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RJ Wright
8/4/82

Linda Lehman
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July 22, 1982

Dr. Robert Wright
U.S. Nuclear Regulatory Commission
M.S. 697 SS
Washington, D.C. 20555

Dear Bob,

I trust your recent trip to Hanford was interesting and informative. No doubt the BWIP evaluation of the geochemistry paper generated some lively discussion. In that regard, I would like to make some comments on the BWIP reply to our paper. My comments are included in the following paragraphs and attachments. The summary of these comments, however, I will give you now - our hypothesis that vertical flow is occuring in the vicinity of the horn of the Columbia River still stands. I have not addressed each individual item listed by Rockwell. However, Bob, if you feel this is necessary, please advise me.

BWIP has one principal difficulty with the geochemistry paper. This stems from their premise that it is not valid to compare the chemistry of waters taken from different hydrostratigraphic units. Factor Analysis, however, is one of several tools designed to undertake just this sort of problem. That is, it looks for linear relationships between all variables. In this case, the variables were the chemical constituents, temperature, pH and depth for 86 wells. As a first cut, I used everything available in the literature as variables. This was slightly refined in the second run which eliminated the non-significantly correlated variable bicarbonate.

R.E. Williams (1982) has used a cluster analysis combined with a type of Factor Analysis (MANOVA) to look at water quality data from several sources. Williams' analysis statistically grouped the data into distinct populations which he correlated to observed hydrogeologic features. Williams was also able to delineate discharge areas.

If our water samples indeed represent 3 isolated hydrostratigraphic units made up of the Saddle Mountains, the Wanapum and the Grande Ronde basalts; then the Factor Analysis technique should have sorted the samples into three groups which displayed consistent chemistry and depth relationships. This however was not the case. Three water types did actually emerge, but they were not sorted by the mentioned hydrostratigraphic intervals. Instead the Factor Analysis indicated mixing between water types. This mixing was interpreted as probable hydraulic upwelling at the horn of the Columbia River. Furthermore, when viewed in the context of local geology and available hydraulic head data, this leads to a discharge hypothesis. (I emphasize at this point that the mechanism for mixing is not perceptable to Factor Analysis, only the trend itself is evident.)

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I was particularly intrigued by the here-to-fore unavailable data that was included in the Rockwell reply. If our mixing hypothesis is correct, the "new" data taken from the Pasco Basin area should support this premise. As a test, I have plotted the "new" data on Piper trilinear diagrams. Figure 1 plots only the wells RHO designates as 1) composite - lower Saddle Mountains/Wanapum (LSM/WP) and 2) Wanapum (WP). This plot illustrates the distribution of water within one hydrostratigraphic interval. According to RHO, this should be one water type only.

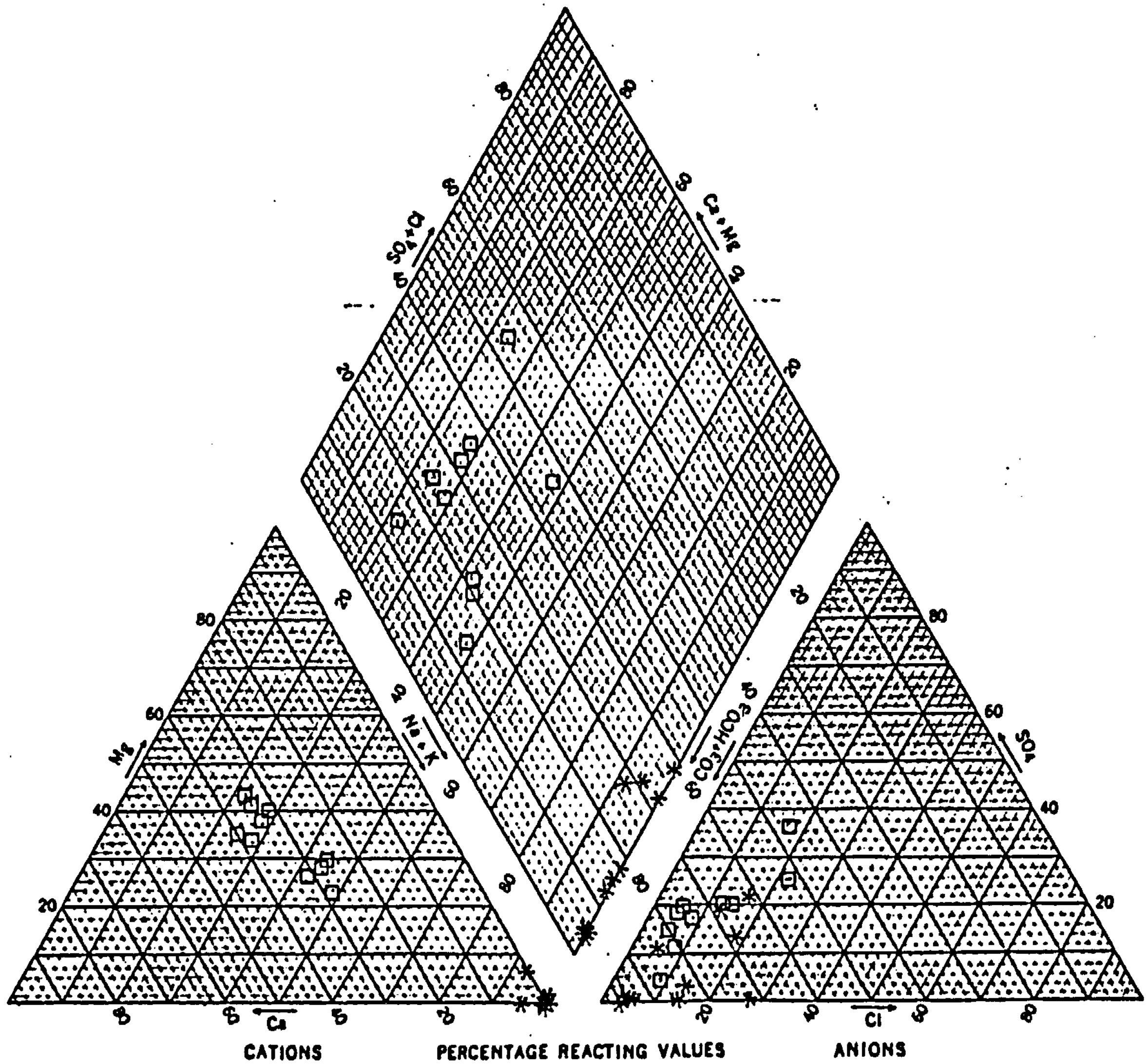
From Figure 1, it can be seen that the (LSM/WP) and the (WP) plot as two distinct water types; a Calcium-Bicarbonate type and a Sodium-Bicarbonate type. The areal distribution of these types is shown as Figure 2. As can be seen, the Sodium-Bicarbonate type falls within the central Pasco Basin. The Calcium-Bicarbonate type surrounds this area.

I digress at this point to quote Freeze and Cherry (1979) on Piper trilinear diagrams.

> "The trilinear diagram represents the concentrations as percentages. Because each analysis is represented by a single point, waters with very different total concentrations can have identical representations on this diagram. A single trilinear diagram has a greater potential to accomodate a larger number of analyses without becoming confusing and is convenient for showing the effects of mixing two waters from different sources. The mixture of two different waters will plot on the straight line joining the two points."

Figure 3 is a plot of all data from Figures 1 and 3 of the Rockwell reply. The additional deep data from the Grande Ronde/Lower Wanapum (GR/LWP) plots as a dominantly Sodium-Chloride-Sulfate type. However, the data points do not tightly cluster as a distinct group, but rather plot on a straight line towards the Sodium-Bicarbonate type. This linear trend is an indicator of mixing between the (GR/LWP) water type and the Sodium-Bicarbonate type within the central Pasco Basin. Notice that no mixing trend is evident between the Calcium-Bicarbonate type and the (GR/LWP) type.

In order to confirm that this mixing trend was real, the USGS water chemistry code "WATMIX" was utilized. This code requires as input, water chemistry from the two types of water that are suspected to be mixing. I used the chemistry data from Well DC-14 (GR) and Well 45 from the geochemistry paper. The WATMIX code calculates theoretical mixing between the two water types. As output, the code will tell you what the theoretical chemical mixture would look like from mixes of 100% DC-14 - 0% Well 45 to 0% DC-14 - 100% Well 45 in 10% increments. This chemistry, when plotted on a trilinear diagram, will



□ Calcium -bicarbonate type   * Sodium-bicarbonate type

Figure 1. Trilinear plot of lower Saddle Mountains/Wanapum composite and Wanapum wells from RHO reply figures 1 and 3.

SELECTED CHEMICAL QUALITY DIAGRAMS FOR GROUNDWATERS WITHIN THE PASCO BASIN.

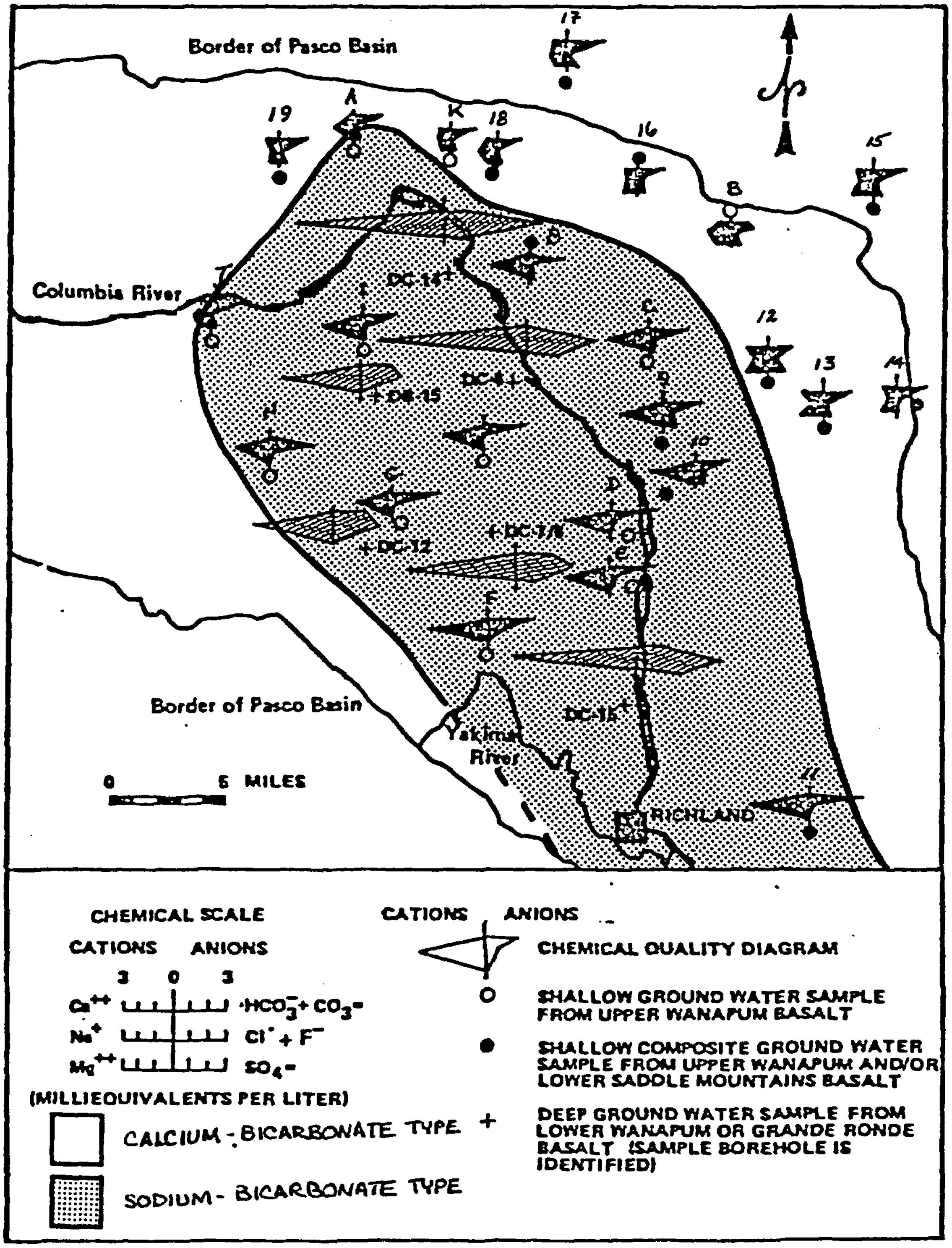


Figure 2. Areal distribution of water types within the lower Saddle Mountains-Wanapum hydrostratigraphic interval.

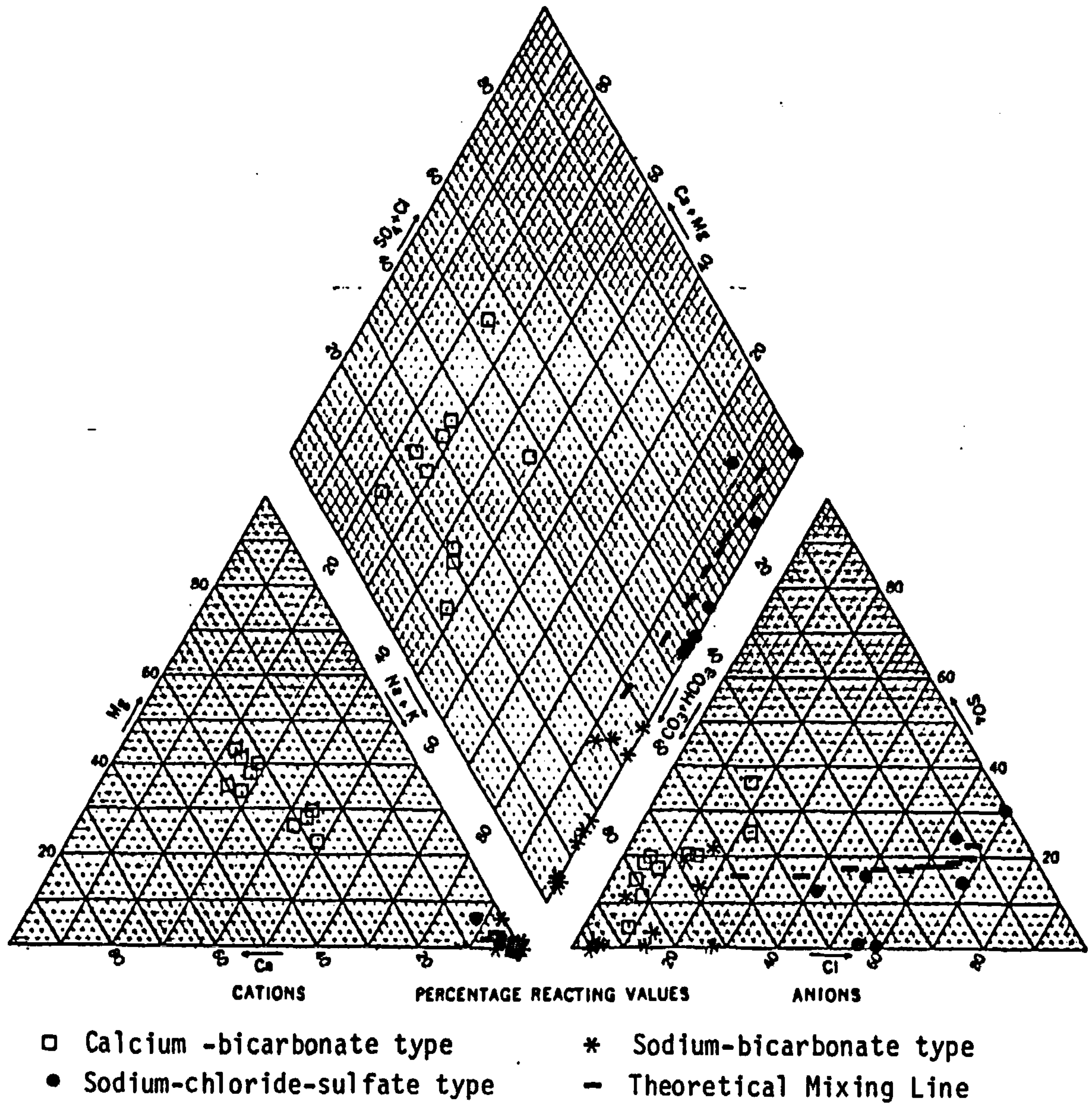
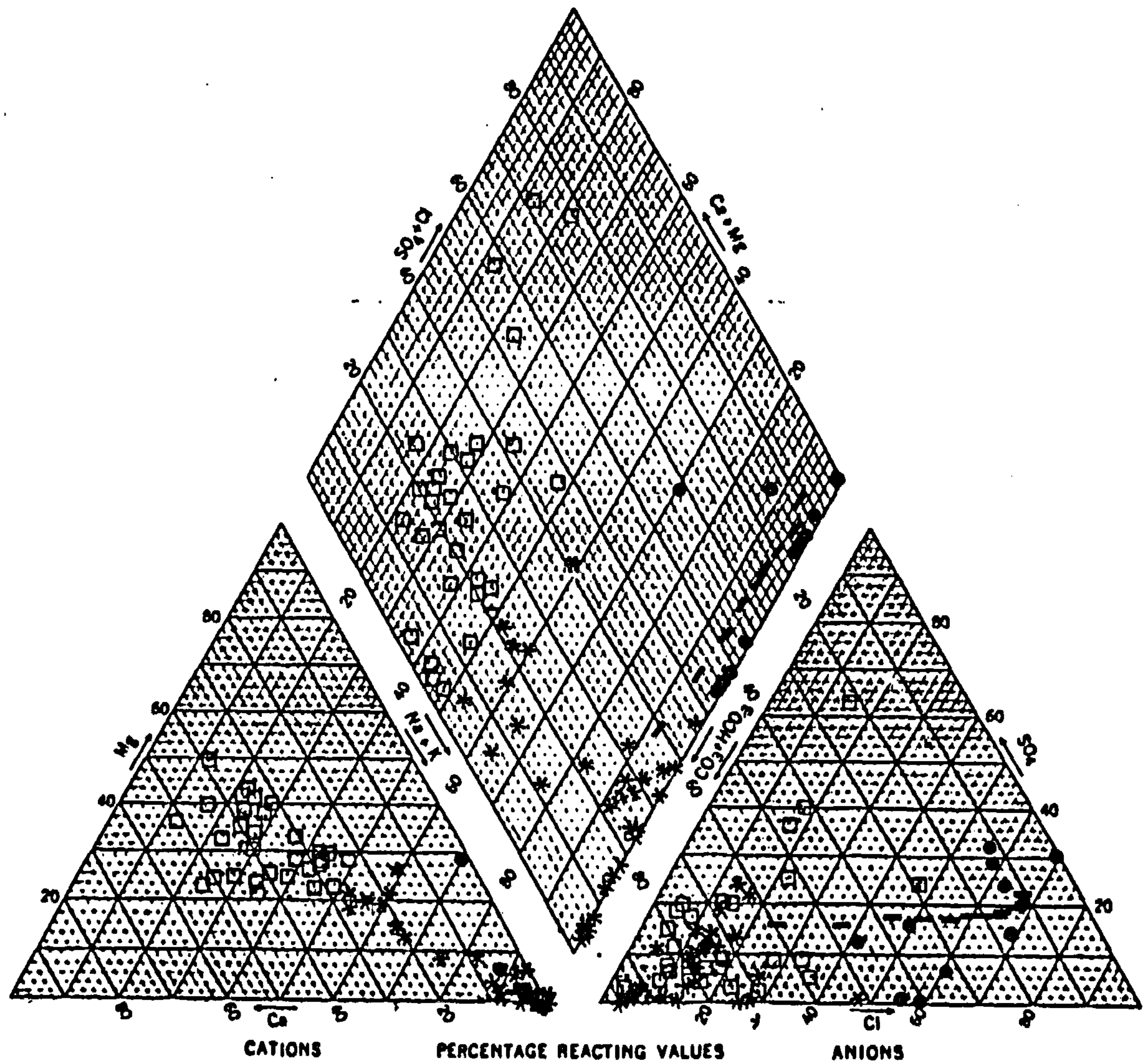


Figure 3. Trilinear plot of all data on RHO reply figures 1 and 3.



□ Calcium -bicarbonate type
● Sodium-chloride-sulfate type
* Sodium-bicarbonate type
— Theoretical Mixing Line

Figure 4. Trilinear plot of all available data in Pasco Basin area.

be the line the real data should follow if true mixing is occurring. This theoretical mixing line is plotted as X's on Figure 3. It can be seen that the field data plot exactly along this line.

Figure 4 is a plot of all available data (RHO reply plus our geochemistry data appendix) for wells lying in the Pasco Basin and immediately adjacent areas. When plotted, this data indicates an additional mixing trend. That of Sodium-Bicarbonate type water mixing with the Calcium-Bicarbonate type. This trend could be the result of cation exchange of calcium for sodium in clays along the flow path. Due to the completeness of the exchange, however, I believe mixing is more probable. Obviously, some combination of the two is also possible.

A plausible geochemical conceptual model emerges as a result of these previous four figures; and is shown schematically as Figure 5. For ease of interpretation the water types have been designated as A, B and C. The Calcium-Bicarbonate type is B; the Sodium-Chloride-Sulfate type is A; and the Sodium-Bicarbonate type is C. Figure 5 demonstrates the mixing hypothesis; i.e., $A + B \rightarrow C$.

The sodium within the type C water comes from the Sodium-Chloride-Sulfate water type A. The bicarbonate in the type C water comes from the Calcium-Bicarbonate water type B. The type C water is actually a gradual mix of A and B going from 100% A - 0% B to 0% A - 100% B, progressing upward through the geologic section.

The Factor Analysis, as well as the fluoride and chloride data from the deep wells, show that this gradient is more pronounced at the horn of the Columbia River. Only more data will show the strength of this trend under other structurally deformed areas.

In conclusion, the results and interpretations described in our geochemistry paper are supported by the available data and still stand.

My recommendations for future data analysis at Hanford include the following:

1. Once more data is released by RHO, run the Factor Analysis again using all available data.

2. All data should be plotted on trilinear diagrams and mixing trends identified.

3. Cluster analysis techniques should be employed to see if additional trends can be detected.

4. The NRC flow model should be modified to reflect knowledge obtained through the chemical analyses and any new hydraulic data released in the SCR. This will involve several steps:

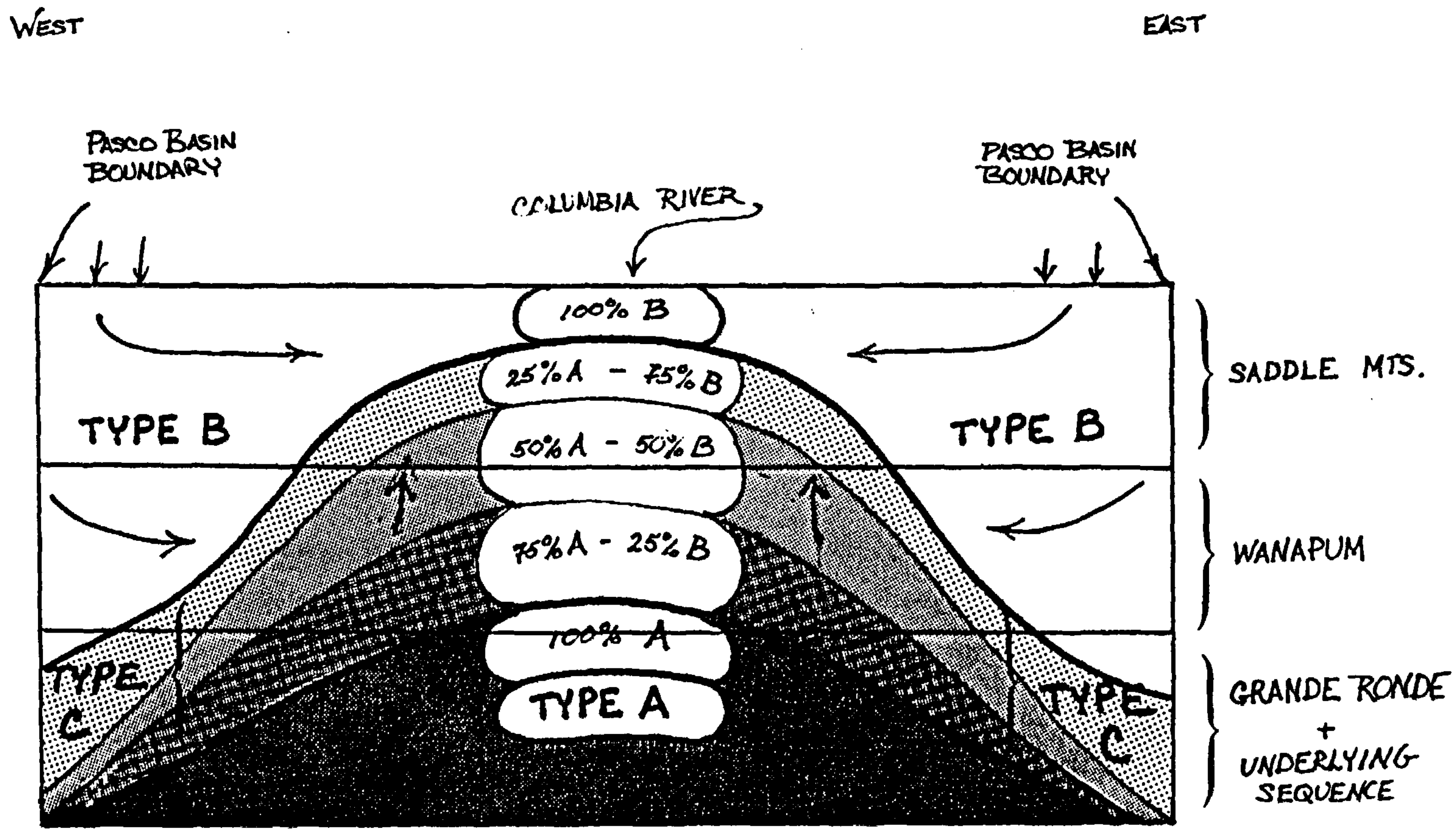


Figure 5. Conceptual Geochemical Model.

A. Transient solute transport of non-reactive constituents such as fluoride and chloride should be run on SWIFT to match observed concentrations. This will provide a calibration tool to pin down the flow velocities.

B. Based on the geochemistry, the present no-flow boundary condition at the bottom of the Grande Ronde layer may no longer be appropriate. A constant flux boundary condition should be employed and model sensitivity then determined. Observed chemical concentrations may then be matched in a calibration procedure by adjusting this flux.

C. All boundary conditions used in the model should be re-examined in light of new head data released in the SCR.

Bob, I am convinced there is vertical flow and discharge occuring at the Columbia River. Although I believe the process is very slow compared to the horizontal flow, I still think it is significant over the time frame of concern. This does not however, necessarily preclude the possibility of establishing a repository in the Columbia River basalt. Even with a vertical flow component, it still might be possible to engineer and monitor a safe repository at Hanford. It could only be done however, if the design engineers have a thorough and accurate understanding of the geology and groundwater flow at the site.

The SCR will outline the field tests which will provide this understanding. I believe it is very important that the field testing program provide data to finally determine whether or not vertical flow exists. Since RHO has already discounted this possibility, it very likely will not. In this case, it will be up to the NRC to continue independent study of the site to point out this and other needs. The strongest tool the NRC has in this regard is the SWIFT model. Properly calibrated, the model can be used to test almost any scenario and find its strengths and weaknesses. The model should be continuously updated as our understanding of the Hanford flow system improves.

I am looking forward to discussing this and other points with you in August.

Sincerely,

Linda

Linda Lehman

Enclosures
cc: T.Verma, WMTD
E.Quinn, WMHL

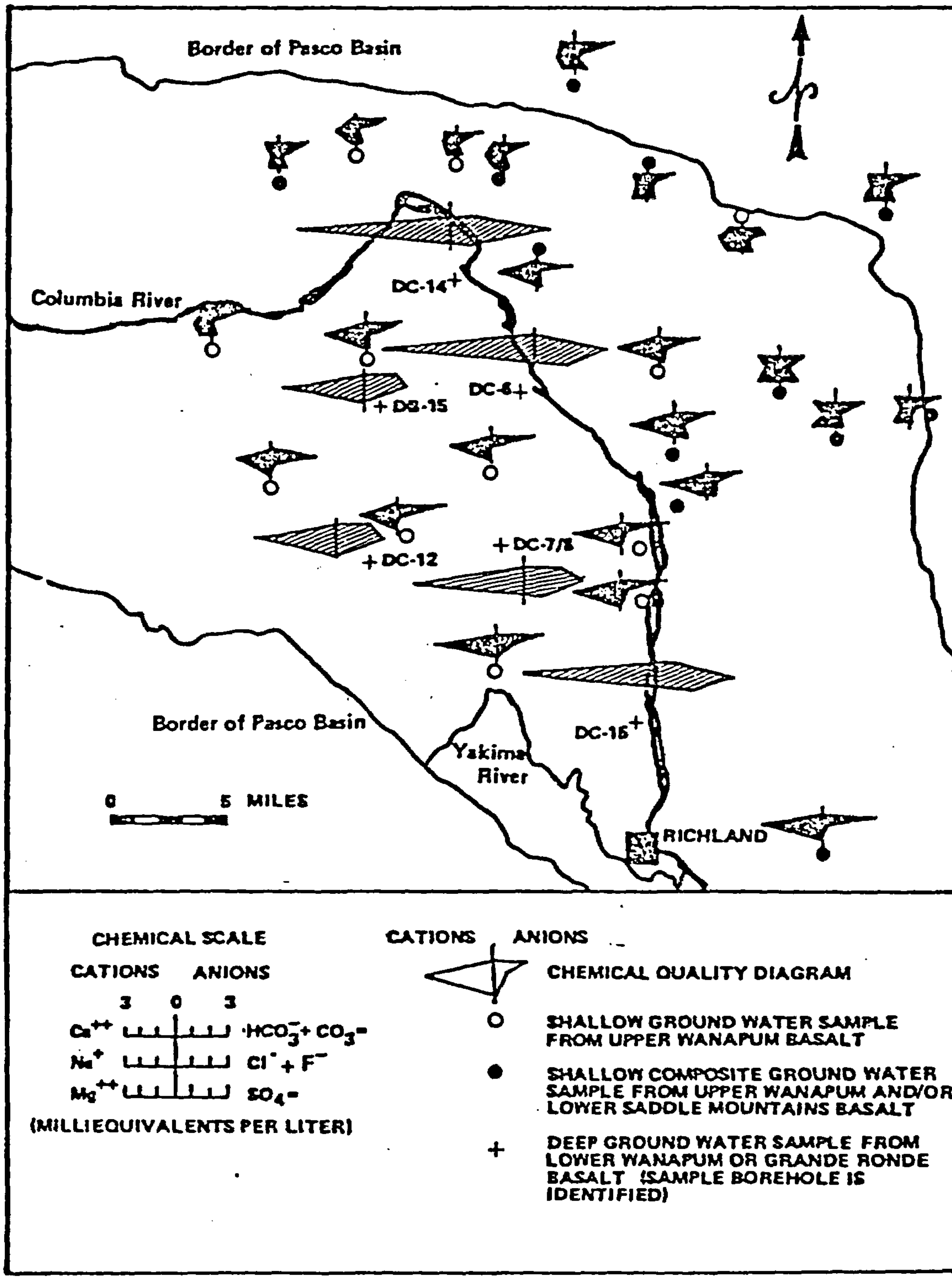
REFERENCES CITED

Freeze, A. and J. Cherry, 1979, Groundwater, Prentice-Hall, Englewood Cliffs, N.J.

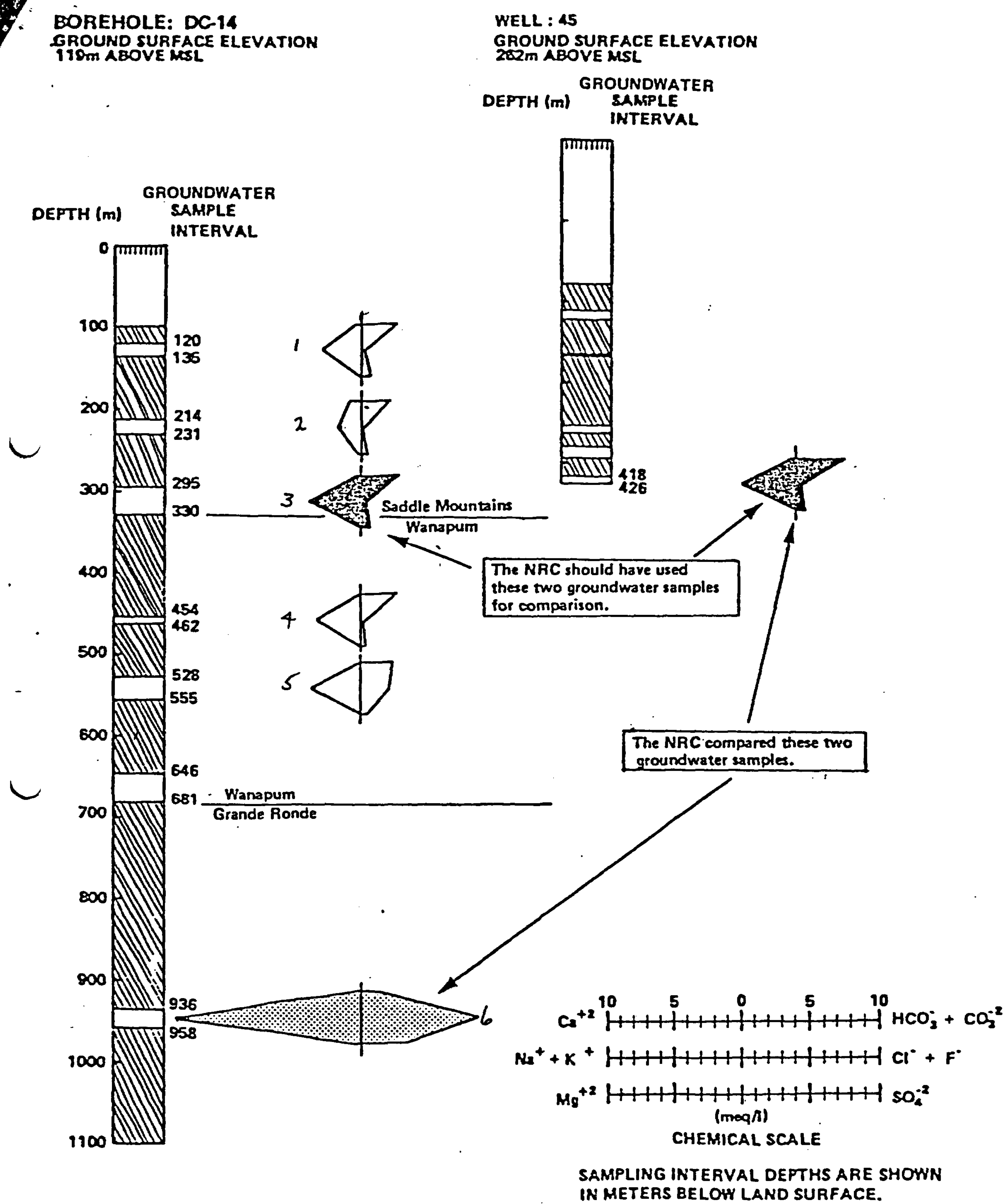
Williams, R.E., 1982, Statistical Identification of Hydraulic Connections Between a Mountain and Internal Mineralized Sources, Groundwater, Vol. 20, No. 4, July - August, 1982, pp. 389 - 524.

FIGURE 1.

SELECTED CHEMICAL QUALITY DIAGRAMS FOR GROUNDWATERS WITHIN THE PASCO BASIN.



AND WELL 45.



BOREHOLE: DC-14
GROUND SURFACE ELEVATION
119m ABOVE MSL
WELL : 45
GROUND SURFACE ELEVATION
282m ABOVE MSL
DEPTH (m)
GROUNDWATER SAMPLE INTERVAL
0
100
200
300
400
500
600
700
800
900
1000
1100
120
136
214
231
295
330
454
462
528
555
646
681
936
958
418
426
1
2
3
4
5
6
Saddle Mountains
Wanapum
Wanapum
Grande Ronde
The NRC should have used these two groundwater samples for comparison.
The NRC compared these two groundwater samples.
Ca^{+2}
$Na^{+} + K^{+}$
Mg^{+2}
10 5 0 5 10
$HCO_3^- + CO_3^{-2}$
$Cl^- + F^-$
SO_4^{-2}
(meq/l)
CHEMICAL SCALE
SAMPLING INTERVAL DEPTHS ARE SHOWN IN METERS BELOW LAND SURFACE.