PiperStiff–An Excel workbook for charting a Piper plot and mapping Stiff diagrams

Piper and Stiff diagrams are plotted and mapped, respectively from water-quality concentrations in milligrams per liter (mg/L). The program converts mg/L to milliequivalents per liter (meq/L). Concentration of major ions are summed for total dissolved solids (TDS) and charge balances are computed. Sites are highlighted if charge balances exceed a user-specified threshold. Constituent concentrations and TDS from a site can be selected and highlighted in the Piper plot (Figure 1). A Stiff diagram is displayed for the selected site.

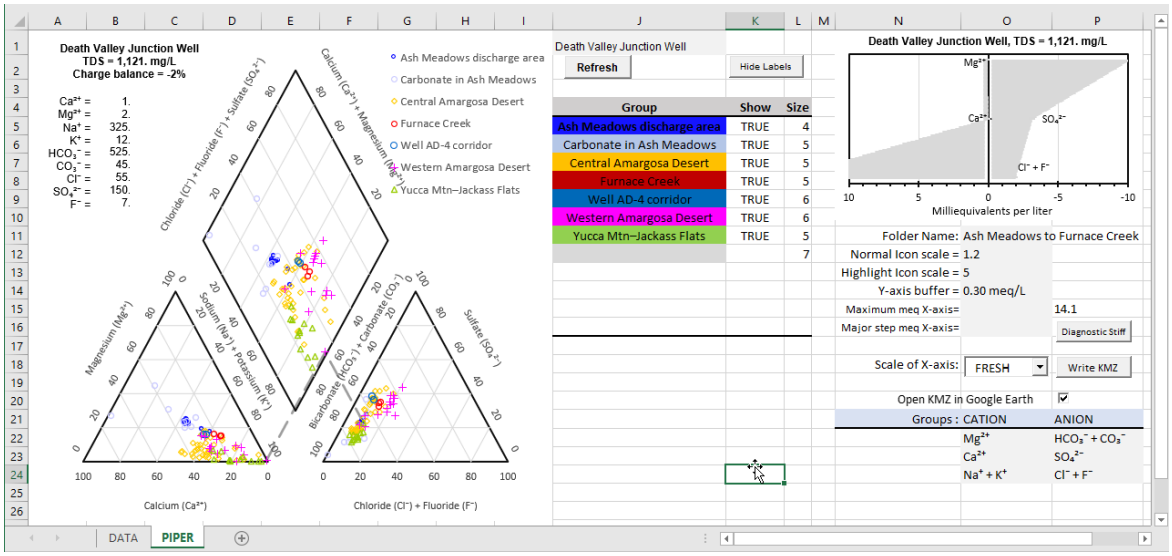


Figure 1.— Piper plot, Stiff diagram, and controls in PiperStiff-QW-2019.xlsm.

Stiff diagrams are written to a KMZ (Google Earth) file where groups of sites can be viewed or hidden (Figure 2). Stiff icon changes to labeled Stiff diagram with site identifier as mouse hovers over an icon. TDS and constituent concentrations in mg/L are displayed as a table after selecting a site.

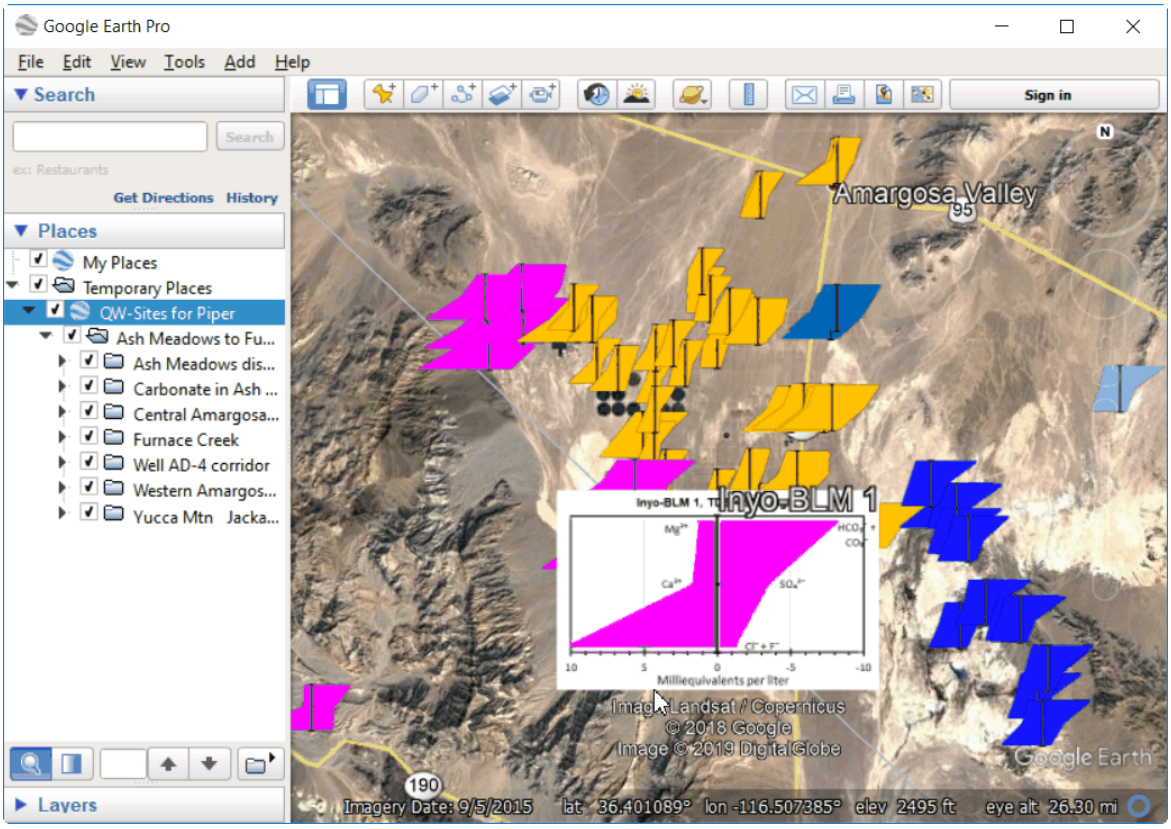
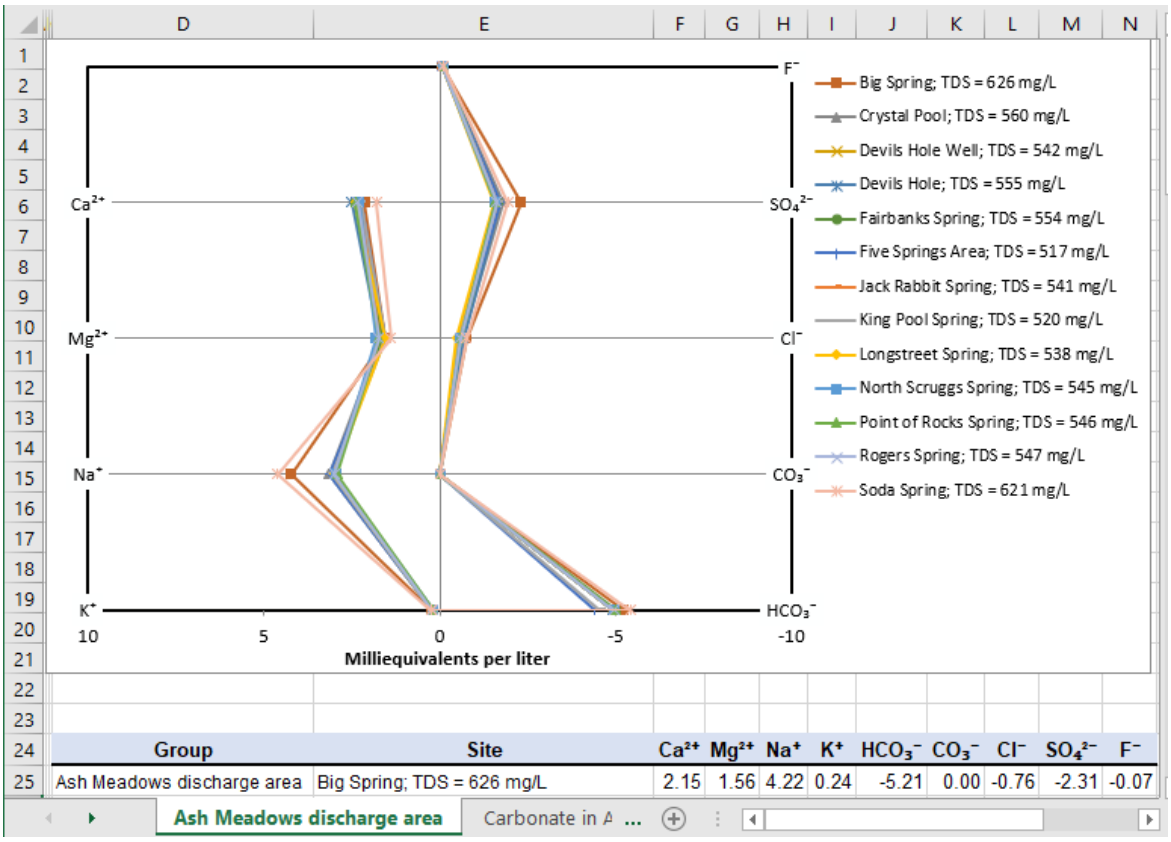


Figure 2.— Stiff diagrams as presented in Google Earth.

Diagnostic Stiff diagrams also can be created in a new workbook, where each site in a group is diagrammed in a single plot (Figure 3). A page is created for each group of sites with an open Stiff diagram of individual ions for each site. Milliequivalents of anions are plotted as negative values in Cartesian plots and are inverted on log plots.



Group	Site	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	HCO_3^{-}	CO_3^{-}	Cl^{-}	SO_4^{2-}	F^{-}
Ash Meadows discharge area	Big Spring; TDS = 626 mg/L	2.15	1.56	4.22	0.24	-5.21	0.00	-0.76	-2.31	-0.07

Figure 3.—Diagnostic Stiff diagrams for groups of sites that are created in a new workbook.

PiperStiff-QW-2019.xlsm and explanatory PDF can be downloaded with the following link. Site locations, names, and analyte concentrations should be arranged in separate workbook and pasted special as values on the DATA page (see Data Entry).

Macros were developed in Excel 2019 and should work in Excel 2013+. Labels have failed when revised by macros in Excel 2010.

Revisions

October 28, 2019—Revisions in version 2 include the following. Sites can be labeled with numbers rather than just text. Specified minimum and maximum values of milliequivalents per liter in Stiff chart are transferred to minimum and maximum values in Stiff icons that are displayed in Google Earth.

November 25, 2019—Revisions in version 3 include the following. Site names are checked for uniqueness. Non-unique site names are made unique by appending occurrence number to repeated site names. For example, sites MW-A, MW-A, and MW-A will be changed to sites MW-A, MW-A2, and MW-A3.

January 19, 2020—Revisions in version 4 include the following. Macro for writing KMZ was revised so CONTROL sheet with icon chart is activated and refreshed prior to writing images to graphic files. Stiff images sometimes did not appear or appeared as X's prior to this bug fix.

April 9, 2020—Revisions in version 5 include the following. Macro for writing KMZ was revised so sites can be identified with numerical values such as dates. Site identifiers appear as decimal days from 1/1/1900 if a user insists on using dates as a site name. Percentage calculations in columns AL:AQ on the hidden CONTROL page were revised to treat empty cells as 0 for unspecified chemical concentrations. Both revisions are less bug fixes than enabling less than ideal usage of the workbook.

July 29, 2020—Revisions in version 6 include the following. CONTROL page is left visible so KMZ macro momentarily can activate page prior to writing STIFF images from chart in range BT1:BV2. Stiff images previously sometimes did not appear or appeared as X's prior to this bug fix. Manually activate the CONTROL page and return to the PIPER page if this error occurs.

January 1, 2021—Revisions in version 7 include the following. Macro for writing KMZ was revised so decimal delimiters in longitude and latitude are written with periods (.) regardless of regional settings in Excel. Thanks to Casper Zoete for identifying and fixing this bug. Functions for plotting Stiff diagrams on a log scale of the X-axis and creating diagnostic Stiff diagrams in a new workbook were added.

May 1, 2021—Revisions in version 8 include the following. Minor correction so that empty columns do not cause diagnostic Stiff macro to fail. Added discussion about entering data as values in a block rather than dragging cells all over the data page.

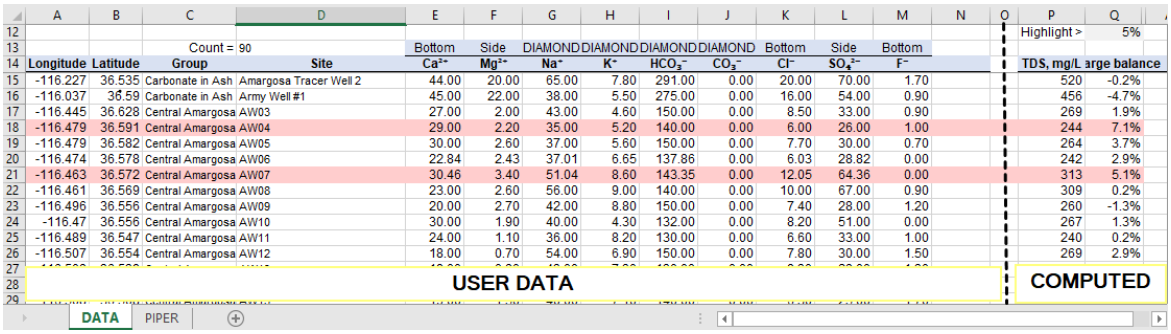
May 4, 2021—Revisions in version 9 include the following. Macro for writing KMZ was revised so decimal delimiters in icon scales and geochemical summaries are written with periods (.) regardless of regional settings in Excel. Thanks to Eduardo Díaz Jiménez for identifying and fixing this bug.

PiperStiff-QW-2019.xlsm Workbook

The workbook consists of two visible pages, DATA and PIPER, and one hidden page, CONTROL. The hidden CONTROL page contains code for translating coordinates and users should not need to edit the page. The table for converting mg/L to meq/L is the exception if a constituent exists other than Bicarbonate (HCO_3^-), Calcium (Ca^{2+}), Carbonate (CO_3^-), Chloride (Cl^-), Fluoride (F^-), Magnesium (Mg^{2+}), Potassium (K^+), Sodium (Na^+), and Sulfate (SO_4^{2-}).

DATA page

Longitude, latitude, data group, site name, and chemical concentrations are specified for each site in columns A-N and from row 15 and down (Figure 4). Longitude and latitude are optional, but KMZ file will not be written without a longitude and latitude for all sites. Groups define series in Piper plot (Figure 1) and Stiff icons of similar color in KMZ file (Figure 2). Columns of chemical concentrations can be ordered to suit user's data sets by changing headings in rows 13 and 14 through pull-down menus. Rows of site data are highlighted where charge balance exceeds a user-defined threshold, cell Q12, which is 5 percent in the example (Figure 4).

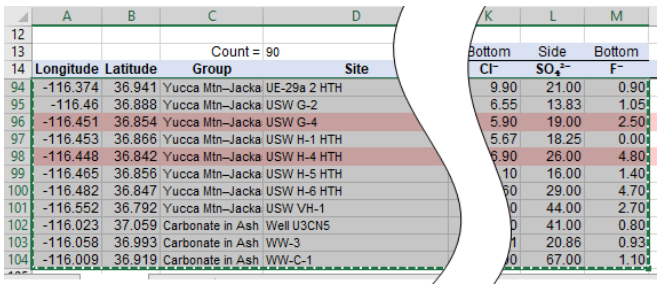


	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
12																Highlight >	5%
13			Count =	90	Bottom	Side	DIAMOND	DIAMOND	DIAMOND	DIAMOND	Bottom	Side	Bottom				
14	Longitude	Latitude	Group	Site	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	HCO_3^{-}	CO_3^{-}	Cl^{-}	SO_4^{2-}	F^{-}			TDS, mg/L	arge balance
15	-116.227	36.535	Carbonate in Ash	Amargosa Tracer Well 2	44.00	20.00	65.00	7.80	291.00	0.00	20.00	70.00	1.70			520	-0.2%
16	-116.037	36.59	Carbonate in Ash	Army Well #1	45.00	22.00	38.00	5.50	275.00	0.00	16.00	54.00	0.90			456	-4.7%
17	-116.445	36.628	Central Amargosa	AW03	27.00	2.00	43.00	4.60	150.00	0.00	8.50	33.00	0.90			269	1.9%
18	-116.479	36.591	Central Amargosa	AW04	29.00	2.20	35.00	5.20	140.00	0.00	6.00	26.00	1.00			244	7.1%
19	-116.479	36.582	Central Amargosa	AW05	30.00	2.60	37.00	5.60	150.00	0.00	7.70	30.00	0.70			264	3.7%
20	-116.474	36.578	Central Amargosa	AW06	22.84	2.43	37.01	6.65	137.86	0.00	6.03	28.82	0.00			242	2.9%
21	-116.463	36.572	Central Amargosa	AW07	30.46	3.40	51.04	8.60	143.35	0.00	12.05	64.36	0.00			313	5.1%
22	-116.461	36.569	Central Amargosa	AW08	23.00	2.60	56.00	9.00	140.00	0.00	10.00	67.00	0.90			309	0.2%
23	-116.496	36.556	Central Amargosa	AW09	20.00	2.70	42.00	8.80	150.00	0.00	7.40	28.00	1.20			260	-1.3%
24	-116.47	36.556	Central Amargosa	AW10	30.00	1.90	40.00	4.30	132.00	0.00	8.20	51.00	0.00			267	1.3%
25	-116.489	36.547	Central Amargosa	AW11	24.00	1.10	36.00	8.20	130.00	0.00	6.60	33.00	1.00			240	0.2%
26	-116.507	36.554	Central Amargosa	AW12	18.00	0.70	54.00	6.90	150.00	0.00	7.80	30.00	1.50			269	2.9%
27																	
28					USER DATA											COMPUTED	

Figure 4.—DATA page in the PiperStiff-QW-2019 workbook where longitude, latitude, data group, site name, and chemical concentrations are specified for each site.

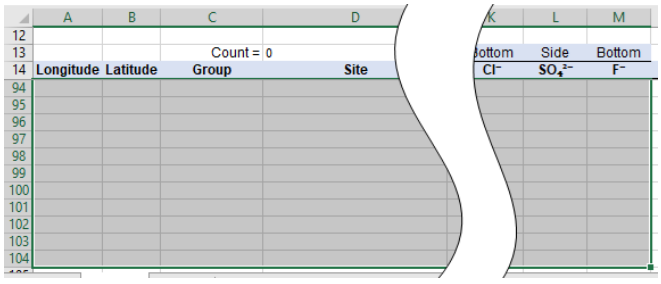
Data Page

Clear existing data between columns A and M and from row 15 to the last entry.

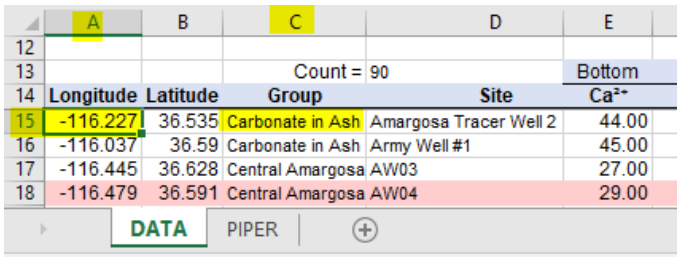
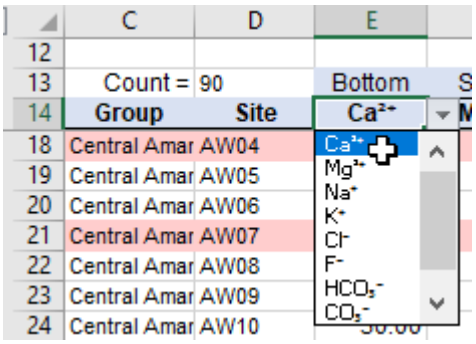
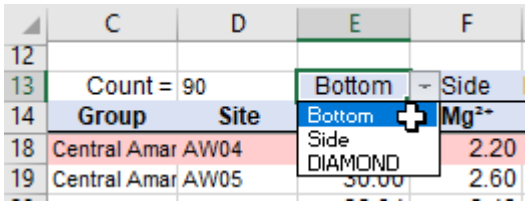
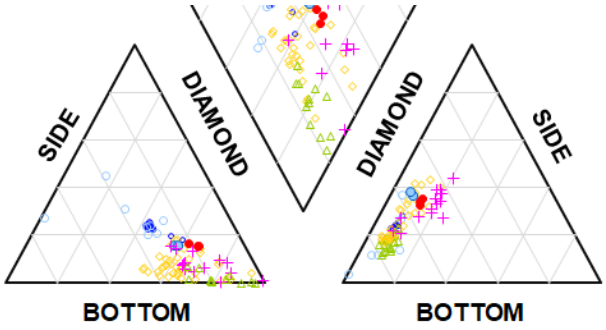
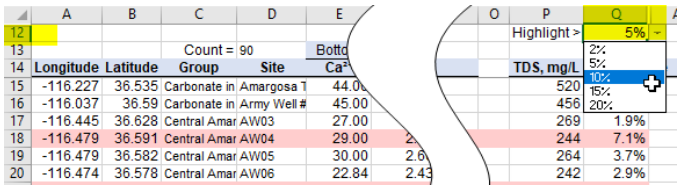


	A	B	C	D	K	L	M
12							
13			Count =	90	Bottom	Side	Bottom
14	Longitude	Latitude	Group	Site	Cl^{-}	SO_4^{2-}	F^{-}
94	-116.374	36.941	Yucca Mtn–Jacka	UE-29a 2 HTH	9.90	21.00	0.90
95	-116.46	36.888	Yucca Mtn–Jacka	USW G-2	6.55	13.83	1.05
96	-116.451	36.854	Yucca Mtn–Jacka	USW G-4	5.90	19.00	2.50
97	-116.453	36.866	Yucca Mtn–Jacka	USW H-1 HTH	5.67	18.25	0.00
98	-116.448	36.842	Yucca Mtn–Jacka	USW H-4 HTH	6.90	26.00	4.80
99	-116.465	36.856	Yucca Mtn–Jacka	USW H-5 HTH	.10	16.00	1.40
100	-116.482	36.847	Yucca Mtn–Jacka	USW H-6 HTH	60	29.00	4.70
101	-116.552	36.792	Yucca Mtn–Jacka	USW VH-1	0	44.00	2.70
102	-116.023	37.059	Carbonate in Ash	Well U3CN5	0	41.00	0.80
103	-116.058	36.993	Carbonate in Ash	WW-3	1	20.86	0.93
104	-116.009	36.919	Carbonate in Ash	WW-C-1	0	67.00	1.10

Empty cells before adding your data.



	A	B	C	D	K	L	M
12							
13			Count =	0	ottom	Side	Bottom
14	Longitude	Latitude	Group	Site	Cl^{-}	SO_4^{2-}	F^{-}
94							
95							
96							
97							
98							
99							
100							
101							
102							
103							
104							

All data for a site is entered on a single row before pasting into workbook. Paste your data to cell to A15 or C15 if longitude and latitude are not included.	
Change headings with the pull-down menus in row 14 to match chemical constituent in columns of user's data.	
Change headings with the pull-down menus in row 13 to match sides of ternary plots of cations and anions. Bottom, side, and diamond are defined relative to ternary plots.	 
Criteria for excessive charge imbalance is specified with a pull-down menu in cell Q12.	

PIPER page—Piper plot

Piper plot and plotting controls are displayed on the PIPER page (Figure 5). A unique list of groups is created and corresponding series in the Piper plot are formatted with the refresh button (cell J2). Symbol colors are assigned by fill colors in column J and are filled with colors in column K if colored. Groups are displayed or hidden by toggling cells TRUE or FALSE in column K. Specific sites are identified by pull-down menu in cell J1.

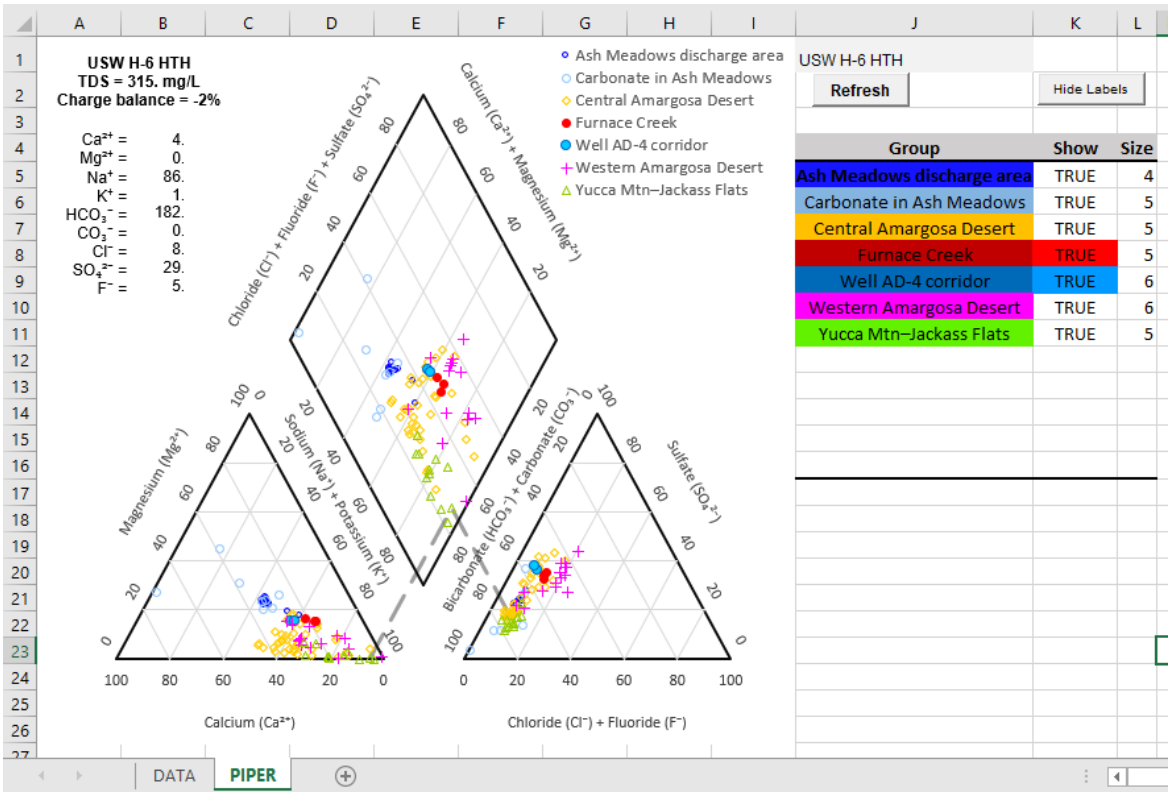
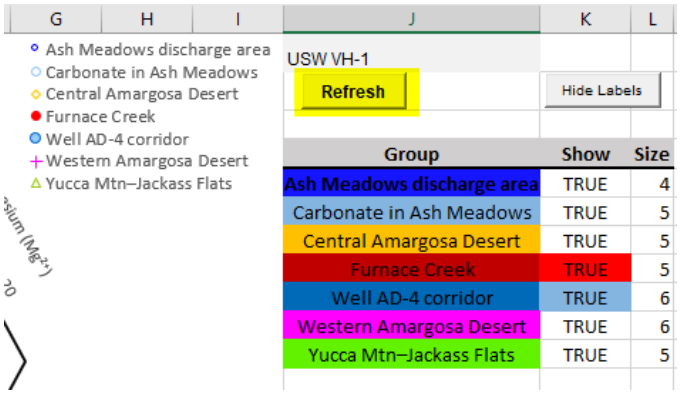
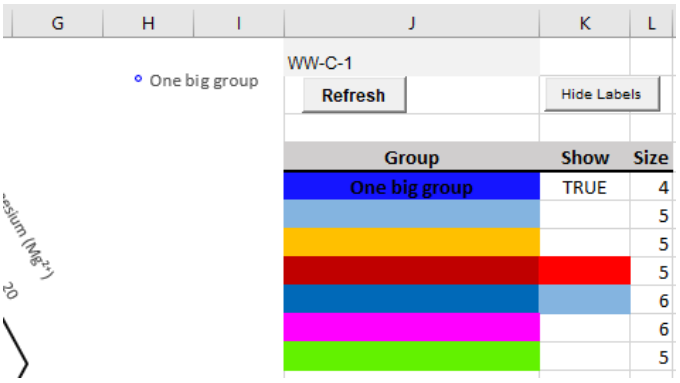
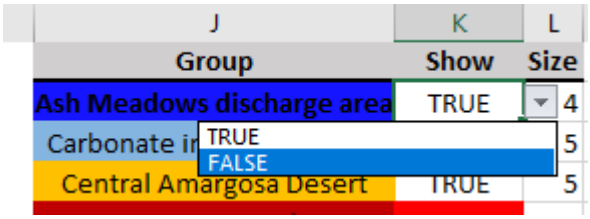
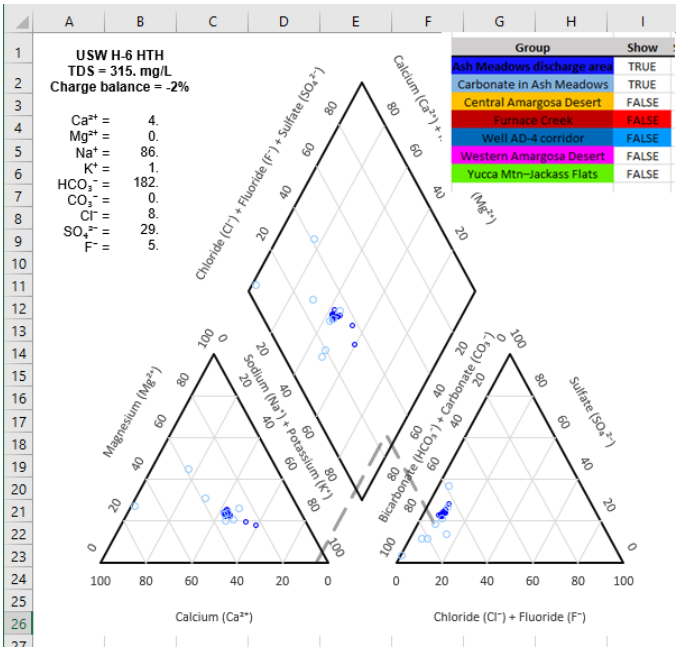
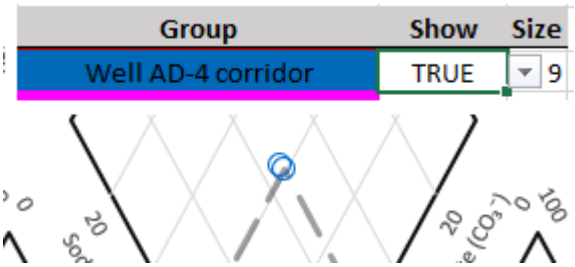
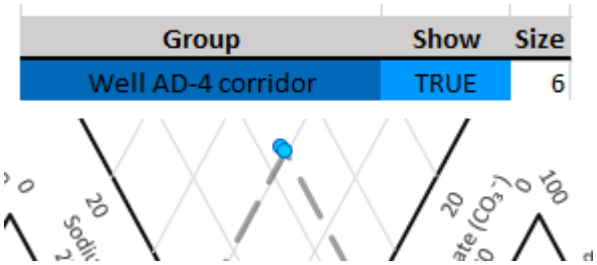
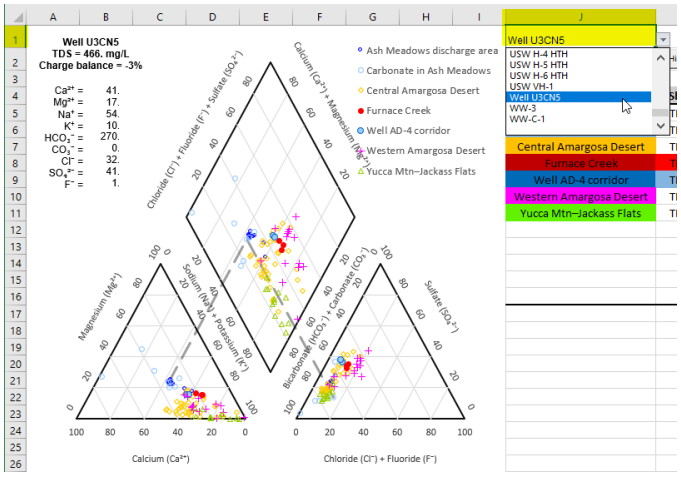
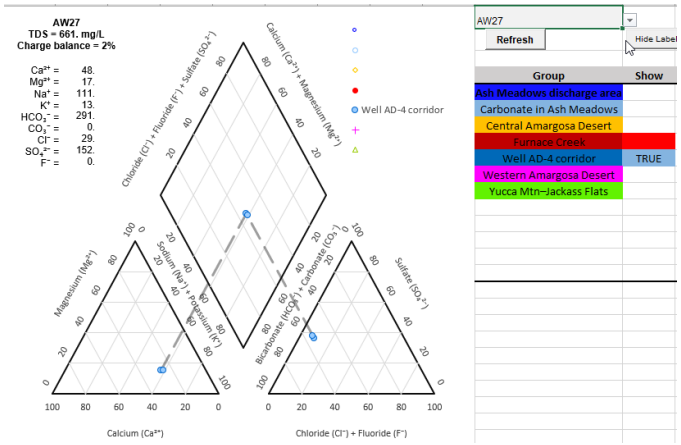


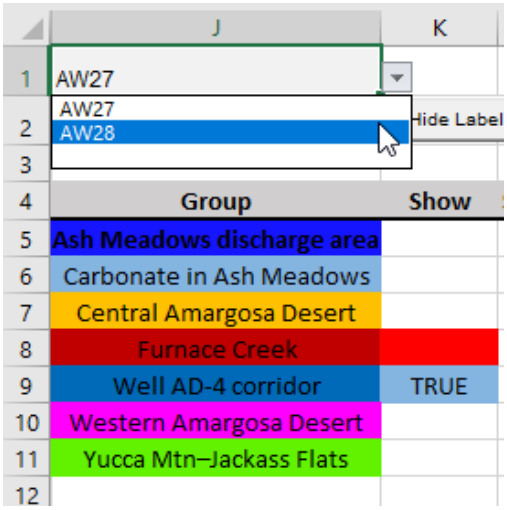
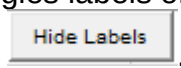
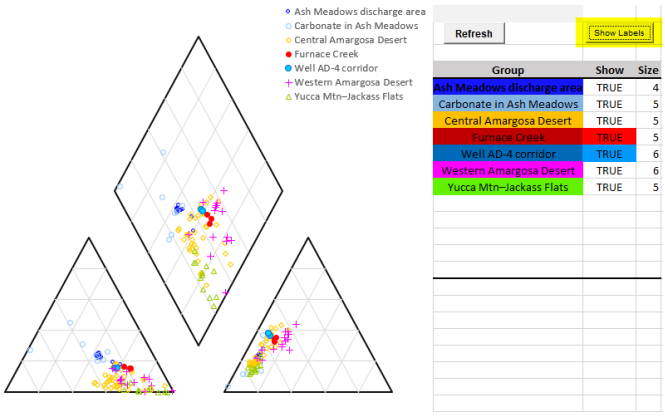
Figure 5.—User controls for Piper plot in the PiperStiff-QW-2019 workbook.

Piper Plot

Refresh button in cell J2. – Creates a list of unique group names in column J. – Maps cell colors in columns J and K to series in Piper plot. – Sizes symbols as specified in column L. Changing all group entries on the DATA page to same label will define	

a single big group. Groups are limited to twelve or less.	New list of 1 group after revising groups on DATA 
Toggle visibility of series with TRUE/FALSE pull-down menus in column K.	
Plot limited to two groups where TRUE specified only in cells K5:K6.	
Effect of cell colors in columns J and K and size specification in column L on series symbols in Piper plot.	 Filled, smaller symbol after refreshing with

	revised show & size specifications. 
Select TDS, charge balance, and concentrations at a site with site selector in cell J1.	
Available sites in site selector limited to sites in visible series.	

For example, wells AW27 and AW28 are the only sites in the Well AD-4 corridor and site selection is limited to these two sites.	
Button in cell K2 toggles labels on  and off  . Site selector also is cleared so that TDS, charge balance, and table of concentrations do not appear.	

Stiff diagrams and KMZ file

Stiff diagrams are created primarily for display in a KMZ file. Icon sizes are user defined and Stiff diagrams are colored by cell colors in column J (Figure 6). X-axis can be toggled from Cartesian to log scale to better display geochemistry of brines.

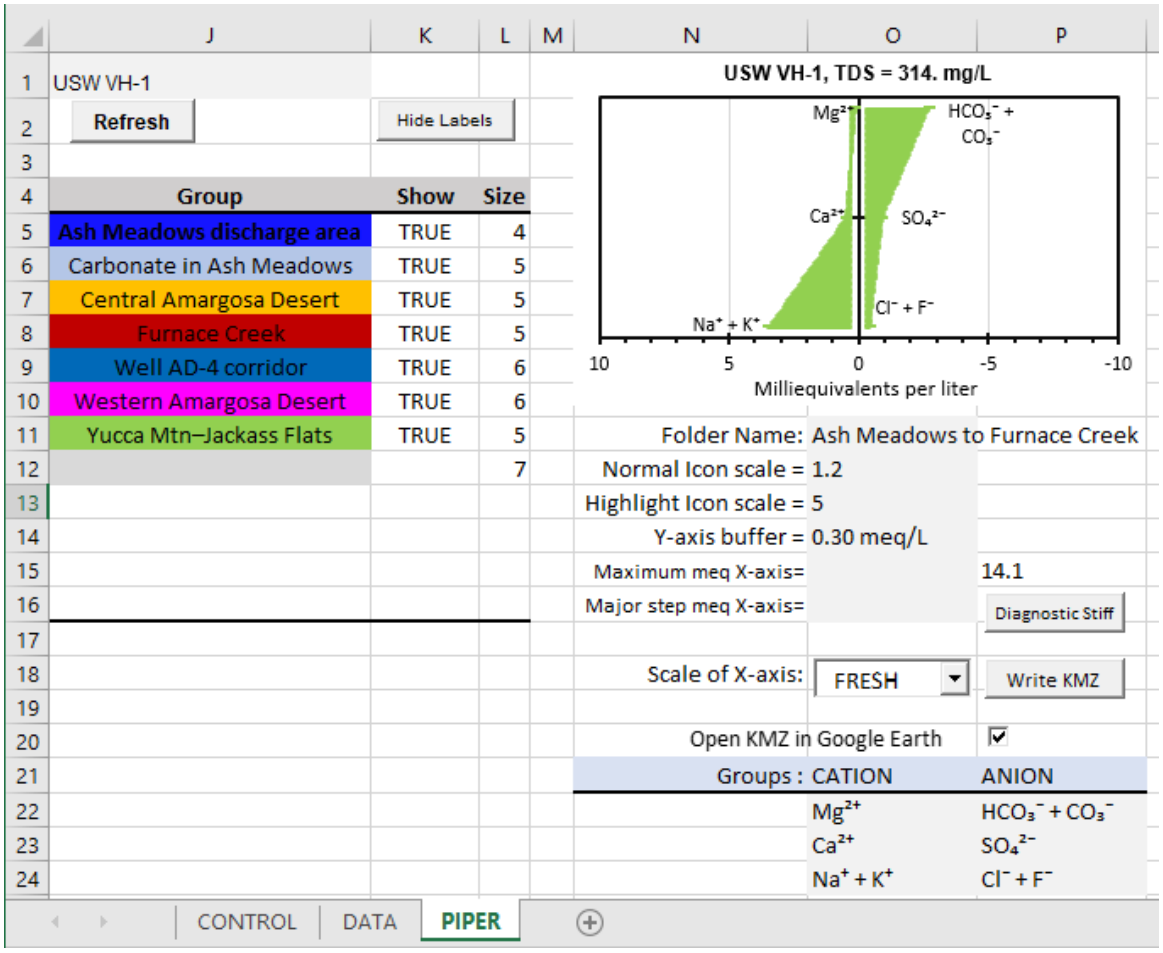
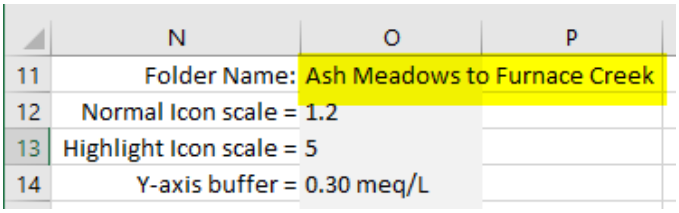
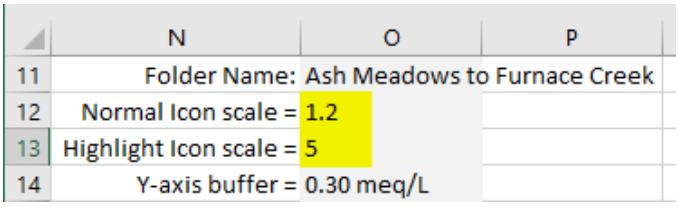
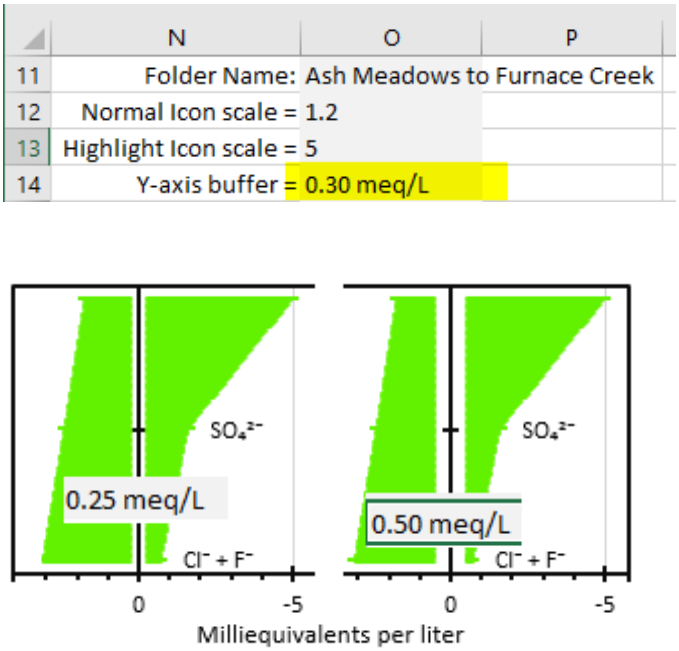
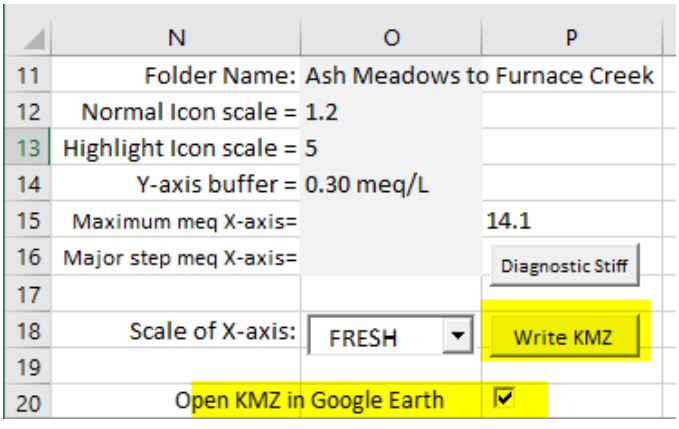
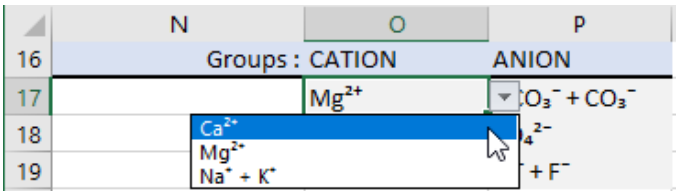
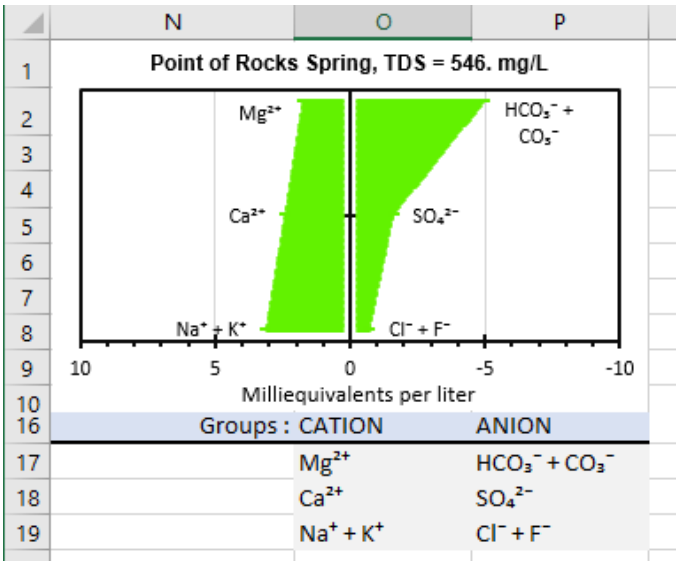
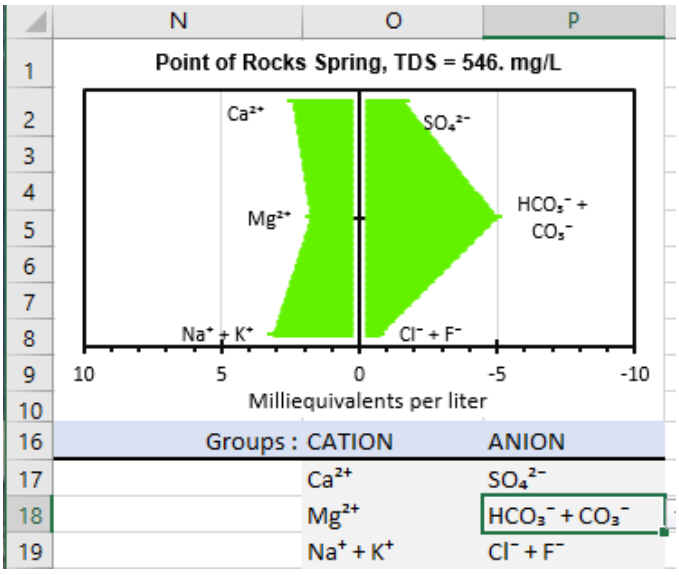
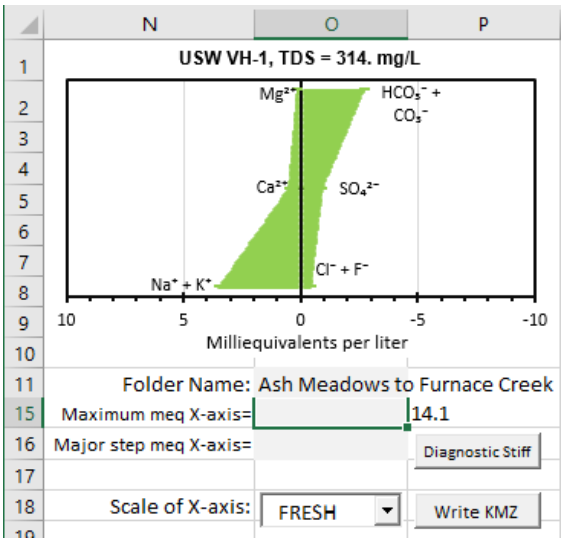
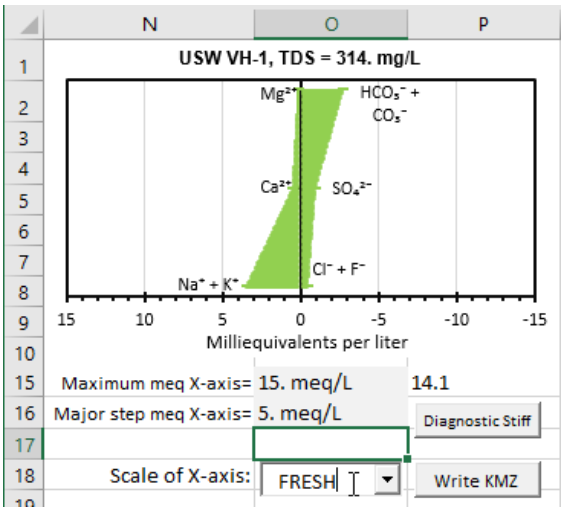
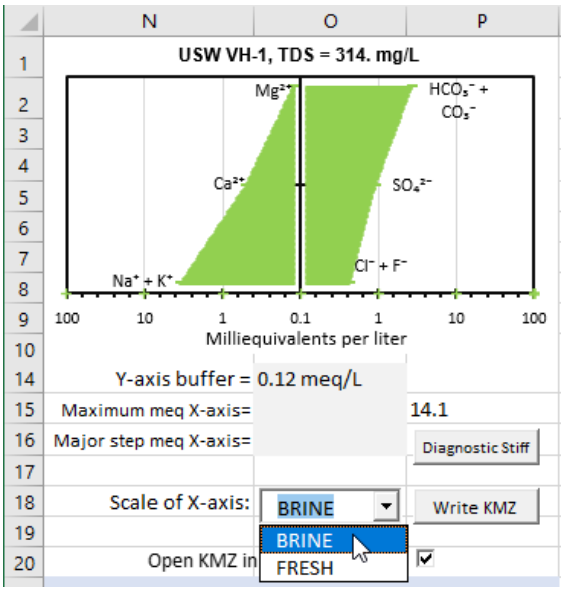


Figure 6.—User controls for Stiff diagrams in the PiperStiff-QW-2019 workbook.

Stiff diagrams and KMZ

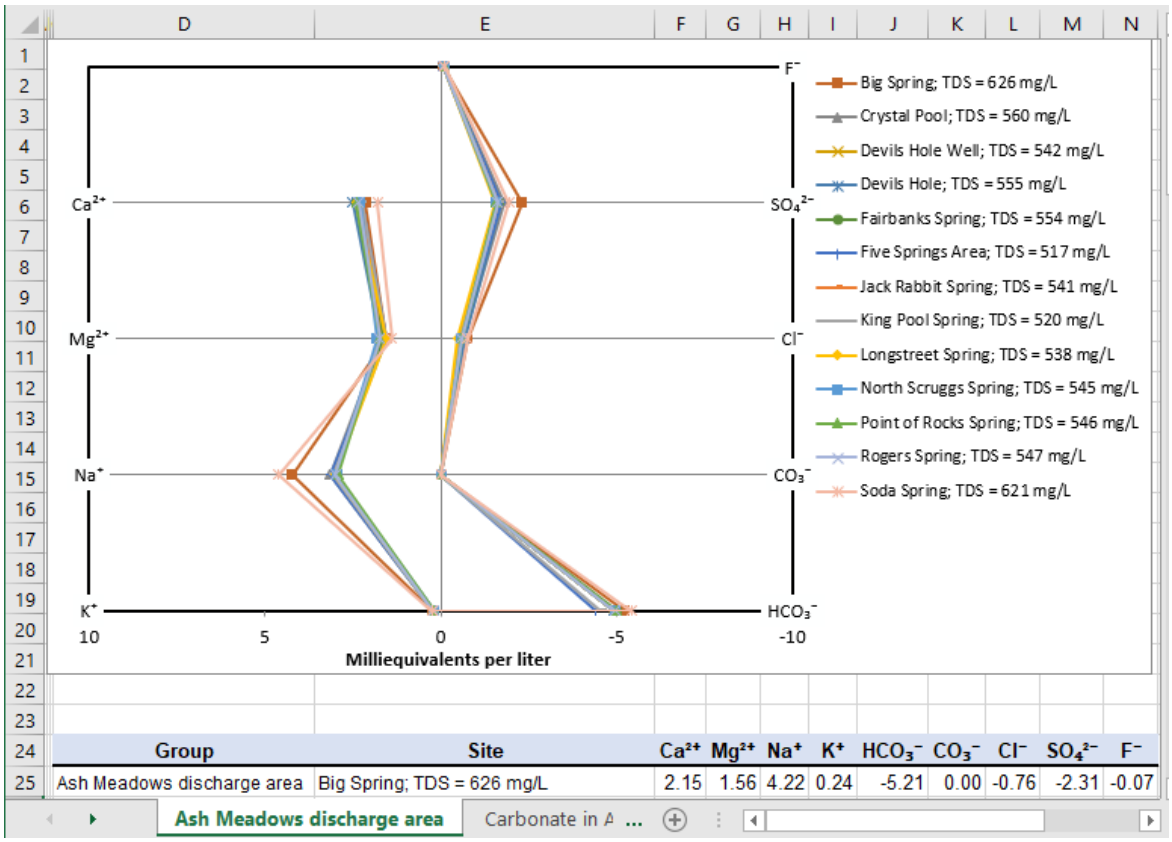
Folder name specifies name of KMZ file that is written in the directory that contains the workbook.	
Icon scales are multipliers that scale placemark icons in Google Earth. Normal defines unselected icon scale and highlight defines icon scale as mouse hovers and on selection.	
Y-axis buffer creates a gap in the Stiff diagram so that the Y-axis remains visible.	
Press **Write KMZ** to create icon images, kml file, and zip output to a KMZ file. KMZ file will be opened automatically if box in cell P20 is checked.	

Vertical order of cations and anions in Stiff diagram are user defined through pull-down menus.	
Example alternative Stiff diagrams where vertical order of cations and anions differed in cells O17:P18.	 Stiff pattern changed by user-ordered ions. 

Default scaling of X-axis of Stiff diagram rounds to maximum value of milliequivalents for an ion, which is reported in cell P15.	
Maximum value of X-axis can be defined manually in cell O15. Labeled steps also can be specified in cell O16. Scales are revised by either double-clicking the combo menu in cell O18 to changing the selection from FRESH to BRINE.	
X-axis scale can be changed to logarithmic for sites with greater range of TDS as occurs with brines. Select BRINE in combo menu in cell O18 to display logarithmic scale. Minimum plottable value of milliequivalents for an ion is specified in cell O14 and is rounded to units of 10. For example, • 0.12 rounds to 0.1 • 0.9 rounds to 0.1 • 1.2 rounds to 1 Maximum and major steps are in powers of 10 for logarithmic scale.	

Diagnostic Stiff diagrams in new workbook

Diagnostic Stiff diagrams also can be created in a new workbook, where each site in a group is diagrammed in a single plot (Figure 7). A page is created for each group of sites with an open Stiff diagram of individual ions for each site. Milliequivalents of anions are plotted as negative values in Cartesian plots and are inverted on log plots.

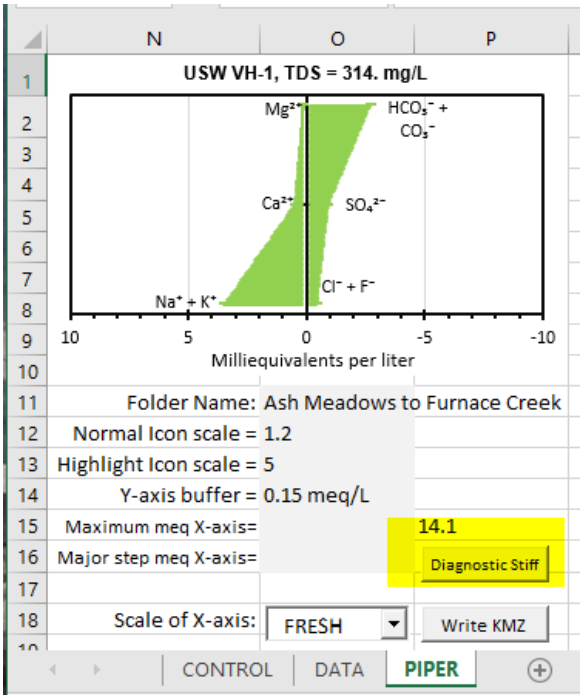
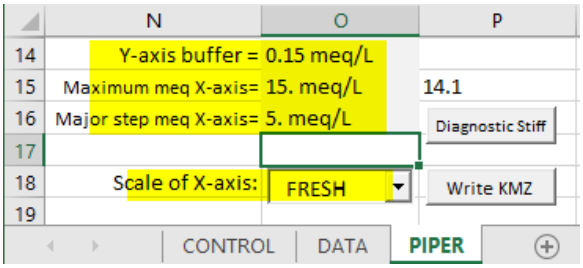
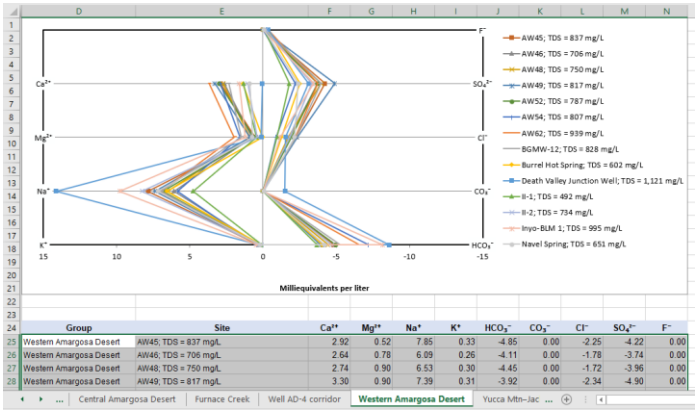


Group	Site	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	HCO_3^-	CO_3^-	Cl^-	SO_4^{2-}	F^-
Ash Meadows discharge area	Big Spring; TDS = 626 mg/L	2.15	1.56	4.22	0.24	-5.21	0.00	-0.76	-2.31	-0.07

Ash Meadows discharge area | Carbonate in A ...

Figure 7.—Diagnostic Stiff diagram in new workbook.

Diagnostic Stiff diagrams

Press “Diagnostic Stiff” button (cell P16) to create diagrams in new workbook.	
X-axis of Stiff diagrams in new workbook will reflect settings in cells O14:O16 and O18.	
A page is created for each group in the new workbook. The distributed example has seven groups which results in seven sheets with an open Stiff diagram on each sheet.	

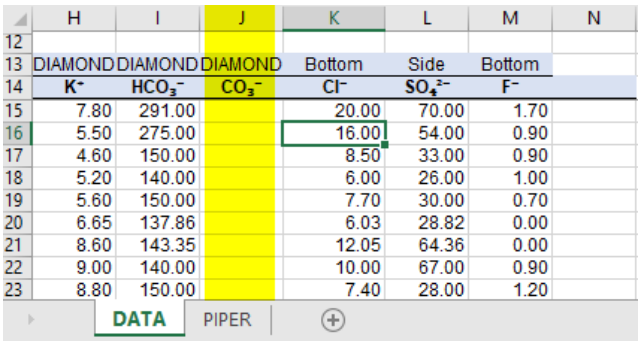
Odd items

The following explanations address items that users have misconstrued.

1. Unused ions can be eliminated.
2. Additional ions can be specified.

Eliminate unused ions

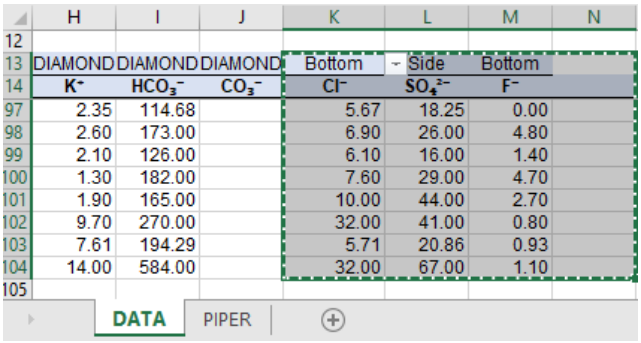
For example, Carbonate (CO_3^-) is not specified and an empty column J on the DATA page does not need to be retained.



	H	I	J	K	L	M	N
12							
13	DIAMOND	DIAMOND	DIAMOND	Bottom	Side	Bottom	
14	K^+	HCO_3^-	CO_3^-	Cl^-	SO_4^{2-}	F^-	
15	7.80	291.00		20.00	70.00	1.70	
16	5.50	275.00		16.00	54.00	0.90	
17	4.60	150.00		8.50	33.00	0.90	
18	5.20	140.00		6.00	26.00	1.00	
19	5.60	150.00		7.70	30.00	0.70	
20	6.65	137.86		6.03	28.82	0.00	
21	8.60	143.35		12.05	64.36	0.00	
22	9.00	140.00		10.00	67.00	0.90	
23	8.80	150.00		7.40	28.00	1.20	

DATA PIPER

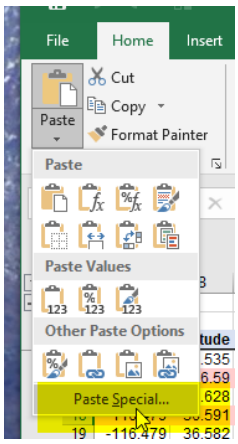
Copy data in columns K13:N104.



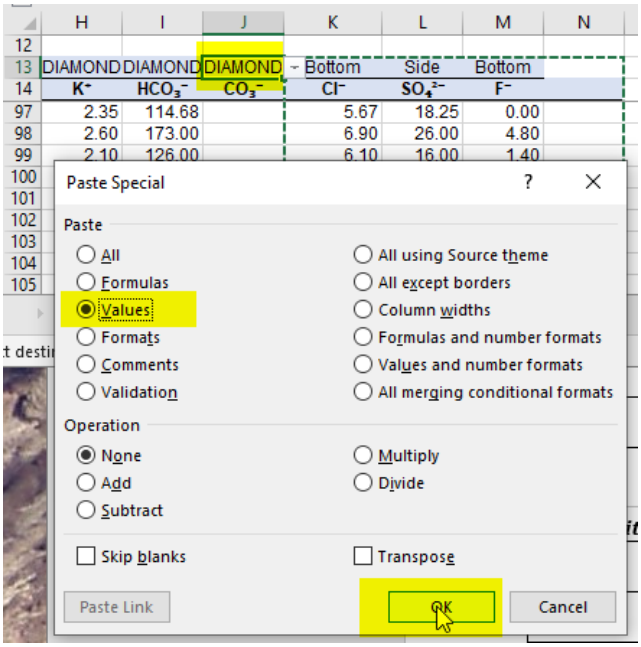
	H	I	J	K	L	M	N
12							
13	DIAMOND	DIAMOND	DIAMOND	Bottom	Side	Bottom	
14	K^+	HCO_3^-	CO_3^-	Cl^-	SO_4^{2-}	F^-	
97	2.35	114.68		5.67	18.25	0.00	
98	2.60	173.00		6.90	26.00	4.80	
99	2.10	126.00		6.10	16.00	1.40	
100	1.30	182.00		7.60	29.00	4.70	
101	1.90	165.00		10.00	44.00	2.70	
102	9.70	270.00		32.00	41.00	0.80	
103	7.61	194.29		5.71	20.86	0.93	
104	14.00	584.00		32.00	67.00	1.10	
105							

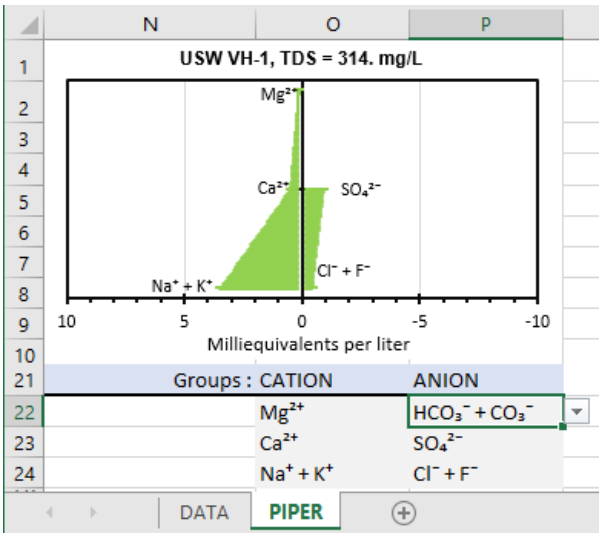
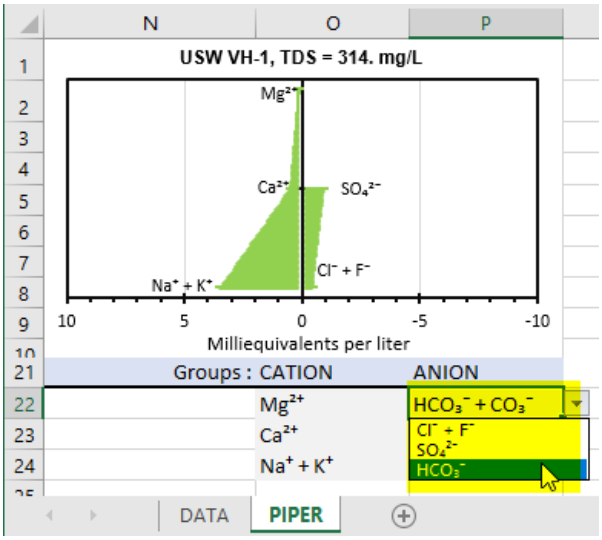
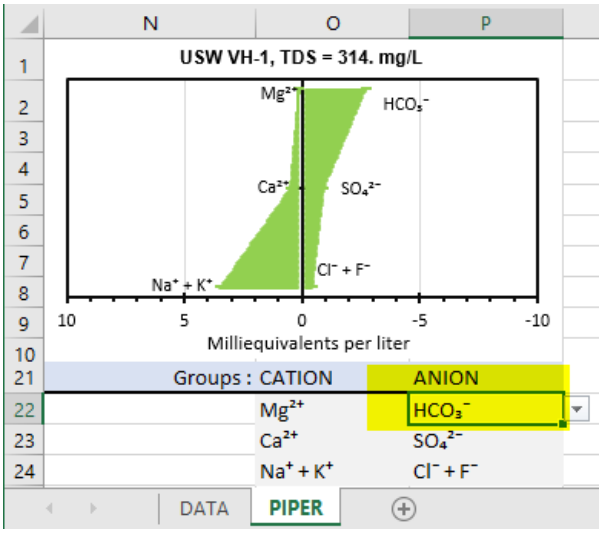
DATA PIPER

Paste special as vales to cell J13.

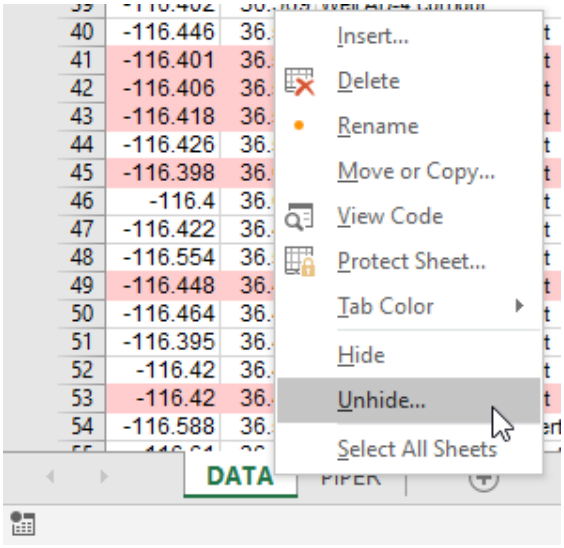
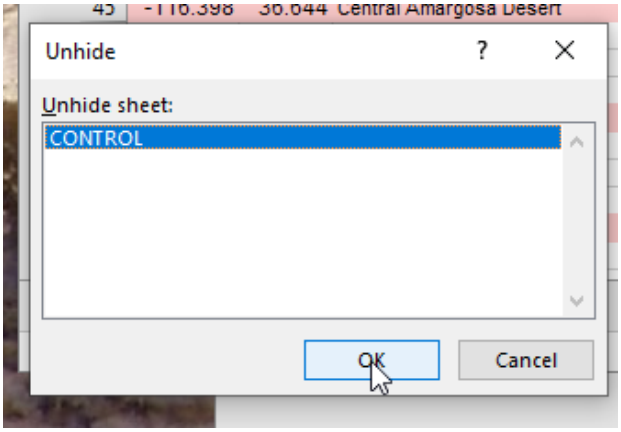
Get paste special form with mouse  or

Keyboard shortcut is,
Alt-key, h, v, s



Activate PIPER page. Select old anion group $HCO_3^- + CO_3^-$ (cell p22).	
Old option $HCO_3^- + CO_3^-$ is no longer available and has been replaced by HCO_3^- in (cell p22).	
Stiff diagram functions correctly after HCO_3^- is specified in (cell p22).	

Add ions

Unhide CONTROL page Right-click on a page tab and select Unhide…	
CONTROL is the only hidden page so click OK on the Unhide form.	
Add ion, charge, conversion, descriptor, and atomic weight of new ion in columns B:F in the first empty row.