Produced Water Chemistries

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Large volumes of co-produced water are brought to the surface everyday during the production operations for oil and gas. Produced water, sometimes referred to as "brine" or "saltwater", can contain formation water from the reservoir, water previously injected into the formation, and chemicals used during the production process. These waters are generally high in dissolved solids and contain some of the chemical characteristics of the formations they were in contact with. Produced water is the largest volume by-product and waste stream associated with oil and gas production. In a report on national produced water volumes and management practices (Clark and Veil, 2009), it was estimated that 98% of produced waters from onshore wells is injected back into the subsurface.

In 2014, more than 442 million barrels of subsurface brine were produced in North Dakota. Available information indicates that approximately 88% was injected back in the subsurface for disposal. Of the other 12%, most was injected into the subsurface for enhanced oil recovery purposes while lesser amounts were managed for beneficial resuse such as the production of heavy drilling mud.

Subsurface brines are a natural feedstock for a variety of industrial minerals and chemicals. Within a broadly similar setting to the Williston Basin, the Michigan Basin has been home to operators such as Dow Chemical Company. To our north, formation water in Saskatchewan has been utilized for the production of calcium and magnesium chloride brines for use in dust suppression on gravel roads and as ballast in tractor tires (Rostron et al., 2002).

Knowing the chemical nature of the produced water from various formations and localities is the first step toward developing beneficial reuse of this waste stream. Water chemistry information collected by the North Dakota Department of Mineral Resources (DMR) was examined for this article.

Methods

The Oil & Gas Division of the DMR maintains a database of water chemistry analyses received from producers operating within the state. As of April 28, 2015 this database contained 7,570 water sample entries, often including multiple samples from a well collected at differing intervals, sample ports, or times. A majority of the samples have been processed for "standard" analyses which include major ions (Ca, Mg, Na, Cl, Fe, K, SO_4, HCO_3, and CO_3) as well as additional measurements such as pH and specific gravity. A simplified culling process derived from Hitchon and Brulotte (1994) was utilized to reject bad data due to poor sampling, laboratory error, or drilling fluid contamination. Sample analyses were eliminated from the dataset if any of the following eight criteria were met:

1) Either Ca, Mg, Cl, SO_4 or $HCO_3 \leq 0$
2) Mg>Ca
3) pH<5 or pH>10
4) OH>0
5) CO_3>0
6) Specific gravity >0 and <1
7) Fe>200 mg/L
8) Cr>4 mg/L

Additional culling was performed by looking for suspect data in the remaining analyses. In all, 1,754 sample analyses (23%) were eliminated from the dataset. Those remaining were sorted by pools, fields, and counties and presented as mean and median concentrations for Ca, Mg, Na, and Cl.

Discussion

Variability in concentrations of the above elements is observed in both a basin-wide pool to pool comparison (fig. 1 and table 1) and within pools further subdivided by fields (table 2) or county (table 3). It is important to note that produced water properties can vary throughout the lifetime of a reservoir. While these data provide a starting point for examining standard brine chemistries throughout the Williston Basin, more extensive data culling should be undertaken prior to any production of isocontour maps for water chemistry across the basin. In particular, attention to the method of production or sampling, for which information was not immediately available for this article, should be considered.

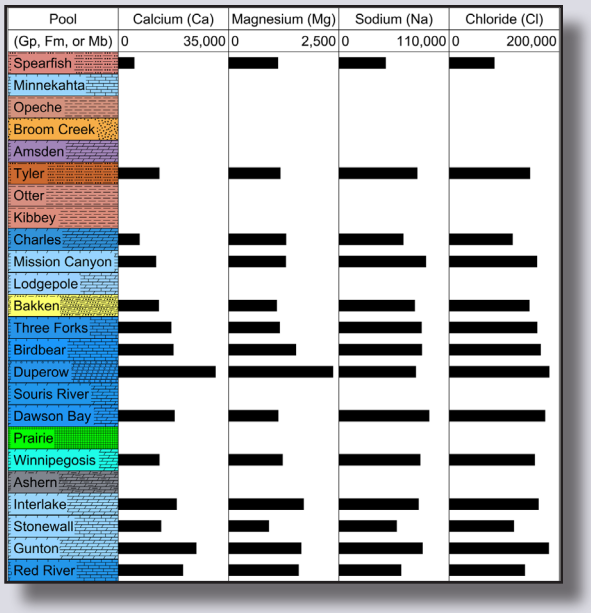

Figure 1. The portion of a typical stratigraphic column in western North Dakota illustrating the data from table 1 and the variability in Ca, Mg, Na, and Cl mean concentrations by pool (formation or member) on a basin-wide basis. Refer to the n values in table 1 for the number of samples included in each pool.

Table 1. Presented are concentrations of Ca, Mg, Na, and Cl for various pools throughout the North Dakota portion of the Williston Basin. All data are in mg/L.

Pool	n	Calcium (Ca)		Magnesium (Mg)		Sodium (Na)		Chloride (Cl)	
		Mean	Median	Mean	Median	Mean	Median	Mean	Median
Spearfish	70	5,060	5,088	1,118	1,064	46,584	48,298	81,883	84,900
Tyler	89	13,000	13,080	1,172	1,102	78,122	80,700	146,427	150,480
Charles	177	6,720	4,180	1,302	1,016	64,216	53,512	114,826	93,408
Mission Canyon	3392	11,964	11,222	1,296	1,209	86,761	95,606	159,107	178,250
Bakken	363	12,834	12,689	1,091	1,111	75,626	77,900	145,268	153,379
Three Forks	16	16,790	16,225	1,158	790	82,380	88,107	159,417	182,843
Birdbear	117	17,474	15,690	1,526	1,320	82,715	85,800	165,758	175,812
Duperow	465	30,843	28,500	2,366	1,952	76,677	78,800	181,352	196,690
Dawson Bay	40	17,844	12,639	1,124	899	89,987	102,950	173,802	186,160
Winnipegosis	48	13,019	7,912	1,223	916	81,079	89,823	155,098	173,780
Interlake	294	18,501	18,053	1,700	1,460	79,425	88,516	161,929	186,436
Stonewall	25	13,577	13,160	912	890	57,575	58,100	117,183	115,752
Gunton	21	24,738	16,232	1,645	1,080	83,393	84,300	180,532	181,956
Red River	575	20,514	11,811	1,586	1,179	62,020	65,778	137,074	167,250

Field	Pool	County	n	Calcium (Ca)		Magnesium (Mg)		Sodium (Na)		Chloride (Cl)	
				Mean	Median	Mean	Median	Mean	Median	Mean	Median
Ambrose		*Divide*	35	18482	17910	784	731	90638	90400	176476	181200
	Mission Canyon		3	18237	15350	894	731	98667	105100	189900	191100
	Bakken		4	8691	10092	1516	1697	86735	96570	157732	175729
	Duperow		16	22866	25190	833	822	84706	85550	176459	182600
	Devonian		4	11625	11240	670	609	91300	92300	165375	162850
	Red River		8	18130	10625	335	304	101113	107800	186400	183600
Antelope		*McKenzie*	141	19816	18188	1957	1770	82378	89424	169661	181980
	Mission Canyon		75	16687	18050	1860	1824	83294	89424	163445	176176
	Sanish		20	12188	13756	932	996	83680	92700	162885	180437
	Three Forks		4	20641	20282	2538	1645	90142	90112	182604	182343
	Bird Bear		5	21245	23655	2048	1384	88411	87191	181362	181000
	Duperow		20	36391	34353	3184	3420	85215	86232	205783	207128
	Dawson Bay		2	26983	26983	2111	2111	45500	45500	129471	129471
	Devonian		2	24120	24120	1428	1428	46510	46510	118468	118468
	Interlake		10	23065	24960	2161	2012	94301	100226	192135	199290
	Winnepeg		1	456	456	33	33	500	500	9598	9598
	Deadwood		2	24470	24470	2488	2488	30090	30090	113201	113201
Cedar Hills		*Bowman*	13	12474	7778	1445	1400	58059	45800	114919	86448
	Red River		13	12474	7778	1445	1400	58059	45800	114919	86448
Fryburg		*Billings*	57	10587	10317	1216	928	60717	63329	115382	125970
	Tyler		29	10626	10840	1257	1276	70580	63329	131129	126958
	Mission Canyon		19	4625	2006	729	342	38548	17063	68559	27460
	Bakken		1	10317	10317	2000	2000	73000	73000	136820	136820
	Duperow		3	34939	33200	3390	3250	75044	78635	187333	191000
	Red River		4	22449	17170	1538	1327	65965	66608	145599	161127
North Tioga		*Burke/Williams*	109	13293	10916	1346	1108	95347	103400	175835	187639
	Misson Canyon		56	10746	11000	1377	1109	107597	107477	189222	188048
	Bakken		11	10183	10916	1066	999	92473	102500	165331	180026
	Three Forks		4	10772	10820	816	666	110825	111550	191183	190483
	Duperow		5	47109	57259	3019	3552	73540	65300	212856	220458
	Dawson Bay		2	34400	34400	3060	3060	74400	74400	192250	192250
	Winnipegosis		6	11356	7738	830	666	77150	80950	142728	142977
	Interlake		14	13750	12673	1067	1092	70457	73200	137258	159400
	Red River		11	11553	9192	1231	1110	85555	82400	159955	165900
Wylie		*Bottineau*	23	4642	5148	1424	1534	78320	94532	133563	162000
	Dakota		1	52	52	41	41	2489	2489	3096	3096
	Charles		3	3265	4180	1080	1415	33343	45940	58417	81000
	Mission Canyon		18	5098	5368	1566	1566	90591	97443	153243	164500
	Mississipian		1	5148	5148	1298	1298	80460	80460	135240	135240

Table 2. Presented are concentrations of Ca, Mg, Na, and Cl for selected oil fields in the North Dakota portion of the Williston Basin. Field data is subdivided by the individual pools sampled within each field. All data are in mg/L.

Table 3. Presented are concentrations of Ca, Mg, Na, and Cl for the Duperow pool. The Duperow pool data is subdivided geographically by county. All data are in mg/L.

Pool	County	n	Calcium (Ca)		Magnesium (Mg)		Sodium (Na)		Chloride (Cl)	
			Mean	Median	Mean	Median	Mean	Median	Mean	Median
Duperow		465	30843	28500	2366	1952	76677	78800	181352	196690
	Billings	56	29713	28858	1839	1464	88802	86209	194248	201390
	Bottineau	2	15681	15681	2367	2367	80680	80680	158437	158437
	Burke	5	47109	57259	3019	3552	73540	65300	212856	220458
	Divide	79	23511	25250	1575	1299	89425	88948	187795	188800
	Dunn	27	34304	41280	2467	2440	74476	72108	183966	198050
	Golden Valley	5	18645	10421	1084	1210	83627	78600	166179	152400
	McKenzie	167	31285	30894	2357	2100	68859	70831	169179	197500
	Mercer	2	26414	26414	3485	3485	64506	64506	161000	161000
	Mountrail	10	40155	42134	4764	4965	66891	67838	189219	203747
	Renville	2	25268	25268	4061	4061	60529	60529	149372	149372
	Slope	6	14030	9820	1030	732	59089	55876	120913	122055
	Stark	2	27313	27313	3410	3410	78982	78982	179665	179665
	Ward	4	21833	22647	3276	3283	52183	50534	130273	127595
	Williams	98	36517	35828	2998	2233	76732	74874	194531	204938

References

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