent magnitude of a particular channel. Simultaneously view decay plots of picked soundings, along with a reference sounding.
    1. Interactively remove geophysical artefacts by clicking on points or data segments.
    2. Alter the channel and repeat a.
    3. Repeat b. until satisfied that data is suitably cleaned.
    4. Interactively clip channel count on soundings with procedure as for a., b. and c. (optional).
11. Smooth voltage data horizontally. Trapezoidal filtering is ideal (optional). Note well that this step is conducted after removal of artefacts which would have spread their mess throughout the data if smoothed.
12. Calculate noise levels from sounding tails and specify ready for inversion. Should telecom cable or powerline noise be encountered, then this step will lead to recovery of shallow information without unduly corrupting deeper information!
13. Determine valid time range for inversion input from each sounding using noise levels specified in step 14.
14. Create EM1DInv inversion input files.
15. Run EM1DInv on each sounding, conjunctively inverting both in-loop and out-of-loop data. This scheduled using batch files and runs overnight, or even over several days or weeks.
16. Run EM1DInv again with lateral constraint (optional – also time consuming).
17. Read inversion output files to create relational *Ohmm.dbf files.
18. View *Ohmm.dbf files in plan view.
    1. Colour proportional to curve fitting RMS error and view to determine an appropriate cut-off RMS threshold. Exercise caution in determining the threshold as data in resistive areas will still be valid at much higher threshold than in conductive areas.
    2. Reject soundings with RMS error greater than the threshold level determined in a..
    3. Colour proportional to resistivity of successively deeper layers. Interactively remove or depth-limit soundings containing artefacts by clicking on points or data segments.
19. View *Ohmm.dbf in 3D – check data more, switching back and forth to 2D view to remove further artefacts.
20. Horizontally smooth the *Ohmm.dbf file to clean up erratic variation in inverted data.
21. Horizontally shift *Ohmm.dbf files to account for antenna offset.
22. –
23. Divide day *Ohmm.dbf files into logical segments (where appropriate) and recombine into *Ohmm.dbf files covering logical geographic extents.
24. Calculate resistivity distribution histograms and combine to make a master histogram for the area.
25. –
26. Re-load regional *Ohmm.dbf files and colour with master histogram equalization (quantization).
27. Query state bore databases and generate a subset of bore data for the area.
28. Interpret the drillers logs into lithological categories.
29. View bore log graphics with the resistivity data for each region.
30. Create graphics of histograms and lithological keys for posting externally.
31. Pack regional *ohm.dbf files and augment with shapefile indexes, projection files etc.
32. Create 3D polygon KML and shapefiles for each region (both resistivity and lithological files).
33. Slice each regional resistivity file into depths and output as *.csv with columns of logarithmically transformed resistivity for external gridding in packages such as Golden Software Surfer 9.
34. Create any other appropriate theme datasets (eg. Depth to maximum resistivity) and 3D graphics (eg. Voxler).
35. Grid and display depth slices, stacked if required in 3D space (Surfer).
36. Organize and refine KML files in Google Earth and select enhanced snapshot views. Combine into a folder and collectively output as a new KMZ file. The KMZ files are compact - Email to interested parties.
37. Collect all graphics in MS Powerpoint (A3 resolution!) and create a report. Make a summary report in MS Word (optional). Generate PDF report.
38. Package job DVD and printing, mailing etc.

Results – digital products

- EC datafiles in resistivity units - Ohm.metres accompany this presentation. There is one column for each layer sampled and one column for the depth to the bottom of each layer sampled. The datafiles are in dBase format and may be read using MS Excel, MS Access or ESRI software. ArcView contains a routine for expanding the dBase files into ESRI shapefiles but in most cases this is already done. Co-ordinates are all WGS84 (equivalent to MGA94 to the degree of accuracy of the survey) and are given as both UTM projection and latitude and longitude decimal degrees. Google Earth KML (or zipped = KMZ) format files are also provided for various 2D themes and in 3D. CSV ASCII files of depth slices also provided for generic loading into any spreadsheet or GIS software.
- **Results – Accompanying CD contents**
- The accompanying CD contains this document, digital data, the power point presentation, the A3Earth Plus. Further explanation is as follows:
- This report is stored as a *.doc (MS Word 2003 format) and *.pdf
- The powerpoint presentation is stored as *.ppt and *.pdf
- The Google Earth datasets are stored as *.KML and/or *.KMZ and are opened using File:Open in Google Earth.
- The A3 maps are stored, ready for viewing as *.pdf or *.jpg files
- Data files *Volt.dbf
- Transformed Data files *Ohmm.dbf.
- Depth slice files *DepthSlice.csv
- ESRI ArcMap file *.Mxd demonstrates access to transformed data files and can be used to locate them all.
- Golden Software Surfer *.srf displays and provides locations of all the gridded data files.
-
- All data is stored in GDA94/MGA94 UTM Zone 55 coordinates (Lat Long, E N, or both).

Production Report

Date	Charge	Details
15/02/13	Demonstration	Survey Farm in afternoon

Total production distance
excluding gaps >60m
= 17.8km

References

- Allen, D.A., 2007, Electrical Conductivity Imaging of Aquifers Connected to Watercourses - A Thesis Focused on the Murray Darling Basin, Australia., 480 pages (http://hdl.handle.net/2100/428, Abstract 0.1 MB; Full Thesis 12 MB)
- Allen, D.A., and Merrick, N.P., 2007, Robust 1D inversion of large towed geo-electric array datasets used for hydrogeological studies: Exploration Geophysics, Vol 38 No 1, ISSN0812-3985; Butsuri Tansa (Japanese) 60.1; and Mulli-Tamsa (Korean) 10.1. (http://www.publish.csiro.au/paper/EG07003.htm, Abstract 0.1 MB; Full Paper 1.7 MB).
- Lee, T., 1984, The effect of a superparamagnetic layer on the transient electromagnetic response of a ground. Geophysical Prospecting 32, 480-496.
- Sørensen, K.I., Auken, E. and Thomsen, P., 2000, TDEM in Groundwater Mapping – A continuous approach: http://hgg.au.dk/media/soerensen2000cpresentation.pdf , Dept. of Earth Sci., Geoph. Lab. Univ. of Aarhus, Denmark.
- Spies, B.R., 1989, Depth of investigation in electromagnetic sounding methods. Geophysics, 54, 872-888