U.S. Geological Survey National Produced Waters Geochemical Database v2.3 (PROVISIONAL)

Documentation

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Disclaimers

Disclaimer for Database

The data you have secured from the U.S. Geological Survey (USGS) National Produced Waters Geochemical Database v2.3 are provisional and subject to revision. The data are released on the condition that neither the USGS nor the United States Government may be held liable for any damages resulting from their authorized or unauthorized use.

Distribution Liability

Although the data have been processed on computer systems at the USGS, U.S. Department of the Interior, no warranty, expressed or implied, is made by the U.S. Geological Survey regarding the utility of the data on any other system, nor shall the act of distribution constitute any such warranty. No responsibility is assumed by the USGS in the use of these data.

Additional Limitations

The information in the USGS National Produced Waters Geochemical Database v2.3 should be used with careful consideration of its limitations. The database is considered sufficiently accurate to provide an indication of tendencies in water composition from geographically and geologically defined areas. It is not appropriate for depiction of modern produced water compositions or examination of trends on small scales. The USGS makes no warranty regarding the accuracy or completeness of information presented in this database. Specific limitations of the database should be considered. Much of the information in the database cannot be independently verified. Methods of collection, sample preservation, analysis, assignment of geologic units and record keeping were not rigorous or standardized. Because of these uncertainties, users are advised to check data for inconsistencies, outliers, and obviously flawed information. Methods of well construction, sample collection and chemical analysis have changed over time. Samples in the database may not be spatially representative and do not necessarily reflect the distribution and relative amount of water produced within a province and among geologic units. No sampling was planned to accurately depict the aggregate water composition of any area whether it be province, state, county or field. The geologic unit nomenclature developed for petroleum production may have changed over time. Water data collected 30 years ago from a province may not resemble water samples from current production. The composition of produced water within a province, field, or even well may change over time as a result of water flooding, recompletion in other intervals, and workovers. Water samples are commonly collected when a well has production problems or during the initial development of a well. Although criteria were applied to remove the obviously contaminated samples, the culling of unrepresentative data is considered incomplete. Most of the obvious redundant entries were removed from this database. Many of the remaining records represent multiple samples of the same well. Therefore aggregate statistics may be weighted by relatively few wells.

Version History

v2.3

Version 2.3 contains new input datasets, new organic analytes, corrections, and an updated more accurate duplicate search algorithm. New datasets include Appalachian Basin Marcellus Shale gas time-series and organic data in PHANMARCELLUS, SHIHMARCELLUS, CHAPMAN, ROWANAKOB, and CLUFF; Permian Basin tight oil and Gulf Coast tight gas data in PERMIANENGLE and UTAUSTIN; Fayetteville Shale data in FAYETTEVILLE; and new geothermal data in NBMGGEOTHERMAL. Some input datasets were removed or replaced. SKEEN from v2.2 is a duplicate of APPALACHIAN data, and was therefore removed for v2.3. ROWANMARCELLUS from v2.2 was updated to ROWANAKOB in v2.3 to include organic data in a different publication using the same samples. All of the data labeled with a “Geothermal” WELLTYPE in v2.2 were removed and replaced with geothermal data from the NBMGGEOTHERMAL database. The data labeled with a “Geothermal” WELLTYPE in v2.2 were from shallow groundwaters, not geothermal wells. Though nine new input datasets have been added, the total number of records has decreased. This is largely related to the removal of samples improperly labeled “geothermal” in v2.2 and also a function of a more precise duplicate search algorithm.

v2.2

Version 2.2 contains new input datasets and changes to the creation and format of the compiled database. New datasets, including KHARAKA, BARNABY, SKEEN, CAPO, ROWANMARCELLUS, HOBBS, KNOWLES, SHOUAKARSTASH, PERMIAN, ILLINOISSTEUBER, and MAFLA fill regional gaps and contain more isotopic information. The three original USGS datasets USGSMAIN, USGSOK, and USGSARK have been combined into a single one named USGSBREIT. Location errors were corrected and new well perforation depths were added from public sources for some data released in the previous version. Extraneous variables were removed and some variables were condensed into a single column. For example, all township and range information has been condensed into a single column TOWNRANGE. MGL and PPM have been condensed into UNITS. LAT, LATAPPROX, LONG, and LONGAPPROX have been condensed into LATITUDE and LONGITUDE, with a note in LATLONGAPX if the spatial data are approximate. All of the lithology columns were condensed into the single column LITHOLOGY. The database is now compiled using R (R Core Team, 2015) using a procedure described below. Variables with cleaned-up categorical data include WELLTYPE, STATE, USGSREGION, BASIN, ERA, and PERIOD. FORMATION names have been cleaned-up for only the Appalachian Basin. Duplicates are now found first within each input dataset and then tested between dataset using more stringent criteria. The new variable TDSUSGS is a reported or calculated value in mg/L for ease of plotting. The new variable SG is a reported or empirically determined specific gravity that allows the user to convert from ppm to mg/L.

v2.1

Version 2.1 corrects errors found in version 2.0 of the database. Incorrect LATITUDE, LONGITUDE, or STATE variables were updated based on API or other well information. Chemical and well data in incorrect columns were placed in the correct columns. Unit problems were fixed for chemistry and specific gravity data. Alkalinity data were put into the correct columns based on the method of measurement. Certain variables not given in the original input datasets, including WELLTYPE and reservoir age information were determined based on well and formation data. Various other errors noted by users were corrected by referring back to the original source of the data. No new datasets were added except IDDB = “WILLISTON,” which is a compilation of the EASTPOPLAR and

BAKKEN entries from version 2.0 of the database along with unpublished data (Thamke, 2014, written communication).

Introduction

During hydrocarbon production, water is typically co-produced from the geologic formations producing oil and gas. Understanding the composition of these produced waters is important to help investigate the regional hydrogeology, the source of the water, the efficacy of water treatment and disposal plans, potential economic benefits of mineral commodities in the fluids, and the safety of potential sources of drinking or agricultural water. In addition to waters co-produced with hydrocarbons, geothermal development or exploration brings deep formation waters to the surface for possible sampling. This U.S. Geological Survey (USGS) Produced Waters Geochemical Database, which contains geochemical and other information for 114,943 produced water and other deep formation water samples of the United States, is a provisional, updated version of the 2002 USGS Produced Waters Database (Breit and others, 2002). In addition to the major element data presented in the original, the new database contains trace elements, isotopes, and time-series data, as well as nearly 100,000 additional samples that provide greater spatial coverage from both conventional and unconventional reservoir types, including geothermal. The database is a compilation of 40 individual databases, publications, or reports. The database was created in a manner to facilitate addition of new data and correct any compilation errors, and is expected to be updated over time with new data as provided and needed. Table 1 shows the abbreviated ID of each input database (IDDB), the number of samples from each, and its reference. Table 2 defines the 190 variables contained in the database and their descriptions. The database variables are organized first with identification and location information, followed by well descriptions, dates, rock properties, physical properties of the water, and then chemistry. The chemistry is organized alphabetically by elemental symbol. Each element is followed by any associated compounds (e.g. H_2S is found after S). After Zr, molecules containing carbon, organic compounds and dissolved gases follow. Isotopic data are found at the end of the dataset, just before the culling parameters.

Database Compilation Procedure

Input Datasets

Modification of the original data or variable names is necessary to create a database with consistent headers, compositional units, and numeric data that can be plotted or analyzed as a whole. One of the main goals of this updated database is to create a compiled dataset where every change to the original datasets is reversible and recorded. Thus if errors are found, there is a coded record that can be adjusted as needed, and the compiled dataset can be easily recreated from the original data files. To meet this goal, the USGS National Produced Waters Geochemical Database v2.3 is compiled using R, a language and environment for statistical computing and graphics (R Core Team, 2016)[1]. An R script is written for each input database that imports the original data, renames the variables to match the template (Table 2), and then appends the existing columns to a template header. Non-numeric characters within numeric variables (for example, ions and pH) are fixed, deleted, or replaced with the following codes:

- <MDL = Less than the Method Detection Limit (e.g. N.D., non-detect, absent)
- <PQL = Less than the Practical Quantification Limit (e.g. Trace, minor, present)
- UNK = Transcription error or otherwise nonsensical entry (e.g. 10K41)
- NA = Not analyzed, unknown (e.g. --, n.a., NA)

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[1] Disclaimer: Use of brand or trade names are for descriptive purpose and do not imply endorsement by the U.S. Government

Censored data for which the MDL is known are left as is (e.g. <10 remains <10 rather than <MDL). Dates are formatted into a consistent date form and extra variables are removed. Units for all variables other than the major and minor ions are defined in Table 2. The major and minor ions are generally reported in units of milligrams per liter (mg/L) or on a mass basis as parts per million (ppm) or its equivalent, milligrams per kilogram (mg/kg). The units used are defined in the UNITS column. The user of this database must be careful to examine the units when using the data and can convert between the two using measurements or estimates of brine density. A calculated TDS variable (TDSUSGS) is described below and has already been converted to mg/L for easy plotting. This variable is different than TDSCALC, which is the reported value calculated by the author of an input dataset or report.

Samples with duplicate American Petroleum Institute well identification (API) codes and chemical concentrations with large numbers of significant figures in common, were culled. It is unlikely that two samples, even from the same well, will have the exact same concentrations for three or more analytes, and therefore such similarities represent true duplicates. API code, calcium (Ca), chloride (Cl), and bicarbonate (HCO_3) concentrations are used for a starting duplicate search. If these analytes were detected in samples that did not appear to be true duplicates, other analytes like Na and Mg were added to the search. Care was taken to avoid false duplicates (e.g. where all three of the initial ions had null data).

Once non-numeric characters were replaced and duplicates were removed, categorical and text variables were cleaned up. Variables such as SOURCE, REFERENCE, WELLTYPE and STATE were defined. Lastly, the new dataset was saved as an intermediate file to be appended to the main database.

Compiled Dataset

Each individual input database is appended to the template using a global R script. The database is further standardized here with:

1. Internally consistent 14-digit API (API)
2. One of eight regions (USGSREGION) defined by the U.S. Geological Survey National Oil and Gas Resource Assessment Team (1995)
3. Basins simplified to 85 different reported names (BASIN)
4. State names (STATE)
5. One of eight well type (WELLTYPE) designations (Conventional Hydrocarbon, Shale Gas, Tight Oil, Tight Gas, Coal Bed Methane, Geothermal, and Groundwater)
6. Geologic Era (ERA)
7. Geologic Period (PERIOD)
8. Formations (FORMATION) have been standardized only for data in the Appalachian Basin.

Duplicates are again removed between input datasets using similar criteria as described above. The duplicate observation retained was generally the one in the database that contained more information.

Calculated Variables

The column SG provides an option for conversion from ppm to mg/L. SG is either the reported specific gravity, or an estimate based on a relationship between the reported specific gravity and the total dissolved solids (TDS) measured in ppm for the entire database. For example, if calcium (Ca) concentrations are in ppm, it simply can be multiplied by SG to obtain Ca concentration in mg/L. This has already been done for the new column TDSUSGS. The intent of the TDSUSGS column is to provide the user with an easy way to plot the most common variable with consistent units. TDSUSGS shows the TDS concentration, in mg/L, in the following order of primacy:

1. the reported measured TDS
2. the reported calculated TDS
3. the sum of all major cations and anions assuming both Na and Cl data exist. TDS concentrations in ppm were converted to mg/L by multiplying by SG.

Culling Data Based on Chemistry

Quality control of the dataset can be performed by culling based on geochemical criteria. In this version 2.3 of the database, the data that fall outside of the bounds of the following criteria are flagged, rather than culled. There are six temporary columns in the database that indicate the failure to meet specific culling criteria, based on those published in Hitchon and Brulotte (1994). An “X” is placed in the columns shown in Table 2 where the sample falls outside of the pH range of 4.5 – 10.5; where Mg > Ca, K > Cl, or K > 5 x Na; and where the charge balance error is greater than 15%.

The data were kept to allow the user to make judgment calls on their quality.

Files Available for Download

The database is available in three different file formats: a comma separated values (.csv) text file, a Microsoft Excel spreadsheet (.xlsx) and an .Rdata file for R users. There are two versions for each of these, one with a “c” suffix and one with an “n” suffix. The “c” files retain all text codes within the numeric variables that describe the data (e.g. “<0.01”, “<MDL”, “<PQL”, or “UNK”). The “n” files remove all non-numeric codes from the numeric variables for easy plotting. The following six files are available for download on the USGS Produced Waters website:

- USGS_Produced_Waters_v2.3c.csv
- USGS_Produced_Waters_v2.3c.xlsx
- USGS_Produced_Waters_v2.3c.Rdata
- USGS_Produced_Waters_v2.3n.csv
- USGS_Produced_Waters_v2.3n.xlsx
- USGS_Produced_Waters_v2.3n.Rdata

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Tables

Table 1. Input databases and datasets

[Short names of input databases, number of samples after removal of duplicates, and references on input databases. Please cite original references in future publications where there are known.]

ID of Database	Samples	Reference
ANTRIM	53	Walter and others (1997)
APPALACHIAN	1,431	Multiple – see references
ARKMOLDOVANYI	88	Moldovanyi and Walter (1992)
BARNABY	72	Barnaby and others (2004)
CAPO	58	Capo and others (2014)
CBM	3,216	Dahm (2013, writen communication)
CHAPMAN	41	Chapman et al. (2012)
CIMAREX	2,888	Cimarex Energy Company (2013, written communication)
CLUFF	19	Cluff et al., (2014)
FAYETTEVILLE	6	Warner et al. (2013)
FERRON	41	Rice (2003)
HOBBS	201	Hobbs and others (2011)
ILLINOIS	747	Meents and others (1952)
ILLINOISSTEUBER	90	Steuber and others (1987); Steuber and Walter (1991)
INDIANA	449	Keller (1983)
KHARAKA	312	Multiple – see references
KNOWLES	101	Powell and others (1963)
MAFLA	1536	Pashin (2013, written communication)
MICHIGAN	393	Vugrinovich (2013, written communication)
MISSISSIPPI	81	Carpenter and others (1974)
MONTANACBM	20	Meredith and others (2010)
NATCARB	10,893	Dept. of Energy, National Energy Technology Laboratory (2013)
NBMGGEOTHERMAL	689	Nevada Bureau of Mines and Geology (2016)
NORTHDAKOTA	7,330	North Dakota Oil and Gas Division (2013)
OHBRINE	561	McDonald and others (2013, written communication)
PALODURO	16	Bassett and others (1983)
PARADOX	91	Hanshaw and Hill (1969)
PASHIN	126	Alabama Geological Survey (2013, written communication)
PERMIAN	32	Steuber and others (1998)

PERMIANENGLE	39	Engle and others (2016)
PHANMARCELLUS	62	Phan and others (2016)
POWDERRIVERCBM	47	Rice and others (2000)
ROCKIES	3,259	Dept. of Energy, National Energy Technology Laboratory (2005)
ROWANAKOB	61	Rowan and others (2015); Akob and others (2015)
SHIHMARCELLUS	114	Shih and others (2015)
SHOUAKARSTASH	126	Shouakar-Stash (2008)
USGSBREIT	69,886	Breit and Otton (2002)
UTAUSTIN	505	Multiple – See references
WILLISTON	50	Peterman and Thamke, 2016; USGS OFRs 2010-1326 & 2012-1149
WYOGCC	9,213	Wyoming Oil and Gas Conservation Commission (2013)
Total	**114,881**	

Table 2. Variable names and descriptions

Variable Name	Description	Samples	Percent
IDUSGS	Unique ID in this database	114,943	100%
IDORIG	ID in original database or publication	114,943	100%
IDDB	ID (name) of input database	114,943	100%
SOURCE	Source of data	75,708	66%
REFERENCE	Publication	7,008	6.1%
LATITUDE	Latitude	103,872	90%
LONGITUDE	Longitude	104,179	91%
LATLONGAPX	Description if LATITUDE or LONGITUDE are approximate	22,611	20%
API	API well number, 14 digits	74,052	64%
USGSREGION	USGS Region	114,943	100%
BASIN	Basin	114,943	100%
BASINCODE	Basin Code	69,598	61%
STATE	State	114,943	100%
STATECODE	State Code	114,721	100%
COUNTY	County	83,841	73%
COUNTYCODE	County Code	82,085	71%
FIELD	Field	96,483	84%
FIELDCODE	Field Code	56,893	49%
WELLNAME	Well name	100,106	87%
WELLCODE	Well Code	16,006	14%
WELLTYPE	Well type	114,943	100%
TOWNRANGE	Township, Range, Section, Quarter	23,073	20%
REGDIST	Regional District	19,203	17%
LOC	Location	4,204	3.7%
QUAD	Quad	109	0.1%
TIMESERIES	Order of time-series data	202	0.2%
DAY	Sample day of time-series data	2,903	2.5%
DATECOMP	Date of well completion	6,415	5.6%
DATESAMPLE	Date of sample collection	85,555	74%
DATEANALYS	Date of analysis	10,146	8.8%
METHOD	Sample Method	67,502	59%
OPERATOR	Well operator	31,258	27%
PERMIT	Well permit holder	8,355	7.3%
DFORM	Geologic formation name of greatest depth	23,838	21%

GROUP	Geologic group name	88	0.1%
FORMATION	Geologic formation name	114,943	100%
MEMBER	Geologic member name	2,433	2.1%
AGECODE	Geologic Age code	55,612	48%
ERA	Geologic Era name	114,943	100%
PERIOD	Geologic Period name	114,943	100%
EPOCH	Geologic Epoch name	23,101	20%
DEPTHUPPER	Upper perforation depth, ft. Depth added here if non-specific.	81,836	71%
DEPTHLOWER	Lower perforation depth, ft	68,017	59%
DEPTHWELL	Reported Total depth of well, ft	42,979	37%
ELEVATION	Elevation of well, ft	21,227	18%
LAB	Laboratory that analyzed the results	12,537	11%
REMARKS	Remarks or comments	7,649	6.7%
LITHOLOGY	Lithology	28,937	25%
POROSITY	Porosity, % reported	26	0.0%
TEMP	Temperature, deg F reported	3,294	2.9%
PRESSURE	Pressure, psi reported	978	0.9%
SG	Specific Gravity, reported or calculated (see text)	79,522	69%
SPGRAV	Specific Gravity, reported	62,461	54%
SPGRAVT	Temperature of Specific Gravity measurement, deg F	30,712	27%
RESIS	Resistivity, Ohm m	65,440	57%
RESIST	Temperature of Resistivity measurement, deg F	57,811	50%
PH	pH	86,630	75%
PHT	Temperature of pH measurement, deg F	1,545	1.3%
EHORP	Eh / Oxidation Reduction Potential, mV	55	0.0%
COND	Conductivity, µS/cm	1,093	1.0%
CONDT	Temperature of Conductivity measurement, deg F	242	0.2%
TURBIDITY	Turbidity	97	0.1%
HEM	Oil and Grease	194	0.2%
MBAS	Surfactants and Detergents	141	0.1%
UNITS	mg/L or ppm, applies to all chemistry unless specified	114,943	100%
TDSUSGS	Total Dissolved Solids, calculated (see text)	109,928	96%
TDS	Total Dissolved Solids, measured	98,166	85%
TDSCALC	Total Dissolved Solids, calculated, as reported in reference	2,176	1.9%
TSS	Total Suspended Solids	1,497	1.3%
CHARGEBAL	Charge balance of major ions, %, reported	3,781	3.3%

chargebalance	Charge balance of major ions, %, calculated	109,217	95%
Ag	Silver	115	0.1%
Al	Aluminum	680	0.6%
As	Arsenic	493	0.4%
Au	Gold	1	0.0%
B	Boron	4,618	4.0%
BO3	Borate	241	0.2%
Ba	Barium	12,498	11%
Be	Beryllium	127	0.1%
Bi	Bismuth	25	0.0%
Br	Bromide	6,548	5.7%
CO3	Carbonate	10,740	9.3%
HCO3	Bicarbonate	98,708	86%
Ca	Calcium	107,478	94%
Cd	Cadmium	188	0.2%
Cl	Chloride	108,646	95%
Co	Cobalt	186	0.2%
Cr	Chromium	2,419	2.1%
Cs	Cesium	456	0.4%
Cu	Copper	1,208	1.1%
F	Fluoride	1,127	1.0%
FeTot	Iron, total	27,567	24%
FeIII	Iron, 3+	559	0.5%
FeII	Iron, 2+	652	0.6%
FeS	Iron sulfide	2	0.0%
FeAl	Iron plus Aluminum, reported as elements	195	0.2%
FeAl2O3	Iron plus Aluminum, reported as oxides	441	0.4%
Hg	Mercury	180	0.2%
I	Iodine	3,659	3.2%
K	Potassium	31,550	27%
KNa	Potassium plus Sodium	8,609	7.5%
Li	Lithium	6,126	5.3%
Mg	Magnesium	103,240	90%
Mn	Mangansese	3,759	3.3%
Mo	Molybdenum	184	0.2%
N	Nitrogen, total	242	0.2%

NO2	Nitrite	94	0.1%
NO3	Nitrate	3,796	3.3%
NO3NO2	Nitrate plus Nitrite	103	0.1%
NH4	Ammonium	1,521	1.3%
TKN	Kjeldahl Nitrogen	134	0.1%
Na	Sodium	96,432	84%
Ni	Nickel	305	0.3%
OH	Hydroxide	398	0.3%
P	Phosphorus	39	0.0%
PO4	Phosphate	321	0.3%
Pb	Lead	359	0.3%
Rh	Rhodium	1	0.0%
Rb	Rubidium	767	0.7%
S	Sulfide	258	0.2%
SO3	Sulfite	105	0.1%
SO4	Sulfate	93,104	81%
HS	Bisulfide	20	0.0%
Sb	Antimony	143	0.1%
Sc	Scandium	43	0.0%
Se	Selenium	287	0.3%
Si	Silica	3,708	3.2%
Sn	Tin	101	0.1%
Sr	Strontium	7,812	6.8%
Ti	Titanium	103	0.1%
Tl	Thallium	100	0.1%
U	Uranium	21	0.0%
V	Vanadium	40	0.0%
W	Tungsten	3	0.0%
Zn	Zinc	1,186	1.0%
ALKHCO3	Alkalinity as HCO3	1,691	1.5%
ACIDITY	Acidity as CaCO3	102	0.1%
DIC	Dissolved Inorganic Carbon	200	0.2%
DOC	Dissolved Organic Carbon	307	0.3%
TOC	Total Organic Carbon	432	0.4%
CN	Cyanide	112	0.1%
BOD	Biochemical Oxygen Demand	114	0.1%

COD	Chemical Oxygen Demand	115	0.1%
BENZENE	Benzene	928	0.8%
TOLUENE	Toluene	898	0.8%
ETHYLBENZ	Ethybenzene	7	0.0%
XYLENE	Xylene	42	0.0%
ACETATE	Acetate	1,145	1.0%
BUTYRATE	Butyrate	11	0.0%
FORMATE	Formate	12	0.0%
LACTATE	Lactate	12	0.0%
PHENOLS	Phenols	108	0.1%
PERC	Tetrachloroethylene	1	0.0%
PROPIONATE	Propionate	15	0.0%
PYRUVATE	Pyruvate	8	0.0%
VALERATE	Valerate	8	0.0%
ORGACIDS	Total Organic Acids	16	0.0%
Ar	Argon gas	17	0.0%
CH4	Methane gas	17	0.0%
C2H6	Ethane gas	8	0.0%
CO2	Carbon Dioxide gas	1,219	1.1%
H2	Hydrogen gas	13	0.0%
H2S	Hydrogen Sulfide gas	3,471	3.0%
He	Helium gas	13	0.0%
N2	Nitrogen gas	18	0.0%
NH3	Ammonia gas	344	0.3%
O2	Oxygen gas	33	0.0%
ALPHA	Alpha particles, pCi/L	136	0.1%
BETA	Beta particles, pCi/L	141	0.1%
dD	δH, per mil	1,039	0.9%
H3	Tritium, ^{3}H, tritium units	26	0.0%
d7Li	δ^{7}Li, per mil	68	0.1%
d11B	δ^{11}B, per mil	166	0.1%
d13C	δ^{13}C, per mil	145	0.1%
C14	^{14}C, pCi/L	3	0.0%
d18O	δ^{18}O, per mil	1,335	1.2%
d34S	δ^{34}S, per mil	16	0.0%
d37Cl	δ^{37}Cl, per mil	259	0.2%

K40	^{40}K, pCi/L	50	0.0%
d81Br	δ^{81}Br	94	0.1%
Sr87Sr86	^{87}Sr/^{86}Sr	1040	0.9%
I129	^{129}I/I, parts per quadrillion	12	0.0%
Rn222	^{222}Rn, pCi/L	134	0.1%
Ra226	^{226}Ra, pCi/L	720	0.6%
Ra228	^{228}Ra, pCi/L	184	0.2%
cull_PH	“X” if pH < 4.5 or pH > 10.5	1,846	1.6%
cull_MgCa	“X” if Mg > Ca	4,136	3.6%
cull_KCl	“X” if K > Cl	280	0.2%
cull_K5Na	“X” if K > 5xNa	53	0.1%
cull_chargeb	“X” if charge balance > 15%	24,188	21%