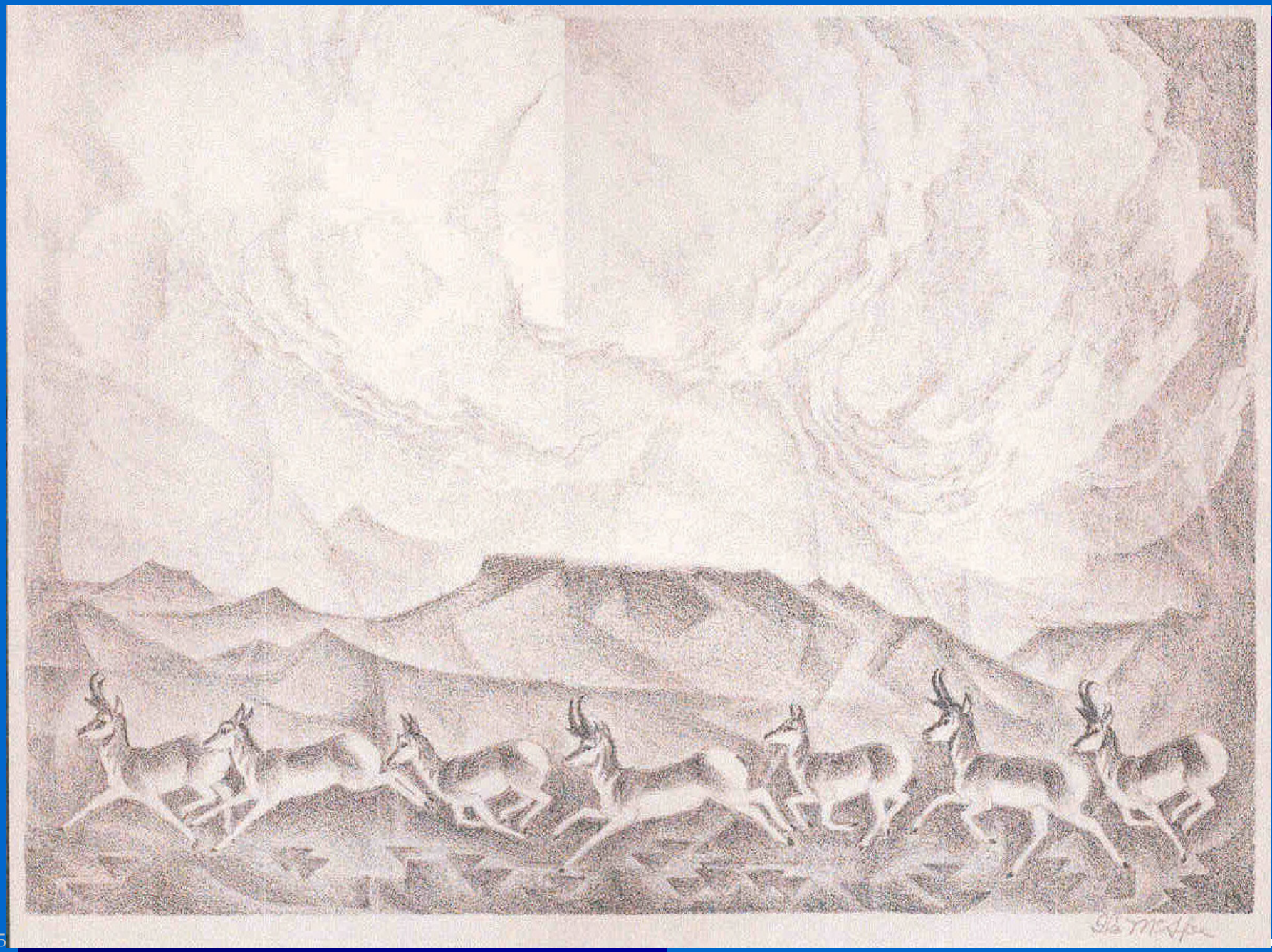


RH
05/05

BASELINE
GROUND WATER QUALITY
CONDITIONS
AT
IN SITU URANIUM WELLFIELDS
IN WYOMING

The Technical Situation

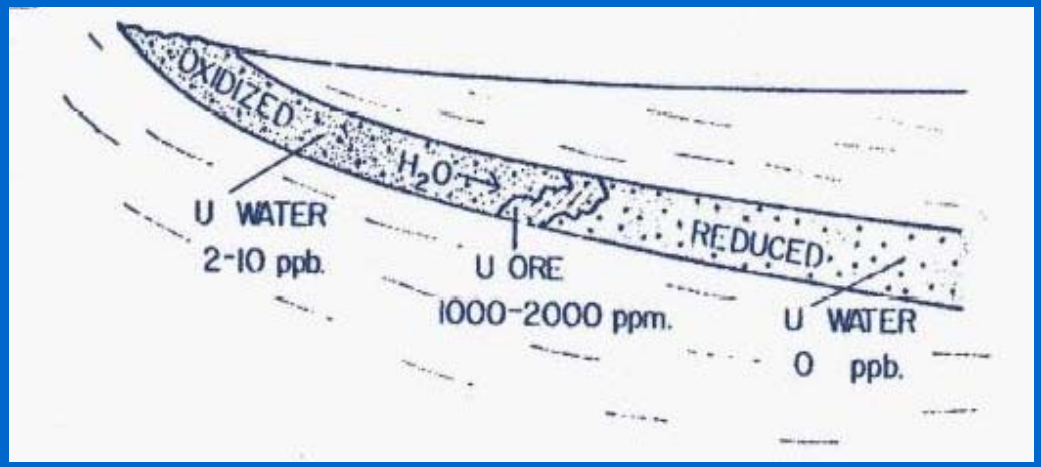
- ✓ Deposition of Wyoming Uranium
- ✓ Collection of Baseline Ground Water Quality Data
- ✓ Range & Distribution of Baseline TDS, Uranium, & Radium Concentrations
- ✓ Statistical Analyses

The Regulatory Situation

- ✓ The ‘Players’
- ✓ Water Testing Requirements

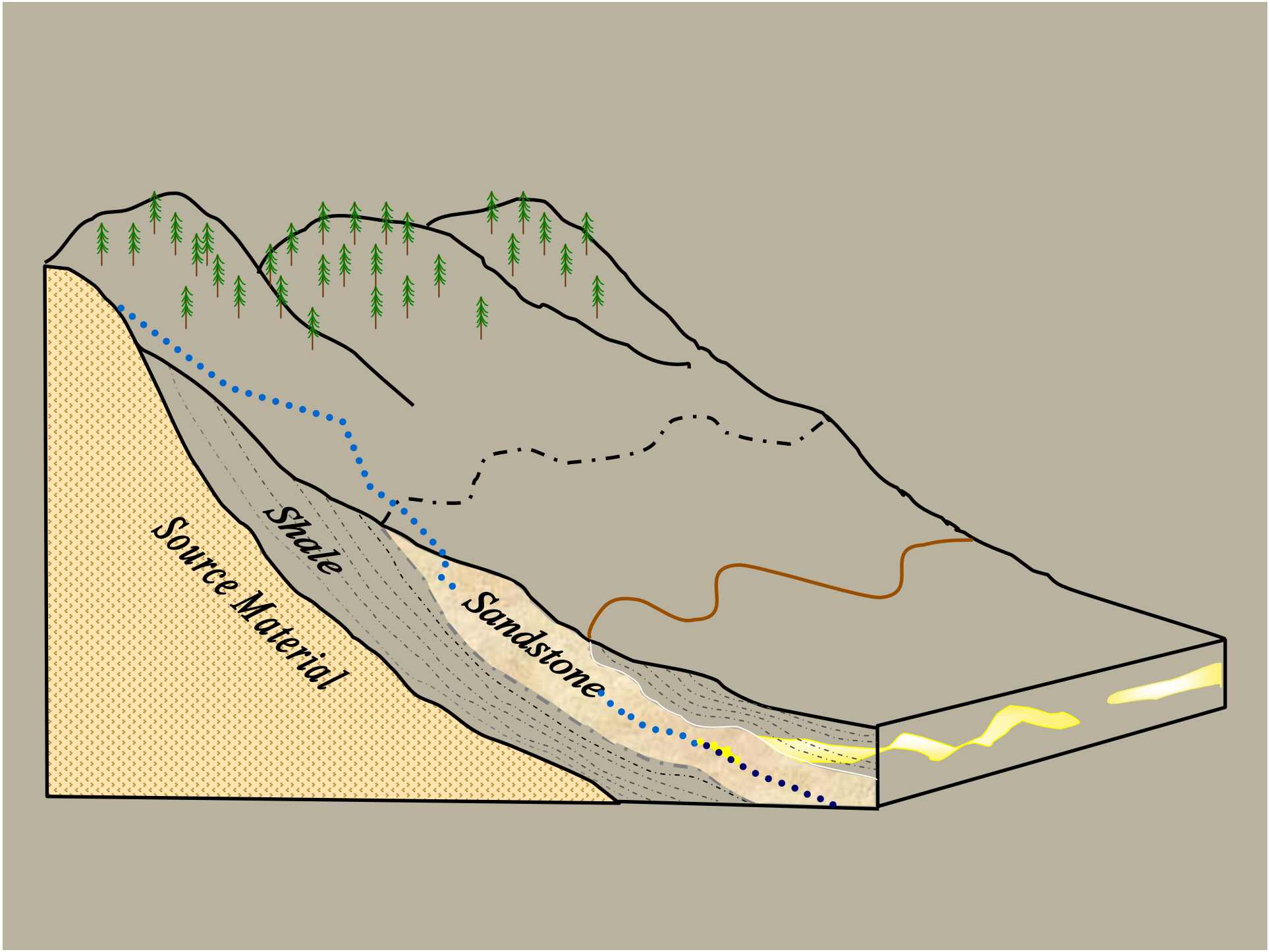
The Technical Situation - Deposition of Wyoming Uranium

Most uranium in Wyoming occurs in 'roll front' deposits in sandstone layers within sandstone/shale sequences in the major geologic basins (e.g. Powder River, Wind River, & Shirley Basins). The distribution of uranium & associated minerals (e.g., selenium) is due to oxidation & reduction conditions in the subsurface formations when the minerals were deposited.



Adapted from De Voto, R. H., 1978, Uranium Geology & Exploration, Lecture Notes & References, Colorado School of Mines, p.29.

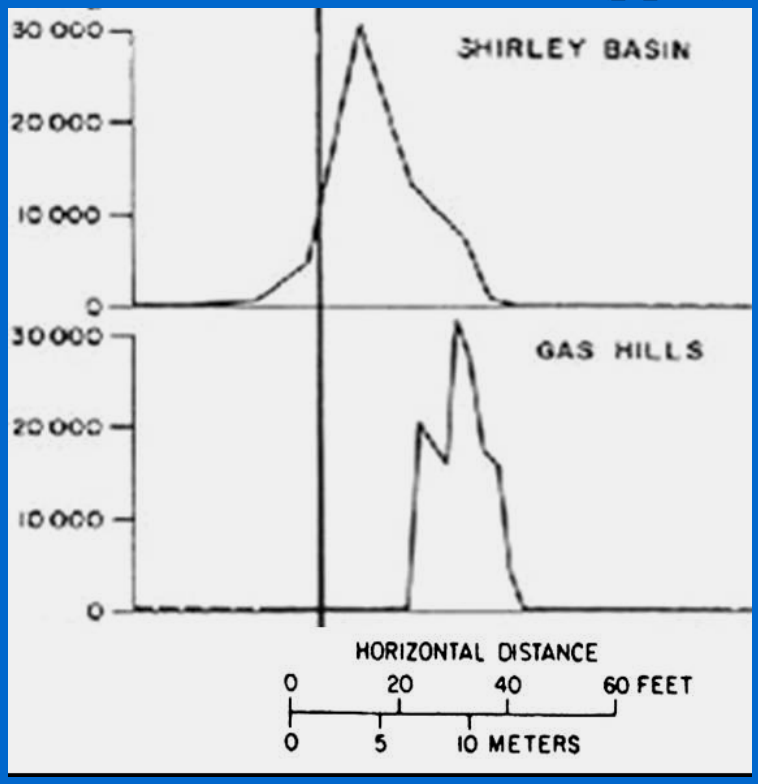
'Roll Front' Uranium Deposit in WY, http://www.wma-minelife.com/uranium.


Source Material
Shale
Sandstone

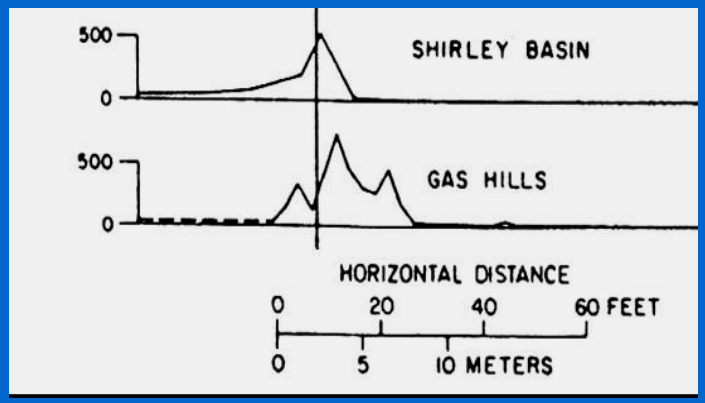
Therefore, Wyoming ore zones are generally long & narrow with sharp differences in ore concentrations ‘inside’ & ‘outside’ the ore zones.

But how is this reflected in the ground water quality?

Uranium in Sandstone (ppm)



Selenium in Sandstone (ppm)

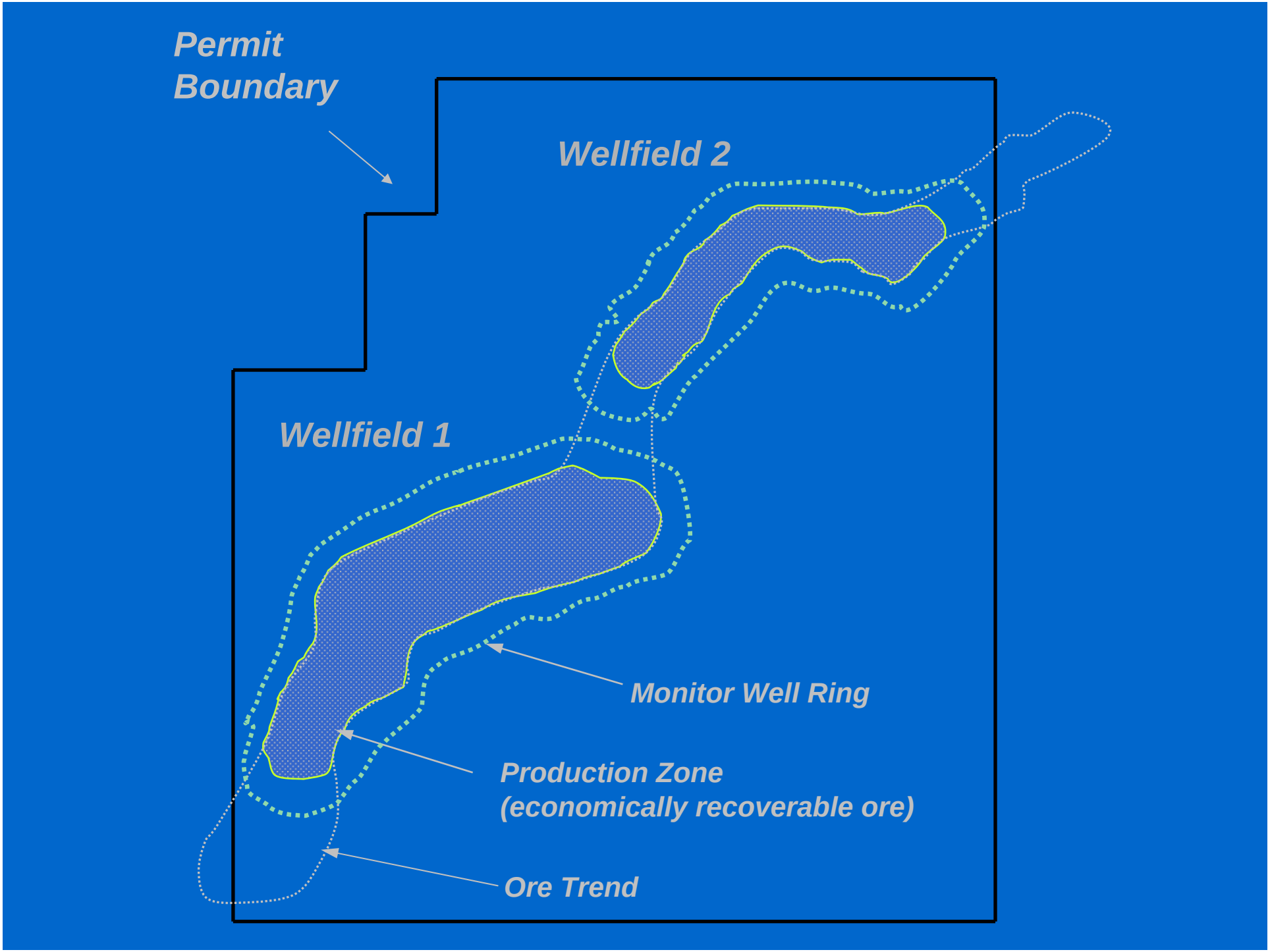


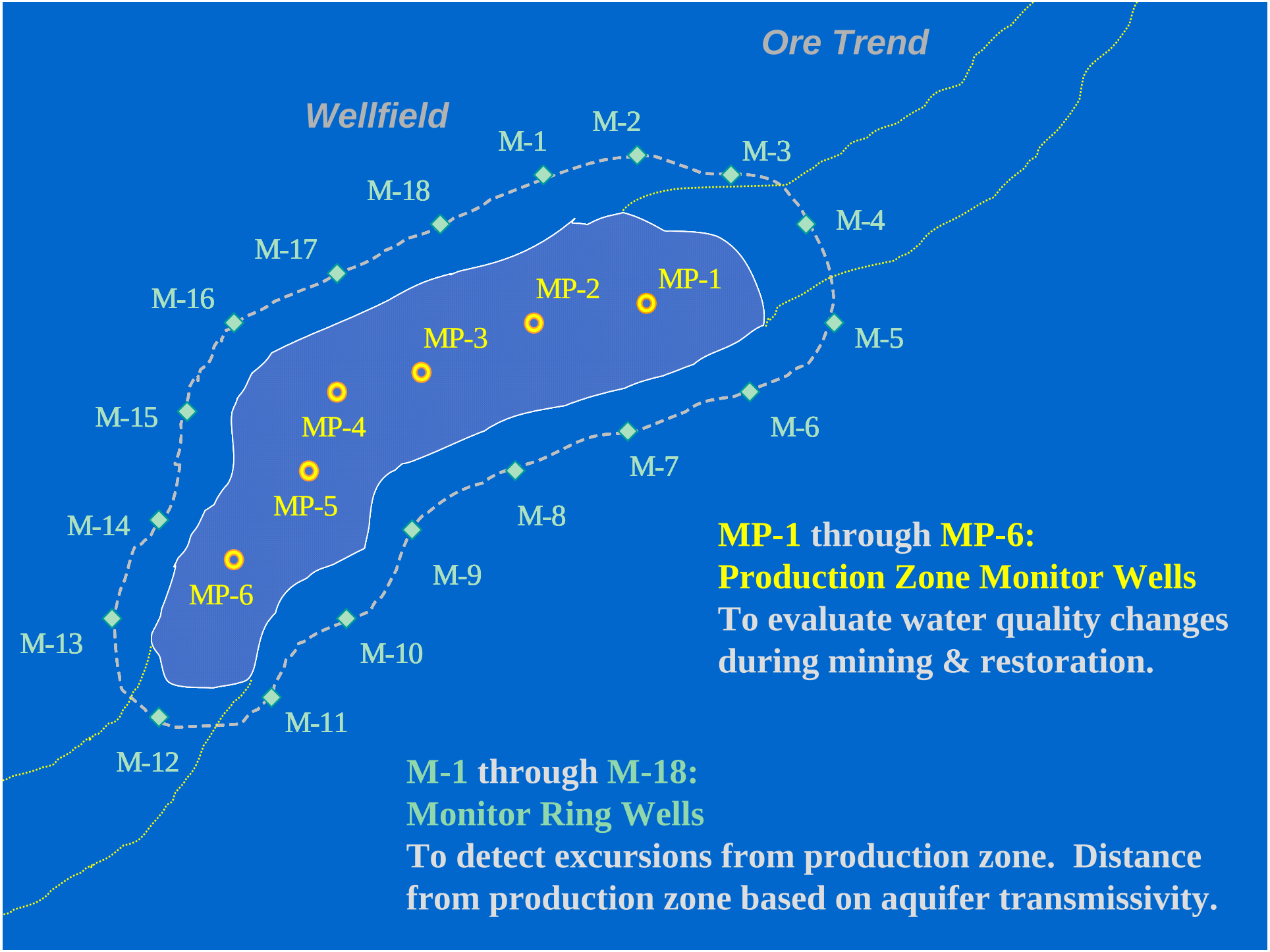
Adapted from E.N. Harshman, 1974, Distribution of elements in some roll-type uranium deposits, in Formation of Uranium Ore Deposits, International Atomic Energy Agency, pp.169-183.

Collection of Baseline Water Quality Data

For in situ mining, in addition to 'permit-wide' or regional baseline ground water quality data, *wellfield-specific* baseline water quality data must be collected prior to start-up of each wellfield.

The dimensions of each wellfield are generally selected by the operator based on what the operator considers to be *commercially producible* from an ore deposit. Therefore, an ore trend may extend beyond a wellfield boundary.


Permit Boundary
Wellfield 2
Wellfield 1
Monitor Well Ring
Production Zone
(economically recoverable ore)
Ore Trend


Ore Trend
Wellfield
M-1
M-2
M-3
M-4
M-5
M-6
M-7
M-8
M-9
M-10
M-11
M-12
M-13
M-14
M-15
M-16
M-17
M-18
MP-1
MP-2
MP-3
MP-4
MP-5
MP-6
MP-1 through MP-6:
Production Zone Monitor Wells
To evaluate water quality changes during mining & restoration.
M-1 through M-18:
Monitor Ring Wells
To detect excursions from production zone. Distance from production zone based on aquifer transmissivity.

Data Evaluated for this Study

Although the baseline water quality samples are analyzed for many parameters, only three were evaluated for this study due to time constraints:

- ✓ **TDS** — **(for general water quality)**
- ✓ **Uranium**
- ✓ **Radium**

(for relationship to ore distribution)

Power Resources, Inc. (PRI) Highlands, Erosion Fabric in F-Wellfield Drainage, 6/98, Quarterly Inspection.

Data Evaluated for this Study

The baseline data for these three parameters was compiled from nine wellfields (three wellfields from each of three mines). Some were older wellfields, some newer, and some were larger, some smaller.

PRI - Highlands, F-Wellfield, 2nd year in operation. 7/98, Quarterly Inspection.

Concentration 'Categories' for Evaluation

TDS

WQD ground water classification system

- LT 500 milligrams/liter (mg/l) - Class I (Domestic)
- 500 – 1,200 mg/l (highest value) - Class III (Livestock)

Uranium

EPA Maximum Contaminant Level (MCL)

- LT/GT 0.03 mg/l

Radium

EPA MCL & WQD classification

- LT 5 picoCuries/liter (pCi/l)
- 5 – 10 pCi/l
- 10 – 100 pCi/l
- GT 100 pCi/l – old WQD 'treatability' limit

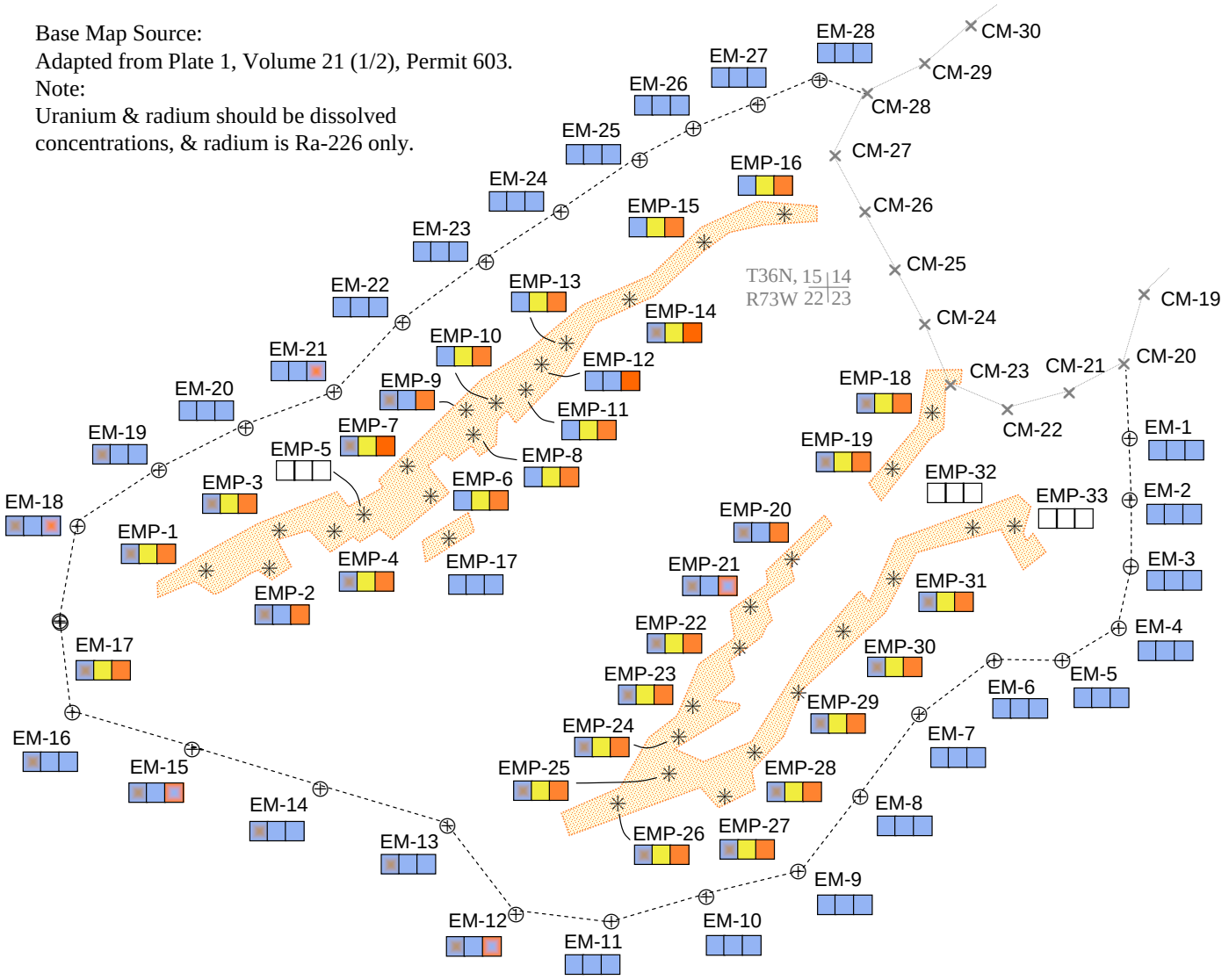
Range & Distribution of TDS, Uranium, & Radium

Some general observations:

- ✓ The distribution of uranium and radium follow the ore zone, but the distribution of TDS does not.
- ✓ The change in uranium and radium concentrations is abrupt from ‘outside’ to ‘inside’ the ore zone.
- ✓ The TDS range in a given wellfield is fairly narrow. The range of uranium and radium concentrations is much wider, particularly in the production zone.
- ✓ The concentrations of uranium and radium, even within the production zone, may not be as high as might be anticipated.

Examples from 3 of the 9 wellfields evaluated for this study....

Base Map Source:
Adapted from Plate 1, Volume 21 (1/2), Permit 603.
Note:
Uranium & radium should be dissolved concentrations, & radium is Ra-226 only.



Explanation

Monitor Well Rings

EM-28 — Wellfield "E" - Baseline Well Location & Number

CM-19 — Wellfield "C" - BaselineWell Location & Number

Production Zone

Pattern Area

EMP-28 — Baseline Monitor Well Location & Number

Baseline Water Quality

Radium (≤5, >5 ≤10, >10 ≤100, >100 pCi/l)

Uranium (≤0.03, >0.03 mg/l)

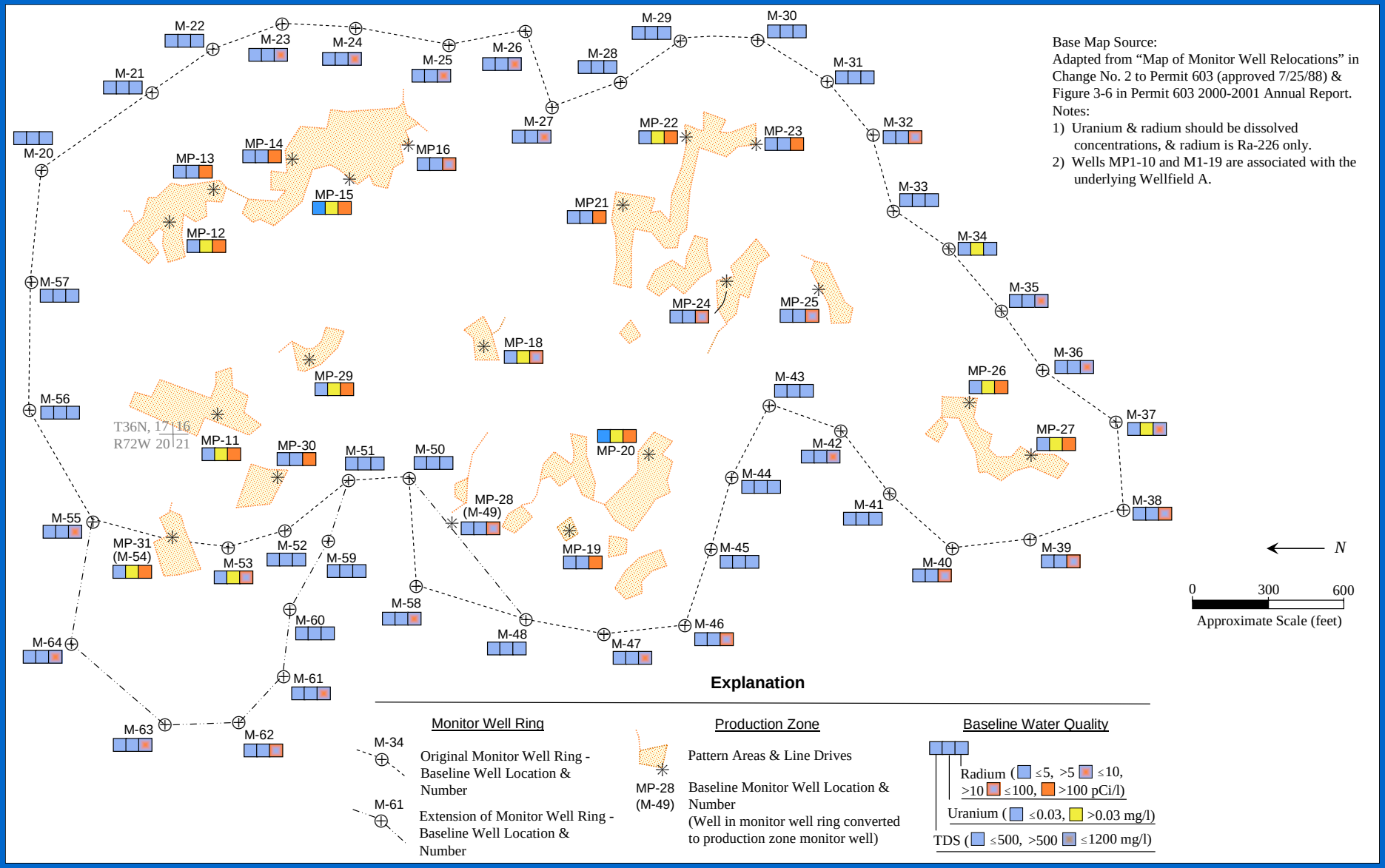
TDS (≤500, >500 ≤1200 mg/l)

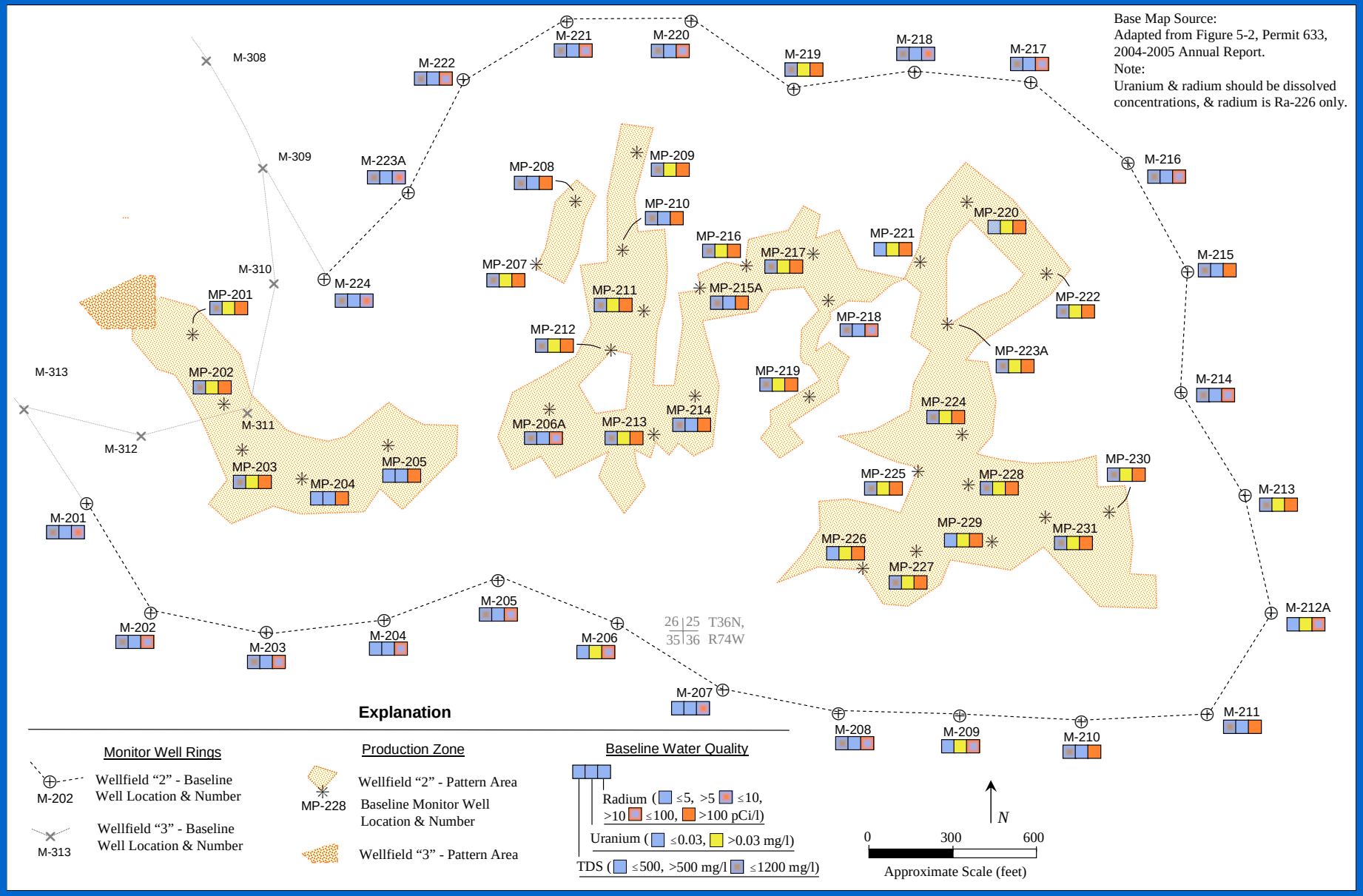
Well location found, but no water quality analyses found.

N

0 600 1200

Approximate Scale (feet)


M-22
M-23
M-24
M-25
M-26
M-27
M-28
M-29
M-30
M-31
M-32
M-33
M-34
M-35
M-36
M-37
M-38
M-39
M-40
M-41
M-42
M-43
M-44
M-45
M-46
M-47
M-48
M-49
M-50
M-51
M-52
M-53
M-54
M-55
M-56
M-57
M-58
M-59
M-60
M-61
M-62
M-63
M-64
M-20
M-21
MP-11
MP-12
MP-13
MP-14
MP-15
MP16
MP-18
MP-19
MP-20
MP21
MP-22
MP-23
MP-24
MP-25
MP-26
MP-27
MP-28 (M-49)
MP-29
MP-30
MP-31 (M-54)
T36N, R72W
17 16
20 21
Base Map Source:
Adapted from "Map of Monitor Well Relocations" in Change No. 2 to Permit 603 (approved 7/25/88) & Figure 3-6 in Permit 603 2000-2001 Annual Report.
Notes:
1) Uranium & radium should be dissolved concentrations, & radium is Ra-226 only.
2) Wells MP1-10 and M1-19 are associated with the underlying Wellfield A.
N
0
300
600
Approximate Scale (feet)
Explanation
Monitor Well Ring
M-34
Original Monitor Well Ring - Baseline Well Location & Number
M-61
Extension of Monitor Well Ring - Baseline Well Location & Number
Production Zone
Pattern Areas & Line Drives
MP-28 (M-49)
Baseline Monitor Well Location & Number
(Well in monitor well ring converted to production zone monitor well)
Baseline Water Quality
Radium (≤5, >5 ≤10, >10 ≤100, >100 pCi/l)
Uranium (≤0.03, >0.03 mg/l)
TDS (≤500, >500 ≤1200 mg/l)


Base Map Source:
Adapted from Figure 5-2, Permit 633, 2004-2005 Annual Report.
Note:
Uranium & radium should be dissolved concentrations, & radium is Ra-226 only.
M-308
M-309
M-310
M-311
M-312
M-313
M-201
M-202
M-203
M-204
M-205
M-206
M-207
M-208
M-209
M-210
M-211
M-212A
M-213
M-214
M-215
M-216
M-217
M-218
M-219
M-220
M-221
M-222
M-223A
M-224
MP-201
MP-202
MP-203
MP-204
MP-205
MP-206A
MP-207
MP-208
MP-209
MP-210
MP-211
MP-212
MP-213
MP-214
MP-215A
MP-216
MP-217
MP-218
MP-219
MP-220
MP-221
MP-222
MP-223A
MP-224
MP-225
MP-226
MP-227
MP-228
MP-229
MP-230
MP-231
26 25 T36N,
35 36 R74W
Explanation
Monitor Well Rings
M-202
Wellfield "2" - Baseline Well Location & Number
M-313
Wellfield "3" - Baseline Well Location & Number
Production Zone
MP-228
Wellfield "2" - Pattern Area
Baseline Monitor Well Location & Number
Wellfield "3" - Pattern Area
Baseline Water Quality
Radium (≤5, >5 ≤10, >10 ≤100, >100 pCi/l)
Uranium (≤0.03, >0.03 mg/l)
TDS (≤500, >500 mg/l ≤1200 mg/l)
N
0
300
600
Approximate Scale (feet)

Statistical Analyses

Box & Whisker Plots of TDS & Uranium

- ✓ Selected for visual & statistical comparison of the medians.
- ✓ Under normal circumstances, data from wells in the monitor ring are not grouped because of the variation in water quality.

Frequency Plots of Radium

- ✓ Selected because of the substantial changes in concentrations over short distances and to better illustrate the distribution.

Statistical Analyses (Box & Whisker Plots)

The *water quality differences* between the wells in the production zone & those in the monitor ring:

TDS - were significant in 4 of the 9 wellfields (and only 3 of 9 if the original wellfield is considered), but those differences are hard to see visually.

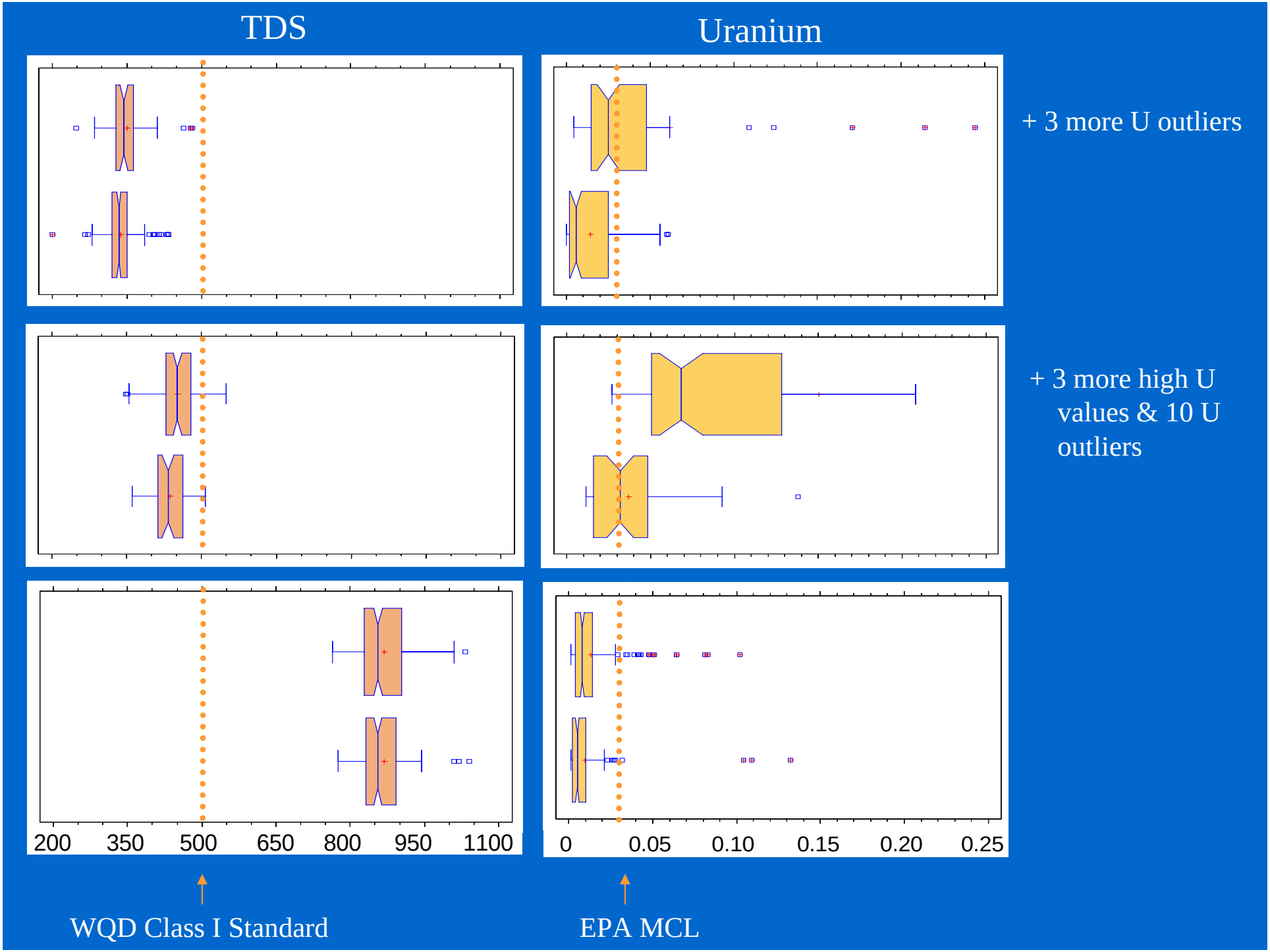
Uranium - were significant in all 9 wellfields, and the differences were generally easy to see.

The *magnitude* of the concentrations:

TDS - were below 500 mg/l with the exception of two wellfields above 500 mg/l and one straddling the mark.

Uranium - were 'all over the map'.

Examples from 3 of the 9 wellfields evaluated for this study....

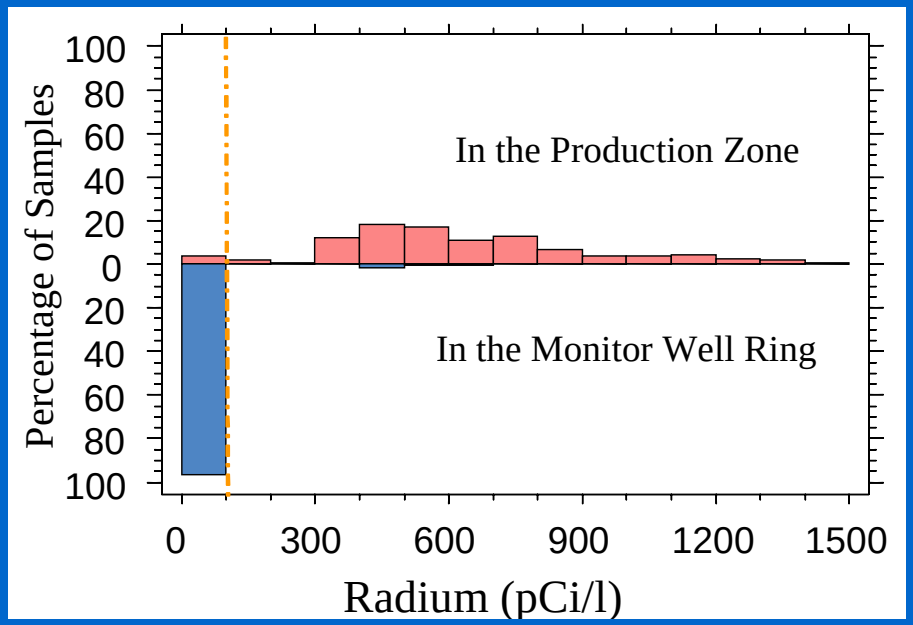

TDS
Uranium
+ 3 more U outliers
+ 3 more high U values & 10 U outliers
200
350
500
650
800
950
1100
0
0.05
0.10
0.15
0.20
0.25
WQD Class I Standard
EPA MCL

Statistical Analyses (Frequency Graphs)

- ✓ In all nine production zones, the vast majority of the baseline radium concentrations exceeded 100 pCi/l.

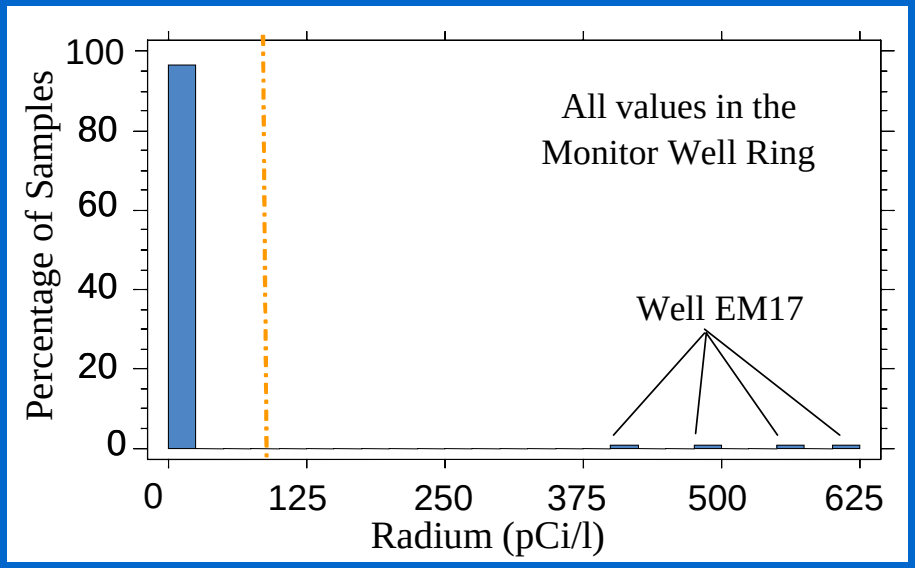
- ✓ In all but one of the monitor rings,
  - The vast majority of the baseline radium concentrations were less than 10 pCi/l, and over half were less than 5 pCi/l; and
  - Any elevated radium concentrations were generally from one well.

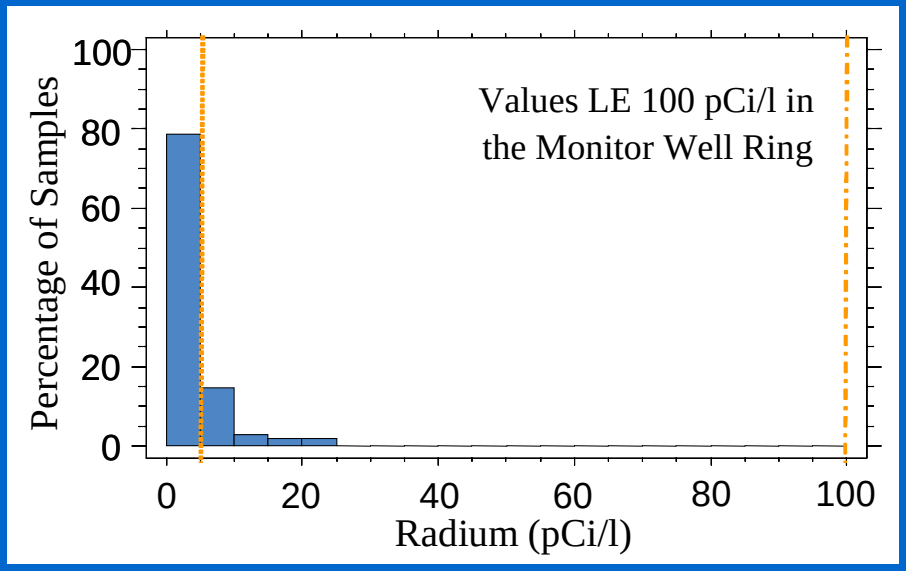
Examples from 3 of the 9 wellfields evaluated for this study....

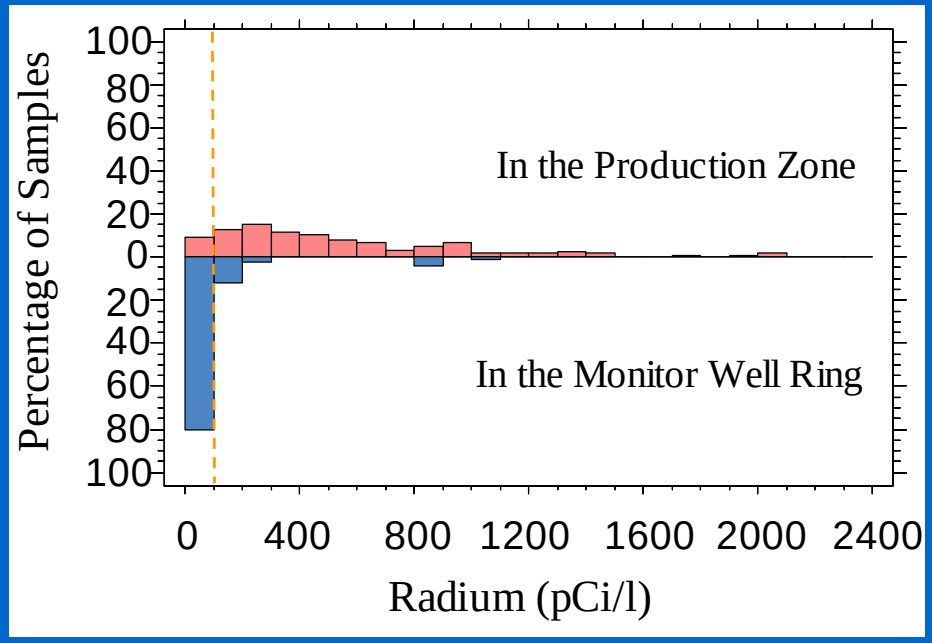


The dashed line at 100 pCi/l represents the former 'treatability limit' for radium per WQD Chapter 8 rules for Class I - Domestic ground water.

The dotted line at 5 pCi/l represents the EPA drinking water standard & the upper limit for Class I - Domestic & Class III - Livestock ground water in WY for radium-226 & 228.

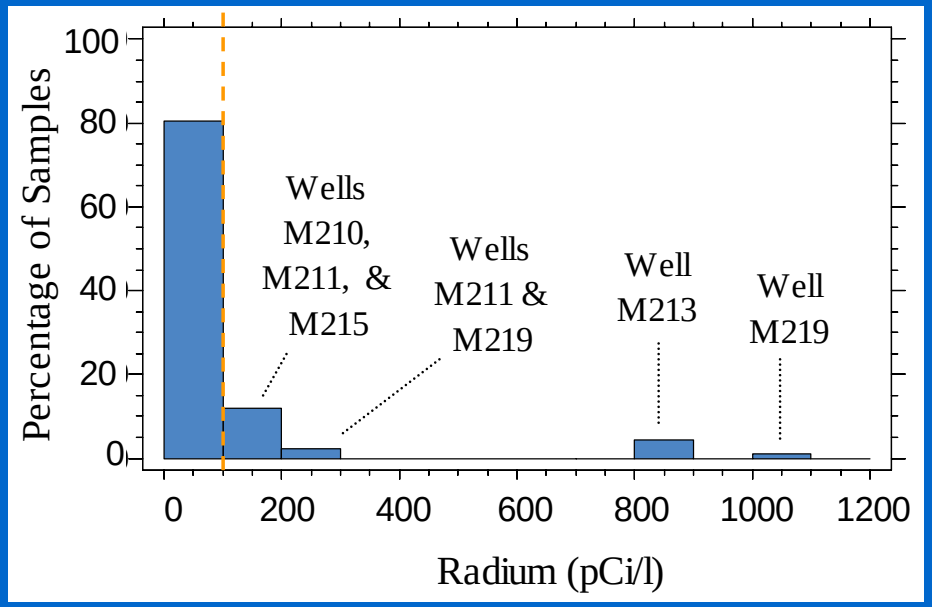


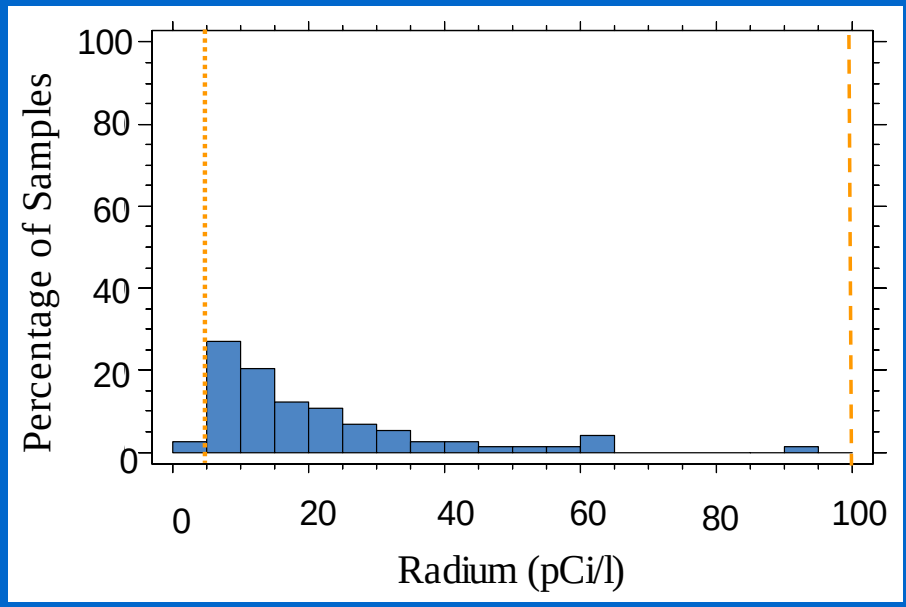


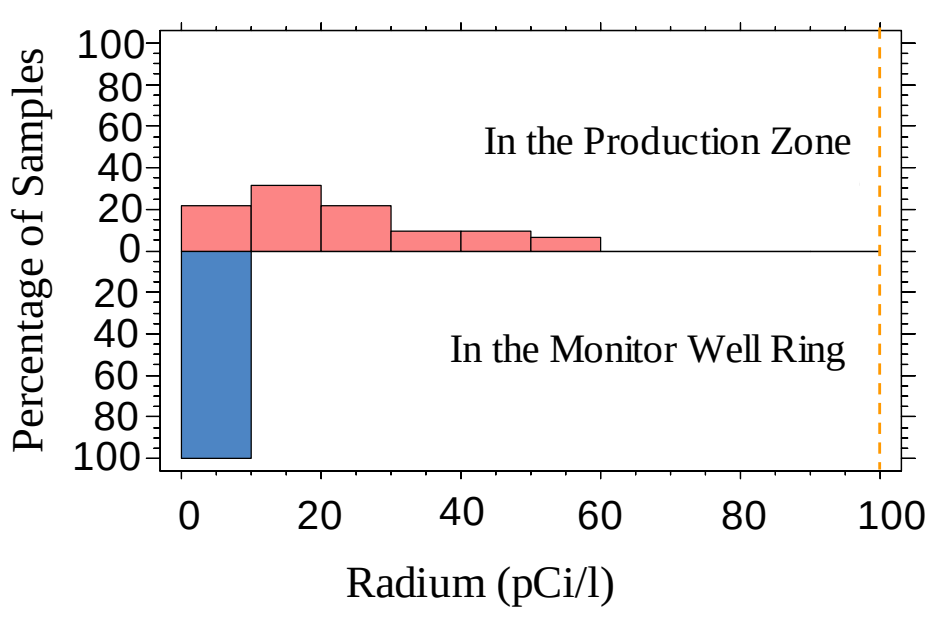


The dashed line at 100 pCi/l represents the former 'treatability limit' for radium per WQD Chapter 8 rules for Class I - Domestic ground water.

The dotted line at 5 pCi/l represents the EPA drinking water standard & the upper limit for Class I - Domestic & Class III - Livestock ground water in WY for radium-226 & 228.



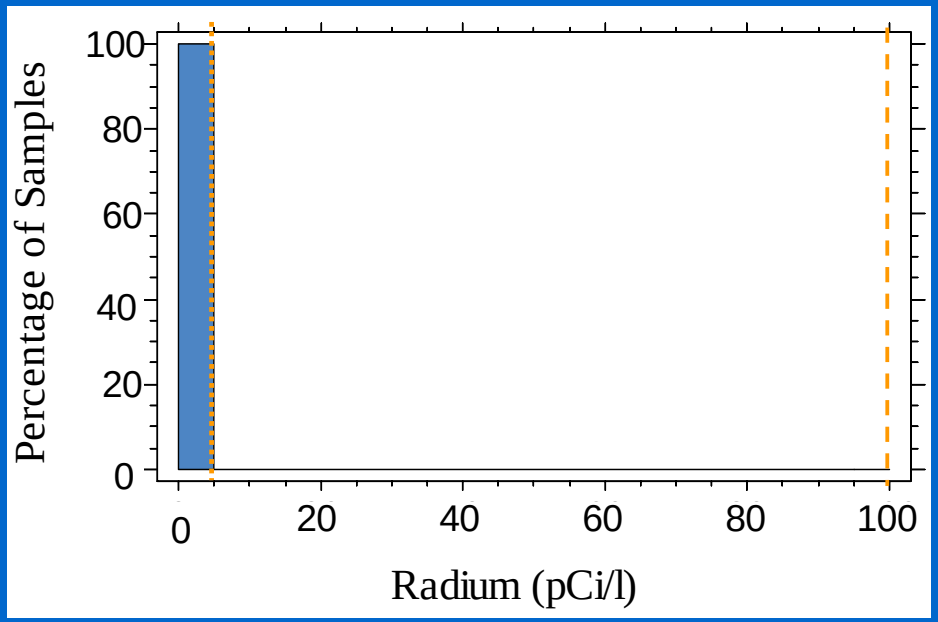




The dashed line at 100 pCi/l represents the former 'treatability limit' for radium per WQD Chapter 8 rules for Class I - Domestic ground water.

The dotted line at 5 pCi/l represents the EPA drinking water standard & the upper limit for Class I - Domestic & Class III - Livestock ground water in WY for radium-226 & 228.

None of the values from this monitor well ring exceed 100 pCi/l.



The Regulatory Situation

The Players:

Water Quality

Federal

EPA

NRC

State

WDEQ

Water Quantity

State

SEO

PRI - Smith Ranch, 5/02

All three agencies with water quality regulations (EPA, NRC, & WDEQ) have different approaches to ground water restoration & rely on the baseline water quality data in different ways….

PRI - Smith Ranch,
Wellfield 4 Pilot Holes,
12/98, Quarterly Inspection.

WDEQ

W.S. § 35-11-103(f) - restoration requirements for in situ mining. Requires protection for all uses for which water was suitable prior to mining. Best practicable technology also defined. WQD ground water classification system used to determine suitability. See also LQD NonCoal Rules, Ch. 11, Sec. 5(a)(ii).

EPA

40 CFR 146.3, & 11 - Injection into aquifer that could serve as Underground Source of Drinking Water (USDW) prohibited unless portion of aquifer can be exempted. In Wyoming, applicable exemption is usually that aquifer is mineral producing. EPA can require restoration of exempted portion to protect adjacent portions of aquifer & does require restoration of exempted portion on Indian Lands, but more stringent requirements generally left to states. EPA does require that USDWs next to exempted portion not be adversely impacted by residual water quality in exempted portion.

NRC

NUREG 1569 - Sec. 6.1.3(4): (a) primary goal - baseline; (b) 2ndary goal - class of use; (c) - protective of public health & safety, environment, & adjacent water. Changing with rule-making?

Water Quality Testing

The parameters which distinguish the ore zone water quality are not parameters for which wells are commonly tested. In fact, there is no requirement that owners of 'individual' wells, who may use wells for domestic and/or stock purposes, test their wells for any parameters. There may often be a suggested list of parameters, but it may or may not include parameters of interest to uranium mine operators (e.g., uranium, radium, & radon).

PRI - Highlands (south of Satellite No.2), Windmill used for livestock supply, 2/99, Quarterly Inspection.

Water Quality Testing

These ‘individual’ wells provide essential water sources on many of the more than 9,000 farms and ranches (not to mention ranchettes) in Wyoming, including those in the areas where uranium mines are located. Plus new water users (e.g., CBM) are arriving.

‘Negley’ Subdivision near area of LQD Permit 522, 1980s.

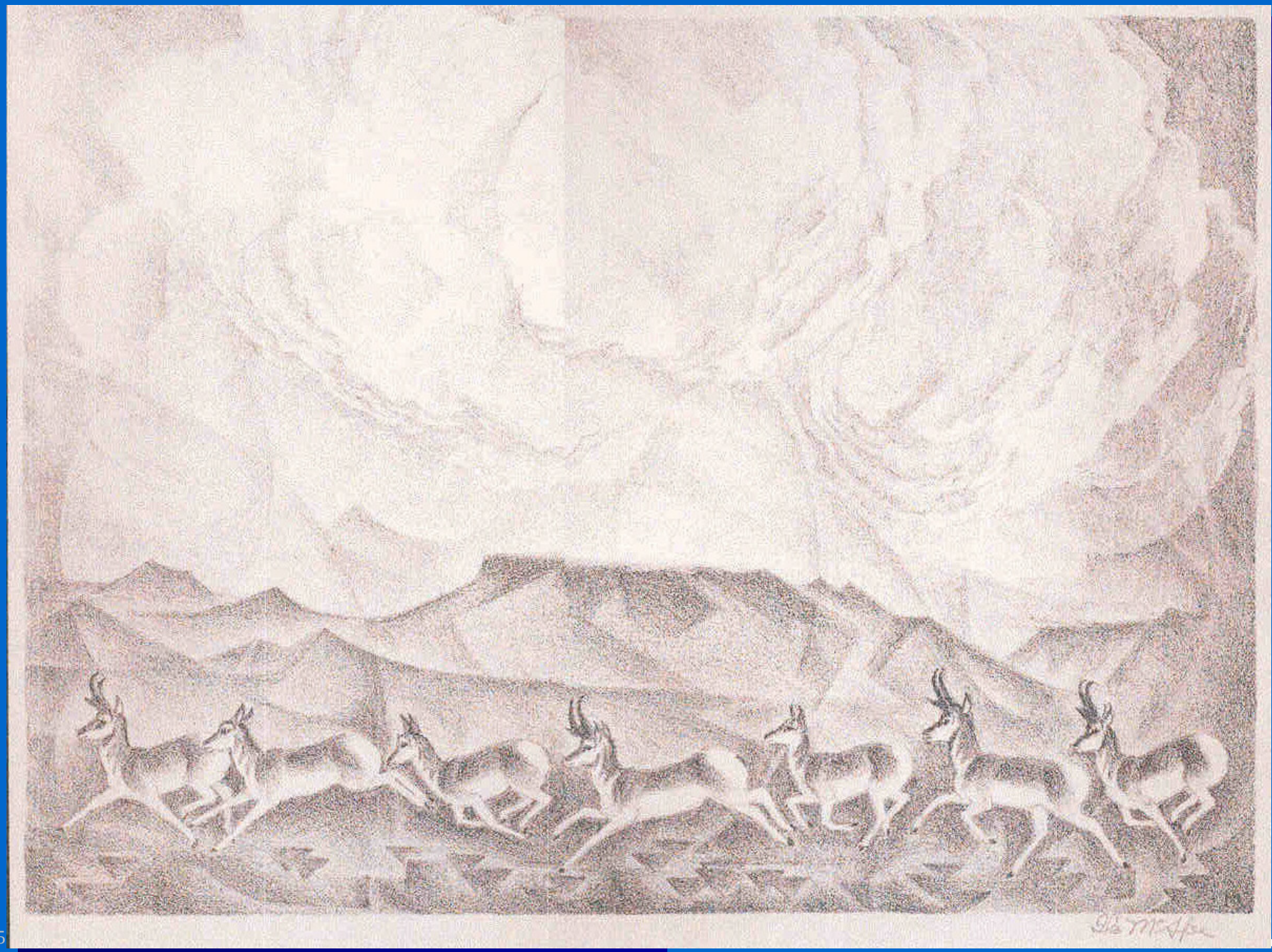
Questions

Do the water quality results vary by uranium mineral assemblages?

Will the results be the same if additional wellfield data is included?

How does water quality at a given location compare to ore percentage?

Best way to ensure baseline data, restoration technology, & regulations stay tied together?



RH
05/05