Pathway for Recovering Valuable Elements Of Interest from Subsurface Brines and Oilfield Produced Waters

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Presentation Outline

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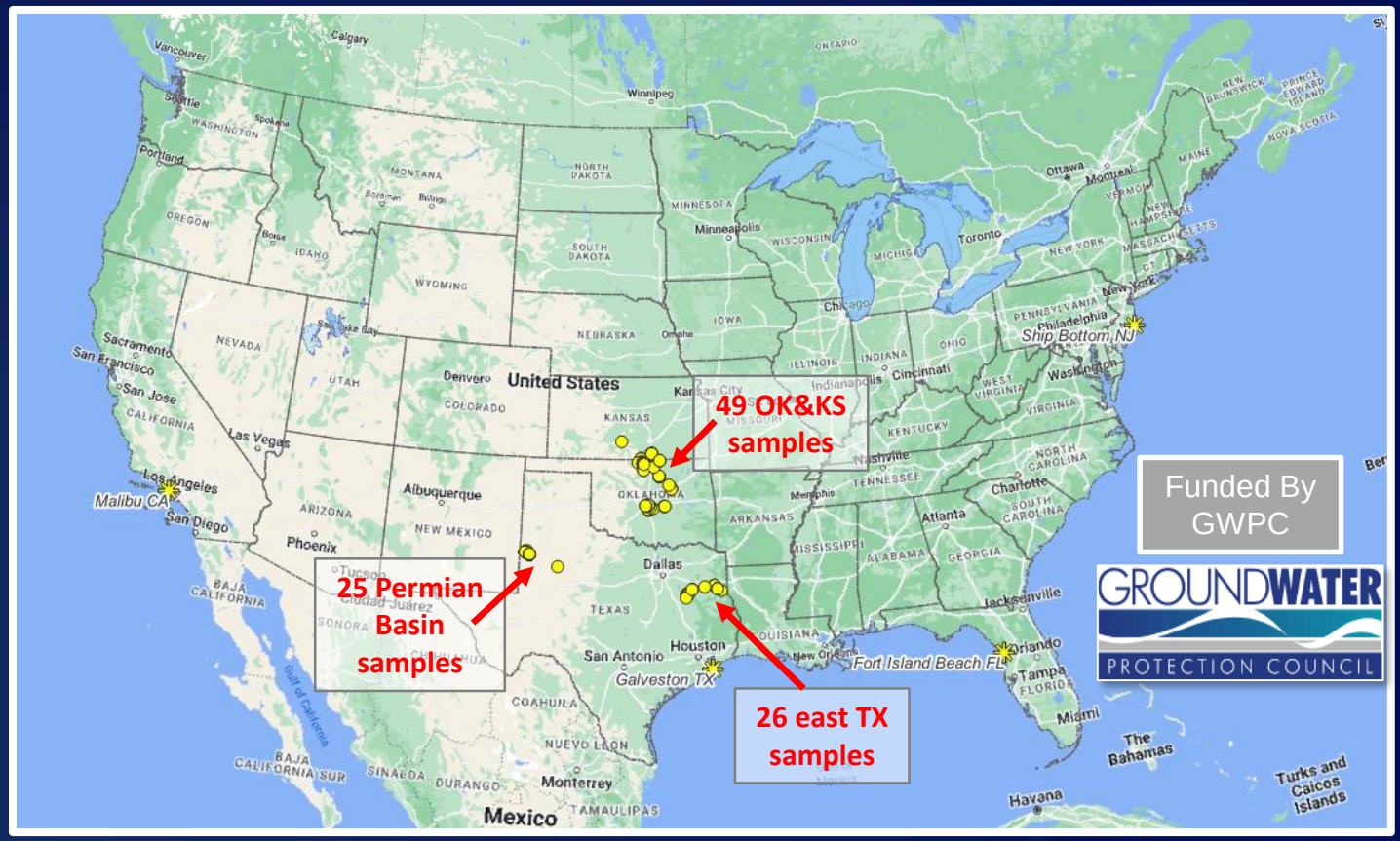
- Pathway for Recovering EOI from Produced Water (PW)
- Introduction to Gross Values (GV)
- GV Case Study: Permian Basin
- GV Case Study: Well OK 005



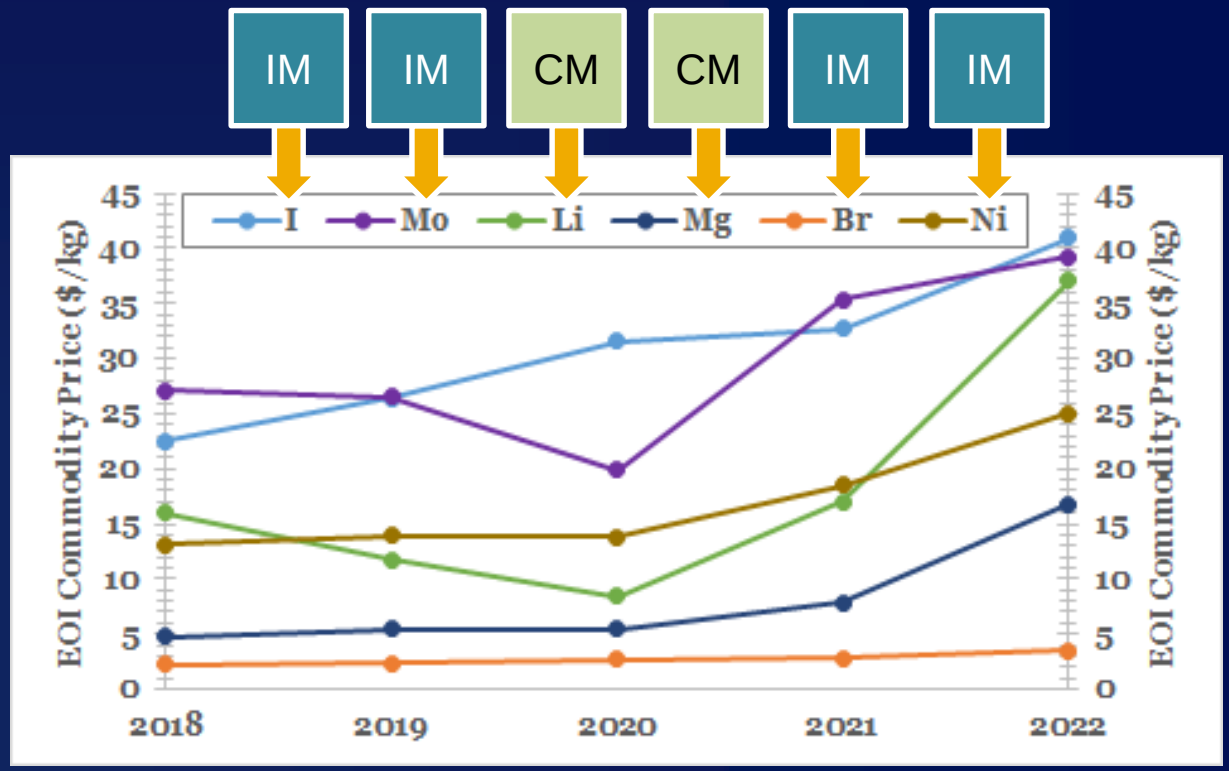
Motivation

***Critical Minerals (CM)* are elements that are critical to the U.S. economic and national security because they have important uses, no viable substitutes, are mostly imported, and face potential disruption in supply.**

Mineral commodities are vital for economic growth, improving the quality of life, providing for national defense, and the overall functioning of modern society. Minerals are being used in larger quantities than ever before and in an increasingly diverse range of applications— from telecommunications (cell phones and computers), to renewable-energy generation (wind turbines, solar photovoltaics, and fuel cells), to clean forms of transportation (electric and hybrid cars).

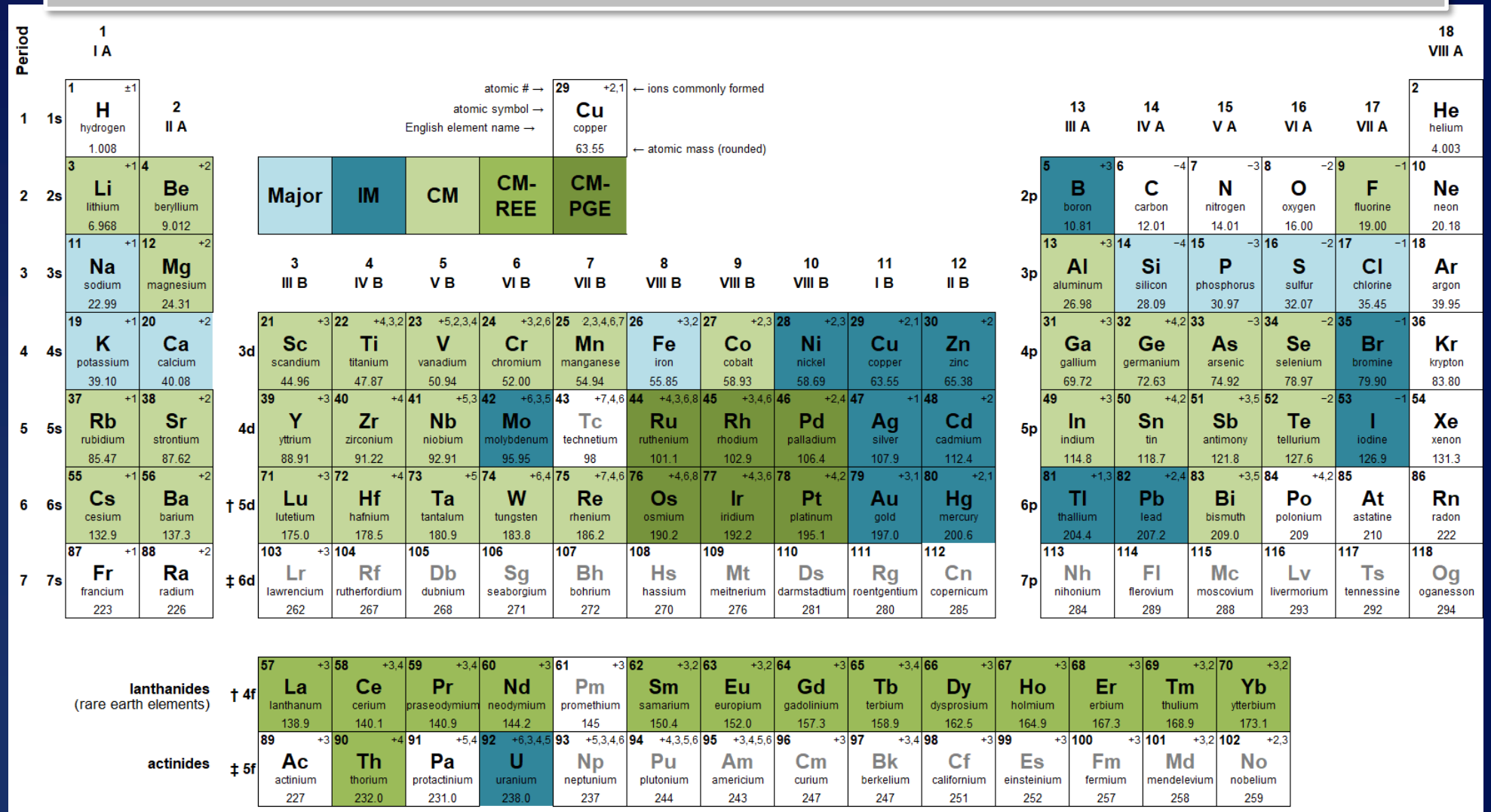
USGS Professional Paper 1802, 2017
American Critical Mineral Independence Act of 2021
American Critical Mineral Exploration and Innovation Act

IM = Industrial Minerals

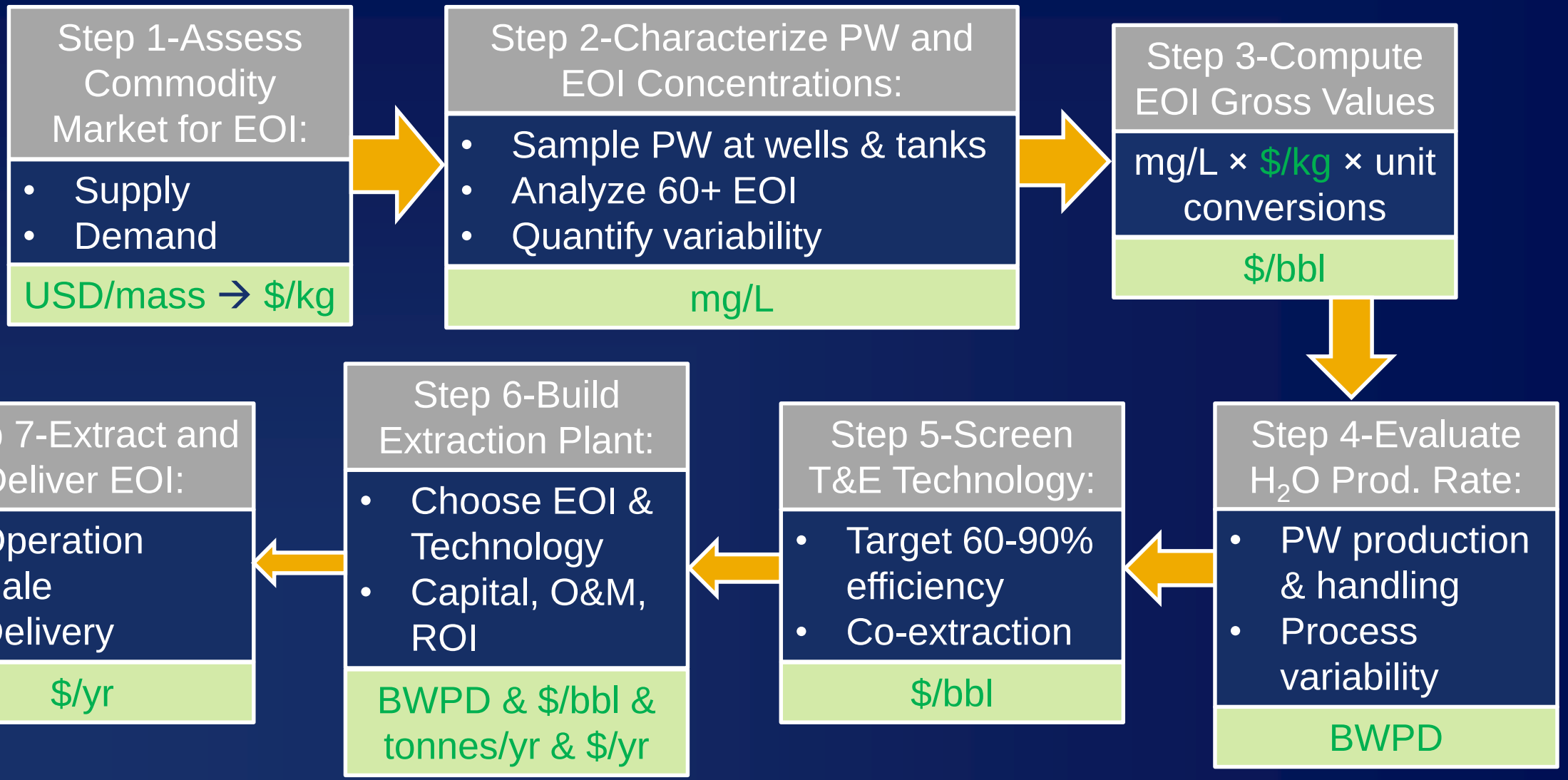


What are Elements of Interest (EOI)?

Elements of Interest (EOI) are elements that may be economically recovered from waters or solid wastes (i.e., $ value > $ extraction cost) .

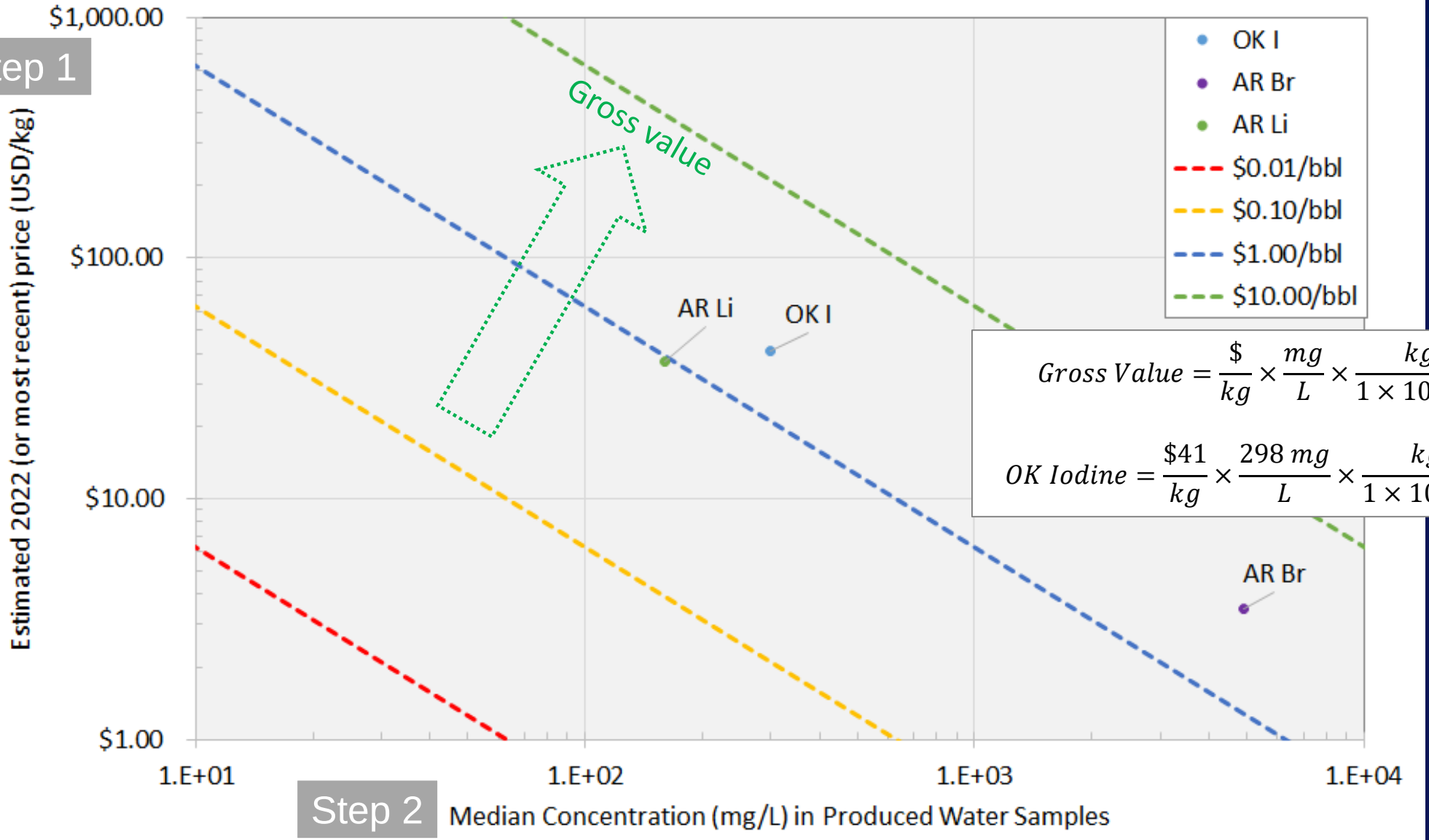


Pathway for Recovering EOI from Subsurface Brines and Oilfield Produced Waters



Introduction to Gross Values (GV) of EOI

Step 1



Step 2

$$Gross\ Value = \frac{\$}{kg} \times \frac{mg}{L} \times \frac{kg}{1 \times 10^6 mg} \times \frac{158.987\ L}{bbl} = \frac{\$}{bbl}$$

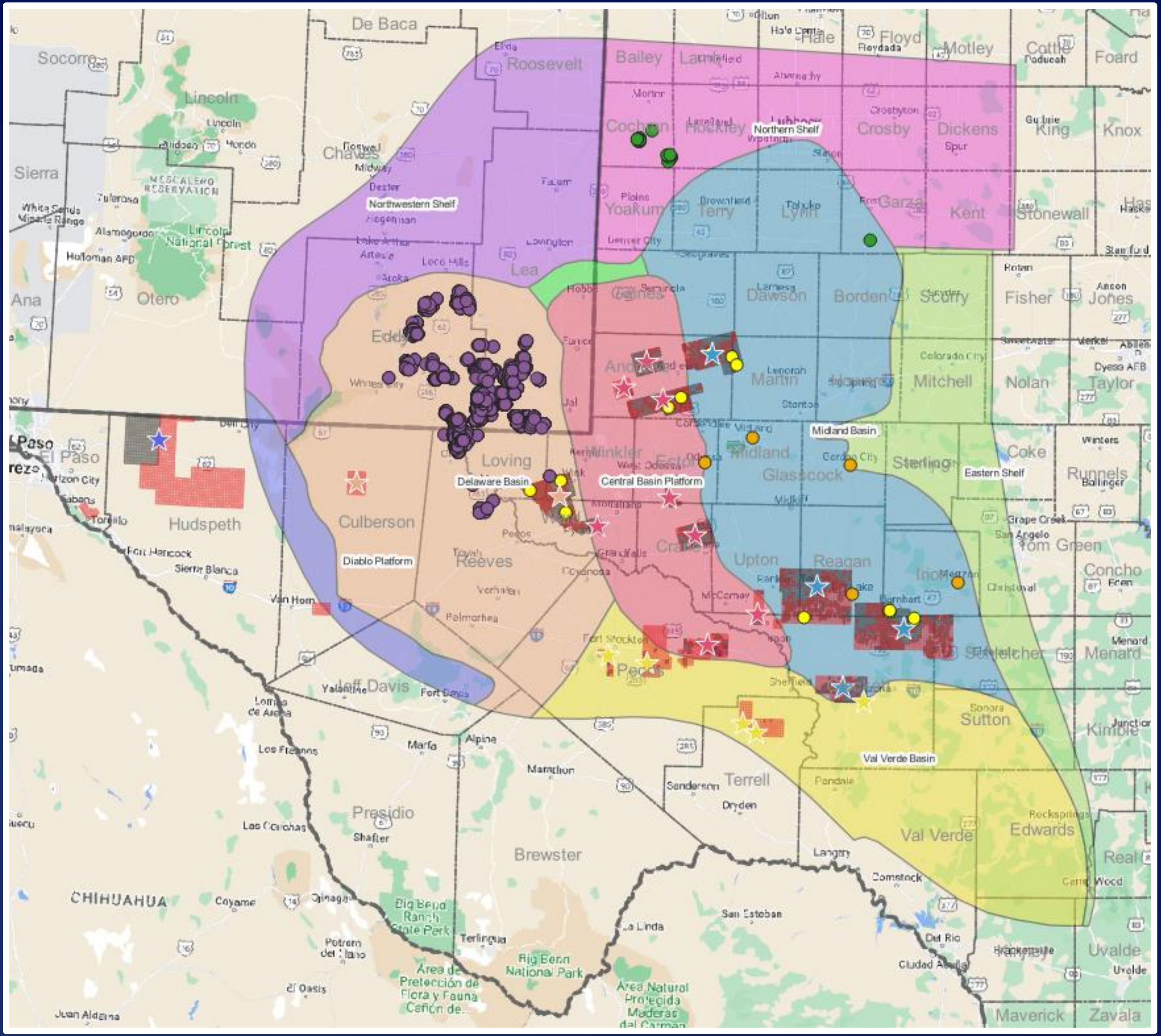
$$OK\ Iodine = \frac{\$41}{kg} \times \frac{298\ mg}{L} \times \frac{kg}{1 \times 10^6 mg} \times \frac{158.987\ L}{bbl} = \frac{\$1.94}{bbl}$$

Step 3

Case Study: MGC and other EOI Data in PB

Murray GeoConsulting, LLC

- MGC samples
- TXULproposed
  - ✓ Central Basin Platform
  - ✓ Delaware Basin
  - ✓ Diablo Platform
  - ✓ Midland Basin
  - ✓ Val Verde Basin
  - ✓
- TXULsamples
- Proprietary Data
- Quillinan Samples
- AvailableParcels
- OG_Lease
- Permian Sub Basins
  - ✓ Central Basin Platform
  - ✓ Delaware Basin
  - ✓ Diablo Platform
  - ✓ Eastern Shelf
  - ✓ Midland Basin
  - ✓ Northern Shelf
  - ✓ Northwestern Shelf
  - ✓ San Simon Channel
  - ✓ Val Verde Basin

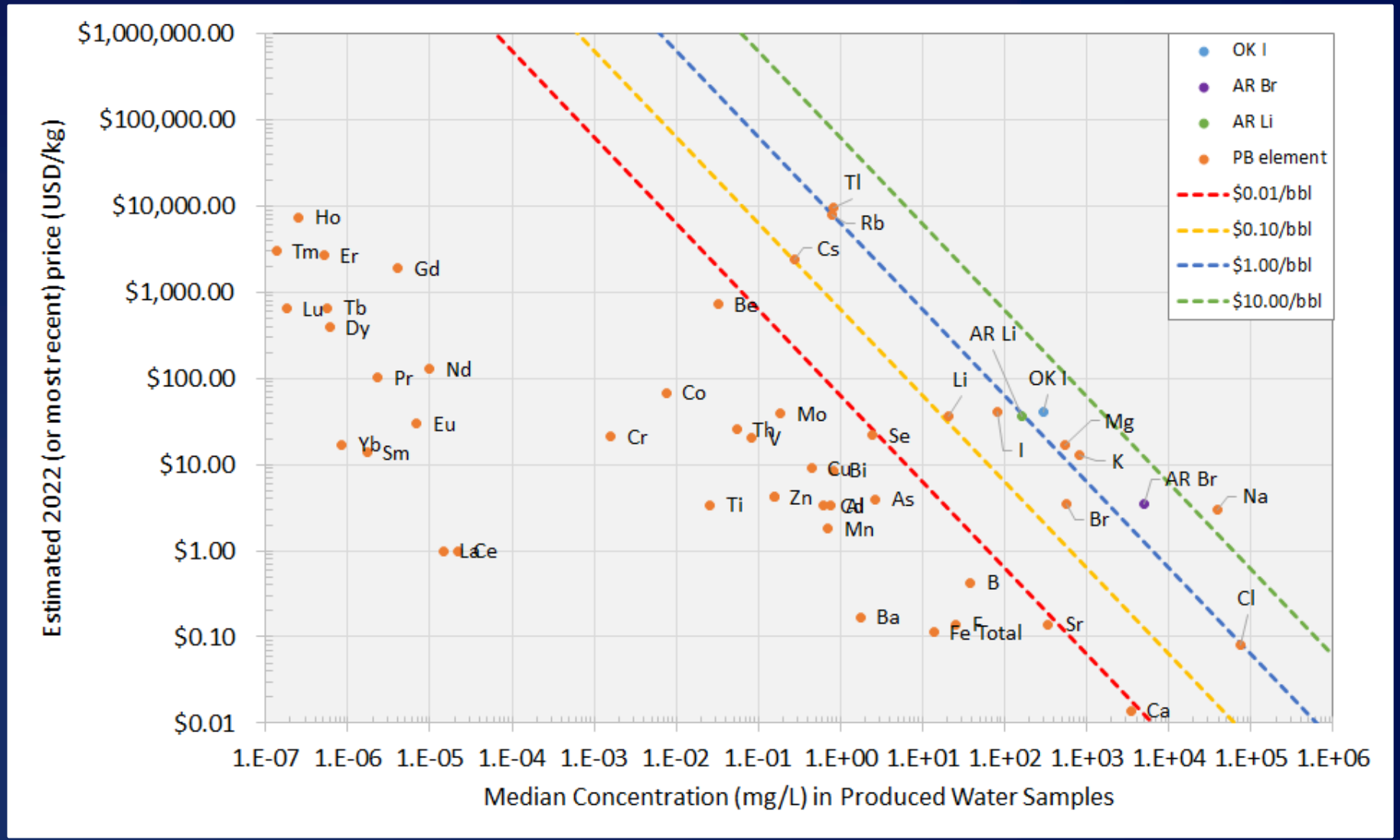


Case Study: 60+ EOI in Permian Basin

- 61 samples in the Permian Basin
- Top 5 highest priced elements detected (Tl, Rb, Ho, Tm, Cs, Be).
- Top 5 highest gross value elements (Na, K, Mg, Tl, Rb)

Cesium (Ce), Erbium (Er), Holmium (Ho), Rubidium (Rb), Scandium (Sc), Tellerium (Te), Thallium (Tl), Thulium (Tm)

Data from Jiang et al. (2022); Quillinan et al. (2018); Murray (2021-unpublished)



Example for Well OK 005

		Step 1		Step 2	Step 3
EOI	EOI name	$/kg in 2022		OK 005 mg/L	EOI Gross Value $/bbl
Al	Aluminum	$	3.31	1.4	$ 0.001
B	Boron	$	0.43	11.9	$ 0.001
Ba	Barium	$	0.17	3.5	$ 0.000
Br	Bromide	$	3.50	996.0	$ 0.554
Ca	Calcium	$	0.01	19580.0	$ 0.044
Cd	Cadmium	$	3.30	0.001	$ 0.000
Cl	Chloride	$	0.08	176,000	$ 2.295
Co	Cobalt	$	68.34	0.0014	$ 0.000
Cr	Chromium	$	21.00	0.0080	$ 0.000
Cs	Cesium	$	2,394.00	0.0666	$ 0.025
Cu	Copper	$	9.04	0.0200	$ 0.000
Eu	Europium	$	30.00	0.0002	$ 0.000
F	Fluoride	$	0.14	4.90	$ 0.000
Fe Total	Iron	$	0.11	18.8	$ 0.000
Ga	Gallium	$	640.00	0.0020	$ 0.000
I	Iodide	$	41.00	71.80	$ 0.468
In	Indium	$	250.00	0.0006	$ 0.000
K	Potassium	$	12.85	992.00	$ 2.027
La	Lanthanum	$	1.00	0.0003	$ 0.000
Li	Lithium	$	37.00	13.8	$ 0.081
Mg	Magnesium	$	16.76	2520.0	$ 6.713
Mn	Manganese	$	1.82	4.3	$ 0.001
Mo	Molybdenum	$	39.25	0.0040	$ 0.000
Na	Sodium	$	3.00	73000	$ 34.818
Ni	Nickel	$	25.00	0.0120	$ 0.000
Rb	Rubidium	$	7,770.00	1.9080	$ 2.357
Sb	Antimony	$	13.89	0.0002	$ 0.000
Sc	Scandium	$	137,000.00	0.0080	$ 0.174
Se	Selenium	$	22.05	2.7600	$ 0.010
Sr	Strontium	$	0.14	1470.0	$ 0.033
Te	Tellerium	$	2,000.00	0.0200	$ 0.006
Tl	Thallium	$	9,400.00	0.0043	$ 0.006
Y	Yttrium	$	43.00	0.0026	$ 0.000
Zn	Zinc	$	4.19	0.2460	$ 0.000
				Total Gross Value	$ 49.615
				Economically Feasible	$ 47.063

- Step 1: Assess Commodity Market for EOI ($/kg)
- Step 2: Characterize PW and EOI Concentrations (mg/L)
- Step 3: Compute EOI Gross Values ($/bbl)
- Step 4: Evaluate PW Rate (BWPD)

Step 4

vol. prod. rate	units	$/unit	$/day
BWPD	700	$ 49.61	$ 34,730.44
BOPD	106	$ 100.00	$ 10,600.00
MCFPD	126	$ 7.90	$ 995.40

In this example, Well OK 005, the gross value of the EOI in the produced water exceeds the value of the oil and gas.

BWPD = barrels of water per day

BOPD = barrels of oil per day

MCFPD = 1000s of cubic feet of gas per day

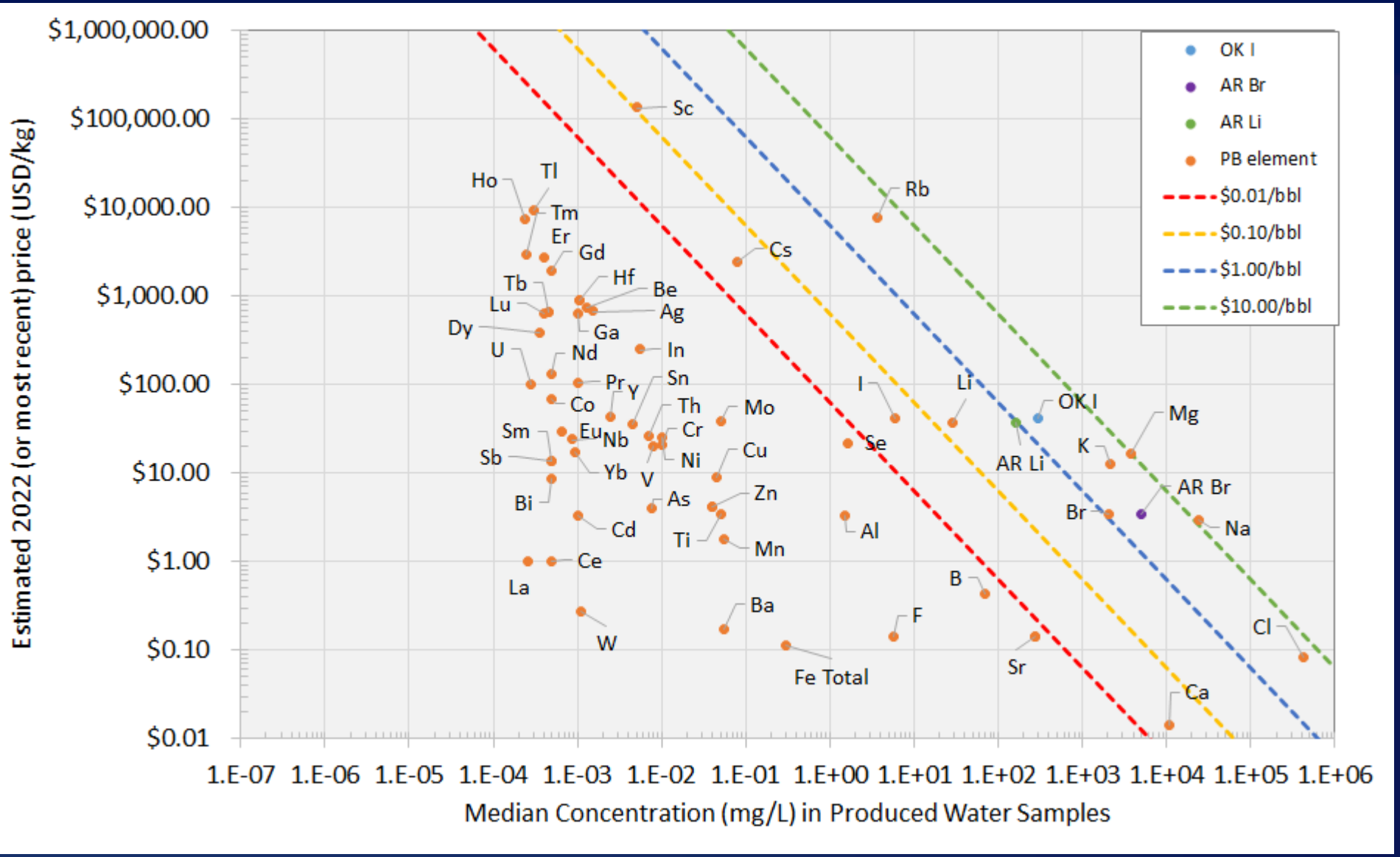
Frequently Asked Questions

1. What type of water analysis does MGC provide?
   - Over 60 Elements of Interest (EOI)
   - Low detection limits
2. What type of samples do you need and where should we take them?
   - Water that is gravity separated from oil – produced water, SWD water, or solids
   - From locations where individual producing wells and formations can be discerned
3. How much does it cost for analysis?
   - With “local” travel, sampling & lab costs are about $600 per sample for 60+ EOI
   - Data evaluation and resource assessment is ≥ $600 per sample
4. What do we get for deliverables from the analysis?
   - Presentation and report showing concentrations (mg/L) for 60+ EOI, gross values ($/bbl) per EOI, per well, per formation, per play, and EOI yield ($/day)
   - Recommendations for prospecting or extraction plant development
5. What are the next steps after the analysis is done? (this could be Step 1)
   - Use your data along with MGC data to complete an Exploratory Data Analysis (EDA) to prospect for “enriched brines” per EOI, per well, per formation, per play
   - Targeted sampling after EDA

Collaboration with Operators

1. Agree on well access, data sharing/publication or confidentiality
2. Coordinate with MGC to sample from producing or SWD wells, or solids/sludge
3. Support costs for EOI sampling and analyses
4. Share info with MGC for producing formation and water vs. oil production rates
5. Provide other relevant data (e.g., produced water quality data)

Case Studies: 60+ EOI in Permian Basin

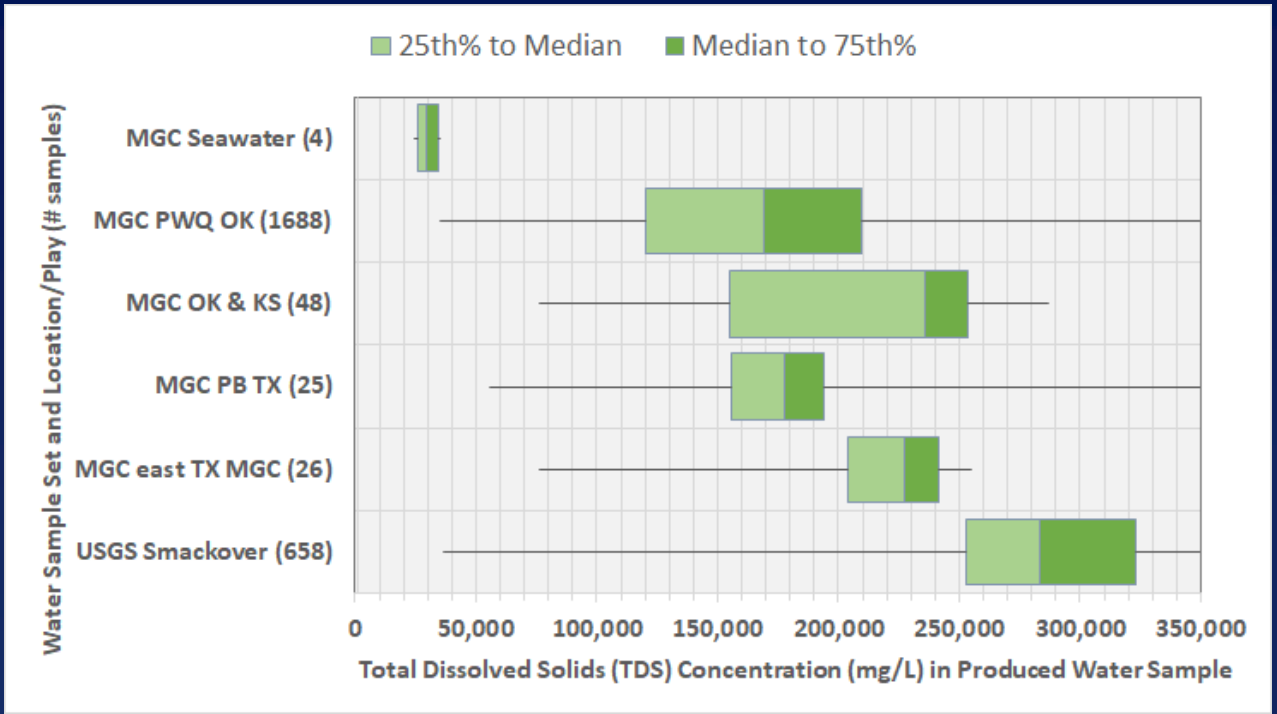


Compute Gross Values for EOI in 25 Permian Basin PW samples

	TDS (mg/L)
min	55,800
25th %	156,000
median	178,000
75th %	193,000
max	537,000

Murray (2023-in preparation)

Economically Feasible?

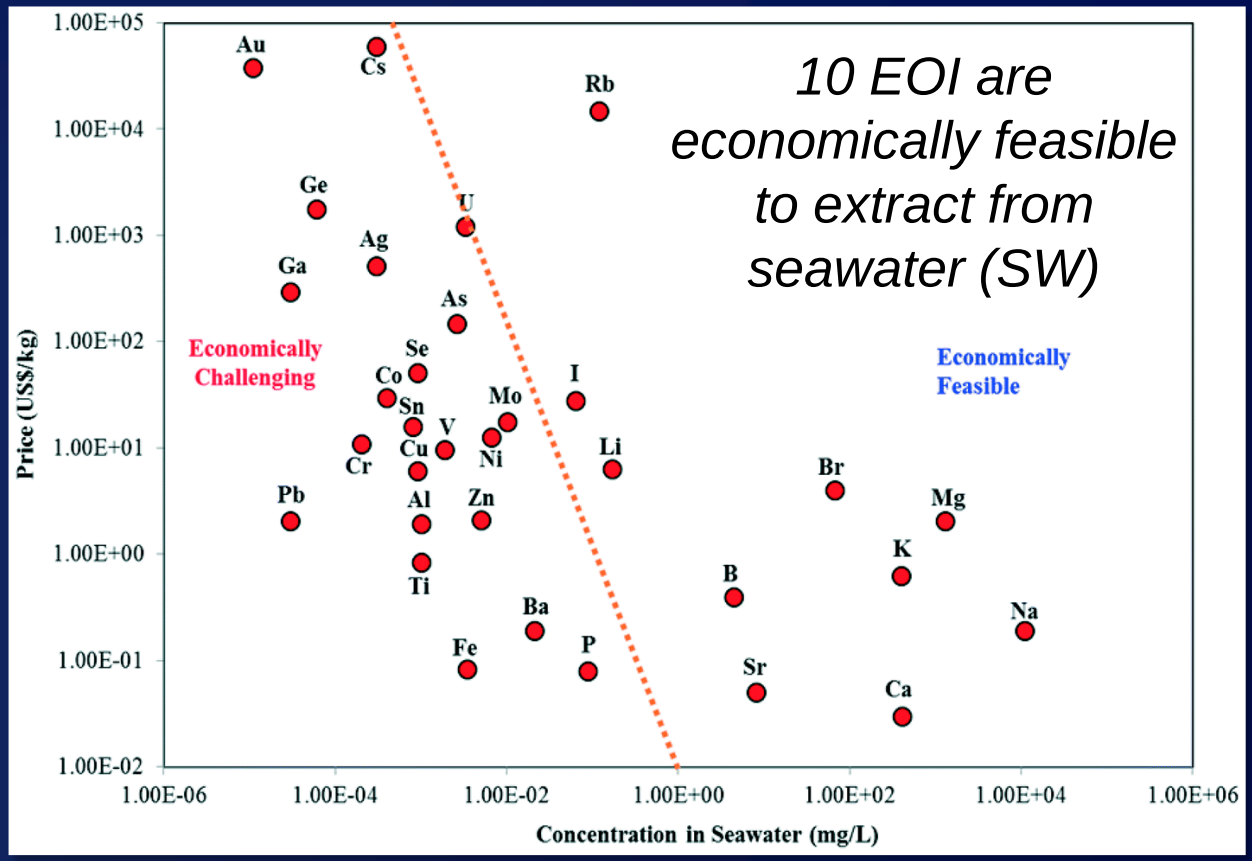


Data collected & compiled by MGC

Total Dissolved Solids (TDS) concentrations (mg/L) of seawater vs. subsurface brine or produced water samples

Figure 2 from Loganathan et al (2017)

Screening of elements that can be economically extracted from seawater based on 2015 USGS mineral commodity summaries.

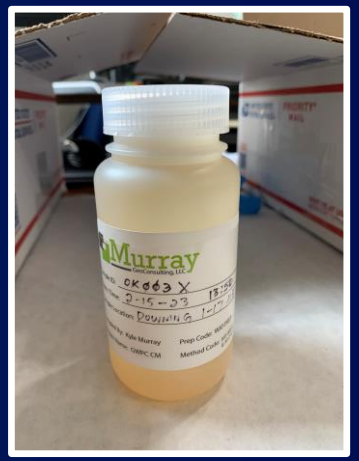


Case Studies: Sampling Points

Sample seawater (SW) at shoreline or in the surf

Best Case: Sample PW from storage tank after gravity separation

Worst Case: Sample PW from wellhead and allow for gravity separation in the field



H_2O Sample for Analyses at Laboratory