CHARACTERIZATION OF BELLOY AND DEBOLT WATER DISPOSAL ZONES IN THE MONTNEY PLAY FAIRWAY, NEBC

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EXECUTIVE SUMMARY

This study addresses the hydrogeological and geomechanical favourability of wastewater injection into the Belloy and Debolt formations in Northeastern British Columbia. Initial work on reservoir characterization and geologic favourability mapping was performed by Petrel Robertson Consulting Ltd., and that work helped define the two focus areas for this analysis. The Belloy focus area is a Northwest-Southeast trending, irregularly shaped strip approximately 20 to 30 km wide centered on the Northeast portion of T.80, R.18W6. The Debolt focus area is also irregularly shaped, approximately 30 km in diameter and centered on E-94-A.

The study is divided into two main components – a hydrogeological analysis and a geomechanical analysis. In the hydrogeological analysis, detailed in section 2.0 of the report, formation pressures in the Belloy, Debolt and overlying Lower Montney formations as well as hydraulic head and formation water salinity in the Belloy and Debolt were determined through a rigorous data screening and quality control process. Due to limited data availability in the focus areas, the hydrogeological analysis was performed over broader study areas in order to reveal trends within the focus areas themselves. In the geomechanical analysis, detailed in section 3.0 of the report, in situ stresses and rock properties were determined using a wide range of data types and applied to the assessment of risk due to injection-induced slip on preexisting fractures or faults. Like in the hydrogeological analysis, regional data were frequently used in the geomechanical analysis when data were limited inside the focus areas.

The results of the hydrogeological analysis indicates that the Belloy and Debolt are hydrodynamically distinct from the Lower Montney in the focus areas. Pressure difference mapping across the contact with the Lower Montney indicates that the pressure difference across the Montney/Belloy boundary ranges from 28 MPa in the southwest to near zero in the northwest. Similarly the pressure difference across the Montney/Debolt boundary ranges from 78 MPa in the foothills region to approximately 4 MPa in the northeast. Hydraulic head in the Belloy ranges from 675m to 775m, consistent with a relatively high permeability aquifer, and shows gradual variation except in a few regions disrupted by faulting. Hydraulic head in the Debolt is more compartmentalized than in the Belloy due to the higher prevalence of faults. Debolt head values range from under 500m to just under 1,200m. Faulting in both areas also has a significant effect on salinity trends, although salinity data were particularly sparse in the Belloy focus area, limiting the ability to make a regional interpretation.

The geomechanical analysis found that in both focus areas, the minimum and maximum principal stresses are both horizontal, and the vertical stress is the intermediate principal stress. The ratio of horizontal stresses ranges from approximately 1.5 to 2. Maximum horizontal stress is generally oriented Northeast-Southwest and is slightly more rotated to the east in the Debolt area than in the Belloy. To the extent possible, fracture populations were measured in image logs throughout the two study areas. Fractures in the Montney tend to strike more to the East-West than in the underlying target formations, especially in the Belloy study area. Fractures also seem less abundant in the Montney. The evaluation of geomechanical risk revealed that, in general, lower pressure increases are required to cause fractures in the Debolt Formation to become critically-stressed than in the Belloy. From a critically-stressed fracture/fault perspective, the southeastern part of the Belloy study area and the southwestern part of the Debolt study area are the most favourable for injection, however it should be noted that there are several mapped faults at the southwestern edge of the Debolt area.

The results of this study are significantly limited by both data availability and the limited evaluation of geomechanical risk. This study should be considered useful for a regional perspective on potential fluid injection sites, but specific injection programs should not be planned without site-specific data gathering and geomechanical modeling, as discussed in section 4.3 of the report.

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1.0 INTRODUCTION

The activity level of horizontal drilling and hydraulic fracturing (fraccing) in the Montney Unconventional Play Fairway (MUPF) in northeastern British Columbia has steadily increased over the last decade. This increased activity has caused a significant increase of the volume of water required for the makeup of frac fluid, and, concomitantly, the disposal of the recovered frac fluid. Identification of locations for the disposal of the waste frac fluids is a key challenge faced by the industry. The responsible and safe disposal of frac fluids has been identified as a component of this process. The possibility of induced seismicity has been identified as a key component of the disposal of these fluids and ensuring the industry maintains its social licence to operate.

This project focuses on the hydrodynamic and geomechanical setting of various identified potential water disposal sites, and investigates the potential long-term sustainability of saline water injection. This investigation integrates hydrogeologic, aquifer/reservoir characterization and geomechanical findings and deals with concerns stemming from aquifer capacity and viability, injectivity and transmissibility, long-term viability of disposal sites, disposal fluid containment and migration, and potential geohazards resulting from disposal operations, including formation stability and induced seismicity.

The MUPF covers approximately 26,000 km^2 and trends southeast to northwest, from the Plains area in the Peace River region, northwestward into the northern Foothills. Table 1.1 lists Montney producing fields active in the southern and northern play areas.

Presently, over 1,400 producing Montney horizontal gas wells produce approximately two billion cubic feet (bcf) of gas daily from the MUPF. The installation of several multi-bcf/day gas pipelines and associated gas processing plants is anticipated over the next few years. These facilities will require the drilling, completion and tie-in of sufficient Montney gas wells to meet and sustain the operational capacity of these plants. To achieve this growth in gas production, many more Montney gas wells will need to be drilled and fracced, compounding the challenges already facing industry regarding issues surrounding safe, reliable, sustainable and responsible frac water disposal.

A sense of the challenge faced by the industry and regulators may be derived by considering the following information derived from the Canadian Discovery Ltd. (CDL) proprietary Well Completions & Frac Database (WCFD) in February 2014. Industry trends show an increase in the use of water as the base fluid for fraccing year-over-year in the Montney play. In 2010, water was used as the base fluid on 82% of Montney completions, and rose to 95% in 2013. Likewise, total water pumped during a frac has increased from 6,600 m^3 in 2010 to over 9,600 m^3 in 2013. The number of frac stages and the volume of water pumped per stage are also trending upward. The average number of stages per frac grew from 9.6 in 2010 to 13.5 in 2013, and the average water volume pumped per stage increased by 125 m^3 from 750 m^3 in 2010 to 875 m^3 in 2013.

1.1 Potential Water Disposal Zones

Key operational and economic considerations are applicable in selecting potential water disposal sites. These parameters include:

- compatibility between the fluid to be injected and the waters in the formation receiving the fluids
- the injector formation does not contain commercial hydrocarbon saturations and the injection location
- a reasonable expectation that the formation contains sufficient reservoir height, average effective porosity, permeability and appropriate reservoir to allow for the necessary injection volumes.

A regional understanding of these parameters indicates that the Permian Belloy Formation (in the South Play Area) and the Mississippian Debolt Formation (North Play Area) represent the best candidates to focus the reservoir characterization efforts. The Mississippian Kiskatinaw Formation was also considered, but was excluded from further analysis, notwithstanding the promising favourability, due to the known tendency of the reservoir to be significantly compartmentalized and, therefore, poorly-suited for injection.

1.2 Reservoir Characterization of Belloy and Debolt

The reservoir characterization portion of this study was performed by Petrel Robertson Consulting Ltd. (PRCL) and was provided as an input to this study as *Characterization of Belloy and Debolt Water Disposal Zones in the Montney Play Fairway, NEBC* (PRCL, 2014). The geological inputs (e.g. Structure, Isopach, Depth and Injection Favourability Maps and tops data) used in this study were derived from this report. Additional stratigraphic tops or structural features were incorporated where necessary to increase the resolution of the hydrodynamic and geomechanical interpretation. This study has been included with this report as Appendix A for reference purposes.

The results of the PRCL study indicate that there are two key areas to be studied within this report. These are the:

- Belloy Area (T.75-83, R.13-83W6)
- Debolt Area (T.87,R.19W6 to 094-G-01/H)

Within each of these areas, focus areas were selected for detailed analysis after discussion with area stakeholders. The two areas are illustrated in Figures 1.1 and 1.2 respectively.

2.0 HYDRODYNAMICS

2.1 Methodology

A similar workflow was applied to determine the hydrodynamic setting of each of the study areas. This procedure may be summarized as:

- Search IHS Hub™ for all DST and AOF pressures for the subject formation within the Study Area
- The results of the initial pressure data search are displayed in a geographic sense through a DST AOF Recovery (All Data) Map and in a Pressure vs. Elevation Graph (All Data) to identify regional trends in the data and where potential outliers occur.

- Perform various Quality Control (QC) procedures to define a high quality data set. This measures include:

  - Drillstem Tests (DSTs) were coded according to the system codified by the Canadian Institute for Formation Evaluation (CIFE). A summary of this process is outlined in Figures 2.1 and 2.2. Only A through D quality tests are deemed suitable for hydrodynamic analysis. Tests coded E through G are possibly of use for determining fluid recovery.
  - Completion (AOF) test data is evaluated to determine the highest pressure at mid-point of perforations and individually evaluated to determine test quality
  - All pressure data is subjected to a CDL proprietary analysis to determine tests affected by production induced drawdown (PID). A summary of this process is outlined in Figure 2.3

- The high graded pressure dataset is re-displayed in a DST AOF Recovery (All Data) Map and a Pressure vs. Elevation Graph (All Data). Water and related hydrocarbon gradient and system trends to identify regional trends in the data and where potential outliers occur.
- A further QC pass is taken through the data to identify points with erroneous recovery, pressure or elevation data
- The final dataset is used to construct Pore Pressure vs Depth Gradient (∇P_p) and Hydraulic Head Maps.
- The IHS Geofluids™ database was searched for formation water recoveries. The results of this search were reviewed for accuracy and reviewed confirm the likely presence of formation water. The resulting data was plotted on a map and contoured to reflect the distribution of formation water salinity in the area.
- For each component of the analysis, pre-existing studies performed by CDL or its predecessor company, Rakhit Petroleum Consulting Ltd. (RPCL) were accessed to maximize the breadth of the interpretation. This studies included:

  - Permocarboniferous Hydrogeology Blueberry, Stoddart & Eagle BC (RPCL-BCPC)
  - Hydrogeologic Atlas, Western Canada Sedimentary Basin (RPCL-HGAT)
  - Montney Regional Hydrogeology Study Phase II (CDL-MRHS-II)

- As a method to illustrate the extent of the pressure difference between the High Pressure Deep Basin (HPDB) setting in the Lower Montney and the underlying Belloy and Debolt aquifers, Maps of the Theoretical Pressure at the Base of the Lower Montney were constructed for each of the Belloy and Debolt Areas. To create these maps, the map grids for the True Vertical Depth (TVD) to the Belloy or Debolt were convolved with the map grids for the ∇P_p grid corresponding to the sub-area. The Lower Montney Theoretical Pressure was calculated in a similar fashion utilizing the Lower Montney ∇P_p grid from the MRHS-II. The pressure grid for the underlying formation was subtracted from the pressure grid for the Lower Montney to determine the pressure difference grids for the respective intervals. It is expected that the higher the pressure difference the higher the flow potential across this boundary should the boundary be breached.

2.2 Belloy Area Interpretation

2.2.1 Data Summary

The pressure search identified the following dataset for Belloy pressure tests:

- Belloy Area (BA):
  - All Data: 362 Tests
  - Screened Pressure Data: 99 Tests
- Belloy Focus Area (BFA):
  - All Data: 64 Tests
  - Screened Pressure Data: 13 Tests

These numbers emphasize the relative paucity of pressure data over the BFA and the need to extrapolate the trends identified in the larger study area and preexisting studies. The pressure test data, illustrated by Enclosure 2.1, are located mainly on the northern edge of the Belloy Area (BA), along the fringe of the BFA. This data concentration is most likely due to an operator focus on structural fault-bounded targets along the northern rim of the Dawson Creek Graben Complex (DCGC). A significant number of the tests recovered water, indicating the presence of a Belloy aquifer in this region. The hydrocarbon recoveries were dominated by gas with only rare oil recoveries in the eastern portion of the area.

When the initial dataset is displayed on a Pressure vs. Elevation Graph (PE) (Enclosure 2.2), the presence of several elements can be discerned. These elements include the presence of a water gradient with several short associated gas gradients. To the far right of the PE graph, a subset of high pressure test values hints at the possible presence of significant overpressuring. Given that the Belloy is expected to reside within an aquifer setting, these high pressure tests required additional testing to confirm their accuracy.

A series of pressure test points are lazily spread along the left side of the PE graph. These points are likely to represent poorly-developed pressure buildups, poor quality tests or wells affected by PID.

By applying the methodology discussed earlier, it was possible to display the high-graded dataset as a finalized Belloy DST AOF Recovery Map (Enclosure 2.3) and Belloy PE graph (Enclosure 2.4). The chief result of this process was the removal of the lower pressures recorded from development wells affected by PID and/or poorly built up tests. The anomalously high pressures were inspected to confirm the stratigraphic assignment. This exercise confirmed that these high pressures are actually associated with Lower Montney pressures. As a result, the pressure data distribution is further constrained to the northern portion of the BA.

2.2.2 Pressure vs. Elevation Graph

On inspection of the high-graded PE graph (Enclosure 2.4), the water gradient is well-established to an elevation of greater than -1,650m subsea. Most of the gas test data lies along gradients closely associated with the water gradient. Data points 359, 11622 and 11848 are posted above their actual elevation to restrict the range of the PE graph and maintain legibility. If these points are migrated down to their true elevations, they reside along the water gradient reinforcing the existence of an extensive water gradient and aquifer in the BA.

Some pressure data points exist in positions significantly distal from the water gradient (WG) and likely represent sections structurally-removed from the regional setting.

2.2.3 Belloy Head Map

The Belloy Head Map (Enclosure 2.5) displays broadly-spaced, smooth contours ranging from 675m to 775m of Hydraulic Head consistent with a relatively high permeability aquifer except in regions disrupted by faulting. This interpretation is buttressed by incorporating the findings in the HGAT study.

2.2.4 Belloy Pressure Depth Gradient Map

Contours on the Belloy Pressure Depth Gradient Map (Enclosure 2.6) range from 9.2 to 10.6 kPa/m which, similarly to the Belloy Head Map, are consistent with an aquifer discretely altered by faulting.

2.2.5 Belloy Salinity Map

Screened salinity data exist primarily in the northeastern portion of the BA with only one formation recovery point in the BFA (Enclosure 2.7). The data range from approximately 100,000 to over 165,000 mg/L TDS. The variations across the BA are primarily attributed to compartmentalization due to faulting interfering in the migration of the primary formation fluid.

The black dashed line extending from the northwestern corner of the map to the southeastern corner outlines a region from which no formation water was recovered as defined in HGAT. This paucity of fluid recovery refers solely to the lack of recovery, not to any indication of pervasive hydrocarbon saturations, notwithstanding the usual correspondence between the lack of formation water recovery and pervasive hydrocarbon saturations.

2.2.6 Lower Montney Pressure Depth Gradient Map

Enclosure 2.8 outlines an extract of this map from MRHS-II. Although there are only two pressure points within the BA, this map includes observations from across the entire range of the Montney Formation, and is assumed to provide an adequate representation of the Lower Montney pressure regime over the BA.

2.2.7 Theoretical Pressures at Belloy Top Mapping

The Belloy True Vertical Depth (TVD) Map (Enclosure 2.9) indicates a generally smooth transition from 1,800m to over 3,600m except for regions affected by faulting, in particular along the edge of the DCGC. As outlined in the Methodology section, the Belloy TVD Map is used in the derivation of the following maps:

- Theoretical Lower Montney Pressure at Belloy Top (Enclosure 2.10)
- Theoretical Belloy Pressure at Belloy Top (Enclosure 2.11)

The resulting Theoretical Pressure Difference across Montney/Belloy Contact Map (Enclosure 2.12) indicates that the pressure difference across the Montney/Belloy boundary ranges from 28 MPa in the southwestern portion of the BA to a pressure difference in the northwestern portion of the BA approaching 0.

2.3 Debolt Area Interpretation

2.3.1 Data Summary

Tests search identified the following dataset for Debolt pressure tests:

- The Debolt Study Area (DA):
  - All Data: 362 Tests
  - Screened Pressure Data: 99 Tests
- Debolt Focus Area (DFA):
  - All Data: 64 Tests
  - Screened Pressure Data: 13

Unlike the BA, the pressure test data, illustrated by Enclosure 2.13 (Debolt DST AOF Recovery Map [All Data]), are fairly well distributed across the DFA in particular and across the DA in general, with the exception of the area north of the DFA. The majority of the pressure data was captured along the western side of the DA from structural culminations created from Laramide thrust fault traps. Tests east of the deformation front tended to produce water and mud recoveries with relatively minor gas recoveries. Previous studies, such as BCPC, indicate the presence of normal faults with possible sealing potential that resulted in minor structural traps.

Similarly to the case in the BA, the initial Debolt PE (Enclosure 2.14) provides the general outline of the main hydrodynamic trends with overprint of incomplete buildups and PID effects on several tests. Extremely high pressures on the right side of the plot are associated with relatively high flow rates, and they bear further investigation in light of the regional expectation that the Debolt does not represent a high pressure deep basin.

The dataset after the application of the QC process clarifies the distribution of pressure systems within the DA as illustrated by the Debolt DST AOF Recovery Map (Enclosure 2.15) and Debolt PE plot (Enclosure 2.16).

2.3.2 Pressure vs. Elevation Graph

The Debolt Hydraulic Gradient (DHG) describes the hydrodynamic setting within the structurally regional Debolt, which also appears to provide a reference system for the Blueberry oil and gas gradients. Water gradients that deviate from the DHG are related to thrust structures, and include the Blueberry West Hydraulic System trend, which is slightly underpressured relative to the DHG, and a Potential High Pressure Debolt Water Gradient associated with the Highway Gas Gradients.

Enclosure 2.15 outlines Debolt gas accumulations within the regional hydrodynamic portion of the DFA. The pressure data allowed the identification of fluid contacts in the Fireweed accumulations. The data associated with the Umbach and Prespatou Pools are insufficient for conclusions regarding fluid contacts.

2.3.3 Debolt Head Map

The Debolt Head Map (Enclosure 2.17) is more highly discrete and disrupted than the Belloy Head Map due to the higher prevalence of faults, which separate the Debolt hydrodynamic systems. As a result of this compartmentalization, the Debolt Head values range from under 500m to just under 1,200m. This range is particularly evident within the thrust-faulted trends.

The lack of Debolt pressure tests in the northern third of the DA limits the confidence in the interpretation of the data. This data deficiency is compensated by the incorporation of interpretations from regional studies.

2.3.4 Debolt Pressure Depth Gradient Map

The variations in the Debolt Pressure Depth Gradient Map (Enclosure 2.18), from 8.2 to 10.6 kPa/m, are primarily the result of the highly-structured nature of the Debolt in this region.

2.3.5 Debolt Salinity Map

Screened salinity data rapidly change from 54,000 to 136,000 mg/L TDS (Enclosure 2.19). These variations are likely due to the structural segregation of the Debolt. Based on the HGAT study, contours ranging from 80,000 to over 120,000 mg/L TDS were applied to illustrate the regional composition of the formation waters.

2.3.6 Theoretical Pressures at Debolt Top Mapping

The Debolt True Vertical Depth (TVD) Map (Enclosure 2.20) describes a range from 1,500m to over 2,200m with generally smooth, evenly-spaced contours except for segments affected by faulting. As outlined in the Methodology section, the Debolt Area TVD Map (Enclosure 2.21) is used in conjunction with the Lower Montney Pressure Depth Gradient Map (Enclosure 2.20) and the Debolt Pressure Depth Gradient Map (Enclosure 2.18) in the derivation of the following maps:

- Theoretical Lower Montney Pressure at Debolt Top (Enclosure 2.22)

- Theoretical Debolt Pressure at Debolt Top (Enclosure 2.23)

The resulting Theoretical Pressure Difference across Montney/Debolt Contact Map (Enclosure 2.24) indicates that the pressure difference across the Montney/Debolt boundary ranges from 78 MPa in the foothills region of the DA to approximately 4 MPa in the northeastern portion of the DA.

3.0 GEOMECHANICS

For any application involving fluid injection into the earth, pressure changes resulting from the injection as well as temperature differentials between the fluid and formation both introduce a risk of compromising the hydraulic integrity of the storage unit by initiating slip on preexisting fractures or faults and/or creating new fractures/faults. Either mechanism can result in seismic events potentially felt at surface or the creation of permeable pathways that could allow the injected fluid to migrate into overlying or underlying units. In addition, injection may cause surface deformation (heave) or damage to nearby wells. A good geomechanical understanding of the area being considered for injection is critical for understanding the magnitude of these risks, and how to mitigate them.

The main objective of the geomechanical portion of this study was to determine the geomechanical setting of the two key study areas, shown in Figures 1.1 and 1.2, and to perform a limited assessment of geomechanical risks should injection take place in these areas in the Belloy and Debolt formations, respectively. A key goal of the analysis was to, as far as the data allowed, determine if certain locations within the study areas are less risky, and are thus more favourable for injection from a geomechanical standpoint, than others.

This section of the report describes the data and workflow used in the geomechanical analysis of both of the Belloy and Debolt study areas including a review of data availability (Section 3.1), characterization of rock properties (Section 3.2), review of drilling experience (Section 3.3), quantification of vertical and minimum principle stress magnitudes and determination of horizontal stress orientations (section 3.4), modeling to determine maximum horizontal stress (Section 3.5) and, finally, characterization of natural fractures and examination of the risk of injection-induced slip on fractures or faults (Section 3.6).

3.1 Data Availability

Because maximum horizontal stress cannot be measured directly or calculated from data such as logs or seismic, it must be modeled based on wellbore failure that is either observed directly using image logs or caliper or inferred from drilling experience (Zoback, 2010). Therefore, much of the work in a geomechanical analysis is in determining the input parameters for the modeling, including, but not limited to, vertical stress, minimum horizontal stress magnitude and azimuth, pore pressure and rock properties. This task requires the analysis of many types of data coming from a variety of sources including public databases, proprietary databases, clients and published literature. The main sources of the data used in this study included:

- From public databases:
  - Lab measurements of mechanical rock properties
  - Well logs including density, caliper, sonic (including cross-dipole and array sonic) and borehole image logs
  - Daily drilling reports
  - Pressure tests
- From CDL's Well Completions & Frac Database:
  - Minifrac/DFIT tests and hydraulic fracture stage instantaneous shut-in pressures (ISIPs)

Data from two project stakeholders for two wells, Secure Inga 200/C-088-J/094-A-12/00 and CNRL HZ Septimus 100/02-08-082-19W6/00, were also used, and included a daily drilling report and an image log.

Enclosures 3.1 and 3.2 show the availability of geomechanical data across the Belloy and Debolt study areas, respectively. Detailed tables summarizing the data availability in each area are provided in Appendix B. As evident from the maps, data coverage is generally less in the Debolt study area than in the Belloy study area. In both areas, much of the data (e.g., data for minimum stress and rock property measurements) was actually acquired in the Montney and Doig formations, because these are the formations that have seen the most development activity. As discussed in detail in later sections, the lack of data in the Belloy and Debolt leads to some uncertainty in the geomechanical parameters in these formations.

3.2 Rock Mechanical Properties

The two main sources of data for characterization of mechanical rock properties are lab measurements on core samples and wireline logs.

3.2.1 Lab Measurements

Lab measurements of rock properties were available from three wells in the Belloy study area. Measurements were made of samples from the Montney and Doig formations (Enclosure 3.1). A database developed for these data can be found in Appendix C. Unfortunately, no lab-based data were found in the Debolt study area.

The available data included measurements of static and dynamic Poisson's ratio and Young's modulus, unconfined compressive strength (UCS), cohesion and friction angle. Figure 3.1 shows the distribution of static and dynamic Young's modulus and Poisson's ratio. Static values were measured using triaxial tests, and dynamic values were measured using ultrasonic testing. Figure 3.2 shows dynamic versus static values for samples from the only well (100/15-34-080-18W6/00) with both types of data in the Montney Formation. No clear relationship between the static and dynamic values is evident in the plots. Such a relationship, if one can be found, can be useful in converting log-based dynamic elastic properties to static values that are then used as input for modeling.

Figure 3.3 shows the distribution of unconfined compressional strength (UCS), cohesion and friction angle from the lab measurements. Figures 3.3a and 3.3b show wide variations in UCS and cohesion in the Doig and Montney formations. Both UCS and cohesion have a wide range of values, which reflects the inherent heterogeneity of these formations.

3.2.2 Wireline Logs

It is common practice to calculate rock properties from wireline logs (e.g., sonic, density, gamma and porosity logs). Log data are more common and easier to find in the public domain than are lab tests on core.

Elastic Properties

Dynamic Poisson's ratio (ν_d) and Young's modulus (E_d) can be calculated from compressional and shear sonic transit times (Δt_c and Δt_s, respectively) and bulk density (ρ_b) using the following equations:

$$\nu_d = \frac{0.5\left(\Delta t_s / \Delta t_c\right)^2 - 1}{\left(\Delta t_s / \Delta t_c\right)^2 - 1} \tag{1}$$

$$E_d = 4\frac{\rho_b}{\Delta t_s^{\,2}} \frac{0.75\left(\Delta t_s / \Delta t_c\right)^2 - 1}{\left(\Delta t_s / \Delta t_c\right)^2 - 1} \tag{2}$$

All the other dynamic elastic properties such as shear modulus, bulk modulus, impedances, plane-strain Young's modulus and brittleness index can then be calculated using these two values. It is important to note that these dynamic values need to be converted to static equivalents for geomechanical applications such as reservoir containment assessment or wellbore stability modeling.

For this study, elastic properties were calculated for 75 wells in the Belloy study area and 55 wells in the Debolt study area (see Enclosures 3.1 and 3.2), although not all of the logs penetrate the Belloy or Debolt formations. Calculations were made for the entire stratigraphic profile from the ground surface to the underburden. All the density and sonic logs used in this study were quality screened prior to the calculations. An example of logs and calculated elastic properties for well 100/16-25-081-19W6/00 in the Belloy study area is shown in Figure 3.4.

Figures 3.5 and 3.6 show stratigraphic variation of both Poisson's ratio and Young's modulus for the Belloy and Debolt study areas, respectively. Both the Belloy and the Debolt have significantly higher elastic properties than the overlying Montney Formation. This difference could have considerable significance in any future reservoir modeling to help understand deformation in and around the injection zones.

Enclosures 3.3, 3.4, 3.5 and 3.6 show the spatial variation of mean calculated Poisson's ratio and Young's modulus and for the Montney/Doig and Belloy formations in the Belloy study area. Likewise, Enclosures 3.7, 3.8, 3.9 and 3.10 show the distribution of the same parameters for the Montney/Doig and Debolt formations in the Debolt study area. While the data points are too sparse to create contoured maps of these properties, the points themselves indicate significant rock property heterogeneity across the two study areas.

Anisotropy

Rock property anisotropy may be caused by a number of factors including depositional processes, rock fabric or natural fractures. If significant, anisotropy can play an important role in mechanical behaviour of rock in response to injection or production.

Logs such as dipole sonic logs or Schlumberger Sonic Scanner logs can be used to investigate rock property anisotropy in directions perpendicular to the wellbore axis. In total, 17 wells in the Belloy study area and five wells in the Debolt study area were found to have logs suitable for the investigation of anisotropy. An example Sonic Scanner log for well 100/08-22-082-20W6/00 in the Belloy study area is shown in Figure 3.7. In this example, zones with relatively high anisotropy, e.g. in the Doig formation, tend to also have lower Poisson's ratio and higher Young's modulus than surrounding zones.

Because of the variety of logging tools and measurement techniques in the data set, the following equation was used to quantify anisotropy in cases where transit time was measured in X and Y directions (Δt_{SX} and Δt_{SY}, respectively):

$$ANI_{XY} = \frac{2*|\Delta t_{SX} - \Delta t_{SY}|}{(\Delta t_{SX} + \Delta t_{SY})} \qquad (3)$$

In cases where fast and slow transit times (Δt_{SS} and Δt_{SF}, respectively) were available, the following equation was used to quantify anisotropy:

$$ANI_{SF} = \frac{2*|\Delta t_{SS} - \Delta t_{SF}|}{(\Delta t_{SS} + \Delta t_{SF})} \tag{4}$$

The stratigraphic distributions of anisotropy are shown in Figures 3.8 and 3.9 for the Belloy and Debolt study areas, respectively. The Belloy Formation shows up to 4% slow-fast anisotropy, compared to less than 2% in the Montney in this study area. Little distinction is seen between units in the limited data from the Debolt study area. This distinction is further emphasized in Figure 3.10, where Poisson's ratio and Young's modulus are plotted for the X and Y directions in the two study areas.

Rock Strength

Rock strength cannot be measured using logs, but numerous empirical relations have been developed for estimating the UCS of rocks based on other measurable properties such as compressional wave velocity and porosity. Excellent overviews may be found in Chang et al. (2006) and Khaksar et al. (2009).

For this study, the following equations were used to determine UCS:

$UCS = 0.77(\frac{304.8}{\Delta t_C})^{2.93}$ for shales (Horsrud, 2001) (5)

$UCS = (\frac{7682}{\Delta t_C})^{1.82}$ for limestone (Militzer, 1973) (6)

$UCS = 1200e^{-.036\Delta t_c}$ for sandstone/siltstone (McNally, 1987) (7)

$UCS = \frac{1}{A*(\Delta t_C - B)C}$ for different rock types (Onyia, 1988) (8)

$UCS = 0.00069\, V_p^{1.385}$ for different rock types (Kelessidis, 2011) (9)

$\varphi = sin^{-1}\left(\frac{V_p - 1000}{V_p + 1000}\right)$ for different rock types (Lal, 1999) (10)

Δt_c in these equations is the compressional sonic transit time in μsec/m, V_p is compressional wave velocity in m/sec, and UCS and φ are uniaxial compressional strength and internal friction angle in MPa and degrees, respectively. The proper equations for individual lithologies were chosen based on mineralogy (determined using strip logs and XRD tests), as well as the limited number of available lab measurements for strength properties.

3.3 Drilling Experience Review

Drilling experience is reviewed to identify events that may provide insight into the geomechanical setting and/or mechanical stability of a given well. Specifically, the goals of this analysis are to characterize and diagnose drilling performance and problems, examine drilling issues as a function of formation/zone and identify the most appropriate intervals for stress modeling. A list of events that may be informative to the geomechanical understanding is provided in Table 3.1.

Data sources for drilling experience may vary. The best information for drilling experience comes from detailed entries in daily drilling reports (a.k.a. drilling tours). Caliper logs can also give important information about wellbore enlargements; excessive enlargement usually results in hole-cleaning problems (tight hole, stuck pipe, excessive cuttings, fill). Data collected electronically during drilling such as rate of penetration, torque, tank volumes and gas levels can reveal drilling issues, inflows and kicks, or fluid gains/losses. Well summaries generally contain a brief summary of each drilling day, and may or may not mention specific drilling problems.

When daily drilling data are available, geomechanically relevant drilling information can be summarized in a graphical format (Figure 3.11 for an example from the Debolt study area), which aids in the geomechanical interpretation. Information types range from reported mud weights displayed as colours along the well trajectory (true vertical depth vs. lateral offset), to casing points and reported drilling events that may provide geomechanical insight (Geomechanics Notes). Drilling days are plotted as either days vs. lateral offset for horizontal wells, or depth vs. days for vertical wells. Both plots are annotated with numbers corresponding to the events under the Geomechanics Notes. Such plots are especially useful in comparing geomechanical drilling experience between wells.

In this study, drilling plots, which were made for three wells in each of the study areas, can be found in Appendix D. The six wells, all of which are vertical or sub-vertical, were chosen based on a variety of factors including availability of supporting data (e.g., image logs) and spatial distribution. In general, drilling problems are relatively minor in the Belloy and Debolt formations. If major drilling problems occur, they are usually observed in shallower or deeper formations. The mud weights used for drilling in the Debolt study area vary between 970-1420 kg/m^3. While the two wells drilled with higher mud weights show minor geomechanical problems during drilling, well 200/C-017-C/094-A-14/00, which was drilled with mud weights of 1,000-1,140 kg/m^3, had more problems (Figure 3.11). In the Belloy study area, a range of 850-1,410 kg/m^3 was used for drilling.

3.4 Stress Characterization

In addition to rock mechanical properties, in situ stresses are critical components of any geomechanical study. It is customary to use a system of three orthogonal principal stresses to define the stress tensor. As a simplifying assumption, one of these principal stresses is usually considered to be vertical (S_v). This assumption is usually legitimate unless the stresses are affected by surficial topography or nearby faulting, folding, salt domes, or underground openings (Fjær et al., 2008). The two horizontal principal stresses that are defined as minimum or maximum horizontal stress (i.e., S_{hmin} and S_{Hmax}, respectively). It is important to know the azimuthal orientation of either S_{hmin} or $S_{H\max}$.

This section covers the data and workflow for defining the magnitudes of the vertical and minimum horizontal in situ stresses and the orientation of the horizontal stresses for this study. Modeling to determine the maximum horizontal stress is discussed in Section 3.5.

3.4.1 Vertical In Situ Stress

Among the three principal stress components, S_v is the most straightforward to estimate, because it represents the weight of the overburden, and it can be calculated by the integration of density logs, which are abundantly available in the public domain. Unfortunately, density logs frequently suffer from problems such as a lack of data at shallow depths or unreliable data in enlarged sections of the wellbore. The estimation of missing data points near the surface can be achieved by fitting an exponential density curve to the first 100m of available real data and assuming a density of 2100 kg/m^3 at the surface. Low-quality data over reasonably short intervals can be replaced by calculating a pseudo density from sonic logs, or by simply using nearby average values in better intervals.

Among more than 2,000 vertical and sub-vertical (with less than 40m of lateral deviation) wells available with density and density correction logs penetrating the Montney, Doig, Belloy or Debolt formations, 85 and 56 wells were chosen for mapping vertical stress in the Belloy and Debolt study areas, respectively. These wells were selected by considering two quality conditions: data started within 700m of the surface, and the percentage of missing or poor quality data was less than 15%. To quantify these quality measures, two quality factors were developed for this study. Missing depth quality factor quantifies the lack of data near surface: 100% describes a complete density log starting from ground surface, and 0% describes a density log with no data above 700m. Missing data quality factor quantifies intervals with poor or missing data: 100% describes a perfect density log with no missing values, and 0% describes a density log with 15% missing/bad values.

An example of the calculation of vertical stress, stress gradient (S_V/depth in TVD), and quality factors is shown in Figure 3.12 for well 100/10-27-082-20W6/00 in the Belloy study area. Enclosures 3.11 and 3.12 show the computer-contoured maps of the average vertical stress gradient for the Montney/Doig and Belloy, respectively, in the Belloy study area. Enclosures 3.13 and 3.14 show similar maps for the Montney/Doig and Debolt formations, respectively, in the Debolt study area. Values range from about 23 to 25.5 kPa/m. It is important to note that in order to build a geomechanical model to assess the effect of fluid storage in the target formation, the entire vertical stress profile from the underburden to overburden is essential. The stratigraphic variations of vertical stress and its depth gradient throughout both the Belloy and Debolt study areas are shown in Figures 3.13 and 3.14, respectively.

3.4.2 Minimum Principal In-situ Stress

Direct measurements via well tests are the most reliable determination of minimum stress. Measurement techniques include regular and extended leak-off tests, microfrac and minifrac (fracture injectivity) tests. Interpretation of fracture gradient or closure from any of these test types is somewhat subjective – different interpreters may derive different values for minimum stress from the same dataset. In some cases, hydraulic fracture treating pressures may also be used in areas where a good relationship between instantaneous shut-in pressure (ISIP) and minimum stress magnitude can be determined, such as in the example shown in Figure 3.15 (data not from this study).

In the absence of any direct data, sometimes regional knowledge can be used; e.g., drillers experienced in an area may have some idea of the value simply from experience. Lost circulation pressures, provided the circulation was lost because the formation was accidentally fractured, may also give an indication of minimum stress. Calculations of stress from well logs or seismic, while common, are not always considered accurate except under limited geological conditions where tectonic components of stress are negligible (Zoback, 2010). Any reported stress values directly from well logs (e.g., multi-component sonic) should be used with great caution and should be compared to well test data whenever available.

In this study, the two main sources of data for minimum stress estimation were closure stress values from minifrac/DFIT tests and ISIP values from hydraulic fractures. The closure pressure from the hydraulic fractures were estimated as 85% of mean Instantaneous Shut-in Pressure (ISIP) values for all frac stages in a single well. Extensive quality control and data filtering were performed to remove low-quality data, especially in the case of multi-stage fracturing of horizontal wells. DFIT values were considered the most reliable, and were used as benchmarks for quality control of the hydraulic fracture-derived values.

In total, eight wells with DFITs and 135 wells with ISIPs were found in the Belloy study area. Only two of these wells had both of these values. In the Debolt study area, one well with a DFIT and 36 wells with ISIPs were found, none of which had both. Enclosures 3.15 and 3.16 are contour maps of minimum principal stress in the Montney and Doig formations in the two study areas. Both maps show a trend of increasing minimum stress from east to west, similar to the trend of increasing pore pressure increase in the Montney Formation (see Enclosures 2.8 and 2.20). Values range from about 15 kPa/m to 22.5 kPa/m. Unfortunately, there is an obvious paucity of data for the storage target units, and only a small amount of minimum stress data were found for these two formations. The limited number of data found in the Belloy, Debolt and other formations are shown in Enclosures 3.17 and 3.18.

3.4.3 Orientation of Horizontal Stresses

Numerous methods have been used over the years in geological studies and mining and petroleum engineering to identify the orientation of in situ stresses. Some of these methods include geological indicators, inference from structure or faults/fractures, seismic/sonic anisotropy, microseismic, tiltmeter data and stress-induced borehole features. Based on data availability, image logs and sonic scanner logs were found useful in identifying horizontal stress orientation in this study.

Only stress-induced wellbore failure (tensile cracks and breakouts) are usually considered to provide local, current and unambiguous indicators of maximum and minimum horizontal stress directions (note that in deviated wells, breakouts do not necessarily occur at the azimuth of the minimum horizontal stress direction). The best data for observing wellbore failure are image logs. Because of the variety in imaging tools and the appearance of features like tensile cracks and breakouts, examples are not provided here, but many can be found in the literature and online (e.g., Thompson, 2009; Pöppelreiter et al., 2010). Figure 3.16a shows part of an image log over a vertical section of well 200/A-018-D/094-A-13/00 in the Debolt study area showing clear breakouts. The orientation of these features projected on the stereonet in Figure 3.16b easily reveals the orientation of horizontal in situ stresses. In total, two wells in the Belloy study area and three wells in the Debolt study area were found to have image logs with quality suitable for identifying stress orientation (Enclosures 3.19 and 3.20). Therefore, a number of wells in the vicinity of the study areas (three and four wells for the Belloy and Debolt study areas, respectively) were also used to properly characterize stress orientation in these areas.

Oriented caliper may also provide breakout orientations (although it will not detect tensile fractures, which are important when modeling stress magnitudes). Unfortunately, no good-quality, oriented calipers were found for this study.

Another increasingly common approach for determining stress orientation is assuming that, when measuring directional anisotropy in seismic and/or shear sonic data, the fast shear direction represents the higher stress direction. In addition to stresses, many other factors such as depositional processes, rock fabrics and natural fractures may influence the seismic/sonic anisotropy of rocks even over different intervals of the same well. Therefore, interpreting these data for stress orientation must be performed with significant caution, and must account for other potential interpretations. If available, dispersion (slowness-frequency) curves for flexural waves can be useful for identifying whether anisotropy is stress-induced, and when it is caused by other factors (Franko et al., 2006). Figure 3.17 shows an example of stress orientation determined from a Schlumberger Sonic Scanner log from well 100/01-27-078-17W6/00 in the Doig Formation very close to the Belloy study area. In total, five wells in the Belloy area were found to have sonic scanner logs useful for identifying stress orientation (Enclosure 3.19). None was found in the Debolt study area.

As Enclosures 3.19 and 3.20 show, maximum horizontal stress is generally oriented Northeast-Southwest across the study areas, which is consistent with regional trends (Heidbach et al., 2009). Some minor variability is seen, particularly on the northwestern edge of the Belloy study area. S_{Hmax} orientation in the Debolt study area seems to be slightly more East-West than in the Belloy study area.

3.5 Modeling to Determine S_{Hmax}

Among the three principal stresses, the maximum horizontal stress (S_{Hmax}) is the most difficult to estimate and, until today, attempts to directly measure this stress component have not led to a publicly-accepted and economically-viable method. In practice, S_{Hmax} magnitude is usually constrained by applying boundary limits based on the known faulting regime or by modeling drilling-induced features like tensile fractures and breakouts. These methodologies can then be used to calibrate models that calculate horizontal stress based on the vertical stress and elastic rock properties.

In modeling drilling-induced features, the magnitude and azimuth of the maximum horizontal stress is determined by finding the value that, given all of the other input parameters (e.g., depth, pore pressure, minimum stress, UCS, hole orientation, mud weight, etc.), predicts the same mechanical wellbore failure as what is observed. Figure 3.18 shows an example of this approach being used in well 200/A-018-D/094-A-13/00, very close to the Debolt study area. The analysis should be performed at multiple depths in a single well and/or in multiple wells to look for consistency or variation in maximum stress magnitude. All of the results should contribute to a unified stress model for the study area, which can then be verified against actual drilling experience determined as described in Section 3.3. This methodology can be applied not only to explain experience in previously drilled wells, but also to predict required mud weights to maintain stability in future wells.

In this study, modeling to determine S_{Hmax} was performed for nine wells in the Belloy study area and six wells in the Debolt study area. The results are shown in Enclosures 3.17 and 3.18. The conditions for selecting these wells were mainly data availability and spatial distribution. Tables 3.2 and 3.3 provide the lists of available data used for S_{Hmax} modeling for the study areas. Four wells in or close to the Belloy study area and six wells in or close to the Debolt study area had image logs that could be used for modeling. The image logs varied in quality from high to low and, therefore, the confidence in the modeled S_{Hmax} magnitudes is higher or lower accordingly.

For the wells with no image logs, data from four-arm and six-arm caliper logs were used to identify breakouts. Figure 3.19 provides an example from well 202/C-025-B/094-H-03/00 in the Debolt study area. Unfortunately, it is very hard to determine the breakout width using calipers. Methodologies presented by Martin et al. (1999) and Zoback et al. (1985) were utilized to provide some idea of minimum breakout width from caliper logs. While using this approach does not necessarily provide a single value for S_{Hmax}, it at least provides tighter constraints on its magnitude.

Tables 3.4 and 3.5 provide the details of the input data used for modeling and the results of S_{Hmax} characterization for the Belloy and Debolt study areas, respectively. Values of S_{Hmax} are in general between about 26 and 32 kPa/m. The formations in which the models were run depended on the formations in which there were data showing stress-induced wellbore failure. The model results are also shown in the maps in Enclosures 3.21 and 3.22 for the two study areas. As discussed, depending on the availability of data, some of the results are given as ranges of possible values for S_{Hmax}.

3.6 Characterization and Analysis of Natural Fractures

3.6.1 Fracture Populations

In addition to their application for determining maximum horizontal stress orientation and magnitude, wellbore image logs are also the primary data source for characterizing natural fractures. Image logs for five wells in the Belloy study area and four in the Debolt study area were interpreted in this project for natural fractures in the storage target units and the Montney Formation. The results of the interpretation are shown in Enclosures 3.23 and 3.24 for the Belloy study area and in Enclosures 3.25 and 3.26 for the Debolt study area. These maps show the uneven distribution of image logs across the study areas, with most of these data located on the western side of the areas. Another factor that is not captured in the maps is the range of image data quality, which may also affect the apparent fracture populations.

Interestingly in both study areas, the fracture orientations in the target formations, Debolt and Belloy, are significantly different from those in the Montney Formation. While several of the Montney fractures are oriented in the W-E and SW-NE direction (i.e. close to the orientation of maximum horizontal stress), the majority of the Belloy and Debolt fracture strikes are in the N-S and NW-SE orientation. The dip of Montney and Debolt fractures is variable between sub-horizontal to sub-vertical, while most of the Belloy fractures have small dips values (less than 40°).

3.6.2 Critically-Stressed Fracture/Fault Analysis

One of the most important components of this study is the determination of whether or not natural fractures or faults in the target formations and the Montney are critically-stressed (Barton et al., 1995). When a fracture is classified as critically-stressed, it means that that the shear stress acting on the fracture plane is relatively high compared to the effective normal stress, to the point where the fracture is no longer stable. On a Mohr diagram, these fractures fall above the line defined by the coefficient of sliding friction. When a fracture is in this particular state, it has almost certainly experienced shear displacement in recent geologic history, and/or it will do so in the present under minor stress or pore pressure variations. Because such fractures cannot form a seal due to the rugose fracture surface and lack of cementation, they tend to be permeable to fluid flow. Such fractures may have implications for containment integrity of the target formations and/or caprock.

The state of being critically-stressed is directly linked to fluid pressure. An increase in fluid pressure leads to a decrease in effective normal stress, but does not affect the shear stress. It, therefore, has the possibility of putting fractures that are not, under natural conditions, critically-stressed into a critical state. This risk can be quantified by calculating the excess pressure (above formation pressure) that would cause fractures of particular orientations to become critically-stressed.

Enclosures 3.27, 3.28, 3.29 and 3.30 show the proximity of fractures at all possible orientations to being critically-stressed for the Belloy, Debolt and Montney formations. The maps are populated with upper hemisphere plots of poles to fracture planes, which allows for the evaluation of all possible fracture orientations with a single plot (horizontal fractures would plot in the centre; poles to increasingly dipping fractures plot outward from the centre in the direction of the fracture dip; vertical fractures would plot along the perimeter). The colours show the amount of additional fluid pressure above pore pressure that is required to put preexisting fractures into a critical state. All of the stereoplots use the same colour scale for easy comparison.

In the Belloy Formation (Enclosure 3.27), the lowest pressure increase at which fractures will become critically-stressed is 10 MPa, at which point fractures dipping to the Northwest and Southeast may slip. In general, pressure increases up to 22 MPa are required to induce slip, and the first fractures/faults to become critically-stressed will be those dipping steeply to the Southeast or Northwest. From a critically-stressed fracture/fault perspective, the southeastern part of the study area is slightly more favourable for injection then the northwestern part.

Generally lower pressure increases in the Debolt Formation will cause fractures to become critically-stressed than in the Belloy (Enclosure 3.28). Pressure increases in the range 8 MPa to 20 MPa are required to induce slip, and the first fractures/faults to become critically-stressed will be those dipping steeply to the Southeast or Northwest. A number of such fractures were identified in wellbore image logs in the relatively faulted Southwestern edge of the study area. If the rest of the study area is less faulted, then the southwestern part of the study area is slightly more favourable for injection then the northwestern part, simply because higher pressures are needed to induce slip.

Fractures/faults in the Montney are closer to being naturally critically-stressed in both study areas (Enclosures 3.29 and 3.30), primarily due to higher pore pressure in the Montney compared to the Belloy or Debolt. This near critically-stressed behaviour may, in fact, have something to do with the prospectivity of the Montney as a resource play. It is important to note that the pore pressure change in the Montney Formation, unlike the storage units, would not be directly related to injection, but will be mainly related to thermo-poro-mechanical changes or pressure transferred through open fractures. More detailed geomechanical modeling than in the scope of this study would be required to understand these potential effects.

4.0 CONCLUSIONS AND RECOMMENDATIONS

4.1 Hydrogeology Conclusions

The results of the hydrogeologic analysis indicates that the Belloy and Debolt are hydrodynamically distinct from the Lower Montney in the focus areas. Pressure difference mapping across the contact with the Lower Montney indicates that the pressure difference across the Montney/Belloy boundary ranges from 28 MPa in the southwest to near zero in the northwest. Similarly the pressure difference across the Montney/Debolt boundary ranges from 78 MPa in the foothills region to approximately 4 MPa in the northeast. Hydraulic head in the Belloy ranges from 675m to 775m, consistent with a relatively high permeability aquifer, and shows gradual variation except in a few regions disrupted by faulting. Hydraulic head in the Debolt is more compartmentalized than in the Belloy due to the higher prevalence of faults. Debolt head values range from under 500m to just under 1,200m. Faulting in both areas also has a significant effect on salinity trends, although salinity data were particularly sparse in the Belloy focus area, limiting the ability to make a regional interpretation.

4.2 Geomechanics Conclusions

All publicly-available data and a small amount of project stakeholder data were extensively queried and quality controlled in order to constrain geomechanical properties in the Belloy and

Debolt formations in the defined study areas. Spatial coverage of data varied significantly by study area and data type. In general, data coverage was better in the Belloy study area than in the Debolt study area.

The analysis found that minimum horizontal stress is approximately 15-22.5 kPa/m and vertical stress is 23 to 25.5 kPa/m across the study areas. Lower bound of 26.5 kPa/m and values as high as 32.5 kPa/m were found for maximum horizontal stress. Maximum horizontal stress is generally oriented Northeast-Southwest and slightly more rotated to the east in the Debolt study area than in the Belloy. A large number of maps, provided in the Enclosures, provide a good overview of spatial variability in stress and rock properties.

To the extent possible, fracture populations were measured in image logs throughout the two study areas. Fractures in the Montney tend to strike more to the East-West than in the underlying target formations, especially in the Belloy study area. Fractures also seem less abundant in the Montney. It is important to note that fracture identification was considerably limited by public image log quality and coverage both spatially and stratigraphically.

A limited evaluation of geomechanical risk was performed by using the in situ stresses to calculate the excess pressure above formation pressure that would induce slip on preexisting fractures and faults. In general, lower pressure increases are required to cause fractures in the Debolt Formation to become critically-stressed, than in the Belloy. From a critically-stressed fracture/fault perspective, the southeastern part of the Belloy study area and the southwestern part of the Debolt study area are the most favourable for injection, however it should be noted that there are several mapped faults at the southwestern edge of the Debolt area.

One of the most important and useful results of this geomechanical analysis is the availability of the determined stresses and rock properties for more detailed geomechanical modeling, as described in the following Recommendations section.

4.3 Recommendations

The geomechanical effects of fluid injection are complex, and call for detailed reservoir modeling far beyond the scope of this study. The results of this study should be considered useful for a regional perspective on potential fluid injection sites, but specific injection programs should not be planned without site-specific data gathering and geomechanical modeling.

The following data, specifically, are strongly recommended to be collected in the target formation and caprock near any planned injection site:

- Core data for lab tests designed specifically to determine rock properties associated with modeling reservoir behavior under injection conditions (e.g, unloading induced by injection, thermal effects, potential hysteresis effects)
- Image logs for natural fracture/fault identification and stress characterization
- Downhole tests for pore pressure and minimum stress

For any industrial-scale waste fluid disposal project, it is strongly recommended that a long-term, Integrated Containment Assessment Program (ICAP) be developed. Primary components of such a program include data acquisition, site characterization, modeling, feasibility assessment, determination of operational criteria and recommendations, field monitoring, and real-time updating (Figure 4.1). Modeling should include integrated fluid flow, heat transfer and geomechanical aspects. A three-dimensional, coupled reservoir-geomechanical model can more realistically assess risks associated with fluid injection by providing information on:

- Injected fluid migration and resulting stress, pressure and temperature distributions over time
- Temperature and pressure-dependent rock property changes
- Maximum injectivity based on induced seismicity risk, caprock integrity considerations and potential surface heave

5.0 REFERENCES

Canadian Discovery Ltd., 2015. Montney Regional Hydrogeology Study, Phase II. Calgary, Alberta

Chang, C., Zoback, M.D., Khaksar, A., 2006. Empirical relations between rock strength and physical properties in sedimentary rocks. Journal of Petroleum Science and Engineering 51. p. 223–237.

Franko, A., Ortiz, M., De, G.S., Renlie, L., Williams, S., 2006. Sonic Investigations in and Around the Boreholes. Oilfield Review, Spring, p 14–33.

Heidbach, O., Tingay, M., Barth, A., Reinecker, J., Kurfeß, D., Müller, B. 2009. The World Stress Map based on the database release 2008, equatorial scale 1:46,000,000, Commission for the Geological Map of the World, Paris, doi:10.1594/GFZ.WSM.Map2009.

Horsrud, P., 2001. Estimating mechanical properties of shale from empirical correlations. SPE Drill. Complet. 16, p. 68–73.

Kelessidis, V.C. 2001. Rock Drillability prediction from in situ determined unconfined compressive strength of rock. The Journal of the Southern African Institute of Mining and Metalurgy, Vol. 11, p. 429-436.

Khaksar, A., Taylor, P.G., Fang, Z., Kayes, T., Salazar, A. and Rahman, K., Rock Strength from Core Logs: Where We Stand and Ways to Go, SPE 121972, 2009.

Lal, M., 1999. Shale stability: drilling fluid interaction and shale strength. SPE Latin American and Caribbean Petroleum Engineering Conference held in Caracas, Venezuela.

Martin C.D., Kaiser, P.K., McCreath, D.R., 1999. Hoek-Brown parameters for predicting the depth of brittle failure around tunnels. Can. Geotech. J., 36(1), p. 136–51.

McNally, G.H., 1987. Estimation of coal measures rock strength using sonic and neutron logs. Geoexploration 24, p. 381–395.

Militzer, H., Stoll, R., 1973. Einige Beitrageder geophysics zur primadatenerfassung im Bergbau, Neue Bergbautechnik. Lipzig 3, p. 21–25.

Onyia, E.C., 1988. Relationships Between Formation Strength, Drilling Strength, and Electric Log Properties, SPE Annual Technical Conference and Exhibition, 2-5 October, Houston, Texas

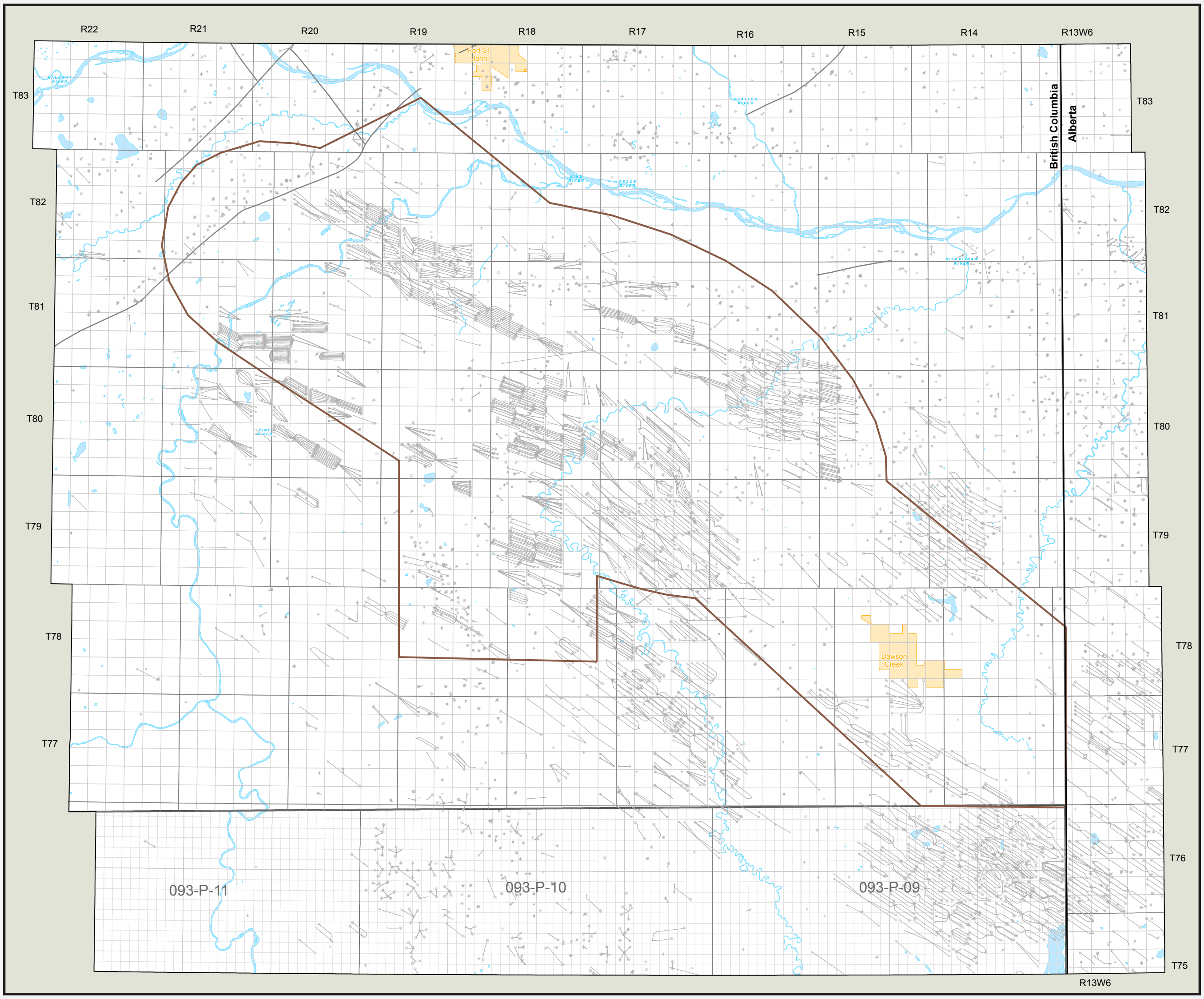
Petrel Robertson Consulting Ltd., 2014, Characterization of Belloy and Debolt Water Disposal Zones in the Montney Play Fairway, NEBC, Calgary, Alberta

Pöppelreiter, M., García-Carballido, C., and Kraaijveld, M.A. (eds.), 2010, Dipmeter and Borehole Image Log Technology, American Association of Petroleum Geologists, Memoir 92.

Rakhit Petroleum Consulting Ltd., 1995. The Hydrogeological Atlas of the Western Canada Sedimentary Basin. Calgary, Alberta

Rakhit Petroleum Consulting Ltd., 2005. Permocarboniferous Hydrogeology of Northeastern British Columbia Blueberry, Stoddart, Eagle. Calgary, Alberta

Zoback, M.D., Moos, D., Mastin, L., Andersson, R.N., 1985. Borehole breakouts and in-situ stress. J. Geophys. Res., 90, p. 5,523–5,530.



Wells

Wells

Wellbore

Culture

Hydro Lake/Major River Features

Town/City

Structural and Geological Features

Fault

Focus Area

Belloy Focus Area

BELLOY AND DEBOLT WATER DISPOSAL ZONES IN THE MONTNEY PLAY FAIRWAY, NEBC

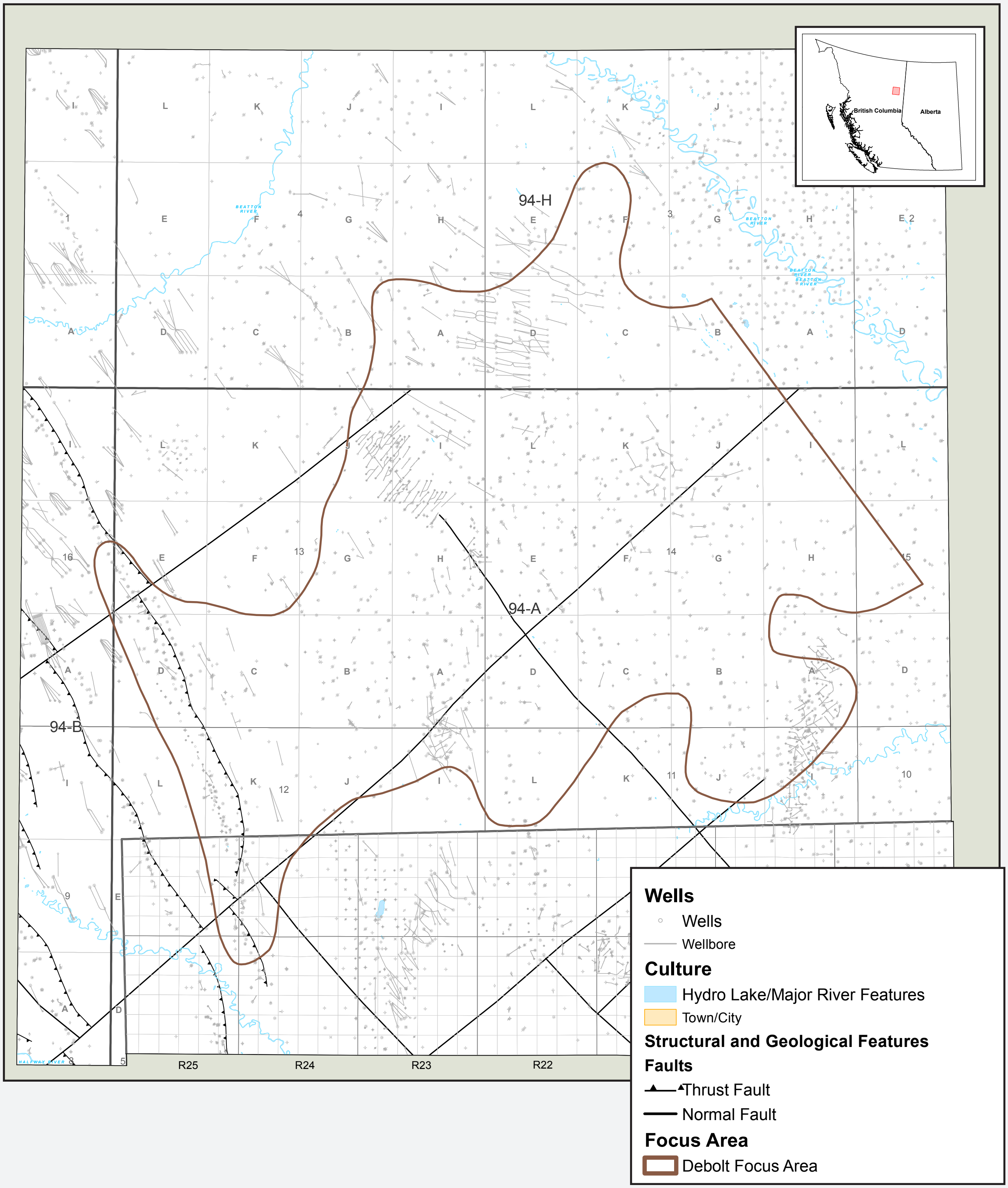
GCWD

Author	N.Watson
Reviewer	S.Hawkes
Graphics	P.Patton
Created	24-Jun-2015

Belloy Area

Canadian Discovery Ltd.

Figure 1.1



BELLOY AND DEBOLT WATER DISPOSAL ZONES IN THE MONTNEY PLAY FAIRWAY, NEBC | GCWD

Author	N.Watson
Reviewer	S.Hawkes
Graphics	P.Patton
Created	24-Jun-2015

Debolt Area

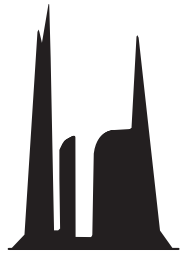
Canadian Discovery Ltd.

Figure **1.2**

Drill Stem Pressure Data

A Best Quality

1. Test mechanically sound - No Plugging/No Skidding
2. Recorder used-chart good pressures compare
3. Flow pressure verify recoveries and/or flow rates
4. Bottom packer held on straddle tests
5. Recorder depths given
6. Recorder within interval tested
7. ISI stabilized. or nearing stabilization with increments
8. Preflow time long enough to release hydrostatic head
9. KB elevation given
10. Two good Shut-Ins required
11. PMAX Range of approximately 1 to 10 lbs. (7 to 69 kPa) from read shut-In pressure
88. Fluid to surface on flows (irregularities)
99. Flows incremented



B Nearing Stabilization

12. Slight mechanical difficulties. but does not affect the test
13. Shut-ins not fully stabilized
15. Recorder pressures disagree from 1 to 19 PSI (7 to 131 kPa) after recorder drag and depth difference
17. PMAX range of approximately 20 to 35 lbs. (138 to 241 kPa) from read shut·in pressure
48. Flow pressures to not verify recoveries
88. Plugging. fluid to surface, resets on flows (irregularities)
99. Flows incremented

C Caution (Plugging)

18. Some mechanical difficulties evident on chart, however, does not appear to affect pressure data
19. Records run above the interval
21. Preflow not opened long enough. possibly slightly supercharged
22. Packer may have leaked slightly
24. Recorder pressures disagree from 20 - 29 PSI (138 to 200 kPa) after recorder drag and depth difference
25. Only one recorder must be within interval
26. PMAX range of approximately 30 to 85 lbs. (207 to 586 kPa) from read shut·in pressure
27. Only one good shut-in
88. Plugging, fluid to surface, resets on flows (irregularities)
99. Flows incremented

D Questionable

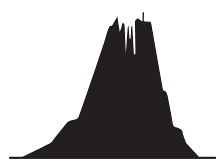
28. Not totally mechanically sound
29. Only one recorder run inside above the interval
30. No recorder depth or questionable
31. No KB elevation
33. Questionable interal depths.
34. Supercharged ISI, FSI follows long valve open period
35. No chart from below bottom packer
36. Recorder pressures disagree from
30 PSI (206.8 kPa) and over after recorder drag and depth difference
37. PMAX range of approximately 80 to 150 lbs. (552 to 1034.2 kPa) from read shut-In pressure
79. Cannot define a valid P-Max (test indicates definite drawdown) P-Max filled with the initial shut-in pressure
88. Plugging, fluid to surface, reset on flows (Irregularities)
99. Flows incremented

E Low Perm, Low Pressure

38. Covers all requirements of Code A, however, low permeability and low pressure, unable to extrapolate
39. Low permeability, low pressure, but problems encountered throughout test
46. Low permeability, relatively high pressure for "E" Code
88. Plugging, fluid to surface resets on flows (irregularities)
99. Flows incremented

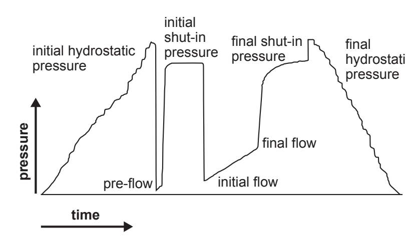
F Low Perm, High Pressure

40. Covers all requirements of Code A, however, low permeability and high pressure (CAUTION: Watch for Cushion)
41. Low permeability, high pressure, but problems encountered throughout test
47. Low permeability, relatively low pressure for "F" code
88. Plugging, fluid to surface resets on flows (irregularities)
99. Flows incremented



G Misrun (Flow Only)

42. No shut-ins taken
43. No useable pressures
44. No useable data
45. Flow only
63. Unable to obtain initial packer seat
64. Lost seat after tool opened
65. No elements ruptured
66. Top elements ruptured
67. Bottom elements ruptured
68. Both elements ruptured
69. Plugged tool
70. Unable to reach test depth
71. Tool-failure
72. Personnel failure
73. Belly spring turning
74. No reason available
75. Other
76. Mud dropped In annulus when tool open (seat held)
77. Skidding tools when opening or during flow
90. Front page only, misrun



These Quality Codes grade drill stem tests according to the following signatures

After: CIFE

BELLOY AND DEBOLT WATER DISPOSAL ZONES IN THE MONTNEY PLAY FAIRWAY, NEBC | GCWD

Author	N.Watson
Reviewer	S.Hawkes
Graphics	P.Patton
Created	24-Jun-2015

Drill Stem Test Quality Code Summary - DST Charts

Canadian Discovery Ltd.

Figure 2.1

Quality Code	Quality Rating	Test Characteristics
A	High Quality	Test mechanically sound, both shut-in pressures have stabilized.
B	Requires Extrapolation	Slight mechanical difficulties, shut-in pressures not fully stabilized, but pressures have been extrapolated and should be accurate.
C	Requires Extrapolation, use with caution	Some mechanical difficulties apparent, shut-in pressures not fully stabilized, but pressures have been extrapolated and can be used with caution.
D	Test Results Questionable	Test not mechanically sound and pressures have not stabilized enough to obtain reasonable extrapolation, thus the results are questionable.
E	Low Perm, Low Pressure, Low Quality	Low permeability, low pressure, but problems encountered throughout testand/or unable to extrapolate. Pressure should NOT be used.
F	Low Perm, High Pressure, Low Quality	Low permeability, high pressure, but problems encountered throughout test and/or unable to extrapolate. Pressure should NOT be used.

Author N.Watson
Reviewer S.Hawkes
Graphics P.Patton
Created 24-Jun-2015

Drill Stem Test Quality Code Summary - Code Descriptors

Canadian Discovery Ltd.

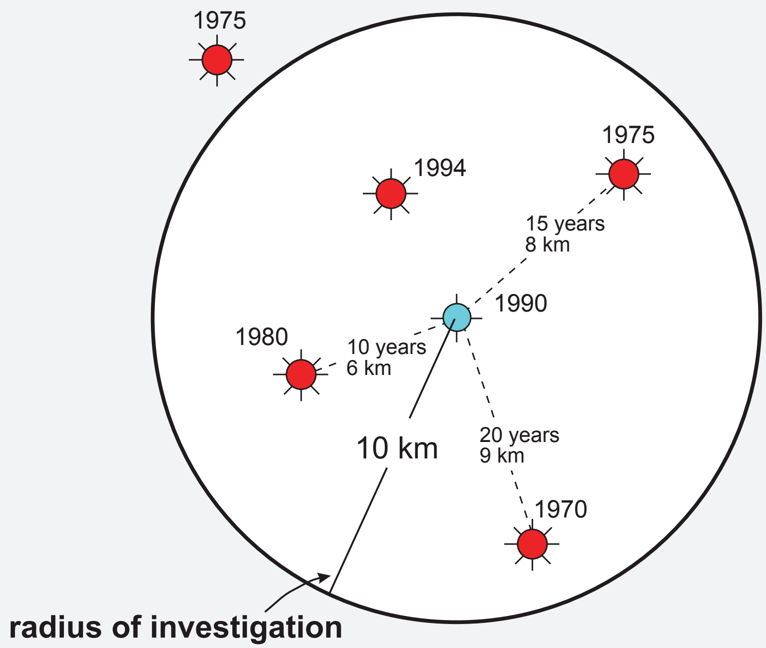
Figure 2.2

For each pressure value, calculate an **Interference Index**

$$I = \sum_{i=1}^{i=n} t_i / r_i^2$$

t: production time in years (pressure test date - initial production date)

r: radial distance between pressure test well and production well in kilometres



1990 Pressure test well with test date

1975 Production well with initial production date

In this case, production wells over 10 km (one township) distant are not considered

Of the 4 production wells within the radius of investigation, only 3 predate the pressure test. The interference index is computed as:

$$I = (15/8^2 + 20/9^2 + 10/6^2)$$

$$I = 0.759$$

BELLOY AND DEBOLT WATER DISPOSAL ZONES IN THE MONTNEY PLAY FAIRWAY, NEBC

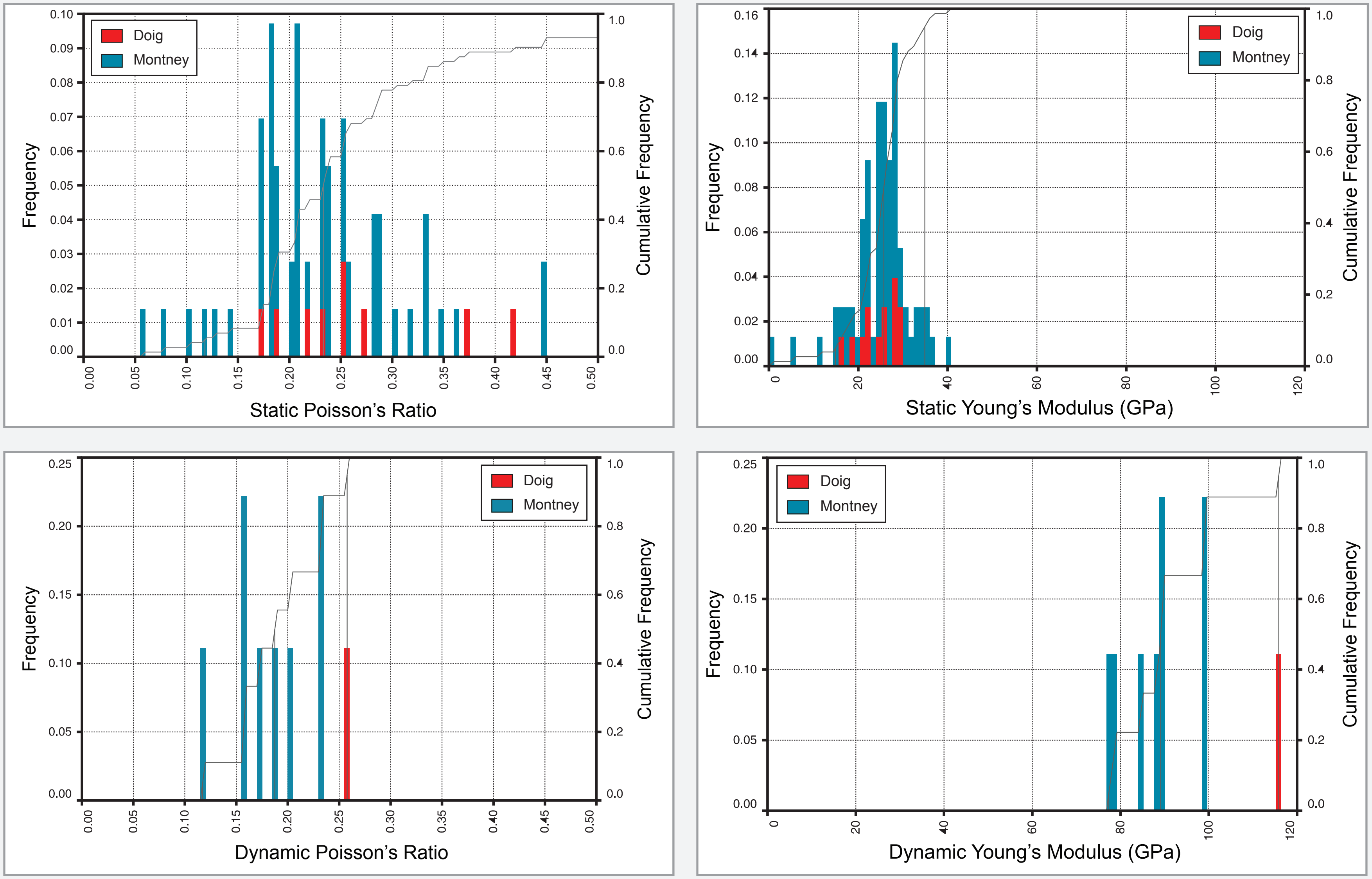
GCWD

Author	M.Soltanzadeh
Reviewer	A. Fox
Graphics	P. Patton
Created	24-Jun-2015

Production Induced Drawdown Theory

Canadian Discovery Ltd.

Figure **2.3**



BELLOY AND DEBOLT WATER DISPOSAL ZONES IN THE MONTNEY PLAY FAIRWAY, NEBC

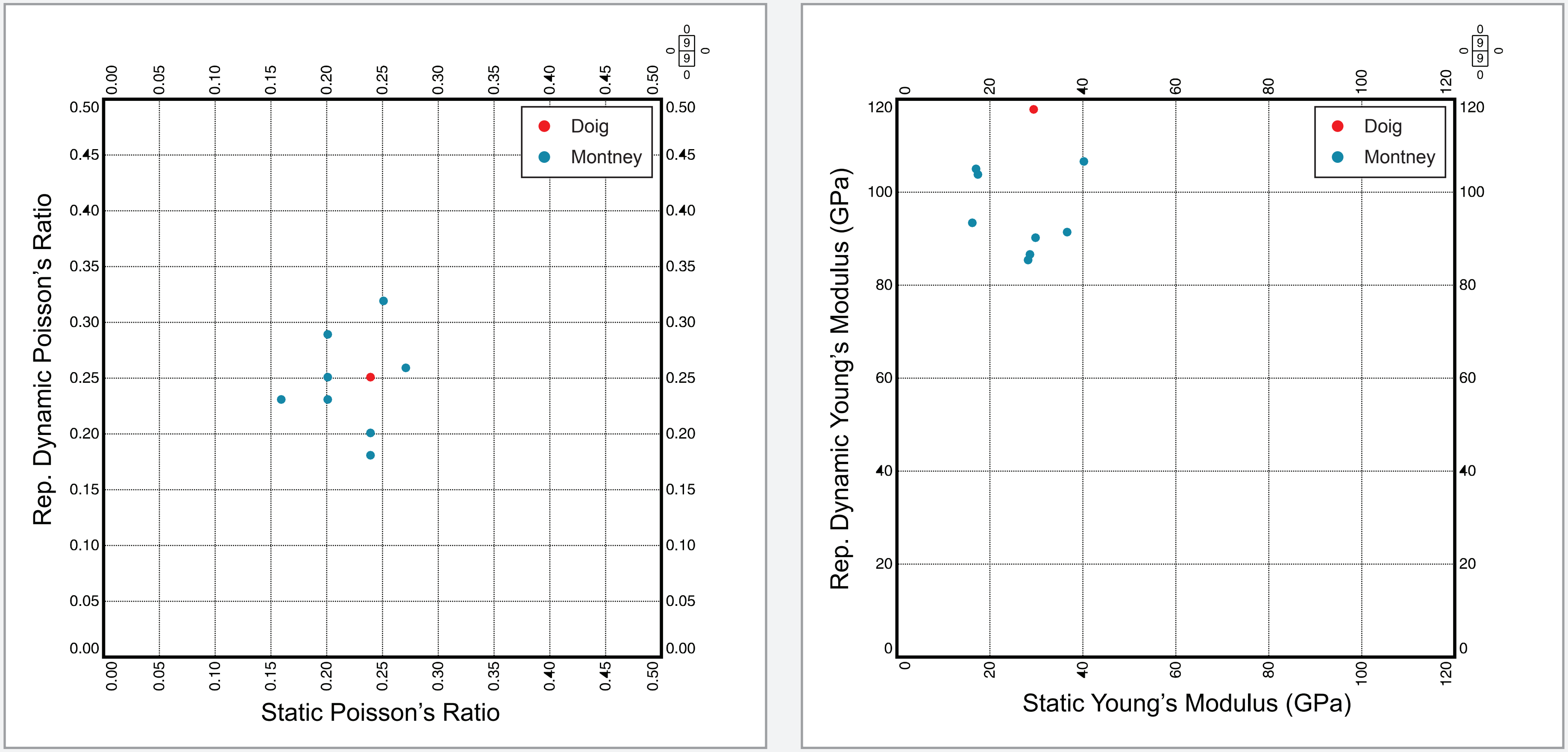
GCWD

Author	M.Soltanzadeh
Reviewer	A. Fox
Graphics	P. Patton
Created	24-Jun-2015

Statistical Distribution of Lab-Based Elastic Rock Properties in the Montney and Doig Formations in the Belloy Study Area

Canadian Discovery Ltd.

Figure **3.1**



BELLOY AND DEBOLT WATER DISPOSAL ZONES IN THE MONTNEY PLAY FAIRWAY, NEBC

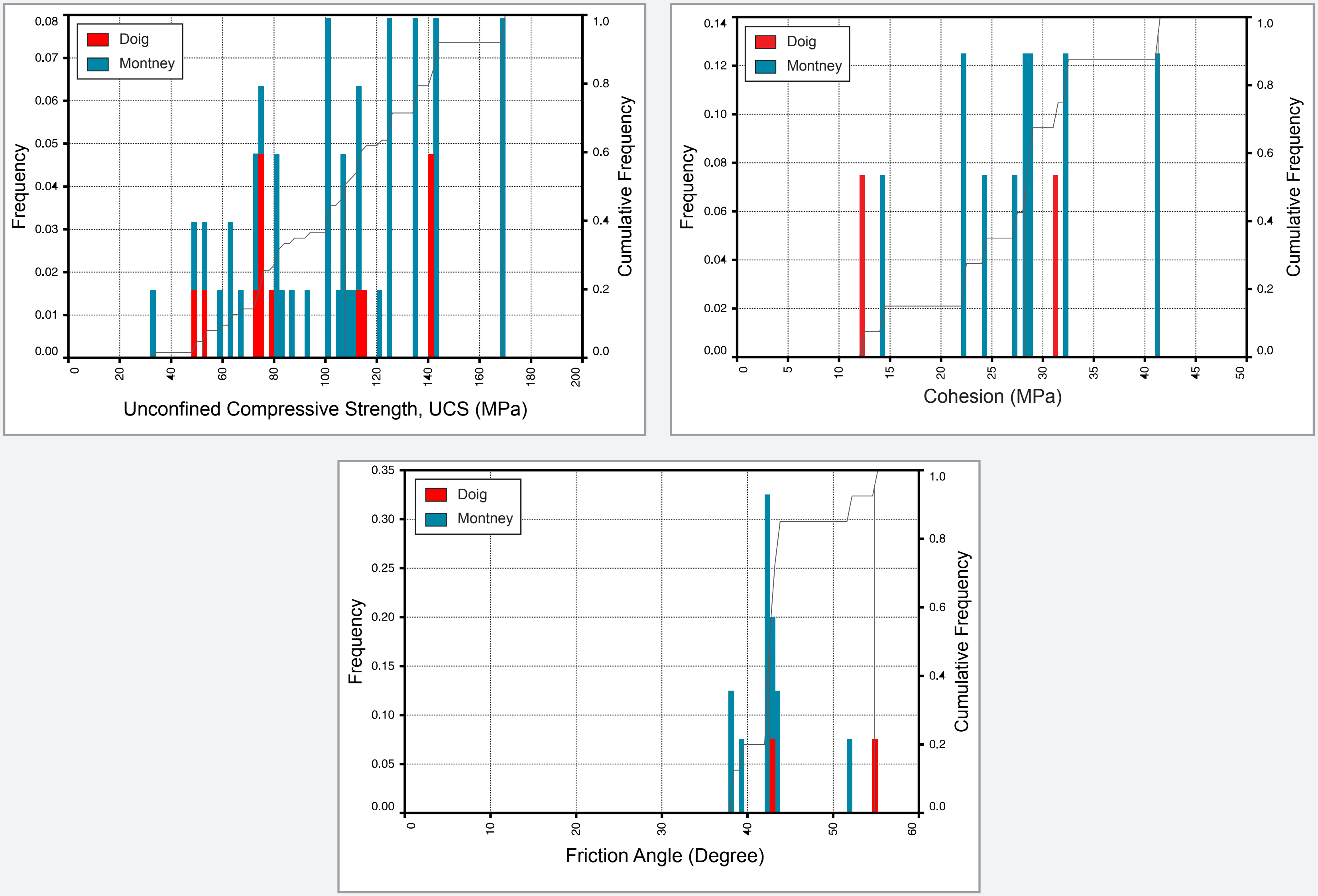
GCWD

Author	M.Soltanzadeh
Reviewer	A. Fox
Graphics	P. Patton
Created	24-Jun-2015

Crossplots between Lab-Based Static and Dynamic Elastic Properties

Canadian Discovery Ltd.

Figure 3.2



BELLOY AND DEBOLT WATER DISPOSAL ZONES IN THE MONTNEY PLAY FAIRWAY, NEBC

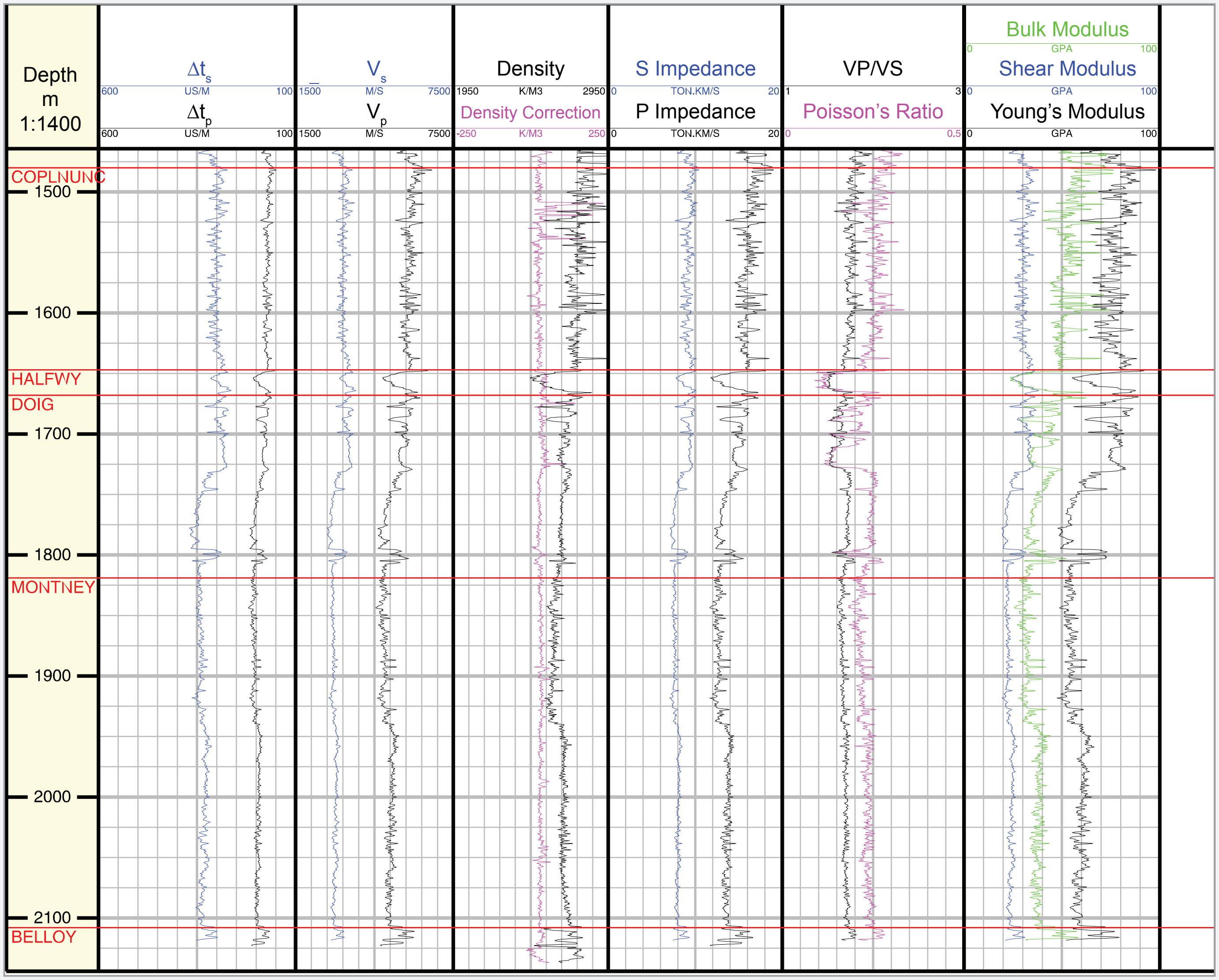
GCWD

Author	M.Soltanzadeh
Reviewer	A. Fox
Graphics	P. Patton
Created	24-Jun-2015

Statistical Distribution of Lab-Based Rock Strength Properties in the Montney and Doig Formations in the Belloy Study Area

Canadian Discovery Ltd.

Figure **3.3**



BELLOY AND DEBOLT WATER DISPOSAL ZONES IN THE MONTNEY PLAY FAIRWAY, NEBC

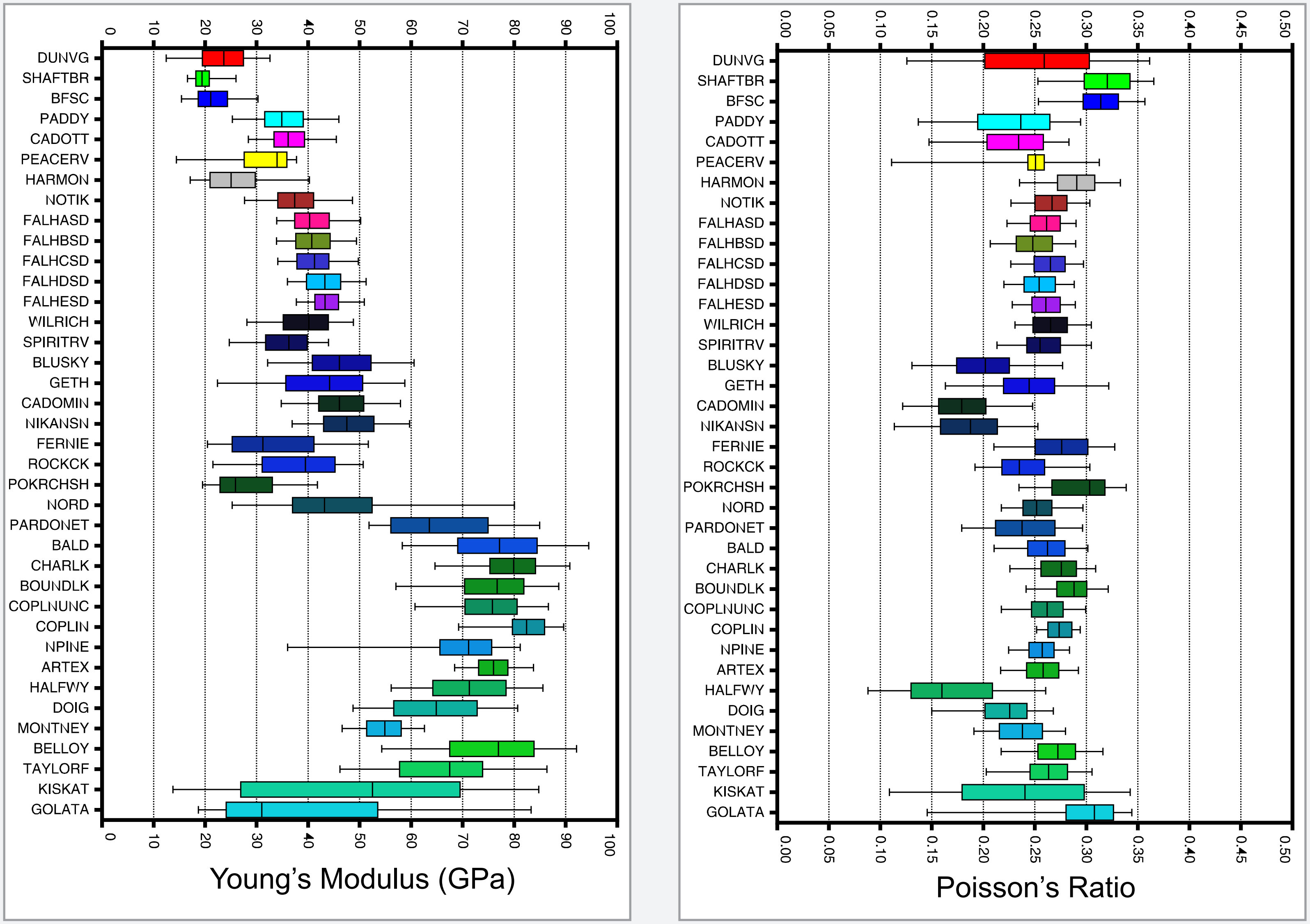
GCWD

Author M.Soltanzadeh
Reviewer A. Fox
Graphics P. Patton
Created 24-Jun-2015

Calculation of Elastic Properties for Well 100/16-25-081-19W6/00 in the Belloy Study Area

Canadian Discovery Ltd.

Figure 3.4



BELLOY AND DEBOLT WATER DISPOSAL ZONES IN THE MONTNEY PLAY FAIRWAY, NEBC

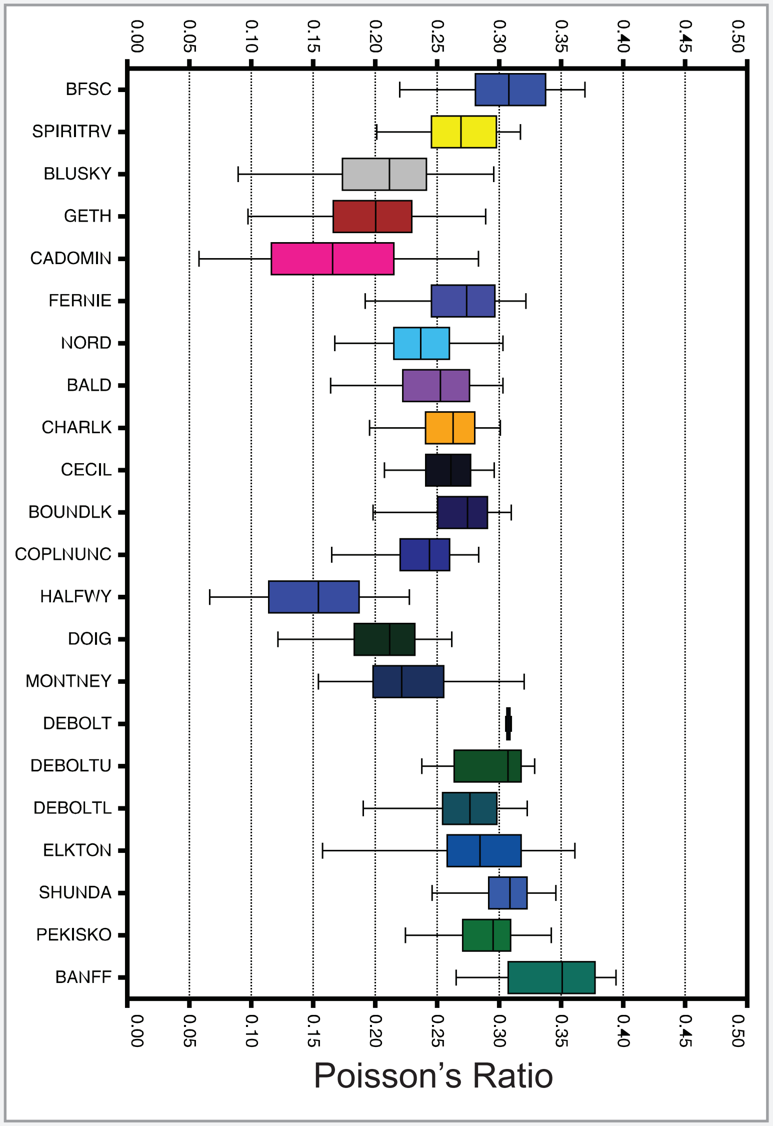
GCWD

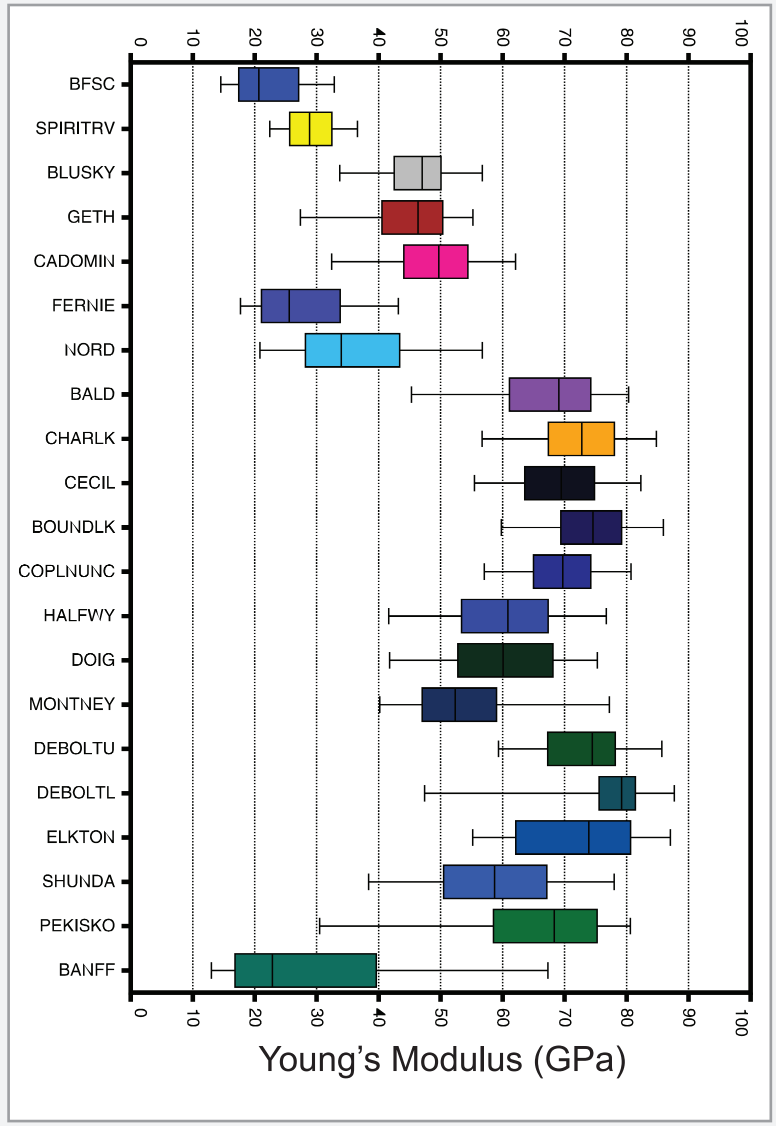
Author	M.Soltanzadeh
Reviewer	A. Fox
Graphics	P. Patton
Created	24-Jun-2015

Stratigraphic Distribution of Elastic Rock Properties for all the 75 Analyzed Wells in the Belloy Study Area

Canadian Discovery Ltd.

Figure **3.5**





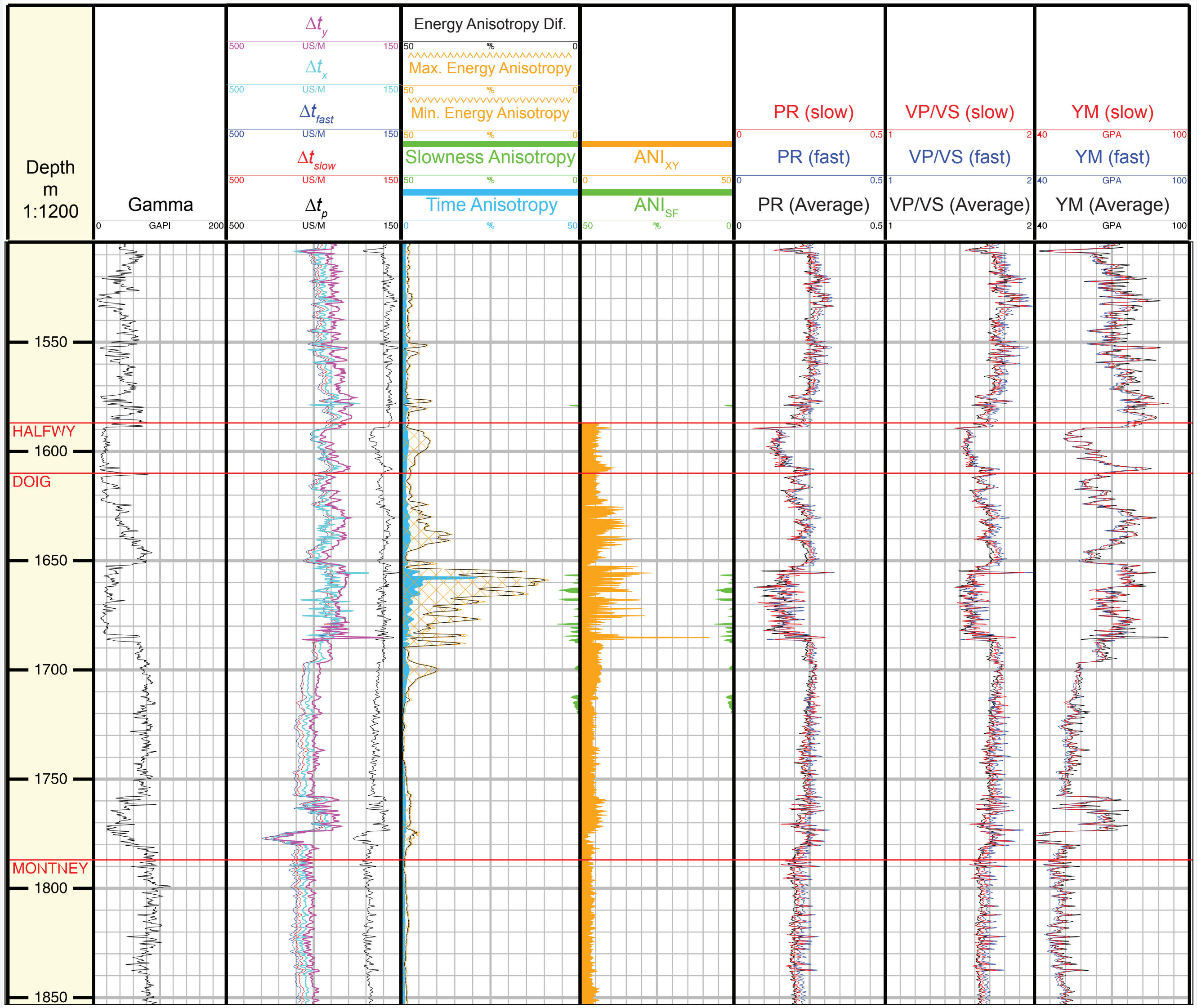
BELLOY AND DEBOLT WATER DISPOSAL ZONES IN THE MONTNEY PLAY FAIRWAY, NEBC | GCWD

Author	M.Soltanzadeh
Reviewer	A. Fox
Graphics	P. Patton
Created	24-Jun-2015

Stratigraphic Distribution of Elastic Rock Properties for all the 55 Analyzed Wells in the Debolt Study Area

Canadian Discovery Ltd.

Figure **3.6**



BELLOY AND DEBOLT WATER DISPOSAL ZONES IN THE MONTNEY PLAY FAIRWAY, NEBC

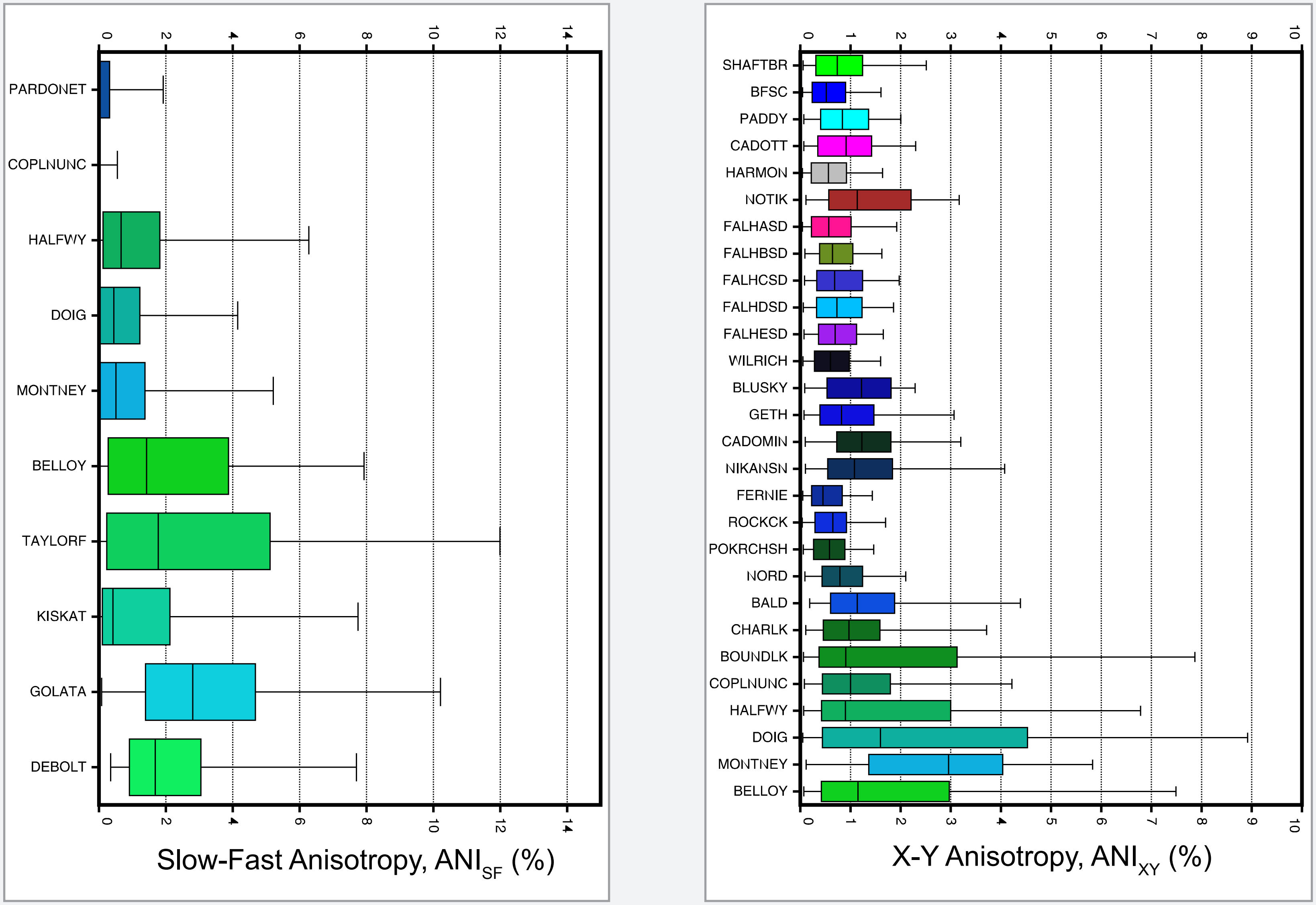
GCWD

Author	M.Soltanzadeh
Reviewer	A. Fox
Graphics	P. Patton
Created	24-Jun-2015

An Example of Anisotropy Analysis for well 100/08-22-082-20W6/00 in the Belloy Study Area

Canadian Discovery Ltd.

Figure 3.7



BELLOY AND DEBOLT WATER DISPOSAL ZONES IN THE MONTNEY PLAY FAIRWAY, NEBC

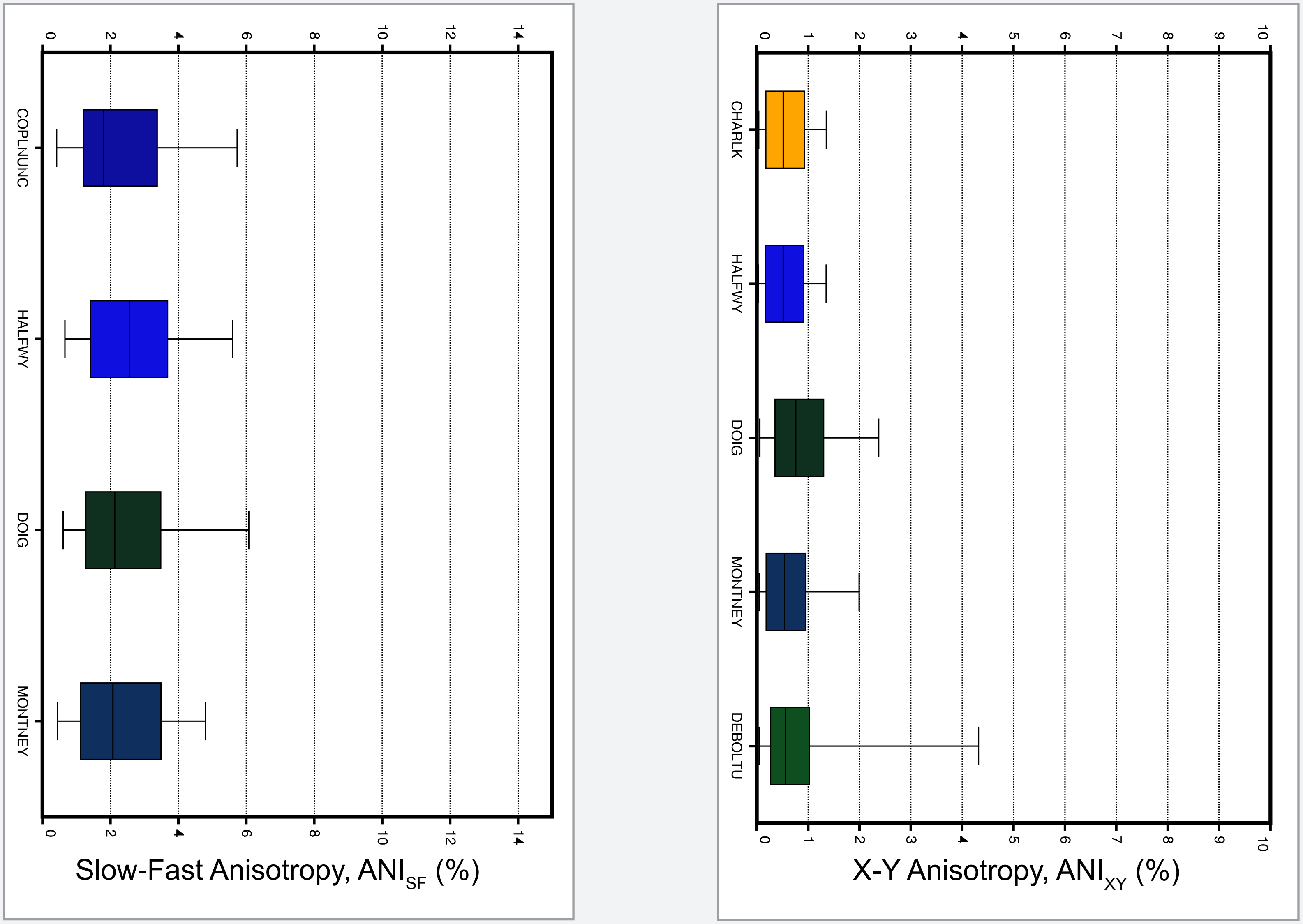
GCWD

Author	M.Soltanzadeh
Reviewer	A. Fox
Graphics	P. Patton
Created	24-Jun-2015

Stratigraphic Distribution of Slow-Fast Anisotropy Index (ANI$_{SF}$) Based on Data from 6 Wells and X-Y Anisotropy Index (ANI$_{XY}$) Based on Data from 11 Wells for the Belloy Study Area

Canadian Discovery Ltd.

Figure
3.8



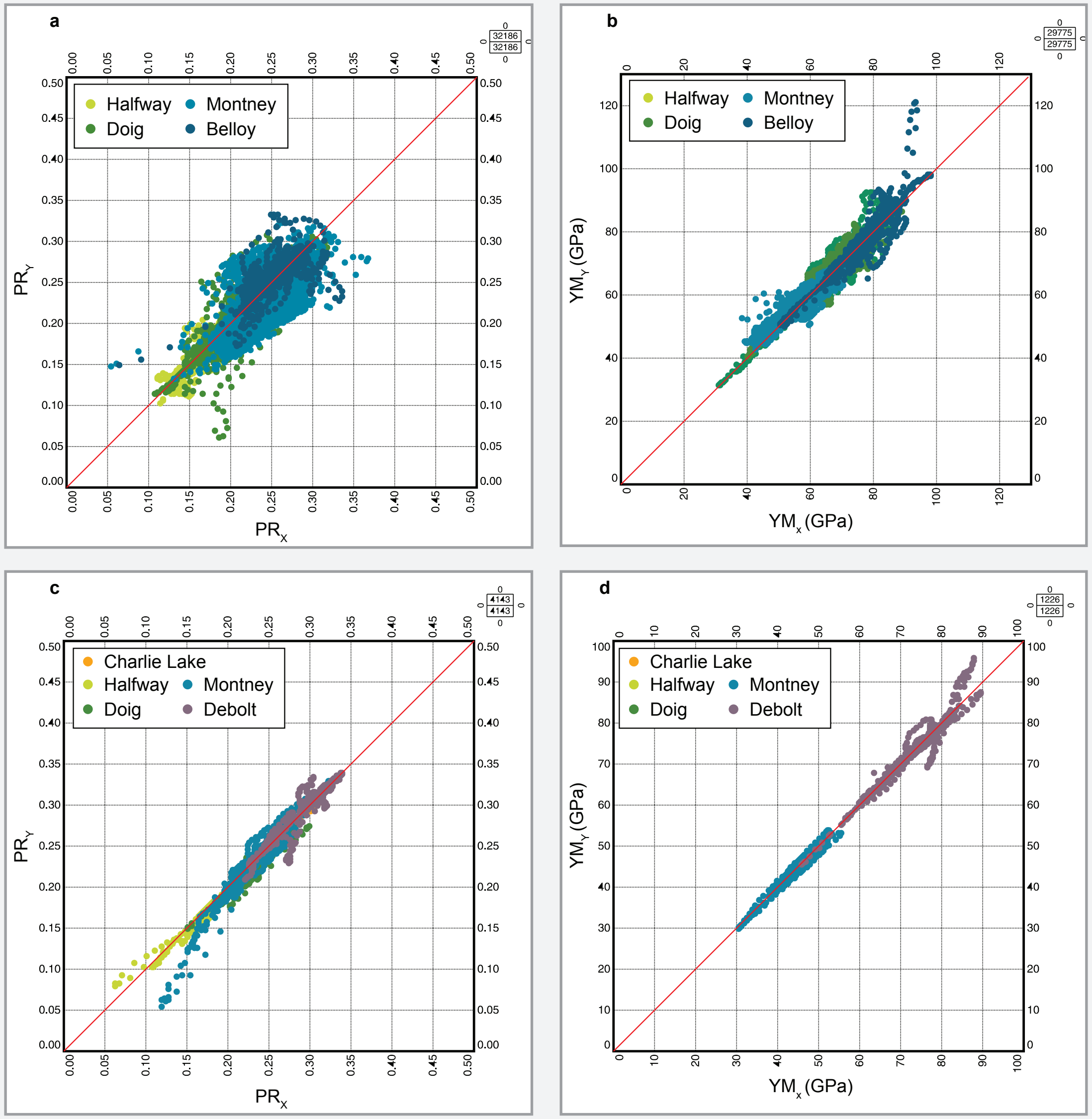
BELLOY AND DEBOLT WATER DISPOSAL ZONES IN THE MONTNEY PLAY FAIRWAY, NEBC	GCWD

Author	M.Soltanzadeh
Reviewer	A. Fox
Graphics	P. Patton
Created	24-Jun-2015

Stratigraphic Distribution of Slow-Fast Anisotropy Index (ANI$_{SF}$) Based on Data from One Well and X-Y Anisotropy Index (ANI$_{XY}$) Based on Data from Two Wells for the Debolt Study Area

Canadian Discovery Ltd.

Figure 3.9



BELLOY AND DEBOLT WATER DISPOSAL ZONES IN THE MONTNEY PLAY FAIRWAY, NEBC

GCWD

Author M.Soltanzadeh
Reviewer A. Fox
Graphics P. Patton
Created 24-Jun-2015

Crossplots between Directional (X-Y) Elastic Properties:
(a) Poisson's Ratio in the Belloy Study Area (b) Young's Modulus in the Belloy Study Area,
(c) Poisson's Ratio in the Debolt Study Area (d) Young's Modulus in the Debolt Study Area

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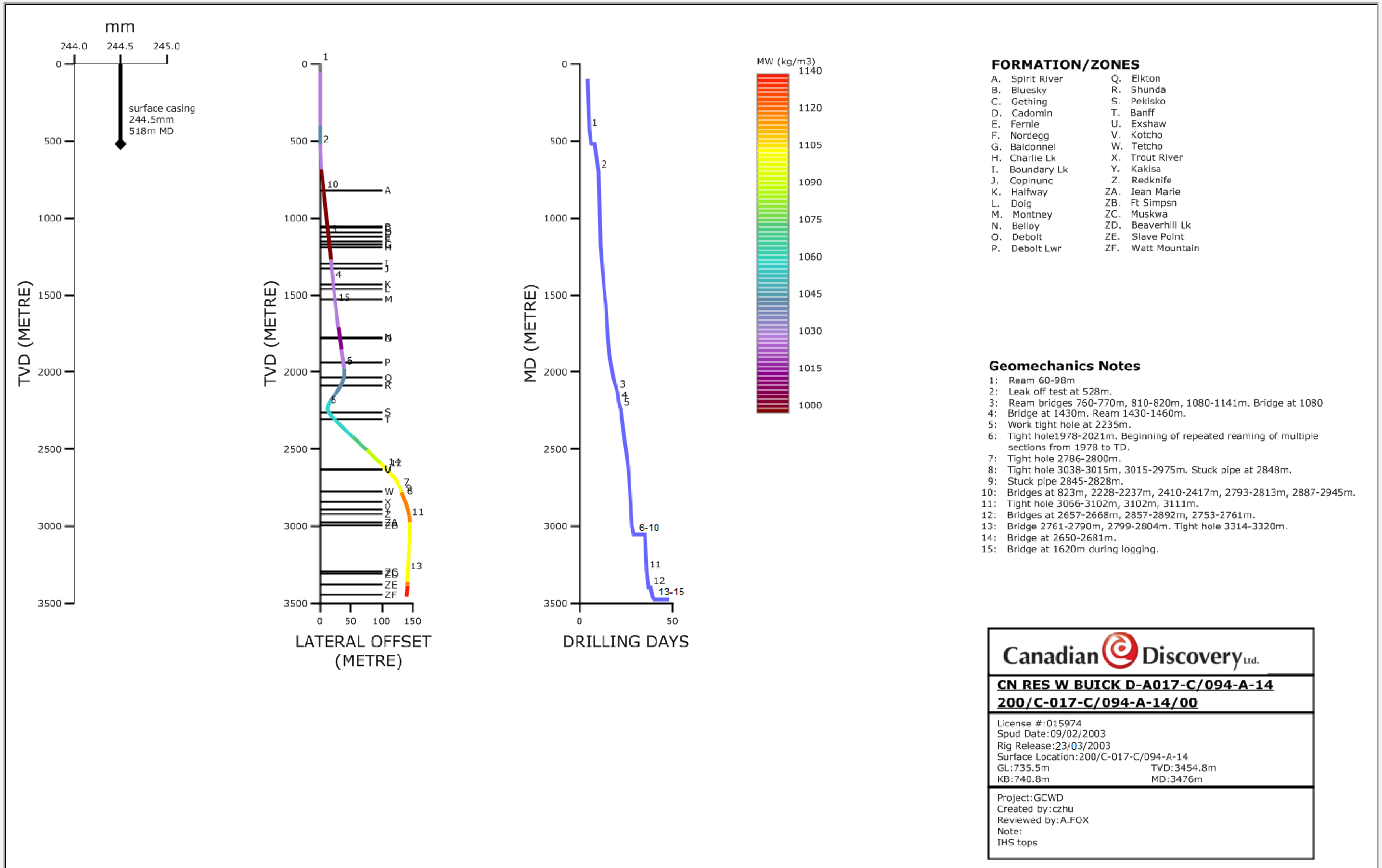
Figure
3.10



BELLOY AND DEBOLT WATER DISPOSAL ZONES IN THE MONTNEY PLAY FAIRWAY, NEBC

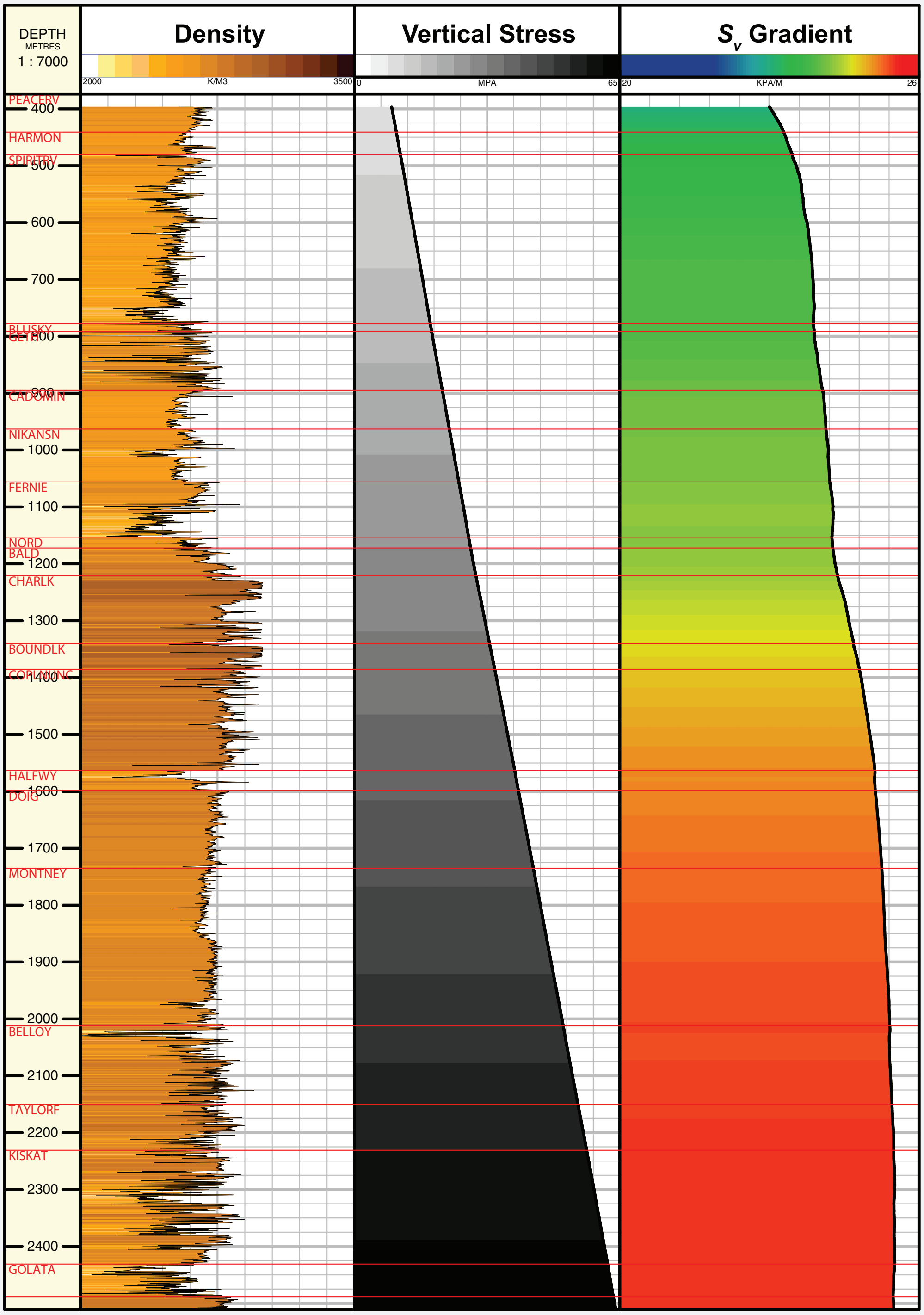
GCWD

Author	M.Soltanzadeh
Reviewer	A.Fox
Graphics	P.Patton
Created	25-Jun-2015

Example of Graphic Drilling Experience Review for Well 200/C-017-C/094-A-14/00 in the Debolt Study Area

Canadian Discovery Ltd.

Figure 3.11



Quality Control Parameters:

- *397m* of missing log at the beginning of the well
- Percentage of missing data: *0%*
- Relative quality compared to a perfect well: *72%*

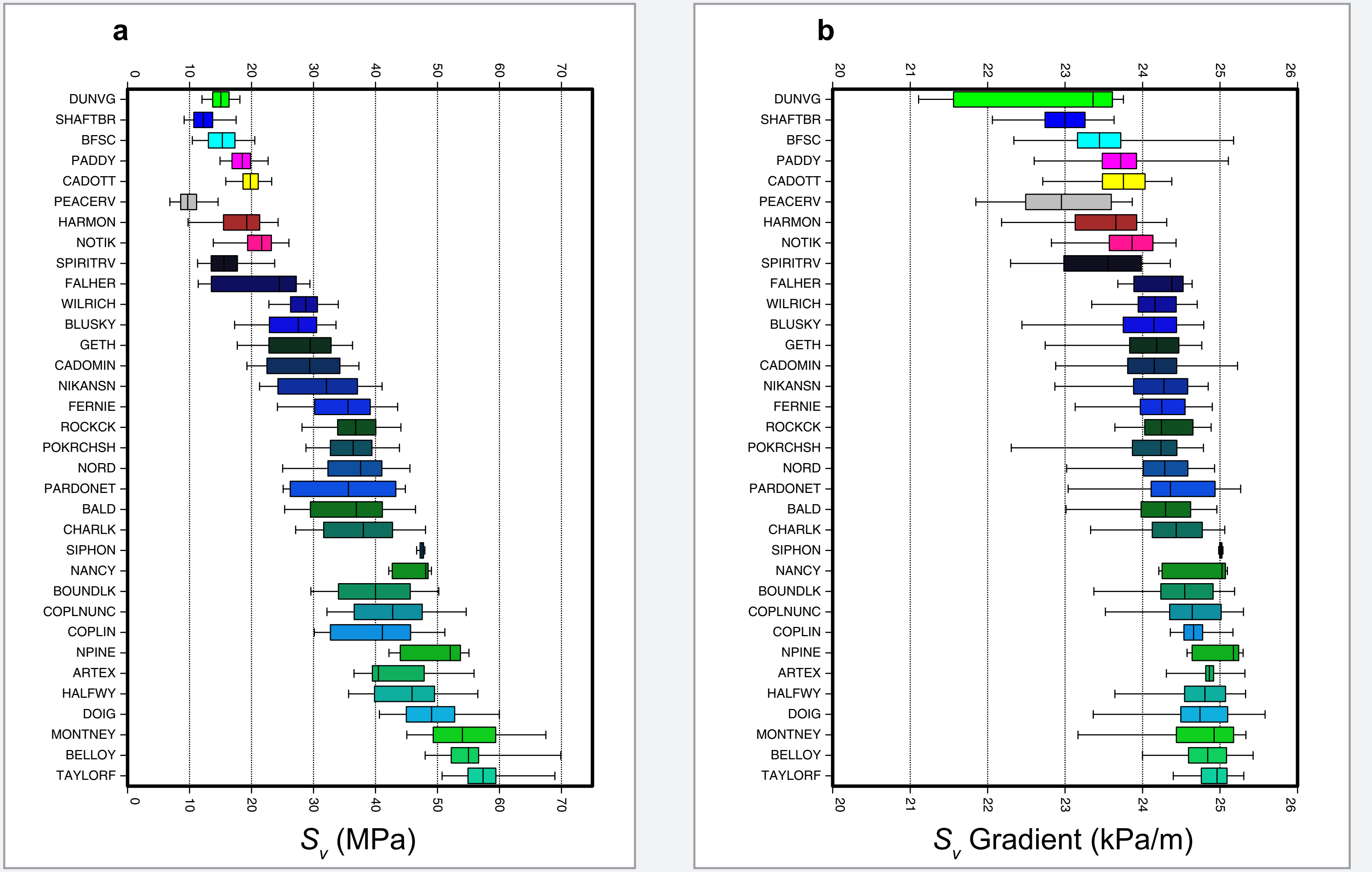
BELLOY AND DEBOLT WATER DISPOSAL ZONES IN THE MONTNEY PLAY FAIRWAY, NEBC | **GCWD**

Author M.Soltanzadeh
Reviewer A.Fox
Graphics P. Patton
Created 24-Jun-2015

Example Calculation of Vertical Stress for Well 100/10-27-082-20W6/00 in the Belloy Study Area

Canadian Discovery Ltd.

Figure **3.12**



BELLOY AND DEBOLT WATER DISPOSAL ZONES IN THE MONTNEY PLAY FAIRWAY, NEBC

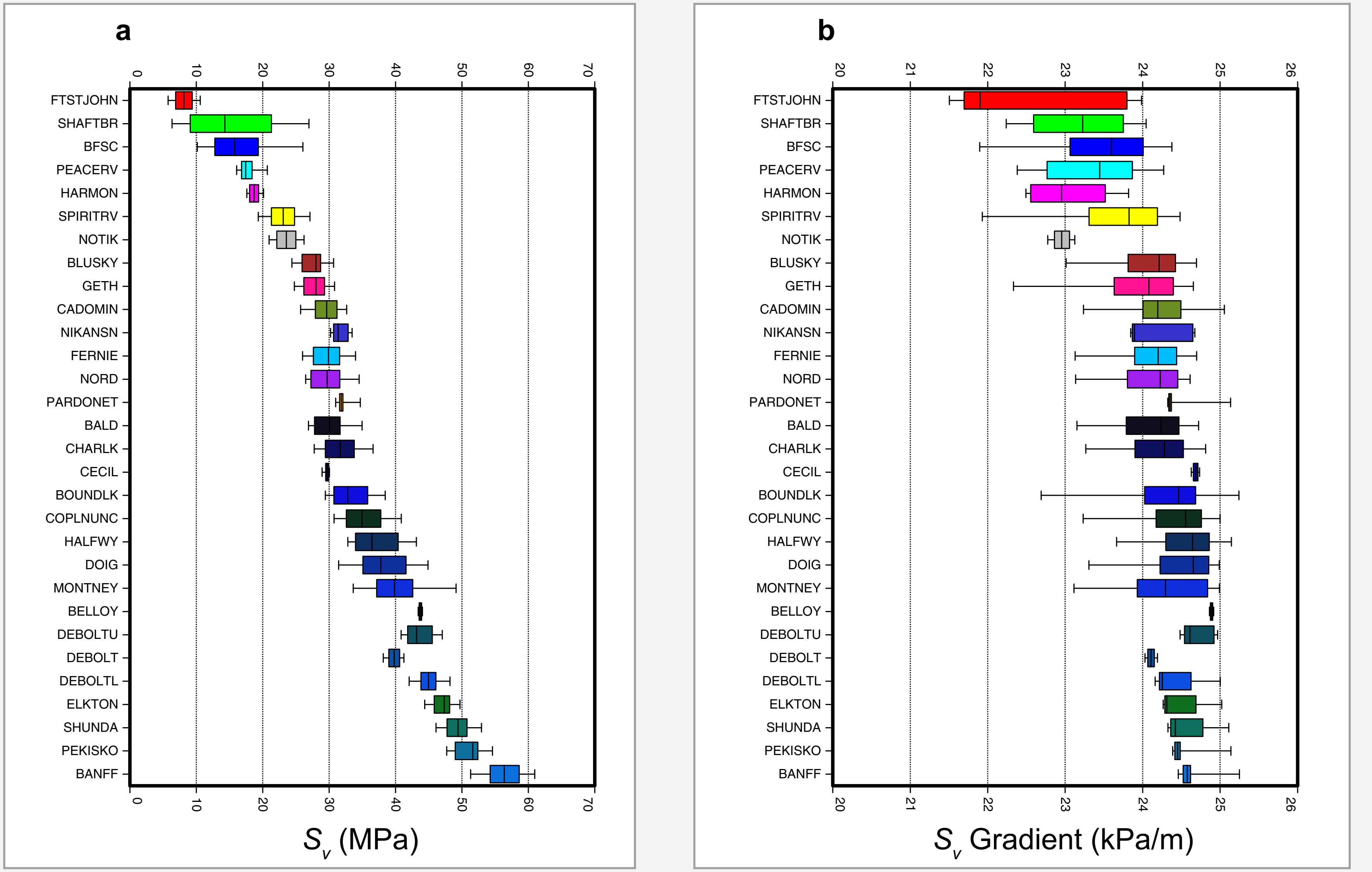
GCWD

Author	M.Soltanzadeh
Reviewer	A. Fox
Graphics	P. Patton
Created	24-Jun-2015

Stratigraphic Variation of (a) Vertical Stress and (b) Stress/Depth Graditent (Depth in TVD) in the Belloy Study Area Based on Data from 86 Wells

Canadian Discovery Ltd.

Figure **3.13**



BELLOY AND DEBOLT WATER DISPOSAL ZONES IN THE MONTNEY PLAY FAIRWAY, NEBC

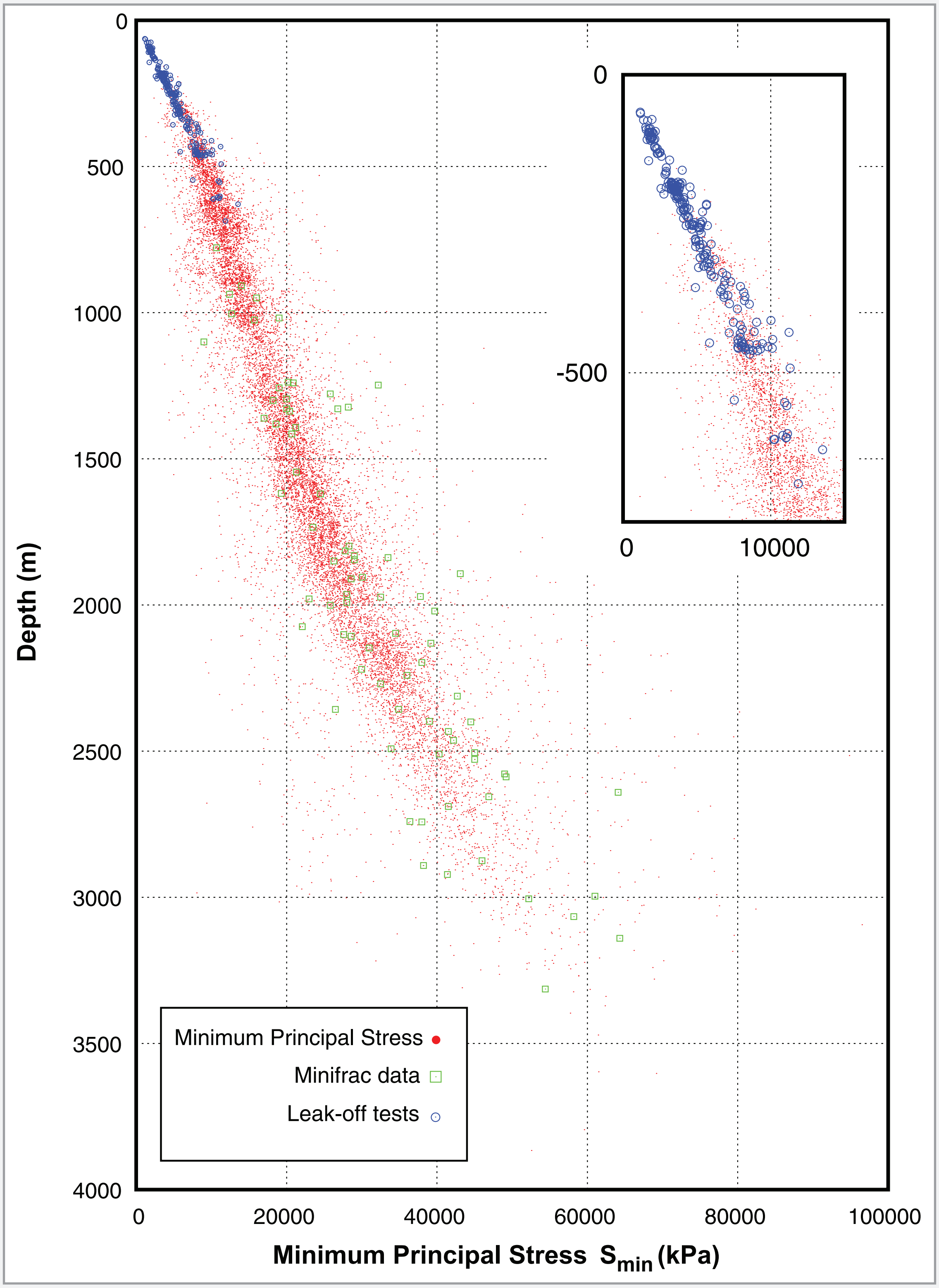
GCWD

Author M.Soltanzadeh
Reviewer A. Fox
Graphics P. Patton
Created 24-Jun-2015

Stratigraphic Variation of (a) Vertical Stress and (b) Stress/Depth Graditent (Depth in TVD) in the Debolt Study Area Based on Data from 56 Wells

Canadian Discovery Ltd.

Figure 3.14



(from CDL's 2006 Stress Analysis – Central Alberta regional study)

BELLOY AND DEBOLT WATER DISPOSAL ZONES IN THE MONTNEY PLAY FAIRWAY, NEBC

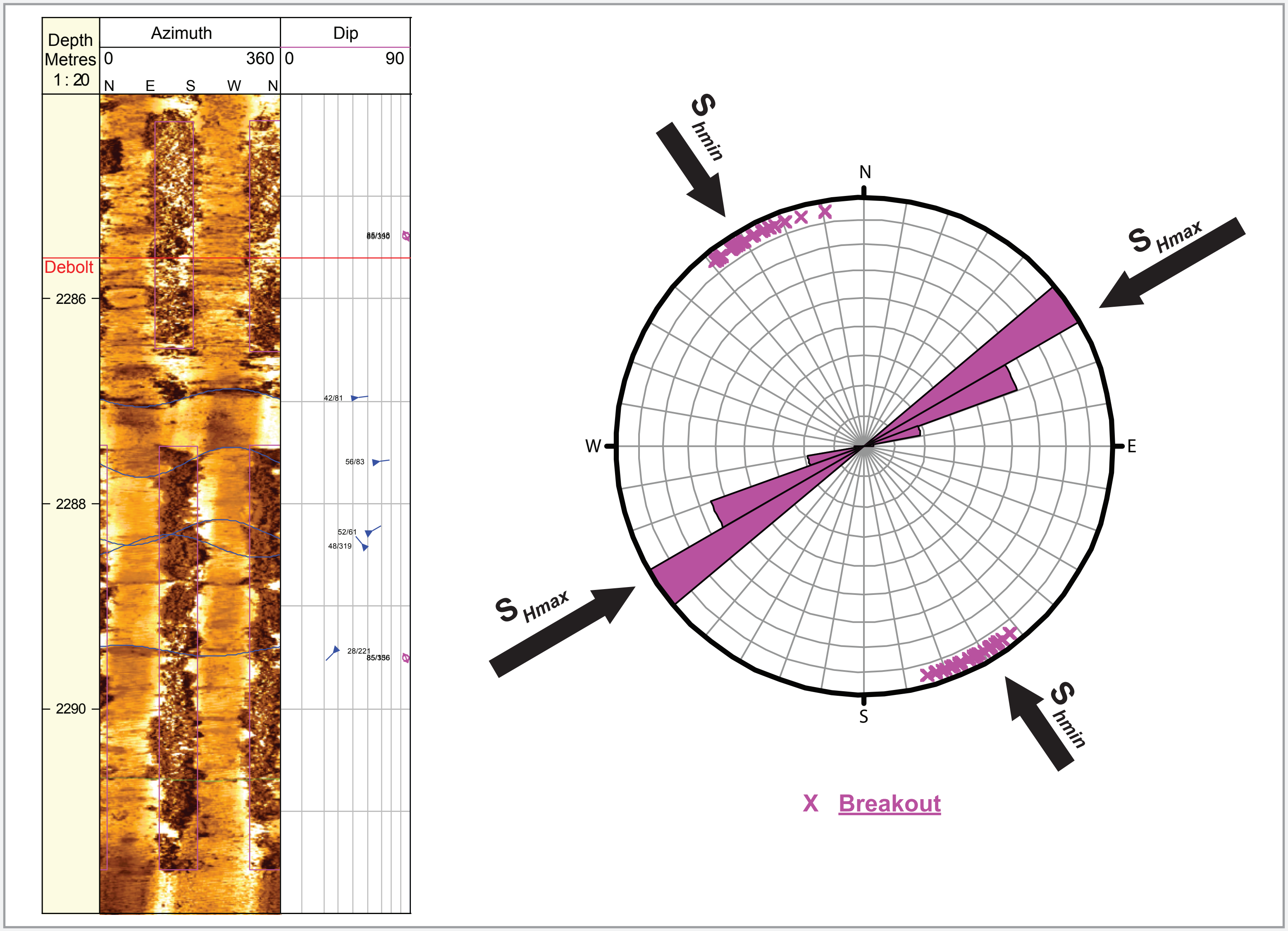
GCWD

Author	N.Watson
Reviewer	S.Hawkes
Graphics	P.Patton
Created	24-Jun-2015

Comparison of Minimum Stress Values Calculated as 85% of Hydraulic Fracture Stage Instantaneous Shut-in Pressures (red) versus those Determined from Leak-off tests (blue) and Minifracs (green) in Central Alberta

Canadian Discovery Ltd.

Figure **3.15**



BELLOY AND DEBOLT WATER DISPOSAL ZONES IN THE MONTNEY PLAY FAIRWAY, NEBC

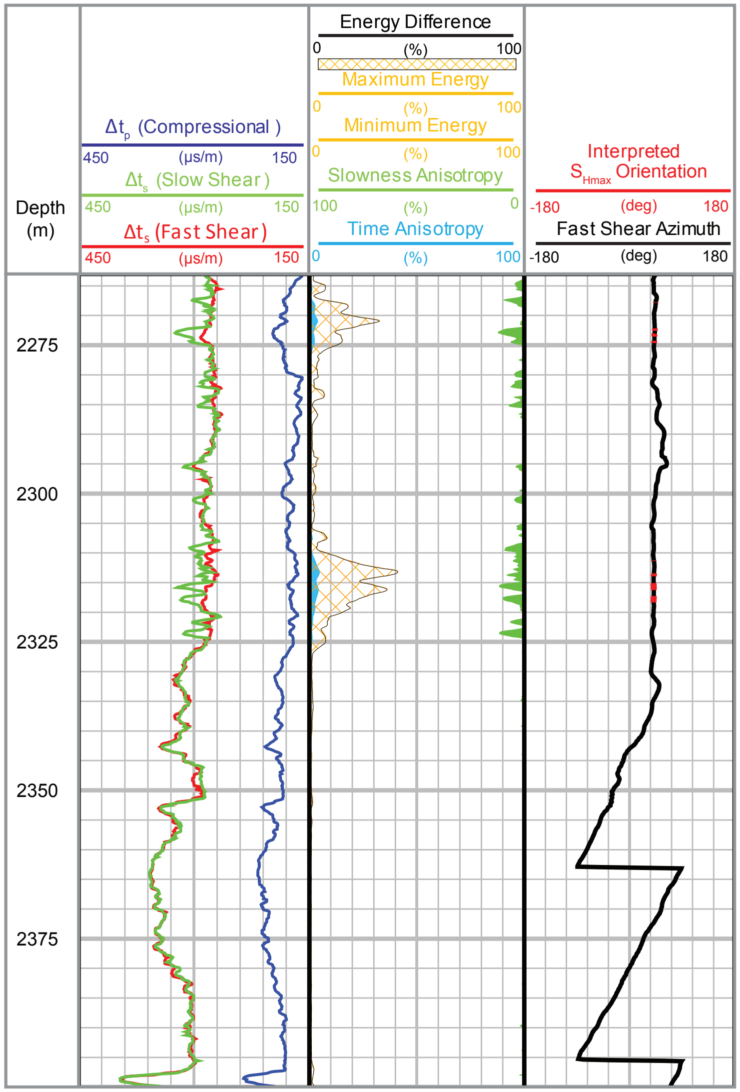
GCWD

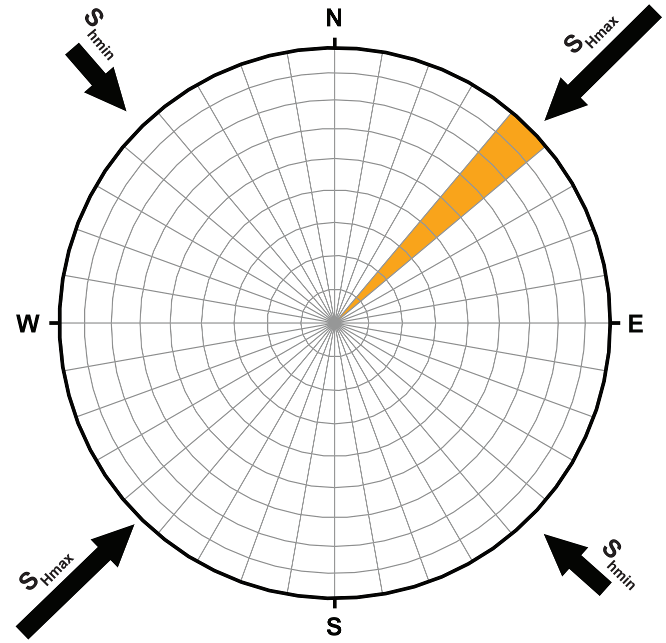
Author	M.Soltanzadeh
Reviewer	A. Fox
Graphics	P. Patton
Created	24-Jun-2015

Example of Borehole Breakouts in an Acoustic Image Log
and the Inferred In Situ Stress Orientation
in Well 200/A-018-D/094-A-13/00 in the Debolt Study Area

Canadian Discovery Ltd.

Figure
3.16





BELLOY AND DEBOLT WATER DISPOSAL ZONES IN THE MONTNEY PLAY FAIRWAY, NEBC

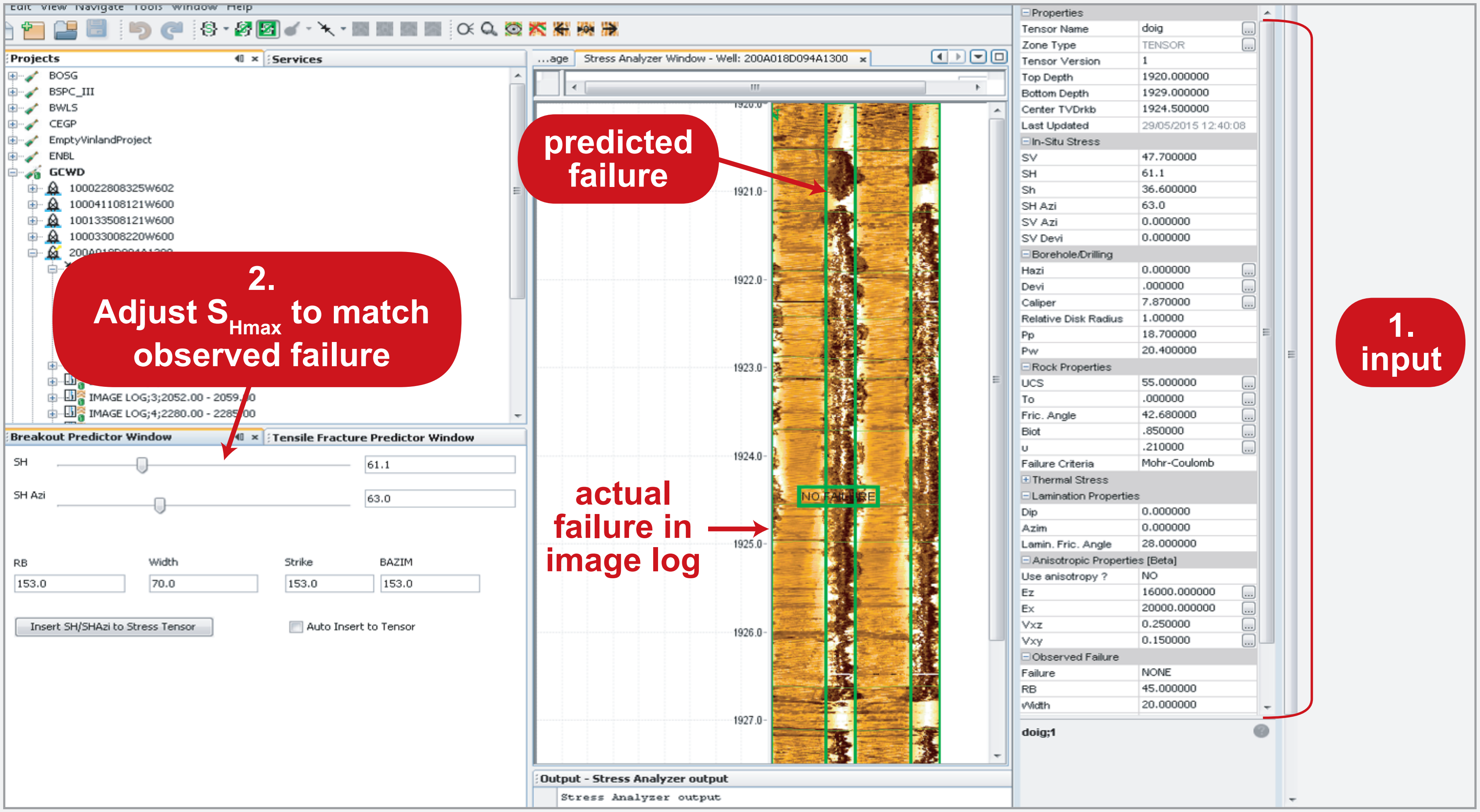
GCWD

Author M.Soltanzadeh
Reviewer A. Fox
Graphics P. Patton
Created 24-Jun-2015

Example of Stress Orientation from Fast Shear Azimuth in a Sonic Scanner Log from Well 100/01-27-078-17W6/00 Very Close to the Belloy Study Area

Canadian Discovery Ltd.

Figure 3.17



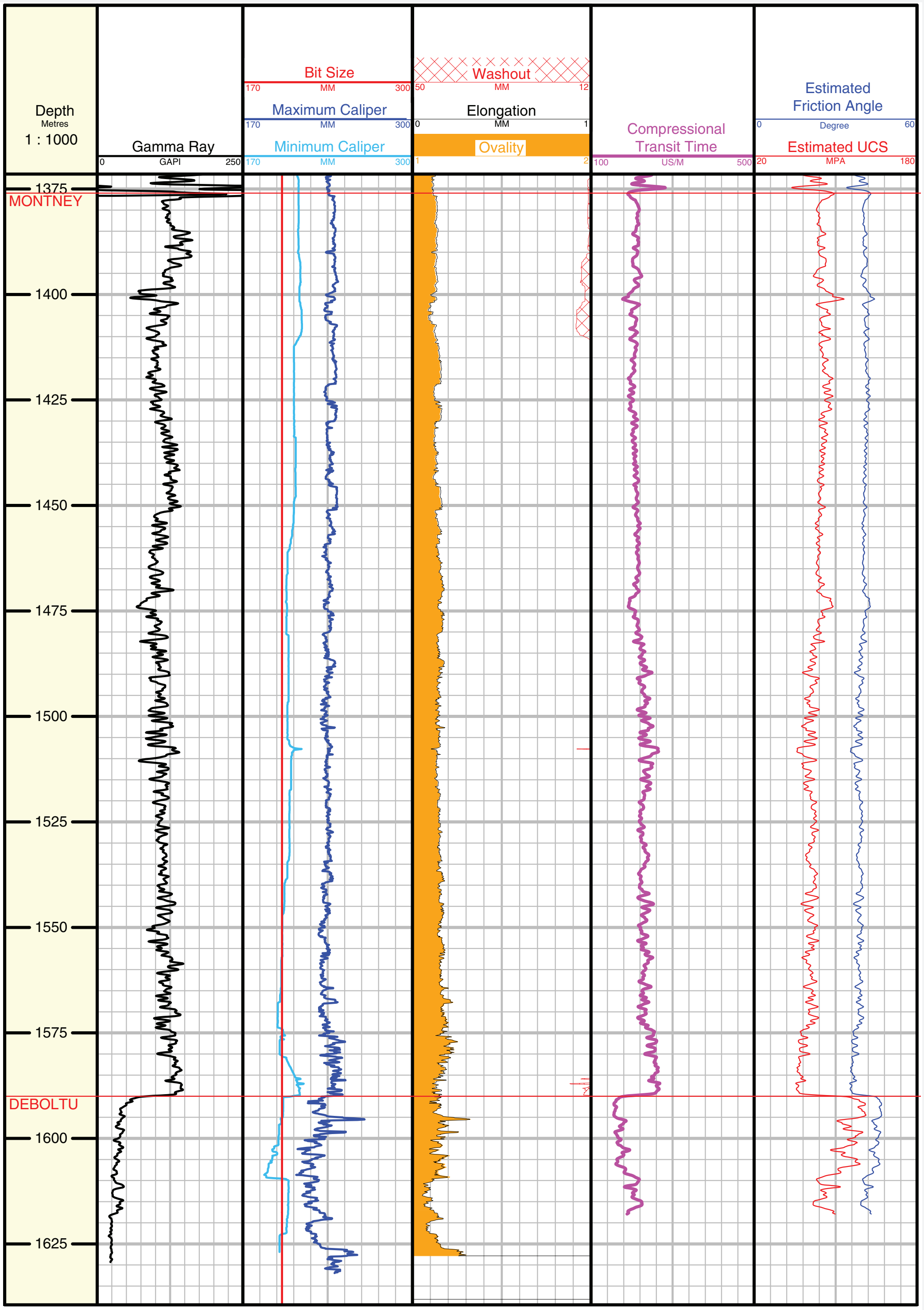
BELLOY AND DEBOLT WATER DISPOSAL ZONES IN THE MONTNEY PLAY FAIRWAY, NEBC | GCWD

Author	M.Soltanzadeh
Reviewer	A. Fox
Graphics	P. Patton
Created	24-Jun-2015

Example of Maximum Horizontal Stress (S_{Hmax}) Modeling Approach Comparing Predicted vs. Actual Wellbore Failure for Well 200/a-018-D/094-A-13/00 Very Close to the Debolt Study Area

Canadian Discovery Ltd.

Figure **3.18**



Note: Estimated strength properties in the last track are based on the correlations introduced by Lal (1999) and Kelessidis (2011). It is important to note that these empirical correlations may not always represent the rock properties accurately.

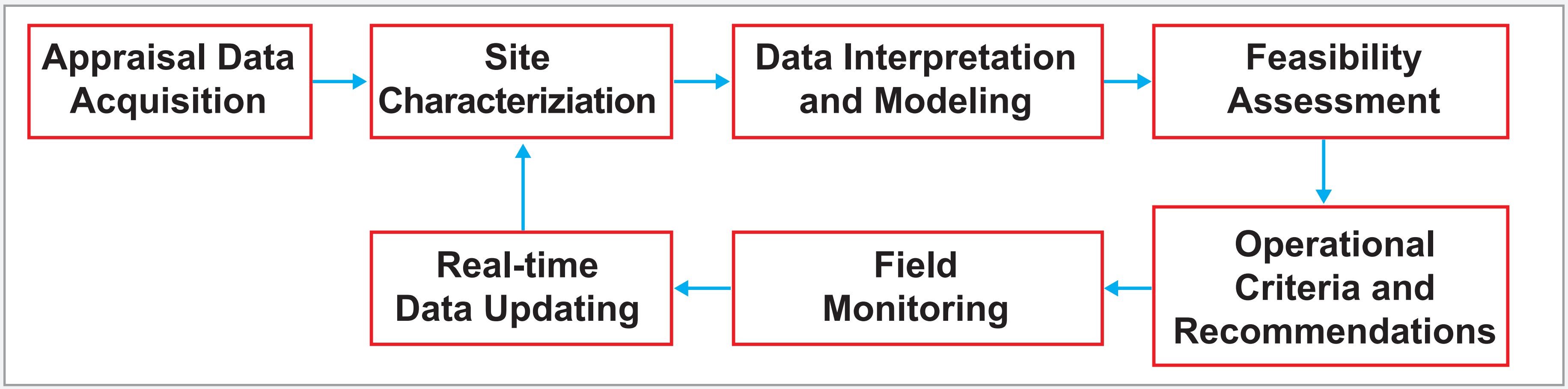
BELLOY AND DEBOLT WATER DISPOSAL ZONES IN THE MONTNEY PLAY FAIRWAY, NEBC | **GCWD**

Author	M.Soltanzadeh
Reviewer	A.Fox
Graphics	P.Patton
Created	24-Jun-2015

Example of Breakout Analysis Based on Caliper Logs for Well 202/c-025-B/094-H-03/00 in the Debolt Study Area

Canadian Discovery Ltd.

Figure **3.19**



BELLOY AND DEBOLT WATER DISPOSAL ZONES IN THE MONTNEY PLAY FAIRWAY, NEBC

GCWD

Author	M.Soltanzadeh
Reviewer	A. Fox
Graphics	P. Patton
Created	24-Jun-2015

The Workflow for
Integrated Containment Assessment Program
(ICAP)

Canadian Discovery Ltd.

Figure 4.1

TABLE 1.1. SOUTHERN AND NORTHERN MONTNEY PRODUCING FIELDS

MUPF	Montney Producing Fields
Southern Play Area	Attachie, Rassey, Briar Ridge, Dawson, Doe, Groundbirch, Heritage, Jackpine, Kelly, Monias, Parkland ,Saturn, Septimus, Sundown, Sunrise, Sunset, Sunset Prairie, Swan, Tower, Tupper, Wilder
Northern Play Area	Altares, Beg, Birch, Blair, Blair Creek, Blueberry, Caribou, Cypress, Daiber, Fireweed, Graham, Green, Gundy, Inga, Jedney, Julienne, Kobes, Lily, Nig, Town, Townsend, Umbach, W. Blueberry, W. Buick, W. Farrell, W. Gundy

TABLE 3.1. POTENTIAL GEOMECHANICS-RELATED DRILLING EVENTS

Mechanisms	Potential Symptoms	Mitigation Tactics
•Excessive breakout or washout due to stress concentration around the well	•Hole cleaning problems, high volumes of cuttings on shakers	•Increase mud weight
•Rock strength anisotropy (weak bedding or fissile rock)	•Stuck pipe, pack off, tight hole	•Modify well trajectory
	•Fill on bottom, tagging high	
	•Cavings	
	-splintery ("pressure"), or	
	-platy/tabular	
•Mud penetration into pre-existing natural fractures or faults	•Hole cleaning problems, stuck pipe, pack off, tight hole	•Change mud weight or type
	•Bridges	•Prevent mud penetration
	•Blocky cavings ("rubble")	
	•Lost circulation that returns when pressure decreases (wellbore "breathing" or "ballooning")	
	•Increasing problems as exposure time increases	
	•Jammed core barrel	
•Unintentional hydraulic fracture	•Lost circulation	•Reduce mud weight
•Chemically-reactive shales (swelling)	•Sloughing shales	•Change mud chemistry, type and/or salinity
	•Bit balling	
	•Swollen shales coming out of the hole	
	•Mud changes (e.g., milky, thick, sticky)	
	•Stuck pipe and pack off	
•Kicks or blowouts	•Unexpectedly high pore pressure	•Raise mud weight

TABLE 3.2. DATA AVAILABILITY FOR S_{HMAX} MODELING IN THE BELLOY STUDY AREA

Logs/tests Available	100033008220W600	100041108121w600	100133508121W600	100052907720W600	100072408016W600	100130208015W600	100153207814W600	100113507916W600	100122508117W600
Image Log	Doig/Montney (Quality D)	Montney/Belloy (Quality C)	Montney/Belloy (Quality A)	Doig (Quality B)					
Dipole	x	x	x	x	x				
Cross-dipole			x		x				
Sonic log	x		x	x	x	x	x	x	x
Caliper	x	x	x	x	x	x	x	x	x
Anisotropy			x						
Density	x		x	x		x	x	x	x
X-ray	x	x	x						
strip-logs			x	x	x	x	x	x	x
Formation Pressure Test	Halfway/Belloy/Taylor flat			Montney		Kiskatinaw			Belloy
core photos	Montney	Doig/Montney							
Modeling Formation	Doig	Montney and Belloy	Montney and Belloy	Doig	Belloy	Belloy	Belloy	Belloy/Montney	Belloy
Type of Failure	Breakouts in Doig	Breakouts seen in Belloy	Breakouts in Montney and Belloy	Breakout in Doig	Wellbore Enlargement	Wellobre Enlargement	Wellobre Enlargement	Wellobre Enlargement	Wellobre Enlargement
Permeability test		x	x						
Source rock analysis		x						x	

TABLE 3.3. DATA AVAILABILITY FOR S_{HMAX} MODELING IN THE DEBOLT STUDY AREA

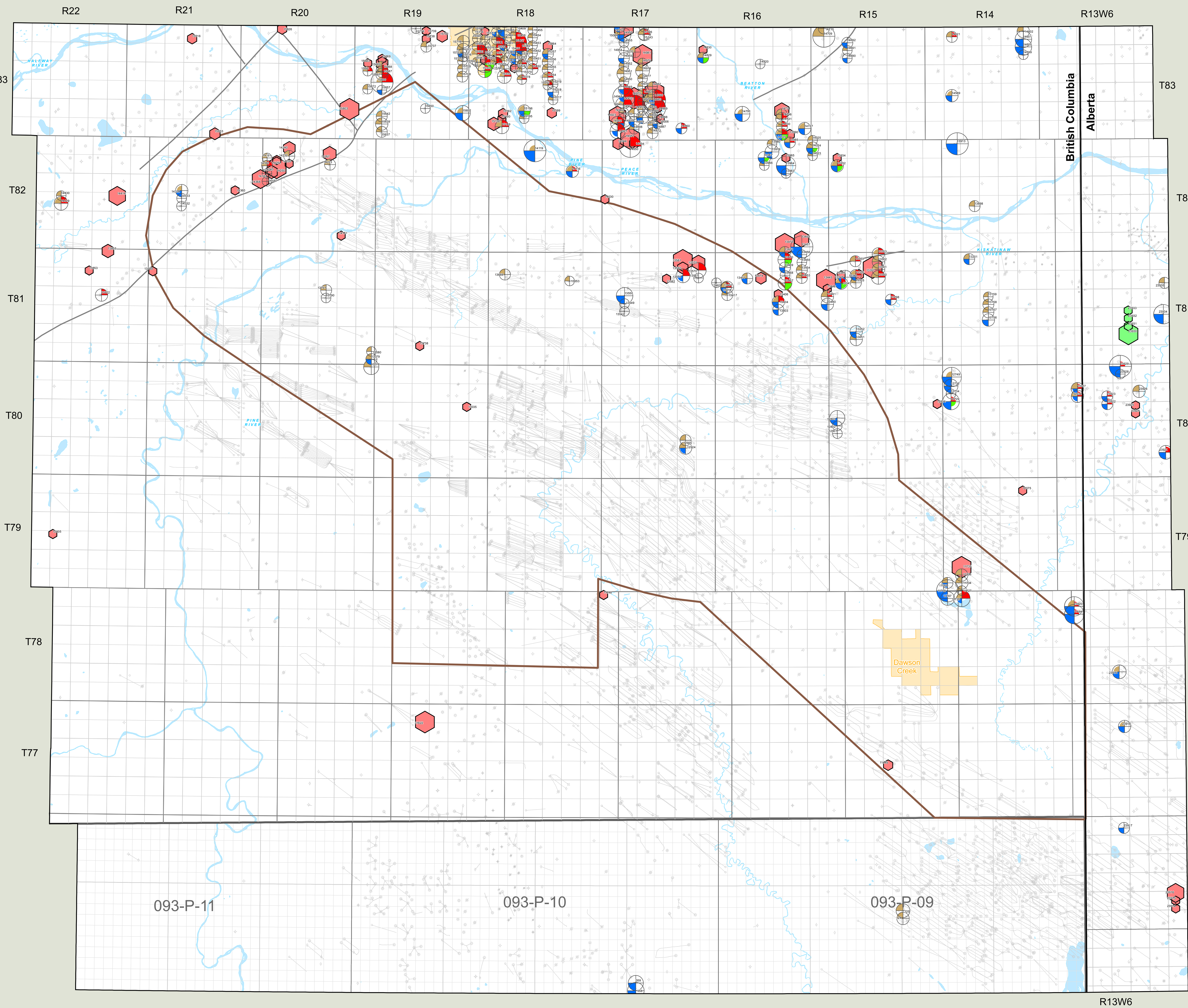
Logs/tests Available	200A018D094A1300	200B007L094A1200	200C017C094A1400	202A041A094H0400	202C025B094H0300	200D067D094H0300
Image Log	Belloy (quality A)	Debolt (Quality B)				
Dipole		no imported				
Cross-dipole						
Sonic log	x	x	x	x	x	x
Caliper	x	x	x	x	x	x
Anisotropy						
Density	x	x	x	x	x	x
X-ray						
strip-logs	x		x	x	x	x
Formation Pressure Test		Debolt			Halfway/Baldonel	Debolt/Montney
core photos					x	
Modeling Formation	Halfway/Doig/Montney/Belloy/Debolt	Debolt	Montney	Debolt	Debolt/Montney	Debolt
Type of Failure	Breakouts entire Imaged depth section	Breakouts in Debolt	Wellbore Enlargement	Wellbore Enlargement	Wellbore Enlargement	Wellbore Enlargement
Permeability test						
Source rock analysis						

TABLE 3.4. INPUT DATA AND S_{HMAX} MODELING RESLUTS IN THE BELLOY STUDY AREA

Well	Formation	Depth Interval	Dominant Lithology	UCS-Model	Type of Failure	Pp (kPa/m)	Sv (kPa/m)	Shmin(kPa/m)	SHmax (kPa/m)	Data Type
100/04-11-081-21W6/00	Montney	225-2258	Shale	Horsrud	No breakouts	11.4	24.4	20.7	<31.5	Image Log
100/04-11-081-21W6/00	Belloy	2341-2350	Limestone	Carbonate-Militzer	Consistent Breakouts	9.6	25	19	32.1	Image Log
100/13-35-081-21W6/00	Lower Montney	2133-2137	Shale	Horsrud	Consistent Breakouts	12	25.3	21.7	32.3	Image Log
100/13-35-081-21W6/00	Belloy	2191-2195	Limestone	Carbonate-Militzer	Consistent Breakouts	10	25.3	19	31.4	Image Log
100/03-30-082-20W6/00	Doig	1681-1687	Shale	Horsrud	Isolated Breakouts	10.2	24.8	22.8	31.5	Image Log
100/03-30-082-20W6/00	Montney	1917-1923	Siltstone	McNally	Consistent Breakouts	11.5	24.7	22	32.5	Image Log
100/05-29-077-20W6/00	Doig	2803-2829	Shale	Horsrud	Consistent Breakouts	11	25.5	22.4	31.6	Image Log
100/07-24-080-16-W6/00	Belloy	2350-2357	Carbonate	Militzer	Isolated Breakout	9.4	24.5	19	>30.2	Caliper
100/13-02-080-15-W6/00	Belloy	2360-2450	Carbonate	Militzer	Consistent Breakouts	9.8	24.4	19	>28	Caliper
100/15-32-078-14W6/00	Belloy	2420-2480	Carbonate	Militzer	Consistent Breakouts	9.9	25.1	19	>26.7	Caliper
100/11-35-079-16W6/00	Belloy	2460-2520	Carbonate	Militzer	Consistent Breakouts	9.6	25.3	19	>27.3	Caliper
100/11-35-079-16W6/00	Montney	2360-2400	Siltstone	Mc-Nally	No Breakouts	14	24.8	21	<29.4	Caliper
100/12-25-081-17W6/00	Belloy	2200-2268	Carbonate	Militzer	Consistent Breakouts	9.6	24.8	19	>30.5	Caliper

TABLE 3.5. INPUT DATA AND S_{HMAX} MODELING RESULTS IN THE DEBOLT STUDY AREA

Well	Formation	Depth Interval	Dominant Lithology	UCS-Model	Type of Failure	Pp (kPa/m)	Sv (kPa/m)	Shmin(kPa/m)	SHmax (kPa/m)	Data Type
200B007L094A1200	Debolt	2102-2111	Dolomite	Kassi-General	Consistent Breakouts	9.3	25.2	17	31.8	Image Log
200B007L094A1200	Debolt	2149-2158	Dolomite	Kassi-General	Induced Tensile Fractures	9.3	25.2	17	31.8	Image Log
200A018D094A1300	Doig	1920-1931	Silstone	Kassi-General	Consistent Breakouts	9.7	24.8	19	31.7	Image Log
200A018D094A1300	Montney	2052-2059	Silstone	Mc-Nally	No Breakouts	14.5	24.8	21	<32.8	Caliper
200A018D094A1300	Debolt	2286-2293	Limestone	Carbonate-Militzer	Consistent Breakouts	8.2	25	17.5	>31.6	Caliper
200C017C094A1400	Montney	1745-1770	Shale	Horsrud	Consistent Breakouts	12.5	24.8	22	>27.1	Caliper
202A041A094H0400	Debolt	1858-1875	Carbonate	Militzer	Consistent Breakouts	8.6	24.8	16.5	>26.4	Caliper
202C025B094H0300	Debolt	1589-1609	Carbonate	Militzer	Consistent Breakouts	8.6	24.1	16.5	>30.4	Caliper
202C025B094H0300	Montney	1380-1580	Shale	Horsrud	Consistent Breakouts	10.5	24.1	16.8	>30.5	Caliper
200D067D094H0300	Debolt	1742-1799	Carbonate	Militzer	Consistent Breakouts	8.6	24.2	16.5	>30.3	Caliper



Key to Recoveries

AOF (Gas Oil)								
DST								
x 10^6 m^3/d	< 3	+ 3	+ 14	+ 28	+ 57	+ 85	+ 113	+ 142
m	< 30	+ 30	+ 150	+ 300	+ 600	+ 900	+ 1200	+ 1500
MMCF/d	< 0.1	+ 0.1	+ 0.5	+ 1.0	+ 2.0	+ 3.0	+ 4.0	+ 5.0
ft	< 100 ft	+ 100 ft	+ 500 ft	+ 1,000 ft	+ 2,000 ft	+ 3,000 ft	+ 4,000 ft	+ 5,000 ft

Note
- Quadrart indicates type of fluid recovered
- Radius indicates volume of fluid recovered

Mud Gas Water Oil

Example Recovery

+ 5 MMCF/d Gas	+ 142 x 10^6 m^3/d Gas
+ 1000 ft Oil-Cut Water	+ 300m Oil-Cut Water
+ 500 ft Mud	+ 150m Mud

Ref Num

Structural and Geological Features

Fault

Focus Area

Belloy Focus Area

1:150,000

0 1.5 3 6 9 12 15 Km

Projection: UTM; Central Meridian -120.0°; North American Datum 1983

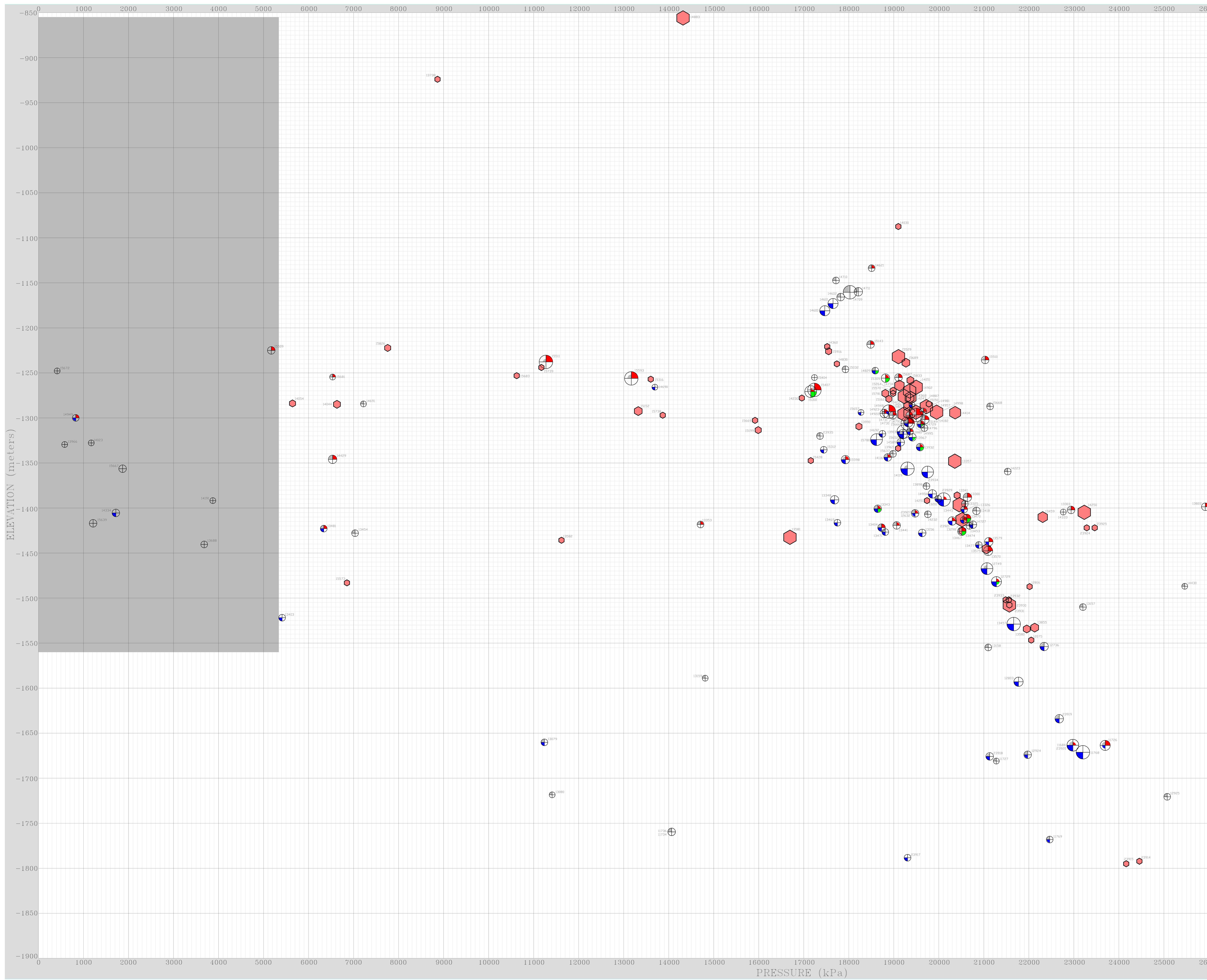
Belloy and Debolt Water Disposal Zones in the Montney Play Fairway, NEBC

Canadian Discovery Ltd.

Data | Intelligence | Expertise

Belloy Area
Belloy DST AOF Recovery (All Data)

Filename: GCWD_BELLOY_ALL_DATA_MAP.mxd		Enclosure
Author: N Watson	Project: GCWD	2.1
Cartographer: C Poletto	Created: 10-April-2015	
Reviewer: S Hawkes	Last Edited: 29-June-2015	



KEY	UWI	DST#	QC	DATE	ELEV	PMAX	FORMATION
124	200/C-070-B/093-P-09/00	8	G	10/21/1959	-2152	28462	BELLOY
125	200/C-070-B/093-P-09/00	9	F	10/23/1959	-2120	28315	BELLOY
358	200/A-010-A/093-P-10/00	6	G	06/10/1973	-2520	33150	BELLOY
359	200/A-010-A/093-P-10/00	7	C	06/10/1973	-2530	32546	BELLOY
11449	100/13-16-077-15-W6/02	2		11/26/2007	-1402	29159	MONTNEY - BELLOY
11522	100/01-18-077-17-W6/02	2		02/07/2009	-1862	37430	MONTNEY - BELLOY
11622	100/02-32-077-19-W6/00	1		02/08/2007	-2304	29577	BELLOY
11684	100/13-30-078-13-W6/00	2	C	02/27/1991	-1663	22978	BELLOY
11726	100/12-31-078-14-W6/00	12	D	03/22/1956	-1664	23696	BELLOY
11727	100/12-31-078-14-W6/00	13	F	03/23/1956	-1681	21277	BELLOY
11734	100/12-31-078-14-W6/00	21	F	09/29/1956	-1760	14065	BELLOY
11736	100/12-31-078-14-W6/00	23	P	09/29/1957	-1760	14065	BELLOY
11768	100/11-36-078-15-W6/00	2	B	09/26/1967	-1671	23201	MONTNEY - BELLOY
11769	100/11-36-078-15-W6/00	3	F	09/29/1967	-1768	22463	BELLOY
11848	100/13-36-078-18-W6/00	1		07/14/2011	-1973	26645	BELLOY - TAYLORF
12075	100/05-35-079-14-W6/00	1		07/03/2009	-1547	22053	BELLOY
12632	100/05-29-080-13-W6/00	3	F	03/27/1990	-1406	19473	MONTNEY - BELLOY
12729	100/03-30-080-14-W6/00	1	A	08/27/1988	-1482	21279	BELLOY
12736	100/03-30-080-14-W6/00	8	D	10/03/1988	-1554	22340	BELLOY
12749	100/06-31-080-14-W6/00	1	A	12/10/1997	-1467	21069	BELLOY
12803	100/06-18-080-15-W6/00	7	C	08/21/1971	-1593	21770	BELLOY
12816	100/15-24-080-15-W6/00	1		10/05/2012	-1487	22017	BELLOY
12924	100/11-11-080-17-W6/00	7	F	10/25/1968	-1674	21974	BELLOY
12925	100/11-11-080-17-W6/00	8	F	10/28/1968	-1721	25074	BELLOY
13079	100/16-36-080-20-W6/00	21	E	11/22/1954	-1660	11238	MONTNEY - BELLOY
13080	100/16-36-080-20-W6/00	22	E	11/30/1954	-1718	11411	BELLOY
13156	100/06-16-081-14-W6/00	12	D	04/03/1957	-1428	19631	BELLOY
13157	100/06-16-081-14-W6/00	13	F	05/29/1957	-1510	23201	BELLOY
13158	100/06-16-081-14-W6/00	14	F	06/02/1957	-1555	21098	BELLOY
13159	100/06-16-081-14-W6/00	15	F	06/07/1957	-1589	14810	BELLOY
13201	100/11-32-081-14-W6/00	1	D	02/18/1977	-1390	19988	BELLOY
13298	100/05-22-081-15-W6/00	1	S	08/28/1988	-1413	20552	BELLOY
13300	100/10-28-081-15-W6/00	1	F	10/02/1962	-1388	20635	MONTNEY - BELLOY
13303	100/10-28-081-15-W6/00	4	F	10/04/1962	-1402	22939	BELLOY
13325	100/06-29-081-15-W6/00	13	D	03/22/1956	-1395	20578	BELLOY
13326	100/06-29-081-15-W6/00	14	D	03/24/1956	-1402	20563	BELLOY
13341	100/15-29-081-15-W6/00	1		06/29/2000	-1386	20407	BELLOY
13343	100/07-30-081-15-W6/00	1	F	07/18/1977	-1401	18643	BELLOY
13348	100/09-30-081-15-W6/00	1	F	10/30/2001	-1391	17684	BELLOY
13353	100/11-32-081-15-W6/00	1	F	02/07/1977	-1418	14707	BELLOY
13357	100/03-33-081-15-W6/03	3		02/25/2003	-1348	20355	BELLOY
13403	100/14-15-081-16-W6/00	1	E	11/21/1999	-1522	5412	BELLOY-TAYLOR FLAT
13404	100/14-15-081-16-W6/00	2	D	11/22/1999	-1422	18728	BELLOY
13418	100/10-19-081-16-W6/00	4	F	07/25/1999	-1403	20836	MONTNEY - BELLOY
13441	100/01-24-081-16-W6/00	3	F	02/28/2004	-1419	19064	MONTNEY - BELLOY
13445	100/09-25-081-16-W6/02	2		09/15/1999	-1396	20455	BELLOY
13453	100/10-26-081-16-W6/00	7	D	08/21/1963	-1420	20681	BELLOY
13454	100/10-26-081-16-W6/00	8	E	08/23/1963	-1428	7033	BELLOY
13457	100/10-26-081-16-W6/00	11	B	08/30/1963	-1529	21663	BELLOY
13459	100/10-26-081-16-W6/02	2		07/05/2000	-1410	22308	BELLOY
13467	100/07-27-081-16-W6/00	5	D	02/23/1968	-1426	20511	BELLOY
13469	100/07-27-081-16-W6/00	7	F	02/25/1968	-1416	17747	BELLOY
13470	100/07-27-081-16-W6/00	8	B	02/28/1968	-1411	20619	MONTNEY - BELLOY
13471	100/07-27-081-16-W6/00	9	C	02/29/1968	-1427	18811	BELLOY
13472	100/07-27-081-16-W6/02	2		06/26/1968	-1413	20517	BELLOY
13474	100/11-28-081-16-W6/00	1		11/21/2006	-1426	20524	BELLOY
13477	100/10-29-081-16-W6/00	2	C	08/24/1972	-1441	20889	BELLOY
13481	100/02-30-081-16-W6/00	3	E	07/27/2000	-1423	6337	BELLOY
13570	100/12-25-081-17-W6/03	3	S	08/14/2005	-1448	21094	BELLOY
13575	100/12-25-081-17-W6/03	3		10/10/2005	-1445	21057	BELLOY
13579	100/13-26-081-17-W6/00	1	B	11/03/2005	-1438	21110	BELLOY
13580	100/13-26-081-17-W6/00	1		12/27/2005	-1534	21953	BELLOY - TAYLORF
13581	100/13-26-081-17-W6/03	3		10/05/2009	-1433	16693	BELLOY
13582	100/11-27-081-17-W6/02	2		06/25/2008	-1436	11618	BELLOY
13688	100/16-30-081-18-W6/00	9	E	04/22/1972	-1440	3682	MONTNEY - BELLOY
13738	100/14-04-081-19-W6/00	1		03/09/1984	-924	8864	COPLNUNC - BELLOY
13822	100/11-22-081-22-W6/00	4	D	10/28/1979	-1399	25920	BELLOY
13853	100/16-28-081-22-W6/00	1		01/06/2012	-1461	33064	BELLOY
13855	100/16-34-081-22-W6/00	1		02/05/2011	-1533	22130	BELLOY - TAYLORF
13898	100/07-17-082-14-W6/00	1	C	07/16/1981	-1376	19725	BELLOY
13913	100/16-31-082-14-W6/00	1	C	03/25/1990	-1315	19221	BELLOY
13932	100/11-30-082-15-W6/00	2	C	08/16/1979	-1332	19584	BELLOY
13965	100/02-27-082-16-W6/00	1		06/01/1955	-1334	19096	BELLOY
13966	100/10-28-082-16-W6/00	1	E	08/03/1980	-1330	582	BELLOY
13967	100/10-28-082-16-W6/00	2	C	08/04/1980	-1322	19413	MONTNEY - BELLOY
13985	100/16-34-082-16-W6/00	5	D	11/16/1979	-1315	19358	BELLOY
13990	100/16-34-082-16-W6/00	1		11/30/2003	-1310	18226	BELLOY
14023	100/04-36-082-16-W6/00	23	E	11/17/1953	-1328	1172	BELLOY
14030	100/13-18-082-17-W6/02	2		10/19/2011	-1088	19101	BELLOY
14044	102/16-31-082-17-W6/00	1		03/22/2004	-1285	6630	BELLOY
14051	100/11-32-082-17-W6/00	1		10/18/1957	-1270	19351	BELLOY
14054	100/15-32-082-17-W6/00	1		04/12/2002	-1284	5643	BELLOY
14116	100/06-26-082-18-W6/00	4	C	10/25/1982	-1344	18865	BELLOY
14119	100/06-33-082-18-W6/00	1	C	02/22/1979	-1356	19304	BELLOY
14171	100/13-02-082-20-W6/02	2		08/26/2011	-1203	30476	MONTNEY - BELLOY
14182	100/12-19-082-20-W6/00	4	C	10/18/1980	-1293	19655	BELLOY
14191	100/12-19-082-20-W6/00	13	E	11/23/1980	-1392	3873	BELLOY-TAYLOR FLAT
14223	100/10-27-082-20-W6/00	2	F	03/17/1980	-1360	21530	BELLOY
14230	100/11-29-082-20-W6/05	5		06/22/2011	-1278	16957	BELLOY
14232	100/11-29-082-20-W6/00	2	F	07/31/1980	-1407	19756	BELLOY-TAYLOR FLAT
14243	100/03-30-082-20-W6/00	1		01/14/2008	-1278	19362	BELLOY
14250	100/07-30-082-20-W6/00	1		06/06/1980	-1405	23231	BELLOY - TAYLORF
14251	100/07-30-082-20-W6/02	2		01/24/1980	-1392	19738	BELLOY
14267	102/02-34-082-20-W6/03	3		12/03/2008	-1287	19315	BELLOY
14333	100/07-17-082-21-W6/00	3	G	07/14/1980	-1405	22765	BELLOY-TAYLOR FLAT
14334	100/07-17-082-21-W6/00	4	E	07/15/1980	-1406	1719	BELLOY-TAYLOR FLAT
14360	100/02-23-082-21-W6/04	4		04/20/2008	-1221	17521	BELLOY
14368	100/16-24-082-21-W6/03	3		02/25/2009	-1278	19374	BELLOY
14414	100/13-14-082-22-W6/00	1		01/06/2012	-1294	20362	BELLOY
14429	100/06-17-082-22-W6/00	6	D	12/14/1979	-1346	6533	BELLOY
14430	100/06-17-082-22-W6/00	7	F	01/04/1980	-1487	25463	BELLOY
14589	100/06-17-083-14-W6/00	2	C	08/07/1982	-1327	19154	BELLOY
14600	100/12-25-083-14-W6/00	2	F	08/10/1989	-1181	17467	BELLOY
14601	100/12-25-083-14-W6/00	3	C	08/11/1989	-1173	17650	BELLOY
14602	100/12-25-083-14-W6/00	4	D	08/11/1989	-1166	17820	BELLOY
14621	100/06-32-083-14-W6/00	1	F	11/20/1988	-1134	18508	BELLOY
14690	100/08-29-083-15-W6/00	8	F	08/15/1957	-1266	13693	BELLOY
14691	100/08-29-083-15-W6/00	9	E	08/16/1957	-1284	7219	BELLOY
14692	100/08-29-083-15-W6/00	10	F	08/19/1957	-1318	18747	BELLOY
14709	100/10-31-083-15-W6/00	2	G	02/04/1979	-1160	18027	BELLOY
14710	100/10-31-083-15-W6/00	3	D	02/05/1979	-1147	17715	BELLOY
14711	100/10-31-083-15-W6/00	4	C	02/08/1979	-1160	18212	BELLOY
14727	100/10-01-083-16-W6/00	4	C	07/07/1978	-1419	20758	BELLOY
14729	100/06-02-083-16-W6/00	1	D	09/13/1979	-1307	19599	BELLOY
14730	100/06-02-083-16-W6/00	2	D	09/14/1979	-1297	19343	MONTNEY - BELLOY
14731	100/06-02-083-16-W6/00	3	B	09/15/1979	-1297	18982	MONTNEY - BELLOY
14734	100/06-02-083-16-W6/00	1		11/06/1979	-1264	19125	BELLOY
14791	100/06-09-083-16-W6/00	8	B	06/19/1967	-1305	19324	BELLOY
14796	100/06-11-083-16-W6/00	3	F	11/25/1979	-1311	19680	BELLOY
14829	100/06-30-083-16-W6/00	6	C	02/07/1991	-1248	18588	BELLOY
14830	100/06-30-083-16-W6/00	1		04/22/1992	-1240	17736	BELLOY
14883	100/07-03-083-17-W6/00	1		07/04/1957	-856	14318	BELLOY
14887	100/16-03-083-17-W6/00	4	D	10/21/1956	-1285	19402	BELLOY
14902	100/10-04-083-17-W6/00	1		10/21/1957	-1266	19496	BELLOY
14922	100/08-05-083-17-W6/00	16	P	04/08/1953	-1295	18788	BELLOY
14923	100/08-05-083-17-W6/00	1		10/01/1953	-1295	19345	BELLOY
14948	100/04-09-083-17-W6/00	11	D	05/29/1956	-1293	18892	BELLOY
14949	100/04-09-083-17-W6/00	12	E	05/30/1956	-1300	827	BELLOY
14956	100/04-09-083-17-W6/00	19	G	07/02/1956	-1384	19857	BELLOY
14957	100/04-09-083-17-W6/00	1		08/07/1956	-1294	19951	BELLOY
14981	100/04-10-083-17-W6/00	1		02/18/1953	-1288	19724	BELLOY
14995	100/10-10-083-17-W6/00	12	D	01/27/1957	-1297	19498	BELLOY
14998	100/10-10-083-17-W6/00	1		06/12/1957	-1294	19489	BELLOY
15032	100/10-28-083-17-W6/00	2	F	10/04/1977	-1246	17926	BELLOY
15143	102/12-34-083-17-W6/00	3	D	08/19/1990	-1218	18484	BELLOY
15149	100/10-05-083-18-W6/02	1	S	03/30/1985	-1302	19690	BELLOY
15150	100/10-05-083-18-W6/02	2		08/21/1985	-1285	19779	BELLOY

KEY	UWI	DST#	QC	DATE	ELEV	PMAX	FORMATION
15152	100/14-05-083-18-W6/00	1		03/17/2003	-1292	13323	BELLOY
15162	100/08-08-083-18-W6/00	1		04/17/1998	-1279	18892	BELLOY
15199	100/06-11-083-18-W6/00	1		07/23/2007	-1314	15988	BELLOY
15264	100/13-14-083-18-W6/03	3		03/18/1997	-1270	18986	BELLOY
15309	100/09-19-083-18-W6/00	8	F	06/28/1956	-1256	18816	MONTNEY - BELLOY
15310	100/09-19-083-18-W6/00	9	F	06/29/1956	-1271	17154	BELLOY
15312	100/09-19-083-18-W6/00	12	F	07/07/1956	-1335	17444	BELLOY
15316	100/09-19-083-18-W6/00	1		04/19/1958	-1257	13601	BELLOY
15404	100/14-21-083-18-W6/00	20	G	07/17/1952	-1255	17237	BELLOY
15407	100/14-21-083-18-W6/00	23	P	07/17/1952	-1269	17237	BELLOY
15423	100/14-21-083-18-W6/00	1		11/04/1955	-1276	19234	BELLOY
15428	102/14-21-083-18-W6/02	2		08/17/1999	-1347	17156	BELLOY
15509	100/03-29-083-18-W6/00	14	S	07/25/1953	-1225	5171	BELLOY
15510	100/03-29-083-18-W6/00	15	S	07/26/1953	-1236	21029	BELLOY
15511	100/03-29-083-18-W6/00	16	S	07/27/1953	-1238	11273	BELLOY
15529	100/03-29-083-18-W6/00	1		07/07/1954	-1232	19104	MONTNEY - BELLOY
15570	100/04-29-083-18-W6/00	1		11/20/1996	-1273	18985	BELLOY
15573	100/01-30-083-18-W6/00	1		08/17/1999	-1483	6852	BELLOY
15593	100/03-30-083-18-W6/00	20	D	07/28/1952	-1256	13169	BELLOY
15598	100/03-30-083-18-W6/00	25	F	08/26/1952	-1346	17926	BELLOY
15637	100/06-05-083-19-W6/00	4	F	02/04/1962	-1340	18981	BELLOY
15639	100/06-05-083-19-W6/00	6	E	02/09/1962	-1417	1213	BELLOY
15652	100/07-12-083-19-W6/00	2	D	07/23/1989	-1318	19199	BELLOY
15657	100/11-17-083-19-W6/00	1	D	03/16/1961	-1294	18271	BELLOY
15666	100/11-17-083-19-W6/00	10	C	03/01/1961	-1306	19309	MONTNEY - BELLOY
15667	100/11-17-083-19-W6/00	11	E	03/06/1961	-1356	1868	BELLOY
15668	100/11-17-083-19-W6/00	12	E	03/09/1961	-1287	21139	MONTNEY - BELLOY
15669	100/11-17-083-19-W6/00	1		03/20/1961	-1303	15918	BELLOY
15672	100/10-18-083-19-W6/00	1	E	09/09/1978	-1248	415	MONTNEY - BELLOY
15681	100/10-19-083-19-W6/00	3	F	11/30/1970	-1255	6534	MONTNEY - BELLOY
15683	100/10-19-083-19-W6/00	1		01/28/1971	-1253	10623	BELLOY
15687	100/11-20-083-19-W6/00	2	C	07/11/1970	-1255	19105	BELLOY
15689	100/11-20-083-19-W6/00	1		07/22/1977	-1239	19269	BELLOY
15738	100/15-27-083-19-W6/00	1		03/15/2004	-1297	13867	BELLOY
15739	100/15-27-083-19-W6/02	2		03/19/2004	-1244	11172	BELLOY
15780	100/13-34-083-19-W6/00	14	F	08/27/1952	-1324	18616	BELLOY
15781	100/07-35-083-19-W6/00	1		02/15/2000	-1273	18811	BELLOY
15803	100/10-12-083-20-W6/02	2		03/30/2004	-1296	19228	BELLOY
15826	100/13-33-083-20-W6/00	1		10/15/2004	-1222	7757	BELLOY
15833	100/02-02-083-21-W6/00	1		01/24/2009	-1258	19369	BELLOY
15916	100/06-34-083-21-W6/00	1		06/26/2008	-1226	17552	BELLOY
23914	100/03-12-076-13-W6/00	1		06/18/2004	-1792	24456	BELLOY
23915	100/03-12-076-13-W6/00	2		03/26/2004	-1795	24163	BELLOY
23917	100/07-33-076-13-W6/00	10	P	02/13/1955	-1788	19305	BELLOY
23918	100/15-28-077-13-W6/00	3	F	02/29/1980	-1676	21130	MONTNEY - BELLOY
23919	102/11-09-078-13-W6/00	1	D	02/04/1972	-1634	22675	BELLOY
23920	100/13-30-078-13-W6/00	2	C	02/27/1991	-1663	22978	BELLOY
23921	100/07-12-080-13-W6/00	1	C	06/25/1989	-1414	20296	BELLOY
23924	100/05-23-080-13-W6/00	1		06/08/2001	-1422	23286	BELLOY
23925	100/05-23-080-13-W6/00	2		05/27/2005	-1422	23463	BELLOY
23927	100/05-29-080-13-W6/00	3	F	03/27/1990	-1406	19473	MONTNEY - BELLOY
23929	100/06-34-080-13-W6/00	2	A	09/11/1984	-1391	20108	BELLOY
23930	100/09-10-081-13-W6/00	1		11/13/2010	-1508	21567	BELLOY
23931	100/09-10-081-13-W6/02	1		11/13/2010	-1508	21567	BELLOY
23932	100/09-10-081-13-W6/02	2		10/14/2011	-1502	21554	BELLOY
23933	100/09-10-081-13-W6/02	3		10/14/2011	-1502	21485	BELLOY
23934	100/10-13-081-13-W6/00	8	C	10/29/1965	-1360	19751	MONTNEY - BELLOY
23935	100/07-25-081-13-W6/00	6	F	01/26/1978	-1320	17361	BELLOY

Canadian Discovery Ltd.

Belloy Area

Belloy Pressure vs. Elevation Graph

(All Data)

Enclosure: 2.2

AUTHOR: N. Watson	CONTOUR INTERVAL:	SCALE: 1000:1250
DRAFTED BY: C. Poletto	DATE: Apr., 2015	PROJECT: GCWD
DATABASE:	FILE: GCWD_BELLOY_ALL DATA_PEGRAPH	

AOF OIL GAS

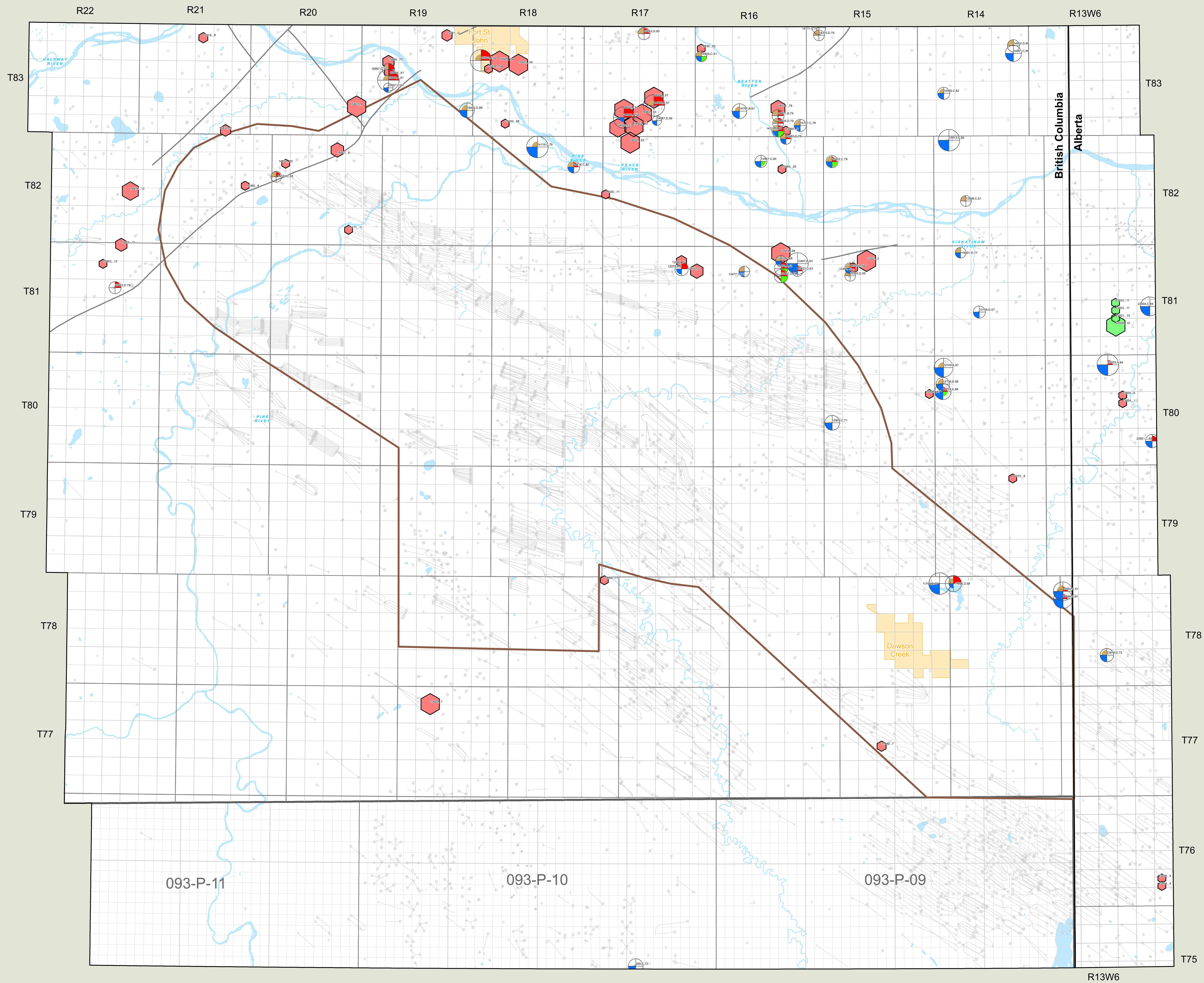
DST

x 10^6 m³/d	< 3	+ 3	+ 14	+ 28	+ 57	+ 85	+ 113	+ 142
meters	< 30	+ 30	+ 150	+ 300	+ 600	+ 900	+ 1200	+ 1500
MMCF/d	< 0.1	+ 0.1	+ 0.5	+ 1.0	+ 2.0	+ 3.0	+4.0	+ 5.0
ft	< 100'	+ 100'	+ 500'	+ 1000'	+ 2000'	+ 3000'	+ 4000'	+ 5000'

NOTE: Quadrant Indicates Type Of Fluid Recovered
Radius Indicates Volume Of Fluid Recovered

MUD GAS WATER OIL

EXAMPLE RECOVERY
+ 5 MMCF/d GAS + 142 x 10^6 m³/d GAS
+ 1000' OIL CUT WATER + 300m OIL CUT WATER
+ 500' MUD + 150m MUD
Reference Number
155



Key to Recoveries

AOF (Gas, Oil)								
DST								
x 10⁶ m³/d	< 3	+ 3	+ 14	+ 28	+ 57	+ 85	+ 113	+ 142
m	< 30	+ 30	+ 150	+ 300	+ 600	+ 900	+ 1200	+ 1500
MMCF/d	< 0.1	+ 0.1	+ 0.5	+ 1.0	+ 2.0	+ 3.0	+ 4.0	+ 5.0
ft	< 100 ft	+ 100 ft	+ 500 ft	+ 1,000 ft	+ 2,000 ft	+ 3,000 ft	+ 4,000 ft	+ 5,000 ft

Note
- Quadrant indicates type of fluid recovered
- Radius indicates volume of fluid recovered

Mud Gas Water Oil

Example Recovery

+ 5 MMCF/d Gas — + 142 x 10^6 m^3/d Gas
+ 1000 ft Oil-Cut Water — + 300m Oil-Cut Water
+ 500 ft Mud — + 150m Mud

Ref Num

Structural and Geological Features

Fault

Focus Area

Belloy Focus Area

1:150,000

0 1.5 3 6 9 12 15 Km

Projection: UTM; Central Meridian -120.0°; North American Datum 1983

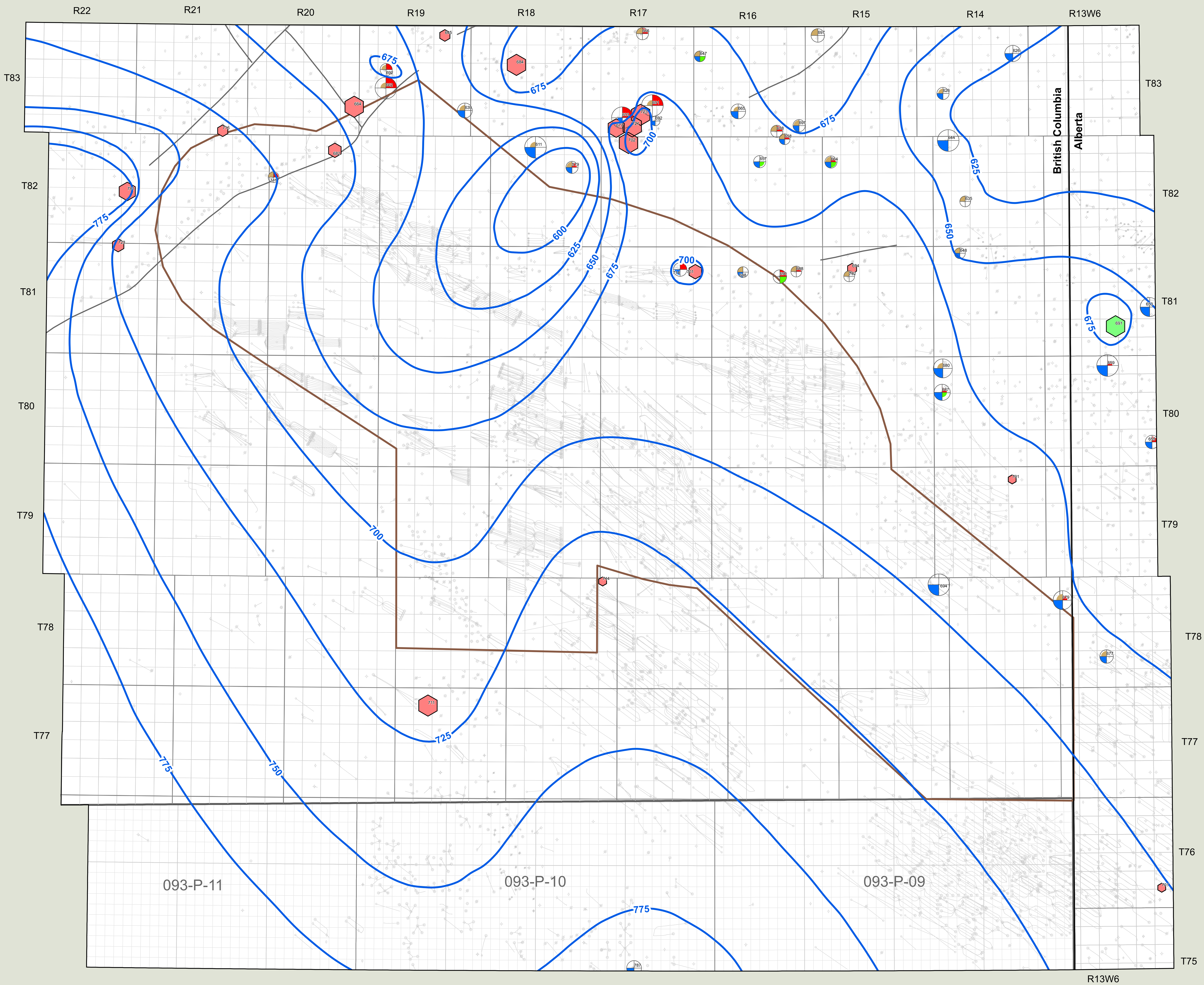
Belloy and Debolt Water Disposal Zones in the Montney Play Fairway, NEBC

Canadian Discovery Ltd.
Data | Intelligence | Expertise

Belloy Area
Belloy DST AOF Recovery
(QC A-D, PID)

Filename: GCWD_BELLOY_DSTAOF_AtoD_PID1		Enclosure
Author: N Watson	Project: GCWD	2.3
Cartographer: C Poletto	Created: 10-April-2015	
Reviewer: S Hawkes	Last Edited: 29-June-2015	

KEY	UWI	DST#	QC	DATE	ELEV	PMAX	FORMATION
359	200/A-010-A/093-P-10/00	7	C	06/10/1973	-2530	32546	BELLOY
11449	100/13-16-077-15-W6/02	2		11/26/2007	-1402	29159	MONTNEY - BELLOY
11622	100/02-32-077-19-W6/00	1		02/08/2007	-2304	29577	BELLOY
11684	100/13-30-078-13-W6/00	2	C	02/27/1991	-1663	22978	BELLOY
11726	100/12-31-078-14-W6/00	12	D	03/22/1956	-1664	23696	BELLOY
11768	100/11-36-078-15-W6/00	2	B	09/26/1967	-1671	23201	MONTNEY - BELLOY
11848	100/13-36-078-18-W6/00	1		07/14/2011	-1973	26645	BELLOY - TAYLORF
12075	100/05-35-079-14-W6/00	1		07/03/2009	-1547	22053	BELLOY
12729	100/03-30-080-14-W6/00	1	A	08/27/1988	-1482	21279	BELLOY
12736	100/03-30-080-14-W6/00	8	D	10/03/1988	-1554	22340	BELLOY
12749	100/06-31-080-14-W6/00	1	A	12/10/1997	-1467	21069	BELLOY
12803	100/06-18-080-15-W6/00	7	C	08/21/1971	-1593	21770	BELLOY
12816	100/15-24-080-15-W6/00	1		10/05/2012	-1487	22017	BELLOY
13156	100/06-16-081-14-W6/00	12	D	04/03/1957	-1428	19631	BELLOY
13201	100/11-32-081-14-W6/00	1	D	02/18/1977	-1390	19988	BELLOY
13325	100/06-29-081-15-W6/00	13	D	03/22/1956	-1395	20578	BELLOY
13326	100/06-29-081-15-W6/00	14	D	03/24/1956	-1402	20563	BELLOY
13341	100/15-29-081-15-W6/00	1		06/29/2000	-1386	20407	BELLOY
13357	100/03-33-081-15-W6/03	3		02/25/2003	-1348	20355	BELLOY
13453	100/10-26-081-16-W6/00	7	D	08/21/1963	-1420	20681	BELLOY
13457	100/10-26-081-16-W6/00	11	B	08/30/1963	-1529	21663	BELLOY
13467	100/07-27-081-16-W6/00	5	D	02/23/1968	-1426	20511	BELLOY
13470	100/07-27-081-16-W6/00	8	B	02/28/1968	-1411	20619	MONTNEY - BELLOY
13471	100/07-27-081-16-W6/00	9	C	02/29/1968	-1427	18811	BELLOY
13472	100/07-27-081-16-W6/02	2		06/26/1968	-1413	20517	BELLOY
13477	100/10-29-081-16-W6/00	2	C	08/24/1972	-1441	20889	BELLOY
13575	100/12-25-081-17-W6/03	3		10/10/2005	-1445	21057	BELLOY
13579	100/13-26-081-17-W6/00	1	B	11/03/2005	-1438	21110	BELLOY
13580	100/13-26-081-17-W6/00	1		12/27/2005	-1534	21953	BELLOY - TAYLORF
13822	100/11-22-081-22-W6/00	4	D	10/28/1979	-1399	25920	BELLOY
13853	100/16-28-081-22-W6/00	1		01/06/2012	-1461	33064	BELLOY
13855	100/16-34-081-22-W6/00	1		02/05/2011	-1533	22130	BELLOY - TAYLORF
13898	100/07-17-082-14-W6/00	1	C	07/16/1981	-1376	19725	BELLOY
13913	100/16-31-082-14-W6/00	1	C	03/25/1990	-1315	19221	BELLOY
13932	100/11-30-082-15-W6/00	2	C	08/16/1979	-1332	19584	BELLOY
13965	100/02-27-082-16-W6/00	1		06/01/1955	-1334	19096	BELLOY
13967	100/10-28-082-16-W6/00	2	C	08/04/1980	-1322	19413	MONTNEY - BELLOY
13985	100/16-34-082-16-W6/00	5	D	11/16/1979	-1315	19358	BELLOY
13990	100/16-34-082-16-W6/00	1		11/30/2003	-1310	18226	BELLOY
14030	100/13-18-082-17-W6/02	2		10/19/2011	-1088	19101	BELLOY
14051	100/11-32-082-17-W6/00	1		10/18/1957	-1270	19351	BELLOY
14116	100/06-26-082-18-W6/00	4	C	10/25/1982	-1344	18865	BELLOY
14119	100/06-33-082-18-W6/00	1	C	02/22/1979	-1356	19304	BELLOY
14171	100/13-02-082-20-W6/02	2		08/26/2011	-1203	30476	MONTNEY - BELLOY
14182	100/12-19-082-20-W6/00	4	C	10/18/1980	-1293	19655	BELLOY
14251	100/07-30-082-20-W6/02	2		01/24/1980	-1392	19738	BELLOY
14267	102/02-34-082-20-W6/03	3		12/03/2008	-1287	19315	BELLOY
14360	100/02-23-082-21-W6/04	4		04/20/2008	-1221	17521	BELLOY
14414	100/13-14-082-22-W6/00	1		01/06/2012	-1294	20362	BELLOY
14589	100/06-17-083-14-W6/00	2	C	08/07/1982	-1327	19154	BELLOY
14601	100/12-25-083-14-W6/00	3	C	08/11/1989	-1173	17650	BELLOY
14602	100/12-25-083-14-W6/00	4	D	08/11/1989	-1166	17820	BELLOY
14710	100/10-31-083-15-W6/00	3	D	02/05/1979	-1147	17715	BELLOY
14711	100/10-31-083-15-W6/00	4	C	02/08/1979	-1160	18212	BELLOY
14727	100/10-01-083-16-W6/00	4	C	07/07/1978	-1419	20758	BELLOY
14729	100/06-02-083-16-W6/00	1	D	09/13/1979	-1307	19599	BELLOY
14730	100/06-02-083-16-W6/00	2	D	09/14/1979	-1297	19343	MONTNEY - BELLOY
14731	100/06-02-083-16-W6/00	3	B	09/15/1979	-1297	18982	MONTNEY - BELLOY
14734	100/06-02-083-16-W6/00	1		11/06/1979	-1264	19125	BELLOY
14791	100/06-09-083-16-W6/00	8	B	06/19/1967	-1305	19324	BELLOY
14829	100/06-30-083-16-W6/00	6	C	02/07/1991	-1248	18588	BELLOY
14830	100/06-30-083-16-W6/00	1		04/22/1992	-1240	17736	BELLOY
14887	100/16-03-083-17-W6/00	4	D	10/21/1956	-1285	19402	BELLOY
14902	100/10-04-083-17-W6/00	1		10/21/1957	-1266	19496	BELLOY
14923	100/08-05-083-17-W6/00	1		10/01/1953	-1295	19345	BELLOY
14948	100/04-09-083-17-W6/00	11	D	05/29/1956	-1293	18892	BELLOY
14957	100/04-09-083-17-W6/00	1		08/07/1956	-1294	19951	BELLOY
14981	100/04-10-083-17-W6/00	1		02/18/1953	-1288	19724	BELLOY
14995	100/10-10-083-17-W6/00	12	D	01/27/1957	-1297	19498	BELLOY
14998	100/10-10-083-17-W6/00	1		06/12/1957	-1294	19489	BELLOY
15143	102/12-34-083-17-W6/00	3	D	08/19/1990	-1218	18484	BELLOY
15150	100/10-05-083-18-W6/02	2		08/21/1985	-1285	19779	BELLOY
15316	100/09-19-083-18-W6/00	1		04/19/1958	-1257	13601	BELLOY
15423	100/14-21-083-18-W6/00	1		11/04/1955	-1276	19234	BELLOY
15529	100/03-29-083-18-W6/00	1		07/07/1954	-1232	19104	MONTNEY - BELLOY
15593	100/03-30-083-18-W6/00	20	D	07/28/1952	-1256	13169	BELLOY
15652	100/07-12-083-19-W6/00	2	D	07/23/1989	-1318	19199	BELLOY
15657	100/11-17-083-19-W6/00	1	D	03/16/1961	-1294	18271	BELLOY
15666	100/11-17-083-19-W6/00	10	C	03/01/1961	-1306	19309	MONTNEY - BELLOY
15669	100/11-17-083-19-W6/00	1		03/20/1961	-1303	15918	BELLOY
15683	100/10-19-083-19-W6/00	1		01/28/1971	-1253	10623	BELLOY
15687	100/11-20-083-19-W6/00	2	C	07/11/1970	-1255	19105	BELLOY
15689	100/11-20-083-19-W6/00	1		07/22/1977	-1239	19269	BELLOY
15781	100/07-35-083-19-W6/00	1		02/15/2000	-1273	18811	BELLOY
15803	100/10-12-083-20-W6/02	2		03/30/2004	-1296	19228	BELLOY
15833	100/02-02-083-21-W6/00	1		01/24/2009	-1258	19369	BELLOY
15916	100/06-34-083-21-W6/00	1		06/26/2008	-1226	17552	BELLOY
23914	100/03-12-076-13-W6/00	1		06/18/2004	-1792	24456	BELLOY
23915	100/03-12-076-13-W6/00	2		03/26/2004	-1795	24163	BELLOY
23919	102/11-09-078-13-W6/00	1	D	02/04/1972	-1634	22675	BELLOY
23920	100/13-30-078-13-W6/00	2	C	02/27/1991	-1663	22978	BELLOY
23921	100/07-12-080-13-W6/00	1	C	06/25/1989	-1414	20296	BELLOY
23924	100/05-23-080-13-W6/00	1		06/08/2001	-1422	23286	BELLOY
23925	100/05-23-080-13-W6/00	2		05/27/2005	-1422	23463	BELLOY
23929	100/06-34-080-13-W6/00	2	A	09/11/1984	-1391	20108	BELLOY
23930	100/09-10-081-13-W6/00	1		11/13/2010	-1508	21567	BELLOY
23931	100/09-10-081-13-W6/02	1		11/13/2010	-1508	21567	BELLOY
23932	100/09-10-081-13-W6/02	2		10/14/2011	-1502	21554	BELLOY
23933	100/09-10-081-13-W6/02	3		10/14/2011	-1502	21485	BELLOY
23934	100/10-13-081-13-W6/00	8	C	10/29/1965	-1360	19751	MONTNEY - BELLOY



Key to Recoveries

AOF (Gas / Oil)								
DST								
x 10^6 m^3/d	< 3	+ 3	+ 14	+ 28	+ 57	+ 85	+ 113	+ 142
m	< 30	+ 30	+ 150	+ 300	+ 600	+ 900	+ 1200	+ 1500
MMCF/d	< 0.1	+ 0.1	+ 0.5	+ 1.0	+ 2.0	+ 3.0	+ 4.0	+ 5.0
ft	< 100 ft	+ 100 ft	+ 500 ft	+ 1,000 ft	+ 2,000 ft	+ 3,000 ft	+ 4,000 ft	+ 5,000 ft

Note
- Quadrant indicates type of fluid recovered
- Radius indicates volume of fluid recovered

Mud / Gas / Water / Oil

Example Recovery

+ 5 MMCF/d Gas — + 142 x 10^6 m^3/d Gas
+ 1000 ft Oil-Cut Water — + 300m Oil-Cut Water
+ 500 ft Mud — + 150m Mud

Fresh Water Hydraulic Head Value (m)

Fresh Water Hydraulic Head (m)

C.I. = 25m

Structural and Geological Features

Faults

Focus Area

Belloy Focus Area

1:150,000

0 1.5 3 6 9 12 15 Km

Projection: UTM; Central Meridian -120.0°; North American Datum 1983

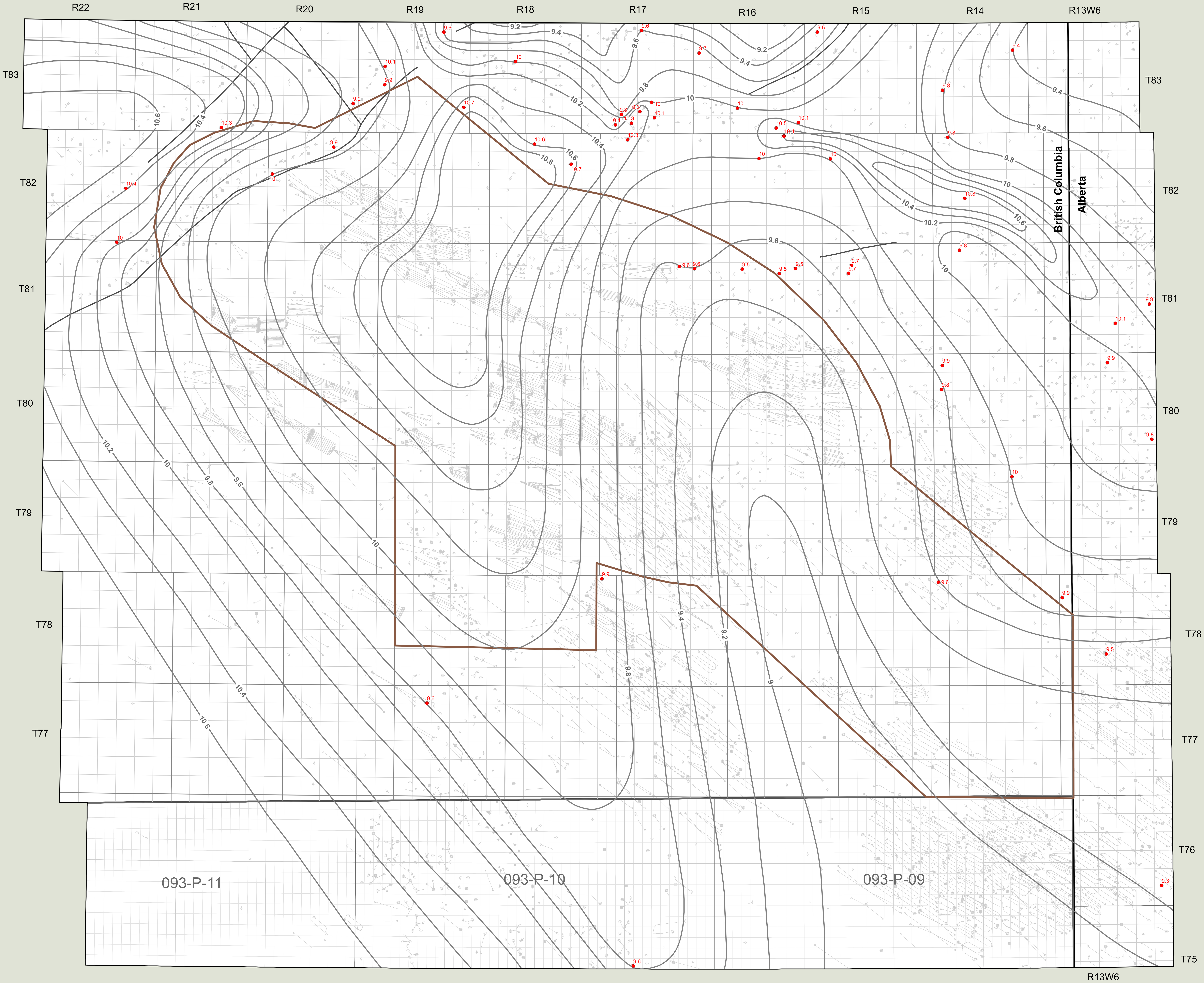
Belloy and Debolt Water Disposal Zones in the Montney Play Fairway, NEBC

Canadian Discovery Ltd.

Data | Intelligence | Expertise

Belloy Area
Belloy Head

Filename: GCWD_BELLOY_HEAD_MAP		Enclosure
Author: C Poletto	Project: GCWD	2.5
Cartographer: C Poletto	Created: 10-April-2015	
Reviewer: N Watson	Last Edited: 29-June-2015	



Belloy Pressure Depth Gradient (kPa/m)

- Belloy Pressure Depth Gradient Value (kPa/m)
- C.I.= 0.2 kPa/m

Structural and Geological Features

- Faults

Focus Area

- Belloy Focus Area

1:150,000

0 1.5 3 6 9 12 15 Km

Projection: UTM; Central Meridian -120.0°; North American Datum 1983

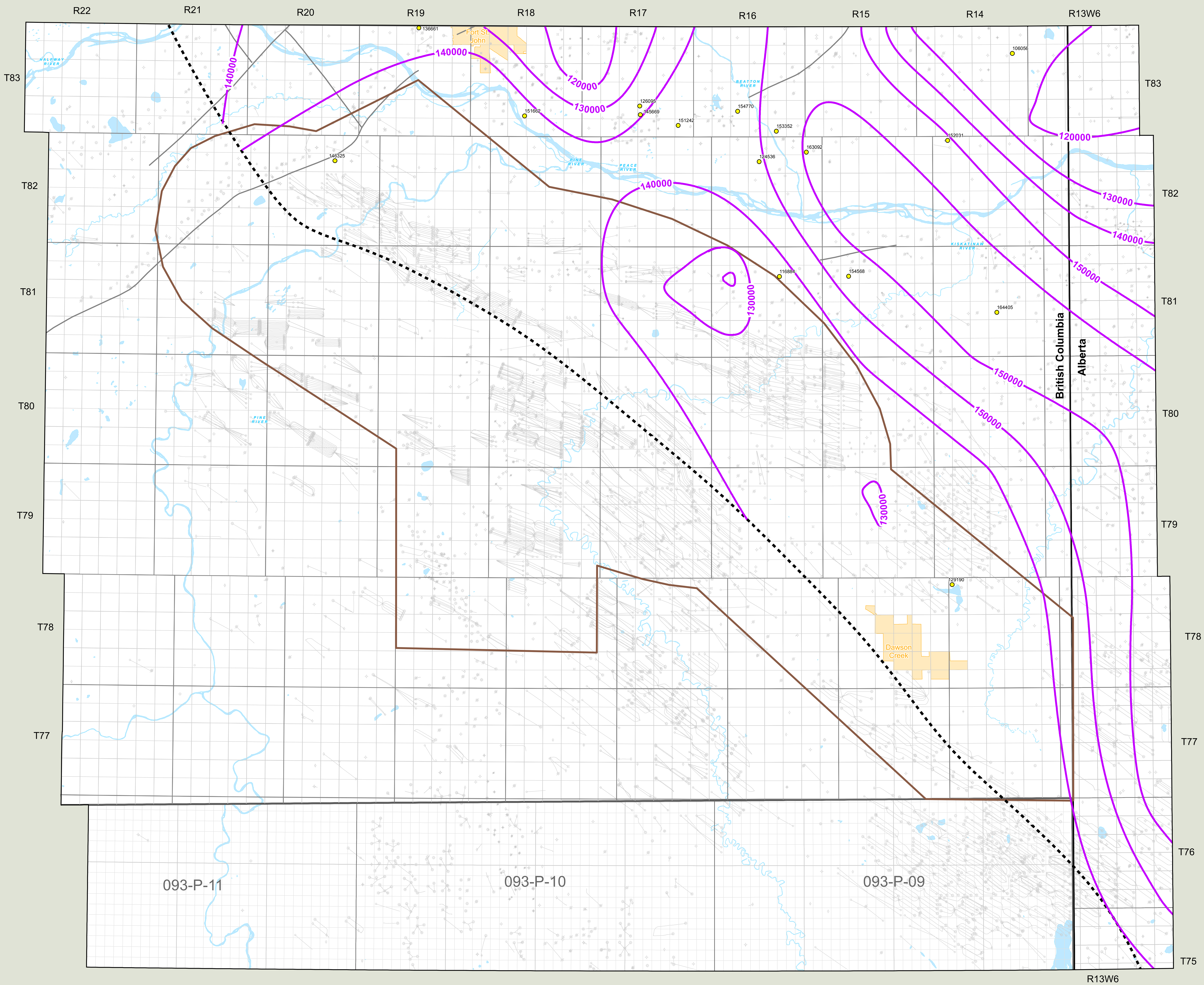
Belloy and Debolt Water Disposal Zones in the Montney Play Fairway, NEBC

Canadian Discovery Ltd.

Data | Intelligence | Expertise

Belloy Area
Belloy Pressure Depth Gradient

Filename: GCWD_BELLOY_PD_MAP		Enclosure
Author: C Poletto	Project: GCWD	2.6
Cartographer: C Poletto	Created: 10-April-2015	
Reviewer: N Watson	Last Edited: 29-June-2015	



Belloy Salinity (mg/L)

- Possible Formation Water Acceptable TDS
- Belloy TDS Contours (mg/L)
- Minimum Downdip Extent of Water Analyses

Structural and Geological Features

- Faults

Focus Area

- Belloy Focus Area

1:150,000

0 1.5 3 6 9 12 15 Km

Projection: UTM; Central Meridian -120.0°; North American Datum 1983

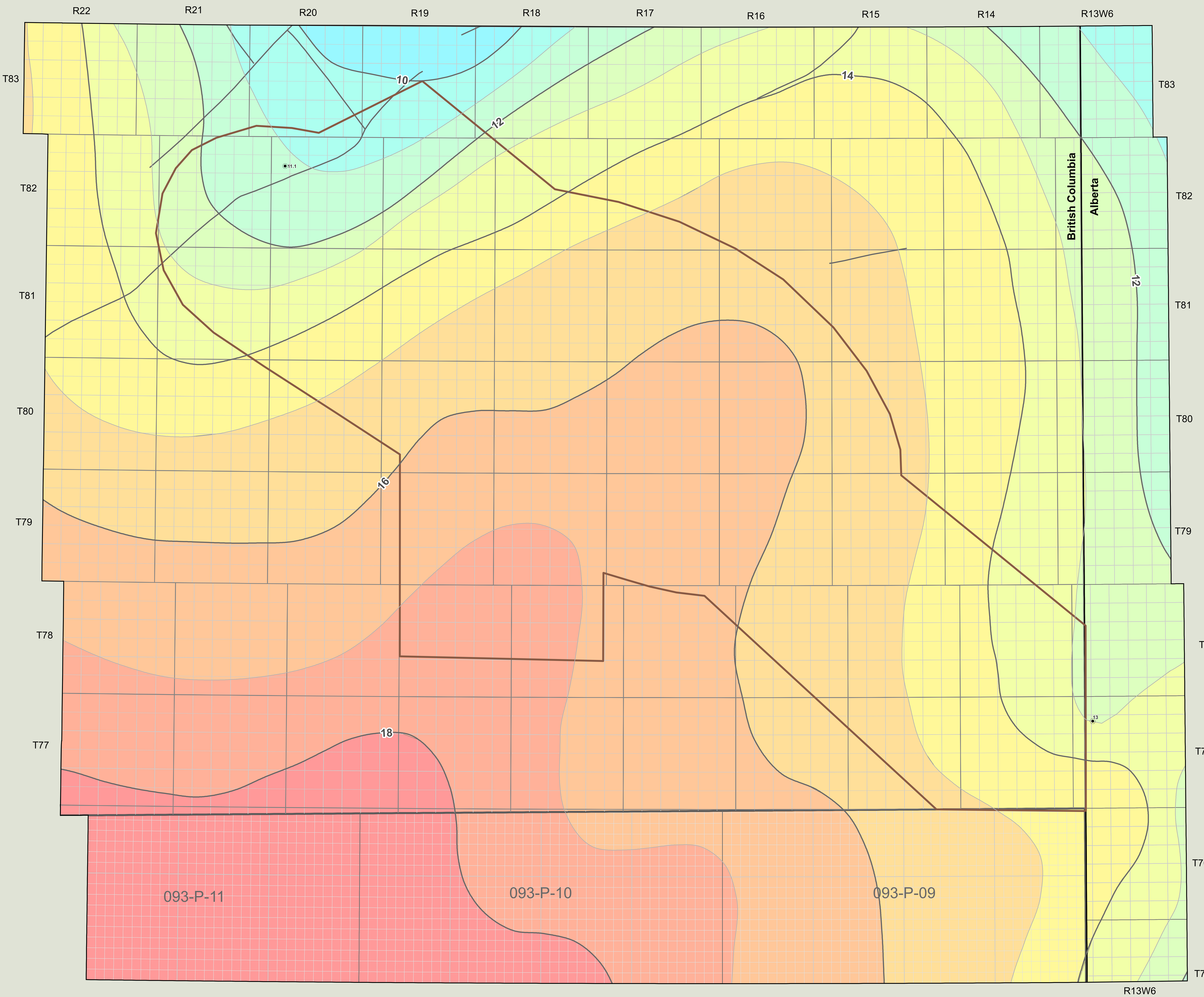
Belloy and Debolt Water Disposal Zones in the Montney Play Fairway, NEBC

Canadian Discovery Ltd.

Data | Intelligence | Expertise

Belloy Area
Belloy Salinity

Filename: GCWD_BELLOY_TDS_MAP		Enclosure
Author: N Watson	Project: GCWD	2.7
Cartographer: C Poletto	Created: 10-April-2015	
Reviewer: S Hawkes	Last Edited: 29-June-2015	



Lower Montney Pressure-Depth Ratio (kPa/m)

- Used in contouring
- C.I. = 1 kPa/m
- 9-10
- 10-11
- 11-12
- 12-13
- 13-14
- 14-15
- 15-16
- 16-17
- 17-18
- 18-19

Well Type

- Dir/Dev
- Horizontal
- Vertical

Structural and Geological Features

- Faults

Focus Area

- Belloy Focus Area

1:150,000

0 1.5 3 6 9 12 15 Km

Projection: UTM; Central Meridian -120.0°; North American Datum 1983

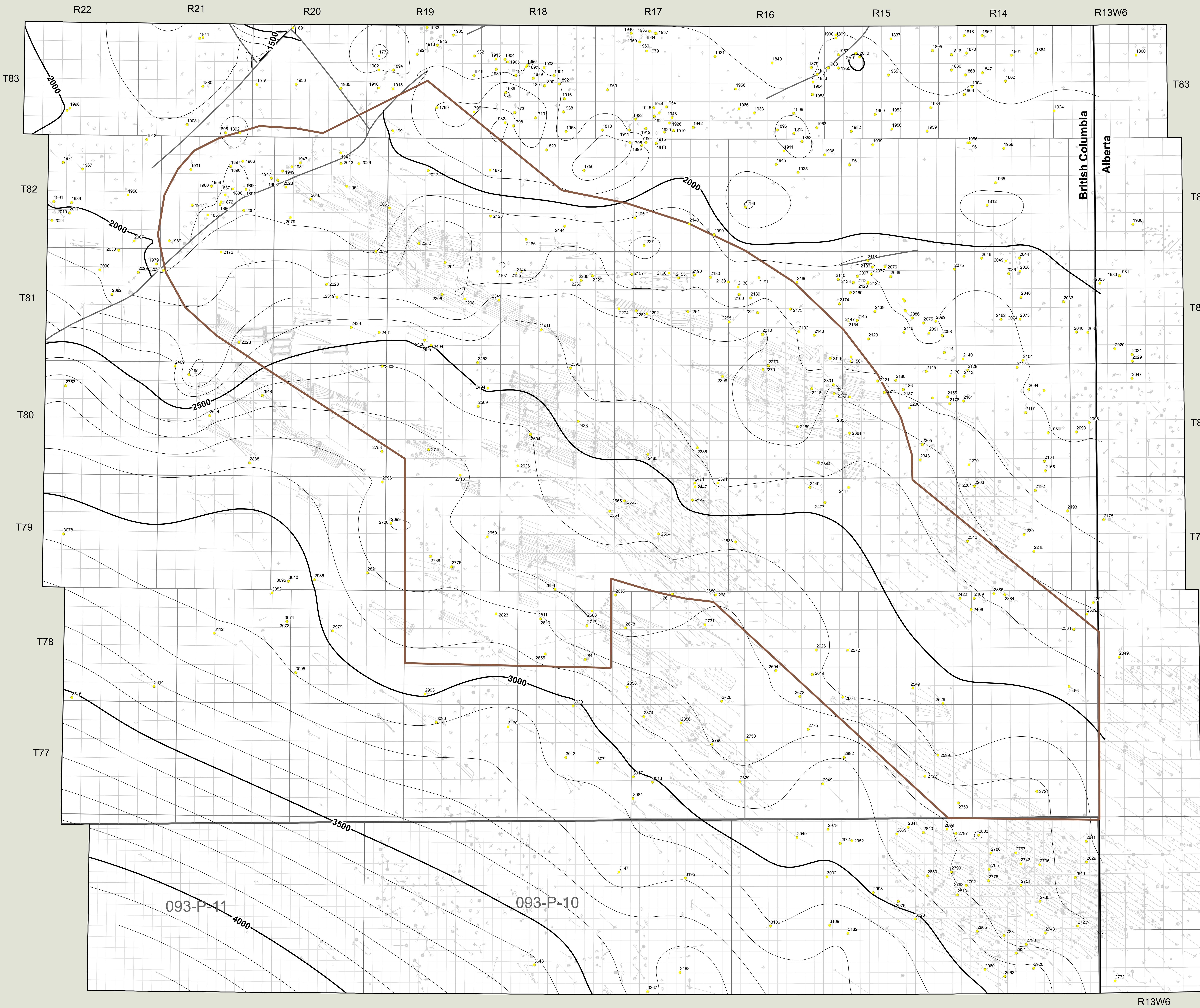
Belloy and Debolt Water Disposal Zones in the Montney Play Fairway, NEBC

Canadian Discovery Ltd.

Data | Intelligence | Expertise

Belloy Area Lower Motney Pressure Depth Gradient

Filename: GCWD_LWR_MNTY_BELLOY_AREA_PD_MAP	Enclosure **2.8**
Author: D Hume	Project: GCWD
Cartographer: C Poletto	Created: 10-April-2015
Reviewer: N Watson	Last Edited: 29-June-2015



Belloy Top TVD (m) (Petrel Robertson, Dec. 2014)

- Belloy Top TVD Value (m)
- C.I.= 100m

Structural and Geological Features

- Faults

Focus Area

- Belloy Focus Area

1:150,000

0 1.5 3 6 9 12 15 Km

Projection: UTM; Central Meridian -120.0°; North American Datum 1983

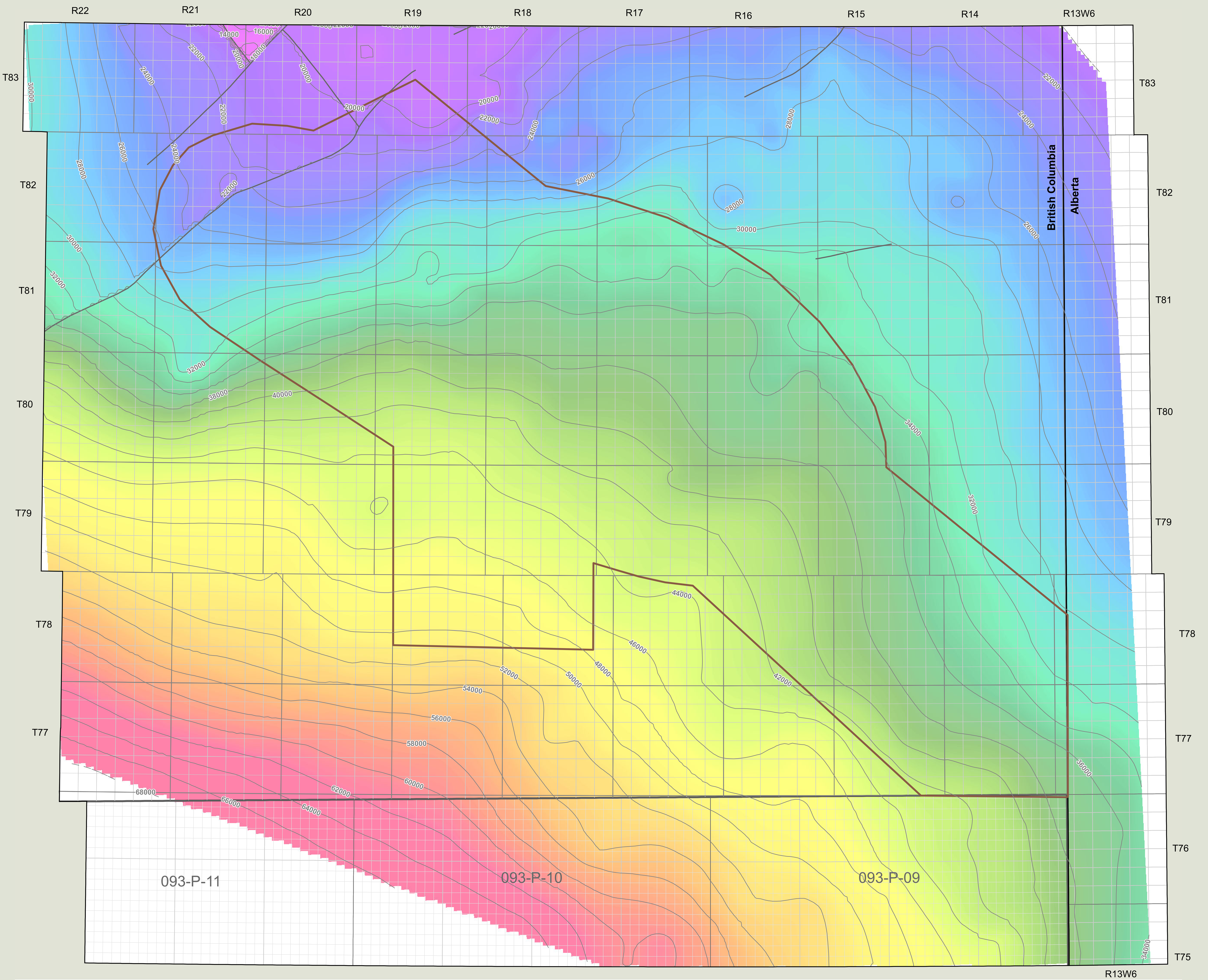
Belloy and Debolt Water Disposal Zones in the Montney Play Fairway, NEBC

Canadian Discovery Ltd.

Data | Intelligence | Expertise

Belloy Area
Belloy TVD

Filename: GCWD_BELLOY_TVD_MAP		Enclosure
Author: Petral Robertson	Project: GCWD	2.9
Cartographer: C Poletto	Created: 10-April-2015	
Reviewer: N Watson	Last Edited: 29-June-2015	



Lower Montney Pressure (kPa/m)

C.I. = 2000 kPa/m

67788.0

13408.3

Structural and Geological Features

Faults

Focus Area

Belloy Focus Area

1:150,000

0 1.5 3 6 9 12 15 Km

Projection: UTM; Central Meridian -120.0°; North American Datum 1983

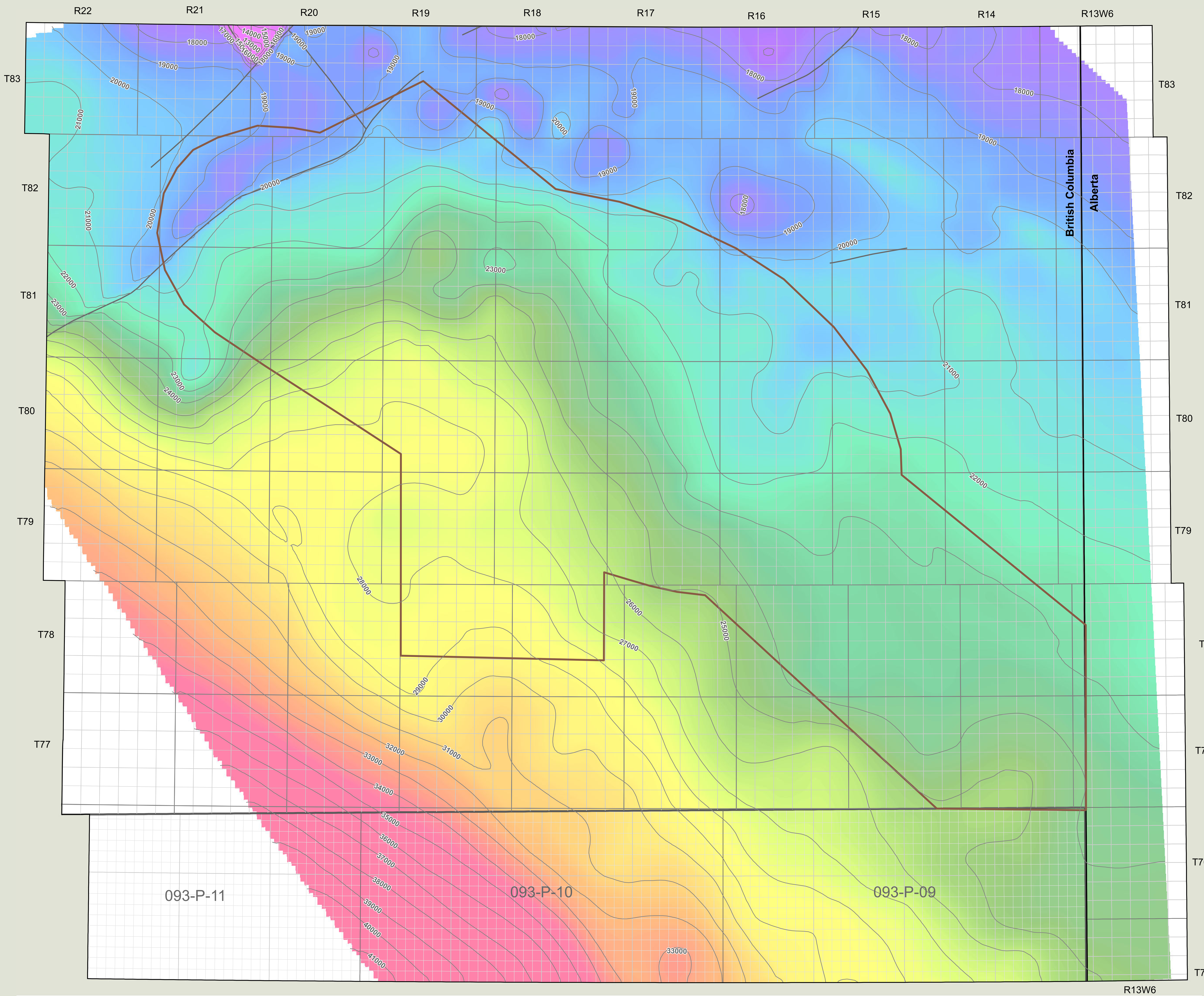
Belloy and Debolt Water Disposal Zones in the Montney Play Fairway, NEBC

Canadian Discovery Ltd.

Data | Intelligence | Expertise

Belloy Area Theoretical Lower Montney Pressure at Belloy Top

Filename: GCWD_LWR_MNTY_BELLOY_AREA_PRES_MAP		Enclosure
Author: S Hawkes	Project: GCWD	2.10
Cartographer: C Poletto	Created: 10-April-2015	
Reviewer: N Watson	Last Edited: 29-June-2015	



Belloy Pressure (kPa/m)

C.I. = 1000 kPa/m

41331.9

12299.2

Structural and Geological Features

Faults

Focus Area

Belloy Focus Area

1:150,000

0 1.5 3 6 9 12 15 Km

Projection: UTM; Central Meridian -120.0°; North American Datum 1983

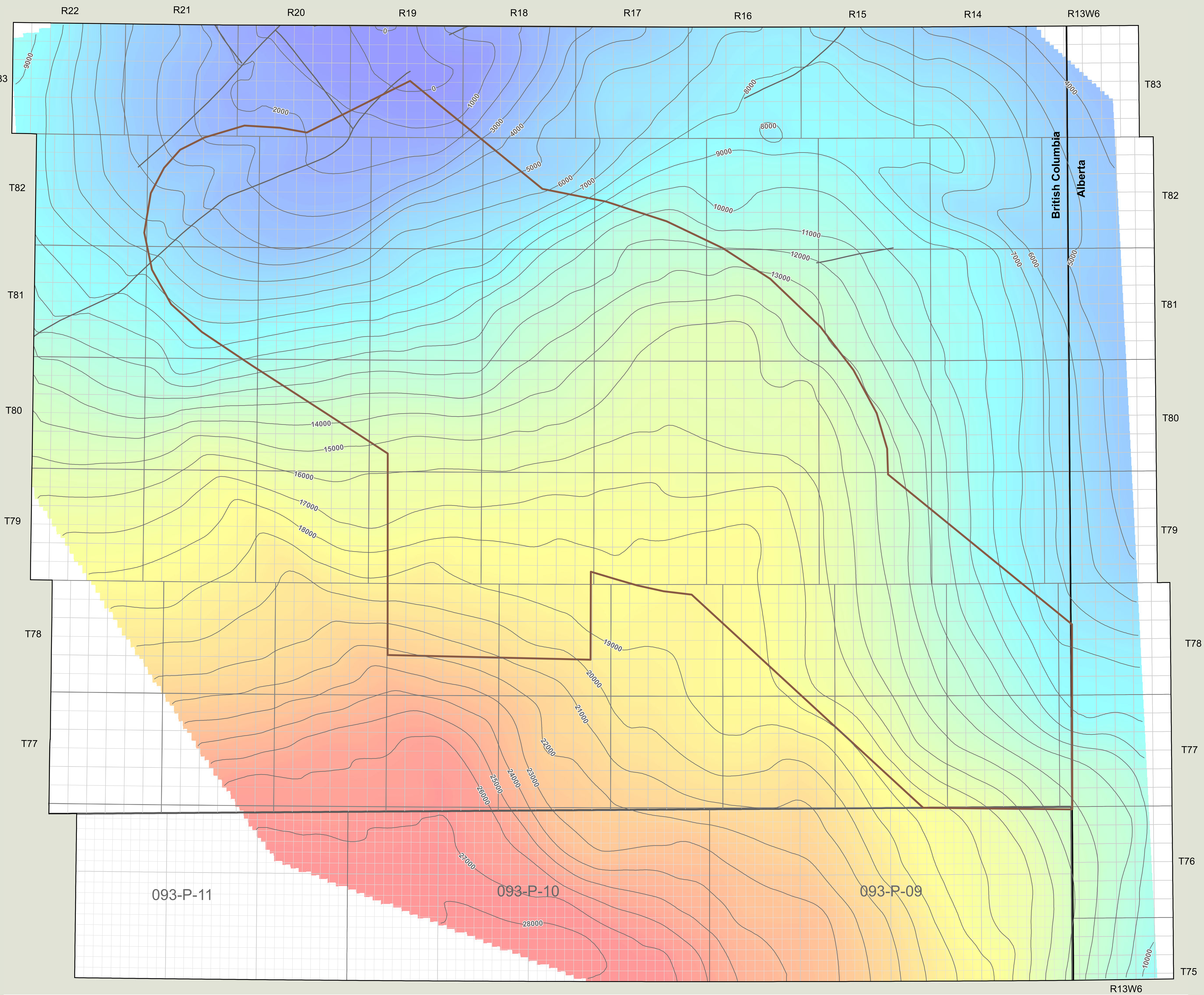
Belloy and Debolt Water Disposal Zones in the Montney Play Fairway, NEBC

Canadian Discovery Ltd.

Data | Intelligence | Expertise

Belloy Area Theoretical Belloy Pressure at Belloy Top

Filename: GCWD_BELLOY_PRES_MAP		Enclosure
Author: S Hawkes	Project: GCWD	2.11
Cartographer: C Poletto	Created: 10-April-2015	
Reviewer: N Watson	Last Edited: 29-June-2015	



Theoretical Pressure Difference across Montney/Belloy Contact (kPa/m)

C.I. = 1000 kPa/m

28514.5

-391.3

Structural and Geological Features

Faults

Focus Area

Belloy Focus Area

1:150,000

0 1.5 3 6 9 12 15 Km

Projection: UTM; Central Meridian -120.0°; North American Datum 1983

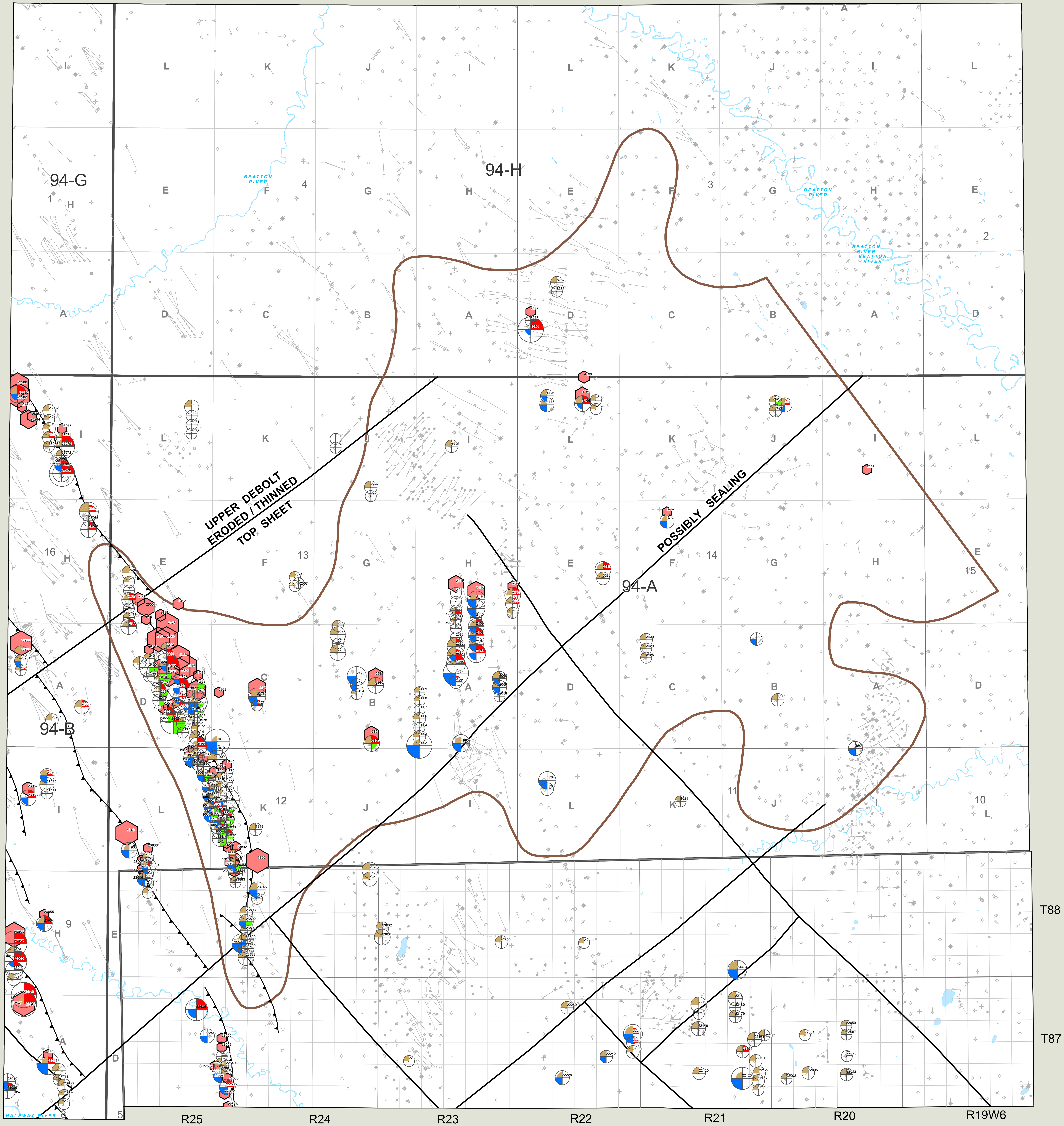
Belloy and Debolt Water Disposal Zones in the Montney Play Fairway, NEBC

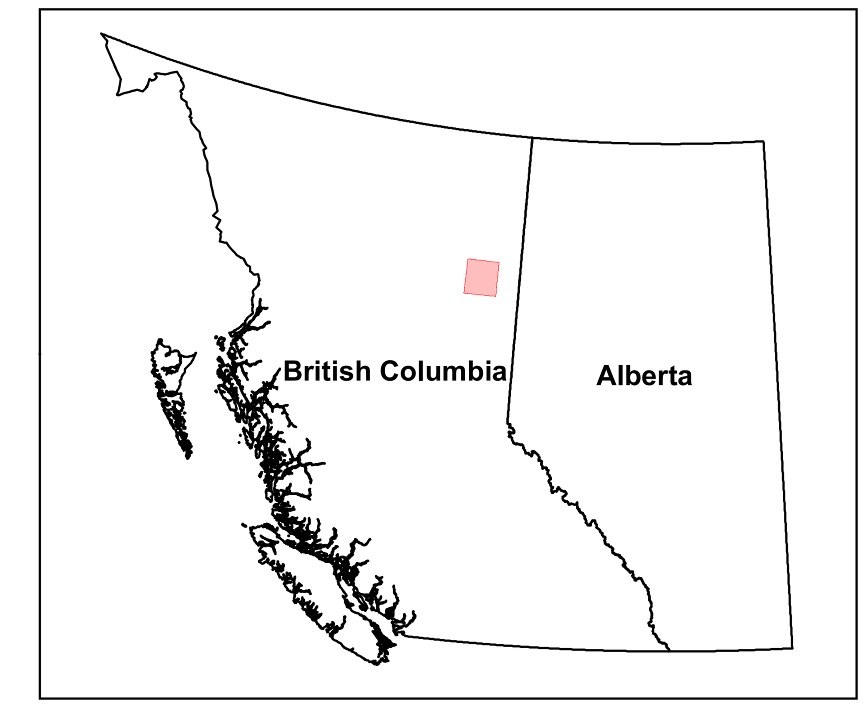
Canadian Discovery Ltd.

Data | Intelligence | Expertise

Belloy Area Theoretical Pressure Difference across Montney/Belloy Contact

Filename: GCWD_BELLOY_PRES_DIF_MAP		Enclosure
Author: S. Hawkes	Project: GCWD	2.12
Cartographer: C Poletto	Created: 10-April-2015	
Reviewer: N Watson	Last Edited: 29-June-2015	





Key to Recoveries

AOF								
DST								
x 10^6 m^3/d	< 3	+ 3	+ 14	+ 28	+ 57	+ 85	+ 113	+ 142
m	< 30	+ 30	+ 150	+ 300	+ 600	+ 900	+ 1200	+ 1500
MMCF/d	< 0.1	+ 0.1	+ 0.5	+ 1.0	+ 2.0	+ 3.0	+ 4.0	+ 5.0
ft	< 100 ft	+ 100 ft	+ 500 ft	+ 1,000 ft	+ 2,000 ft	+ 3,000 ft	+ 4,000 ft	+ 5,000 ft

Mud Gas Water Oil

Example Recovery

+ 5 MMCF/d Gas
+ 1000 ft Oil-Cut Water
+ 500 ft Mud

+ 142 x x 10^6 m^3/d Gas
+ 300m Oil-Cut Water
+ 150m Mud

Ref Num

Note

Quadrant indicates type of fluid recovered

Radius indicates volume of fluid recovered

Structural and Geological Features

Thrust Fault

Normal Fault

Focus Area

Debolt Focus Area

1:150,000

0 3 6 9 12 15 Km

Projection: UTM; Central Meridian -121.5; North American Datum 1983

Belloy and Debolt Water Disposal Zones in the Montney Play Fairway, NEBC

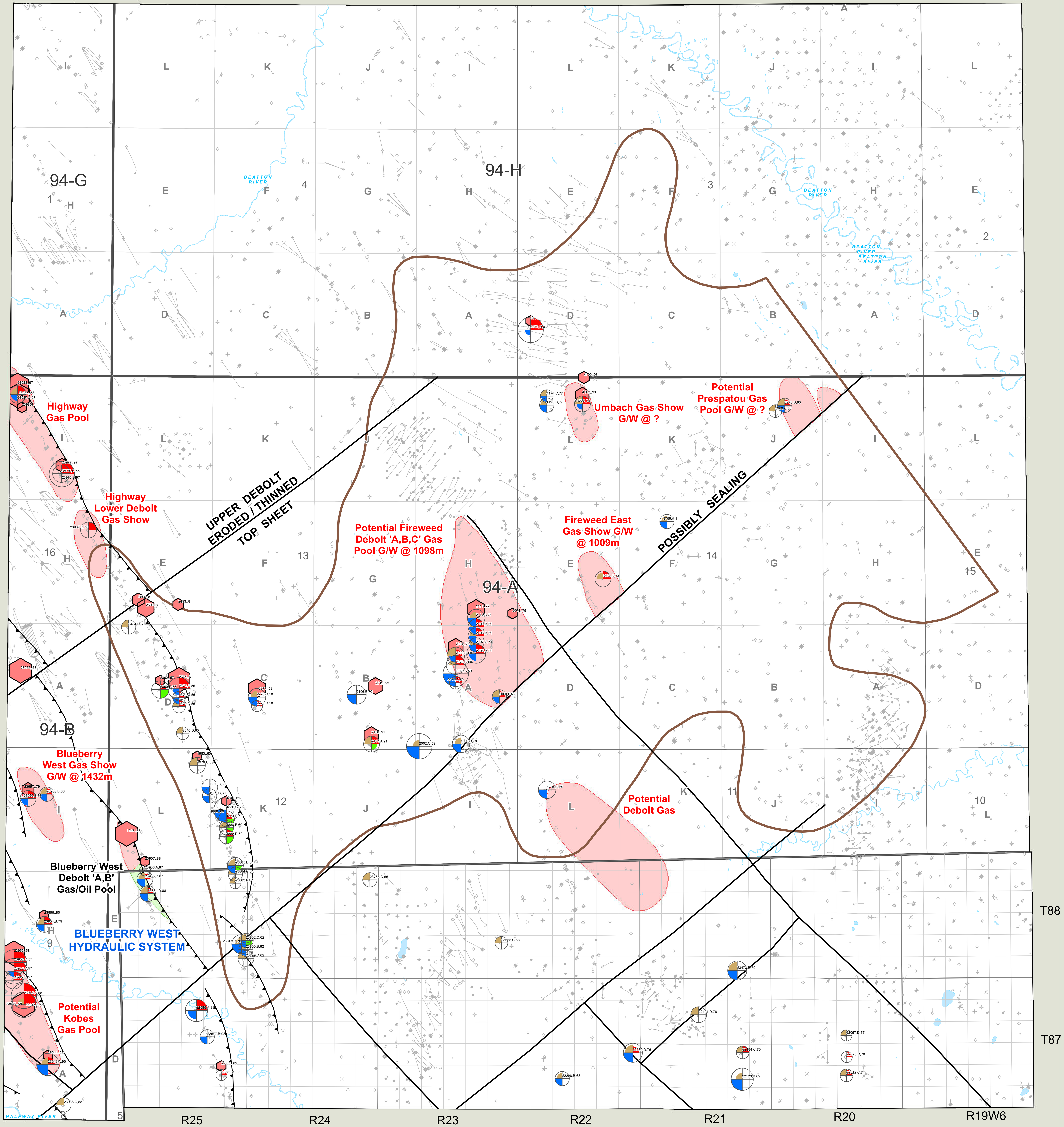
Canadian Discovery Ltd.

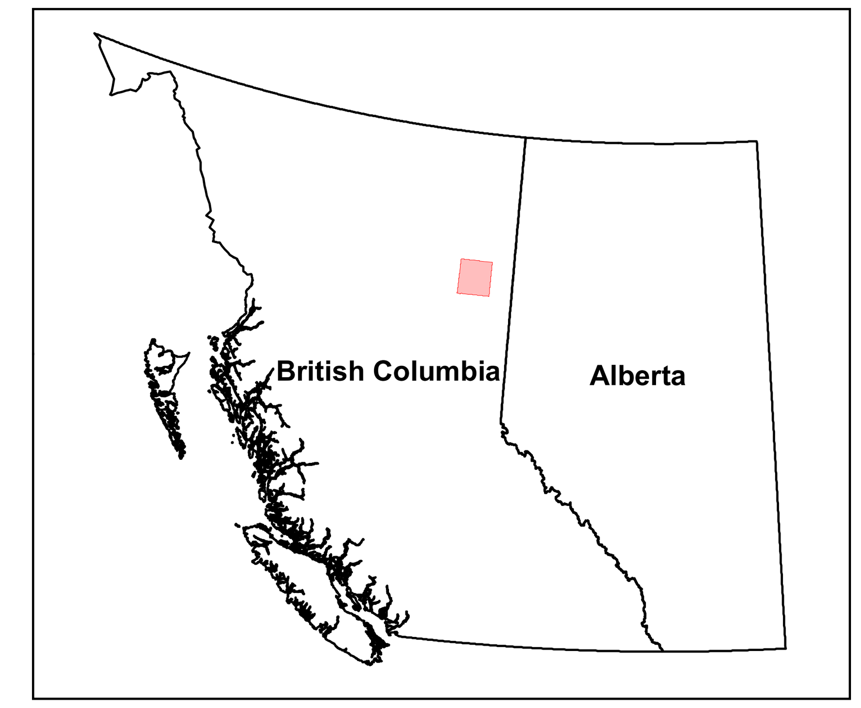
Data | Intelligence | Expertise

Debolt Area
Debolt DST AOF Recovery
(All Data)

Filename: GCWD_DEBOLT_ALL_DATA_MAP.mxd		Enclosure
Author: N Watson	Project: GCWD	2.13
Cartographer: C Poletto	Created: 10-April-2015	
Reviewer: N Watson	Last Edited: 29-June-2015	


Canadian Discovery Ltd.
Debolt Area
Debolt Pressure vs. Elevation Graph
(All Data)
Enclosure: 2.14
AUTHOR:
CONTOUR INTERVAL:
SCALE: 1000:1250
DRAFTED BY: C. Poletto
DATE: APR., 2015
PROJECT: GCWD
DATABASE:
FILE: GCWD_DEBOLT_ALL_DATA_PEGRAPH
AOF
OIL
GAS
DST
x 10⁶ m³/d < 3 + 3 + 14 + 28 + 57 + 85 + 113 + 142
meters < 30 + 30 + 150 + 300 + 600 + 900 + 1200 + 1500
MMCF/d < 0.1 + 0.1 + 0.5 + 1.0 + 2.0 + 3.0 +4.0 + 5.0
ft < 100' + 100' + 500' + 1000' + 2000' + 3000' + 4000' + 5000'
NOTE: Quadrant Indicates Type Of Fluid Recovered
Radius Indicates Volume Of Fluid Recovered
EXAMPLE RECOVERY
MUD
GAS
WATER
OIL
+ 5 MMCF/d GAS
+ 1000' OIL CUT WATER
+ 500' MUD
+ 142 x 10⁶ m³/d GAS
+ 300m OIL CUT WATER
+ 150m MUD
Reference Number
155
KEY UWI DST# QC DATE ELEV PMAX FORMATION
ELEVATION (meters)
PRESSURE (kPa)





Key to Recoveries

AOF								
DST								
x 10^6 m^3/d	< 3	+ 3	+ 14	+ 28	+ 57	+ 85	+ 113	+ 142
m	< 30	+ 30	+ 150	+ 300	+ 600	+ 900	+ 1200	+ 1500
MMCF/d	< 0.1	+ 0.1	+ 0.5	+ 1.0	+ 2.0	+ 3.0	+ 4.0	+ 5.0
ft	< 100 ft	+ 100 ft	+ 500 ft	+ 1,000 ft	+ 2,000 ft	+ 3,000 ft	+ 4,000 ft	+ 5,000 ft

Mud Gas Water Oil

Example Recovery

+ 5 MMCF/d Gas + 142 x x 10^6 m^3/d Gas
+ 1000 ft Oil-Cut Water + 300m Oil-Cut Water
+ 500 ft Mud + 150m Mud

Ref Num, QC, Date - 155, B, 88

Note

Quadrant indicates type of fluid recovered

Radius indicates volume of fluid recovered

Structural and Geological Features

Thrust Fault

Normal Fault

Focus Area

Debolt Focus Area

1:150,000

0 3 6 9 12 15 Km

Projection: UTM; Central Meridian -121.5; North American Datum 1983

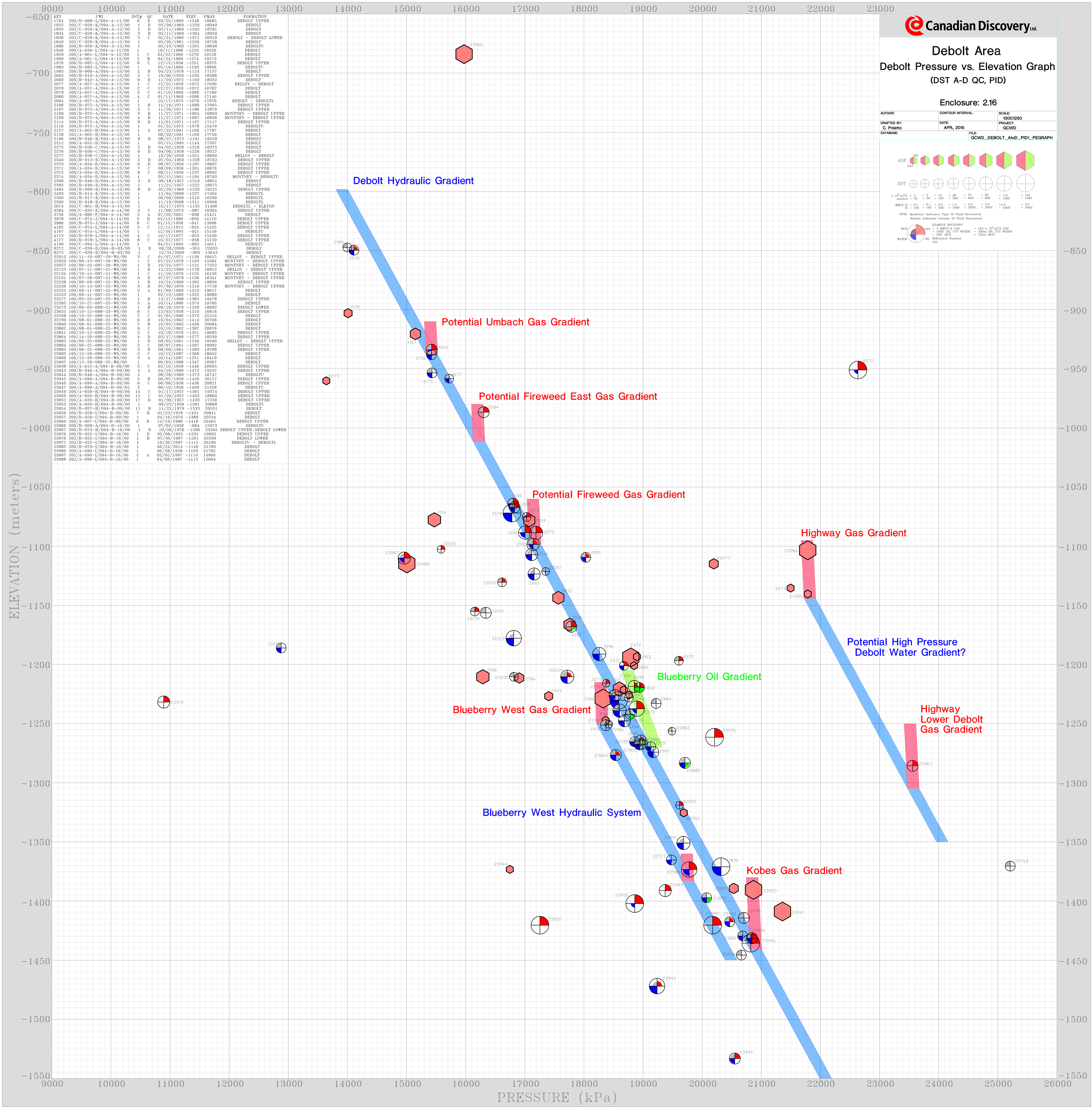
Belloy and Debolt Water Disposal Zones in the Montney Play Fairway, NEBC

Canadian Discovery Ltd.

Data | Intelligence | Expertise

Debolt Area
Debolt DST AOF Recovery
(QC A-D, PID)

Filename: GCWD_DEBOLT_DSTAOF_AtoD_MAP.mxd		Enclosure
Author: N Watson	Project: GCWD	2.15
Cartographer: C Poletto	Created: 10-April-2015	
Reviewer: N Watson	Last Edited: 29-June-2015	



Canadian Discovery Ltd.

Debolt Area

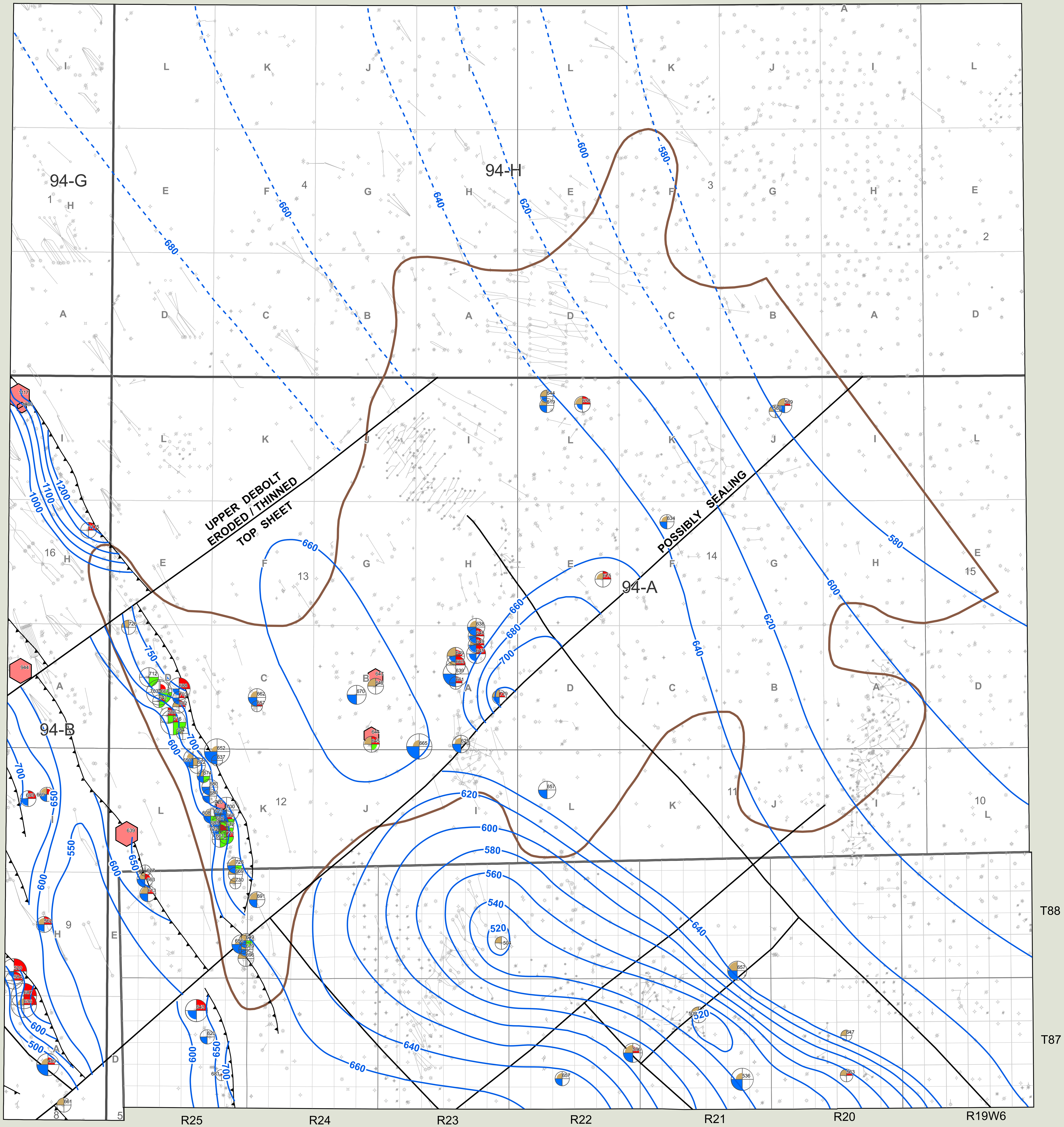
Debolt Pressure vs. Elevation Graph

(DST A-D QC, PID)

Enclosure: 2.16

AUTHOR:	CONTOUR INTERVAL:	SCALE: 1000:1250
DRAFTED BY: C. Poletto	DATE: APR., 2015	PROJECT: GCWD
DATABASE:	FILE: GCWD_DEBOLT_AtoD_PID1_PEGRAPH	

KEY	UWI	DST#	QC	DATE	ELEV	PMAX	FORMATION
1704	200/D-068-L/094-A-11/00	6	D	03/25/1969	-1248	18685	DEBOLT UPPER
1832	202/C-029-K/094-A-12/00	1	D	02/09/1960	-1220	18940	DEBOLT
1833	202/C-029-K/094-A-12/00	2	B	02/11/1960	-1242	18781	DEBOLT
1834	202/C-029-K/094-A-12/00	3	B	02/11/1960	-1264	18959	DEBOLT
1836	202/C-029-K/094-A-12/00	5	C	02/21/1960	-1371	20319	DEBOLT - DEBOLT LOWER
1840	202/C-029-K/094-A-12/00	1		05/26/1961	-1226	18758	DEBOLT
1886	200/D-050-K/094-A-12/00	1		05/19/1960	-1201	18848	DEBOLTU
1946	200/A-039-L/094-A-12/00	1		10/11/1988	-1229	18326	DEBOLT
1959	200/A-061-L/094-A-12/00	1	C	04/22/1960	-1270	19129	DEBOLT
1960	200/A-061-L/094-A-12/00	2	B	04/24/1960	-1274	19173	DEBOLT
1976	200/D-082-L/094-A-12/00	8	C	12/15/1956	-1251	18375	DEBOLT UPPER
1983	200/D-082-L/094-A-12/00	1		05/19/1960	-1193	18896	DEBOLTU
1993	200/B-006-A/094-A-13/00	2	B	04/23/1978	-1124	17157	DEBOLT
2002	200/B-010-A/094-A-13/00	2	C	10/06/1959	-1230	18588	DEBOLT UPPER
2060	200/B-042-A/094-A-13/00	9	D	11/29/1972	-1109	18032	DEBOLT
2077	200/A-057-A/094-A-13/00	1	C	12/22/1959	-1075	17030	BELLOY - DEBOLT
2078	200/A-057-A/094-A-13/00	2	C	12/27/1959	-1072	16782	DEBOLT
2079	200/A-057-A/094-A-13/00	3	C	01/10/1960	-1089	17189	DEBOLT
2080	200/A-057-A/094-A-13/00	4	C	01/11/1960	-1098	17140	DEBOLT
2094	200/A-057-A/094-A-13/00	1		10/17/1975	-1078	17076	DEBOLT - DEBOLTL
2106	200/D-075-A/094-A-13/00	1	B	11/19/1971	-1088	17005	DEBOLT UPPER
2107	200/D-075-A/094-A-13/00	2	C	11/26/1971	-1186	12879	DEBOLT UPPER
2108	200/D-075-A/094-A-13/00	3	B	11/27/1971	-1064	16803	MONTNEY - DEBOLT UPPER
2109	200/D-075-A/094-A-13/00	4	B	11/27/1971	-1067	16826	MONTNEY - DEBOLT UPPER
2114	200/D-075-A/094-A-13/00	9	B	12/01/1971	-1107	17117	DEBOLT UPPER
2116	200/D-075-A/094-A-13/00	1		01/22/1972	-1078	15470	DEBOLTU
2157	202/A-005-B/094-A-13/00	1	A	07/22/1991	-1168	17787	DEBOLT
2158	202/A-005-B/094-A-13/00	1		08/29/1991	-1166	17756	DEBOLT
2196	200/B-046-B/094-A-13/00	8	B	08/27/1972	-1191	18259	DEBOLT
2212	200/A-055-B/094-A-13/00	1		05/15/1993	-1144	17567	DEBOLT
2275	200/B-036-C/094-A-13/00	5	D	04/02/1958	-1216	18375	DEBOLT
2276	200/B-036-C/094-A-13/00	6	D	04/06/1958	-1226	18527	DEBOLT
2277	200/B-036-C/094-A-13/00	1		10/28/1958	-1221	18600	BELLOY - DEBOLT
2340	200/B-013-D/094-A-13/00	2	D	07/04/1960	-1228	18762	DEBOLT UPPER
2370	200/A-034-D/094-A-13/00	6	D	08/07/1956	-1197	19607	DEBOLT UPPER
2371	200/A-034-D/094-A-13/00	7	C	08/09/1956	-1201	18676	DEBOLT UPPER
2372	200/A-034-D/094-A-13/00	8	C	08/11/1956	-1237	18892	DEBOLT UPPER
2374	200/A-034-D/094-A-13/00	1		05/15/1961	-1194	18793	MONTNEY - DEBOLTU
2390	200/D-046-D/094-A-13/00	3	D	08/18/1957	-1219	18851	DEBOLT
2392	200/D-046-D/094-A-13/00	1		11/21/1957	-1222	18675	DEBOLT
2484	200/D-099-D/094-A-13/00	8	D	02/20/1960	-1233	19221	DEBOLT UPPER
2493	200/D-014-E/094-A-13/00	1		12/04/2008	-1227	17404	DEBOLTL
2500	202/B-017-E/094-A-13/00	1		06/09/2008	-1210	16290	DEBOLTL
2506	200/D-018-E/094-A-13/00	1		11/19/2008	-1211	16906	DEBOLTL
2674	202/C-001-H/094-A-13/00	1		10/17/1975	-1135	21496	DEBOLTL - ELKTON
3584	200/C-032-E/094-A-14/00	3	C	11/08/1973	-987	16304	DEBOLT UPPER
3756	200/A-086-F/094-A-14/00	2	A	07/29/2001	-938	15421	DEBOLT
3978	200/C-074-J/094-A-14/00	3	D	02/13/1980	-850	14110	DEBOLT UPPER
3986	200/B-075-J/094-A-14/00	8	C	01/15/1958	-847	13998	DEBOLT UPPER
4165	200/C-074-L/094-A-14/00	3	C	12/11/1974	-934	15425	DEBOLT UPPER
4167	200/C-074-L/094-A-14/00	1		12/30/1993	-921	15149	DEBOLTU
4173	200/D-078-L/094-A-14/00	4	C	10/17/1977	-953	15430	DEBOLT UPPER
4177	200/D-078-L/094-A-14/00	8	C	10/22/1977	-958	15720	DEBOLT UPPER
4190	200/C-094-L/094-A-14/00	1		04/21/1993	-903	14011	DEBOLTU
8272	200/C-039-D/094-H-03/00	1	D	09/26/2000	-951	22635	DEBOLT
8275	200/C-039-D/094-H-03/00	1		12/31/2000	-960	13643	DEBOLT
22012	100/11-10-087-20-W6/00	3	C	01/07/1971	-1130	16615	BELLOY - DEBOLT UPPER
22020	100/06-15-087-20-W6/00	1	C	07/22/1978	-1103	15584	MONTNEY - DEBOLT UPPER
22057	100/06-22-087-20-W6/00	1	D	10/24/1977	-1121	17352	MONTNEY - DEBOLT UPPER
22123	100/07-11-087-21-W6/00	1	B	12/22/1969	-1178	16812	BELLOY - DEBOLT UPPER
22134	100/10-14-087-21-W6/00	1	C	11/10/1970	-1155	16156	MONTNEY - DEBOLT UPPER
22191	100/07-28-087-21-W6/00	3	D	07/27/1978	-1156	16341	MONTNEY - DEBOLT UPPER
22228	100/06-09-087-22-W6/00	1	B	10/24/1968	-1265	18856	DEBOLT UPPER
22239	100/10-13-087-22-W6/00	3	D	07/30/1976	-1210	17718	MONTNEY - DEBOLT UPPER
22552	100/09-11-087-25-W6/00	3	A	01/09/1989	-1319	19617	DEBOLT
22553	100/09-11-087-25-W6/00	1		02/13/1989	-1325	19689	DEBOLT
22577	100/05-23-087-25-W6/00	1	B	12/17/1998	-1365	19478	DEBOLT UPPER
22585	100/10-27-087-25-W6/00	3	A	10/14/1988	-1373	19780	DEBOLT
23473	100/06-02-088-21-W6/00	1	B	09/18/1979	-1239	18602	DEBOLT LOWER
23655	100/10-12-088-23-W6/00	8	C	12/03/1958	-1210	16816	DEBOLT UPPER
23768	100/10-25-088-24-W6/00	7	C	01/05/1966	-1370	25210	DEBOLT
23799	100/08-01-088-25-W6/00	6	D	10/04/1962	-1414	20706	DEBOLT
23800	100/08-01-088-25-W6/00	7	B	10/02/1962	-1430	20684	DEBOLT
23802	100/08-01-088-25-W6/00	9	C	10/10/1962	-1397	20076	DEBOLT
23841	100/10-12-088-25-W6/00	2	C	10/18/1970	-1351	19683	DEBOLT UPPER
23864	100/14-20-088-25-W6/00	4	D	03/17/1988	-1277	18539	DEBOLT UPPER
23883	100/06-25-088-25-W6/00	1	D	08/05/1961	-1256	19490	BELLOY - DEBOLT UPPER
23884	100/06-25-088-25-W6/00	2	C	08/07/1961	-1267	18992	DEBOLT UPPER
23885	100/06-25-088-25-W6/00	3	D	08/09/1961	-1283	19708	DEBOLT UPPER
23905	100/12-29-088-25-W6/00	2	C	10/12/1987	-1268	18942	DEBOLT
23906	100/12-29-088-25-W6/00	3	A	10/14/1987	-1251	18419	DEBOLT
23907	100/12-29-088-25-W6/00	1		06/03/1988	-1247	18367	DEBOLT
23938	202/A-015-A/094-B-09/00	5	C	02/16/1958	-1446	20663	DEBOLT UPPER
23943	200/B-046-A/094-B-09/00	4	A	04/16/1990	-1472	19237	DEBOLT UPPER
23944	200/B-046-A/094-B-09/00	1		08/28/1990	-1373	16747	DEBOLTU
23945	200/A-099-A/094-B-09/00	5	B	06/07/1958	-1420	20177	DEBOLT UPPER
23946	200/A-099-A/094-B-09/00	6	C	06/08/1958	-1436	20821	DEBOLT UPPER
23947	200/A-099-A/094-B-09/02	2		08/10/1958	-1409	21358	DEBOLTU
23949	200/A-020-H/094-B-09/00	14	C	01/17/1957	-1391	19374	DEBOLT UPPER
23950	200/A-020-H/094-B-09/00	15	C	01/20/1957	-1402	18860	DEBOLT UPPER
23952	200/A-020-H/094-B-09/00	17	D	01/30/1957	-1420	17256	DEBOLT UPPER
23953	200/A-020-H/094-B-09/00	1		09/23/1958	-1391	20868	DEBOLTU
23954	200/D-057-H/094-B-09/00	11	B	11/22/1979	-1533	20551	DEBOLT
23956	200/D-059-I/094-B-09/00	7	B	02/23/1978	-1431	20841	DEBOLT
23957	200/D-059-I/094-B-09/00	1		04/16/1979	-1389	20534	DEBOLT
23960	200/A-067-I/094-B-09/00	6	B	12/19/1988	-1418	20465	DEBOLT UPPER
23966	200/B-069-A/094-B-16/00	1		07/02/1958	-684	15973	DEBOLTU
23967	200/D-073-H/094-B-16/00	1	D	10/28/1976	-1286	23565	DEBOLT UPPER-DEBOLT LOWER
23970	200/B-025-I/094-B-16/00	1	D	05/08/1955	-1232	10892	DEBOLT UPPER
23976	202/B-025-I/094-B-16/00	1	B	07/30/1997	-1261	20209	DEBOLT LOWER
23977	202/B-025-I/094-B-16/00	1		10/30/1997	-1115	20196	DEBOLTU - DEBOLTL
23985	200/B-079-I/094-B-16/00	1		06/24/2014	-1140	21785	DEBOLT
23986	200/A-090-I/094-B-16/00	1		06/28/1958	-1103	21785	DEBOLT
23987	202/A-090-I/094-B-16/00	2	A	02/02/1997	-1110	14960	DEBOLT
23988	202/A-090-I/094-B-16/00	1		04/08/1997	-1115	15004	DEBOLT



Key to Recoveries

AOF
Gas Oil

DST

x 10^6 m^3/d	< 3	+ 3	+ 14	+ 28	+ 57	+ 85	+ 113	+ 142
m	< 30	+ 30	+ 150	+ 300	+ 600	+ 900	+ 1200	+ 1500
MMCF/d	< 0.1	+ 0.1	+ 0.5	+ 1.0	+ 2.0	+ 3.0	+ 4.0	+ 5.0
ft	< 100 ft	+ 100 ft	+ 500 ft	+ 1,000 ft	+ 2,000 ft	+ 3,000 ft	+ 4,000 ft	+ 5,000 ft

Note
- Quadrant indicates type of fluid recovered
- Radius indicates volume of fluid recovered

Mud Gas Water Oil

Example Recovery
+ 5 MMCF/d Gas
+ 1000 ft Oil-Cut Water
+ 500 ft Mud
+ 142 x 10^6 m^3/d Gas
+ 300m Oil-Cut Water
+ 150m Mud

Fresh Water Hydraulic Head Value (m)

Debolt Fresh Water Hydraulic Head
C.I. Varies

Structural and Geological Features
Thrust Fault
Normal Fault

Focus Area
Debolt Focus Area

1:150,000

0 3 6 9 12 15 Km

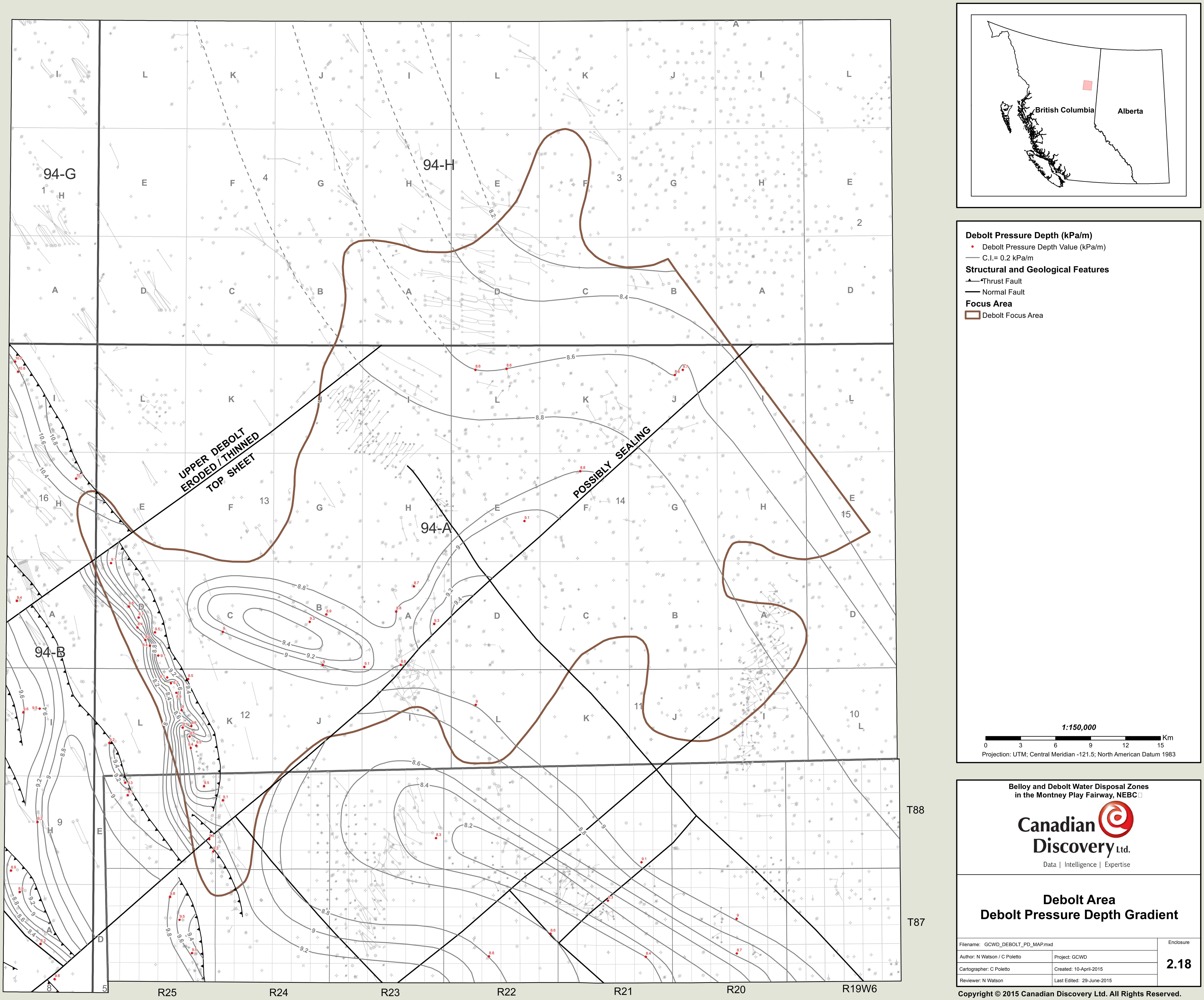
Projection: UTM; Central Meridian -121.5; North American Datum 1983

Belloy and Debolt Water Disposal Zones in the Montney Play Fairway, NEBC

Canadian Discovery Ltd.
Data | Intelligence | Expertise

Debolt Area
Debolt Head

Filename: GCWD_DEBOLT_HEAD_MAP.mxd		Enclosure
Author: N Watson / C Poletto	Project: GCWD	2.17
Cartographer: C Poletto	Created: 10-April-2015	
Reviewer: N Watson	Last Edited: 29-June-2015	



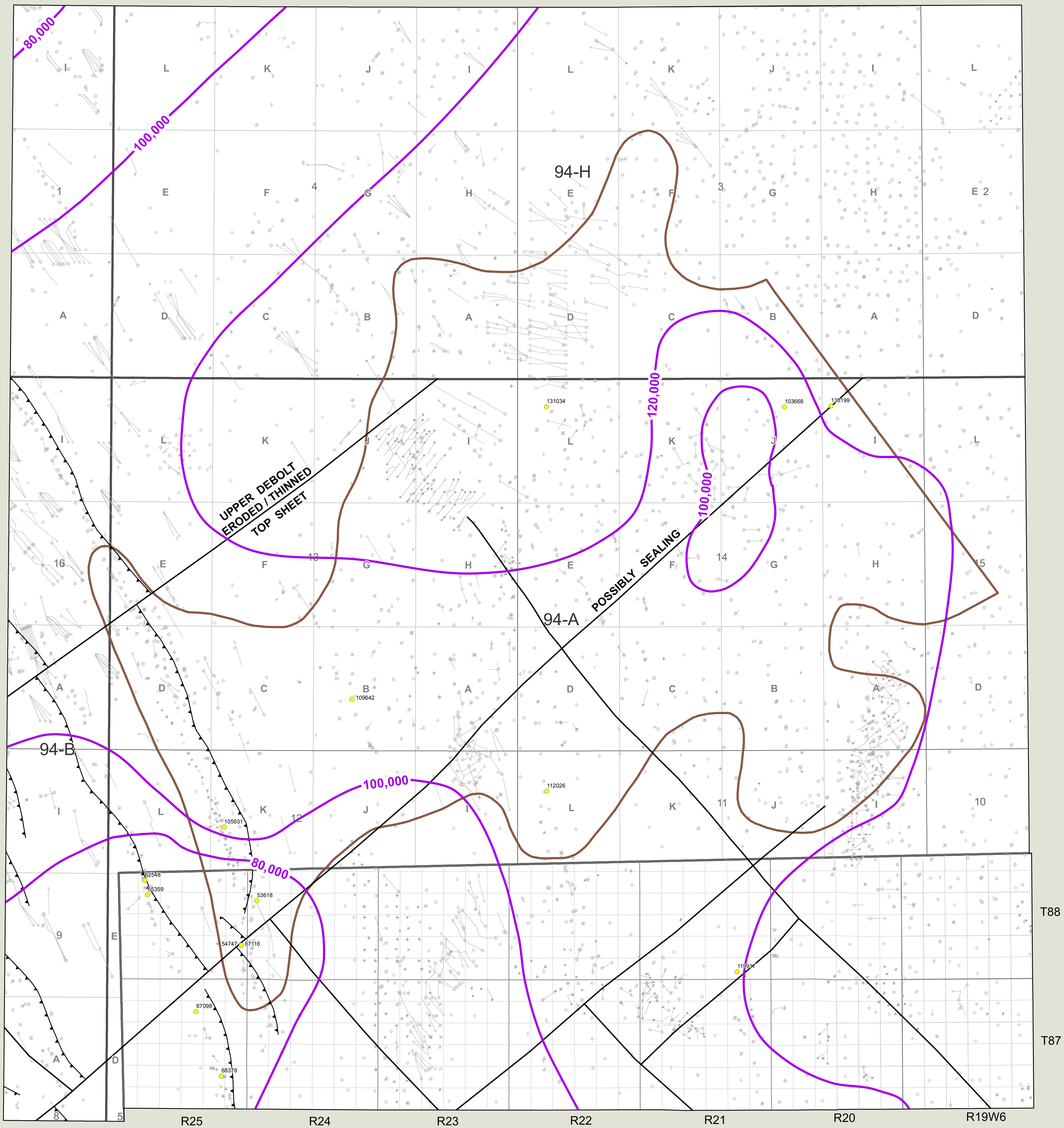
Belloy and Debolt Water Disposal Zones in the Montney Play Fairway, NEBC

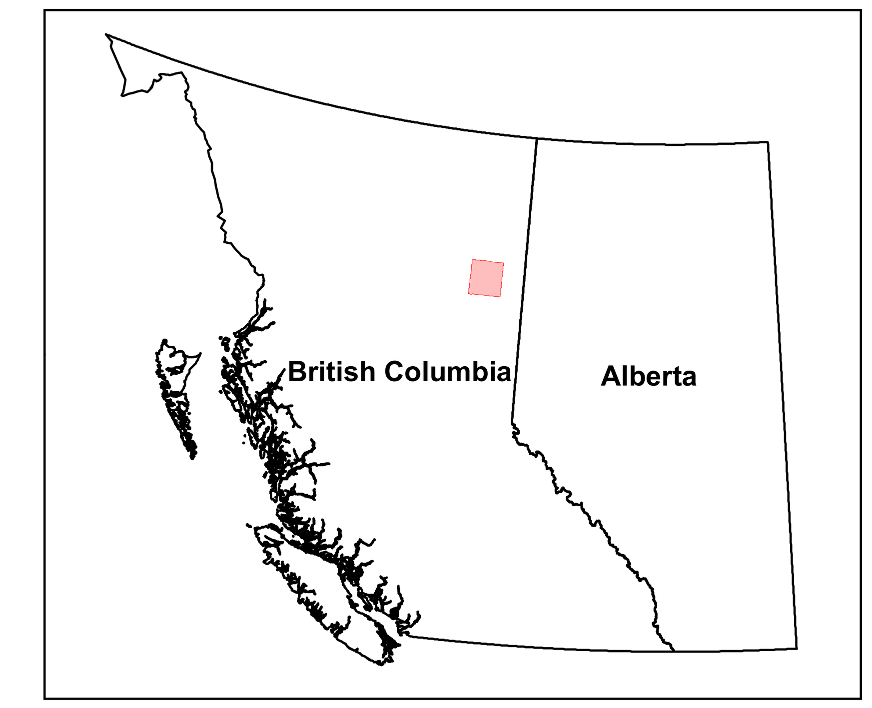
Canadian Discovery Ltd.

Data | Intelligence | Expertise

Debolt Area
Debolt Pressure Depth Gradient

Filename: GCWD_DEBOLT_PD_MAP.mxd		Enclosure
Author: N Watson / C Poletto	Project: GCWD	2.18
Cartographer: C Poletto	Created: 10-April-2015	
Reviewer: N Watson	Last Edited: 29-June-2015	





Debolt Salinity (mg/L)

- Possible Formation Water Acceptable TDS
- C.I. = 20,000 mg/L

Structural and Geological Features

- Thrust Fault
- Normal Fault

Focus Area

- Debolt Focus Area

1:150,000

0 3 6 9 12 15 Km

Projection: UTM; Central Meridian -121.5; North American Datum 1983

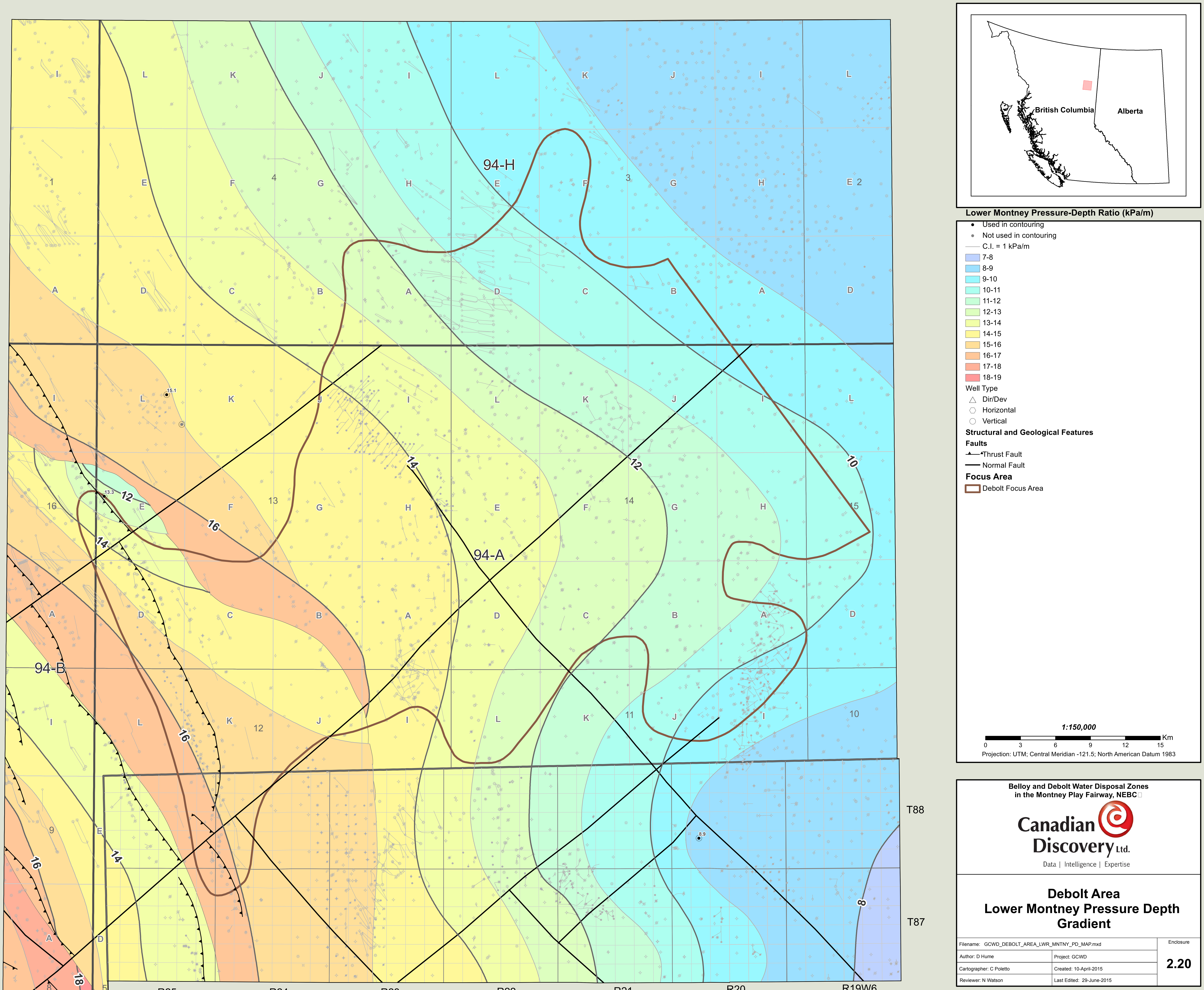
Belloy and Debolt Water Disposal Zones in the Montney Play Fairway, NEBC

Canadian Discovery Ltd.

Data | Intelligence | Expertise

Debolt Area
Debolt Salinity

Filename: GCWD_DEBOLT_TDS_MAP.mxd	Enclosure 2.19
Author: N Watson	Project: GCWD
Cartographer: C Poletto	Created: 10-April-2015
Reviewer: N Watson	Last Edited: 29-June-2015



Lower Montney Pressure-Depth Ratio (kPa/m)

- Used in contouring
- Not used in contouring
- C.I. = 1 kPa/m
- 7-8
- 8-9
- 9-10
- 10-11
- 11-12
- 12-13
- 13-14
- 14-15
- 15-16
- 16-17
- 17-18
- 18-19

Well Type
- Dir/Dev
- Horizontal
- Vertical

Structural and Geological Features

Faults
- Thrust Fault
- Normal Fault

Focus Area
- Debolt Focus Area

1:150,000

0 3 6 9 12 15 Km

Projection: UTM; Central Meridian -121.5; North American Datum 1983

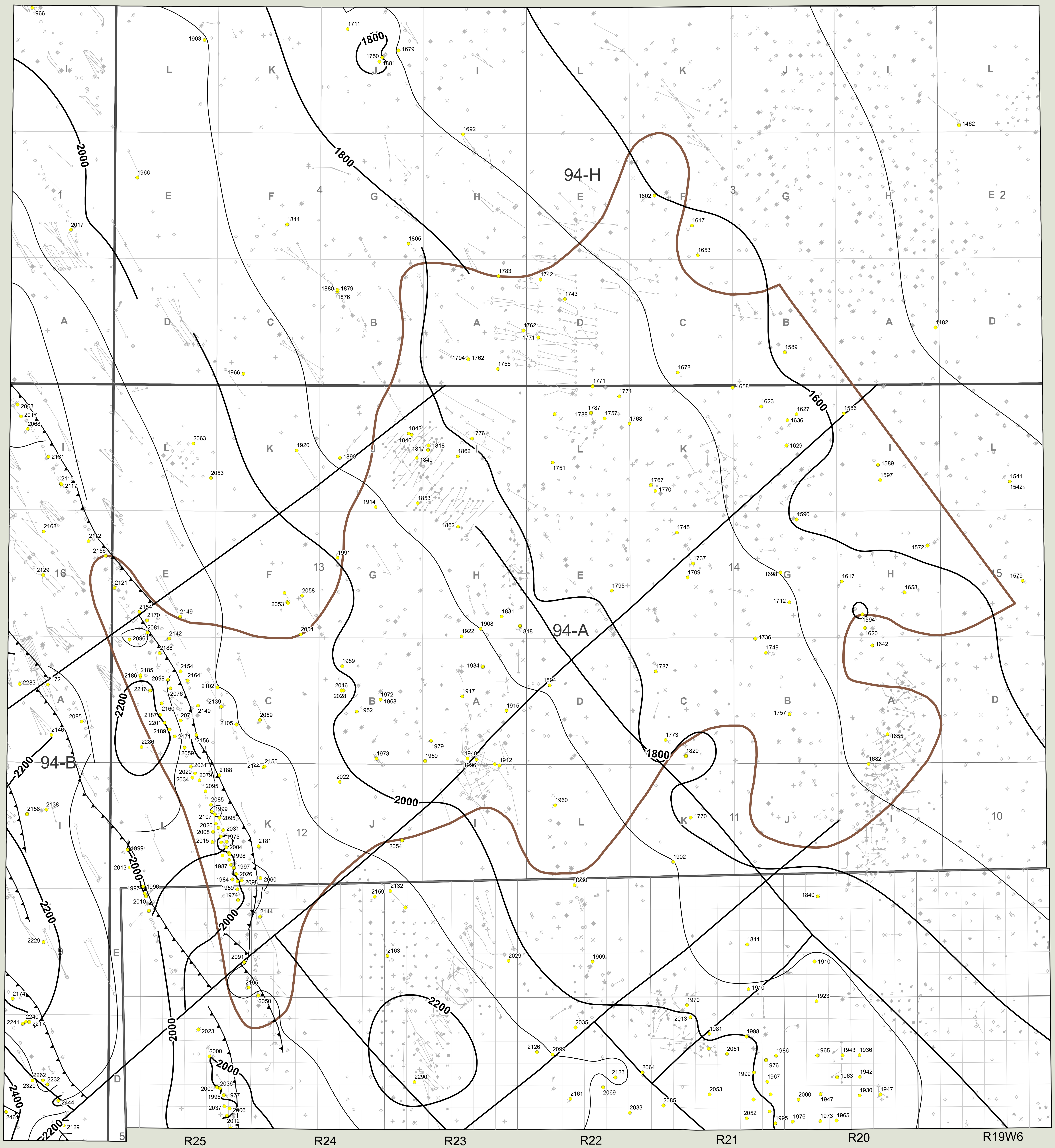
Belloy and Debolt Water Disposal Zones in the Montney Play Fairway, NEBC

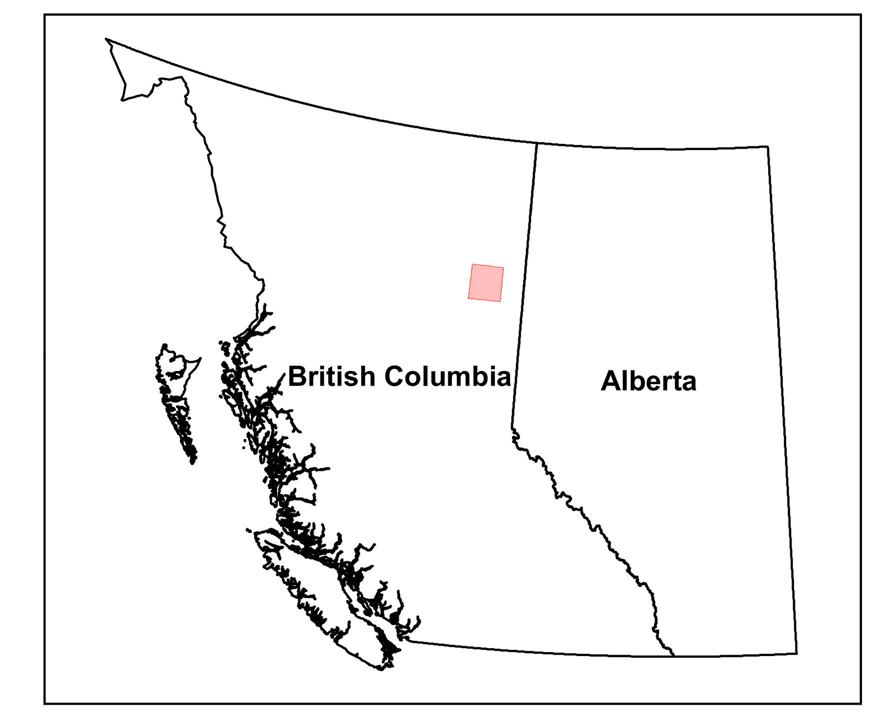
Canadian Discovery Ltd.

Data | Intelligence | Expertise

Debolt Area Lower Montney Pressure Depth Gradient

Filename: GCWD_DEBOLT_AREA_LWR_MNTNY_PD_MAP.mxd		Enclosure
Author: D Hume	Project: GCWD	2.20
Cartographer: C Poletto	Created: 10-April-2015	
Reviewer: N Watson	Last Edited: 29-June-2015	





Debolt Top TVD (m) (Petrel Robertson, Dec. 2014)

- Debolt Top TVD Value (m)
- C.I. = 100m

Structural and Geological Features

Faults

- Thrust Fault
- Normal Fault

Focus Area

- Debolt Focus Area

1:150,000

0 3 6 9 12 15 Km

Projection: UTM; Central Meridian -121.5; North American Datum 1983

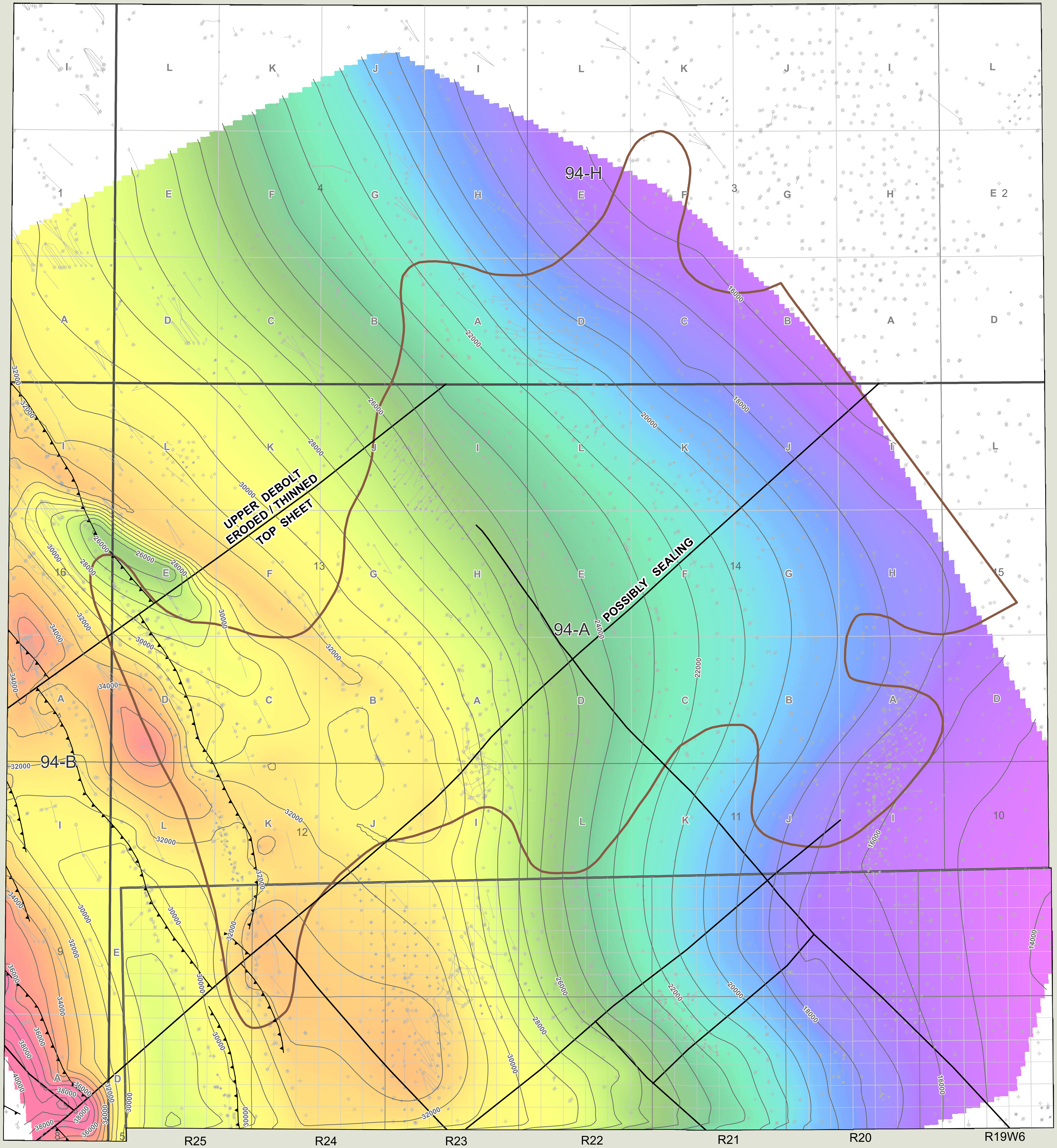
Belloy and Debolt Water Disposal Zones in the Montney Play Fairway, NEBC

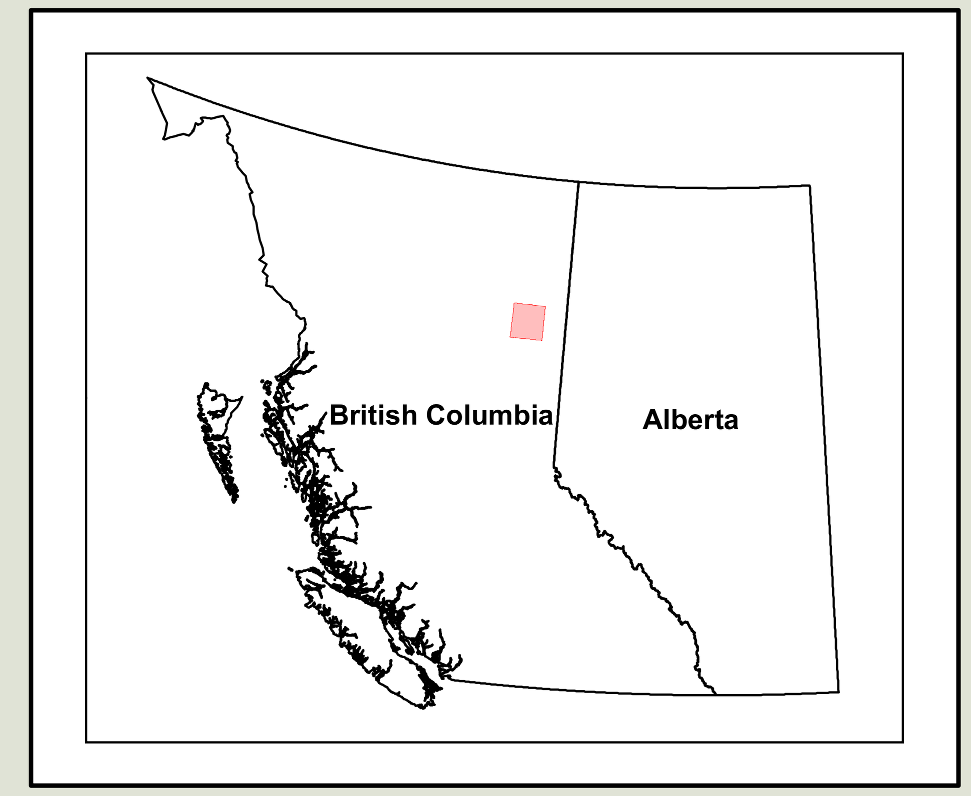
Canadian Discovery Ltd.

Data | Intelligence | Expertise

Debolt Area
Debolt TVD

Filename: GCWD_DEBOLT_TVD_MAP.mxd		Enclosure
Author: Petrel Robertson	Project: GCWD	2.21
Cartographer: C Poletto	Created: 10-April-2015	
Reviewer: N Watson	Last Edited: 29-June-2015	





Lower Montney Pressure (kPa/m)

C.I. = 1000 kPa/m

40449.1

13739.6

Structural and Geological Features

Thrust Fault

Normal Fault

Focus Area

Debolt Focus Area

1:150,000

0 3 6 9 12 15 Km

Projection: UTM; Central Meridian -121.5; North American Datum 1983

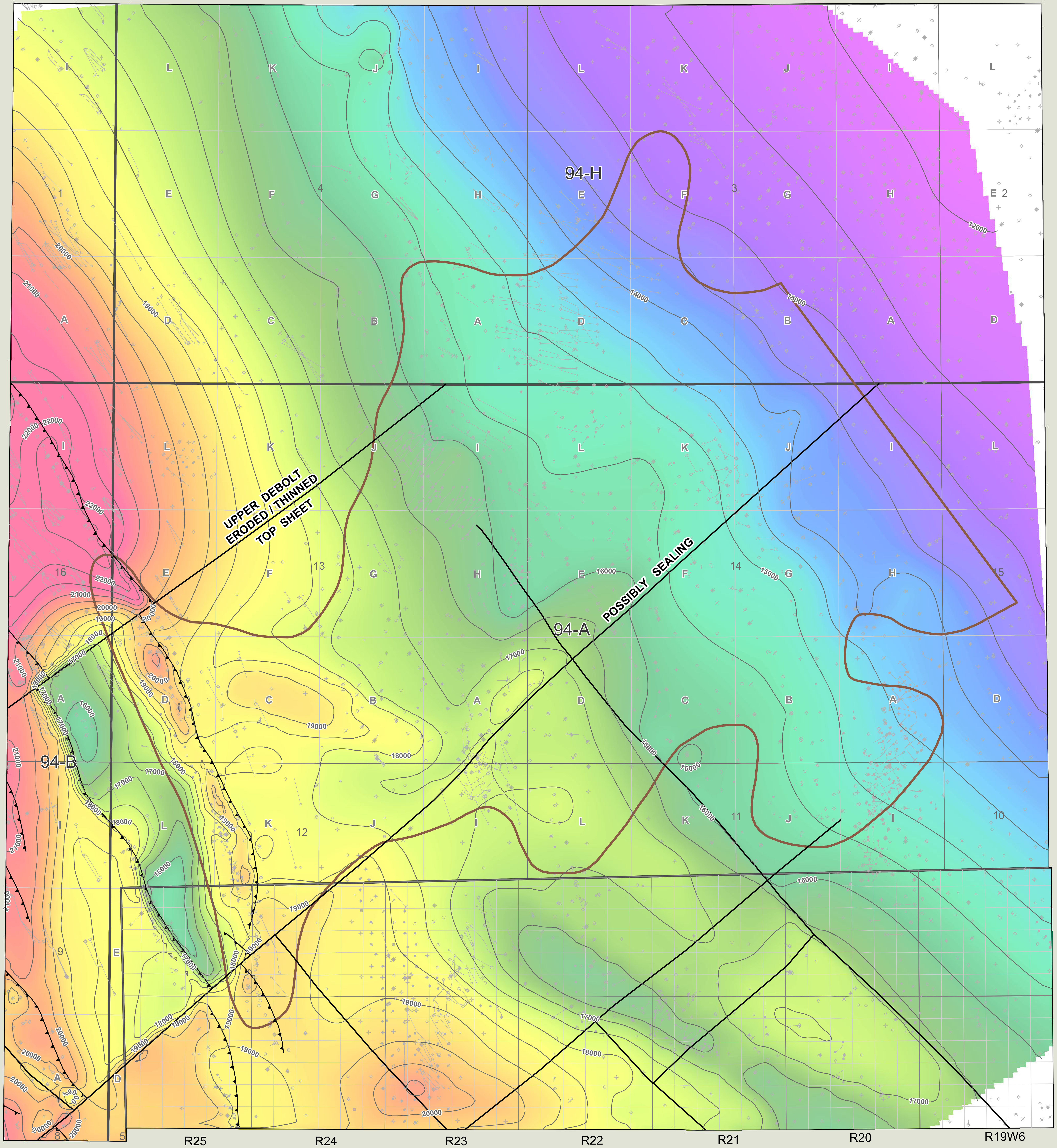
Belloy and Debolt Water Disposal Zones in the Montney Play Fairway, NEBC

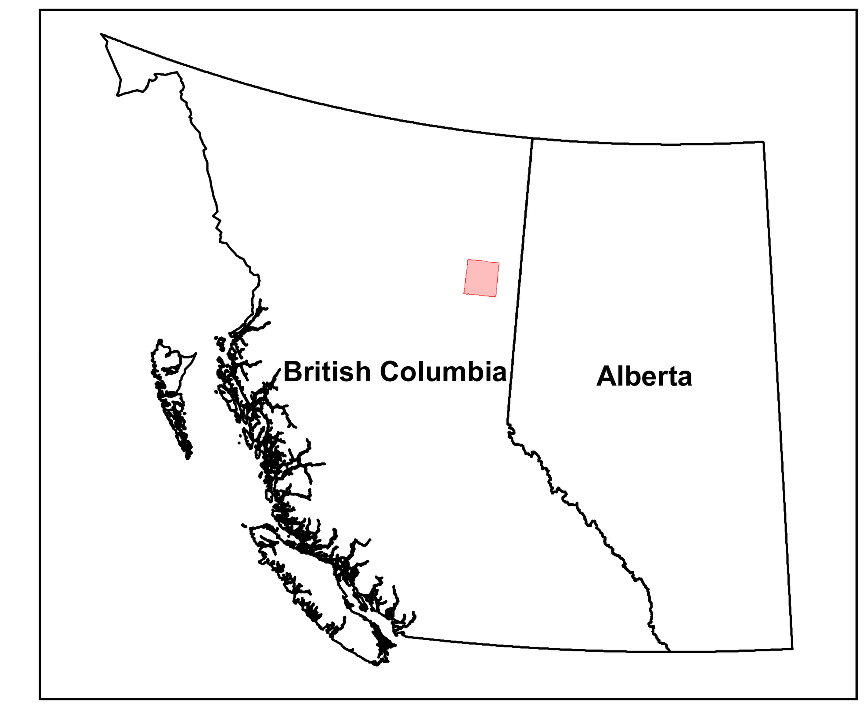
Canadian Discovery Ltd.

Data | Intelligence | Expertise

Debolt Area Theoretical Lower Montney Pressure at Debolt Top

Filename: GCWD_DEBOLT_AREA_LWR_MNTY_PRES_MAP.mxd		Enclosure
Author: N Watson	Project: GCWD	2.22
Cartographer: C Poletto	Created: 10-April-2015	
Reviewer: N Watson	Last Edited: 29-June-2015	





Debolt Pressure (kPa/m)
C.I. = 500 kPa/m
22964.8
11793.6

Structural and Geological Features
Thrust Fault
Normal Fault

Focus Area
Debolt Focus Area

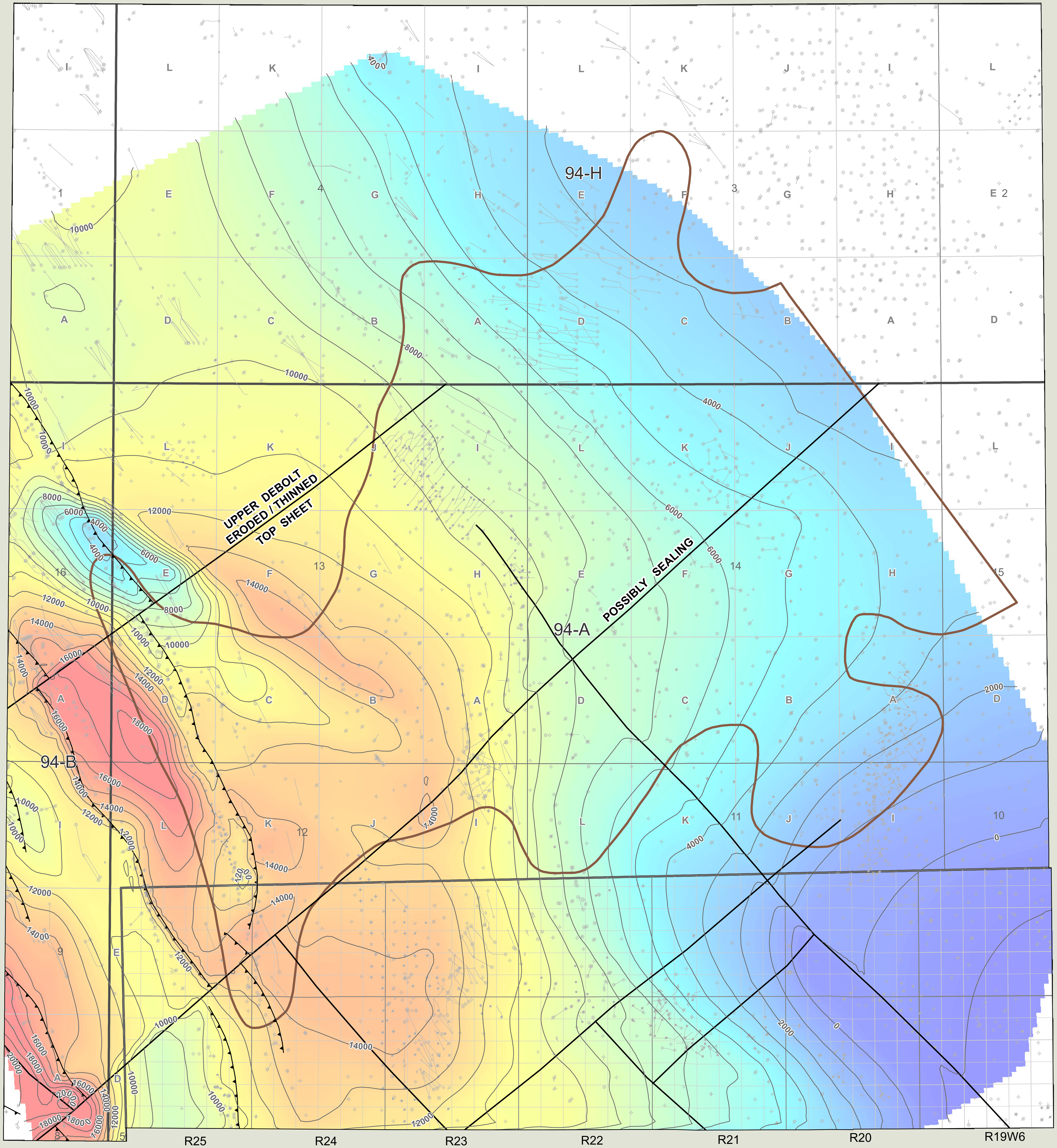
1:150,000
0 3 6 9 12 15 Km
Projection: UTM; Central Meridian -121.5; North American Datum 1983

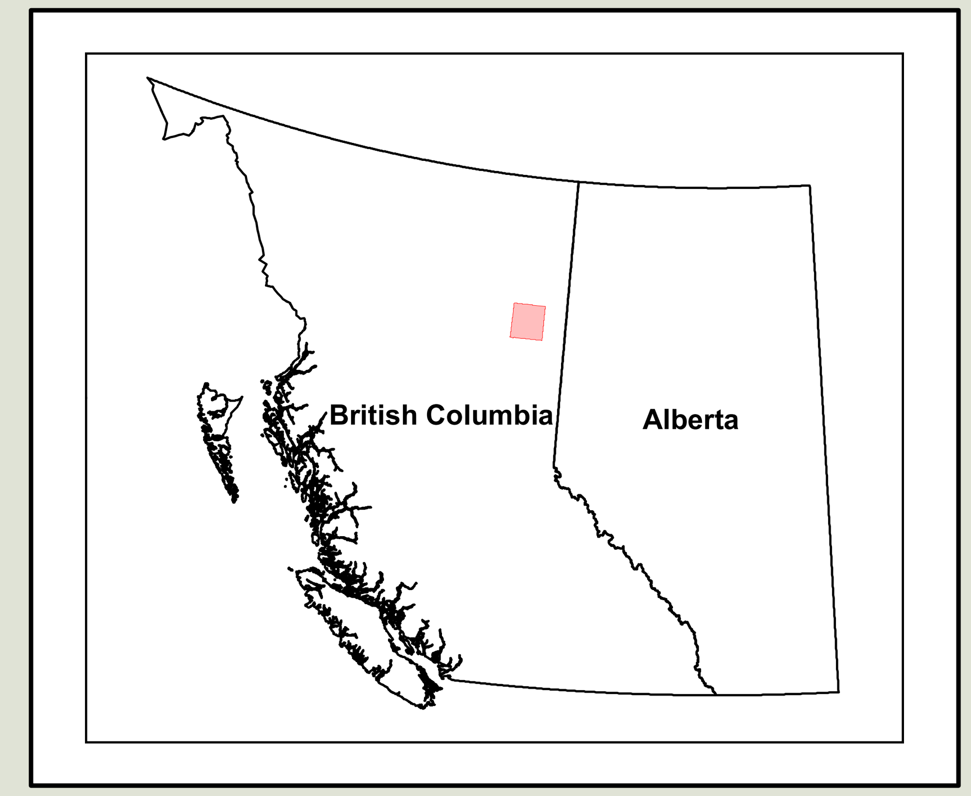
Belloy and Debolt Water Disposal Zones in the Montney Play Fairway, NEBC

Canadian Discovery Ltd.
Data | Intelligence | Expertise

Debolt Area Theoretical Debolt Pressure at Debolt Top

Filename: GCWD_DEBOLT_PRES_MAP.mxd		Enclosure
Author: N Watson	Project: GCWD	2.23
Cartographer: C Poletto	Created: 10-April-2015	
Reviewer: N Watson	Last Edited: 29-June-2015	





Theoretical Pressure Difference across Montney/Debolt Contact (kPa/m)

C.I.= 1000 kPa/m

21299.1

-1605.58

Structural and Geological Features

Thrust Fault

Normal Fault

Focus Area

Debolt Focus Area

1:150,000

0 3 6 9 12 15 Km

Projection: UTM; Central Meridian -121.5; North American Datum 1983

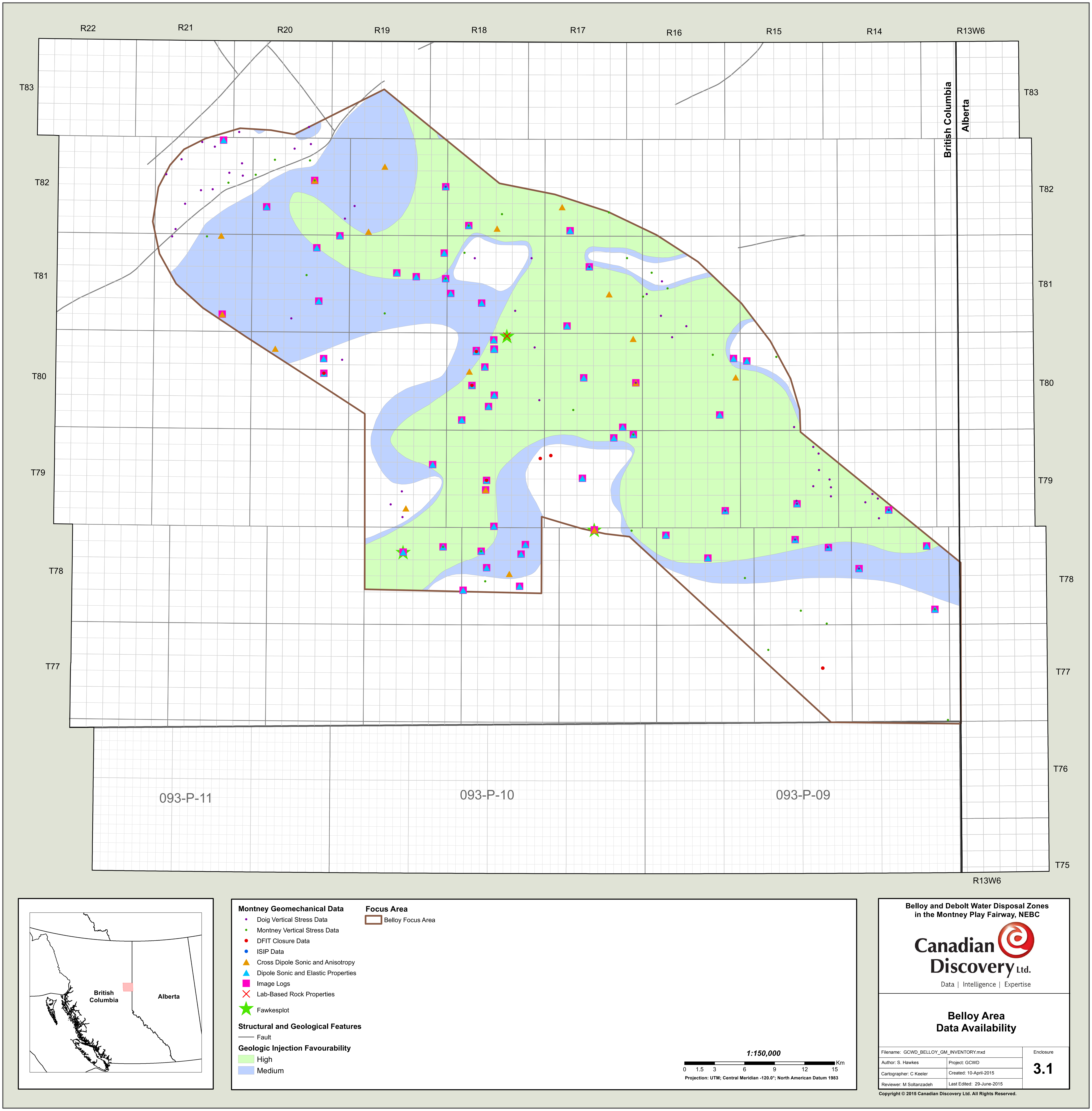
Belloy and Debolt Water Disposal Zones in the Montney Play Fairway, NEBC

Canadian Discovery Ltd.

Data | Intelligence | Expertise

Debolt Area Theoretical Pressure Difference across Montney/Debolt Contact

Filename: GCWD_DEBOLT_PRES_DIFF_MAP.mxd		Enclosure
Author: N Watson	Project: GCWD	2.24
Cartographer: C Poletto	Created: 10-April-2015	
Reviewer: N Watson	Last Edited: 29-June-2015	



R22
R21
R20
R19
R18
R17
R16
R15
R14
R13W6
T83
T82
T81
T80
T79
T78
T77
T76
T75
British Columbia
Alberta
093-P-11
093-P-10
093-P-09
British Columbia
Alberta
Montney Geomechanical Data
Doig Vertical Stress Data
Montney Vertical Stress Data
DFIT Closure Data
ISIP Data
Cross Dipole Sonic and Anisotropy
Dipole Sonic and Elastic Properties
Image Logs
Lab-Based Rock Properties
Fawkesplot
Structural and Geological Features
Fault
Geologic Injection Favourability
High
Medium
Focus Area
Belloy Focus Area
1:150,000
0 1.5 3 6 9 12 15 Km
Projection: UTM; Central Meridian -120.0°; North American Datum 1983
Belloy and Debolt Water Disposal Zones in the Montney Play Fairway, NEBC
Canadian Discovery Ltd.
Data | Intelligence | Expertise
Belloy Area Data Availability
Filename: GCWD_BELLOY_GM_INVENTORY.mxd
Enclosure
3.1
Author: S. Hawkes
Project: GCWD
Cartographer: C Keeler
Created: 10-April-2015
Reviewer: M Soltanzadeh
Last Edited: 29-June-2015
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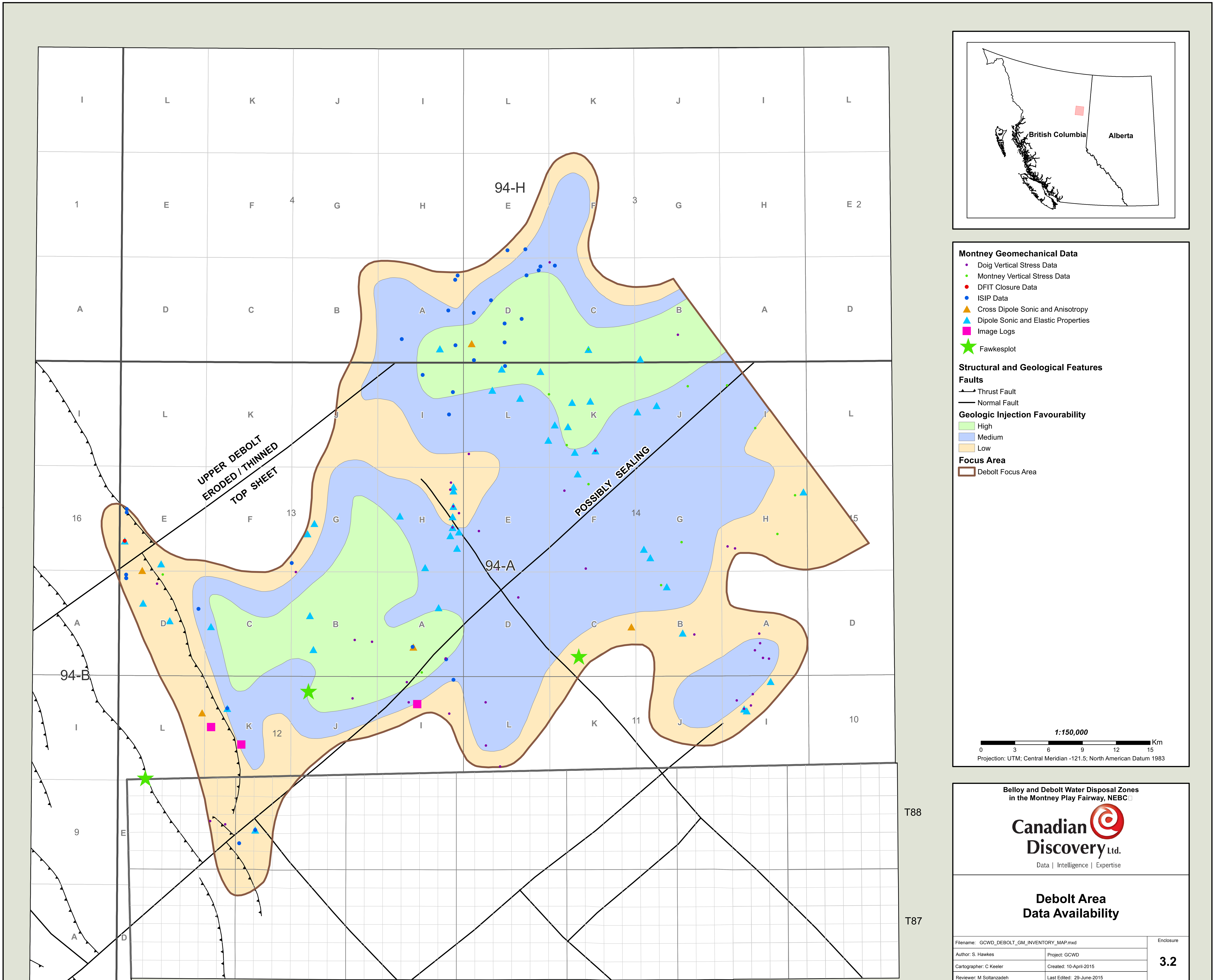
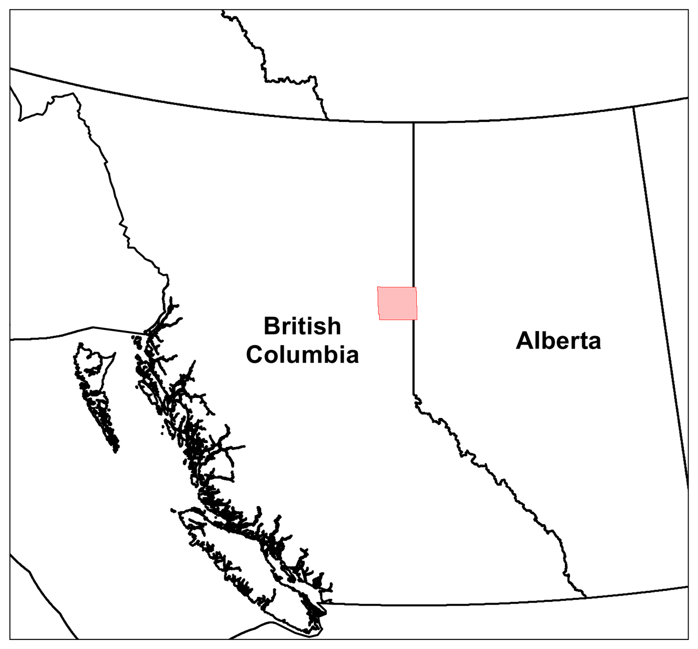

Montney Geomechanical Data
Doig Vertical Stress Data
Montney Vertical Stress Data
DFIT Closure Data
ISIP Data
Cross Dipole Sonic and Anisotropy
Dipole Sonic and Elastic Properties
Image Logs
Fawkesplot
Structural and Geological Features
Faults
Thrust Fault
Normal Fault
Geologic Injection Favourability
High
Medium
Low
Focus Area
Debolt Focus Area
1:150,000
0 3 6 9 12 15 Km
Projection: UTM; Central Meridian -121.5; North American Datum 1983
British Columbia
Alberta
94-H
94-A
94-B
UPPER DEBOLT ERODED / THINNED TOP SHEET
POSSIBLY SEALING
T88
T87
R25
R24
R23
R22
R21
R20
R19W6
Belloy and Debolt Water Disposal Zones
in the Montney Play Fairway, NEBC
Canadian Discovery Ltd.
Data | Intelligence | Expertise
Debolt Area
Data Availability
Filename: GCWD_DEBOLT_GM_INVENTORY_MAP.mxd
Author: S. Hawkes
Project: GCWD
Cartographer: C Keeler
Created: 10-April-2015
Reviewer: M Soltanzadeh
Last Edited: 29-June-2015
Enclosure
3.2



Poisson's Ratio - Montney/Doig
- 0.18 - 0.20
- 0.21 - 0.22
- 0.23 - 0.24
- 0.25 - 0.26
- 0.27 - 0.28
- 0.29 - 0.30

Structural and Geological Features
- Fault

Focus Area
- Belloy Focus Area

1:150,000

0 1.5 3 6 9 12 15 Km

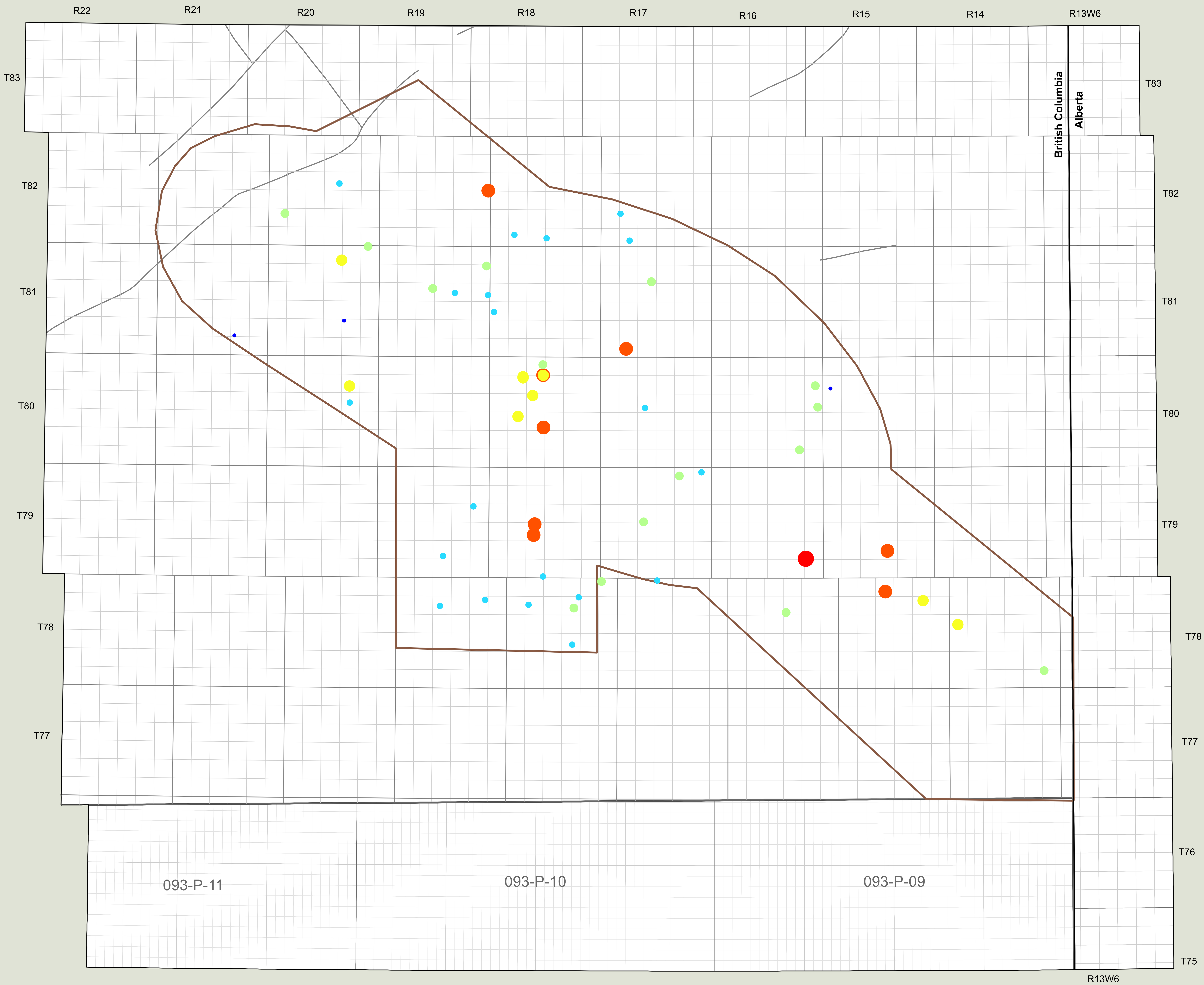
Projection: UTM; Central Meridian -120.0°; North American Datum 1983

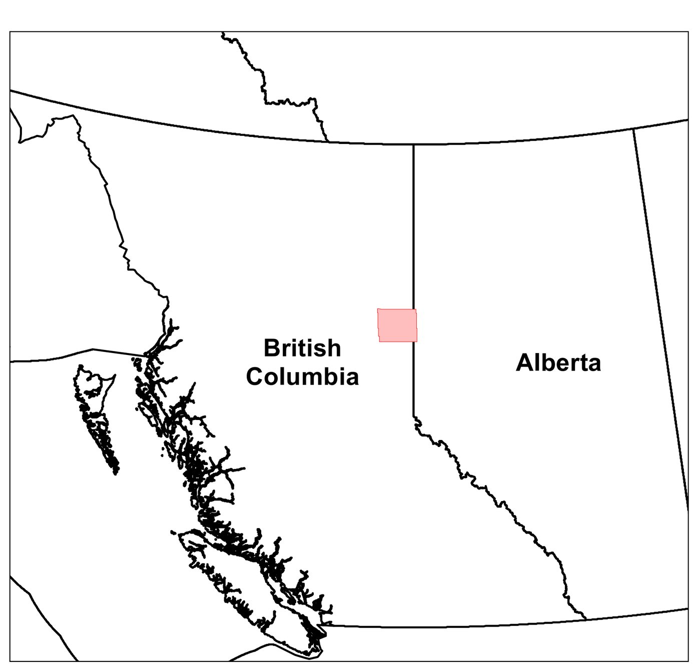
Belloy and Debolt Water Disposal Zones in the Montney Play Fairway, NEBC

Canadian Discovery Ltd.
Data | Intelligence | Expertise

Belloy Area
Montney/Doig
Poisson's Ratio Distribution

Filename: GCWD_BELLOY_PR_MAP.mxd		Enclosure
Author: S. Hawkes	Project: GCWD	3.3
Cartographer: C Keeler	Created: 10-April-2015	
Reviewer: M Soltanzadeh	Last Edited: 30-June-2015	





Young's Modulus - Montney/Doig

- 45.97 - 50.00
- 50.01 - 55.00
- 55.01 - 60.00
- 60.01 - 65.00
- 65.01 - 70.00
- 70.01 - 75.00

Structural and Geological Features

- Fault

Focus Area

- Belloy Focus Area

1:150,000

0 1.5 3 6 9 12 15 Km

Projection: UTM; Central Meridian -120.0°; North American Datum 1983

Belloy and Debolt Water Disposal Zones in the Montney Play Fairway, NEBC

Canadian Discovery Ltd.

Data | Intelligence | Expertise

Belloy Area Montney/Doig Young's Modulus Distribution

Filename: GCWD_BELLOY_YM_MONTNEY.mxd	
Author: S. Hawkes	Project: GCWD
Cartographer: C Keeler	Created: 10-April-2015
Reviewer: M Soltanzadeh	Last Edited: 29-June-2015

Enclosure

3.4

Poisson's Ratio

- 0.210 - 0.220
- 0.221 - 0.240
- 0.241 - 0.260
- 0.261 - 0.280
- 0.281 - 0.300
- 0.301 - 0.320

Focus Area

- Belloy Focus Area

Structural and Geological Features

- Fault

Geologic Injection Favourability

- High
- Medium

1:150,000

0 1.5 3 6 9 12 15 Km

Projection: UTM; Central Meridian -120.0°; North American Datum 1983

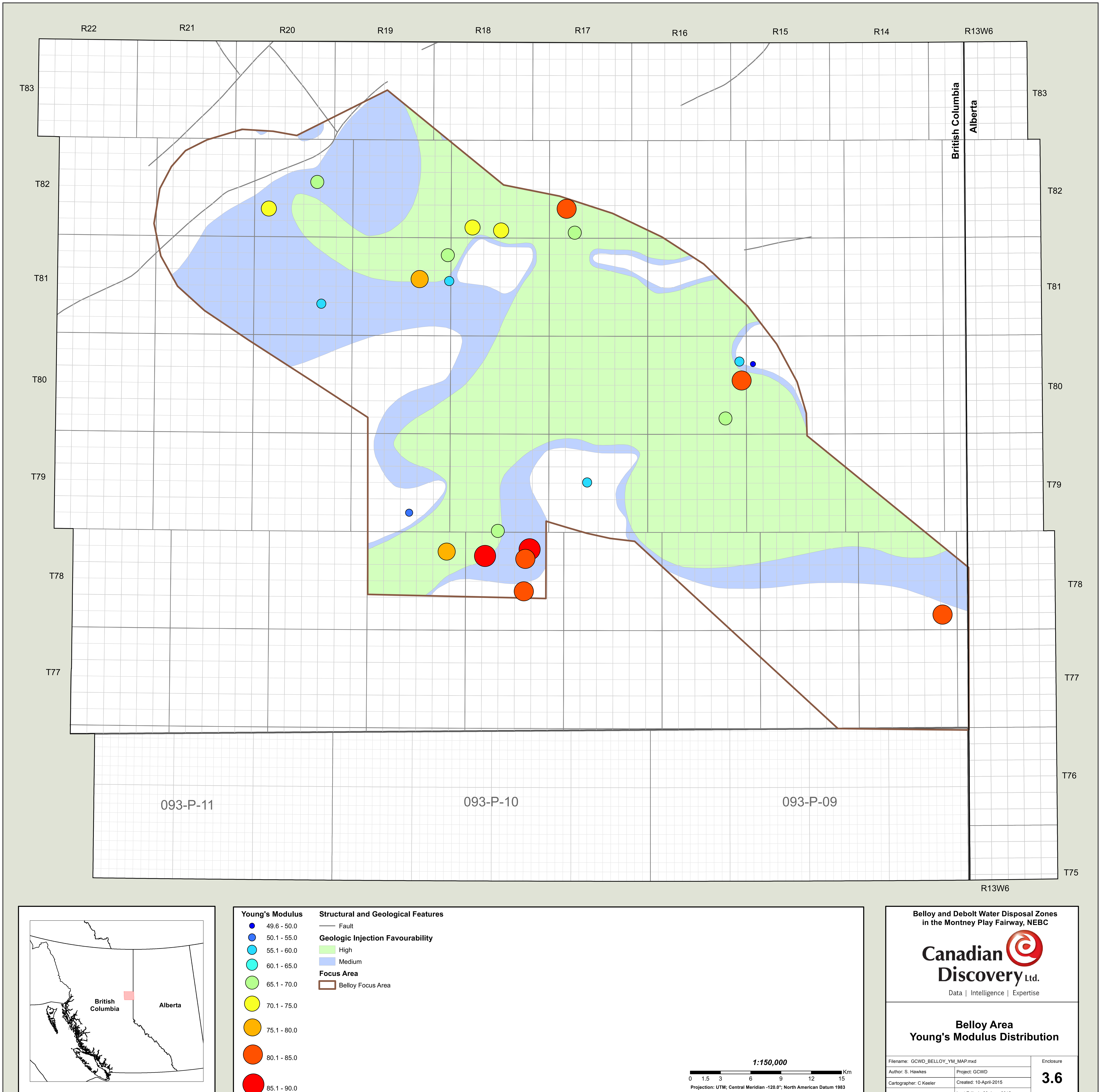
Belloy and Debolt Water Disposal Zones in the Montney Play Fairway, NEBC

Canadian Discovery Ltd.

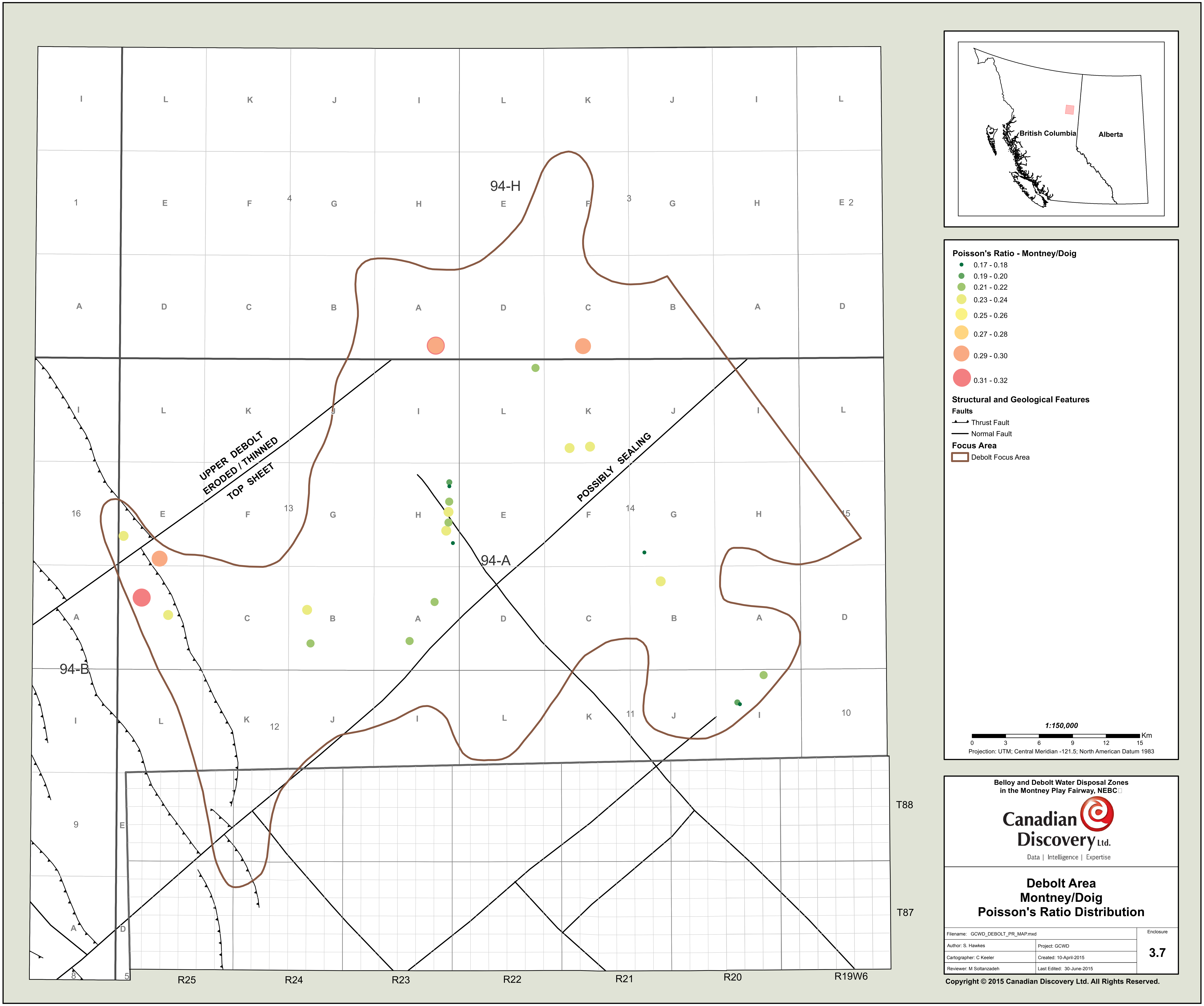
Data | Intelligence | Expertise

Belloy Area
Poisson's Ratio Distribution

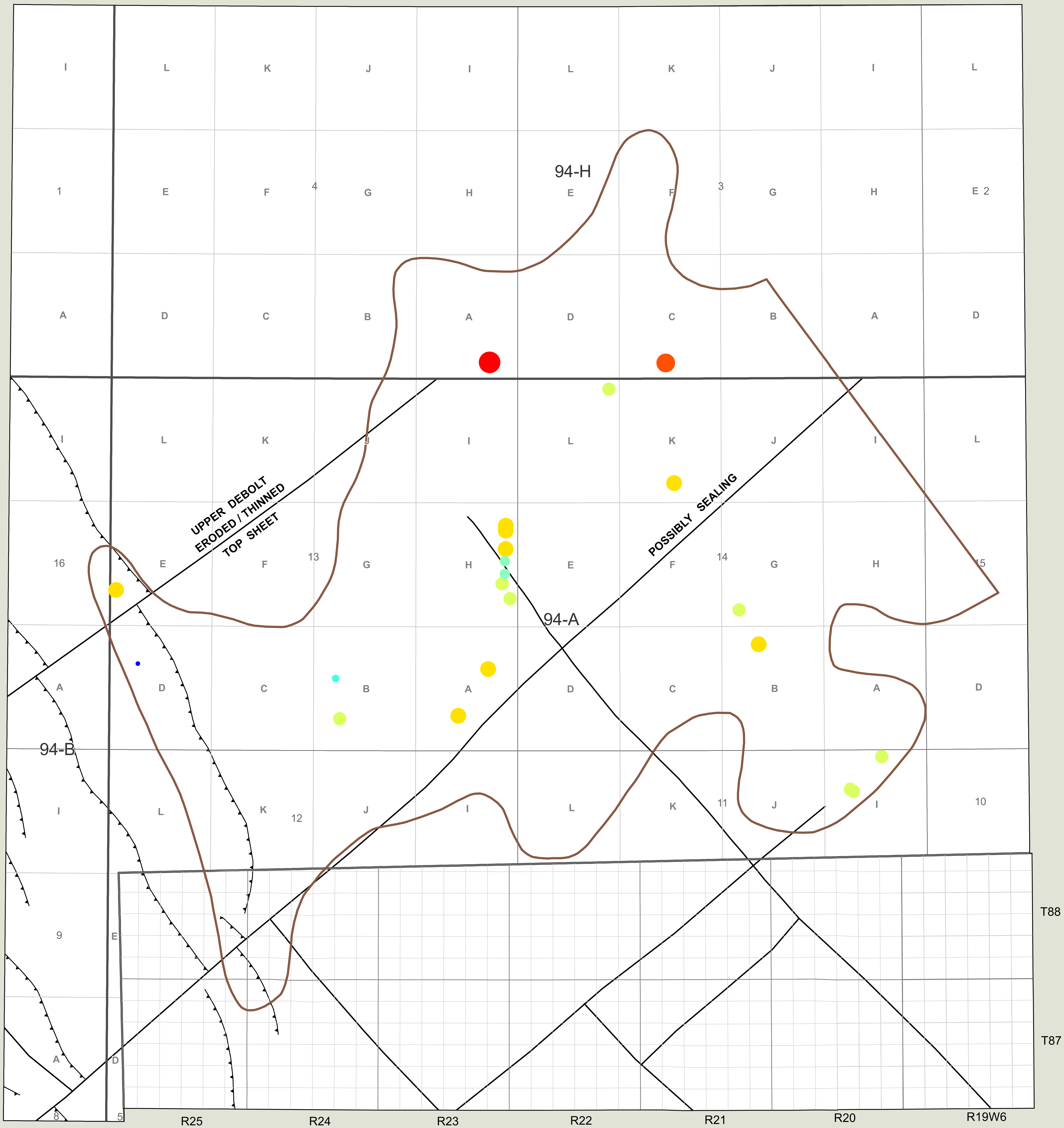
Filename: GCWD_BELLOY_PR_MAP.mxd		Enclosure
Author: S. Hawkes	Project: GCWD	3.5
Cartographer: C Keeler	Created: 10-April-2015	
Reviewer: M Soltanzadeh	Last Edited: 29-June-2015	

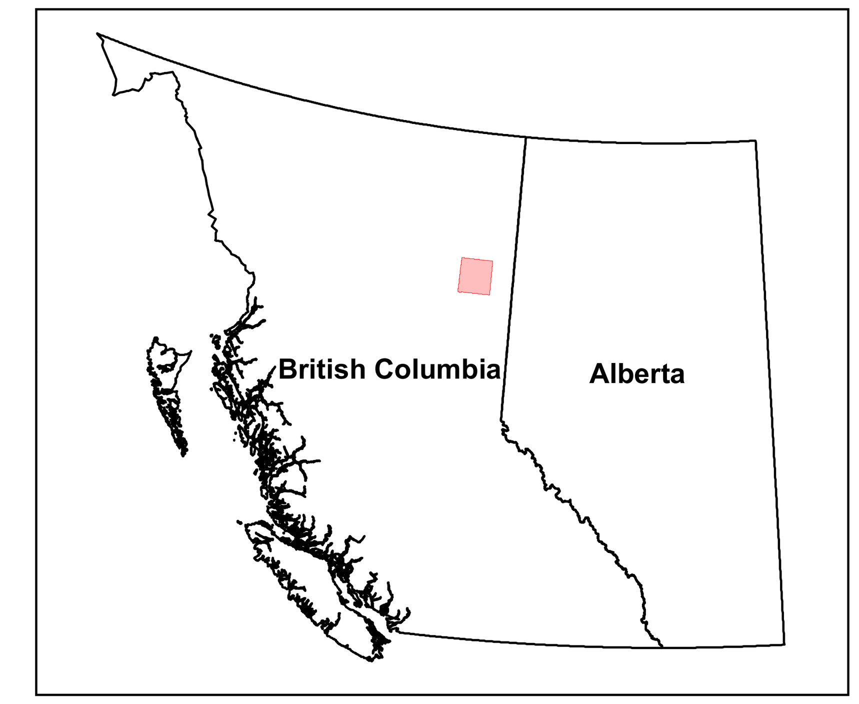


R22
R21
R20
R19
R18
R17
R16
R15
R14
R13W6
T83
T82
T81
T80
T79
T78
T77
T76
T75
British Columbia
Alberta
093-P-11
093-P-10
093-P-09
British Columbia
Alberta
Young's Modulus
49.6 - 50.0
50.1 - 55.0
55.1 - 60.0
60.1 - 65.0
65.1 - 70.0
70.1 - 75.0
75.1 - 80.0
80.1 - 85.0
85.1 - 90.0
Structural and Geological Features
Fault
Geologic Injection Favourability
High
Medium
Focus Area
Belloy Focus Area
1:150,000
0 1.5 3 6 9 12 15 Km
Projection: UTM; Central Meridian -120.0°; North American Datum 1983
Belloy and Debolt Water Disposal Zones
in the Montney Play Fairway, NEBC
Canadian Discovery Ltd.
Data | Intelligence | Expertise
Belloy Area
Young's Modulus Distribution
Filename: GCWD_BELLOY_YM_MAP.mxd
Author: S. Hawkes
Project: GCWD
Cartographer: C Keeler
Created: 10-April-2015
Reviewer: M Soltanzadeh
Last Edited: 29-June-2015
Enclosure
3.6



94-H
94-A
94-B
UPPER DEBOLT ERODED / THINNED TOP SHEET
POSSIBLY SEALING
T88
T87
R25
R24
R23
R22
R21
R20
R19W6
British Columbia
Alberta
Poisson's Ratio - Montney/Doig
0.17 - 0.18
0.19 - 0.20
0.21 - 0.22
0.23 - 0.24
0.25 - 0.26
0.27 - 0.28
0.29 - 0.30
0.31 - 0.32
Structural and Geological Features
Faults
Thrust Fault
Normal Fault
Focus Area
Debolt Focus Area
1:150,000
0 3 6 9 12 15 Km
Projection: UTM; Central Meridian -121.5; North American Datum 1983
Belloy and Debolt Water Disposal Zones in the Montney Play Fairway, NEBC
Canadian Discovery Ltd.
Data | Intelligence | Expertise
Debolt Area
Montney/Doig
Poisson's Ratio Distribution
Filename: GCWD_DEBOLT_PR_MAP.mxd
Author: S. Hawkes
Project: GCWD
Cartographer: C Keeler
Created: 10-April-2015
Reviewer: M Soltanzadeh
Last Edited: 30-June-2015
Enclosure
3.7





Young's Modulus - Montney/Doig

- 44.90 - 45.00
- 45.01 - 50.00
- 50.01 - 55.00
- 55.01 - 60.00
- 60.01 - 65.00
- 65.01 - 70.00
- 70.01 - 75.00

Structural and Geological Features

Faults

- Thrust Fault
- Normal Fault

Focus Area

- Debolt Focus Area

1:150,000

0 3 6 9 12 15 Km

Projection: UTM; Central Meridian -121.5; North American Datum 1983

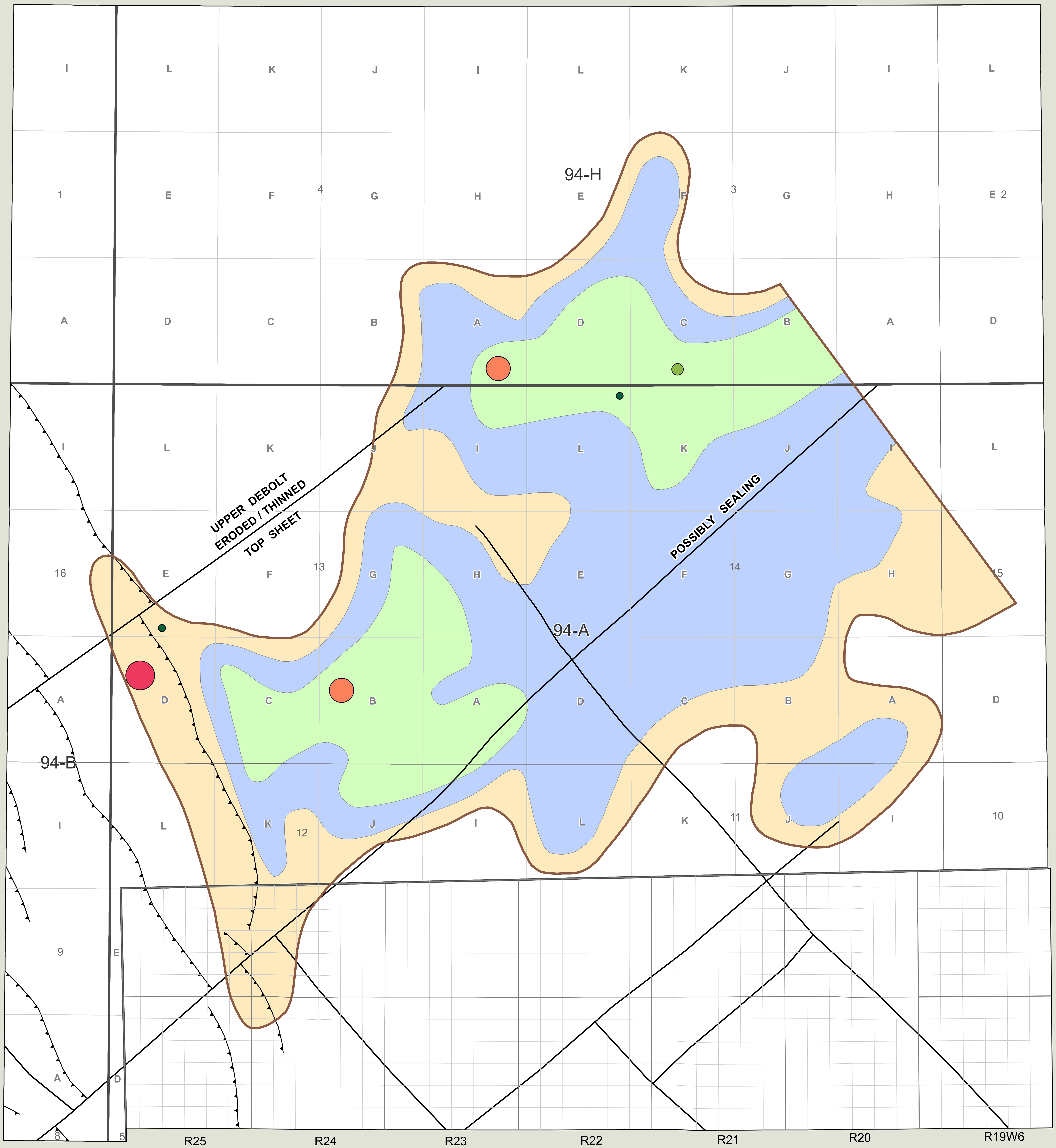
Belloy and Debolt Water Disposal Zones in the Montney Play Fairway, NEBC

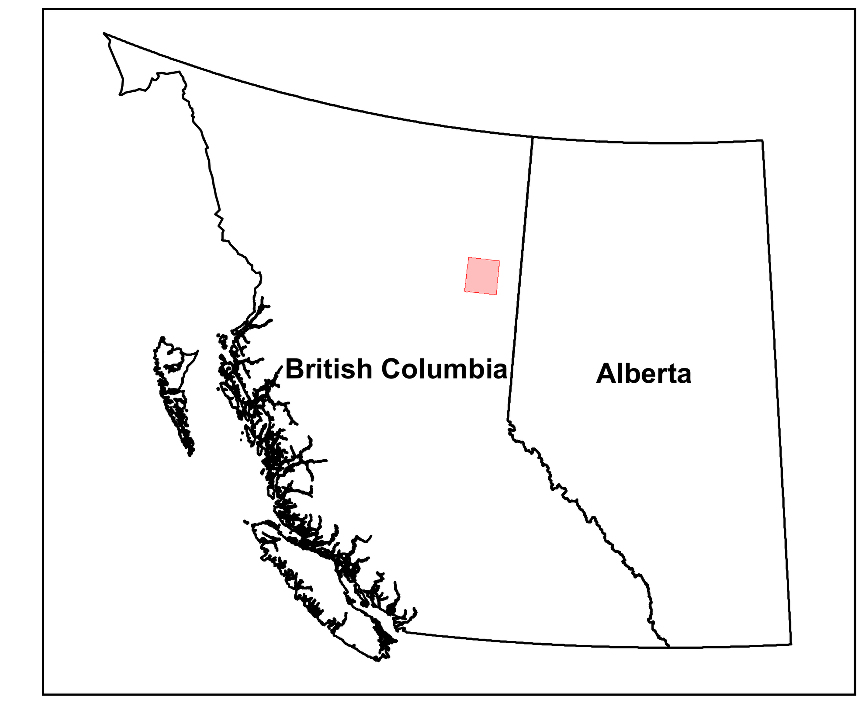
Canadian Discovery Ltd.

Data | Intelligence | Expertise

Debolt Area Montney/Doig Young's Modulus Distribution

Filename: GCWD_DEBOLT_YM_MONTNEY.mxd		Enclosure
Author: S. Hawkes	Project: GCWD	3.8
Cartographer: C Keeler	Created: 10-April-2015	
Reviewer: M Soltanzadeh	Last Edited: 30-June-2015	





Poisson's Ratio
- 0.260 - 0.270
- 0.271 - 0.280
- 0.281 - 0.290
- 0.291 - 0.300
- 0.301 - 0.310
- 0.311 - 0.320

Structural and Geological Features

Faults
- Thrust Fault
- Normal Fault

Geologic Injection Favourability
- High
- Medium
- Low

Focus Area
- Debolt Focus Area

1:150,000

0 3 6 9 12 15 Km

Projection: UTM; Central Meridian -121.5; North American Datum 1983

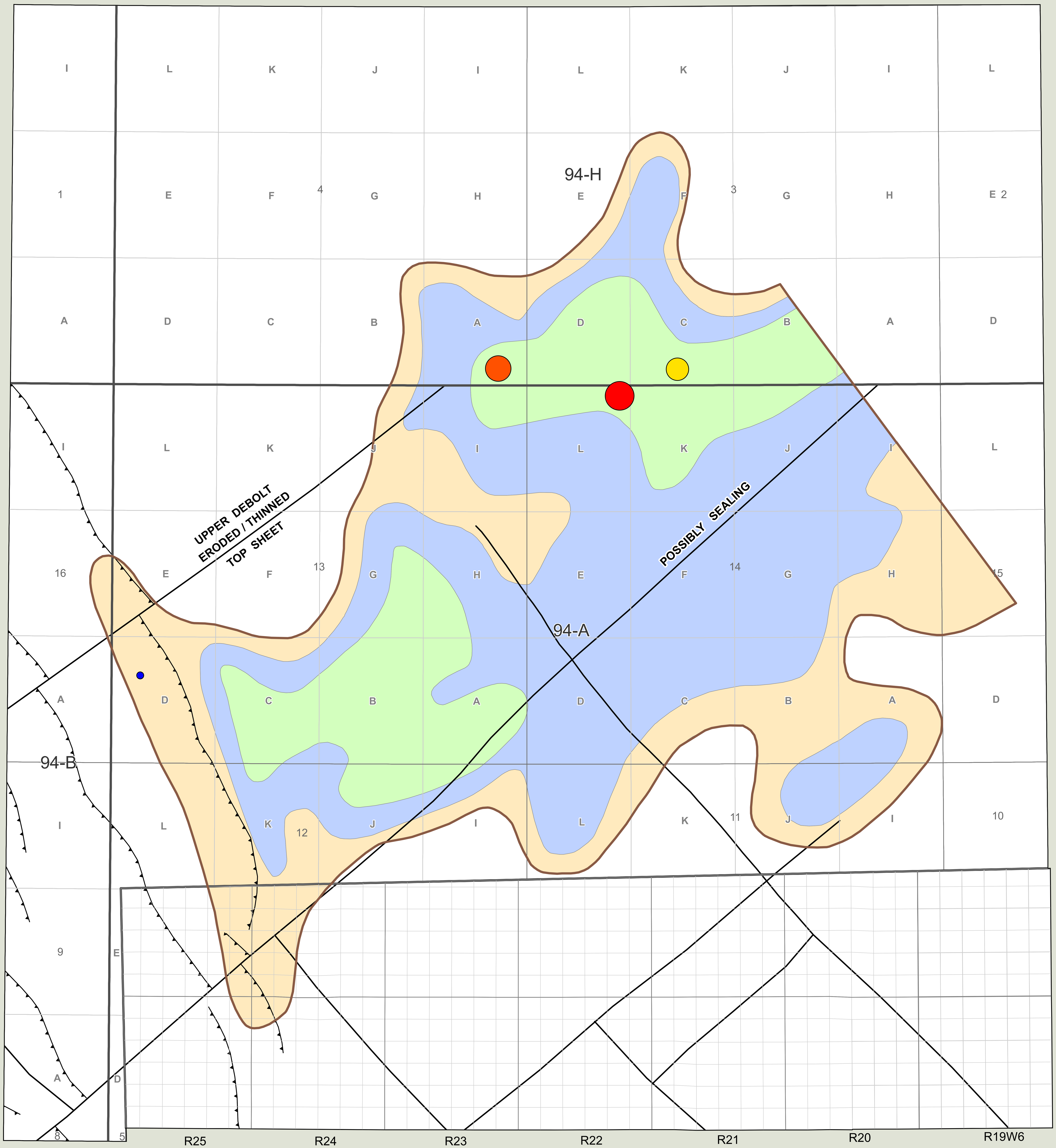
Belloy and Debolt Water Disposal Zones in the Montney Play Fairway, NEBC

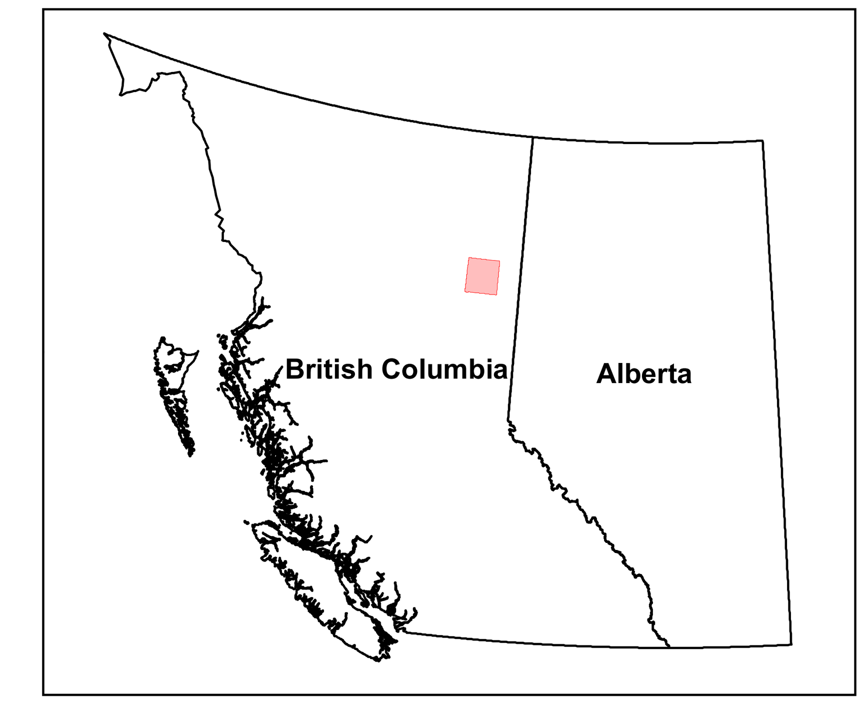
Canadian Discovery Ltd.

Data | Intelligence | Expertise

Debolt Area
Poisson's Ratio Distribution

Filename: GCWD_DEBOLT_PR_MAP.mxd		Enclosure
Author: S. Hawkes	Project: GCWD	3.9
Cartographer: C Keeler	Created: 10-April-2015	
Reviewer: M Soltanzadeh	Last Edited: 29-June-2015	





Young's Modulus

- 44.90 - 45.00
- 45.01 - 50.00
- 50.01 - 55.00
- 55.01 - 60.00
- 60.01 - 65.00
- 65.01 - 70.00
- 70.01 - 75.00
- 75.01 - 80.00

Structural and Geological Features

Faults

- Thrust Fault
- Normal Fault

Geologic Injection Favourability

- High
- Medium
- Low

Focus Area

- Debolt Focus Area

1:150,000

0 3 6 9 12 15 Km

Projection: UTM; Central Meridian -121.5; North American Datum 1983

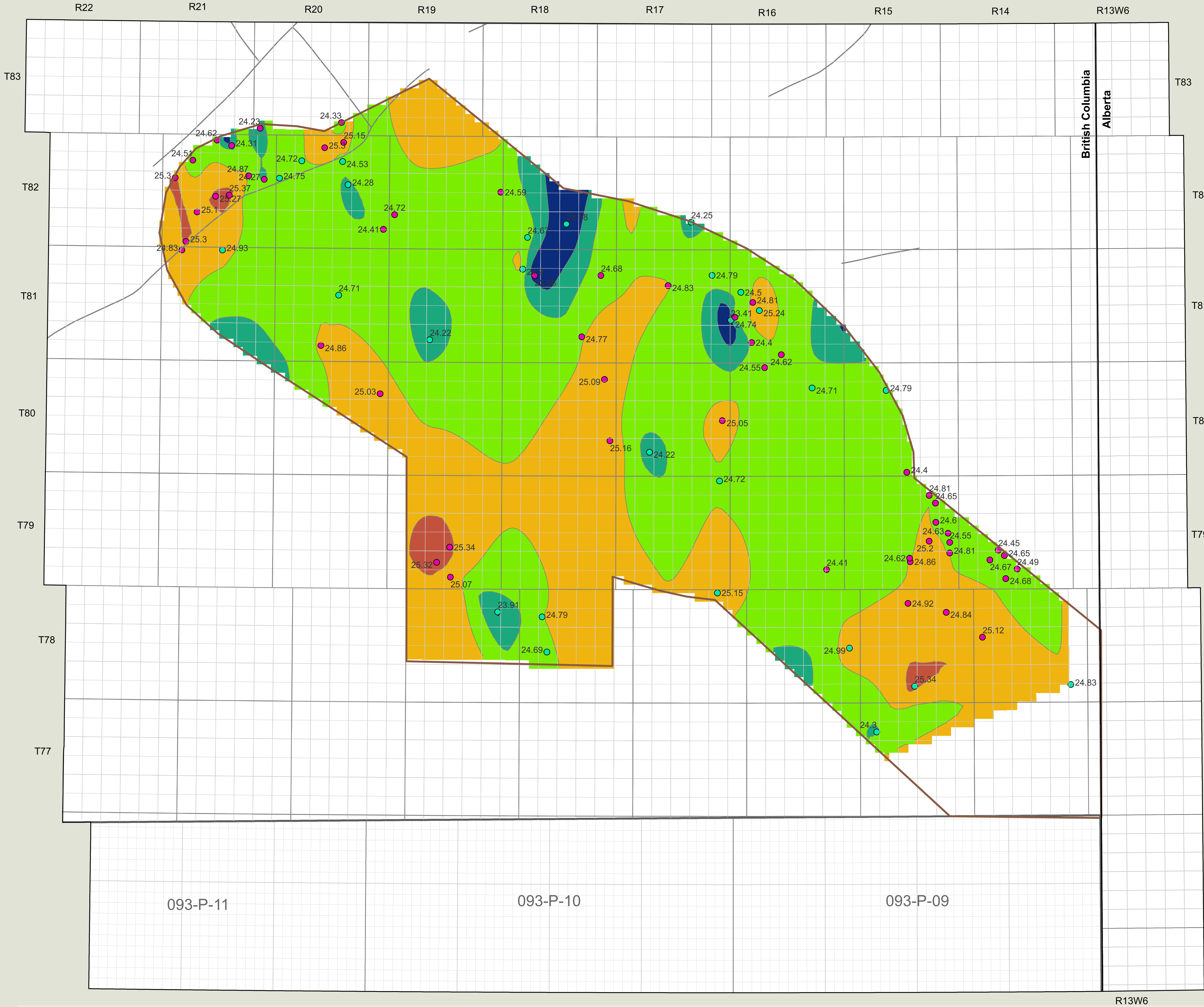
Belloy and Debolt Water Disposal Zones in the Montney Play Fairway, NEBC

Canadian Discovery Ltd.

Data | Intelligence | Expertise

Debolt Area
Young's Modulus Distribution

Filename: GCWD_DEBOLT_YM_MAP.mxd		Enclosure
Author: S. Hawkes	Project: GCWD	3.10
Cartographer: C Keeler	Created: 10-April-2015	
Reviewer: M Soltanzadeh	Last Edited: 29-June-2015	



Structural and Geological Features

- Fault

Montney Vertical Stress Gradient (kPa/m)

- Montney Vertical Stress Gradient Value (Original)
- Montney Vertical Stress Gradient Value (Corrected)
- C.I. = 0.4
- 23.6 - 24
- 24.1 - 24.4
- 24.5 - 24.8
- 24.9 - 25.2
- 25.3 - 25.6

1:150,000

0 1.5 3 6 9 12 15 Km

Projection: UTM; Central Meridian -120.0°; North American Datum 1983

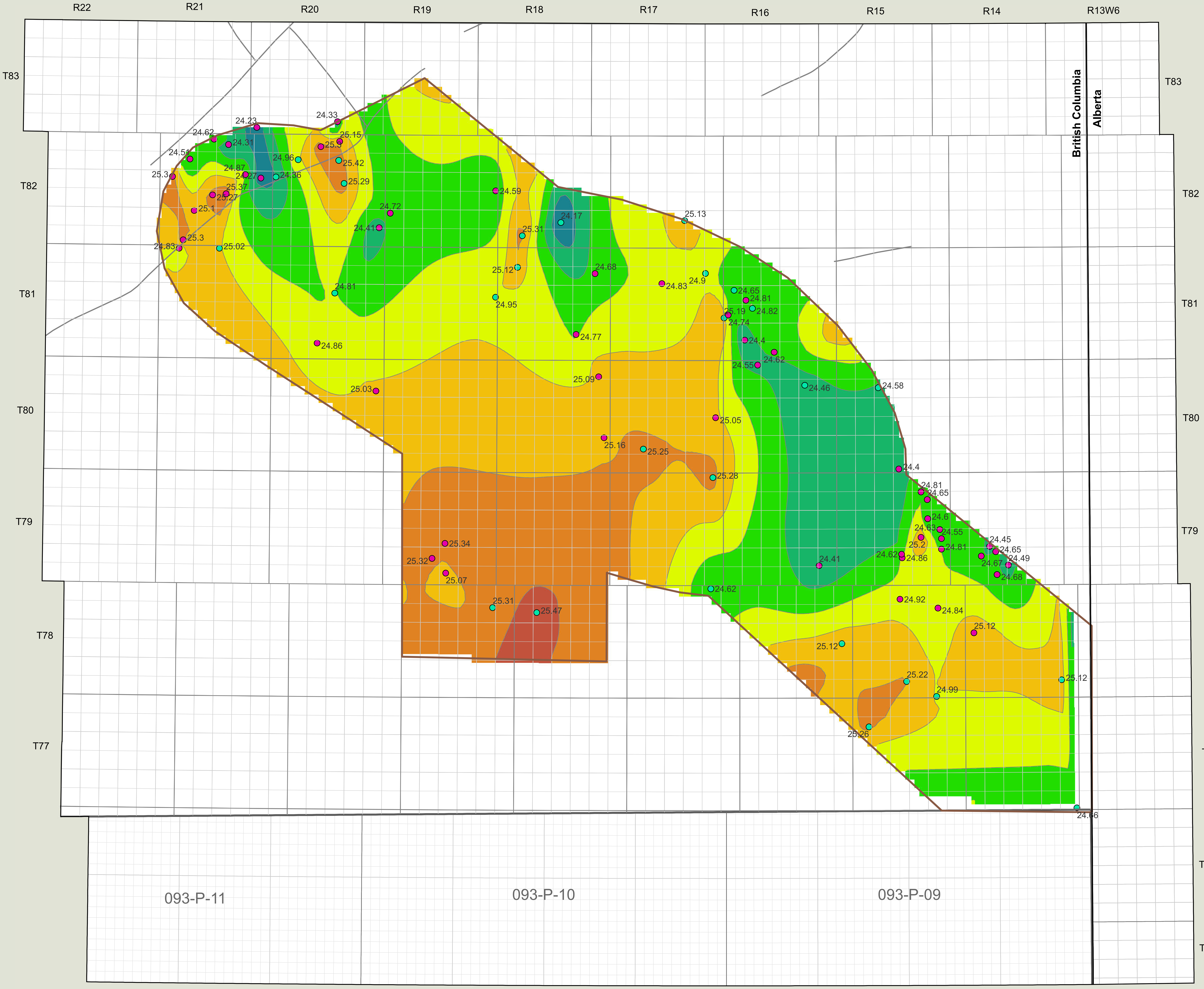
Belloy and Debolt Water Disposal Zones in the Montney Play Fairway, NEBC

Canadian Discovery Ltd.

Data | Intelligence | Expertise

Belloy Area
Montney/Doig Vertical Stress

Filename: GCWD_BELLOY_MONTNEY_SV_MAP.mxd		Enclosure 3.11
Author: S. Hawkes	Project: GCWD	
Cartographer: C Keeler	Created: 10-April-2015	
Reviewer: M Soltanzadeh	Last Edited: 29-June-2015	



Belloy Vertical Stress Gradient (kPa/m)

- Belloy Veritcal Stress Gradient Value (Original)
- Belloy Veritcal Stress Gradient Value (Corrected)
- C.I. = 0.2
- 24.2 - 24.2
- 24.3 - 24.4
- 24.5 - 24.6
- 24.7 - 24.8
- 24.9 - 25
- 25.1 - 25.2
- 25.3 - 25.4
- 25.5 - 25.6

Structural and Geological Features

- Fault

Focus Area

- Belloy Focus Area

1:150,000

0 1.5 3 6 9 12 15 Km

Projection: UTM; Central Meridian -120.0°; North American Datum 1983

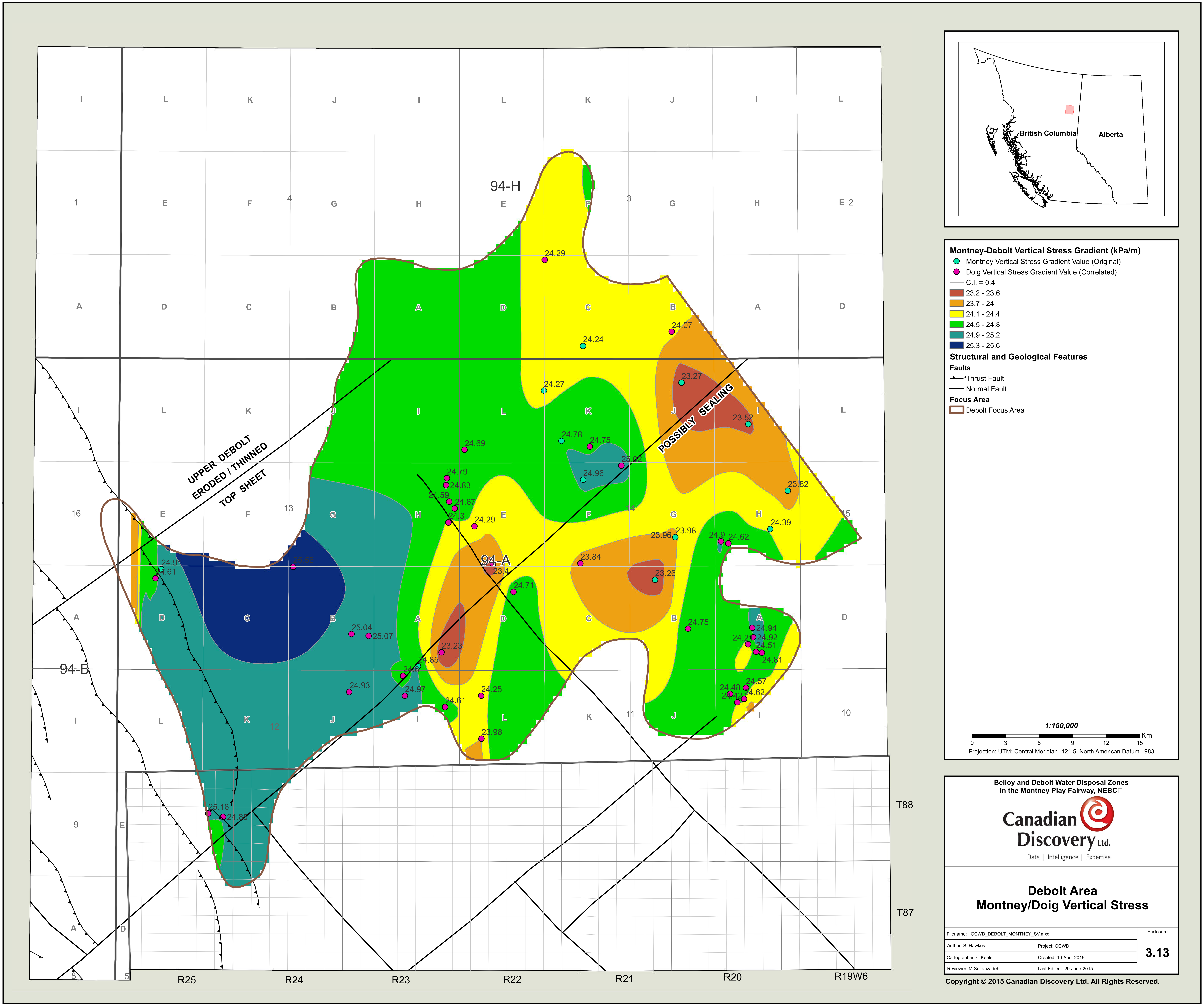
Belloy and Debolt Water Disposal Zones in the Montney Play Fairway, NEBC

Canadian Discovery Ltd.

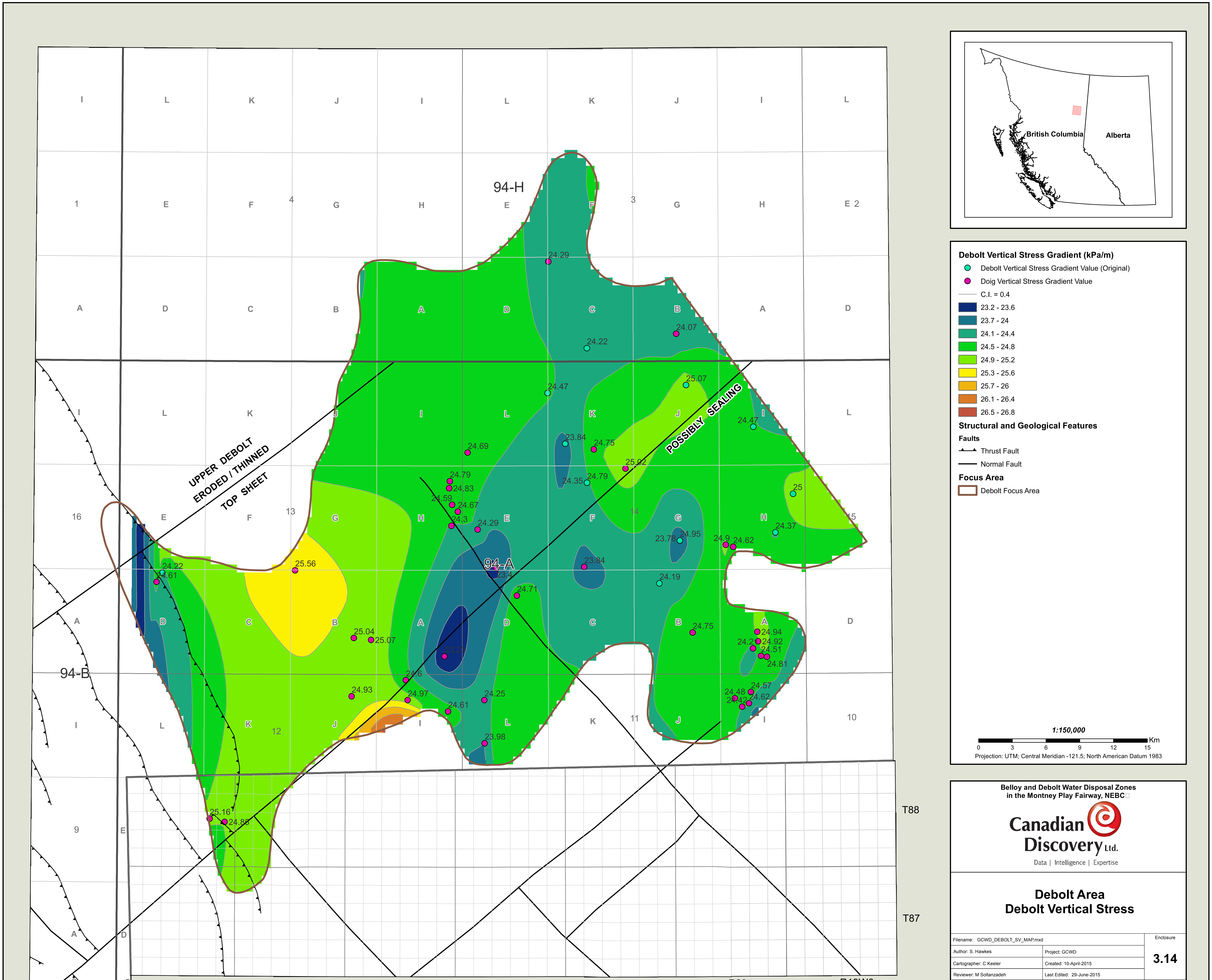
Data | Intelligence | Expertise

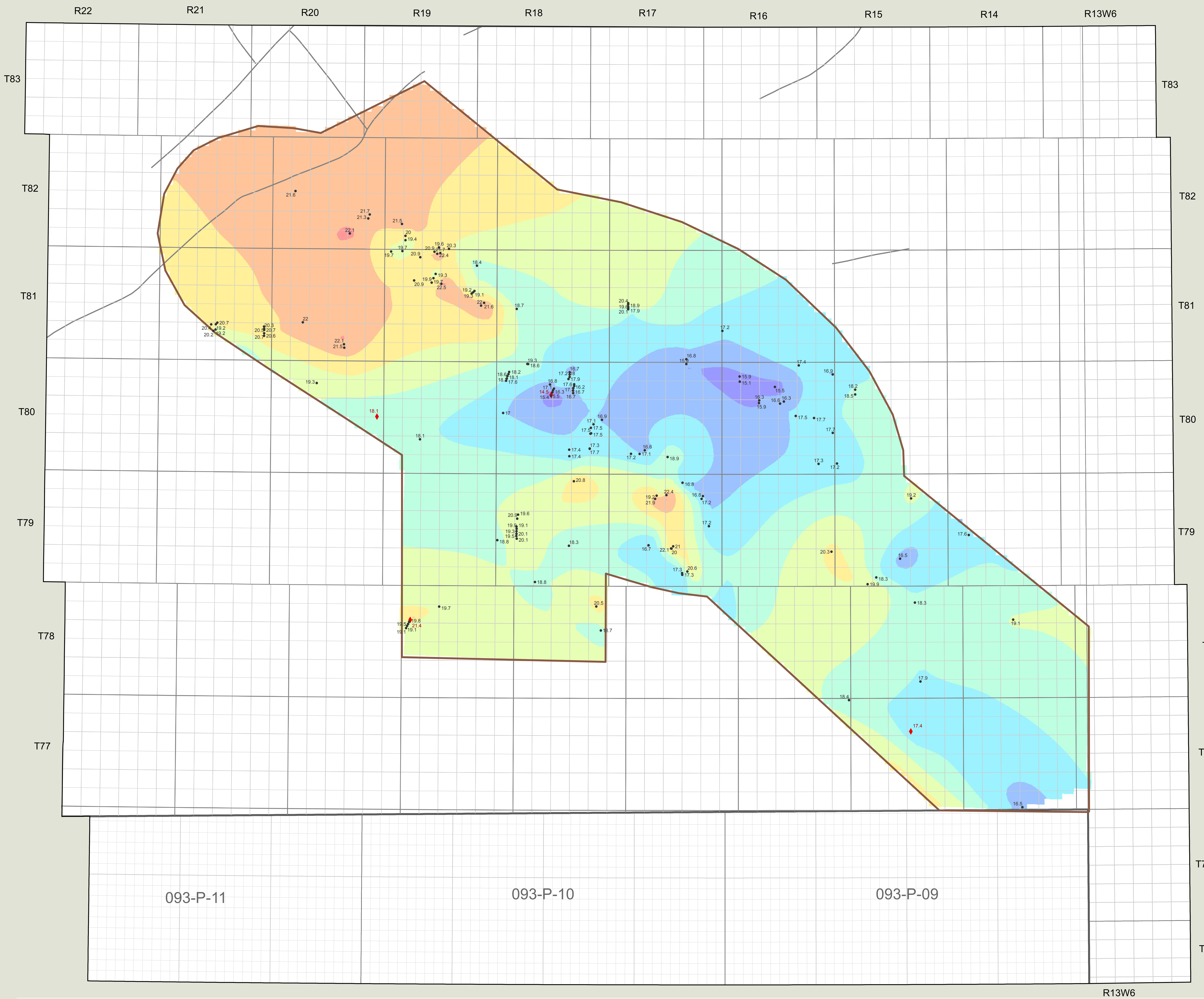
Belloy Area
Belloy Vertical Stress

Filename: GCWD_BELLOY_SV_MAP.mxd		Enclosure
Author: S. Hawkes	Project: GCWD	3.12
Cartographer: C Keeler	Created: 10-April-2015	
Reviewer: M Soltanzadeh	Last Edited: 29-June-2015	



94-H
94-A
94-B
UPPER DEBOLT ERODED / THINNED TOP SHEET
POSSIBLY SEALING
T88
T87
R25
R24
R23
R22
R21
R20
R19W6
British Columbia
Alberta
Montney-Debolt Vertical Stress Gradient (kPa/m)
Montney Vertical Stress Gradient Value (Original)
Doig Vertical Stress Gradient Value (Correlated)
C.I. = 0.4
23.2 - 23.6
23.7 - 24
24.1 - 24.4
24.5 - 24.8
24.9 - 25.2
25.3 - 25.6
Structural and Geological Features
Faults
Thrust Fault
Normal Fault
Focus Area
Debolt Focus Area
1:150,000
0 3 6 9 12 15 Km
Projection: UTM; Central Meridian -121.5; North American Datum 1983
Belloy and Debolt Water Disposal Zones in the Montney Play Fairway, NEBC
Canadian Discovery Ltd.
Data | Intelligence | Expertise
Debolt Area
Montney/Doig Vertical Stress
Filename: GCWD_DEBOLT_MONTNEY_SV.mxd
Author: S. Hawkes
Project: GCWD
Cartographer: C Keeler
Created: 10-April-2015
Reviewer: M Soltanzadeh
Last Edited: 29-June-2015
Enclosure
3.13


94-H
94-A
94-B
UPPER DEBOLT ERODED / THINNED TOP SHEET
POSSIBLY SEALING
T88
T87
R25
R24
R23
R22
R21
R20
R19W6
British Columbia
Alberta
Debolt Vertical Stress Gradient (kPa/m)
Debolt Vertical Stress Gradient Value (Original)
Doig Vertical Stress Gradient Value
C.I. = 0.4
23.2 - 23.6
23.7 - 24
24.1 - 24.4
24.5 - 24.8
24.9 - 25.2
25.3 - 25.6
25.7 - 26
26.1 - 26.4
26.5 - 26.8
Structural and Geological Features
Faults
Thrust Fault
Normal Fault
Focus Area
Debolt Focus Area
1:150,000
0 3 6 9 12 15 Km
Projection: UTM; Central Meridian -121.5; North American Datum 1983
Belloy and Debolt Water Disposal Zones in the Montney Play Fairway, NEBC
Canadian Discovery Ltd.
Data | Intelligence | Expertise
Debolt Area
Debolt Vertical Stress
Filename: GCWD_DEBOLT_SV_MAP.mxd
Author: S. Hawkes
Project: GCWD
Cartographer: C Keeler
Created: 10-April-2015
Reviewer: M Soltanzadeh
Last Edited: 29-June-2015
Enclosure
3.14



Shmin Test Type

- DFIT
- ISIP
- 15.3 - 16
- 16.1 - 17
- 17.1 - 18
- 18.1 - 19
- 19.1 - 20
- 20.1 - 21
- 21.1 - 22
- 22.1 - 23

Structural and Geological Features

- Fault

Focus Area

- Belloy Focus Area

1:150,000

0 1.5 3 6 9 12 15 Km

Projection: UTM; Central Meridian -120.0°; North American Datum 1983

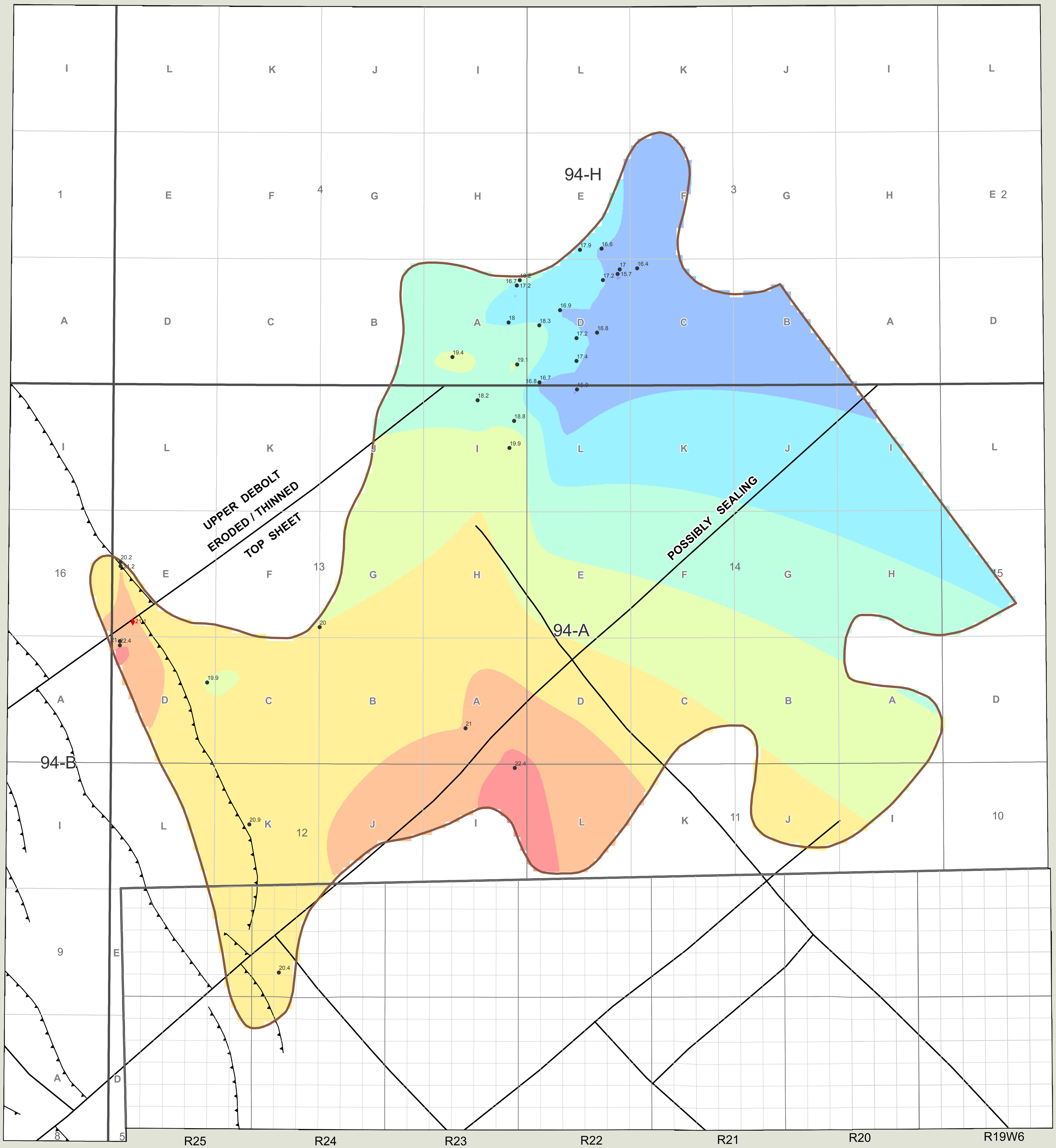
Belloy and Debolt Water Disposal Zones in the Montney Play Fairway, NEBC

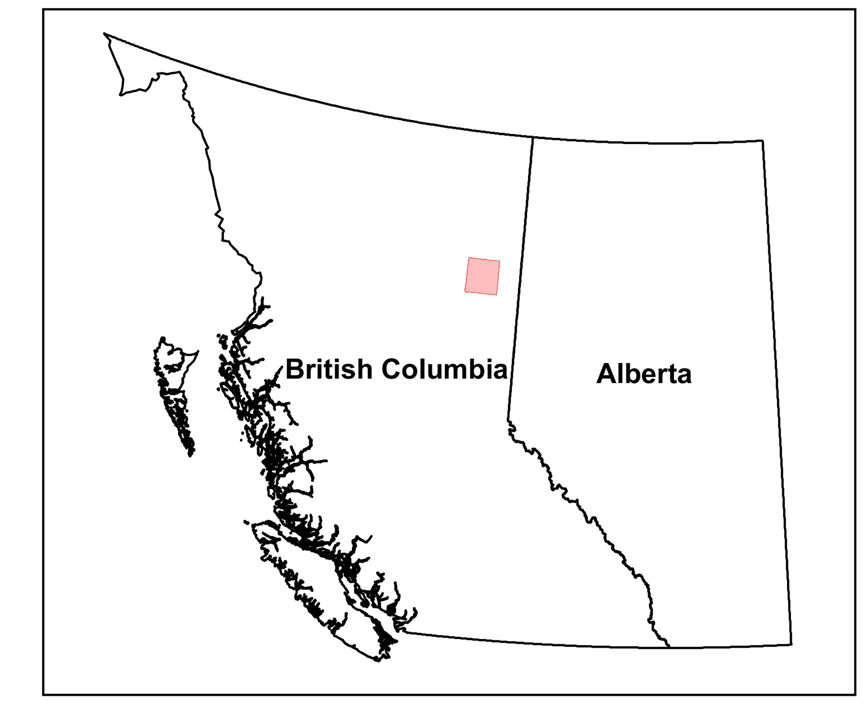
Canadian Discovery Ltd.

Data | Intelligence | Expertise

Belloy Area Montney/Doig Minimum Principal Stress

Filename: GCWD_ISIP_085_BELLOY.mxd		Enclosure
Author: S. Hawkes	Project: GCWD	3.15
Cartographer: C Keeler	Created: 10-April-2015	
Reviewer: M Soltanzadeh	Last Edited: 29-June-2015	





Shmin Test Type
- DFIT
- ISIP

- 15.8 - 16
- 16.1 - 17
- 17.1 - 18
- 18.1 - 19
- 19.1 - 20
- 20.1 - 21
- 21.1 - 22
- 22.1 - 23

Structural and Geological Features

Faults
- Thrust Fault
- Normal Fault

Focus Area
- Debolt Focus Area

1:150,000

0 3 6 9 12 15 Km

Projection: UTM; Central Meridian -121.5; North American Datum 1983

Belloy and Debolt Water Disposal Zones in the Montney Play Fairway, NEBC

Canadian Discovery Ltd.
Data | Intelligence | Expertise

Debolt Area Montney/Doig Minimum Principal Stress

Filename: GCWD_Shmin_ISIP_085_DEBOLT.mxd		Enclosure
Author: S. Hawkes	Project: GCWD	3.16
Cartographer: C Keeler	Created: 10-April-2015	
Reviewer: M Soltanzadeh	Last Edited: 29-June-2015	

Minimum Principal Stress Gradient (kPa/m)
- Belloy Minimum Principal Stress Gradient Value
- Debolt Minimum Principal Stress Gradient Value
- Halfway Minimum Principal Stress Gradient Value

Structural and Geological Features
- Fault

Geologic Injection Favourability
- High
- Medium

Focus Area
- Belloy Focus Area

1:150,000

0 1.5 3 6 9 12 15 Km

Projection: UTM; Central Meridian -120.0°; North American Datum 1983

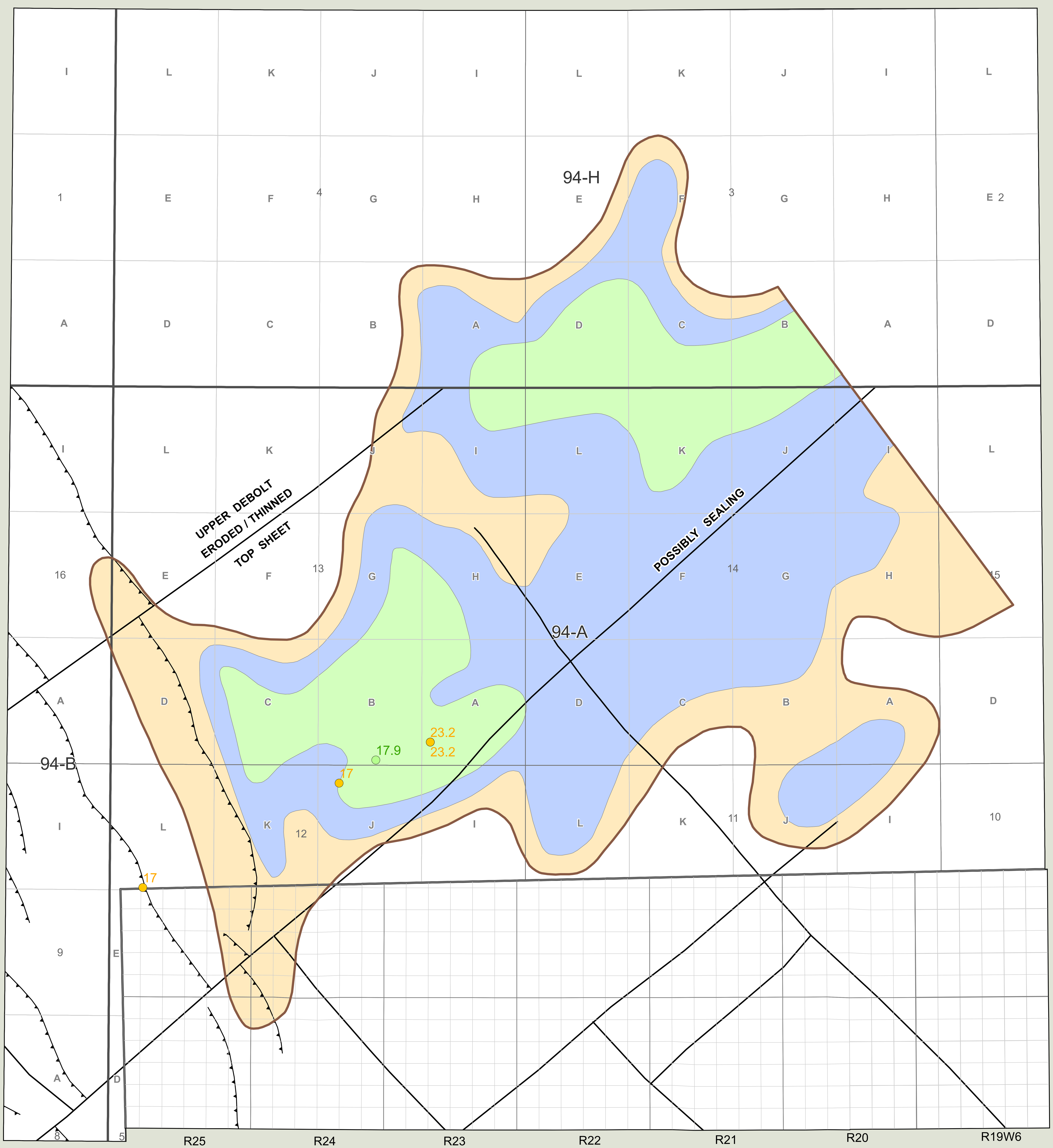
Belloy and Debolt Water Disposal Zones in the Montney Play Fairway, NEBC

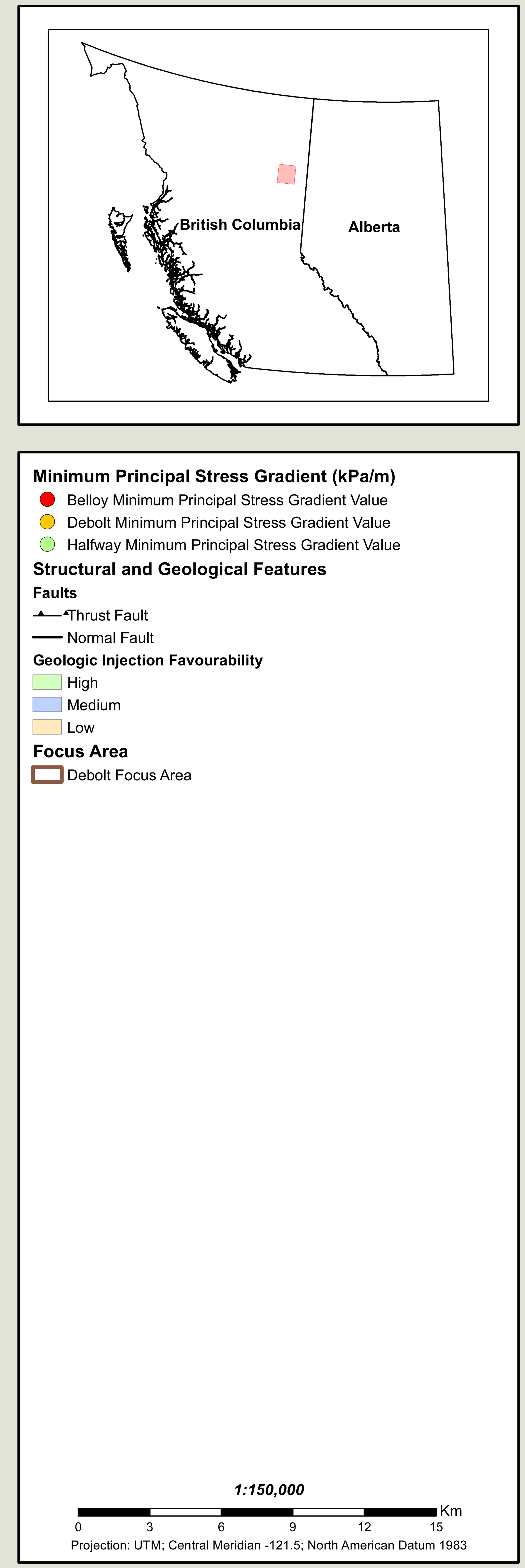
Canadian Discovery Ltd.

Data | Intelligence | Expertise

Belloy Area
Minimum Principal Stress
Other Formations

Filename: GCWD_BELLOY_ISIP_MAP.mxd		Enclosure
Author: S. Hawkes	Project: GCWD	3.17
Cartographer: C Keeler	Created: 10-April-2015	
Reviewer: M Soltanzadeh	Last Edited: 29-June-2015	





Belloy and Debolt Water Disposal Zones
in the Montney Play Fairway, NEBC

Canadian Discovery Ltd.
Data | Intelligence | Expertise

Debolt Area
Minimum Principal Stress
Other Formations

Filename: GCWD_DEBOLT_ISIP_MAP.mxd		Enclosure
Author: S. Hawkes	Project: GCWD	3.18
Cartographer: C Keeler	Created: 10-April-2015	
Reviewer: M Soltanzadeh	Last Edited: 29-June-2015	

Fast Shear Sonic Orientation

- Above Zone of Interest Shear Sonic Orientation
- Doig & Montney Shear Sonic Orientation

SHmax Orientation from Image Logs

- Above Zone of Interest SHmax Orientation
- Montney SHmax Orientation
- Belloy SHmax Orientation

Structural and Geological Features

- Fault

Geologic Injection Favourability

- High
- Medium

Focus Area

- Belloy Focus Area

1:150,000

0 1.5 3 6 9 12 15 Km

Projection: UTM; Central Meridian -120.0°; North American Datum 1983

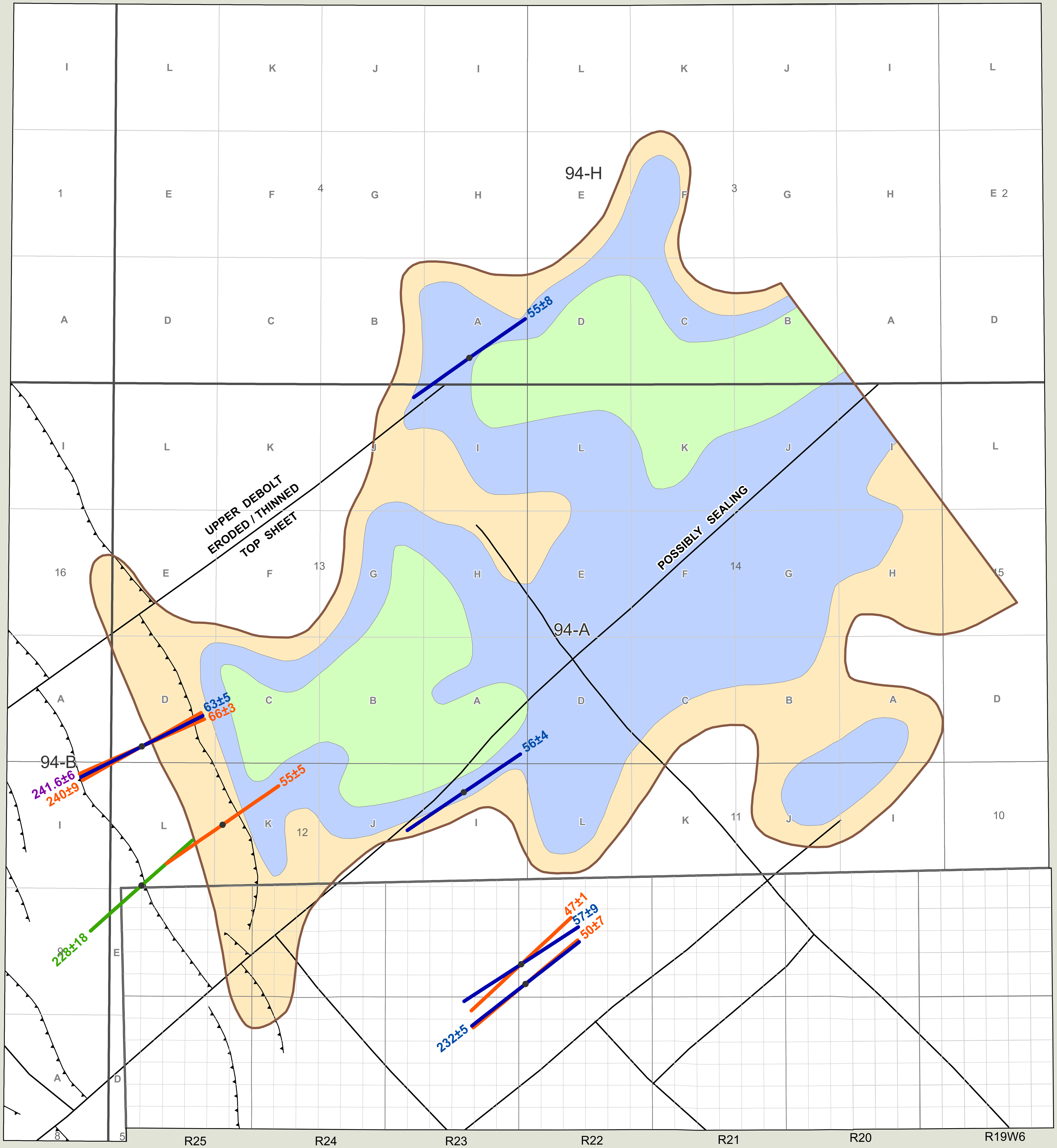
Belloy and Debolt Water Disposal Zones in the Montney Play Fairway, NEBC

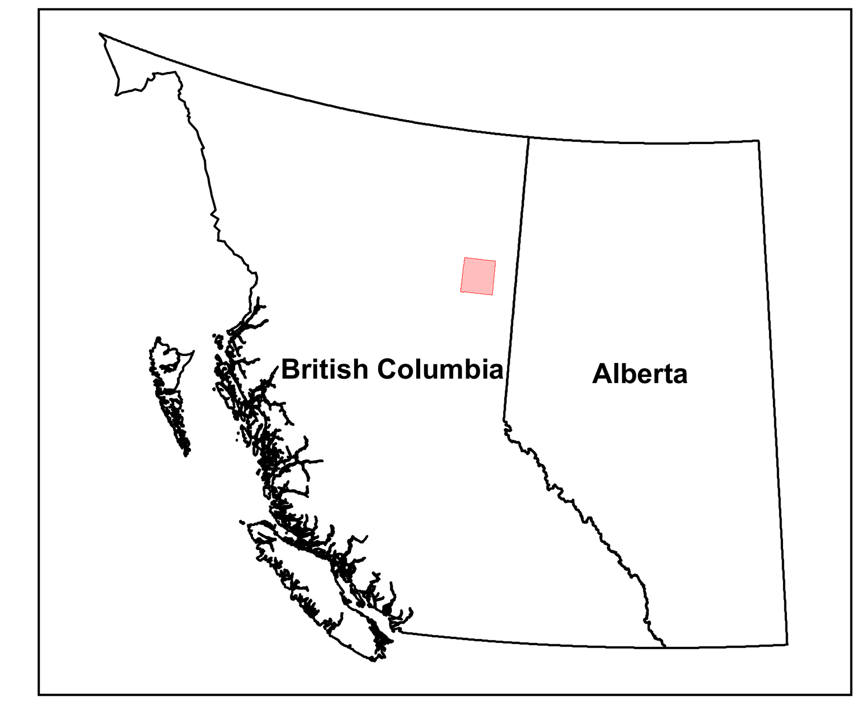
Canadian Discovery Ltd.

Data | Intelligence | Expertise

Belloy Area Stress Orientation

Filename: GCWD_BELLOY_STRESS_ORIENTATION_MAP.mxd		Enclosure
Author: S. Hawkes	Project: GCWD	3.19
Cartographer: C Keeler	Created: 10-April-2015	
Reviewer: M Soltanzadeh	Last Edited: 29-June-2015	





SHmax Orientation From Image Logs
- Above Zone of Interest SHmax Orientation
- Doig SHmax Orientation
- Montney SHmax Orientation
- Belloy SHmax Orientation
- Debolt SHmax Orientation
- Below Zone of Interest SHmax Orientation

Structural and Geological Features

Faults
- Thrust Fault
- Normal Fault

Geologic Injection Favourability
- High
- Medium
- Low

Focus Area
- Debolt Focus Area

1:150,000

0 3 6 9 12 15 Km

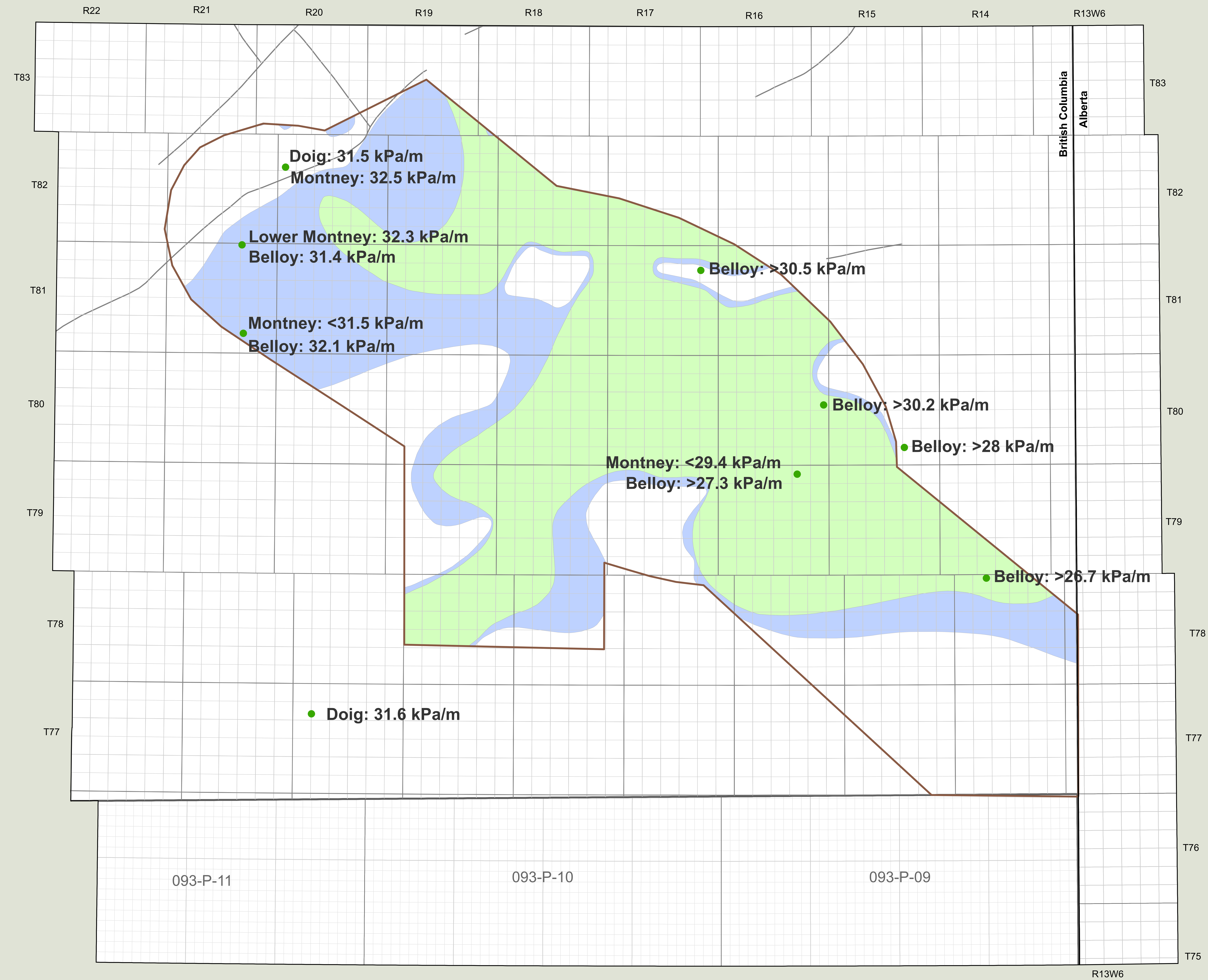
Projection: UTM; Central Meridian -121.5; North American Datum 1983

Belloy and Debolt Water Disposal Zones in the Montney Play Fairway, NEBC

Canadian Discovery Ltd.
Data | Intelligence | Expertise

Debolt Area Stress Orientation

Filename: GCWD_DEBOLT_STRESS_ORIENTATION_MAP.mxd		Enclosure
Author: S. Hawkes	Project: GCWD	3.20
Cartographer: C Keeler	Created: 10-April-2015	
Reviewer: M Soltanzadeh	Last Edited: 29-June-2015	



Maximum Horizontal Stress Gradient (kPa/m)

Maximum Horizontal Stress Gradient Value

Structural and Geological Features

Fault

Geologic Injection Favourability

High

Medium

Focus Area

Belloy Focus Area

1:150,000

0 1.5 3 6 9 12 15 Km

Projection: UTM; Central Meridian -120.0°; North American Datum 1983

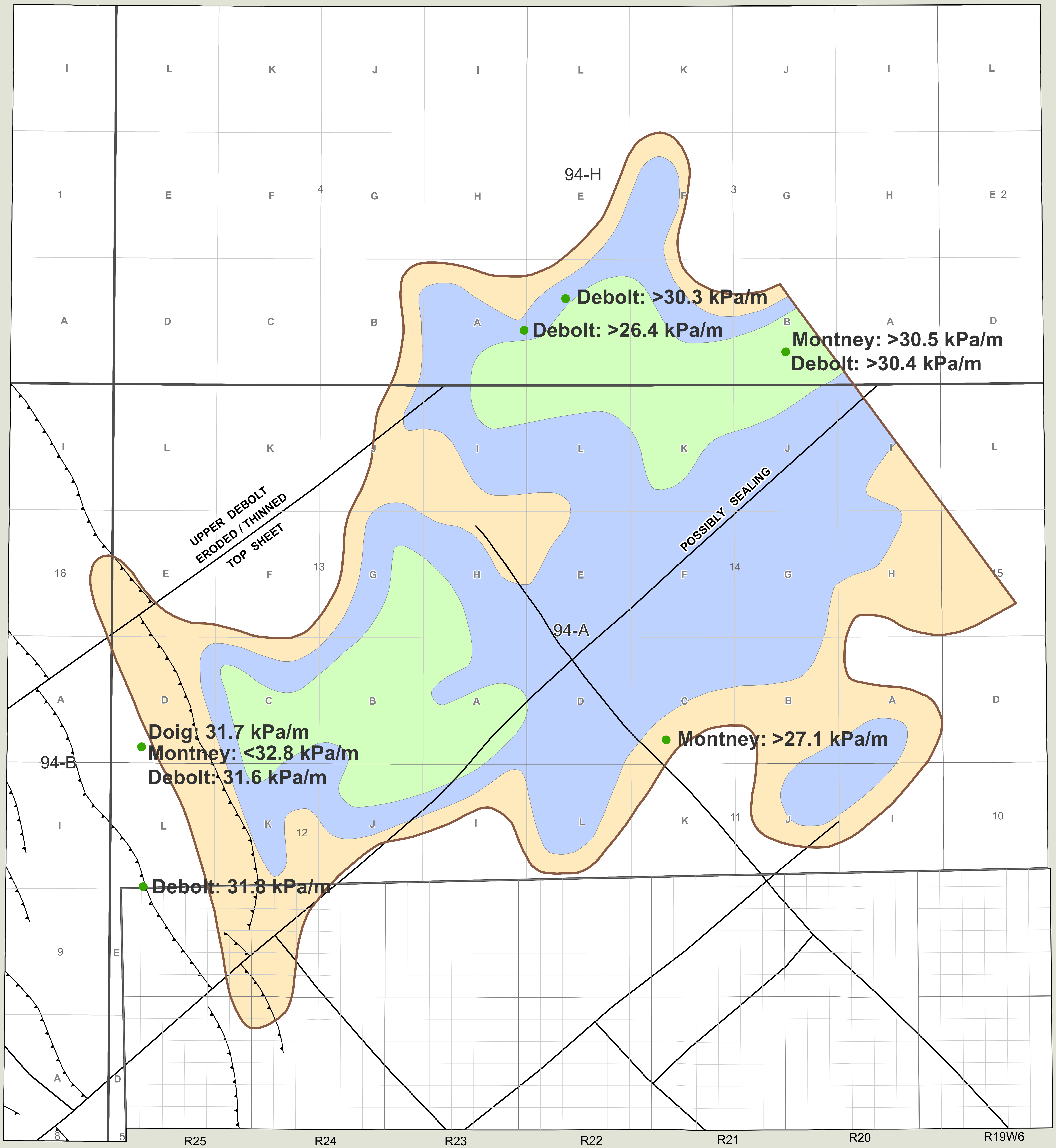
Belloy and Debolt Water Disposal Zones in the Montney Play Fairway, NEBC

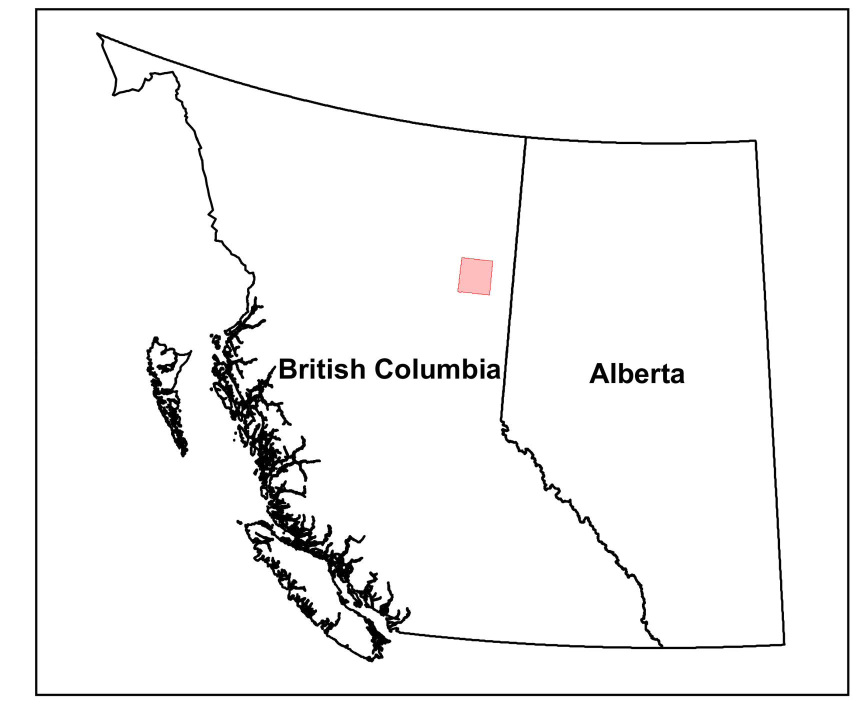
Canadian Discovery Ltd.

Data | Intelligence | Expertise

Belloy Area Maximum Horizontal Stress

Filename: GCWD_BELLOY_SHMAX_ESTIMATES_MAP.mxd		Enclosure
Author: S. Hawkes	Project: GCWD	3.21
Cartographer: C Keeler	Created: 10-April-2015	
Reviewer: M Soltanzadeh	Last Edited: 29-June-2015	





Maximum Horizontal Stress Gradient (kPa/m)

- Maximum Horizontal Stress Gradient Value

Structural and Geological Features

Faults

- Thrust Fault
- Normal Fault

Geologic Injection Favourability

- High
- Medium
- Low

Focus Area

- Debolt Focus Area

1:150,000

0 3 6 9 12 15 Km

Projection: UTM; Central Meridian -121.5; North American Datum 1983

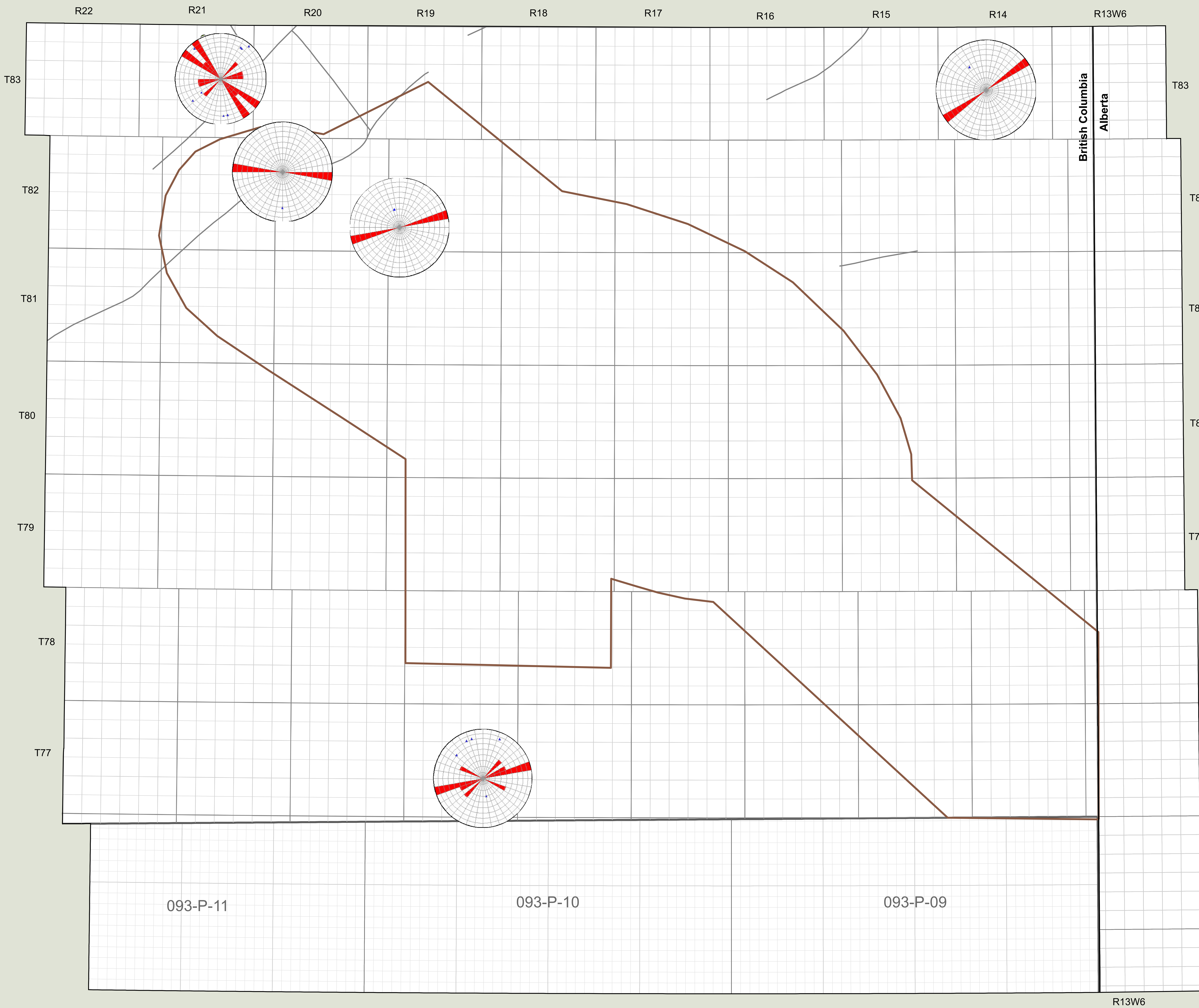
Belloy and Debolt Water Disposal Zones in the Montney Play Fairway, NEBC

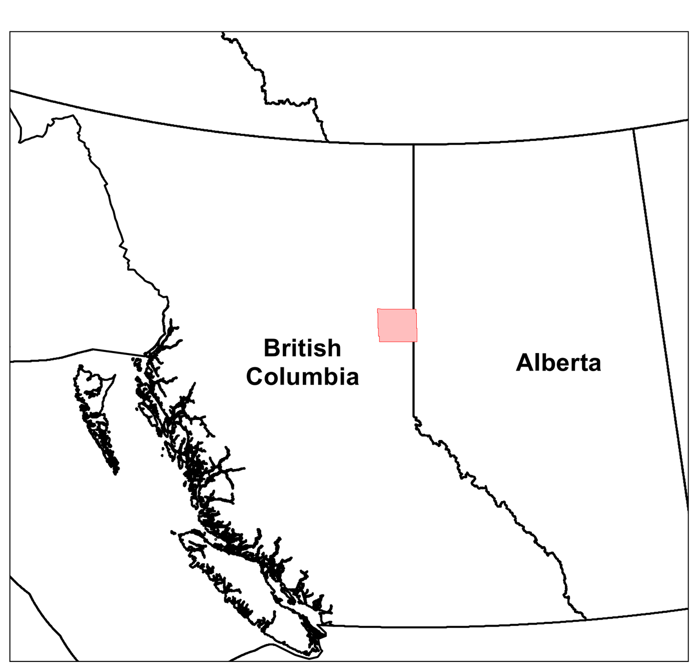
Canadian Discovery Ltd.

Data | Intelligence | Expertise

Debolt Area
Maximum Horizontal Stress

Filename: GCWD_DEBOLT_SHMAX_ESTIMATES_MAP.mxd		Enclosure
Author: S. Hawkes	Project: GCWD	3.22
Cartographer: C Keeler	Created: 10-April-2015	
Reviewer: M Soltanzadeh	Last Edited: 29-June-2015	





Structural and Geological Features

Fault

Focus Area

Belloy Focus Area

1:150,000

0 1.5 3 6 9 12 15 Km

Projection: UTM; Central Meridian -120.0°; North American Datum 1983

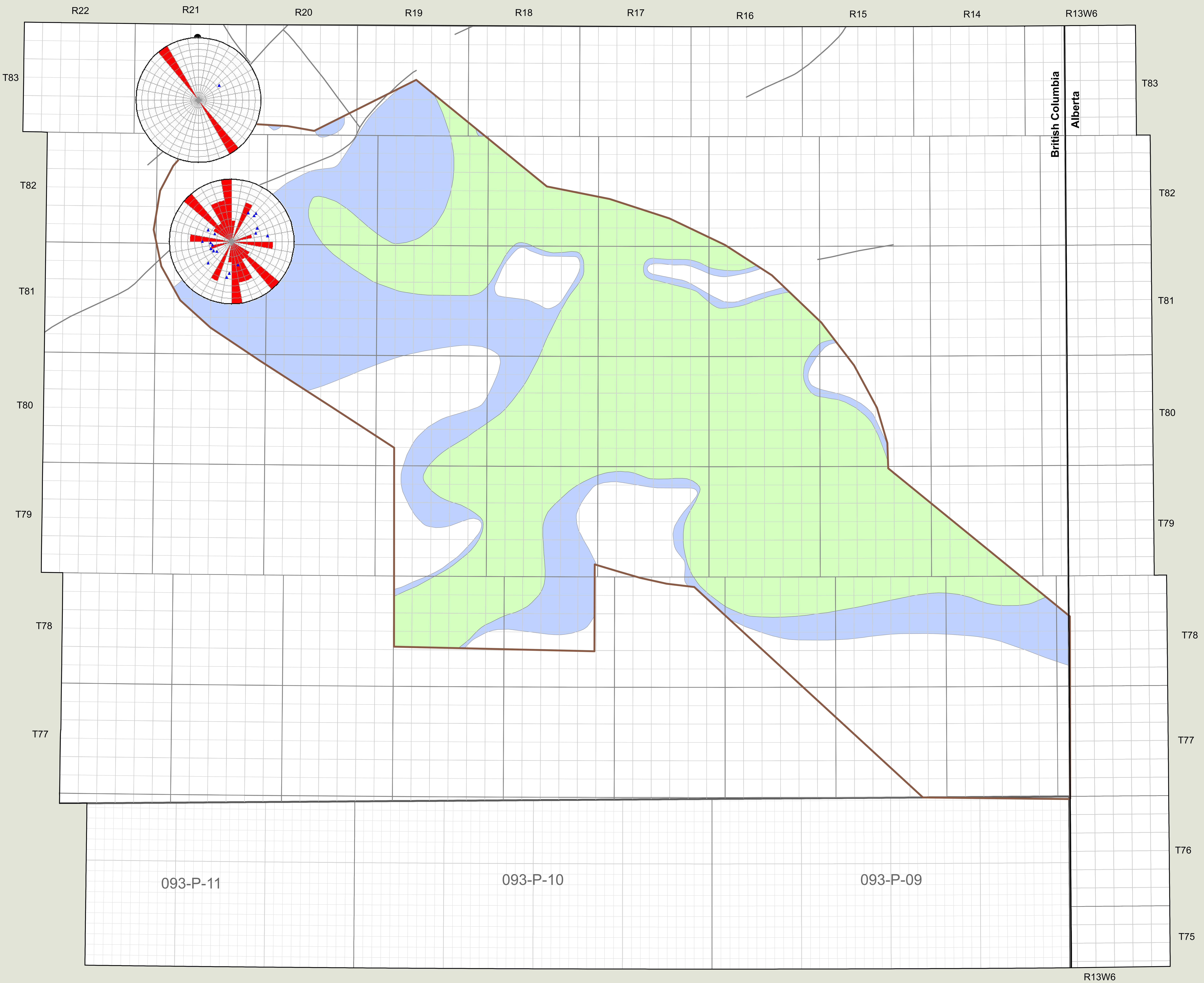
Belloy and Debolt Water Disposal Zones in the Montney Play Fairway, NEBC

Canadian Discovery Ltd.

Data | Intelligence | Expertise

Belloy Area Montney/Doig Natural Fracture Orientation

Filename: GCWD_BELLOY_MONTNEY_NF_STEREONET_MAP.mxd	Enclosure
Author: S. Hawkes	Project: GCWD
Cartographer: C Keeler	Created: 10-April-2015
Reviewer: M Soltanzadeh	Last Edited: 29-June-2015
	3.23



Structural and Geological Features

Fault

Geologic Injection Favourability

High

Medium

Focus Area

Belloy Focus Area

1:150,000

0 1.5 3 6 9 12 15 Km

Projection: UTM; Central Meridian -120.0°; North American Datum 1983

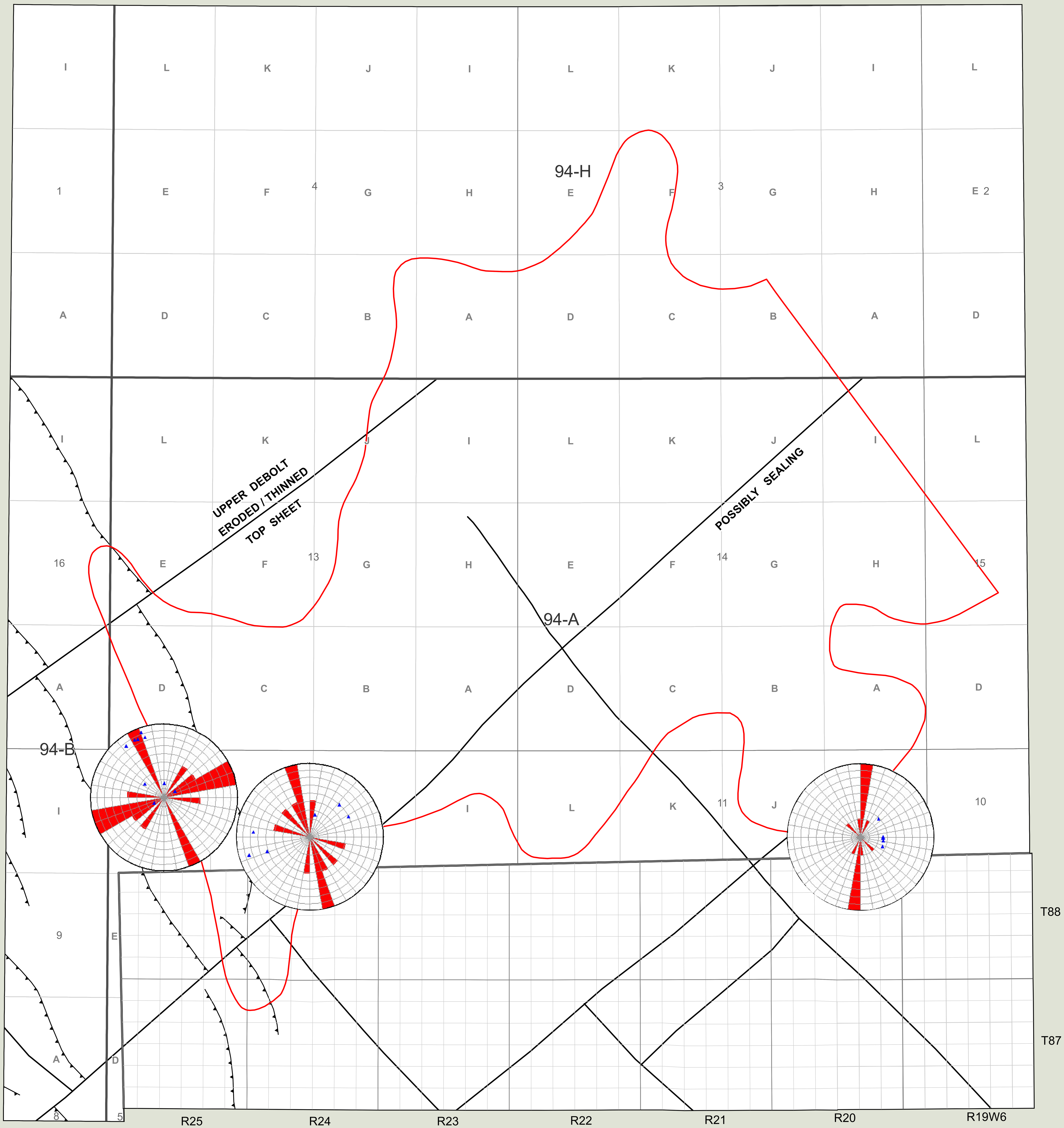
Belloy and Debolt Water Disposal Zones in the Montney Play Fairway, NEBC

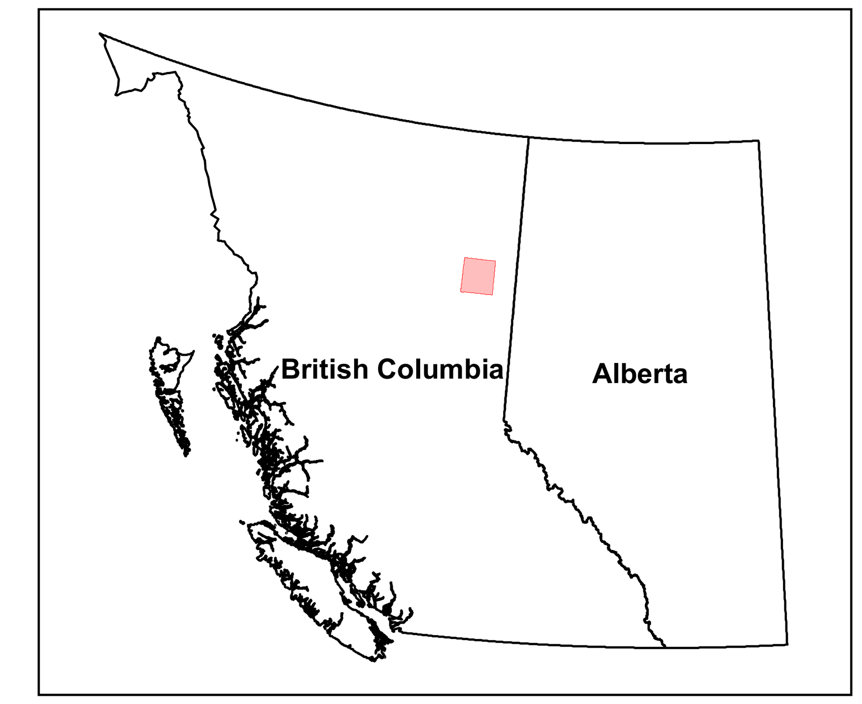
Canadian Discovery Ltd.

Data | Intelligence | Expertise

Belloy Area
Belloy Natural Fracture Orientation

Filename: GCWD_BELLOY_BELLOY_NF_STEREONET_MAP.mxd		Enclosure
Author: S. Hawkes	Project: GCWD	3.24
Cartographer: C Keeler	Created: 10-April-2015	
Reviewer: M Soltanzadeh	Last Edited: 29-June-2015	





Structural and Geological Features

Faults

- Thrust Fault
- Normal Fault

Geologic Injection Favourability

- High
- Medium
- Low

1:150,000

0 3 6 9 12 15 Km

Projection: UTM; Central Meridian -121.5; North American Datum 1983

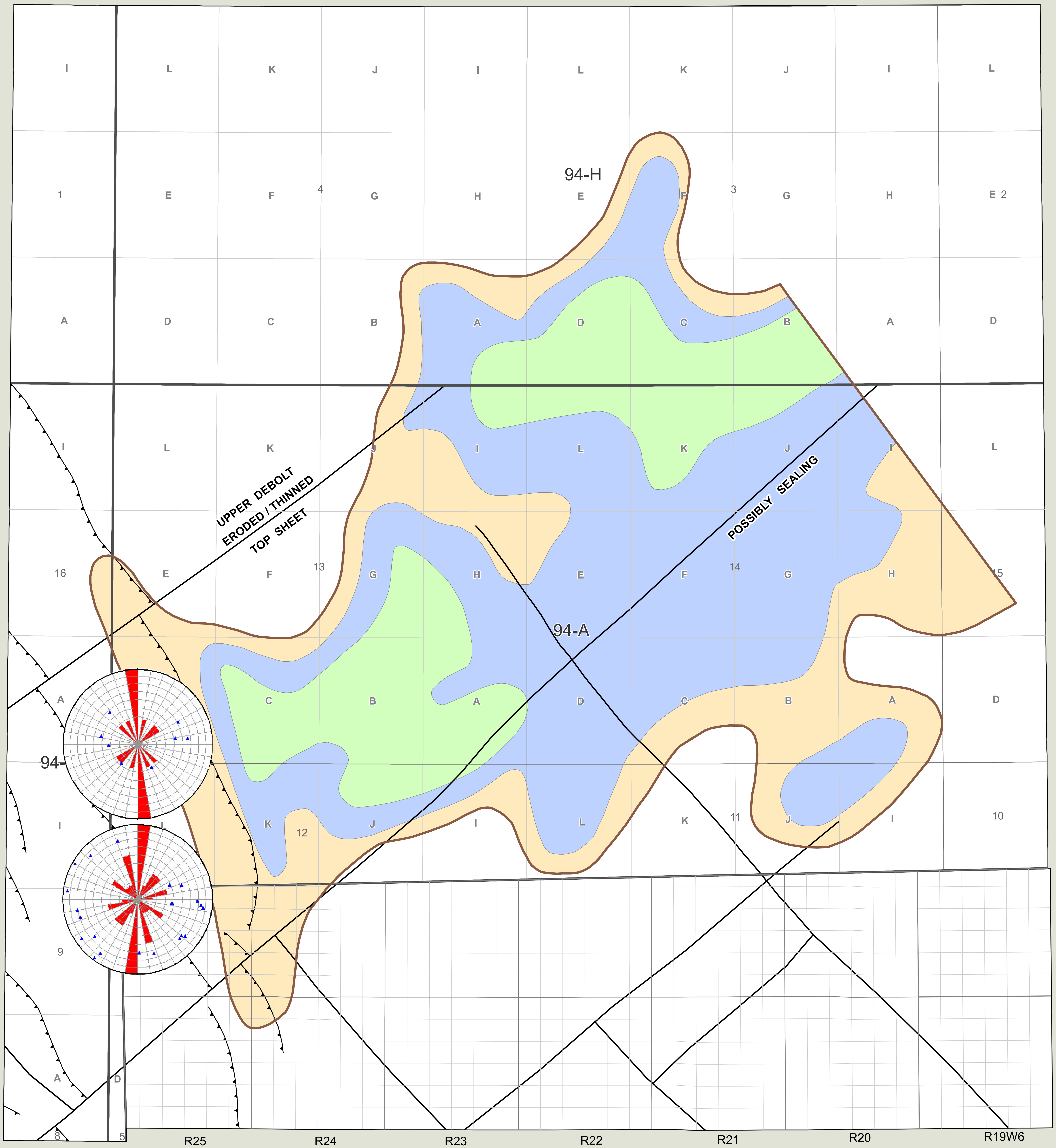
Belloy and Debolt Water Disposal Zones in the Montney Play Fairway, NEBC

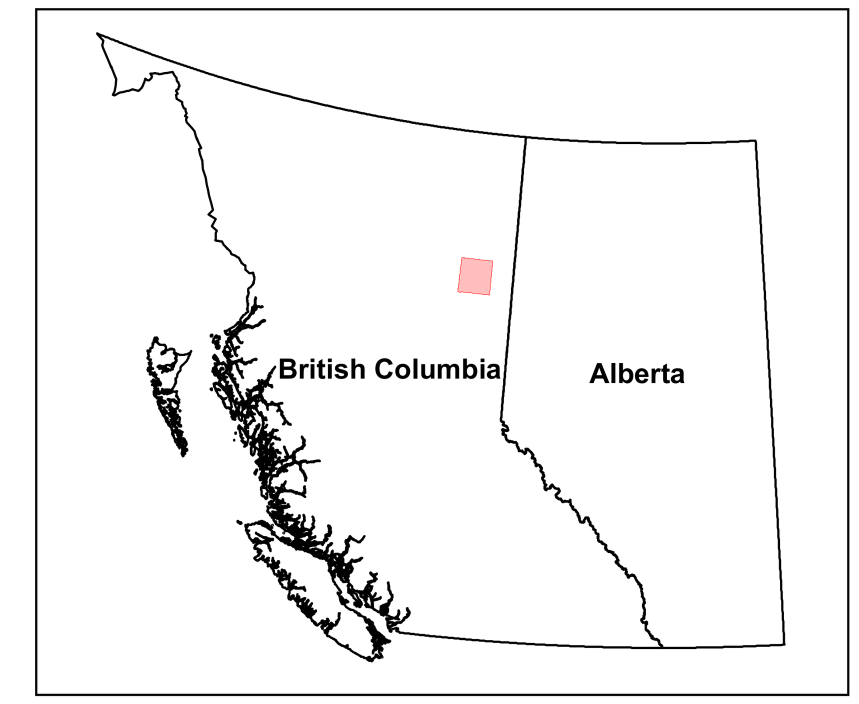
Canadian Discovery Ltd.

Data | Intelligence | Expertise

Debolt Area Montney/Doig Natural Fracture Orientation

Filename: GCWD_DEBOLT_MONTNEY_NF_STEREONET.mxd		Enclosure
Author: S. Hawkes	Project: GCWD	3.25
Cartographer: C Keeler	Created: 10-April-2015	
Reviewer: M Soltanzadeh	Last Edited: 29-June-2015	





Structural and Geological Features

Faults

- Thrust Fault
- Normal Fault

Geologic Injection Favourability

- High
- Medium
- Low

Focus Area

- Debolt Focus Area

1:150,000

0 3 6 9 12 15 Km

Projection: UTM; Central Meridian -121.5; North American Datum 1983

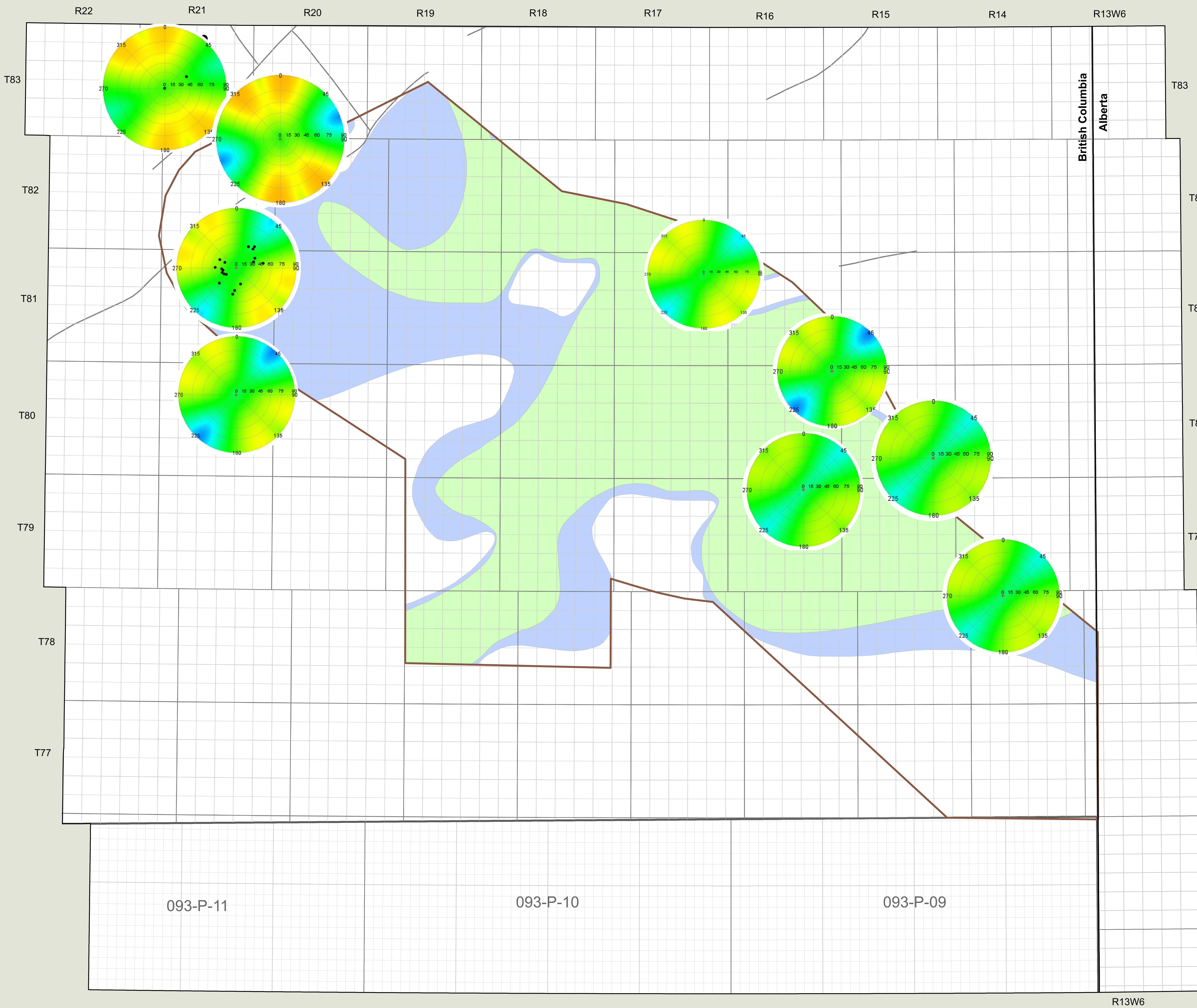
Belloy and Debolt Water Disposal Zones in the Montney Play Fairway, NEBC

Canadian Discovery Ltd.

Data | Intelligence | Expertise

Debolt Area Debolt Natural Fracture Orientation

Filename: GCWD_DEBOLT_DEBOLT_NF_STEREONET.mxd		Enclosure
Author: S. Hawkes	Project: GCWD	3.26
Cartographer: C Keeler	Created: 10-April-2015	
Reviewer: M Soltanzadeh	Last Edited: 29-June-2015	



Structural and Geological Features

Fault

Geologic Injection Favourability

High

Medium

Focus Area

Belloy Focus Area

ΔP [MPA]: 60, 55, 50, 45, 40, 35, 30, 25, 20, 15, 10, 5, 0

1:150,000

0 1.5 3 6 9 12 15 Km

Projection: UTM; Central Meridian -120.0°; North American Datum 1983

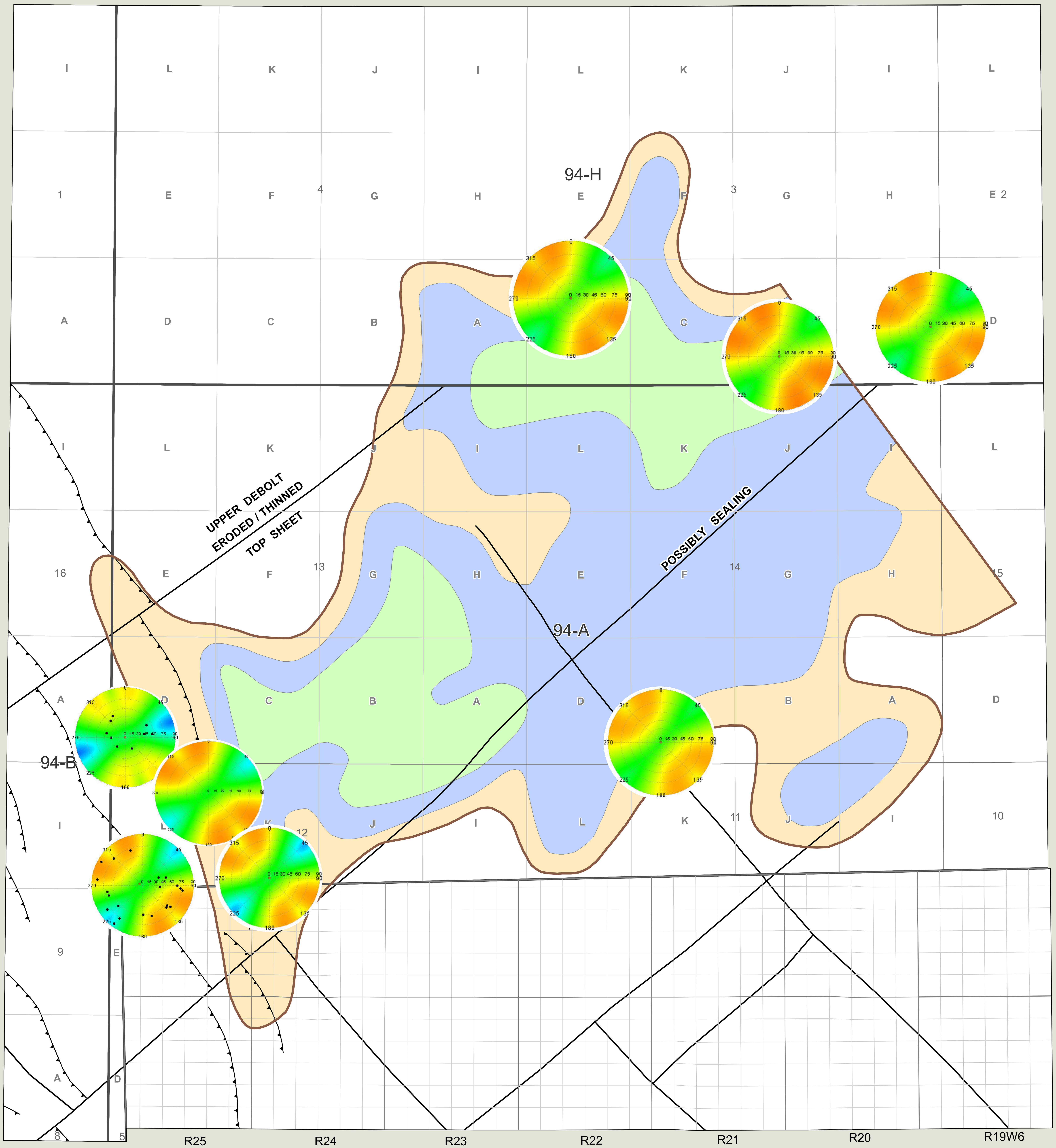
Belloy and Debolt Water Disposal Zones in the Montney Play Fairway, NEBC

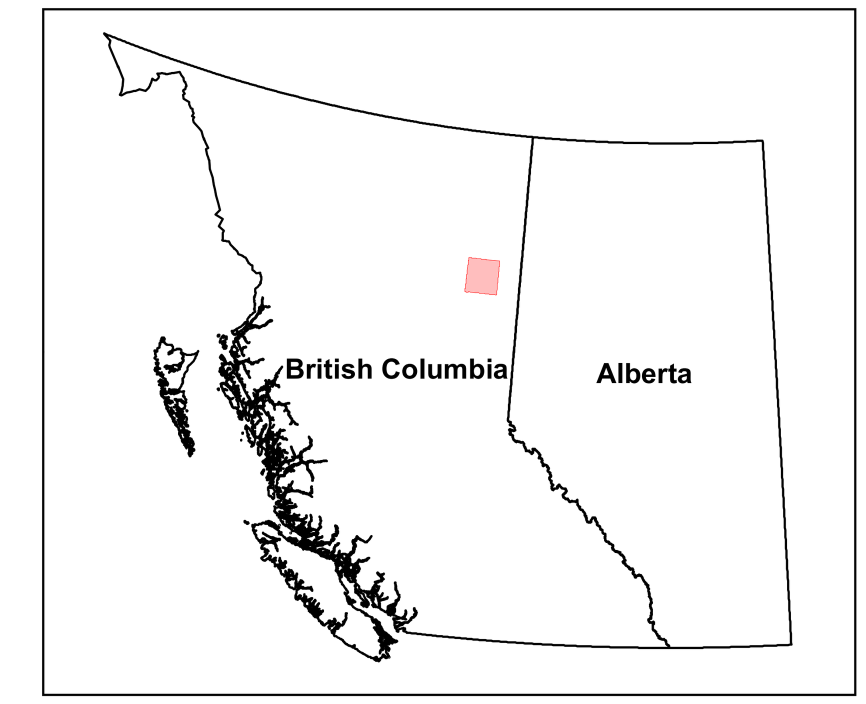
Canadian Discovery Ltd.

Data | Intelligence | Expertise

Belloy Area
Belloy Critically-Stressed Fracture Analysis

Filename: GCWD_BELLOY_BELLOY_CSF.mxd		Enclosure
Author: S. Hawkes	Project: GCWD	3.27
Cartographer: C Keeler	Created: 10-April-2015	
Reviewer: M Soltanzadeh	Last Edited: 29-June-2015	





ΔP [MPA]
60
55
50
45
40
35
30
25
20
15
10
5
0

Structural and Geological Features

Faults

- Thrust Fault
- Normal Fault

Geologic Injection Favourability

- High
- Medium
- Low

Focus Area

- Debolt Focus Area

1:150,000

0 3 6 9 12 15 Km

Projection: UTM; Central Meridian -121.5; North American Datum 1983

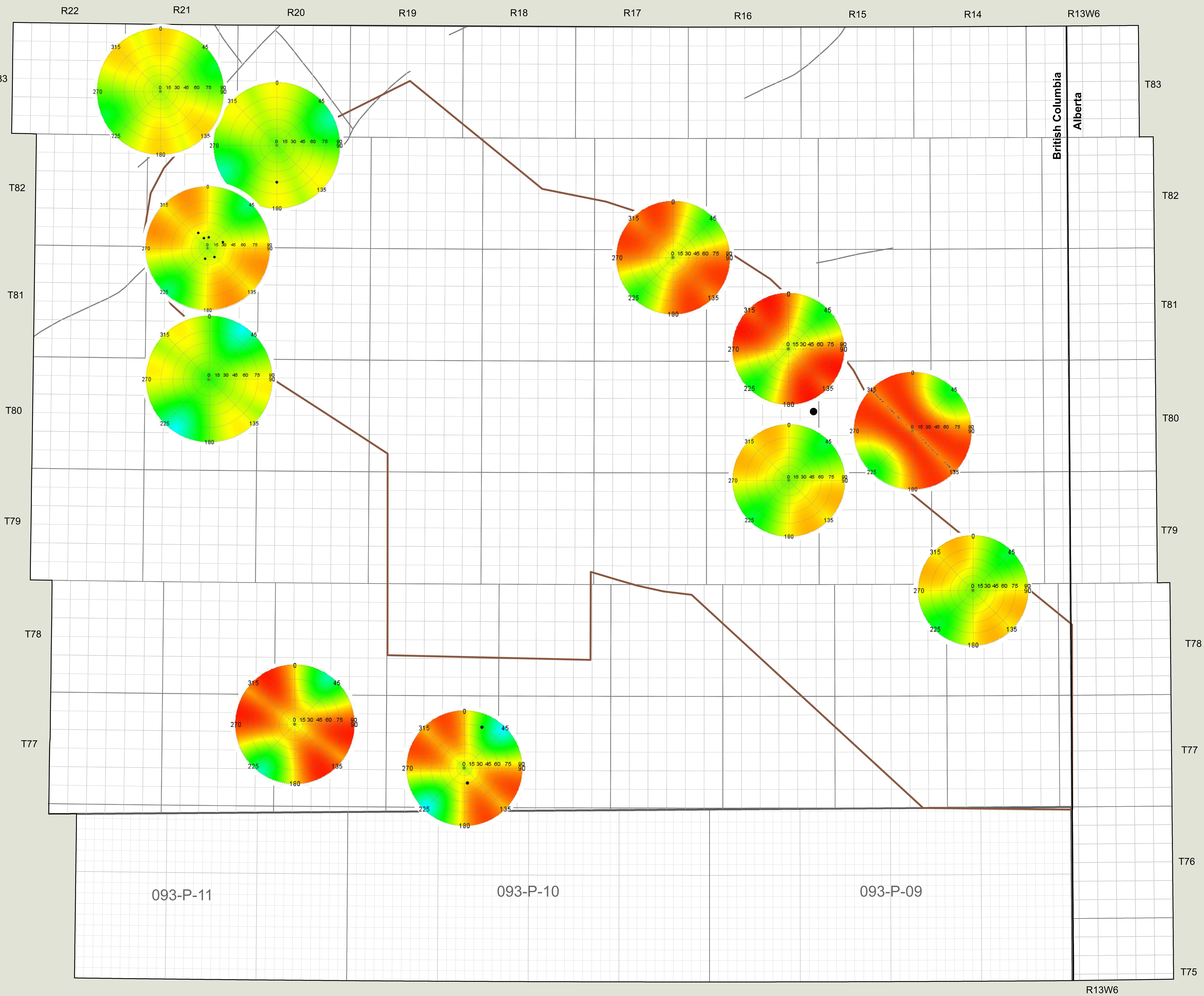
Belloy and Debolt Water Disposal Zones in the Montney Play Fairway, NEBC

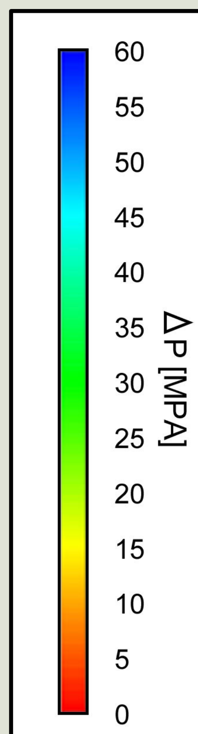
Canadian Discovery Ltd.

Data | Intelligence | Expertise

Debolt Area
Debolt Critically-Stressed Fracture Analysis

Filename: GCWD_DEBOLT_DEBOLT_CSF.mxd		Enclosure
Author: S. Hawkes	Project: GCWD	3.28
Cartographer: C Keeler	Created: 10-April-2015	
Reviewer: M Soltanzadeh	Last Edited: 29-June-2015	





Structural and Geological Features

Fault

Focus Area

Belloy Focus Area

1:150,000

0 1.5 3 6 9 12 15 Km

Projection: UTM; Central Meridian -120.0°; North American Datum 1983

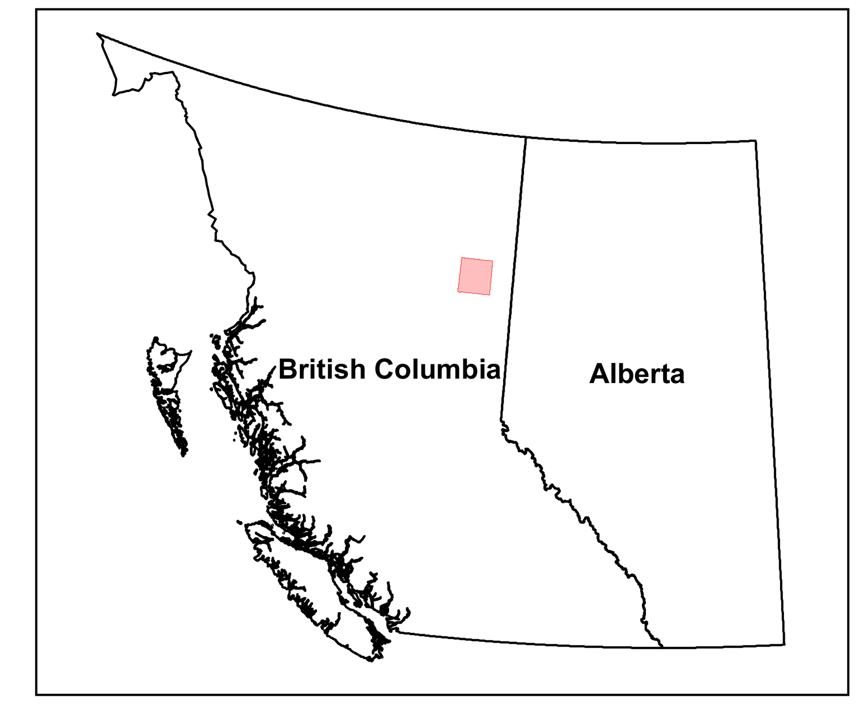
Belloy and Debolt Water Disposal Zones in the Montney Play Fairway, NEBC

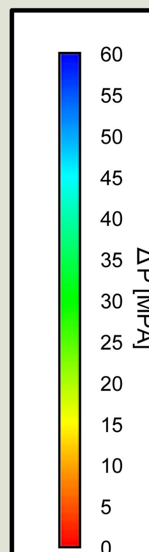
Canadian Discovery Ltd.

Data | Intelligence | Expertise

Belloy Area Montney/Doig Critically-Stressed Fracture Analysis

Filename: GCWD_BELLOY_MONTNEY_CSF.mxd	Enclosure
Author: S Hawkes	Project: GCWD
Cartographer: C Keeler	Created: 10-April-2015
Reviewer: M Soltanzadeh	Last Edited: 29-June-2015
	3.29





Structural and Geological Features

Faults

Thrust Fault

Normal Fault

Focus Area

Debolt Focus Area

1:150,000

0 3 6 9 12 15 Km

Projection: UTM; Central Meridian -121.5; North American Datum 1983

Belloy and Debolt Water Disposal Zones in the Montney Play Fairway, NEBC

Canadian Discovery Ltd.

Data | Intelligence | Expertise

Debolt Area Montney/Doig Critically-Stressed Fracture Analysis

Filename: GCWD_DEBOLT_MONTNEY_CSF.mxd		Enclosure
Author: S. Hawkes	Project: GCWD	3.30
Cartographer: C Keeler	Created: 10-April-2015	
Reviewer: M Soltanzadeh	Last Edited: 29-June-2015	

APPENDIX A

CHARACTERIZATION OF BELLOY AND DEBOLT WATER DISPOSAL ZONES IN THE MONTNEY PLAY FAIRWAY, NEBC
(Digital Only)

APPENDIX B

BELLOY GEOMECHANICS INVENTORY LIST
(Digital Only)
DEBOLT GEOMECHANICS INVENTORY LIST
(Digital Only)

APPENDIX C

LAB-BASED ROCK PROPERTIES DATABASE
(Digital Only)

APPENDIX D

LAB-BASED ROCK PROPERTIES DATABASE
(Digital Only)