Geohazard and Infrastructure Modeling and Monitoring in 3D with the Mapped Underworld Dimension (MUD™) System:

Auracle Geospatial

CASE STUDY: BC WATER

2022

AURACLE GEOSPATIAL

OVERVIEW

Auracle is a remote sensing and geospatial technology company specializing in airborne and satellite applications that serve global clients in mineral exploration, oil and gas, engineering, natural resource management, waste management, railways and defense.

Auracle's technology maps and models the Earth's surface down to bedrock—hundreds of meters underground and through water. The 3D **M**apped **U**nderworld **D**imension (MUD™) Model, the foundation of our technology, makes it possible to "see through" water, vegetation, ice, trees, rocks and soil to identify structures and lithologies. This technology makes it possible to explore and map, from space, with millimeter-level accuracy, day or night, through all weather, and in remote or inaccessible areas. With the MUD™ system, we can measure as little as 2mm of movement in any location, in 3D. Auracle's systems require no permits, are cost effective, are completely discrete, and provide actionable information to key decision-makers.

Auracle also generates highly accurate Continuous Surface Elevation Models© (CSEMs), specializing in shallow lake and river bottoms. These elevation models replace manual surveys of shallow lakes and rivers in geophysics, particularly gravity surveys and provide valuable terrain information needed in exploration.

Using high-definition satellite video and imagery, we construct Hyperspatial Digital Elevation Models© (HDEMs) as a monitoring system that identifies subtle movements and changes in infrastructure such as pipelines, dams, ports, landfills, roads, and bridges. This early warning system supplies our clients with a cost-effective way to monitor and manage potential environmental damage caused by geo-hazards, industrial activities, and natural disasters.

Imbedded in each project is our commitment to environmental responsibility, efficiency, and economic success. Our methods create no unnecessary human footprint, require no social license, and do not cause cultural interference.

TECHNICAL ADVANCEMENTS

MAPPED UNDERWORLD DIMENSION (MUD™)

Over the last 20 years, Auracle has developed a unique method of using satellites and other airborne systems, to monitor, detect and map the impact of structural movement on surface and subsurface assets such as pipelines, railroads, bridge abutments, slopes, mines, and other critical infrastructure and assets. Auracle's pioneering work began in satellite hyperspectral and synthetic aperture radar. Further advancements in satellite radar tasking and analytic systems paved the way to look through vegetation, land cover and water providing the ability to define subsurface geological structures, features and units. With exposing the non-outcropping near surface, Auracle corrected and improved geological maps and models with structural features including non-apparent strike and dip.

In 2012, Auracle began experimentation to identify and analyze features and combinations of variables that could be used as surface and subsurface 'training sites', from which signals data would be developed as search parameters for geohazards. By combining proprietary acquisition and processing algorithms, Auracle developed a robust automated tool for identifying and monitoring geohazards. This system works at, near and under the earth's surface to "see" through deep vegetation, ice, snow, water, and overburden. The MUD™ system was born.

Our positionally accurate fused radar technology uses subsequent satellite images collected over time to provide a reliable "state of change" analysis. This allows Auracle to alert and define existing and potential hazards for operators. The MUD™ system replaces point or grid-based surveys to precisely detect movement or deformation under the Earth's surface, resulting in actual not derived ground information.

KEY FEATURES

- Monitors surface and subsurface movement well in advance of events that threaten infrastructure
- Operates day and night, through all weather
- Measures as little as 2 mm of change in 3D
- Creates no human footprint and requires no permit

MUD™, the foundation of this monitoring technology "sees" structure to monitor geohazards through:

- 100 meters of water
- 100 meters of sand and tills
- dense valley vegetation
- 30 meters of glacial ice and deep glacial tills

Satellite Borne C Band Synthetic Aperture Radar Monitoring Types					
	Conventional Change Detection				**Auracle 3D MUD™**
	CCD	InSAR	DiffinSAR	PSinSAR	
Monitoring Frequency	>20 Days	>20 Days	>20 Days	>20 Days	**<40 Hours**
2.5mm Displacement Minima Detectable	x	✓	✓	✓	✓
Complete Area	x	x	x	x	✓
Eliminates Layover	x	x	x	x	✓
Eliminates Distortion	x	x	x	x	✓
Uniform Spatial Accuracy	x	x	x	x	✓
Models and Monitors on Surface	✓	✓	✓	✓	✓
Models and Monitors Under Land Surfaces	x	x	x	x	✓
Models and Monitors Under Water	x	x	x	x	✓

Table 1 – SAR Monitoring Types Comparison to MUD™

POINT CLOUDS AND SECTION VIEWS

Point clouds are produced, in cases of land use, from the stereo radar pair using Auracle's proprietary algorithm. The clouds are then fused and further analyzed in 3D for density using a search radius of 5 meters and are not vertically exaggerated. In addition, these 3D Point Clouds represent competent reflectors at and under the earth surface which can be analyzed for their variability and used to correct and aid 3D seismic and other geophysical inversions. Auracle's 3D Point Clouds represent the subsurface and like LiDAR can be viewed using common XYZ or LAZ format software.

The following figures illustrate the ability to identify the differentiation, showing the 4 variables previously discussed:

- Difference in densities
- Difference in textures
- Differences in resistivities
- Structural bounds

In addition, signals representing these variables form the signature of:

- Underlying Bedrock
- Various composition alluvial facies
- Saturated material

AURACLE GEOSPATIAL | USA CORP

CASE STUDY: BC WATER STUDY

The BC Water case provides evidence of how the 3D MUD™ system can locate, model and monitor subsurface water resources, in areas that are impossible to survey due to impediments such as buildings, roads, parking areas, infrastructure and other obstructions.

CASE STUDY: BC Water Study

In this case study, Auracle's 3D MUD™ system is applied in the search for near surface groundwater, in areas that are impossible to survey with ground penetrating radar or other forms of geophysical survey. In the study area, there are many impediments such as buildings, roads, parking lots, infrastructure and other constructs. In these and other areas the Auracle MUD™ system is recommended. The intent of this study is to demonstrate the verity of using the Auracle MUD 3D™ system which uses satellite data to locate water in complex, difficult or remote areas.

The test and training site contained 3 established artesian commercial water-well occurrences, located on Vancouver Island, British Columbia, Canada. These 3 water wells were drilled by James Fyfe BA Sc, P. Eng. of BC Water Ltd, who also provided drill logs that defined the locations and depths of overlying material (Appendix A).

Image 1: Shows a view of the surface obstructions within the study area.

Image 1. View of the study area looking east including steel buildings, roadway and industrial park

Image 2: Shows further surface obstructions such as a heliport, roadways, buildings and industrial yards.

Image 2. View of the study area looking west with heliport, buildings, roadway and industrial park

Image 3: This plan view optical image of the study area showing the vast amount of apparent surface obstructions.

Image 3. Optical Image of the study area

Image 4: The location of 3 water well surface locations on a 3D MUD™ radar map, with the wells shown in black.

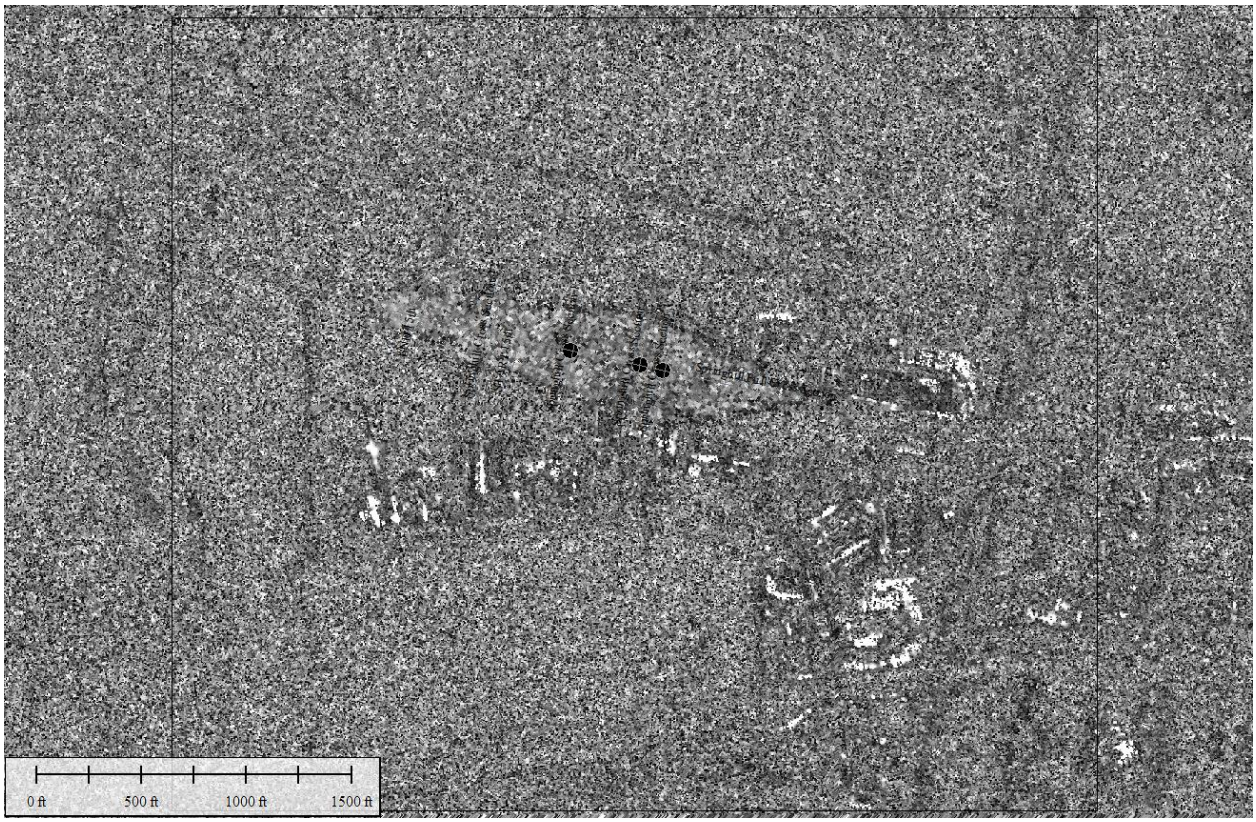

Image 4. 3 well locations shown in black

Image 5: In this image, the subsurface syncline which traps the water is clearly seen in the 3D MUD™ plan view image and is outlined for emphasis.

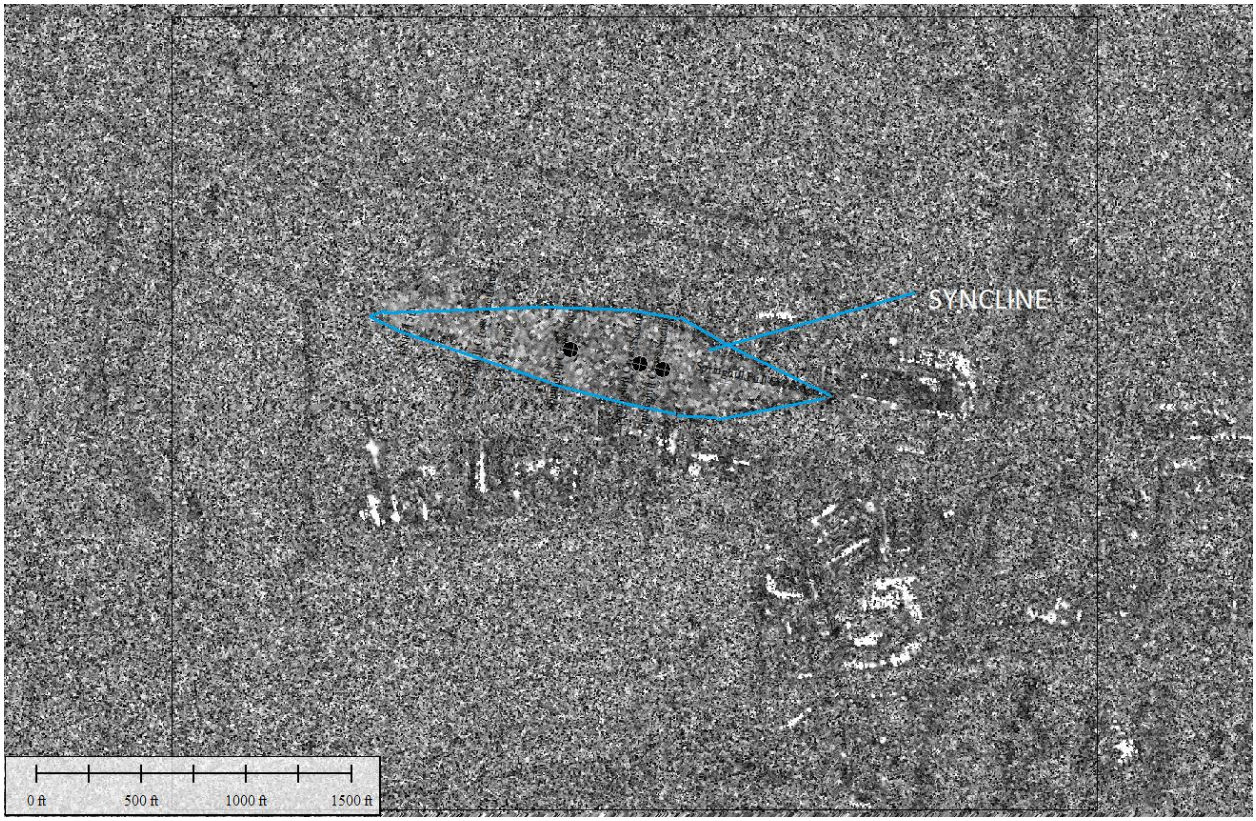

Image 5. Outline of syncline

Image 6: This is a long section from West to East of the points or reflectors under the surface showing density together with the intersection points from the drill log. The apparent curvature of the subsurface groundwater system is also seen in the image. The blue log points are where water is encountered between the blue dots.

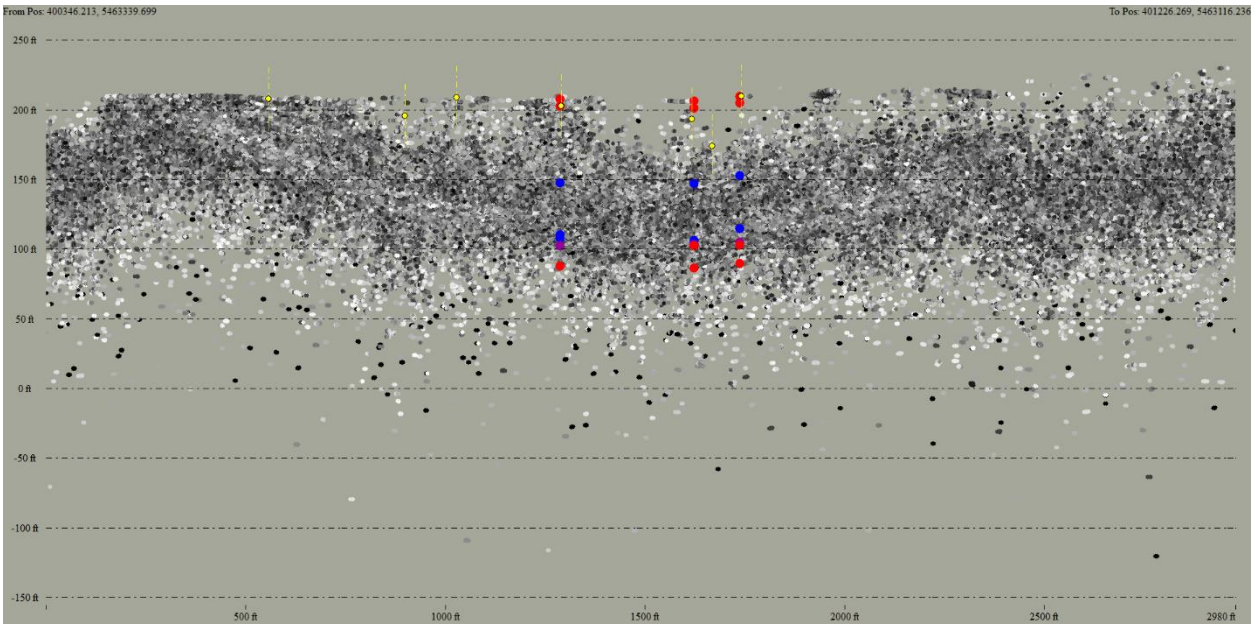

Image 6. Apparent curvature and intersecting drill points

Image 7: Showing the machine classification of the ground water barriers in blue.

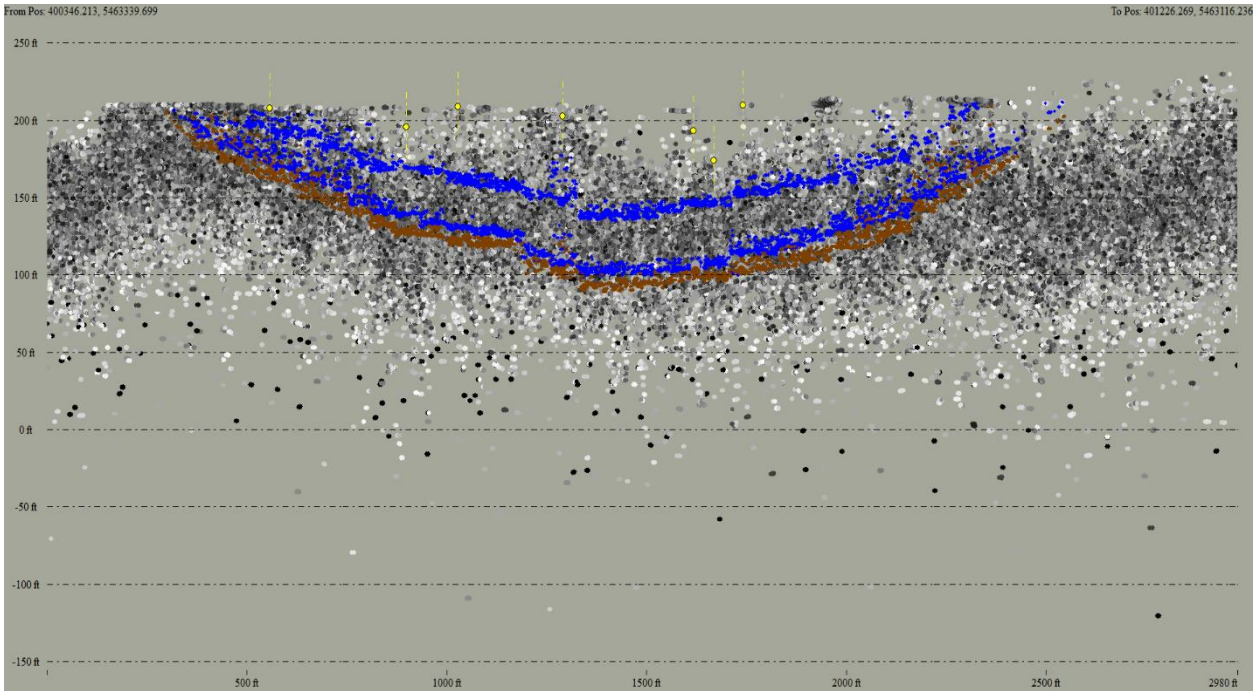

Image 7.

Image 8: Showing the delineation of the machine classifications and their alignment with the BC Water Drilling water intersections.

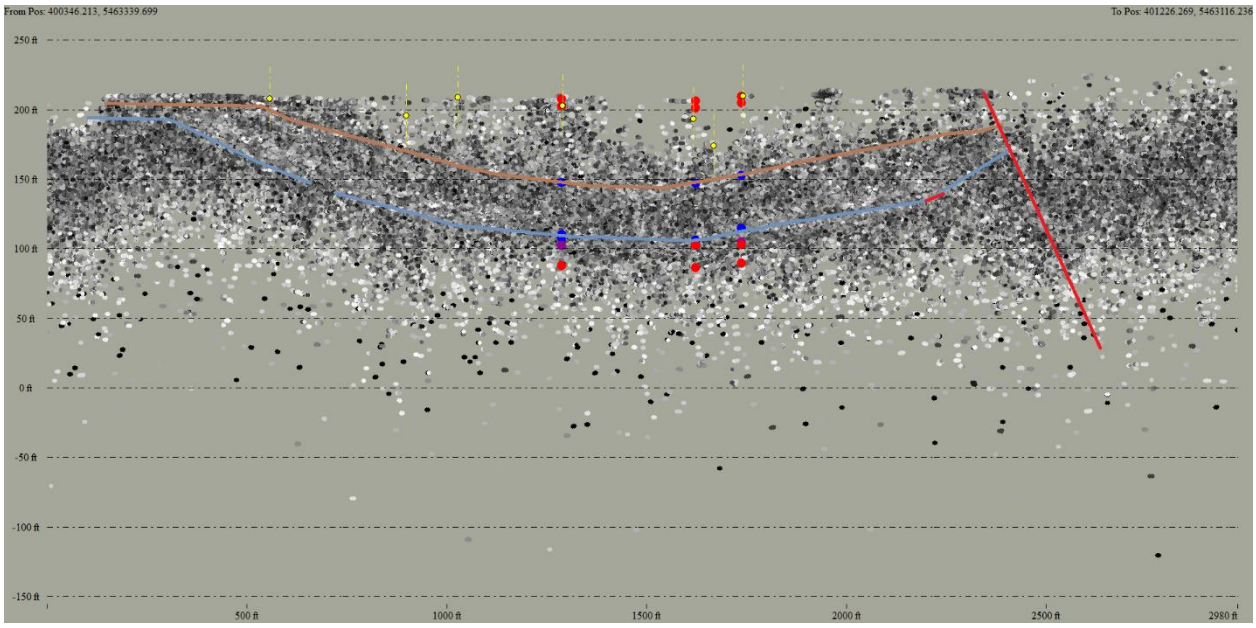

Image 8.

Image 9: Labels depicting the groundwater location between the boundary lines. This encapsulation is the pressure generator causing the artesian wells.

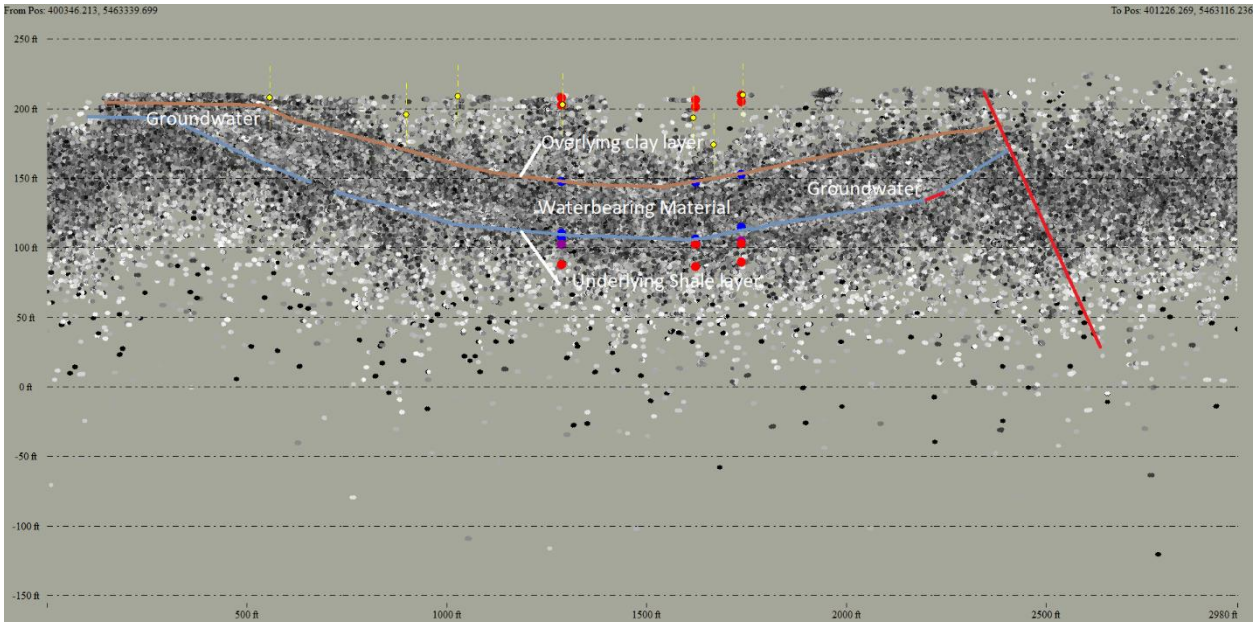

Image 9.

Image 10: Plan View of 3D MUD™ point cloud showing Section 2 Line Location.

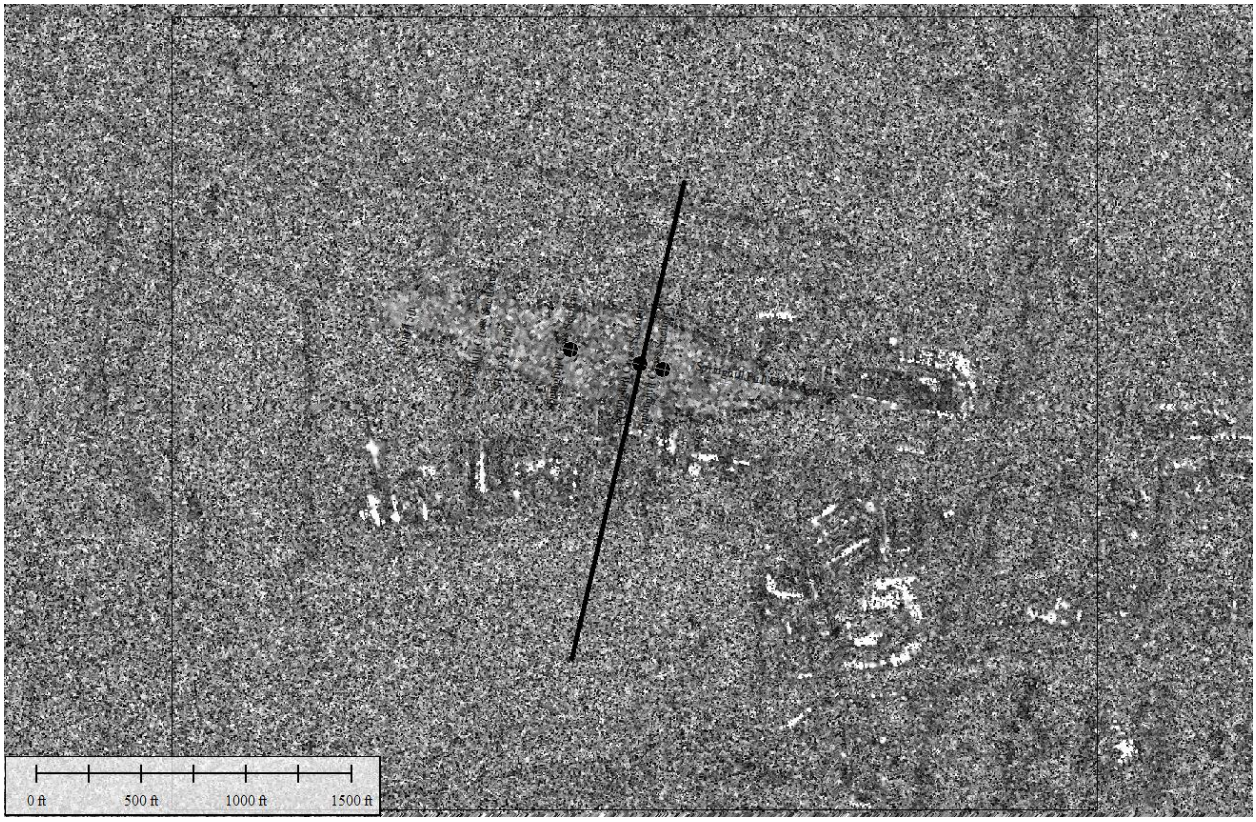

Image 10. Section 2 reference line

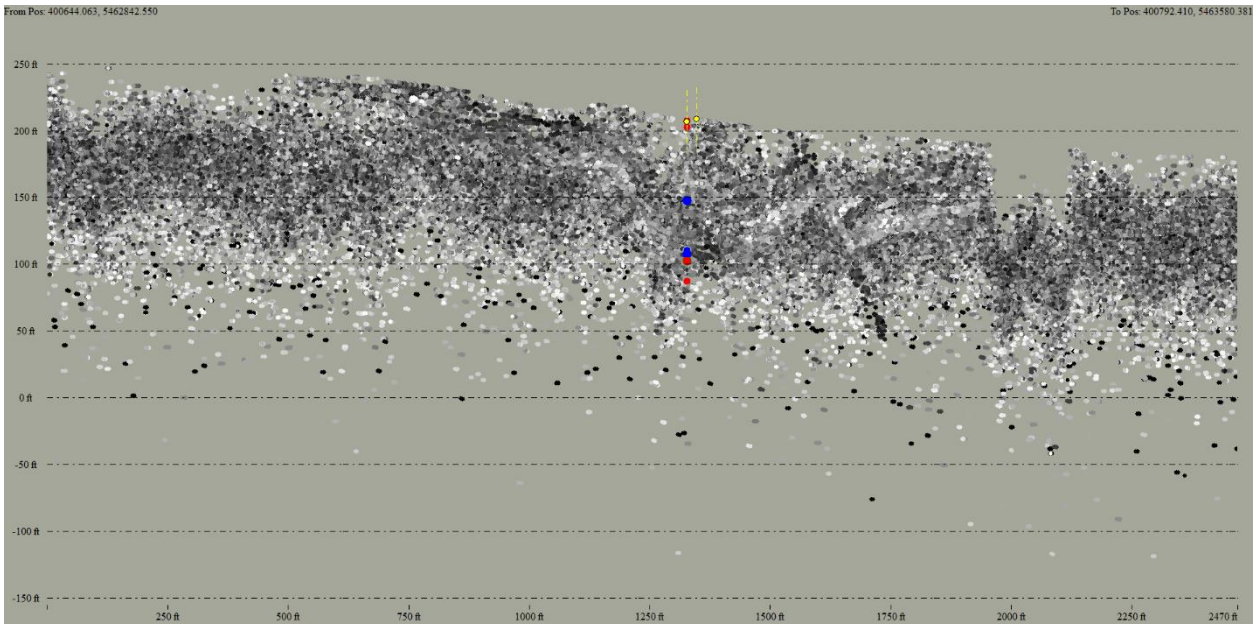

Image 10a. Section 2 Volume slice of point cloud with drill water intercepts as blue dots

Image 11: Differential Classification of the South to North Volume Slice or section showing underlying shale in gold, water in blue and overlying clay in brown. The blue dots of the water intercepts within the drill log align with water class.

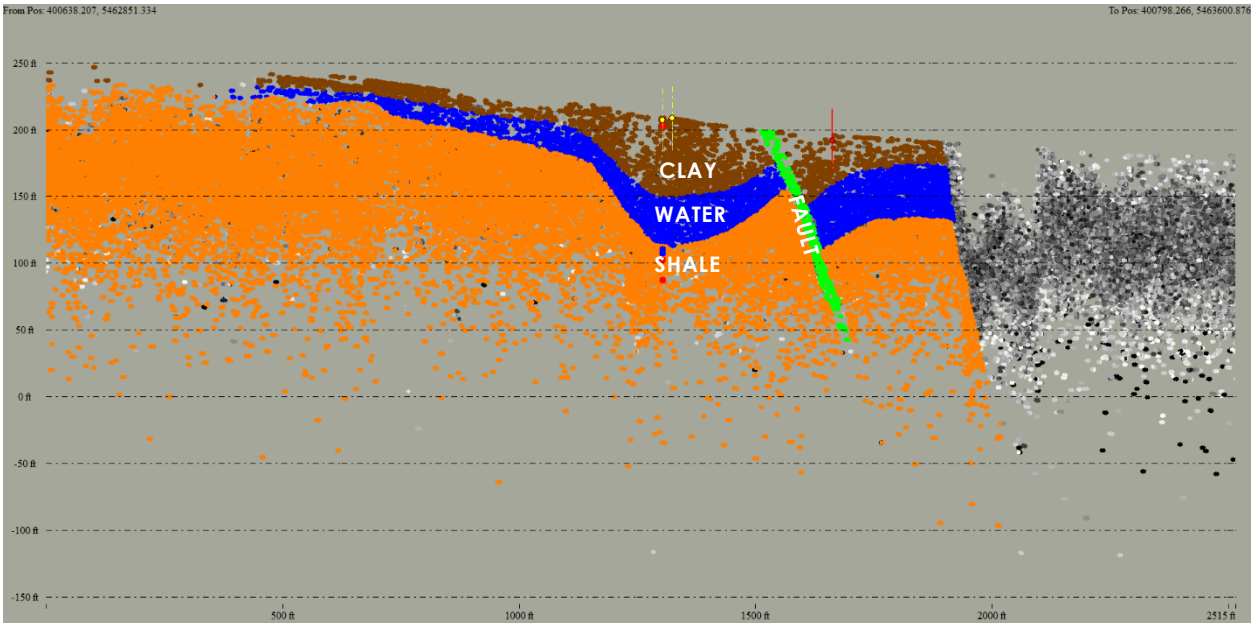

Image 11. South to North volume slice

CONCLUSION

In this case study, Auracle successfully applied its 3D MUD™ system to verify water well surface locations. Using known artesian wells, the MUD™ system with its machine classification component discretely and anonymously developed signal combinations that:

- indicate probable groundwater type occurrences in difficult to access areas of deep ground cover and water cover
- identify the capping material
- locate higher absorbing inner water bearing material
- define an impervious bottom material

This data forms a base model for potential 3D monitoring which can be used to determine changes to water levels at, on and under the ground. Our work can be conducted over large areas during summer or winter and creates no human footprint or other environmental impact and requires no permits to conduct. This ability reduces the cost and time to advance exploration and development.

There is also a video presentation available for this case study.

THIRD PARTY OBSERVATIONS
by Paul Metcalfe Ph.D. P.Geol. FGS

My training is predominantly in the fields of volcanology, igneous petrology and mineral exploration. I also have experience in the geology of the Nanaimo area and in remote sensing, particularly the interpretation of processed satellite-based synthetic aperture radar (SAR) data. In these capacities, I have visited the property itself, have observed the multiplicity and intensity of anthropogenic disturbance there and agree entirely with Auracle's assessment of the near-impossibility of conducting a comprehensive assessment of the study area using conventional surface-based geoscience.

For clarity, I participated neither in development nor application of the Mapped Underworld Dimension (MUD™) System, nor am I an interested party. Furthermore, I will receive neither direct nor indirect consideration from this review, excepting only remuneration for my time.

I have examined the well logs, point clouds in plan and section and the three-dimensional video which demonstrates the model generated by the MUD™ System. The processed SAR Images 4 and 5 clearly show a contrast in physical properties in the subsurface in the shape of an elongate trough, tapered at the ends. As indicated by all three drill logs, this is an area underlain by unconsolidated sediments immediately overlying shale bedrock. This last is assigned to the Cretaceous Nanaimo Group by regional mapping. The unconsolidated sediments, from the compact till layer downhole, are probably Pleistocene and their basal contact with the shale an unconformity. The syncline, as such, is therefore presented only in the shale and the trough occupied by the unconsolidated sediments was formed before the deposition, probably by preferential erosion along a bedding plane. Such troughs are common in the exposed Nanaimo Group, and I have observed them directly in excavations on my own property on Gabriola Island.

Both long and cross sections of the trough are vividly depicted by the processed SAR data. In particular, the three-dimensional geometry of the SAR-mapped body with distinct physical properties entirely agrees with the observed intersections of the water-saturated sand layer described in the drill logs. In addition, the planar, moderately dipping discontinuities noted in both longitudinal and cross sections of the aquifer are consistent with the orientation of major faults in the general area. I consider this a credible model for the exploration and monitoring of aquifers.

APPENDIX A

Fyfe WELL & WATER SERVICES

(Division of Fyfe Holdings Ltd.)
1541 Winchester Road, Qualicum Beach, B.C. V9K 1Y2
T: 250.752.4986 F: 250.752.4987

CUSTOMER/CLIENT:	VANDERVELDT INVESTMENTS LTD.		**Proposed Lot A - Well Tag: 23748**
CONTACT :	Keith Brown - Development Consultant	PHONE:	Office: 250.758.3307
MAILING ADDRESS:	C/O: Keith Brown Associates Ltd. - 5102 Somerset Drive, Nanaimo, BC V9T 2K6		
WELL LOCATION:	1390 SPRINGHILL ROAD, ERRINGTON, BC	GPS: N 49° 18.829' W 124° 21.954'	Elev: 225 Ft AMSL

PROPOSED USE:					
	Residential	X	Commercial		Community
X	Water Supply		GeoExchange		Monitoring

TYPE OF WORK:				
	Well Tag ID No.:	23748		
X	New Well	Method:	X	Air Rotary
	Deepened			Cable Tool
	Reconditioned/Altered		X	Dual Rotary

WELL DIMENSIONS:		
Diameter of Production Well:	6	Inches
Total Depth Drilled:	120	Feet
Depth of Completed Well:	100	Feet

CONSTRUCTION DETAILS:								
Well Casing:					X	Welded		
6	in	250	wall	0	ft. to	91	ft.
8	in	250	wall	0	ft. to	20	ft.
Drive Shoe:	x	Y		N	Size:		in.
Surface Seal:					X	Yes		in.
Material used in seal:				neat cement grout				
Well Liner:					Yes	X	No	
Type / Size					PVC	4.5	in.	

WELL SCREEN INFORMATION:							
6t	in. dia.	riser	slot frm.	89	ft. to	91	ft.
6t	in. dia.	25	slot from	91	ft. to	95	ft.
6t	in. dia.	25	slot frm.	96	ft. to	100	ft.
Total Well Screen Assembly Length:						11	ft.

WELL INFORMATION SUMMARY:					
Final Well Depth:			100	Ft/in	
Total Surface Seal Installed:			20	Ft/in	
Estimated Well Yield:			10+	US gpm	
Static Water Level:			artesian	Feet	
Well Development Information:					
Development method:	X	Air	Bail	X	Pump
Development time (hrs):		2			12
Water Quality Notes (eg: Taste, Odour, Colour, Sand, etc.)					
Water Quality Report: See engineering report					

STRATUM (FT)		MATERIAL DESCRIPTION	CASING (FT/IN)	
			section	*total*
		LITHOLOGY	**10-in Casing**	
		Unconsolidated:	0	20/01
0	5	- loose, brown silty sand & gravel	-20/01	0
5	60	- Till; very compact, grey, stoney	**8-in Surface Casing**	
60	105	Water Bearing:	0	20/01
		- loose, brown medium brown		
97	105	- fine grey silty sand, decrease	**6-in Prod. Casing**	
		in water output	0	19/05
		Consolidated:	20/01	39/06
		- Shale bedrock; medium, grey	19/01	58/07
	120	End of Drilling	20/00	78/07
		- install well screen at 100 ft	20/00	98/07
			20/01	118/08
			-15/08	103/00
			-11/09	91/03
Notes:		- Artesian (neat cement) surface		
		seal constructed between 12-in		
		borehole and 8-in steel casing		
		- Artesian pressure controlled and		
		stopped with welded flange and		
		discharge valve assembly.		
		Well Completion Summary		
		Total Depth Drilled	120	ft bgs
		Depth of Completed Well (BGS)	100	ft btoc
		2 - 25 slot stainless steel screens		
		Static Water Level (BGS)	artesian	
		Estimated Yield (USgpm)	10+	USgpm
		Casing stick up	2	ft ags

WELL CONSTRUCTION PERSONNEL:			
Driller:	Jim Fyfe	License Number:	WD 05101401
Crewman:	Evan Busby	Engineer/Tech:	I. Kawij, P.Eng.
Start Date:	Nov 20, 2016	Completion Date:	Nov 23, 2016
Driller's Signature:	Jim Fyfe		

Fyfe WELL & WATER SERVICES

(Division of Fyfe Holdings Ltd.)
1541 Winchester Road, Qualicum Beach, B.C. V9K 1Y2
T: 250.752.4986 F: 250.752.4987

CUSTOMER/CLIENT:	VANDERVELDT INVESTMENTS LTD.		**Proposed Lot B - Well Tag: 23746**
CONTACT :	Keith Brown - Development Consultant	PHONE:	Office: 250.758.3307
MAILING ADDRESS:	C/O: Keith Brown Associates Ltd. - 5102 Somerset Drive, Nanaimo, BC V9T 2K6		
WELL LOCATION:	1390 SPRINGHILL ROAD, ERRINGTON, BC	GPS: N 49° 18.818' W 124° 21.871'	Elev: 225 Ft AMSL

PROPOSED USE:					
	Residential	X	Commercial		Community
X	Water Supply		GeoExchange		Monitoring

TYPE OF WORK:				
	Well Tag ID No.:	23746		
X	New Well	Method:	X	Air Rotary
	Deepened			Cable Tool
	Reconditioned/Altered		X	Dual Rotary

WELL DIMENSIONS:		
Diameter of Production Well:	6	Inches
Total Depth Drilled:	120	Feet
Depth of Completed Well:	104	Feet

CONSTRUCTION DETAILS:							
Well Casing:				X	Welded		
6	in	250	wall	0	ft. to	99	ft.
8	in	250	wall	0	ft. to	20	ft.
Drive Shoe:	x	Y		N	Size:		in.
Surface Seal:				X	Yes		in.
Material used in seal:					neat cement grout		
Well Liner:					Yes	X	No
Type / Size					PVC	4.5	in.

WELL SCREEN INFORMATION:							
6t	in. dia.	30	slot frm.	100	ft. to	104	ft.
6t	in. dia.	Riser	slot from	98	ft. to	100	ft.
	in. dia.		slot frm.		ft. to		ft.
Total Well Screen Assembly Length:						6	ft.

WELL INFORMATION SUMMARY:				
Final Well Depth:			104	Ft/in
Total Surface Seal Installed:			20	Ft/in
Estimated Well Yield:			10+	US gpm
Static Water Level:			artesian	Feet
Well Development Information:				
Development method:	X	Air	Bail	X Pump
Development time (hrs):		2		12
Water Quality Notes (eg: Taste, Odour, Colour, Sand, etc.)				
Water Quality Report: See engineering report				

STRATUM (FT)		**MATERIAL DESCRIPTION**	**CASING** (FT/IN) *section*	*total*
		LITHOLOGY	**10-in Casing**	
		Unconsolidated:	0	20/01
0	5	- loose, brown silty sand & gravel	-20/01	0
5	59	- Till; very compact, grey, stoney	**8-in Surface Casing**	
59	103	Water Bearing:	0	20/01
		- loose, brown medium brown		
	100	- increase in gravel & course sand	**6-in Prod. Casing**	
	103	Consolidated:	0	20/01
		- Shale bedrock; medium, grey	20/00	40/01
	120	End of Drilling	19/00	60/01
		- install well screen at 104 ft	20/00	80/01
			20/00	100/01
			20/00	120/01
			-8/01	112/00
			-12/11	99/01
Notes:		- Artesian (neat cement) surface		
		seal constructed between 12-in		
		borehole and 8-in steel casing		
		- Artesian pressure controlled and		
		stopped with welded flange and		
		discharge valve assembly.		
		Well Completion Summary		
		Total Depth Drilled	120	ft bgs
		Depth of Completed Well (BGS)	104	ft btoc
		1 - 30 slot stainless steel screen		
		Static Water Level (BGS)	artesian	
		Estimated Yield (USgpm)	50+	USgpm
		Casing stick up	2	ft ags

WELL CONSTRUCTION PERSONNEL:			
Driller:	Jim Fyfe	License Number:	WD 05101401
Crewman:	Evan Busby	Engineer/Tech:	I. Kawij, P.Eng.
Start Date:	Nov 20, 2016	Completion Date:	Nov 24, 2016
Driller's Signature:	Jim Fyfe		

Fyfe WELL & WATER SERVICES

(Division of Fyfe Holdings Ltd.)
1541 Winchester Road, Qualicum Beach, B.C. V9K 1Y2
T: 250.752.4986 F: 250.752.4987

CUSTOMER/CLIENT: VANDERVELDT INVESTMENTS LTD. **Proposed Lot C - Well Tag: 23747**
CONTACT: Keith Brown - Development Consultant PHONE: Office: 250.758.3307
MAILING ADDRESS: C/O: Keith Brown Associates Ltd. - 5102 Somerset Drive, Nanaimo, BC V9T 2K6
WELL LOCATION: 1390 SPRINGHILL ROAD, ERRINGTON, BC GPS: N 49° 18.814' W 124° 21.843' Elev: 225 Ft AMSL

PROPOSED USE:					
	Residential	X	Commercial		Community
X	Water Supply		GeoExchange		Monitoring

TYPE OF WORK:			
	Well Tag ID No.:	23747	
X	New Well	Method:	X Air Rotary
	Deepened		Cable Tool
	Reconditioned/Altered		X Dual Rotary

WELL DIMENSIONS:		
Diameter of Production Well:	6	Inches
Total Depth Drilled:	120	Feet
Depth of Completed Well:	107	Feet

CONSTRUCTION DETAILS:							
Well Casing:				X	Welded		
6	in	250	wall	0	ft. to	102	ft.
8	in	250	wall	0	ft. to	20	ft.
Drive Shoe:	x	Y		N	Size:		in.
Surface Seal:				X	Yes		in.
Material used in seal:				neat cement grout			
Well Liner:					Yes	X	No
Type / Size					PVC	4.5	in.

WELL SCREEN INFORMATION:							
6t	in. dia.	100	slot frm.	103	ft. to	107	ft.
6t	in. dia.	Riser	slot from	101	ft. to	103	ft.
	in. dia.		slot frm.		ft. to		ft.
Total Well Screen Assembly Length:						6	ft.

WELL INFORMATION SUMMARY:			
Final Well Depth:		107	Ft/in
Total Surface Seal Installed:		20	Ft/in
Estimated Well Yield:		50+	US gpm
Static Water Level:		artesian	Feet
Well Development Information:			
Development method:	X Air	Bail	X Pump
Development time (hrs):	2		12
Water Quality Notes (eg: Taste, Odour, Colour, Sand, etc.)			
Water Quality Report: See engineering report			

STRATUM (FT)		MATERIAL DESCRIPTION	CASING (FT/IN) section	total
		LITHOLOGY	**10-in Casing**	
		Unconsolidated:	0	20/01
0	5	- loose, brown silty sand & gravel	-20/01	0
5	57	- Till; very compact, grey, stoney	**8-in Surface Casing**	
57	105	Water Bearing:	0	20/01
		- loose, brown medium brown		
95	105	- v. coarse grey sand & gravel	**6-in Prod. Casing**	
	105	Consolidated:	0	20/01
		- Shale bedrock; medium, grey	20/00	40/01
	120	End of Drilling	19/00	60/01
		- install well screen at 107 ft	20/00	80/01
			20/00	100/01
			12/11	113/00
			-3/06	109/06
			-6/11	102/05
Notes:		- Artesian (neat cement) surface		
		seal constructed between 12-in		
		borehole and 8-in steel casing		
		- Artesian pressure controlled and		
		stopped with welded flange and		
		discharge valve assembly.		
		Well Completion Summary		
		Total Depth Drilled	120	ft bgs
		Depth of Completed Well (BGS)	107	ft btoc
		1 - 100 slot stainless steel screen		
		Static Water Level (BGS)	artesian	
		Estimated Yield (USgpm)	50+	USgpm
		Casing stick up	2	ft ags

WELL CONSTRUCTION PERSONNEL:			
Driller:	Jim Fyfe	License Number:	WD 05101401
Crewman:	Evan Busby	Engineer/Tech:	I. Kawij, P.Eng.
Start Date:	Nov 15, 2016	Completion Date:	Nov 18, 2016
Driller's Signature:	Jim Fyfe		