Gridding & Mapping of Laboratory Measured Brine Data Animation Java Applet

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Introduction

The Gridding and Mapping of Laboratory Measured Brine Data Animation Web Application is an interactive process that assists the user in building simple color contour maps of Brine Data Well data and presenting the data as an animation at each Sampled Data Time slice. The "contour" map uses a "colorlith" presentation, i.e. mapping 3 brine data curves to 3 primary colors, Red, Green and Blue and mixing the colors to create a final color based on the magnitude of the selected brine data curves. The Gridding & Mapping module first appeared in PfEFFER Pro an Excel Spread Sheet Program developed by the Kansas Geological Survey, released 1998. It also appeared in GEMINI (**G**eo-**E**ngineering **M**odeling through **IN**ternet **I**nformatics) web application developed by Kansas Geological Survey 2000 – 2003 as part of Volumetrics Module. A stand-alone Gridding & Mapping Web App was one of the first web apps developed as part of the Gemini Tools in November of 2003. The 2003 version was designed for a user to enter any type of data for the group of wells, core data, tops thickness, etc. The data was saved as XML Extensible Markup Language Project Files. The program automatically accessed the saved data between dialogs. This new version focuses on the CO_2 Wells with Brine Data. The data is stored on the CO_2 ORACLE Database Tables at the Kansas Geological Survey (KGS). A series of ORACLE PL/SQL Stored Procedures were created to access this data. This version is very dependent on the KGS database.

Peter L. Briggs[1] identified a method to assist geologist in well log interpretation by creating a color log presentation. His method provided a means to combine three different log curves from one well into one image track that varies along the depth by assigning each curve to a specific primary color of red, green and blue. His method assumed that the primary colors would appear to the human eye as orthogonal and miscible where the resulting color image would preserve all the information of the original log curves. The color image presentation of well log data reduced the number of displays competing for the interpreter's attentions by uniting the three log curves into one display and relieved the burden of mentally combining data from several separate displays. Overall the color log images presented log data to the user in a form that differs from the conventional log presentation and relied on the human perceptions and pattern recognition skills. The term Colorlith was first introduced by David Collins[2] in a USGS paper discusses the visualization of subsurface geology as achieved by COLORLITH, a software system… Many of the GEMINI Tools use a "Colorlith" plot track to illustrate the lithology at a glance. This

(1) Color display of well logs, Peter L. Briggs, Mathematical Geology, Volume 17, Number 4, May 1985.
(2) Color Images of Kansas Subsurface Geology from Well Logs, D. R. Collins and J. H. Doveton, Computer & Geosciences, Vol. 12, No. 4B, pp.519-526 1986

program extends this concept to the Gridding & Mapping web app with the brine data curves since there are a number of data types that are created for each water sample for each well. The idea of using the brine data magnitudes to create the color "contour" map would reflect the general chemistry of the brine data. The influence of the CO_2 injected into the Mississippian might alter the brine chemistry which could be mapped over time by the color changes on the Gridding and Mapping Web App.

To access Gridding and Mapping of Laboratory Measured Brine Data Animation web site go to http://www.kgs.ku.edu/PRS/Ozark/Software/GRID_LAB/index.html at the top of the web page there is a menu "Main Page|Applet|Help|Copyright & Disclaimer|". Select the "Applet" menu
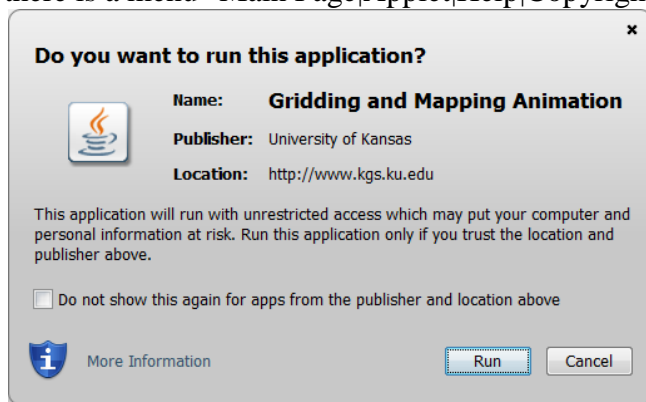
option a "Warning - Security" Dialog will appear *("Do you want to run this application?")*. The program has to be able to read and write to the user's PC and access the Kansas Geological Survey (KGS) Database and File Server, ORACLE requires this dialog. The program does not save your files to KGS, but allows you to access the KGS for well information. The program does not use Cookies or any hidden software. The blue shield on the warning dialog is a symbol that the Java web app is created by a trusted source, which is the University of Kansas. Select the "Run" Button, which will show the Brine Data "Enter" Panel illustrated below,

Enter
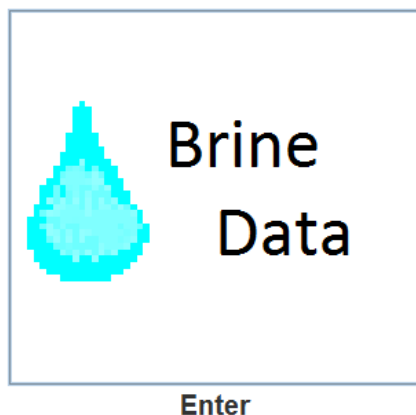
Select the Brine Data Icon button and the Brine Data Dialog will display with a list of the measured brine data of the monitoring wells in the Brine Data table.

Brine Data Dialog

This program is designed to create a gridding and mapping animation of the 15 monitoring wells in around the Wellington KGS 2-28 CO_2 Sequestration Well using a "colorlith" presentation of the brine data, i.e. 3 brine data curves mapped to 3 colors Red, Green and Blue respectively and mixes the color to reflect the general chemistry. The idea is that by picking and plotting the right three curves that may be especially sensitive to the brine chemistry and reflect the CO_2 interaction and see a change in the presentation on the map over time by the color changes.

Close this dialog and all dialogs opened by this dialog.

Begin Animation of Brine Data.

Radio Buttons:
- **Raw Data** - Use the raw measured brine data in animation.
- **Normalized Data** - Use the normalized brine data in animation.

The brine data for the 15 monitoring wells are automatically downloaded when the user starts the program and loaded into this dialog. The program also automatically checks each of the brine data curves and determines which column should be initially deselected, i.e. if any column is populated with all zeros the check box is unchecked or if the column is populated with less than

20% of data column greater than zero. This is done because the Principal Component Java Functions will not compute the eigenvalues or eigenvector if any of the columns have only zeros. The program will send a warning to the user which columns have zeros and disable functionality of the dialog. The applet allows the user to view an animation of the raw measured data or the normalized data by selecting the "Get Normalize Data" button.

Brine Data:

		✔ Na	✔ K	✔ Mg	✔ Ca	✔ Sr	☐ Ba	✔ MnII	✔ FeII	☐ FeIII	☐ Zn	✔ Cl	☐ Br	✔ BO3	✔ HCO3	✔ SO4	✔ PH

API-Number	Na	K	Mg	Ca	Sr	Ba	MnII	FeII	FeIII	Zn	Cl	Br	BO3	HCO3	SO4	PH
15-191-43882	66007.6	357.1	3062.3	12464.6	608.2	0.0	0.7	14.5	0.0	0.0	128012.0	0.0	37.3	128.1	1255.0	6.5
15-191-43882	60900.0	380.0	2910.0	12700.0	0.0	0.5	0.7	0.0	14.0	0.0	132000.0	550.0	0.0	0.0	570.0	5.75
15-191-43882	71063.5	326.8	3133.4	13219.1	657.1	0.0	0.7	15.3	0.0	0.0	136600.0	0.0	40.7	36.6	629.6	6.0
15-191-10107	70686.3	293.1	3848.0	11762.7	1165.0	2.7	1.0	44.3	0.0	0.0	139549.0	0.0	35.8	115.9	705.0	5.4
15-191-10107	67398.0	281.4	4175.0	13467.2	1335.9	2.7	0.5	21.2	0.0	3.1	147200.0	0.0	45.7	48.8	402.2	5.9
15-191-10092	61936.3	507.4	2427.8	12792.3	463.1	0.0	1.7	93.1	0.0	0.0	117042.0	0.0	47.5	91.5	996.0	5.2
15-191-10092	58020.8	441.7	2317.8	12411.2	425.2	0.0	0.6	7.3	0.0	0.0	123900.0	0.0	43.0	48.8	701.2	5.8
15-191-10093	60171.1	393.7	2511.9	12246.0	458.9	0.0	0.8	14.8	0.0	0.0	110894.0	0.0	38.7	122.0	1600.0	5.3
15-191-10093	68521.9	412.7	2780.1	13706.1	545.5	0.0	0.9	19.6	0.0	0.0	130300.0	0.0	43.6	36.6	784.4	5.9

Normalization through Principal Components Analysis:

Get Normalize Data   2.0   % from Anions/Cations equal to 1.0

Get Normalize Data Button – Automatically normalizes the Raw Brine Data with respect to +/- 2.0% Cations/Anions Ratio = 1.0

This dialog allows the user to normalize the raw brine data to "correct" the measured data with the respect to the Anions/Cations ratio of 1.0 using principal component analysis. This process is basically automatic the user decides on the level of "good" with respect the Anions/Cations ratio as +/- N % from 1.0, 2.0 % is the default value.

The principal component analysis is automatic when the "Get Normalize Data" Button is selected. The program will automatically take the columns that are checked and normalize and transfer the data back to the main dialog and enable the "Normalized Data" radio button. The Principal Components dialog will display so you can view the plots of the data. The only thing the user can do with the principal components analysis is choose which columns they wish to include in the normalization process and to change the "% from Anions/Cations equal to 1.0" text field, which is 2.0% by default. Also note that the program will automatically re-sum the TDS for each row for the normalized data set. This provides the user with 2 data sets one raw and the other normalized to a level of "good" with respect to the Anions/Cations ratio of 1.0.

The bottom panel is the basic control to select the 3 brine data curves to map to the 3 colors Red, Green and Blue respectively and automatically mixes the color to reflect the general chemistry. At the top of the panel is a "warning" to select the boxes from left R-Red to right B-Blue otherwise the color mix will not plot correctly. The "Clear Selection" button allows the user to clear the selection so they can select a different set of curves. The user will note next to each Curve row is a set of labels **X**, **?**, or a **G**, as indicators on the number of samples within each of the curves. If the curve you are selecting has data for all rows then you will see the Green **G** for good data curve, if you have 20% to 99% of the curve rows filled you will see an Orange **?** for

questionable curve data, and if you have from 0 to 19% of the curve rows filled you will see a Red **X** for bad curve "do not select". The bottom table shows the statistics of the data for the complete data set. The plot icon button will only enable when the user has selected the 3 curves for plotting.

Select check boxes from left R-Red to right B-Blue otherwise the color mix will not plot correctly.

MNEM	Min	5%	25%	Mean	Median	75%	95%	Max
PH	5	5.2	5.325	5.805	5.761	6.175	6.5	6.5
TDS	181,296.1	187,391.74	195,781.6	200,935.2	203,252.711	213,777.075	229,134.735	234,381.7
SO4	402.2	621.71	684.5	827.7	904.879	1,153.75	1,609	1,660

The "Clear Selection" button resets the check boxes so the user can choose a different set of curves, the Statistics Table is also cleared.

The applet is automatically downloading the brine data for this animation from a ORACLE PL/SQL Stored Procedure,

http://chasm.kgs.ku.edu/ords/iqstrat.co2_gridding_pkg.getDateXML?sID=LAB

This data set is all the data that is necessary to create an animation over time. Each data set will have a Group ID ("LAB") and a Group Number starting at 0, 1, 2, … etc. Each number also represents a date the well was sampled, i.e. 0 is 12 May 2015, 1 is 11 June 2015, etc. The wells were automatically group to simplify the process. The color limits for each date is set at the beginning using the statistics table at the bottom of the Brine Data Frame and every time slice is set to those limits, i.e. 5% is the minimum value and 95% is the maximum value. The data over time is plotted to the same limits in the hope of observing brine chemistry changes over time with respect to the wells.

The user has the choice of just working with the raw measured brine data or to create a normalized data set by selecting the "Get Normalize Data" button. As stated above the user can check or uncheck the data curves they wish to use in the normalization process as well as selecting the "% from Anions/Cations equal to 1.0" text field value to set a "good" level for "correcting" the raw brine data, the default value is 2.0 %.

"Get Normalize Data" Button

Buttons to display dialogs & plots and to save as images as Portable Network Graphics (PNG). Color Legend for brine data cells that are colored.

Brine Data imported in units of meq/l with table cells colored if the data falls outside 1.5 standard deviations.

Brine Data showing data greater than 1.5 standard deviations

○ Original Data ○ Good Data ○ Data Below 1 ○ Data Above 1 ○ Normalized

Sigma * -3.0 -2.6 -2.4 -2.3 -2.2 -2.1 -2.0 -1.9 -1.8 -1.7 -1.6 -1.5

1.5 1.6 1.7 1.8 1.9 2.0 2.1 2.2 2.4 2.5 3.0

API-Number	Na	K	Mg	Ca	Sr	MnII	FeII	Cl	BO3	HCO3	SO4	PH
15-191-10107	3074.65	7.49	316.7	586.96	26.59	0.03	1.58	3936.5	1.82	1.89	14.67	5.4
15-191-10087	2827.9	9.12	225.96	663.37	12.16	0.03	0.79	3684.06	2.24	0.89	14.6	5.2
15-191-10076	2701.17	9.97	200.0	608.78	0.0	0.03	0.0	3497.88	0.0	0.0	13.47	5.88
15-191-11442	2657.74	8.95	208.26	604.28	10.78	0.02	0.44	3406.03	1.95	1.89	30.7	5.6
15-191-11442	2806.99	8.52	229.72	687.97	11.78	0.02	0.56	3737.65	2.11	0.59	20.4	6.3
15-191-10078	2496.73	11.89	213.99	578.84	0.0	0.04	0.0	3300.42	0.0	0.0	14.4	5.98
15-191-10078	2832.67	8.86	235.6	693.73	12.22	0.04	0.8	3723.55	2.18	0.89	17.22	6.2
15-191-10134	2867.65	8.92	214.13	635.83	11.97	0.02	0.52	3698.16	2.04	0.59	12.01	6.5
15-191-43882	2871.14	9.13	252.04	621.98	13.88	0.02	0.51	3611.05	1.9	2.09	26.12	6.5
15-191-43882	3091.06	8.35	257.89	659.63	14.99	0.03	0.54	3853.31	2.07	0.59	13.1	6.0
15-191-10092	2694.05	12.97	199.81	638.33	10.57	0.06	3.33	3301.6	2.42	1.49	20.73	5.2
15-191-10093	2617.27	10.06	206.74	611.07	10.47	0.03	0.52	3128.18	1.97	1.99	33.31	5.3
15-191-10093	2980.5	10.55	228.81	683.93	12.45	0.03	0.7	3675.59	2.22	0.59	16.33	5.9
15-191-10087	2814.38	10.01	210.33	625.69	12.54	0.03	0.84	3352.77	2.1	1.19	17.65	5.2
15-191-10076	2817.72	9.58	214.08	637.74	11.51	0.03	0.72	3402.82	2.21	1.39	17.23	5.3
15-191-10078	2520.36	10.5	205.18	590.15	10.09	0.06	1.88	3039.26	2.31	1.99	29.77	5.2
15-191-10096	2565.14	11.1	198.32	610.84	10.34	0.03	0.26	3165.69	1.97	1.19	24.46	5.6
15-191-10096	2839.07	10.24	207.3	651.18	11.45	0.04	0.6	3607.89	2.11	0.59	16.41	6.2
15-191-10134	2691.93	9.24	209.56	624.63	11.01	0.03	0.5	3279.49	1.99	1.79	25.6	5.2
15-191-10083-0002	2468.41	10.34	201.58	579.92	9.86	0.06	1.49	3041.41	2.27	1.19	34.56	5.2
15-191-10136	2729.22	9.06	214.23	618.41	10.87	0.03	0.46	3291.22	1.99	1.49	22.69	6.1
15-191-10077	2700.01	9.25	202.95	615.79	10.66	0.07	1.23	3253.9	1.91	1.69	28.73	5.6
15-191-10077	3067.23	9.01	223.66	701.72	12.49	0.08	1.86	3664.31	2.25	0.89	13.19	5.9
15-191-19005	2662.57	9.09	209.08	606.36	11.02	0.04	0.44	3263.1	2.01	1.49	23.94	5.0
15-191-19005	2779.31	9.16	212.09	636.14	11.64	0.04	0.51	3393.11	2.14	1.19	16.28	5.3
15-191-19005	2917.9	8.6	223.44	665.96	12.44	0.04	0.58	3650.21	2.32	0.89	17.55	5.7
15-191-00395-0001	2674.01	8.92	207.25	609.7	10.68	0.03	0.43	3088.71	1.99	1.19	24.04	5.3
15-191-43882	2648.97	9.71	239.5	633.73	0.0	0.02	0.0	3723.55	0.0	0.0	11.86	5.75
15-191-10107	2931.62	7.19	343.62	672.01	30.49	0.01	0.75	4152.32	2.33	0.79	8.37	5.9
15-191-10092	2523.74	11.29	190.76	619.32	9.7	0.02	0.26	3495.06	2.19	0.79	14.59	5.8
15-191-10087	2561.98	12.22	198.35	578.84	0.0	0.03	0.0	3526.09	0.0	0.0	13.2	5.87
15-191-10076	2646.4	8.01	216.8	646.7	10.95	0.03	0.67	3717.91	2.07	0.99	15.7	6.3
15-191-11442	2435.84	10.99	195.06	588.82	0.0	0.02	0.0	3526.09	0.0	0.0	13.51	5.73
15-191-10134	2453.24	11.09	195.06	573.85	0.0	0.02	0.0	3554.3	0.0	0.0	13.47	5.81
15-191-10083-0002	2322.74	12.22	187.65	538.92	0.0	0.02	0.0	3300.42	0.0	0.0	14.19	6.31
15-191-10083-0002	2411.67	9.05	201.16	594.78	9.89	0.02	0.66	3495.06	2.24	0.79	20.15	6.5
15-191-10136	2418.44	10.79	193.41	558.88	0.0	0.03	0.0	3582.51	0.0	0.0	13.17	5.8
15-191-10136	2729.93	8.2	216.61	622.67	11.32	0.02	0.4	3746.12	2.0	0.99	18.34	6.4

Table showing the Mean and Standard Deviation of the wells that are displayed.

	Na	K	Mg	Ca	Sr	MnII	FeII	Cl	BO3	HCO3	SO4	PH
Mean	2,706.614	9.727	218.597	623.091	9.916	0.032	0.653	3,496.508	1.666	0.947	18.834	5.761
Sigma	195.257	1.336	31.133	38.097	6.557	0.015	0.662	255.462	0.882	0.654	6.518	0.44

○ Original Data ○ Good Data ○ Data Below 1 ○ Data Above 1 ○ Normalized

Close this dialog and all dialogs opened by this dialog.

Display the Covariance Matrix Table.

Display the Eigenvector Matrix & Eigen values Tables.

Display the Principle Components Score Plot.

Display the Brine Data Anions/Cations Ratio Plot.

Save dialog or plots as a Portable Network Graphics (PNG) file with the option of creating a Portable Document Format (PDF) file.

Radio Buttons:
• **Original Data** – Displays all the imported brine data ordered by "Good" brine data set, Brine Data Anions/Cations Ratio below 1.0, Brine Data Anions/Cations Ratio above 1.0.
• **Good Data** – Displays the "Good" brine data set, i.e. wells with measured brine data falling +/- "% from Anions/Cations equal to 1.0" text field value with respect to Anions/Cations Ratio equal to 1.0.
• **Data Below 1** – Displays the Brine Data Anions/Cations Ratio below 1.0 - "% from Anions/Cations equal to 1.0" text field value with respect to Anions/Cations Ratio equal to 1.0.
• **Data Above 1** – Display the Brine Data Anions/Cations Ratio above 1.0 + "% from Anions/Cations equal to 1.0" text field value with respect to Anions/Cations Ratio equal to 1.0.
• **Normalized** – Displays all the brine data normalized to the "Good" brine data set ordered by "Good" brine data set, Brine Data Anions/Cations Ratio below 1.0, Brine Data Anions Ratio above 1.0.

Display the Covariance Table Dialog

Brine Data Covariance Matrix

|	Na	K	Mg	Ca	Sr	MnII	FeII	Cl	BO3	HCO3	SO4	PH
Na	1.0	-0.615	0.654	0.766	0.7	0.093	0.311	0.566	0.528	0.275	-0.219	0.035
K	-0.615	1.0	-0.634	-0.489	-0.687	0.168	-0.007	-0.503	-0.495	-0.351	0.006	-0.143
Mg	0.654	-0.634	1.0	0.389	0.763	-0.222	0.163	0.691	0.254	0.17	-0.29	0.088
Ca	0.766	-0.489	0.389	1.0	0.511	0.13	0.277	0.492	0.594	0.114	-0.194	0.133
Sr	0.7	-0.687	0.763	0.511	1.0	0.001	0.451	0.387	0.779	0.59	0.082	-0.092
MnII	0.093	0.168	-0.222	0.13	0.001	1.0	0.67	-0.384	0.247	0.262	0.304	-0.359
FeII	0.311	-0.007	0.163	0.277	0.451	0.67	1.0	-0.108	0.569	0.518	0.28	-0.341
Cl	0.566	-0.503	0.691	0.492	0.387	-0.384	-0.108	1.0	0.001	-0.331	-0.711	0.501
BO3	0.528	-0.495	0.254	0.594	0.779	0.247	0.569	0.001	1.0	0.708	0.393	-0.168
HCO3	0.275	-0.351	0.17	0.114	0.59	0.262	0.518	-0.331	0.708	0.999	0.731	-0.414
SO4	-0.219	0.006	-0.29	-0.194	0.082	0.304	0.28	-0.711	0.393	0.731	1.0	-0.378
PH	0.035	-0.143	0.088	0.133	-0.092	-0.359	-0.341	0.501	-0.168	-0.414	-0.378	1.0

Covariance Matrix Table Dialog Buttons:

 Close this dialog.

 Save covariance matrix table as a Portable Network Graphics (PNG) file with the option of creating a Portable Document Format (PDF) file.
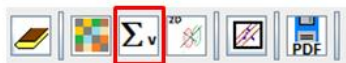
Display the Eigenvector Matrix & Eigen values Table Dialog

Brine Data Eigenvector Matrix

	1	2	3	4	5	6	7	8	9	10	11	12
Na	0.045	-0.081	-0.4	0.042	0.455	0.577	-0.124	-0.264	0.005	0.181	-0.101	-0.399
K	0.04	-0.234	0.191	-0.261	-0.005	0.468	0.594	0.121	0.103	0.317	0.117	0.354
Mg	0.407	0.226	0.061	-0.36	-0.378	0.209	-0.107	0.234	0.47	-0.114	-0.205	-0.344
Ca	-0.198	0.243	0.248	-0.013	-0.493	0.103	0.153	-0.429	-0.398	0.306	-0.092	-0.341
Sr	-0.667	-0.166	0.007	-0.411	0.145	-0.172	0.204	0.165	0.162	-0.159	0.037	-0.429
MnII	0.04	-0.201	0.261	-0.303	0.072	-0.106	-0.574	0.11	-0.032	0.565	0.339	-0.045
FeII	-0.076	0.258	-0.33	0.445	-0.139	-0.086	0.206	0.457	0.147	0.414	0.313	-0.222
Cl	0.05	-0.678	0.227	0.422	-0.146	-0.058	0.006	0.145	0.082	0.109	-0.433	-0.23
BO3	0.575	-0.183	-0.075	-0.188	0.158	-0.36	0.379	-0.042	-0.324	-0.054	0.233	-0.361
HCO3	0.025	0.153	0.638	0.327	0.246	0.286	-0.006	0.102	0.0	-0.318	0.38	-0.245
SO4	-0.064	-0.39	-0.305	-0.011	-0.489	0.309	-0.175	0.074	-0.228	-0.354	0.447	-0.004
PH	-0.021	0.151	0.007	-0.132	0.11	0.178	-0.08	0.623	-0.629	-0.027	-0.35	0.01

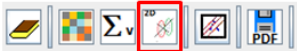|	1	2	3	4	5	6	7	8	9	10	11	12
Eigen	0.013	0.062	0.071	0.15	0.171	0.246	0.415	0.575	0.837	1.312	3.475	4.673
%	0.1	0.5	0.5	1.2	1.4	2	3.4	4.7	6.9	10.9	28.9	38.9

Eigenvector Matrix & Eigen values Table Dialog Buttons:

 Close this dialog.

 Save Eigenvector matrix & Eigen values panel as a Portable Network Graphics (PNG) file with the option of creating a Portable Document Format (PDF) file.

Display the Principal Components Scores Plot

Modify Limits button allows the user to change the titles and the X & Y Axis limits.

Principal Components Scores Plot Buttons:

 Close this dialog.

 Save principal components scores plot as a Portable Network Graphics (PNG) file with the option of creating a Portable Document Format (PDF) file.
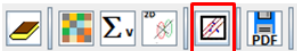
Display the Anions/Cations Cross Plot

Modify Limits button allows the user to change the titles and the X & Y Axis limits.

Anions/Cations Cross Plot Buttons:
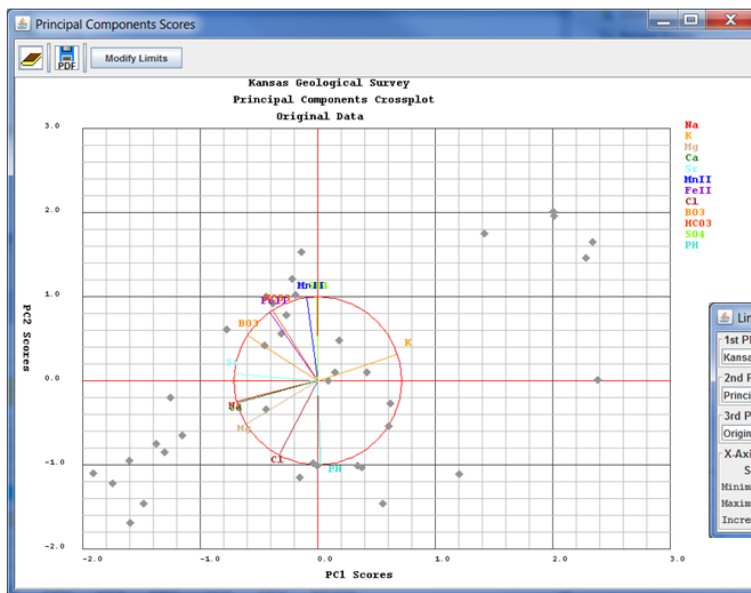
 Close this dialog.

 Save anions/cations cross plot as a Portable Network Graphics (PNG) file with the option of creating a Portable Document Format (PDF) file.

Save Brine Principal Components Panel as a Portable Network Graphics (PNG) Image File

Click on the PDF Icon Button at the top of the "Brine Principal Components" Dialog to open the "Select a Different Directory Path" Dialog.
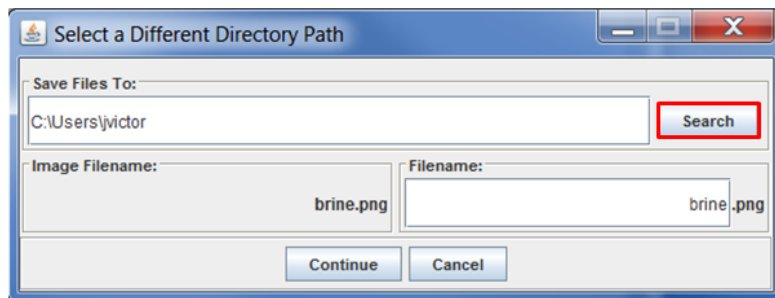
Select the "Search" Button in the "Select a Different Directory Path" Dialog to search your PC for the correct directory path.

Highlight the Directory you wish to place the PNG File.

Select the "Select" Button.
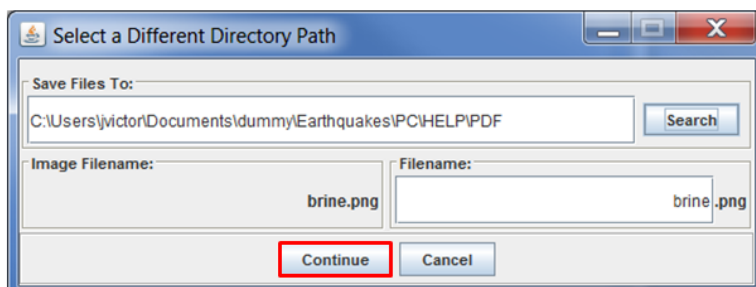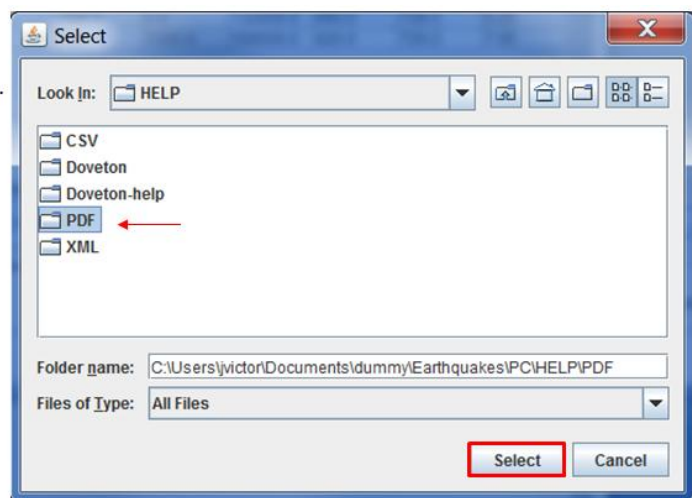
The Directory path is transferred to the "Save Files To:" text field.

"brine" is the default filename, you can alter the name to any name you wish. The "File save as:" text field will show what the file name will be saved as.

Select the "Continue" Button to save file.

The PNG Image File is created along with a HTML file to display the PNG image. At the top of the HTML File is a link that allows the user to create a PDF document of the PNG Image File.
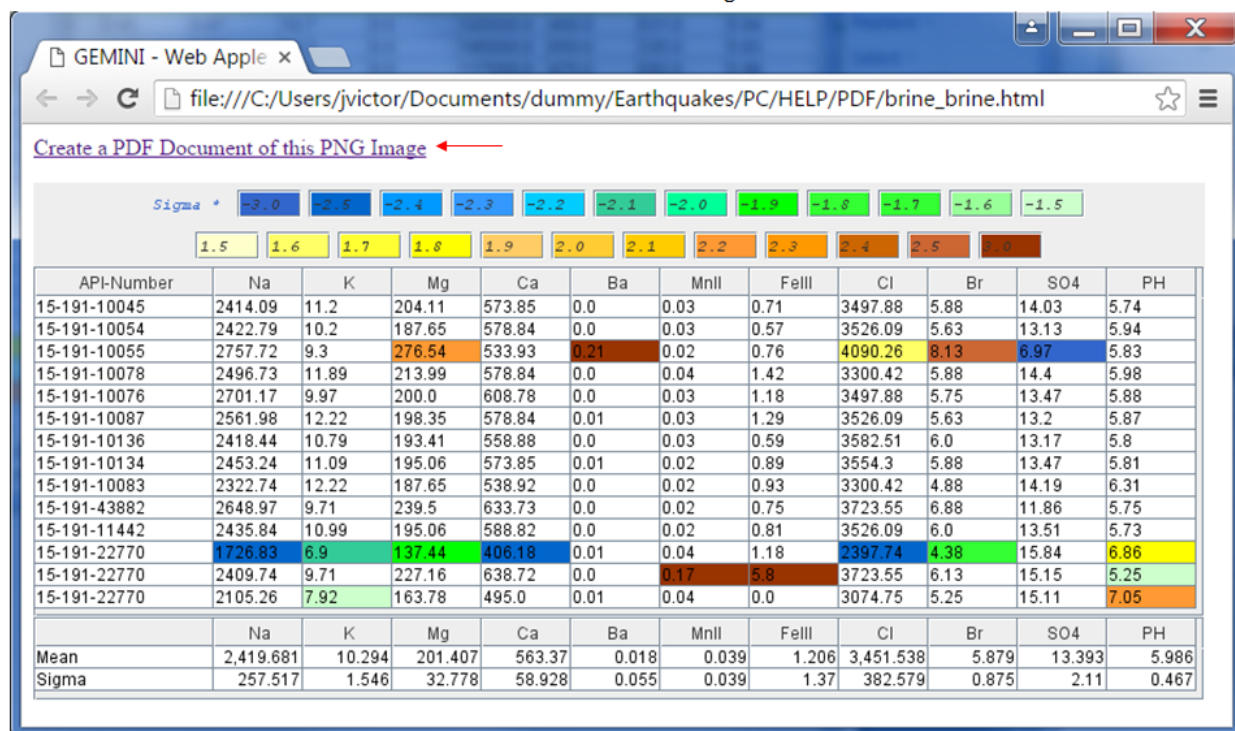
If the Covariance Matrix Dialog, Principal Components Scores Plot, etc. are displayed then the PNG button automatically retrieves the image from those dialogs and creates a PNG image of each and displays it at the same time the Brine Principal Components PNG Image is displayed.

It the default name "brine" for the Brine Principal Components PNG Image is used then the each of the other images will append a distinct phrase to distinguish it from the main dialog PNG Image plot, i.e.

- Covariance Matrix Panel PNG File will have the name brine_cov.png
- Eigenvectors & eigenvalues Panel PNG File will have the name brine_eign.png
- Principal Components Scores Plot PNG File will have the name brine_Xplot.png
- Anions/Cations Plot PNG File will have the name brine_plot.png

Normalization Brine Data to +/- 2% of the Anions/Cations Ratio of 1.0

The "Begin Normalization Process" Button on the "Brine Data" Dialog allows the user to force the brine data set to a "Corrected" Value. The default "% from Anions/Cations equal to 1.0" text field is 2.0, which implies the "Good" data set will fall between 1.02 and 0.98 inclusive. The web app separates the brine data above 1.02 and labels it as "Data Above 1" and brine data below 0.98 as "Data Below 1". In this specific example the data above 1.0 is K-State & Baker Hughes measured data and the data below is Baker Hughes measured data. The "Good" data set has at least 2 measurements of K-State in the data set with the rest being from the Baker Hughes data set.
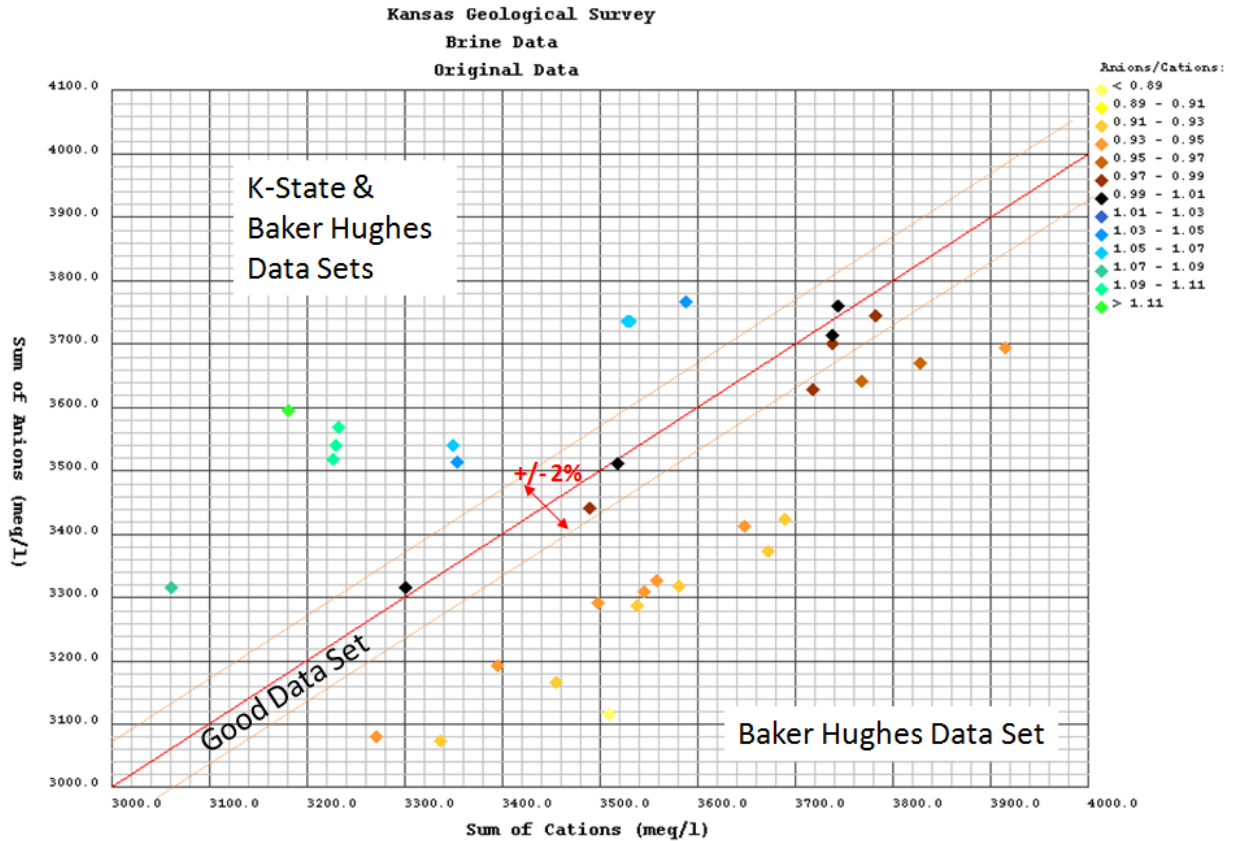
The web app performs all the processing in the background, the user can only change the "% from Anions/Cations equal to 1.0" text field. The process begins by constructing the Covariance matrix for the "Good" data set, since this will be used in correcting the above and below data sets. Covariance [cov(x,y)] matrix is a measure how much each data column vary from the mean with respect to each other.

$$\text{cov}(x,y) = \frac{\sum_{i=1}^{N} (x_i - \overline{x})(y_i - \overline{y})}{(N-1)}$$

where x is the mean of brine data column k divided by σ_k where x_i is the individual brine data divided by σ_k, subscript i represents the well, subscript k represents the brine data column, e.g. cov (Na, Ca) is sum over the Na (Sodium cation) and Ca (Calcium cation) columns of the normalized data set.

Covariance Matrix – Good Data Set

y → (X →)

	Na	K	Mg	Ca	Sr	MnII	FeII	Cl	BO3	HCO3	SO4	PH
Na	1.0	-0.894	0.774	0.254	0.89	-0.221	0.895	0.971	0.627	0.53	-0.251	-0.158
K	-0.894	1.0	-0.625	-0.347	-0.88	0.477	-0.826	-0.856	-0.779	-0.723	-0.184	0.158
Mg	0.774	-0.625	1.0	-0.139	0.861	0.13	0.905	0.752	0.319	0.589	-0.17	-0.364
Ca	0.254	-0.347	-0.139	1.0	0.115	-0.087	0.138	0.413	0.625	-0.098	0.028	0.338
Sr	0.89	-0.88	0.861	0.115	1.0	-0.238	0.975	0.846	0.723	0.801	0.067	-0.3
MnII	-0.221	0.477	0.13	-0.087	-0.238	1.0	-0.045	-0.161	-0.423	-0.312	-0.406	-0.127
FeII	0.895	-0.826	0.905	0.138	0.975	-0.045	0.999	0.865	0.663	0.741	-0.043	-0.383
Cl	0.971	-0.856	0.752	0.413	0.846	-0.161	0.865	0.999	0.647	0.414	-0.291	-0.055
BO3	0.627	-0.779	0.319	0.625	0.723	-0.423	0.663	0.647	1.0	0.632	0.303	-0.04
HCO3	0.53	-0.723	0.589	-0.098	0.801	-0.312	0.741	0.414	0.632	1.0	0.562	-0.498
SO4	-0.251	-0.184	-0.17	0.028	0.067	-0.406	-0.043	-0.291	0.303	0.562	0.999	-0.153
PH	-0.158	0.158	-0.364	0.338	-0.3	-0.127	-0.383	-0.055	-0.04	-0.498	-0.153	0.999

Covariance Matrix

$$C = \begin{bmatrix} cov(Na, Na) & cov(Na, K) & cov(Na, Mg) & \ldots & cov(Na, SO_4) & cov(Na, PH) \\ cov(K, Na) & cov(K, K) & cov(K, Mg) & \ldots & cov(K, SO_4) & cov(K, PH) \\ cov(Mg, Na) & cov(Mg, K) & cov(Mg, Mg) & \ldots & cov(Mg, SO_4) & cov(Mg, PH) \\ & & \cdot & & & \cdot \\ & & \cdot & & & \cdot \\ & & \cdot & & & \cdot \\ cov(SO_4, Na) & cov(SO_4, K) & cov(SO_4, Mg) & \ldots & cov(SO_4, SO_4) & cov(SO_4, PH) \\ cov(PH, Na) & cov(PH, K) & cov(PH, Mg) & \ldots & cov(PH, SO_4) & cov(PH, PH) \end{bmatrix}$$

To compute the Eigenvectors and Eigenvalues this web app uses JAMA a Java Matrix Package (http://math.nist.gov/javanumerics/jama/).

"JAMA is a basic linear algebra package for Java. It provides user-level classes for constructing and manipulating real, dense matrices. It is meant to provide sufficient functionality for routine problems, packaged in a way that is natural and understandable to non-experts. It is intended to serve as the standard matrix class for Java."

JAMA Java Functions:
C represents the symbol for the Covariance Matrix
The eigenvalues & eigenvectors JAMA functions are listed as follows

E_v = C.eig(), where the eig() function computes the eigenvalues & eigenvectors of the covariance matrix C.

The eigenvalues can be retrieved as follows, Eigenvalues = E_v.getRealEigenvalues() and the eigenvectors can then be retrieve as follows, Eigenvectors = E_v.getV().

Eigenvector [V] =

0.327	0.403	-0.063	-0.397	0.43	-0.379	0.109	0.131	-0.174	-0.179	0.12	-0.363	Na
-0.071	0.43	-0.38	0.01	0.406	0.388	-0.408	-0.065	0.123	0.041	0.155	0.369	K
0.155	0.219	0.487	0.109	0.027	0.55	0.202	-0.309	-0.046	0.084	0.359	-0.313	Mg
0.283	0.208	-0.138	0.288	-0.096	0.181	0.25	0.155	0.532	-0.489	-0.332	-0.099	Ca
0.426	-0.564	-0.425	0.145	0.196	0.17	-0.222	-0.15	-0.049	0.061	0.056	-0.384	Sr
-0.039	-0.192	0.067	-0.096	0.105	-0.356	0.039	-0.339	0.657	-0.064	0.494	0.11	MnII
-0.179	0.222	-0.401	-0.373	-0.633	0.104	-0.129	-0.084	0.105	0.034	0.165	-0.376	FeII
-0.728	-0.122	-0.168	0.182	0.328	0.08	0.223	0.077	-0.067	-0.288	0.106	-0.35	Cl
-0.152	-0.077	0.448	-0.241	0.135	0.068	-0.624	0.05	0.265	-0.11	-0.345	-0.305	BO3
-0.066	0.358	-0.038	0.595	-0.005	-0.397	-0.168	-0.189	0.077	0.416	-0.128	-0.302	HCO3
-0.096	-0.022	-0.128	-0.36	0.24	0.133	0.414	-0.323	0.212	0.445	-0.497	-0.028	SO4
-0.016	0.061	-0.028	0.007	-0.065	-0.118	-0.09	-0.751	-0.31	-0.492	-0.228	0.114	PH

Construct an Adjusted Data Matrix from the Brine Data Matrix by subtracting the mean of each column.

Adjusted Data Matrix $[Am] = [\ (X_{ik} - \overline{X}_k)\ ]$

where $\overline{X}_k$ is the mean of brine data column k
X_{ik} is the individual brine data; i=well, k=brine data

Compute the Final Data [F] matrix as the Eigenvector [V] times the transpose of the Adjusted Data $[Am]^T$ matrix,

$$[F] = [V] \text{ X } [Am]^T$$

The Original Data [B] matrix can be found by multiplying the transpose of the Feature Vector $[V]^T$ times the Fine Data [F] matrix plus the Original Mean $[X_o]$ of the "Good" data set,

$$[B] = [V]^T \text{ X } [F] + [X_o].$$

The above equation also works even if a feature vector is constructed from the eigenvectors where not all the eigenvectors are included. If the eigenvector is used on the Adjusted Data Matrix and the Original Mean is added back then the original Brine data matrix should be reproduced. This is the basis of the correction of the above and below data sets.

Above 1	Na	K	Mg	Ca	Sr	MnII	FeII	Cl	BO3	HCO3	SO4	PH
Mean	2,553.143	10.069	216.18	602.593	6.577	0.022	0.249	3,619.948	0.985	0.395	14.232	6.015
Sigma	175.587	1.742	44.944	40.028	9.454	0.006	0.315	218.241	1.134	0.46	3.122	0.295

Good	Na	K	Mg	Ca	Sr	MnII	FeII	Cl	BO3	HCO3	SO4	PH
Mean	2,783.188	9.215	230.545	632.47	10.688	0.029	0.586	3,623.031	1.542	0.842	17.184	5.883
Sigma	169.714	1.28	36.729	44.885	8.355	0.008	0.505	206.226	0.961	0.732	6.028	0.454

Below 1	Na	K	Mg	Ca	Sr	MnII	FeII	Cl	BO3	HCO3	SO4	PH
Mean	2,763.225	9.745	214.965	631.009	11.524	0.04	0.916	3,371.769	2.113	1.311	22.194	5.563
Sigma	172.211	1.076	16.267	30.786	1.331	0.018	0.756	241.447	0.154	0.471	6.459	0.426

The normalization process assumes that the "Good" Data set is correct and that for some reason the measurements Below the 2% of the Anions/Cations ratio of 1.0 has below average values of Chlorides, which could have saturated the measurements results. Above the 2% of Anions/Cations ratio of 1.0 has below average values of Sodium and Calcium. This analysis is not suggesting that the data is in error only that the Brine data for Below and Above data sets will be modified to fit the "Good" Data set mean value.

The "Good" Data eigenvectors and Means will be used to correct the Brine data for the Below and Above data sets. In the same manner as the "Good" brine data set, the Adjusted Data Matrix will be constructed for the Below and Above data sets using their respective means. Then the "Good" eigenvectors and "Good" means will be used to compute the "original" data sets as if the above and below were measured as the original good data, the final equation is used to compute the corrected data sets,

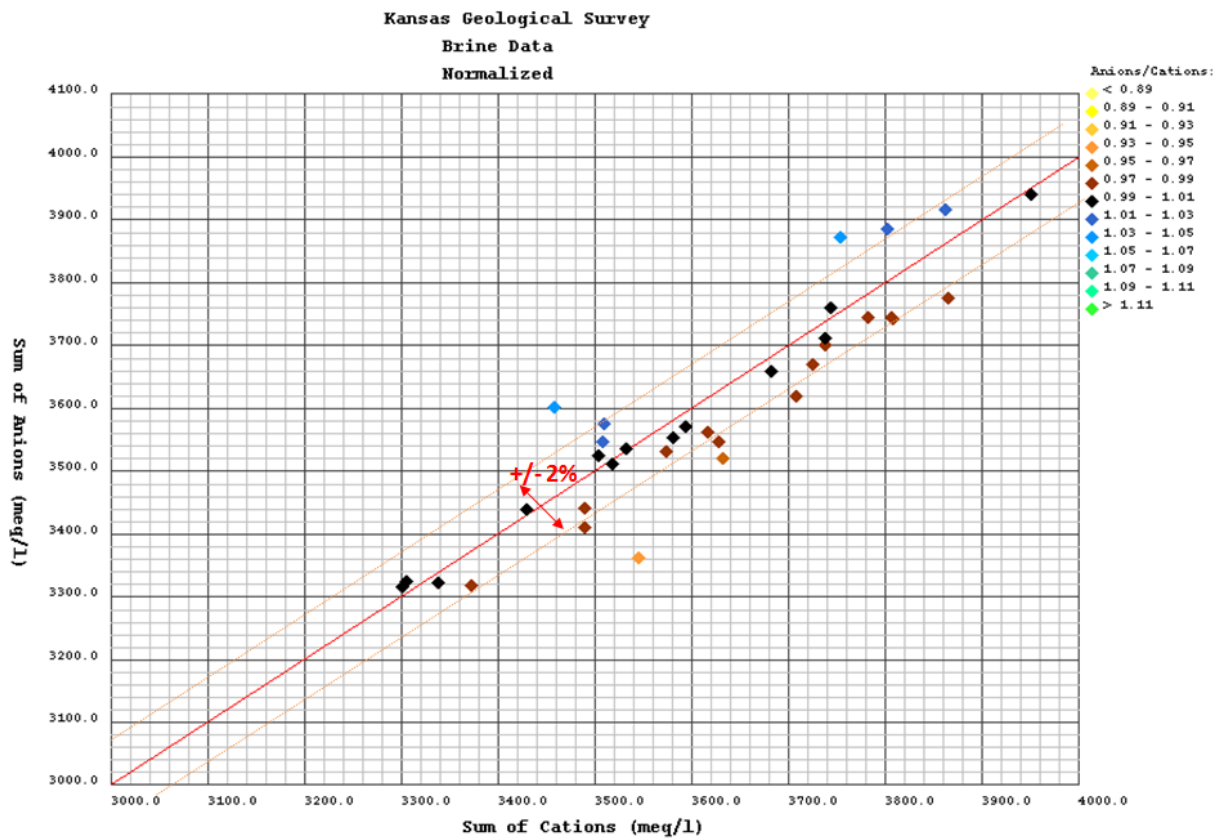$[B] = [Vg]^T X [[Vg] X [Am_R]^T] + [Xg].$

where [Vg] is the eigenvector of the "Good" data set
[Xg] is the "Good" mean matrix
[Am_R] is the Adjusted Data Matrix for either the Below or Above data sets.
[B] is the "new Original" data set of the Below or Above Brine data.

Using the above equation on the Above & Below data sets the data is corrected to the 2% range limit as illustrated below,

Comparison of the Original Brine Data with the Normalized Brine Data

Original Data Set

Sigma * | -3.0 | -2.5 | -2.4 | -2.3 | -2.2 | -2.1 | -2.0 | -1.9 | -1.8 | -1.7 | -1.6 | -1.5
1.5 | 1.6 | 1.7 | 1.8 | 1.9 | 2.0 | 2.1 | 2.2 | 2.3 | 2.4 | 2.5 | 3.0

"Good Brine Data" 0.98 ≥ Cations/Anions ≤ 1.02

"Baker Hughes Data" Cations/Anions < 0.98

"K-State Data" & "Baker Hughes Data" Cations/Anions > 1.02

API-Number	Na	K	Mg	Ca	Sr	MnII	FeII	Cl	BO3	HCO3	SO4	PH
15-191-10107	3074.65	7.49	316.7	586.96	26.59	0.03	1.58	3936.5	1.82	1.89	14.67	5.4
15-191-10087	2827.9	9.12	225.96	663.37	12.16	0.03	0.79	3684.06	2.24	0.89	14.6	5.2
15-191-10076	2701.17	9.97	200.0	608.78	0.0	0.03	0.0	3497.88	0.0	0.0	13.47	5.88
15-191-11442	2657.74	8.95	208.26	604.28	10.78	0.02	0.44	3406.03	1.95	1.89	30.7	5.6
15-191-11442	2806.99	8.52	229.72	687.97	11.78	0.02	0.56	3737.65	2.11	0.59	20.4	6.3
15-191-10078	2496.73	11.89	213.99	578.84	0.0	0.04	0.0	3300.42	0.0	0.0	14.4	5.98
15-191-10078	2832.67	8.86	235.6	693.73	12.22	0.04	0.8	3723.55	2.18	0.89	17.22	6.2
15-191-10134	2867.65	8.92	214.13	635.83	11.97	0.02	0.52	3698.16	2.04	0.59	12.01	6.5
15-191-43882	2871.14	9.13	252.04	621.98	13.88	0.02	0.51	3611.05	1.9	2.09	26.12	6.5
15-191-43882	3091.06	8.35	257.89	659.63	14.99	0.02	0.54	3853.31	2.07	0.59	13.1	6.0
15-191-10092	2694.05	12.97	199.81	638.33	10.57	0.06	3.33	3301.6	2.42	1.49	20.73	5.2
15-191-10093	2617.27	10.06	206.74	611.07	10.47	0.02	0.52	3128.18	1.97	1.99	33.31	5.3
15-191-10093	2980.5	10.55	228.81	683.93	12.45	0.03	0.7	3675.59	2.22	0.59	16.33	5.9
15-191-10087	2814.38	10.01	210.33	625.69	12.54	0.03	0.84	3352.77	2.1	1.19	17.65	5.2
15-191-10076	2817.72	9.58	214.08	637.74	11.51	0.03	0.72	3402.82	2.21	1.39	17.23	5.3
15-191-10078	2520.36	10.5	205.18	590.15	10.09	0.06	1.88	3039.26	2.31	1.99	29.77	5.2
15-191-10096	2565.14	11.1	198.32	610.84	10.34	0.03	0.26	3165.69	1.97	1.19	24.46	5.6
15-191-10096	2839.07	10.24	207.3	651.18	11.45	0.04	0.6	3607.89	2.11	0.59	16.41	6.2
15-191-10134	2691.93	9.24	209.56	624.63	11.01	0.03	0.5	3279.49	1.99	1.79	25.6	5.2
15-191-10083-0002	2468.41	10.34	201.58	579.92	9.86	0.06	1.49	3041.41	2.27	1.19	34.56	5.2
15-191-10136	2729.22	9.06	214.23	618.41	10.87	0.03	0.46	3291.22	1.99	1.49	22.69	6.1
15-191-10077	2700.01	9.25	202.95	615.79	10.66	0.07	1.23	3253.9	1.91	1.69	28.73	5.6
15-191-10077	3067.23	9.01	223.66	701.72	12.49	0.08	1.86	3664.31	2.25	0.89	13.19	5.9
15-191-19005	2662.57	9.09	209.08	606.36	11.02	0.04	0.44	3263.1	2.01	1.49	23.94	5.0
15-191-19005	2779.31	9.16	212.09	636.14	11.64	0.04	0.51	3393.11	2.14	1.19	16.28	5.3
15-191-19005	2917.9	8.6	223.44	665.96	12.44	0.04	0.58	3650.21	2.32	0.89	17.55	5.7
15-191-00395-0001	2674.01	8.92	207.25	609.7	10.68	0.03	0.43	3088.71	1.99	1.19	24.04	5.3
15-191-43882	2648.97	9.71	239.5	633.73	0.0	0.02	0.0	3723.55	0.0	0.0	11.86	5.75
15-191-10107	2931.62	7.19	343.62	672.01	30.49	0.01	0.75	4152.32	2.33	0.79	8.37	5.9
15-191-10092	2523.74	11.29	190.76	619.32	9.7	0.02	0.26	3495.06	2.19	0.79	14.59	5.8
15-191-10087	2561.98	12.22	198.35	578.84	0.0	0.03	0.0	3526.09	0.0	0.0	13.2	5.87
15-191-10076	2646.4	8.01	216.8	646.7	10.95	0.03	0.67	3717.91	2.07	0.99	15.7	6.3
15-191-11442	2435.84	10.99	195.06	588.82	0.0	0.02	0.0	3526.09	0.0	0.0	13.51	5.73
15-191-10134	2453.24	11.09	195.06	573.85	0.0	0.02	0.0	3554.3	0.0	0.0	13.47	5.81
15-191-10083-0002	2322.74	12.22	187.65	538.92	0.0	0.02	0.0	3300.42	0.0	0.0	14.19	6.31
15-191-10083-0002	2411.67	9.05	201.16	594.78	9.89	0.02	0.66	3495.06	2.24	0.79	20.15	6.5
15-191-10136	2418.44	10.79	193.41	558.88	0.0	0.03	0.0	3582.51	0.0	0.0	13.17	5.8
15-191-10136	2729.93	8.2	216.61	622.67	11.32	0.02	0.4	3746.12	2.0	0.99	18.34	6.4

	Na	K	Mg	Ca	Sr	MnII	FeII	Cl	BO3	HCO3	SO4	PH
Mean	2,706.614	9.727	218.597	623.091	9.916	0.032	0.653	3,496.508	1.666	0.947	18.834	5.761
Sigma	195.257	1.336	31.133	38.097	6.557	0.015	0.662	255.462	0.882	0.654	6.518	0.44

Covariance Matrix – Original Data Set

	Na	K	Mg	Ca	Sr	MnII	FeII	Cl	BO3	HCO3	SO4	PH
Na	1.0	-0.615	0.654	0.766	0.7	0.093	0.311	0.566	0.528	0.275	-0.219	0.035
K	-0.615	1.0	-0.634	-0.489	-0.687	0.168	-0.007	-0.503	-0.495	-0.351	0.006	-0.143
Mg	0.654	-0.634	1.0	0.389	0.763	-0.222	0.163	0.691	0.254	0.17	-0.29	0.088
Ca	0.766	-0.489	0.389	1.0	0.511	0.13	0.277	0.492	0.594	0.114	-0.194	0.133
Sr	0.7	-0.687	0.763	0.511	1.0	0.001	0.451	0.387	0.779	0.59	0.082	-0.092
MnII	0.093	0.168	-0.222	0.13	0.001	1.0	0.67	-0.384	0.247	0.262	0.304	-0.359
FeII	0.311	-0.007	0.163	0.277	0.451	0.67	1.0	-0.108	0.569	0.518	0.28	-0.341
Cl	0.566	-0.503	0.691	0.492	0.387	-0.384	-0.108	1.0	0.001	-0.331	-0.711	0.501
BO3	0.528	-0.495	0.254	0.594	0.779	0.247	0.569	0.001	1.0	0.708	0.393	-0.168
HCO3	0.275	-0.351	0.17	0.114	0.59	0.262	0.518	-0.331	0.708	0.999	0.731	-0.414
SO4	-0.219	0.006	-0.29	-0.194	0.082	0.304	0.28	-0.711	0.393	0.731	1.0	-0.378
PH	0.035	-0.143	0.088	0.133	-0.092	-0.359	-0.341	0.501	-0.168	-0.414	-0.378	1.0

- 0.30 – -0.40
- 0.40 – -0.65
- 0.65 – -0.99
1.00 (0.999)
0.80 – 0.99
0.65 – 0.80
0.30 – 0.65

Kansas Geological Survey
Brine Data
Original Data

Kansas Geological Survey
Principal Components Crossplot
Original Data

Pc₁	Pc₂	
-0.399	-0.101	Na
0.354	0.117	K
-0.344	-0.205	Mg
-0.341	-0.092	Ca
-0.429	0.037	Sr
-0.045	0.339	MnII
-0.222	0.313	FeII
-0.23	-0.433	Cl
-0.361	0.233	BO3
-0.245	0.38	HCO3
-0.004	0.447	SO4
0.01	-0.35	PH

Feature Vector [V] =

The Principal Component Scores Matrix [PC Scores] are gray diamonds.

The Feature Vector is represented as colored lines around a red unit circle, where each Feature Vector row is normalized to unit circle.
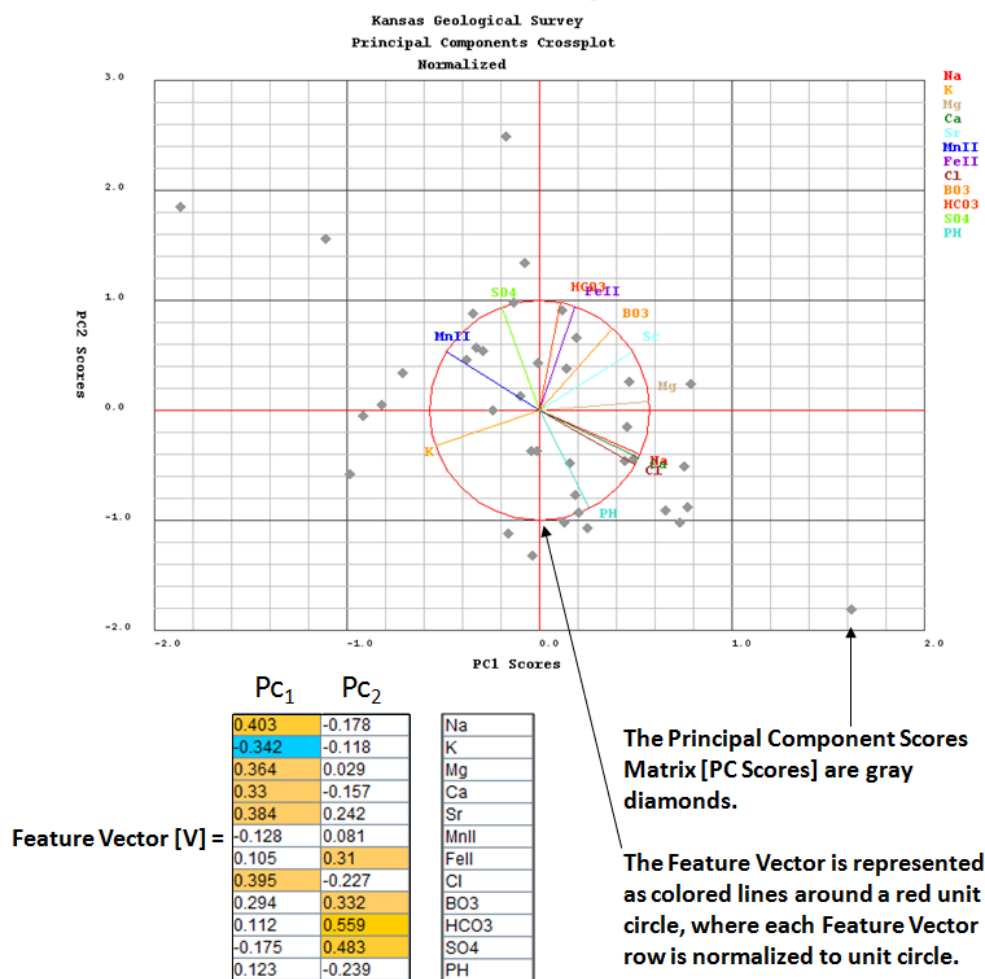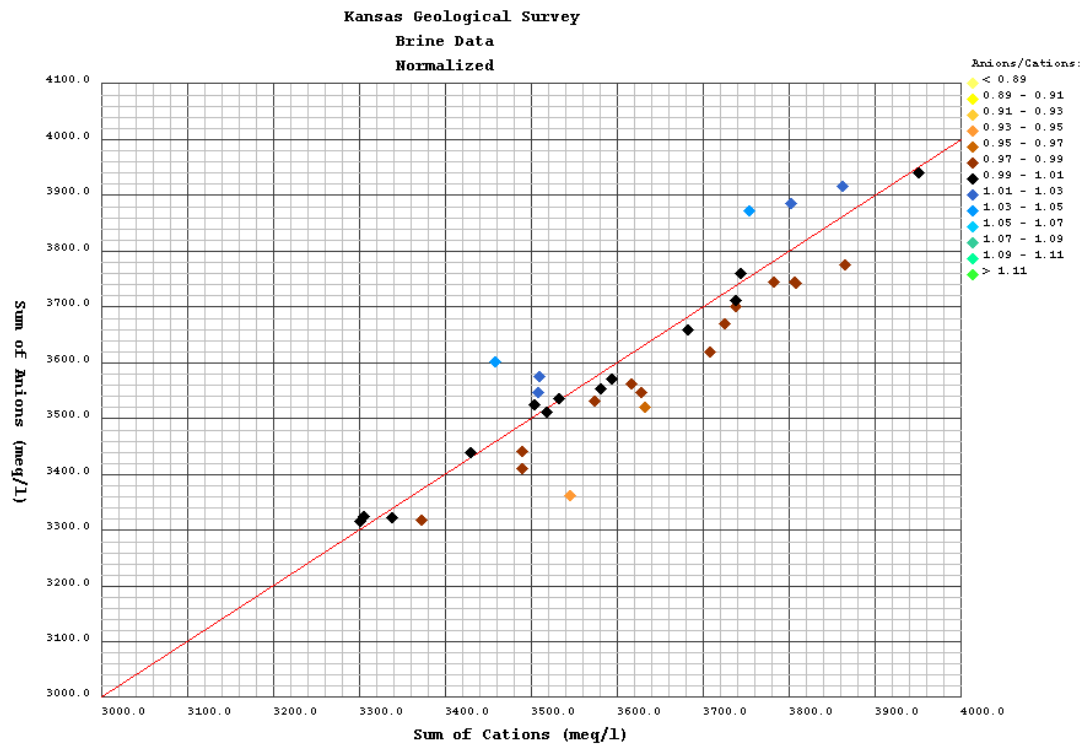
Normalized Data Set

Sigma *	-3.0	-2.5	-2.4	-2.3	-2.2	-2.1	-2.0	-1.9	-1.8	-1.7	-1.6	-1.5
	1.5	1.6	1.7	1.8	1.9	2.0	2.1	2.2	2.3	2.4	2.5	3.0

"Good Brine Data" 0.98 ≥ Cations/Anions ≤ 1.02

"Baker Hughes Data" Cations/Anions < 0.98

"K-State Data" & "Baker Hughes Data" Cations/Anions > 1.02

API-Number	Na	K	Mg	Ca	Sr	MnII	FeII	Cl	BO3	HCO3	SO4	PH
15-191-10107	3074.65	7.49	316.69	586.96	26.58	0.02	1.57	3936.5	1.82	1.89	14.67	5.39
15-191-10087	2827.9	9.12	225.96	663.37	12.16	0.02	0.79	3684.06	2.24	0.89	14.6	5.19
15-191-10076	2701.17	9.96	200.0	608.78	0.0	0.03	0.0	3497.88	0.0	0.0	13.46	5.88
15-191-11442	2657.74	8.94	208.26	604.28	10.77	0.02	0.44	3406.03	1.94	1.88	30.7	5.6
15-191-11442	2806.99	8.51	229.72	687.97	11.78	0.01	0.55	3737.65	2.11	0.59	20.39	6.29
15-191-10078	2496.73	11.88	213.99	578.84	0.0	0.04	0.0	3300.42	0.0	0.0	14.39	5.98
15-191-10078	2832.67	8.86	235.6	693.73	12.22	0.03	0.79	3723.55	2.17	0.89	17.21	6.19
15-191-10134	2867.65	8.92	214.13	635.83	11.97	0.01	0.52	3698.16	2.03	0.59	12.01	6.49
15-191-43882	2891.1	8.59	267.61	623.44	13.04	0.0	0.18	3862.31	1.32	1.62	21.1	6.81
15-191-43882	3111.02	7.81	273.46	661.09	14.15	0.0	0.21	4104.57	1.49	0.12	8.08	6.31
15-191-10092	2714.01	12.43	215.38	639.79	9.73	0.04	3.0	3552.86	1.84	1.02	15.71	5.51
15-191-10093	2637.23	9.52	222.31	612.53	9.63	0.0	0.19	3379.44	1.39	1.52	28.29	5.61
15-191-10093	3000.46	10.01	244.38	685.39	11.61	0.01	0.37	3926.85	1.64	0.12	11.31	6.21
15-191-10087	2834.34	9.47	225.9	627.15	11.7	0.01	0.51	3604.03	1.52	0.72	12.63	5.51
15-191-10076	2837.68	9.04	229.65	639.2	10.67	0.01	0.39	3654.08	1.63	0.92	12.21	5.61
15-191-10078	2540.32	9.47	220.75	591.61	9.25	0.04	1.55	3290.52	1.73	1.52	24.75	5.51
15-191-10096	2585.1	10.56	213.89	612.3	9.5	0.01	-0.06	3416.95	1.39	0.72	19.44	5.91
15-191-10096	2859.03	9.7	222.87	652.64	10.61	0.02	0.27	3859.15	1.53	0.12	11.39	6.51
15-191-10134	2711.89	8.7	225.13	626.09	10.17	0.01	0.17	3530.75	1.41	1.32	20.58	5.51
15-191-10083-0002	2488.37	9.8	217.15	581.38	9.02	0.04	1.16	3292.67	1.69	0.72	29.54	5.51
15-191-10136	2749.18	8.52	229.8	619.87	10.03	0.01	0.13	3542.48	1.41	1.02	17.67	6.41
15-191-10077	2719.97	8.71	218.52	617.25	9.82	0.05	0.9	3505.16	1.33	1.22	23.71	5.91
15-191-10077	3087.19	8.47	239.23	703.18	11.65	0.06	1.53	3915.57	1.67	0.42	8.17	6.21
15-191-19005	2682.53	8.55	224.65	607.82	10.18	0.02	0.11	3514.36	1.43	1.02	18.92	5.31
15-191-19005	2799.27	8.62	227.66	637.6	10.8	0.02	0.18	3644.37	1.56	0.72	11.26	5.61
15-191-19005	2937.86	8.06	239.01	667.42	11.6	0.02	0.25	3901.47	1.74	0.42	12.53	6.01
15-191-00395-0001	2693.97	8.38	222.82	611.16	9.84	0.01	0.1	3339.97	1.41	0.72	19.02	5.61
15-191-43882	2879.01	8.85	253.86	663.6	4.11	0.02	0.33	3726.63	0.55	0.44	14.81	5.61
15-191-10107	3161.66	6.33	357.98	701.88	34.6	0.01	1.08	4155.4	2.88	1.23	11.32	5.76
15-191-10092	2753.78	10.43	205.12	649.19	13.81	0.02	0.59	3498.14	2.74	1.23	17.54	5.66
15-191-10087	2792.02	11.36	212.71	608.71	4.11	0.03	0.33	3529.17	0.55	0.44	16.15	5.73
15-191-10076	2876.44	7.15	231.16	676.57	15.06	0.03	1.0	3720.99	2.62	1.43	18.65	6.16
15-191-11442	2665.88	10.13	209.42	618.69	4.11	0.02	0.33	3529.17	0.55	0.44	16.46	5.59
15-191-10134	2683.28	10.23	209.42	603.72	4.11	0.02	0.33	3557.38	0.55	0.44	16.42	5.67
15-191-10083-0002	2552.78	11.36	202.01	568.79	4.11	0.02	0.33	3303.5	0.55	0.44	17.14	6.17
15-191-10083-0002	2641.71	8.19	215.52	624.65	14.0	0.02	0.99	3498.14	2.79	1.23	23.1	6.36
15-191-10136	2648.48	9.93	207.77	588.75	4.11	0.03	0.33	3585.59	0.55	0.44	16.12	5.66
15-191-10136	2959.97	7.34	230.97	652.54	15.43	0.02	0.73	3749.2	2.55	1.43	21.29	6.26

	Na	K	Mg	Ca	Sr	MnII	FeII	Cl	BO3	HCO3	SO4	PH
Mean	2,783.185	9.207	230.538	632.467	10.685	0.021	0.583	3,623.029	1.535	0.839	17.177	5.874
Sigma	167.957	1.301	30.493	35.711	6.182	0.014	0.593	221.99	0.73	0.515	5.46	0.388

Covariance Matrix – Normalized Data Set

	Na	K	Mg	Ca	Sr	MnII	FeII	Cl	BO3	HCO3	SO4	PH
Na	1.0	-0.626	0.737	0.73	0.659	-0.216	0.151	0.95	0.398	0.014	-0.61	0.28
K	-0.626	1.0	-0.624	-0.47	-0.697	0.281	0.034	-0.585	-0.56	-0.396	0.043	-0.186
Mg	0.737	-0.624	0.999	0.402	0.819	-0.267	0.205	0.743	0.343	0.256	-0.31	0.058
Ca	0.73	-0.47	0.402	1.0	0.449	-0.082	0.169	0.731	0.546	-0.096	-0.444	0.311
Sr	0.659	-0.697	0.819	0.449	1.0	-0.261	0.367	0.622	0.771	0.533	-0.104	0.05
MnII	-0.216	0.281	-0.267	-0.082	-0.261	0.999	0.52	-0.241	-0.133	-0.107	0.051	-0.157
FeII	0.151	0.034	0.205	0.169	0.367	0.52	0.999	0.113	0.434	0.35	0.055	-0.177
Cl	0.95	-0.585	0.743	0.731	0.622	-0.241	0.113	1.0	0.353	-0.078	-0.623	0.357
BO3	0.398	-0.56	0.343	0.546	0.771	-0.133	0.434	0.353	0.999	0.557	0.128	0.12
HCO3	0.014	-0.396	0.256	-0.096	0.533	-0.107	0.35	-0.078	0.557	0.999	0.602	-0.188
SO4	-0.61	0.043	-0.31	-0.444	-0.104	0.051	0.055	-0.623	0.128	0.602	1.0	-0.164
PH	0.28	-0.186	0.058	0.311	0.05	-0.157	-0.177	0.357	0.12	-0.188	-0.164	0.999

Legend:
- -0.30 – -0.40
- -0.40 – -0.65
- -0.65 – -0.99
- 1.00 (0.999)
- 0.80 – 0.99
- 0.65 – 0.80
- 0.30 – 0.65

Kansas Geological Survey
Brine Data
Normalized

Anions/Cations:
< 0.89
0.89 - 0.91
0.91 - 0.93
0.93 - 0.95
0.95 - 0.97
0.97 - 0.99
0.99 - 1.01
1.01 - 1.03
1.03 - 1.05
1.05 - 1.07
1.07 - 1.09
1.09 - 1.11
> 1.11

Kansas Geological Survey
Principal Components Crossplot
Normalized

Na
K
Mg
Ca
Sr
MnII
FeII
Cl
BO3
HCO3
SO4
PH

	Pc₁	Pc₂		
Feature Vector [V] =	0.403	-0.178	Na	
	-0.342	-0.118	K	
	0.364	0.029	Mg	
	0.33	-0.157	Ca	
	0.384	0.242	Sr	
	-0.128	0.081	MnII	
	0.105	0.31	FeII	
	0.395	-0.227	Cl	
	0.294	0.332	BO3	
	0.112	0.559	HCO3	
	-0.175	0.483	SO4	
	0.123	-0.239	PH	

The Principal Component Scores Matrix [PC Scores] are gray diamonds.

The Feature Vector is represented as colored lines around a red unit circle, where each Feature Vector row is normalized to unit circle.

18

Map Brine Data Frame

The "Map Brine Data" Frame is basically the Gridding & Mapping Control Panel. The frame has 2 sections the upper or check boxes of possible brine data types that were analyzed for the well group. The check boxes are grouped in 3 separate panels, "Other Brine Data Types, Cations, and Anions. There are 3 check boxes for each brine data type, R-Red, G-Green and B-Blue. The user will note next to each Curve row is a set of labels **X**, **?**, or a **G**, as indicators on the number of samples within each of the curves. If the curve you are selecting has data for all rows then you will see the Green **G** for good data curve, if you have 20% to 99% of the curve rows filled you will see an Orange **?** for questionable curve data, and if you have from 0 to 19% of the curve rows filled you will see a Red **X** for bad curve "do not select". The program is designed to allow the user to select up to 3 brine data curves and to map each curve with a primary color to form a "Colorlith" of the brine data on the Gridding & Mapping Well Map Plot.

As the user selects each brine data curve for plotting the program computes a statistical analysis of the data, i.e. computing the Minimum, Maximum, Mean, Median, etc. of the brine data curve in the second section. The data is presented so the user knows the spread of the data. The program automatically selects the 5% and 95% for the minimum and maximum plot values and places them in the text fields at the bottom of the panel for the color selected. The user can change the values, which will change the color of the Gridding & Mapping Plot Area.

Example: Magnesium, Calcium Cations and Sulfate Anion Brine Data Well Map:

Starting with the upper panels this example will generate a Gridding & Mapping Brine Data Well Map for the Magnesium, Calcium Cations and Sulfate Anion.

Select the R (Red) Check box in the Magnesium Curve Row. This action will perform a number of steps,

1. All other check boxes under the R (Red) column are disabled.
2. The Magnesium data spread is computed and inserted in the statistics table.

The user can then select the G (Green) Check box in the Calcium Curve Row and then the B (Blue) Check box in the Sulfate Curve Row as illustrated below.

The data has been entered and the user only needs to select the "Plot Map" button, which will display the Gridding & Mapping Brine Data Well Map. The user will also notice that the "Create Report" Button will then be enabled. The user can generate a Output Web Page for this data selection if they wish. The user can also modify the Colorlith minimum and maximum limits for each color, which will automatically be reflected in the plot.

The color map reflects the brine chemistry for the Magnesium-Calcium Cations and Sulfate Anion. The Colorlith Red-Green-Blue color mix is controlled by the minimum and maximum displayed in the lower panel of the "Map Brine Data" Frame. The Brine Data Well Map will have dark and light colors, dark being the maximum of the color mix or maximums of the Mg-Ca-SO4 data values and light the minimum of the color mix or minimums of the Mg-Ca-SO4 data. Each Red, Green and Blue Color goes from 0 – Maximum Brine Data Value to 255 – Minimum Brine Data Value. The value of the specific curve set the value of the color, i.e.

Color Value = 255 – [255 * (brine data value – Minimum) / (Maximum – Minimum)]

This is done for each curve for each cell and the cell is then painted to the color of the Red-Green-Blue color values. If all the colors are set to 0 then the grid cell is black and this indicates that the maximum value for all the selected curves was used. If all the colors are set to 255 then the grid cell is white and this indicates that the minimum value for all the selected curves was used. If the brine data was proportional between the wells, i.e. they brine data changes by a factor "A" then you would expect the color to be grays. The brine data is not necessarily proportional, in that the concentration of Calcium, Magnesium and Sulfate is the same by only a factor of "A" for each well. This gives the color of the map. The Sulfate will be at a maximum for some wells and a minimum for others and the same for the Calcium and Magnesium will vary across the well area.
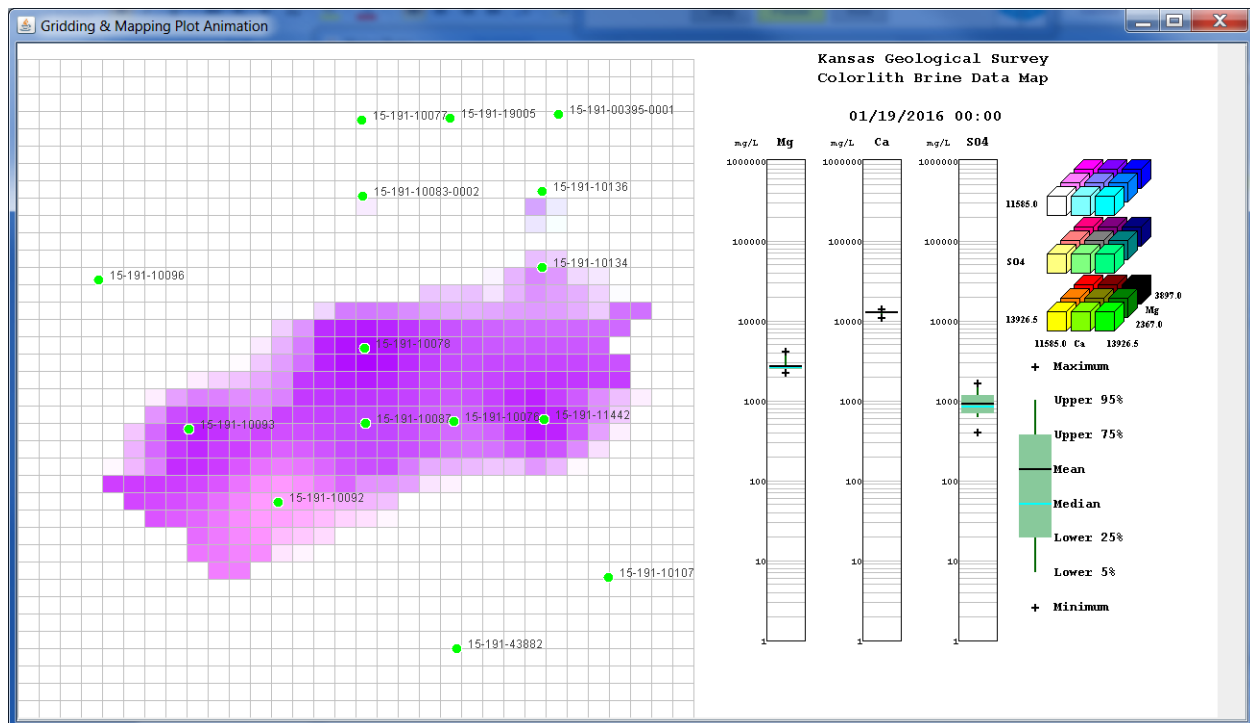
The plot icon button will only enable when the user has selected the 3 curves for plotting and will show the brine gridding & mapping map for the first sampled data. The Animation Control Dialog will appear at the top of the screen.

Animation Control Dialog

To start the animation select the "Run" Button, which will turn yellow and each Wellington field brine data sampled date will appear with the date & time appearing in the 4th title on each plot. Select the "Pause" Button, which will turn yellow and pause the animation at the event. Select the "Run" Button to resume the animation. Select the "Stop" Button, which will turn yellow and reset to the first sampled date.
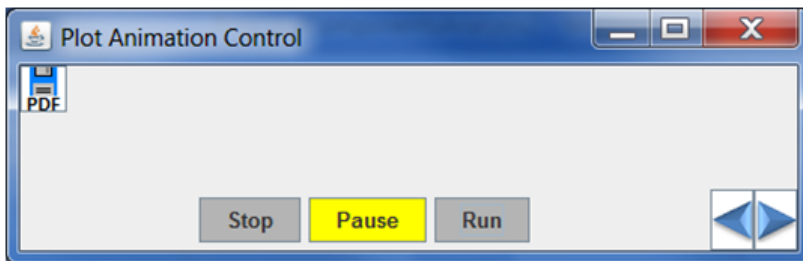
PDF – capture a specific time event and make PNG images with the capability of converting each image into a PDF document.

Stop animation – stop animation and reset to beginning event.

Pause animation – stop animation at event.

Run animation – steps through each event at 1 second intervals.

Previous – steps back one event.

Next – steps forward one event.