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Technical Review
Code of Practice for the Discharge of Produced Water from Coalbed Gas Operations in British Columbia

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INTRODUCTION

British Columbia is in the initial phase of coal bed methane (CBM) exploration and production. CBM production requires an operator to dewater coal seam aquifers to release the methane gas for capture. It is likely the producer will have to dispose of a large amount of water related to CBM production.

The British Columbia Ministry of Water, Land and Air Protection proposed a Code of Practice to regulate the discharge of produced water.[1] The Code envisions two means of disposal of this water – to surface water or to shallow groundwater. The Code does not envision more sustainable means of disposal such as reinjection into depleted coal seams or deep injection into aquifers beneath the coal seams.[2]

The Code establishes minimum discharge standards, requires an impact assessment prior to discharge for some proposals and establishes procedures for monitoring and recordkeeping. The purpose of this review is to comment on the level of protection from potential degradation the proposed Code provides to the waters of British Columbia.

The Code establishes parameters that the operator must meet to discharge to British Columbia streams. Based on the amount of water actually and projected to be produced, this practice could result in a substantial additional flow in some streams. The Ministry should require specific discharge permits for each proposed operation instead of a code of practice because of the poor water quality possible in discharges from CBM facilities. This would require the operator to analyze and disclose the potential impacts to the receiving waters. The application should be available for a 45 day public review and comment period. The Ministry should have the ability to require changes to the discharge, including requiring mitigation.

An individual permit-type process appears to be in place in Alberta, where a technical assessment is required, and permission must be granted before discharge from either the Alberta Energy and Utilities Board or Alberta Environment.[3]

Problems with the general permit approach to CBM development are presently being experienced in Wyoming, where a general permit for the construction of in-stream holding ponds was invalidated by a federal court due to inadequate oversight,[4] and where the State regulatory agency recently discovered the construction of unauthorized holding ponds, again due to a lack of enforcement oversight.[5]

[1] Code of Practice Intentions Paper – December 2004, British Columbia Ministry of Water, Land and Air Protection, December 2004 (see References)
[2] See Kuipers et al (2004) for a review of sustainable water management for CBM production.
[3] Alberta Environment, April 2004, p. 2.
[4] Casper Star-Tribune, Sunday, January 9, 2005, Article: Judge Kills General Dam-Building, by Dustin Bleizeffer
[5] Casper Star-Tribune, Tuesday, January 11, 2005, Article: State Steps Up CBM Enforcement, by Dustin Bleizeffer

DISCHARGE STANDARDS

This report provides a review of the Code of Practice and assesses it with standard hydrologic techniques and compares it to other water quality standards.

A discharge standard is a measure of water quality or quantity which the discharger must meet. Discharge standards may also provide other limits to the discharge such as the method of discharge or the requirements for mixing.

The Code requires the discharger to evaluate options for beneficial use of the produced water (page 2).[6] It is always preferable to use the produced water as a replacement for using additional clean water. However, the Code should specify minimal circumstances under which the discharger will be required to apply the water to a beneficial use. The discharger should use its produced water as a substitute for other sources of water whenever practicable. Using produced water as a substitute for clean water should not make the project uneconomic, but the producer should not avoid using produced water as substitute for clean water just because there is a measurable cost associated with this substitution.

The Code also limits the amount of discharge which a producer may add to a stream.

> "The receiving stream should have a minimum dilution ratio of 10 to 1 for the entire discharge from an operation before discharge." (page 2).

This should be clarified because the term "entire discharge" suggests that the discharger may add up to 10% of the flow volume of the stream or that the discharge may be 10% of the streamflow at any point on the hydrograph. The sentence should be rewritten as follows:

> The maximum discharge from an operation should not exceed that which would be diluted at least 10:1 by the receiving stream at its lowest flow.

The discharge to a perennial or seasonal stream must occur so that there are no negative impacts on stream habitat features (page 2). To meet this requirement, the Code should be clarified to require each proposed discharge be analyzed by a qualified fluvial morphologist. Baseflow dominant streams are those with a low flood flow to baseflow ratio. Baseflow streams will be most affected by a discharge that increases the flow in the stream by 10 percent, the maximum discharge allowed under the 10:1 dilution requirements of the Code. The fluvial morphologist should consider the effects of increasing the streamflow on bedload transport and the baseflow channel. If the discharge limit is 10% of the receiving stream's baseflow, it is unlikely that a discharge limited to 10% of the stream's low flow will affect the stream at flood flows. However, if the Code discharge limit can be construed to allow discharge equal to 10% of the receiving water flow at any time, then the effects during flood flows, including those on downstream flooding, must be considered. The Code should be clarified as to the intent of the dilution requirements.

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[6] Citations in parentheses are listed page numbers of the Code of Practice unless otherwise noted.

The discharge must also be designed for maximum dispersion (page 2). This is a good requirement and should lead to the use of a diffuser or other similar type of discharge mechanism that spreads the discharge horizontally across a significant portion of the entire stream, while not impeding the migration of fish around the discharge.

The Code describes a perennial stream as one which flows for at least 9 months of the year.[7] The Code should be more specific in defining perennial and seasonal to consider a longer reach of stream. Headwaters streams may be perennial for a reach and then seasonal downstream if it is a losing stream. Or, some streams may have perennial reaches caused by geologic conditions spread along the total stream length. If a stream is perennial at the discharge point but then goes dry within a short distance downstream, the effects of the discharge will be similar to those from a discharge to a dry stream. In other words, the lower standards required for discharge to perennial streams would effectively be those used for the seasonal stream.

An assessment report must be prepared by a qualified professional only if one of the following conditions is met: (1) discharge is into a perennial or seasonal stream within 5 km upstream of an existing drinking water source; (2) discharge is to the ground via infiltration within 2 km downstream of an existing drinking water well or drinking water source on any nearby stream; or (3) into a perennial or seasonal stream within 2 km upstream of an existing irrigation water source (page 2). However, to meet best practices, as stated above, each and every proposed discharge should be analyzed by a qualified professional – not just select discharges. Also, the Code must define who a qualified professional is (see below).

The requirement for an assessment only includes discharges near drinking water or irrigation uses; protection of aquatic habitat appears to be less important. The Code should require an assessment of the effect of the discharge on aquatic life as well. A number of the potential constituents in a CBM discharge to surface waters could cause impacts on aquatic organisms, especially salmonids, including total dissolved solids (TDS).[8] There is no present BC aquatic standard for TDS. The BC drinking water standard for TDS is 500 mg/L (aesthetic objective).[9] If a discharge to surface waters is anticipated, the discharge should be carefully characterized for its contaminants, and the proposed discharge schedule carefully reviewed to ensure the discharge will be protective of aquatic resources in critical times, e.g. during spawning and in low-flow conditions.

The assessment must "evaluate the need for protective measures and management recommendations for drinking water and irrigation water sources" (page 2). There is no requirement that the producer implement any of these measures. To be useful, the assessment should include mandatory measures that the producer must implement to mitigate or avoid negative impacts.

[7] The *Handbook of Hydrology* (Maidment, 1992) describes perennial as that "which never dries up" (Mosley and McKerchar, 1992).

[8] Recent research in Alaska has shown that TDS can affect salmonids at levels as low as 250 mg/l. See Stekoll, et al., 2003, p. 1.

[9] British Columbia Water Quality Guidelines, 1998/2001, Table 1: Water Quality Guidelines for Drinking and Recreational Water Uses

The assessment must be provided to “affected drinking water and irrigation water users” (page 3) but there is no provision for the user to actually provide comments. The Code would be much more protective of the human environment if it required the producer to consider the comments of those affected by the discharge and to take measures to protect those as well.

Required Discharge Water Quality Standards

The Code provides discharge water quality standards for discharge to both perennial and seasonal streams. However, the constituents regulated are limited to total dissolved solids (TDS), total suspended solids (TSS), chloride, temperature, dissolved oxygen (DO), and LC-50’s for rainbow trout and daphnia magna. For discharge to seasonal streams, the standards add a limit for boron concentrations. (page 3)

Table 1, a table of various water quality parameters observed at other CBM sites in North America, is attached to this document. Parameters on the table suggest that additionally the Code should limit concentration of sodium, arsenic and sodium adsorption ratio (SAR).

Arsenic is carcinogenic. The World Health Organization (WHO) recommends the concentration limit be 0.01 mg/l. If water with an arsenic concentration of 0.11 mg/l, as observed in the Black Warrior basin of Alabama, is diluted by a 10:1 ratio, the arsenic concentration in the receiving water will increase by more than the WHO standard. Therefore, the Code should limit the arsenic concentrations. This is an especially good policy because it is not unusual for groundwater to be contaminated with naturally occurring arsenic.

Sodium, like chloride, is a part of TDS (and SAR to be discussed below). It should be considered whether the regulation of TDS and chloride (often found proportionately to sodium) will suffice.

To protect irrigation uses and riparian vegetation, it is also important to regulate the SAR, or sodicity, of the water. SAR is a measure of the proportion of sodium in the water. Usually SAR less than 3.0 will not be a threat to vegetation, SAR greater than 12.0 is considered sodic and threatens the survival of vegetation by increasing soil swelling (dispersion) and reducing soil permeability (Kuipers et al, 2004). Land application of sodic and/or saline rich coalbed methane water for dust suppression or irrigation can degrade the soils, increasing the risk of soil erosion. Direct discharge of CBM water into streams can also cause channel erosion and loss of sodic and saline sensitive riparian vegetation. The compounding effects of discharging water with high SAR is that it produces soils that are unsuitable for agriculture, grazing, and it creates hazards such as fugitive dust from wind and increased sediment loading of local streams and rivers from surface runoff and damages the stream channel integrity (Kuipers et al, 2004).

Discharge Location

The Code requires that the water quality not exceed the LD50 for both rainbow trout and *Daphnia magna* (page 3). If the discharge is allowed to take place at up to the LD50 level, even at a minimum 10:1 dilution, there could be an area in the receiving water where acutely toxic levels exist. Acutely toxic discharges should not be allowed and discharge points should not be located in sensitive areas of the waterbody, like a spawning zone or area with high densities of aquatic organisms. The permitting process should require the assessment of impacts to stream biota at proposed discharge points and provide for a means to assess the suitability of the discharge location.

The Code establishes different standards for discharge into perennial and seasonal streams (page 3). The more stringent standards for discharge into seasonal streams probably relate to the fact that there is no way to require the discharge to be diffused across the stream when it reaches a perennial stream. Discharge from seasonal streams will create substantial degraded zones from the confluence to the point of sufficient mixing to reduce the toxic conditions. Often, a seasonal stream may be used as the conveyance for the discharge to a perennial stream. A producer should not be allowed to use a seasonal stream for conveyance so that it may avoid the construction of a discharge diffuser. Discharge to seasonal streams should be allowed only when there is a substantial distance between the point of CBM production and the perennial stream. Also, the changes in water quality along the seasonal stream should be monitored and limits should be established at the confluence with the perennial stream. Due to evapoconcentration and reaction with the sediments and streambank, the water quality of the stream at the confluence with the perennial stream may be substantially different than at the point of discharge to the seasonal stream. A good example is the extra turbidity and suspended sediments that may be caused by flow on a normally dry stream.

Discharge to seasonal streams will frequently infiltrate to the groundwater just as if it was discharged to a ground disposal facility (page 4) such as a rapid infiltration basin. Therefore, the same requirements applied to a ground disposal facility should be required of a discharge to a seasonal stream. However, there may be circumstances, especially in the drier eastern regions of British Columbia, where discharge to normally dry streams with the intent of complete infiltration is desirable. To accommodate this situation, the Code may want to reconsider the requirement that a seasonal stream into which discharge will occur always discharge into a perennial stream (page 3).

Degradation

Degradation refers to the decrease in water quality caused by the discharge of a waste to a river or stream. If the water quality of the discharge is poorer than that in the receiving water, the quality of the receiving water will become poorer.

The standards allow the discharge of water with substantially poorer quality than usually exists in pristine British Columbia streams. Water with total dissolved solids (TDS) concentration of 4000 mg/l and chloride concentration of 1500 mg/l, as allowed by the proposed guidelines (page 3), can substantially degrade the receiving waters even with the dilution standards. At a 10:1 dilution, the discharge water will increase the TDS concentration by 400 mg/l. The receiving water will likely have some ambient TDS, therefore the discharge could increase the TDS concentrations to levels that exceed drinking water standards. In pristine streams where TDS could be less than 100 mg/l, the discharge could increase the concentrations by more than five times.

TDS mostly consists of inorganic salts including principally calcium, magnesium, potassium, sodium, bicarbonates, chlorides and sulfates. BC Standards limit TDS concentrations in drinking water to 500 mg/l for aesthetic and taste reasons.[10] High TDS also leads to corrosion. The concentration of chloride is limited to 250 mg/l.[11] Some sources recommend an upper limit of 1000 mg/l for aquatic organisms,[12] while more recent research indicated that impacts from TDS can be documented to at least 250 mg/l (the lowest concentration tested).[13] Any stream with concentrations of 600 mg/l or higher will exceed 1000 mg/l limit if 4000 mg/l water is added with a 10:1 dilution. Also, the effect of high TDS concentrations in conjunction with other constituents is unknown and must be accounted for in an impact assessment.

The standards should be changed to avoid or minimize degradation. To avoid degradation, the standards should be set equal to the quality of the receiving water up to a maximum such as the 500 mg/l BC drinking water standard. Alternatively, the discharge TDS concentration should be limited to either the BC drinking water standard or 1000 mg/l to increase the assurance that CBM development does not degrade the waters of British Columbia. Standards for other constituents should be set similar to the proposal for TDS.

Cumulative Impacts

The proposed Code appears to not limit the number of operations that could discharge into the same stream or into seasonal streams that discharge into the perennial stream with many dischargers. The Code should be more specific in this regard and consider the following issues.

The proposed Code establishes at least a minimum 10:1 dilution of the discharge. However, there is no definition of operation or limit to the number of operations that may occur along the same stream. It appears that the Code allows the discharge from an operation to add to the baseline flow in a stream so that downstream discharges actually have a larger stream to discharge in to. The baseline quality at downstream locations then reflects an altered condition. The Code should be changed to prevent this from happening.

One way of limiting this would be to define the term ‘discharge’. Many CBM fields contain hundreds or even thousands of wells. The length of pipe or open channel required to collect all of the water and discharge it to a stream at one point may be quite substantial. It may be less expensive for an operator to discharge from individual or small collections of wells to streams. This may be seen in the CX Ranch area of Montana where the discharge permit allows up to 11 discharge locations but sets cumulative limits.[14] Without a limit on the number of dischargers, the Code does not prevent this least cost, maximal impact means of discharge. To limit the cumulative impacts of CBM production, the Code should limit the number of discharge points on

[10] British Columbia Water Quality Guidelines, 1998/2001, Table 1: Water Quality Guidelines for Drinking and Recreational Water Uses
[11] British Columbia Water Quality Guidelines, 1998/2001, Table 1: Water Quality Guidelines for Drinking and Recreational Water Uses
[12] Chapman et al. (2000)
[13] Stekoll, et al., 2003, p. 1
[14] See the Final Environmental Impact Statement for Coal Bed Methane Development, Montana.

the stream, establish a maximum cumulative discharge, require a minimum distance among points, and require a detailed assessment of the cumulative impacts of the entire development and foreseeable future developments on a stream.

MONITORING AND RECORD KEEPING

Monitoring Program

The Code states that the monitoring program will be designed and supervised by a qualified professional (page 6). The qualified professional has a great deal of discretion to specify the constituents to be monitored (page 5). Some parameters, including temperature, total dissolved solids, total suspended sediment, sodium, sulfate, dissolved oxygen and sodium adsorption ratio – which can be problems in CBM discharges – should be specified in the Code.

Rather than a reporting trigger for these substances, all of the monitoring data should be included in the annual report. It is common practice to require that all constituents, when measured, be reported even if they are not on the standard list of constituents for a discharge.

Monitoring Reports

An Assessment Report that would include all monitoring data is required annually (page 6). Although these reports must be kept for the life of the operation, the reports will not routinely be submitted to BC regulators. BC regulators would see monitoring data only if a requirement or standard of the Code was not met, or if a 'deleterious environmental change' were to occur (page 4).

The Code should define "deleterious environmental change". It currently relies on the operator or its consultants to determine when the data show that a deleterious environmental change has taken place. The Code should establish a means for oversight of that operator or consultant monitoring. It would be useful to have the monitoring data submitted to the ministry on a regular basis rather than just "on the request of a director".

Although submittal of monitoring data would be required 'on the request of a director' (page 4), it appears that the public would not have access to the data, unless it is voluntarily released by the discharger. Public access to monitoring data is not only important to establish public confidence that the discharger is meeting its permit obligations and improve public acceptance of CBM development, it also allows the public to supplement provincial regulatory oversight in the early detection of problem data trends. Since BC regulators would likely see monitoring data only if there is an exceedance of Code requirements or standards, it is not likely that routine scrutiny of monitoring data that would reveal trends toward an exceedance would be noticed by regulators. And even in situations where regulators do receive all monitoring data, it is our experience that they seldom have the time to review this data for negative trends. If the public is concerned about these discharges, and they have access to the monitoring data, they can not only see whether requirements are being met, but can also provide the detailed scrutiny sometimes necessary to detect negative trends, which hopefully lead to early solution of problems.

Filing with the Ministry and public access to monitoring reports should be included as a requirement of the Code.

Qualified Professionals

The Code relies heavily on the 'Qualified Professional' to analyze the potential for contamination, design a plan for monitoring this potential contamination, actually oversee the monitoring, and report the results to BC regulators. There is no reference in the Code to a definition of a Qualified Professional.

Implementation of the Code depends on both the professional expertise and the professionalism of the Qualified Professional. In order to ensure that the qualified Professionals are doing a good job on a project-by-project basis, there should be spot inspections by Provincial regulators to ensure that monitoring plans are being carried out as designed. Qualified Professionals should be certified, and re-certified by the Province.

The Province must recognize that there is potential for Qualified Professionals to be co-opted to a lesser or greater extent by the people they depend upon for their livelihood. In order to prevent this from happening, and since a good portion of the regulatory authority normally invested in the government is being delegated to the Qualified Professionals, the Province should take care to define just who and what a Qualified Professional is, and to ensure that there is a mechanism to ensure accountability for this delegated authority.

Produced Water Characterization

The operator must determine the quality of the water to be discharged before the discharge actually commences. While laudable, this is difficult in practice because it requires pumping water from the coal seam before there is a place to actually discharge it. The quality of produced water may change with time from the initial pumping because the high flow velocity may leach contaminants or may allow air to reach the soils and oxidation to occur. Therefore, it is essential that test wells be constructed with holding ponds into which a well may discharge for a sufficient period of time that the water quality stabilizes. During a test, the operator will sample the water initially and repeatedly until the water quality stabilizes. Care must be taken to assure that the pumping has lasted long enough to stress the coal seam aquifer so that potential changes could occur.

Receiving Environment Baseline Monitoring

The purpose of baseline monitoring is to establish the characteristics of the receiving water, surface or ground. Future monitoring can be compared with this baseline to determine the changes caused by the discharge of CBM water. Although it logically follows that baseline data must be taken before a discharge changes the character of the receiving water, the guidelines do not explicitly state this. It is essential that baseline monitoring be completed before any produced water discharges occur.

CONCLUSION

British Columbia has proposed a new code of practice for permitting water discharges from coal bed methane productions into surface and groundwater. The proposed Code establishes discharge quality and quantity limits and procedures for monitoring discharges and ambient water conditions. The proposed Code establishes a means for reporting to the environment ministry, but not to the public.

From this review, we conclude that, while there are some positive aspects, the proposals fall short of the standards necessary to protect the waters of British Columbia from degradation. Problems with a general permit approach to CBM regulation are being experienced in Wyoming. An approach that would be more protective of water resources would be to require specific discharge permits for each proposed operation, as is done in neighboring Alberta.

While the code requires the producer to consider alternatives to disposal of the CBM water, it should also require that the CBM water be put to beneficial use if feasible. It is also good that diffusers will be required to minimize the mixing zone below the discharge point, but the requirements for dilution will still allow the concentration of various contaminants to increase by up to 10% of the concentration in the discharge. In pristine British Columbia streams, the concentration of TDS or chloride could increase substantially. The standards and the minimal dilution requirements allow water quality to be reduced. The standards for specific discharges should be that the quality of the discharge not be any worse, within a measurement error, than the quality of the stream. An alternative standard could be to limit the discharge to BC drinking water standards and aquatic life standards.

The Code is also not clear on several points. The Code should be made specific to limit the discharge flow rate to 10% of the receiving water's low flow. The Code should better define perennial and seasonal so that a perennial stream has a long reach that qualifies as perennial.

The Code needs to better define "Qualified Professional" and deleterious environmental change. The present Code approach depends heavily on the professional competency and conduct of the Qualified Professional, yet there is no definition of, standards for, or accountability of these individuals.

The Code should also provide for public review of the monitoring data.

Perhaps the most substantial effects could result from the cumulative impacts of the discharge. The Code should establish a minimum distance between discharges to the same stream or groundwater aquifer. This would help prevent contaminant loads from building up to deleterious levels.

Coal bed methane production and the concomitant water disposal is now beginning and will likely continue for several decades. It is essential to get the standards right at the beginning because it would be difficult to improve standards on an operator which has been developing CBM for years. It is also essential to get the standards right to assure the acceptance of the process by the public.

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Table 1: Selected Water Quality Characterization Data for CBM Well Fields in North America
(Alberta Geological Survey 2003)

Water Chemistry	Horseshoe Canyon Formation (Alberta, Canada)		Powder River Basin, WY		Piceance Basin, CO		San Juan Basin CO, NM, AZ, UT		Black Warrior Basin, AL	
	Max (mg/L)	Min (mg/L)	max (mg/L)	Min (mg/L)	Max (mg/L)	Min (mg/L)	Max (mg/L)	min (mg/L)	max (mg/L)	min (mg/L)
Na	861.00	112.00	800.00	110.00	2673.00	1976.00	5939.00	3674.00	3100.00	570.00
Ca	128.00	2.70	69.00	5.90	1839.00	13.20	118.70	6.50	100.00	2.50
Mg	23.50	0.20	46.00	1.60	7.77	0.00	39.00	2.88	34.00	1.10
As	0.0022	<0.0002	0.0026	<0.0002					0.11	0.00
Fe	0.16	<0.01	4.90	0.20					1.50	0.05
K	8.90	2.00	18.00	3.80					6.00	2.00
HCO_3^-	1720.00	384.00			6612.00	5250.00	14701.00	6083.00	1120.00	670.00
Cl-	229.00	0.50	64.00	5.20	600.00	4.00	2499.00	668.00	4200.00	450.00
SO_4^{2-}	1320.00	1.00	17.00	0.01	135.50	8.32	166.80	0.00		
Meq Na	37.45	4.87	34.80	4.78	116.27	85.95	258.34	159.82	134.85	24.79
Meq Ca	6.39	0.13	3.44	0.29	91.77	0.66	5.92	0.32	4.99	0.12
Meq Mg	1.93	0.02	3.79	0.13	0.64	0.00	3.21	0.24	2.80	0.09
SAR	**18.36**	**17.72**	**18.30**	**10.37**	**17.11**	**149.77**	**120.90**	**301.66**	**68.33**	**75.57**