Water Resistivity Atlas Of Western Canada Abstract

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1.0) PROJECT CONCEPT

Accessing reliable water resistivity data often takes longer than the time required to use it. Therefore, as project budgets are broken down, a large portion of the cost is assigned to data acquisition and screening. This product was created to help reduce those project costs. A natural companion to GEOFLUIDS, the Water Resistivity Atlas of Western Canada (Rw Atlas) maps Rw values from only those water analyses representative of formation waters, subdividing them into meaningful stratigraphic units.

Stratigraphically indexed maps provide quick and easy access to individual water resistivity (Rw) values and the Atlas format allows for data comparisons in three dimensions. The statistical analysis included with each map layer adds clarity to regional trends seen on the maps. The Rw Atlas will direct users to reliable Rw values as well as provide a benchmark against which to compare and validate proprietary data.

2.0) OBJECTIVES

The primary objective of this project is to provide industry with the most reliable and complete water resistivity data in a meaningful and user friendly environment. The regional stratigraphic mapping identifies local and regional variations in Rw through successive stratigraphic units, providing users with a reliable background data set from which to judge any Rw value.

3.0) IMPROVEMENTS OVER HISTORICAL Rw CATALOGUES

Rakhit Petroleum Consulting Ltd.'s (RPCL) Rw Atlas introduces significant improvements over existing Rw catalogues. Since 1971 the petroleum industry has had access to the Canadian Well Logging Society's (CWLS) Formation Water Resistivities of Canada catalogue. To date this hard copy product has been the best resource for "reliable", publically available Rw data. However, it has become apparent that while being the best product of its time, it is no longer adequate. Since the last edition was printed in 1987, over 158,000 wells have been drilled in Alberta and British Columbia alone. Along with this increase in available data comes an improvement in data screening techniques. A statement made in the preface of the CWLS catalogue illustrates the limitations of the day:

"Over 81,000 water analysis were available for this catalogue and consequently, computers were used wherever possible in the sorting of this information. This data base consists of analysis of waters recovered from drill stem tests. Analyses of production waters were not available in computer sensitive form and therefore were not used in the catalogue."

The new Rw Atlas accesses over 200,000 water analyses digitally captured in RPCL's GEOFLUIDS database. GEOFLUIDS contains all publically available water analysis data, including those from absolute open flow (AOF), production and drill stem tests (DST). All of this data has been screened and classified with rigorous statistical and spatial analyses. Present day technology also allows for completeness when presenting Rw data. Rw Atlas maps are published as portable document format (pdf) files accessible through Adobe Acrobat. Acrobat enables the user to zoom in on a given area up to 1600% of its original size.

Limitations of the CWLS Rw catalogue regarding completeness were recognized by the authors. In the write-up entitled '"The Rw Catalogue" - How Good is the Data?', E.T. Connolly states,

"It is this method of filtering, using all available samples, that should be done, by formation (sic), to give representative formation water samples. Such massive filtering of water samples, however, is beyond the resources and time available for assembling this water resistivity catalogue."

Connolly goes on to predict that,

"explorationists must become more familiar with information available from properly sampled formation waters and the use of expanded routine chemical analyses. As a result of these newer techniques future data bases will contain a high volume of valid resistivity and salinity data. Future "Rw" catalogues would then benefit from these more sophisticated filtering techniques."

The new Rw Atlas represents eight years of data capture and screening by RPCL. Sophisticated filtering techniques include chemical screening of the data in an attempt to identify and classify both formation waters and contaminated analyses. For instance, in isolated areas of fresh water influx it is now understood that true formation waters may have pH values greater than 8.4 (see Appendix: Screening the GEOFLUIDS File). The consequence of meteoric recharge introducing higher pH waters into the subsurface is formation waters containing both HCO_3- and CO_3^{2}-. Screens used in the CWLS catalogue assumed that the presence of CO_3^{2}-- indicated mud filtrate contamination, and thus removed such analyses from the data set. This potentially lead to inadequate data distribution and incorrect definitions of the real Rw in a given zone and location. Data with pH values less than 6.0 were also classified as invalid and removed from the CWLS data set. In some areas this hard cut off is not valid as deep, over pressured, saline brines can exhibit pH values as low as 4.0. Examples of such brines can be found in the Beaverhill Lake Group in southern Alberta.

4.0) METHODOLOGY

This Rw Atlas contains a high grade sub-set of the previously screened water analyses from GEOFLUIDS. The Rw data was divided into hydrostratigraphic units, constrained within geological edges and screened against water salinity. Statistical methods were used to identify data distribution trends within and between hydrostratigraphic units. Figure 1 is a flow chart illustrating the key steps in our methodology. These steps are discussed in detail below.

4.1) Acquire Data

Reservoir water chemistries, complex as they are, may be masked or totally replaced by the

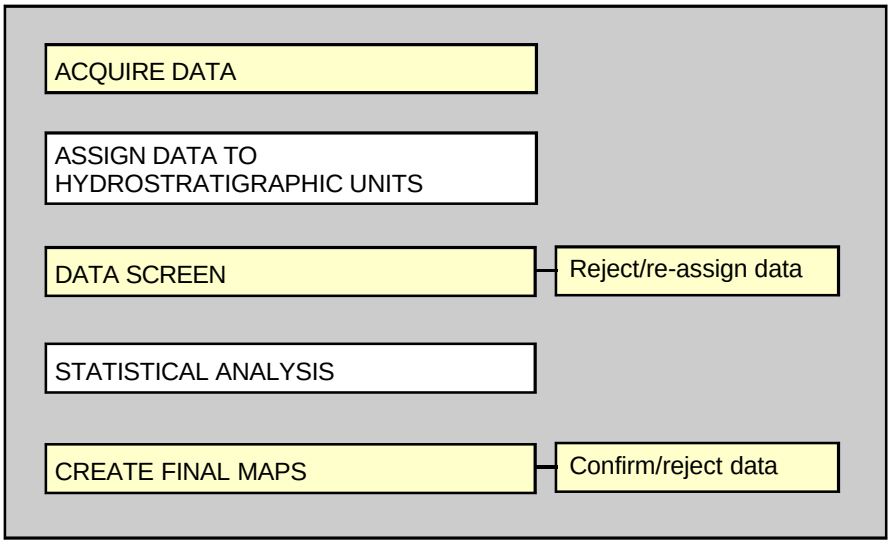

Figure 1 - Key Steps in the Rw Atlas Project

interaction of drilling and completion fluids. RPCL's screening methodologies (see Appendix) evaluated ionic composition and ion ratios to identify naturally occurring formation waters, drilling and completion fluid contaminants and samples from mis-assigned stratigraphic intervals. This project accessed only those analyses from RPCL's GEOFLUIDS database identified as representing true formation waters.

Geological surfaces and edges used to constrain the Rw data were taken from the Geological Atlas of the Western Canada Sedimentary Basin (Mossop and Shetsen, 1994), hereafter called the CSPG Atlas. Digital tops for the Lea Park Formation were required to divide the Belly River Rw data into Upper and Basal Belly River Hydrostratigraphic Units**.**

LATE CRETACEOUS	Upper Belly River Basal Belly River Milk River Medicine Hat Sandstone Cardium Viking
EARLY CRETACEOUS	Upper Mannville Lower Mannville
JURASSIC	Jurassic
TRIASSIC	Halfway
PERMIAN	Belloy
MISSISSIPPIAN	Mississippian
DEVONIAN	Wabamun Nisku Leduc Slave Point Gilwood/Sulphur Point Keg River Granite Wash
SILURIAN/ORDOVICIAN	Silurian
CAMBRIAN	Basal Cambrian Sandstone

Table 1 - Hydrostratigraphic Units

4.2) Assign Data to Hydrostratigraphic Units

GEOFLUIDS stratigraphic assignments 'as reported' by operators were assigned to RPCL's Western Canada Stratigraphic Model (WCSM). The WCSM provides a consistent framework to organize and manage stratigraphic data. Using the WCSM, data was then assigned to one of 21 Hydrostratigraphic Units (see Table 1) based on the hydrostratigraphic model used in RPCL's Hydrogeological Atlas of the Western Canada Sedimentary Basin (Hydrogeologic Atlas).

This method of assigning data, based on the GEOFLUIDS 'as reported' stratigraphic assignments, could not be applied to the Belly River analyses as most did not differentiate between Upper and Basal Belly River tests. Data was assigned to these units by first creating a Lea Park structure map. Belly River sampling intervals were then draped over this surface and the analyses were assigned a digital Lea Park top. Rw values were then separated into the Upper and Basal Belly River units based on the elevation of the analyses sampling interval, according to the criteria set forth in Table 2.

Hydrostratigraphic Unit Geological Extent	Basal Belly River Sample Elevation (m)	Upper Belly River Sample Elevation (m)
Upper Limit	Lea Park + 40	Lea Park + 260
Lower Limit	Lea Park -10	Lea Park + 40

Table 2 - Criteria used to separate the Belly River analyses into the Upper and Basal Belly River Hydrostratigraphic Units; based on the elevation of the sample interval in relation to the Lea Park Formation.

4.3) Data Screen

The high grade Rw values from the GEOFLUIDS database were selected by stratigraphic unit, posted on maps and further evaluated against the total dissolved solids (TDS) maps from the Hydrogeological Atlas. Figure 2 shows a graph representing the power regression relationship of TDS vs. Rw (at 25°C). Using the empirical relationship observed in Figure 2, the equation

$$Rw = TDS^{-0.854\,387} \times 4.516\,86$$

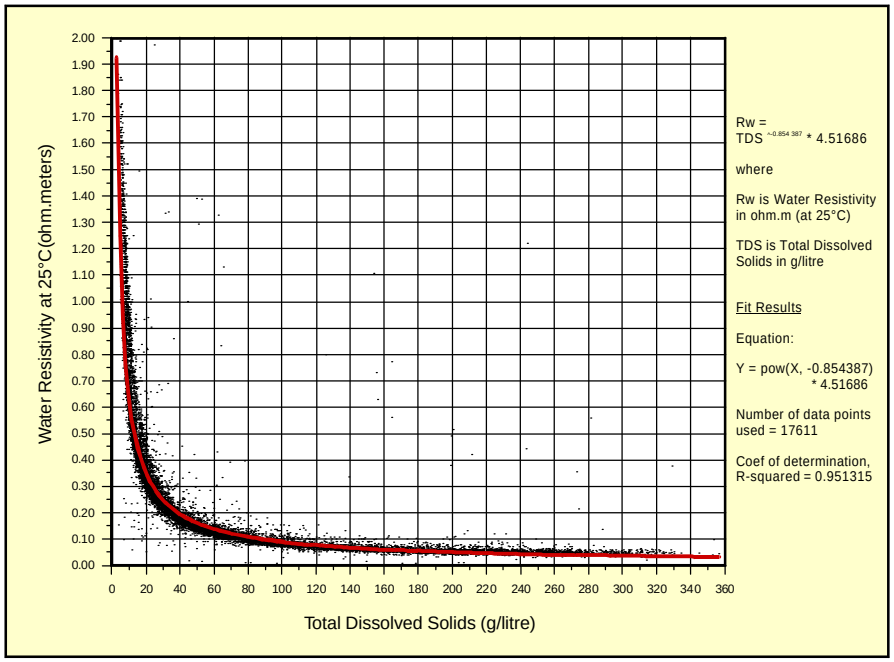

Figure 2 - Rw vs. TDS showing empirical relationship of formation waters sampled throughout the Western Canada Sedimentary Basin (taken from RPCL's Hydrogeological Atlas.

can be used to calculate an approximate Rw value given any TDS value. At low TDS there is a high variation in acceptable Rw values, while at high TDS the range of acceptable Rw values is much smaller. The screening process took into account this asymptotic relationship by applying a sliding error bar to the range of acceptable Rw values for a given range of TDS values. Each Rw values. value was screened against the contoured TDS value at its exact location using the acceptable data range definitions shown in Table 3. Any value which was either greater than or less than the range of acceptable Rw values for that TDS was flagged and removed from the data set.

TDS Range (g/litre)	Rw Range (ohm.m)	Acceptable Error (ohm.m)
< 10	0.80 - 2.00	+/- 0.20
10 - 20	0.30 - 0.80	+/- 0.20
20 - 30	0.15 - 0.42	+/- 0.15
30 - 40	0.15 - 0.25	+/- 0.15
40 - 50	0.15 - 0.20	+/- 0.15
50 - 60	0.10 - 0.17	+/- 0.10
60 - 70	0.10 - 0.15	+/- 0.10
70 - 80	0.09 - 0.13	+/- 0.07
80 - 100	0.08 - 0.10	+/- 0.07
100 - 120	0.07 - 0.10	+/- 0.05
> 120	0.03 - 0.06	+/- 0.05

Table 3 - Rw vs. TDS screening criteria with sliding error bar; based on empirical relationship seen in Figure 2.

4.4) Statistical Analysis

Three statistical graphs were included with each hydrostratigraphic unit. Frequency occurrence histograms were calculated using one hundred class intervals to show the modal distribution of Rw values. Percent frequency graphs normalized this data by dividing the number of analyses in each class interval by the total number of analyses used in that map unit. When compared with one another, these normalized graphs provide evidence for several trends that are consistent throughout the stratigraphic section (see Observations of Trends). A final histogram was calculated to divide the data on each map into four or five categories based on each category containing approximately the same number of Rw values. Each category was assigned a colour which was then applied to the data on the maps. Strong contrasts in colour over small spatial areas represent rapid changes in Rw. Conversely, large areas dominated by one category represent areas of relatively uniform Rw.

4.5) Create Final Maps

Final maps were created after a second manual screening of the data was performed. Anomalous data was re-checked against local variations in TDS to confirm similar changes in water salinity. In this way data points missed during the first screen were either confirmed and retained or identified as incorrect and removed from the final mapping data set. Colours for the data classification categories were finalized and relevant geologic edges for each hydrostratigraphic unit were added. In the case of a single well containing multiple analyses, the colour of the data point was assigned corresponding to the lowest valid Rw value. All other valid Rw values for that well were then offset above the lowest value in increasing order, with the appropriate colour coding applied to the text. The Rw Atlas is available as a companion to GEOFLUIDS where a full reporting of the sampling conditions and ionic compositions for each water analyses can be found.

5.0) OBSERVATIONS OF TRENDS

5.1) Basinal Trends

Generally, younger (shallower) stratigraphic horizons in the WCSB contain fresher waters than older (deeper) horizons. This trend is confirmed by the TDS maps in the Hydrogeologic Atlas. The Rw Atlas also reflects this trend, showing a steady decrease in maximum Rw with depth. According to Figure 2 this decrease in Rw is asymptotically related to an increase in water salinity. This change in Rw made it difficult to accurately compare shallow hydrostratigraphic units with deeper hydrostratigraphic units. Units were therefore separated into groups based on total Rw range, as set forth in Table 4. Trends within each group were then identified by directly comparing the Water Resistivity Occurrence and Percentage Frequency histograms for the units in that group.

Group	Hydrostratigraphic Unit	Total Rw Range	Class Interval Size (100 class intervals)
1	Upper Belly River Basal Belly River	0.0-3.0	0.03
2	Milk River Medicine Hat Sandstone Cardium Viking Upper Mannville Lower Mannville Jurassic Mississippian	0.0-2.0	0.02
3	Halfway Belloy Wabamun Nisku Leduc Slave Point	0.0-0.5	0.005
4	Gilwood/Sulphur Point Keg River Granite Wash Silurian Basal Cambrian Sandstone	0.0-0.2	0.002

Table 4 - Groups of hydrostratigraphic units based on total Rw range with varying class interval sizes used to calculate Water Resistivity Occurrence and Percentage Frequency histograms.

5.2) Trends Within Groups

Figure 3 shows two trends including the decrease in Rw with depth mentioned above. The second trend, repeated in each group, is a change from multi-modal distribution of the data to a uni-modal distribution. The youngest hydrostratigraphic unit in each group has Rw values distributed across the entire Rw range. Downward through each group the data focuses towards the lower range of Rw values until a shift to the next group of units is made. There are a few exceptions to these trends as seen in the Percentage Frequency histograms for the Jurassic, Halfway and Belloy Hydrostratigraphic Units. The Jurassic data has a multi-modal distribution while the Halfway and Belloy waters lack the higher resistivities seen in the overlying and underlying units. In each case these hydrostratigraphic units appear to be hydrodynamically isolated from the units above and below.

5.3) Trends Within Hydrostratigraphic Units

The colour coding system used throughout the Rw Atlas allows for regional trends within each hydrostratigraphic unit to be easily identified. The Rw data for each unit was divided into four or five categories, with each category containing approximately the same number of Rw values. The range of values in each category is different for each hydrostratigraphic unit, but each category is given the same colour code. Therefore, throughout the Rw Atlas the black control points represent the lowest Rw values while the pink and red control points represent the higher Rw values.

One general trend that is seen throughout most of the hydrostratigraphic units is the presence of higher resistivities along the subcrop edges. This trend can be seen in the Basal Belly River, Viking,

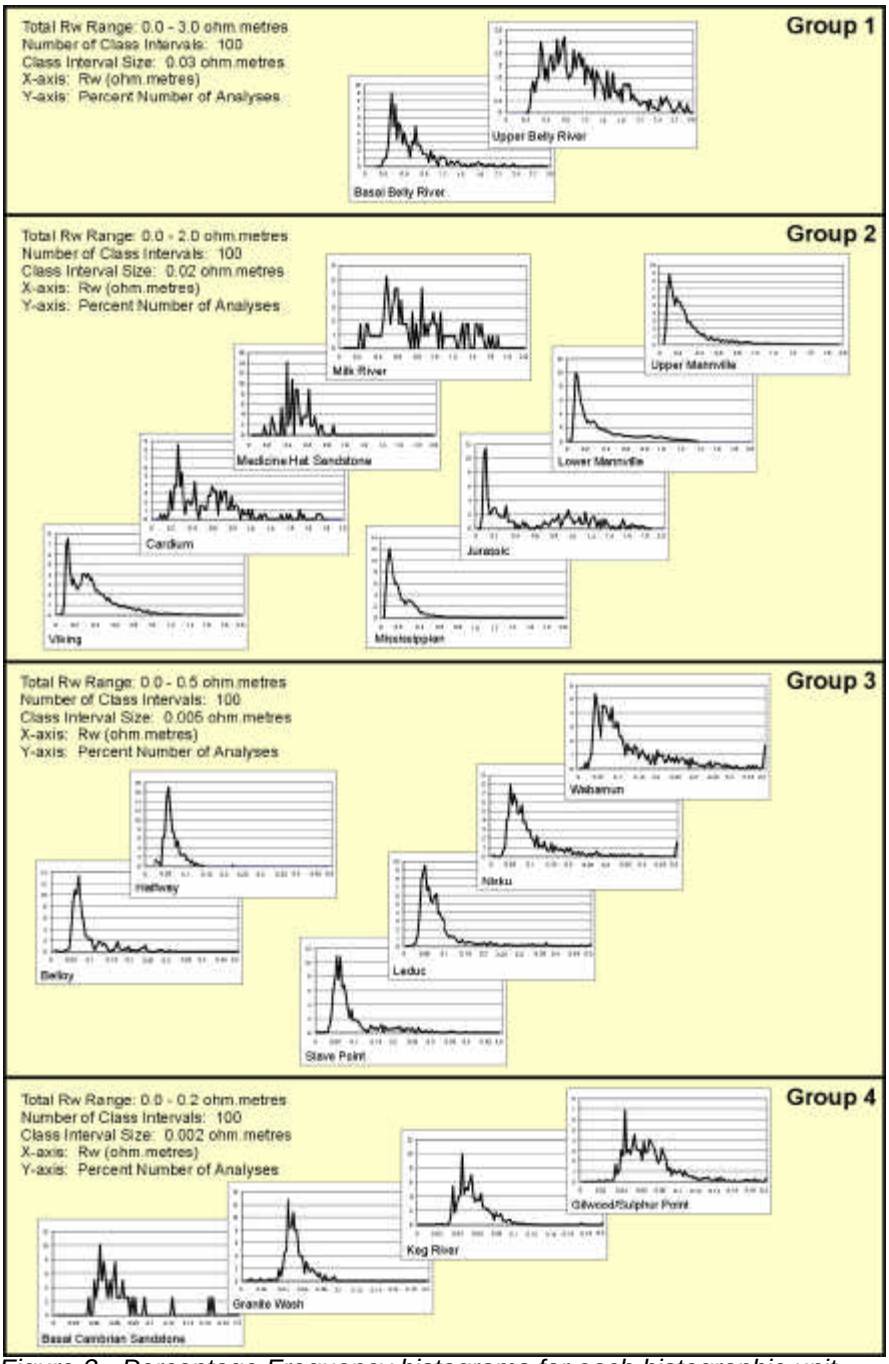

Figure 3 - Percentage Frequency histograms for each histographic unit, divided into four groups based on total Rw range. Trends include a steady decrease in Rw with depth and a repeated change in distribution from multi-modal toward a uni-modal distribution. (Silurian not included due to lack of data.)

Upper and Lower Mannville, Halfway, Belloy and especially in the Mississippian, Wabamun, Nisku and Leduc. In these units, the data near the subcrop edge may reflect the migration of higher Rw waters from the topographic highlands (i.e. Birch, Pelican Mountains, etc.) through the Cenozoic sediments and into the underlying strata.

Other areas often dominated by higher Rw values include the Sweet Grass Arch area in southern Alberta and the Peace River Arch area in northwestern Alberta. Evidence of fresh water influx from these areas is seen in the Viking, Lower Mannville and Upper Mannville units. In the Viking, the southwest corner of Alberta is dominated by a large cluster of the highest Rw values which grade northward into lower Rw values. The gradational trend is overprinted by two arms of relatively high Rw values penetrating deep into the areas otherwise dominated by lower Rw values. The scope of this Rw Atlas does not allow for detailed interpretations as to the cause of these anomalies, but their presence should stimulate questions regarding Viking water characteristics in southern Alberta. In the Lower Mannville, the Peace River Arch is outlined by the colour codes with higher Rw values in the core of the arch radiating outwards toward lower Rw values. Beneath the Lower Mannville, Rw values remain low throughout this area suggesting the deeper hydrostratigraphic units do not experience the same effects of fresh water influx from the Peace River Arch. Evidence for fresh water influx throughout the Sweet Grass Arch area can, however, be seen as far down in the section as the Nisku.

Several units show a significant change in Rw across the subcrop edges of underlying units. The relationship is best observed in the Viking, Upper Mannville and Lower Mannville where the position of the Mississippian subcrop edge in west-central Alberta (T. 30-40, R. 1W4-1W5) effects the Rw values. North and northeast of the Mississippian subcrop edge, Late Cretaceous sediments unconformably overly Devonian sediments. The sharp change in Rw from high values south of the Mississippian subcrop edge to lower values north of the subcrop edge in these units may provide evidence for the vertical migration of saline (lower Rw) Devonian waters into Cretaceous aged rocks.

6.0) CONCLUSION

Regional stratigraphic mapping of Rw data provides valuable information regarding the make up of formation waters in the WCSB. The maps show regional and stratigraphic variability, important for validating specific Rw values. Influences of meteoric recharge significantly raise the Rw values in specific areas including the Peace River Arch, Sweet Grass Arch and along subcrop edges in northeastern Alberta. Across underlying subcrop edges there is evidence of geological controls affecting Rw distribution. The evident trends in Rw lead to simple inferences regarding significant changes in formation water chemistry, salinity and migration.

APPENDIX: Screening The GEOFLUIDS File

A database of chemical analyses of western Canadian "water samples" recovered from oil industry wells is maintained by the ERCB in Alberta and by equivalent government agencies in B.C., Saskatchewan, Manitoba, the Yukon and the N.W.T. RPCL has entered this information into a computer database called GEOFLUIDS.

"Water samples" are routinely recovered during drilling, testing, completion and production operations, and may consist primarily of true formation water or of contaminants: usually mud filtrates or some type of completion fluid. The contaminants may have been sampled deliberately, they may have leaked into the recovery vessel from the borehole, or have been produced from the invaded zone. RPCL has devised procedures to recognize formation waters and to identify the different types of contaminants that are used in western Canadian oil wells. The RPCL screening procedure highgrades the data in GEOFLUIDS by assigning a fluid type flag to each analysis.

The criteria used to screen the raw data and assign each fluid sample one of 24 possible flags (outlined in Table A) are discussed below.

Code	Screened Water Type	Numeric Code	Number of Analyses	Percent Frequency
UNKN	Unknown	00	542	0.29%
MFGC	Mud Filtrate GelChem	04	20,131	10.73%
MFKC	Mud Filtrate KCl	05	11,584	6.18%
AWCF	Acid Water/Completion Fluid	07	5,905	3.15%
CBCA	Carbonate-Bicarbonate Analytical Error	10	1,243	0.66%
MISS	Mis-assigned Formation	14	65	0.03%
ANAL	Ionic Imbalance/Analytical Error	15	6,851	3.65%
INCM	Incomplete	16	51,716	27.57%
INHB	Corrosion Inhibitor	17	2,625	1.40%
ALCH	Alcohol Contamination	18	186	0.10%
FRSH	Fresh Water	19	4,519	2.41%
CACW	Contaminated Acid/Completion Water	20	0	0.00%
CKCL	KCl Contaminated	21	2,631	1.40%
CGCM	GelChem Contaminated	22	11,495	6.13%
PFWD	Possible Fm. Water Diluted	23	1,484	0.79%
PFWV	Possible Fm. Water Very Low TDS	24	4,635	2.47%
PFWL	Possible Fm. Water Low TDS	25	6,338	3.38%
PFWT	Possible Fm. Water Acceptable TDS	26	55,149	29.40%
WCND	Water from Condensation	27	81	0.04%
PFWH	Possible Fm. Water, High TDS	28	306	0.16%
RFWT	Real Fm. Water, Acceptable TDS	29	5	0.00%
KKIL	Potassium Chloride Completion Fluid	30	72	0.04%
MFCA	Mud Filtrate Calcium Chloride Based	31	3	0.00%
		Total	187,566	100%

Table A - GEOFLUIDS Water Type Flags with Numbers of Analyses

a) Incomplete Analysis
To avoid receiving this designation, data measuring several major cations and anions (i.e., chloride (Cl), bicarbonate (HCO_3), sulphate (SO_4), calcium (Ca) and magnesium (Mg)) must be reported.

If a sodium (Na) concentration is not reported, a stoichiometric calculation is performed to calculate Na by difference:

Na by diff. (meq). = sum of anions (meq) sum of cations (meq)

b) Analytical Error
Aqueous solutions exhibit electrical neutrality. Thus if all ion concentrations in a fluid have been correctly determined, the milliequivalent sum of the cations should balance the milliequivalent sum of the anions. In GEOFLUIDS, a 10% ionic imbalance was allowed. Any analysis with an ionic imbalance exceeding 10% was flagged as having analytical problems. Phase equilibria for reactions involving carbon dioxide (CO_2) and water indicate the ionic species carbonate (CO_3) can only exist in a solution if the pH exceeds 8.1. Analyses were flagged as having analytical problems if CO_3 was reported for a solution with pH less than 8.1.

c) Parameter Limits To Identify Obvious Contaminants
A series of parameter limits were designated to identify particular types of contaminants as follows:

ACID WATER/COMPLETION FLUID
- pH < 4.5
- Ca/Cl > 0.3 and pH < 5.7
- Na/Ca < 1.2

- Na/Ca < 5 and Na/Mg < 10 AND pH < 6
- Na/Cl < 0.4 and pH < 6.8

CORROSION INHIBITOR
- SO_4/Cl > 1.5 and TDS Ratio > 1.5
- SO_4/Cl > 1 and TDS Ratio > 1.5 and pH > 8.5
- SO_4/Cl > 10
- TDS Ratio = TDS @ 110°C / TDS @ Ignition

KCl MUD FILTRATE/KILL FLUID
- Na/K < 20

ALCOHOL
- Density < 0.95 AND Density > 0

GEL CHEM MUD FILTRATE
- Na/Cl > 5
- Na/Cl > 3.5 AND SO_4/Cl > 1.5

MINIMUM TOTAL DISSOLVED SOLIDS
- Based on a minimum acceptable TDS, defined stratigraphically.

Carbon Dioxide Species	pH			
	< 6.4	>6.4,< 8.3	> 8.3,<10.33	> 10.33
Carbonic Acid $(H_2CO_3)aq$	$(H_2CO_3)aq$	not present	not present	not present
Bicarbonate $(HCO_3^-)aq$	not present	$(HCO_3^-)aq$	$(HCO_3^-)aq$	not present
Carbonate $(CO_3^{2-})aq$	not present	not present	$(CO_3^{2-})aq$	$(CO_3^{2-})aq$

Table B- Carbon dioxide species and their occurrence in waters of varying pH.

Historically hard cut offs were applied to the data based on assumptions regarding the pH of the sampled water. RPCL recognize local phenomena which allow for true formation waters having pH values lower than 6.0 or higher than 8.4. Often, all such analyses are classified as acid or mud filtrate contaminants. This may be valid for most subsurface brines, but should not be applied to shallower horizons. CO_2 dissolves in water to form three species; $(H_2CO_3)_{aq}$, $(HCO_3^-)_{aq}$ and $(CO_3^{2-})_{aq}$.

The relative proportion of the various dissolved species of CO_2 is an equilibrium reaction controlled by the pH of the water. As shown in Table B, the only dissolved species of CO_2 in acidic waters with a pH < 6.4 is H_2CO_3. In basic waters with a pH > 10.3, the only dissolved species of CO_2 present will be CO_3^{2-}. The majority of formation waters have pH values that fall between these two endpoints. This means that many formation waters will have a water composition that contains more than one species of dissolved CO_2.

$H_2O + CO_2 = H_2CO_3$
$H_2CO_3 = H^+ + HCO_3^-$
$CO_3^{2-} = H^+ + CO_3^{2-}$

For waters with pH values between 6.4 and 8.3,HCO_3- will be the only dissolved species of CO_2 present. But at pH = 8.3 HCO_3- begins to alter to HCO_3-. Therefore for waters with pH values between 8.3 and 10.3, both HCO_3- and CO32- will be present. At pH = 10.3, all of the HCO_3- will have altered to CO_3^{2-}.

RPCL recognizes that most subsurface brines have a pH of less than 8.3 and therefore do not have CO_3^{2-}. Recharging meteoric waters, however, are often basic with pH values exceeding 8.3. Therefore in shallow horizons where strong vertically downward directed groundwater recharge is possible, formation waters may have pH values exceeding 8.3. The consequence of this meteoric recharge with high pH waters is that the formation waters will typically contain both HCO_3- and CO_3^{2-}. Local scale flow systems can therefore be a controlling factor of water composition. Generic water chemistry screening criteria must account for this variability. A generic water chemistry screening cut off for pH values > 8.4, while valid for most subsurface brines, will not be valid for these types of waters and will therefore remove valid water samples from the data set.

Additionally, a hard cut off of pH < 6 is not entirely valid as deep, high pressured, very saline brines can exhibit pH values as low as 4.0. Examples of such brines can be found in the Beaverhill Lake Group in southern Alberta.

The remaining two steps discussed below are performed on subsets of each provincial database after dividing the data into meaningful stratigraphic units, referred to as "Hydrostratigraphic Units". Each hydrostratigraphic unit is defined as a group of contiguous formations (generally reservoir rock) separated from other formations by a regionally continuous aquitard.

d) Ionic Ratio Cross Plotting (Multivariate Cluster Analysis)
A series of cross plots of various ionic constituents are constructed to flag contaminants that were not identifiable through parameter limits. Each graph is edited manually using the cluster analysis technique to identify and remove contaminated analyses.

e) Nearest Neighbour TDS Mapping
A final mapping stage is performed on the formation waterlike data remaining after the above procedures. The TDS concentration of each sample is compared with the TDS values of the samples from the nine closest wells within a 10 km radius of the sample well. The eight highest TDS values from this group of analyses are used to calculate an average TDS. The percentage difference in TDS between the sample of interest and the average of its nearest neighbour group is then calculated. Cumulative frequency distribution graphs of the percent difference from the average are constructed and any analysis with a large percentage difference is flagged as having either Very Low TDS or Low TDS depending on the difference magnitude. The flagged sample is then removed from the data set and the procedure repeated. After the second iteration the radius of investigation is increased to 20 km and two more iterations are performed. The data remaining after this step are flagged as Possible Formation Water Acceptable TDS (PFWT), representing our initial interpretation of the chemical signature for a valid formation water.

f) Continuing Data Entry and Screening
As new data are released by the provincial and territorial agencies they are entered into the raw data files. These data are screened and high graded using the basic procedures established in the initial screening.

g) Screening Re-Evaluation
As further hydrochemical work is performed by RPCL in local and intermediate scale projects, the initial water chemistry flags are re-evaluated. If RPCL believes the initial evaluation is incorrect, a new flag will be assigned based on a higher level of understanding due to detailed work.