North Dakota Geological Survey
Geologic Investigations No. XX

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EXPLORATION FOR SHALLOW NATURAL GAS IN NORTH DAKOTA BY FID FIELD SCREENING OF GROUND-WATER WELLS

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2009

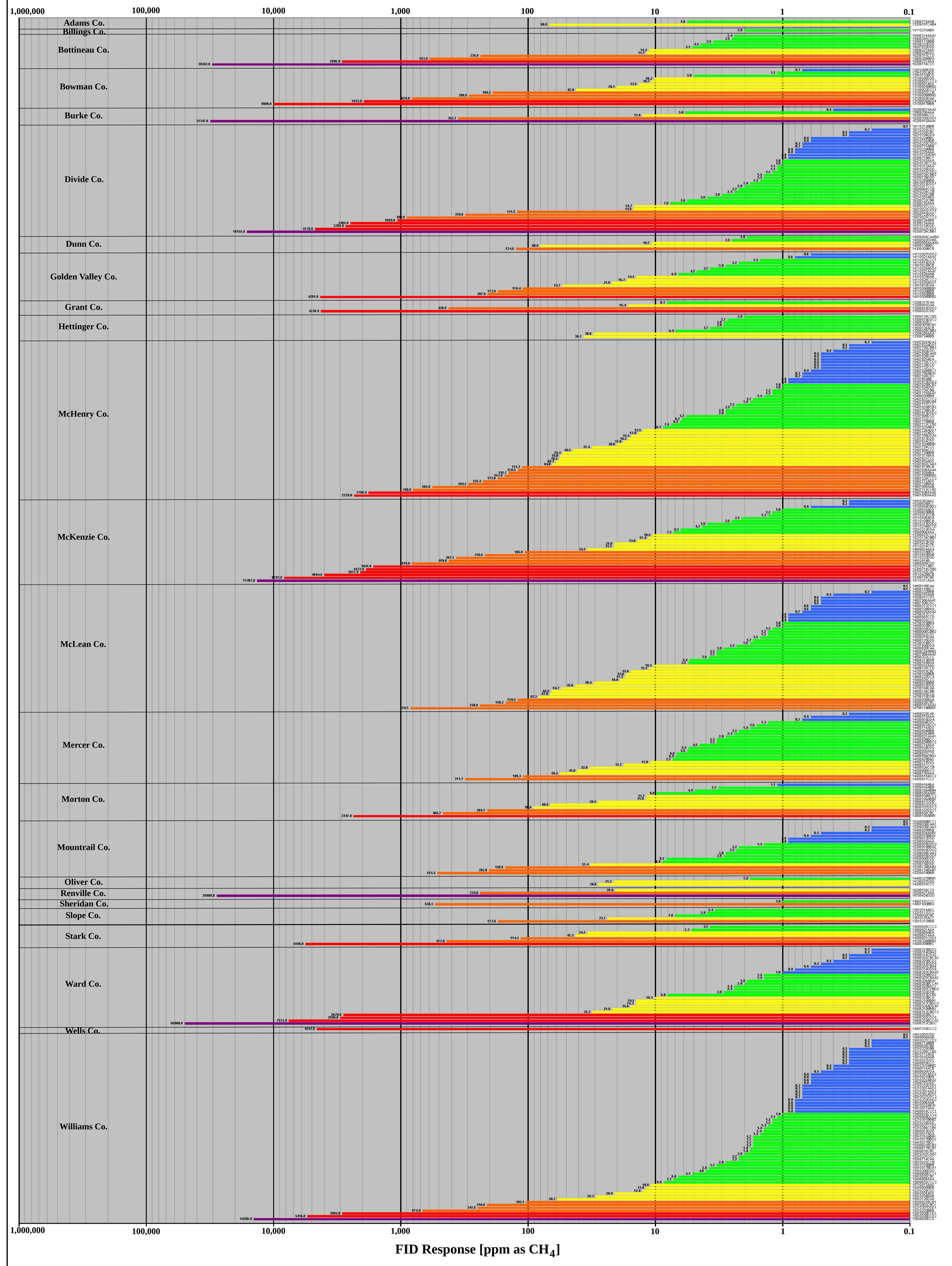

Figure 9. Comparison of positive FID instrument responses interpreted as shallow gas occurrences for wells field screened in western North Dakota in 2006-2009. Data grouped alphabetically by county from top to bottom. Data within each county grouping is sorted by [CH_4] in ascending order (i.e. lowest to highest). Bars are color coded with increasing values changing from cooler to warmer color based on the order of magnitude of FID instrument response: blue = 0 to 1 ppm, green = 1 to 10 ppm, yellow = 10 to 100 ppm, orange = 100 to 1,000 ppm, red = 1,000 to 10,000 ppm, and purple = 10,000 to 1,000,000 ppm. Monitoring well identification numbers are displayed at the right of each respective bar. Well identification format is in ND State Water Commission database format as Township, Range, Section and 1/4, 1/4, 1/4 (e.g. 01ABC) sections. Nested wells are commonly listed with an appended 1, 2, 3 etc., attached to the well identification (e.g. 01ABC2).

ABSTRACT

Exploration for natural gas occurrences in ground-water wells completed within unconsolidated Pleistocene glacial sediments and Cretaceous bedrock of the Fox Hills and Hell Creek Formations reveal numerous potential occurrences of shallow natural gas in North Dakota, possibly providing insight into areas of gas generation, migration, and accumulation in the shallow (<1,524 m) subsurface. More than 3,000 wells throughout North Dakota were tested during the 2006 - 2009 field seasons for the occurrence of methane using portable flame-ionization-detector (FID) instrumentation. Ground-water observation wells within Steele, Renville, Bottineau, Emmons, Kidder, Stutsman, Rolette, Towner, Ward, Barnes, Morton, LaMoure, Burleigh, McHenry, Pierce, Sheridan, Benson, and Logan counties, along with ground-water observation and stock-supply wells in Oliver, Mercer, Dunn, Billings, Stark, Slope, McLean, Traill, Griggs, Ransom, Richland and Sargent counties, have been field screened. Over 740 occurrences have been documented with FID responses ranging from 0.2 ppm to 50,000 ppm (5%), as methane in air. Preliminary assessments indicate that the majority of documented methane occurrences continue to be associated with the presence of lignite, either as detritus within the aquifer sedimentary matrix, or as stratiform beds within the monitored interval. These results suggest localized shallow methanogenesis along with potential migration and accumulation from underlying organic-laden Cretaceous sediments.

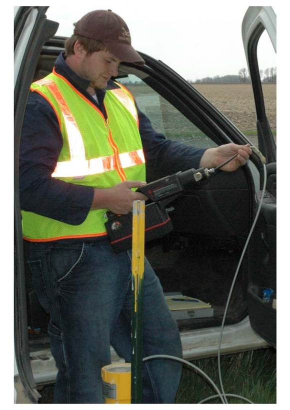

Figure 1. Conducting shallow gas field screening with a portable flame-ionization detector (FID) at a ground-water observation well in Cass County, North Dakota. The portable FID is fitted with an extended sample line consisting of flexible 1/4" (6.5 mm) O.D. polyethylene hose. The sample line is lowered directly into the well to a point just above the level of groundwater in the well, at which time a reading of gas flux across the groundwater/atmospheric interface (GWI) is collected.

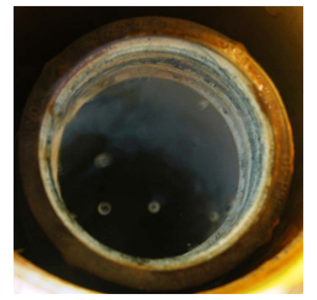

Figure 2. Shallow gas bubbles flowing in a slightly artesian ground-water observation well (162-83-15CCD) located in northwestern Bottineau County, North Dakota. This well is located near several oil and gas producing fields and is screened within sands overlying carbonaceous siltstone and sandstone bedrock of the Hell Creek Formation. Diameter of the polyvinylchloride (PVC) well casing is 2-in. (5-cm).

North Dakota Shallow Gas FID Field Screening Summary								
		Wells Investigated Summary				Range of FID Instrument Response		
County	Year	Wells Investigated	Wells Field Screened	Wells with a positive FID response (>0.0)	Wells with no FID response (0.0)	Low (ppm as CH4)	High (ppm as CH4)	Average (ppm as CH4)
Traill	2009	39	11	1	10	1,075	1,075	1,075
Griggs	2009	110	94	20	74	0.2	2,063	165
Ransom	2009	362	179	30	149	0.2	186	17
Richland	2009	317	147	28	119	0.5	28,123	1,066
Oliver	2009	35	7	3	4	1.8	28	17
Mercer	2009	115	38	24	14	0.3	103	11
Dunn	2009	271	27	5	22	1.9	124.6	55
Billings	2009	121	14	1	13	2	2	2
Golden Valley	2009	75	29	16	13	0.6	4,291	307
Stark	2009	168	35	7	28	3.7	5,596	890
Slope	2009	63	31	5	26	3.4	172.6	42
Bowman	2009	104	47	13	34	0.7	24,250	2,124
Mountrail	2009	111	35	19	16	0.1	515.5	51
McLean	2009	433	212	44	168	0.1	839.1	42
Grant	2009	58	18	4	14	8.1	4,238.0	1,171
Adams	2009	41	8	2	6	5.6	68.0	36.8
Hettinger	2009	43	15	8	7	2.0	36.7	11
McIntosh	2009	114	48	11	37	1.5	79.7	16
McKenzie	2009	378	68	29	39	0.3	13,487	1,152
Williams	2009	334	167	66	101	0.1	14,290	364
Burke	2009	65	20	5	14	0.4	31,347	6,344
Divide	2009	195	88	38	50	0.1	16,155	751
Cass	2009	187	102	20	82	0.4	5,620	321
Sargent	2009	561	289	40	249	0.2	933.0	51
Wells	2009	113	77	22	55	0.1	4,567	316
2009-Total		4,413	1,806	461	1,344			
Sheridan	2008	71	7	2	5	1	538.3	297
Benson	2008	341	127	9	118	0.5	223.7	44
Logan	2008	127	75	12	63	3.4	41.5	16
2008-Total		539	209	23	186			
Ward	2007	151	79	27	52	0.2	50,000	2,353
Barnes	2007	51	28	5	23	0.3	2,897	520
Morton	2007	48	29	12	17	1.1	2,347	271
LaMoure	2007	287	195	49	146	0.4	3,712	252
Burleigh	2007	143	64	18	46	1.1	1,208	211
McHenry	2007	433	350	55	295	0.2	2,329	131
Steele	2007	21	9	3	6	2	146.3	79
Pierce	2007	148	105	8	97	1.7	71.7	18
2007-Total		1282	859	177	682			
Renville	2006	34	8	3	5	20.6	28,000	9,420
Bottineau	2006	110	33	11	22	2.4	30,362	3,102
Emmons	2006	109	50	12	38	1.6	775	196
Kidder	2006	451	377	63	314	0.2	840.5	41.1
Stutsman	2006	170	107	21	86	0.4	182	27
Towner	2006	78	31	6	25	0.2	32.8	8
Rolette	2006	114	52	10	42	0.6	15.2	5
2006-Total		1066	658	126	532			
Project Totals		7,300	3,532	787	2,744			

Table 1. A total of 3,532 shallow ground-water observation wells were field screened for the presence of combustible gas using a portable flame-ionization detector (FID) calibrated to a predetermined concentration of CH_4 in air (100 ppm low-span calibration and 10,000 ppm high-span calibration) during the 2006 - 2009 field seasons. Approximately 22% (787 wells) returned positive instrument responses for potential shallow gas occurrence as methane. The remaining 78% (2,744 wells) showed no response for shallow gas. Nearly 50% of the wells planned for investigation and field screening were found to have been destroyed or abandoned in the field.

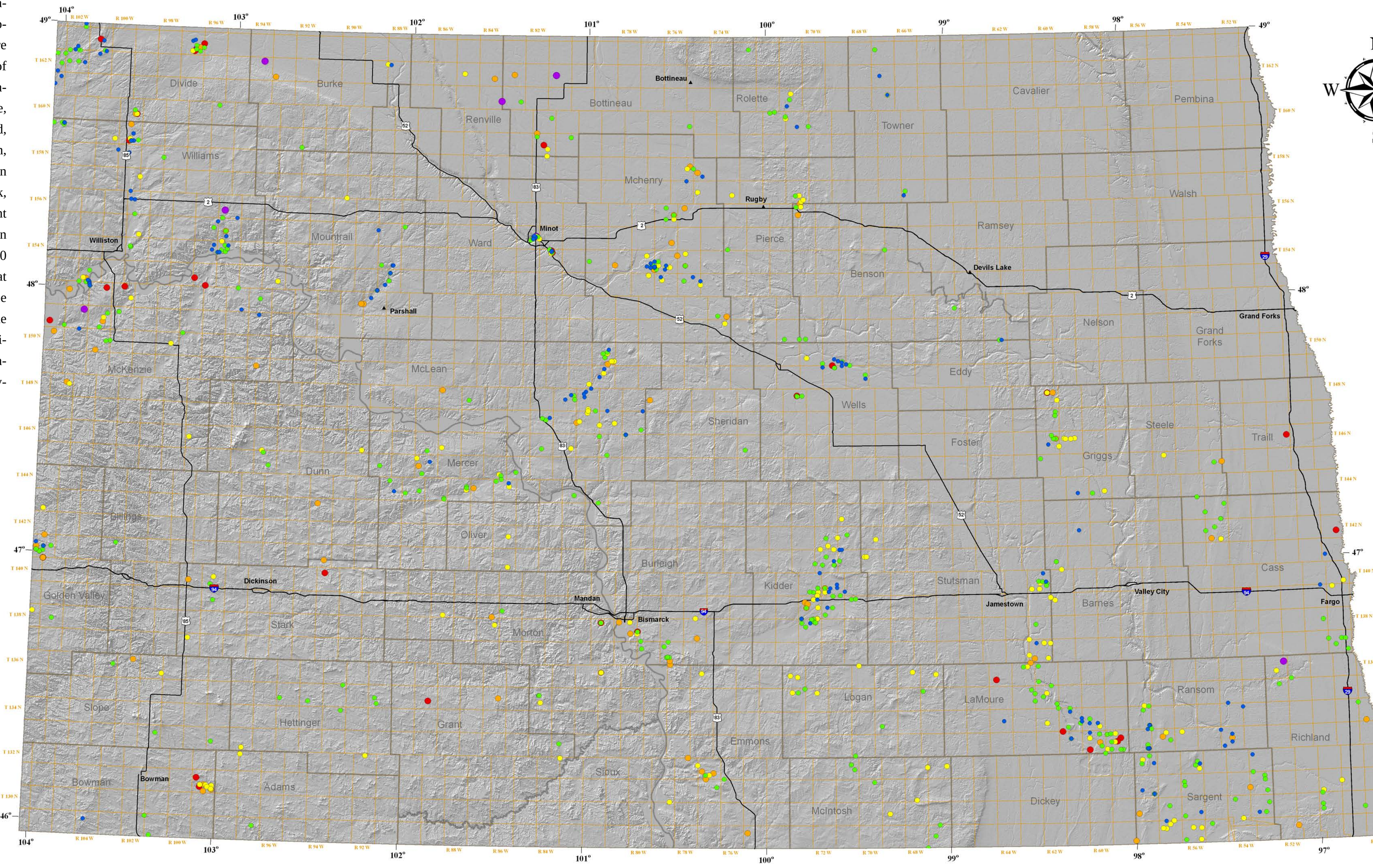

Figure 3. Shaded-relief map of North Dakota with the locations of ground-water wells field screened with an occurrence of shallow gas as CH_4. Symbols are color-coded indicating the range of flame-ionization detector (FID) instrument response recorded within the well at the groundwater/atmospheric interface (GWI). Well locations are color coded from cooler to warmer colors based on the order of magnitude of FID instrument response: blue = 0 to 1 ppm, green = 1 to 10 ppm, yellow = 10 to 100 ppm, orange = 100 to 1,000 ppm, red = 1,000 to 10,000 ppm, and purple = 10,000 to 1,000,000 ppm.

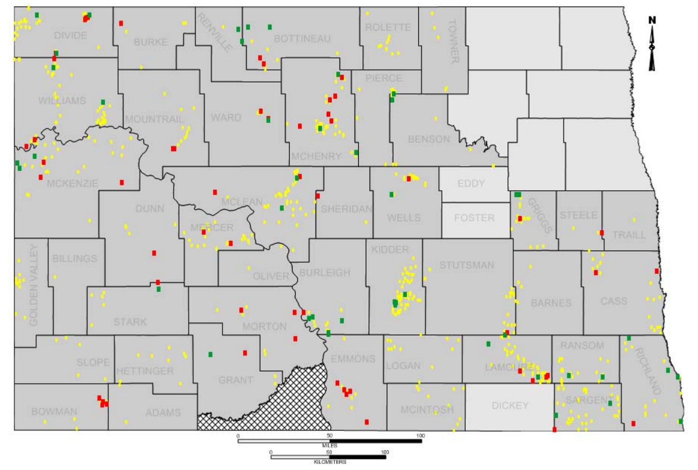

Figure 7. Locations of wells in North Dakota where a CH_4 occurrence was detected.

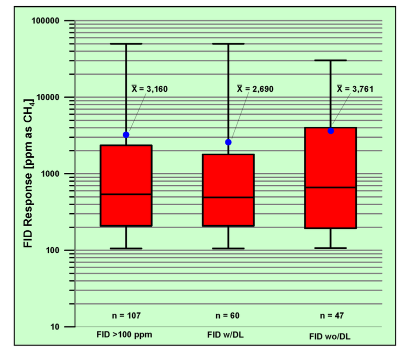

Figure 6. Whisker plot comparing the results of FID response (as CH_4) for all wells field screened with a result > 100 ppm. A comparison of values where lignites do and do not occur follows. Overall FID responses range higher within the group of values containing coals, either as detritus or in beds. Mean FID response is higher within wells where no carbonaceous material is reported.

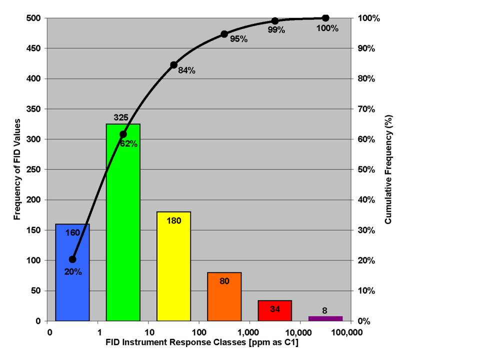

Figure 5. Frequency distribution of 787 FID instrument responses (as C1 in ppm) described within six logarithmic intervals from zero to 100,000. The 1 ppm to 10 ppm interval contained the majority (41%) of the responses. FID values in the 10 ppm to 100 ppm (23%) range were second, followed by FID values in the zero ppm to 1 ppm range (20%). Only 8 values (1%) were reported that were greater than 10,000 ppm. None of the values within the 10,000 ppm to 100,000 ppm methane concentration interval were greater than 50,000 ppm. The cumulative percentage trend through the data is shown with the curved black line. 90% of the FID instrument responses as C1 were below 100 ppm.

DISCUSSION

The investigation of shallow natural gas occurrences within existing ground-water observation wells in 43 selected counties in North Dakota was conducted during the 2006, 2007, 2008, and 2009 field seasons. A total of 7,300 well sites, consisting of historic and existing ground-water observation and stock wells, drilled in the county for the purposes of ground-water monitoring of unconsolidated and shallow bedrock aquifers, and livestock water supply, were included in the field component of this investigation (Table 1). Each of these well sites were visited in the field in order to (1) determine the actual existence of the well, (2) to verify its location, and (3) perform flame-ionization detector field screening for possible shallow natural gas occurrences. 3,768 well sites were not found during the investigation, suggesting that well usage has been discontinued at these locations or the wells have been abandoned or destroyed. 3,532 well site locations were verified to have a ground-water observation or stock well at their prescribed point and were subsequently field screened.

Each well was field screened for the presence of combustible gases using a portable FID calibrated to CH_4 (101 ppm low-span or 10,000 ppm high-span) in air. The FID was used solely for field screening on all wells (Figure 1). FID response was collected at the top of well casing (TOC) and just above the groundwater/atmospheric interface (GWI), after the collection of a water level reading within the well using an electric well tape. For flowing wells (Figure 2) or stock water supply wells, FID response was collected from a headspace sample collected from the produced waters. Of the existing wells field screened, 787 returned positive FID responses (Figure 3), ranging from 0.1 to >50,000 ppm (5%) as CH_4 in air (Figure 4); 2,744 of the wells showed no response (i.e., a 0.0 ppm as CH_4 in air instrument reading) during field screening at both the TOC and GWI. Over the course of this investigation, field observations have shown that it is commonly more likely (i.e. >95% of the time) to detect CH_4 at the GWI or higher in the air column within a given well. It has been less typical to detect CH_4 emanating directly from the well TOC. CH_4 was most frequently detected in relatively low concentrations within the range of 1.0 to 10.0 ppm (Figure 5). Detrital lignites were common in over 50% of the wells tested where a CH_4 occurrence of greater than 100 ppm was found. Overall, the average value of CH_4 detected in wells where the presence of detrital lignite was not found, was slightly higher (+1,071 ppm) at 3,761 ppm (Figure 6). These wells tend to be located within ground-water zones found at the unconformable contact between subcropping Cretaceous marine shales of the Pierre Formation and overlying subglacial sediments consisting dominantly of low-permeability tills of the Coleharbor Group found dominantly in eastern North Dakota (Figure 7). FID results for counties in eastern North Dakota (Figure 8) tend to have broader distributions in the range of 0.1 to 100 ppm. FID results for counties in western North Dakota (Figure 9) tend to have narrower distributions that range from 0.1 to 10,000 ppm. This may be related to the existence of coal, and oil & gas deposits present in the Williston Basin.

The occurrence of FID responses are somewhat constrained to the boundaries of existing aquifers by the overall distribution of well locations as the majority of the wells field screened are monitoring shallow glaciofluvial aquifer systems. FID field screening is not a stand-alone analytical tool. It must be used in conjunction with additional analytical methods and procedures. A positive FID instrument response indicates that the presence of CH_4 is highly likely at the well since the instrument is selectively sensitive to CH_4 and is calibrated specifically to a predetermined concentration of CH_4 in air. However, excessive moisture and low oxygen levels or high values of carbon dioxide can influence FID response. A confirmatory gas analysis is required to determine and quantify the absolute presence and concentration of CH_4 and other hydrocarbons that may be present in conjunction with FID field screening results.

The reconnaissance level field screening results presented here in summary fashion and individually in the separate county studies referenced herein, are intended to aid in the selection of future candidate well locations and or areas to conduct additional sampling and analysis and potentially focus future oil and gas exploration and field investigative efforts.

REFERENCES

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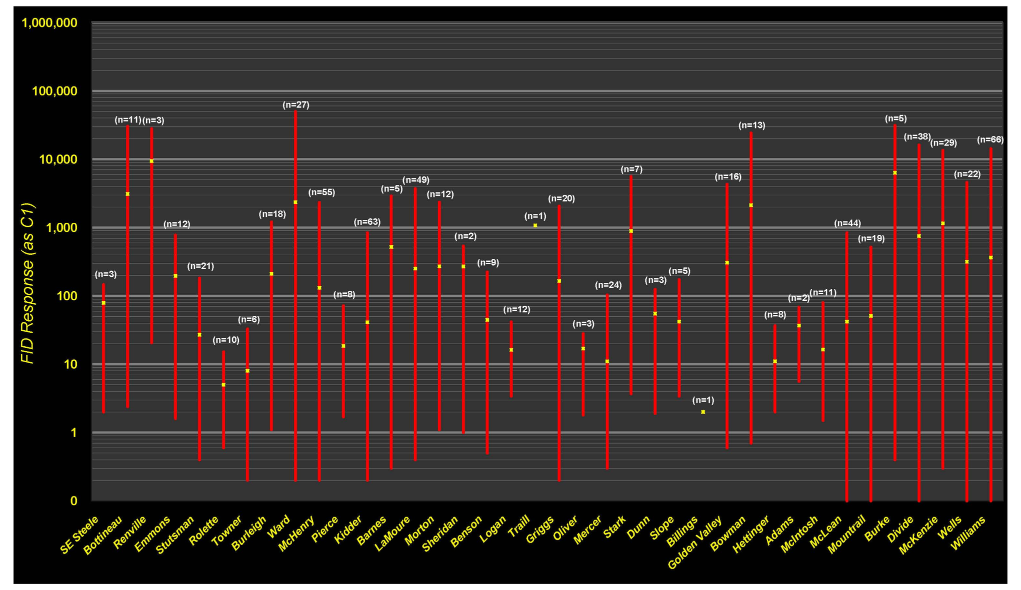

Figure 4. Comparison of the ranges and means of flame-ionization detector (FID) instrument responses (ppm as CH_4 in air) by county, in relative order of investigation. SE Steele, Bottineau, Renville, Emmons, Stutsman, Rolette, and Towner Counties were completed in 2006. Burleigh, Ward, McHenry, Pierce, Kidder, Barnes, LaMoure, and Morton Counties were completed in 2007, Sheridan, Logan, and Benson Counties were completed in 2008. The remaining 19 counties, from Traill to Williams, were completed in 2009. Generally, wells were field screened on a county by county basis. Wells in counties where shallow gas occurrences were most likely (e.g. Renville and Bottineau Counties) based on historical data and occurrences, were field screened first. Counties in "frontier" areas in eastern North Dakota were subsequently field screened. Counties in western North Dakota (e.g. Bowman, McKenzie, Renville, Ward), tend to show relatively higher mean values than other counties investigated. Mean values range across four orders of magnitude from 2 ppm to 9,420 ppm (as CH_4 in air). Concentration ranges per county are depicted by the vertical red bar with the minimum and maximum values reported as the top and bottom ends of the bar, respectively. Mean values are shown at their respective position along the bar as yellow squares. The number of shallow gas occurrences per group (i.e. the n-value) is displayed at the top of each bar.

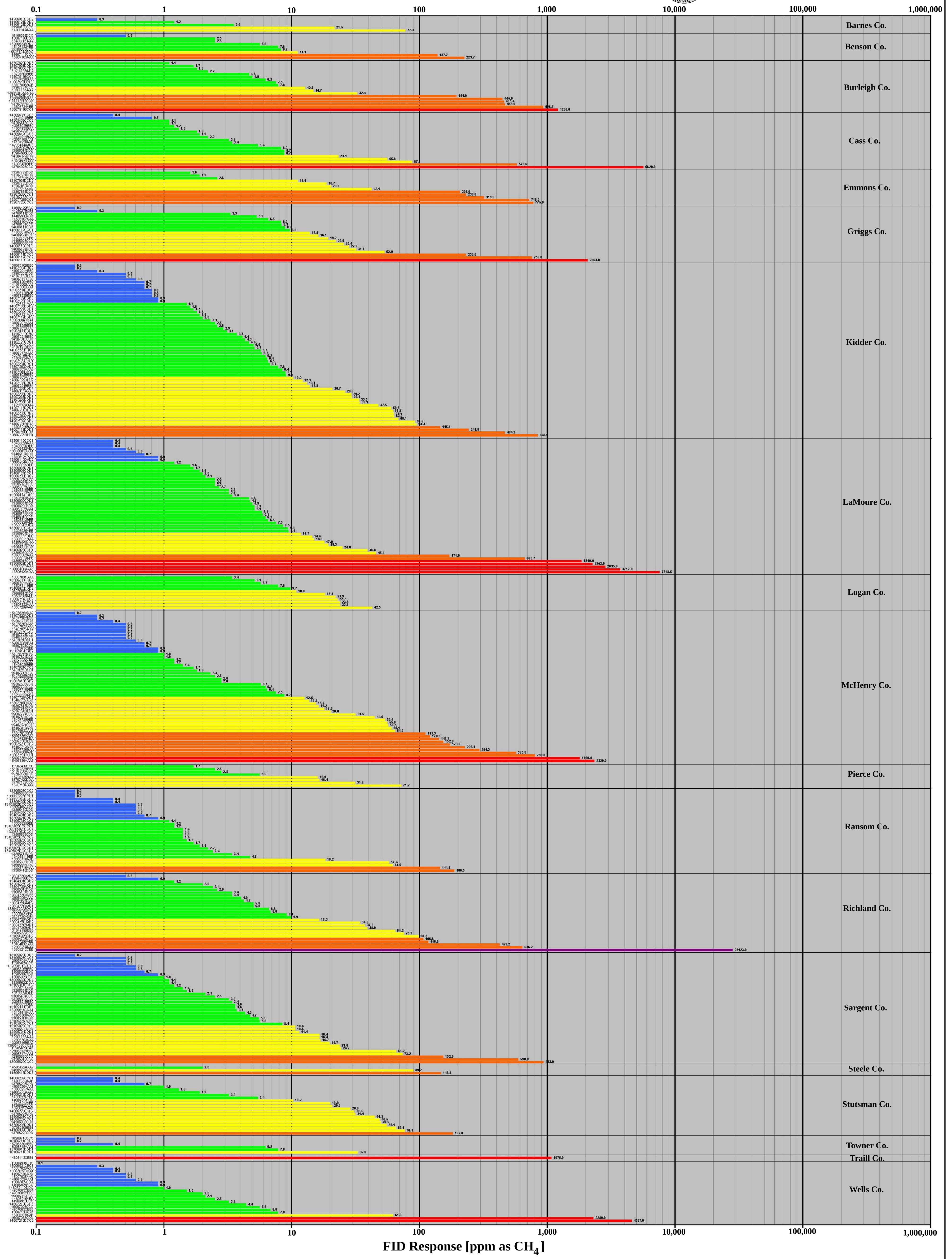

Figure 8. Comparison of positive FID instrument responses interpreted as shallow gas occurrences for wells field screened in eastern North Dakota in 2006-2009. Data grouped alphabetically by county from top to bottom. Data within each county grouping is sorted by [CH_4] in ascending order (i.e. lowest to highest). Bars are color coded with increasing values changing from cooler to warmer color based on the order of magnitude of FID instrument response: blue = 0 to 1 ppm, green = 1 to 10 ppm, yellow = 10 to 100 ppm, orange = 100 to 1,000 ppm, red = 1,000 to 10,000 ppm, and purple = 10,000 to 1,000,000 ppm. Monitoring well identification numbers are displayed at the left of each respective bar. Well identification format is in ND State Water Commission database format as Township, Range, Section and 1/4, 1/4, 1/4 (e.g. 01ABC) sections. Nested wells are commonly listed with an appended 1, 2, 3 etc., attached to the well identification (e.g. 01ABC2).