1 HYDROLOGY SUPPLEMENT

1.1 INTRODUCTION

Yates Petroleum Corporation (Yates) proposes to develop coal bed methane (CBM) within the middle reaches of the Indian Creek drainage watershed approximately nine stream miles west and upstream of the Powder River (Map 1). This development will include a total of two CBM wells drilled to produce from the Big George coal seam. The CBM discharge water from all wells will be interconnected to a project total of two CBM water outfalls to ground surface that will flow immediately into a total of two on-channel reservoirs that will contain the discharged CBM water (Map 2). Maps, figures, tables, and appendices containing supporting data referenced in the WDEQ Application Form and this Supplement follow this text.

The estimated CBM water budget indicates that the two reservoirs should have adequate capacity to contain all CBM water produced annually. In the case of reservoir overflow resulting from a sufficiently large storm event, the reservoir basin mixing analyses indicate that resultant water quality at the mouth of the mixing watersheds will be within the typical effluent water quality standards for Powder River Basin permits.

Because no downstream irrigation was identified between Yates' outfalls and the Powder River, no Irrigation Compliance Points are proposed. If any of Yates' reservoirs overflow, surface water samples will be collected from the Tributary Monitoring Point (TRIB) on each of the reservoir-containing tributaries to Indian Creek just above the confluence with Indian Creek.

1.2 WELLS AND WATER PRODUCTION

Yates plans to produce two CBM wells within the Corsair CS State CBM project (Table 1). The wells will be completed in the Big George coal at total depths ranging from 2042 to 2175 feet below ground surface. Map 2 shows the proposed layout of the water management facilities, including the locations of the proposed CBM wells, water lines, outfalls, and on-channel reservoirs.

The annual water production (inflow) estimates are based on pumping rates over the year from September 2003 to August 2004 (Table 2) researched from the Wyoming Oil and Gas Conservation Commission (WOGCC) database on line. Historical production data compiled from these 15 wells, selected from adjacent leases producing from the Big George coal, indicate that an approximate initial maximum rate of approximately 42 gallons per minute (gpm) per well from the coal is expected. As the water production rates decline in the first wells to be produced, additional wells will be placed in production, and water will be routed to reservoirs as available capacity allows.

1.3 WATER OUTFALLS

Yates seeks to permit two outfalls to discharge CBM water immediately above the high water line of the two on-channel reservoirs within the Indian Creek watershed (Map 2 and Table 3). Outfalls will be piped and valves will be installed such that both wells will be connected to

Exhibit H

both project outfalls to allow maximum flexibility in water routing. CBM water will be routed to discharges depending on available reservoir capacity, proximity of an outfall point to the well, etc. The outfall points will consist of an energy dissipation structure and rip-rapped spillway designed to reduce erosion and oxygenate the water as it flows overland to the reservoirs. A typical outfall design schematic is illustrated in Figure 1.

1.4 WATER STORAGE FACILITIES

Yates proposes to manage CBM water within the Corsair project watersheds by containing the water within two on-channel reservoirs located on intermittent tributaries to Indian Creek, a tributary to the Powder River. The total capacity of the two reservoirs is estimated at 40.1 acre-feet (Table 4). However, in the event of a sufficiently large storm event (see discussion in Section 1.5 below), one or more of the reservoirs would discharge to these tributaries to Indian Creek. Reservoir water will be used beneficially for stock watering and wildlife (Appendix A).

All on-channel reservoirs have been designed by a Wyoming-registered Professional Engineer in accordance with the WSEO requirements. All structures proposed for this development will be permitted by WSEO, and the reservoir dimensions were referenced from the corresponding WSEO reservoir permit application (Table 4 and Appendix B).

1.5 WATER BUDGET

The proposed CBM water budget estimate indicates that the CBM water to be produced annually can be totally contained within the Corsair project reservoirs. A total project maximum inflow of approximately 0.120 million gallons per day (MGD = 83.3 gpm) is estimated (Table 5). The production estimates are conservatively high and based on maximum, not average, site well flow rates determined from the WOGCC area production (Table 2). Water production rates are expected to decrease exponentially over time.

Estimating infiltration through and evaporation from these reservoirs, the annual outflow from the reservoirs (465 ac-ft/yr) will exceed the inflow (134 ac-ft/yr) assuming recent area water production rates, with increasing excess capacity as water production declines or stabilizes over time. Subtracting the ratio of annual inflow to annual outflow from one (1-(134 ac-ft/yr / 465 ac-ft/yr)) indicates an average excess reservoir capacity of approximately 71 percent (Table 5).

Assuming the maximum production rate (Table 2) from each well and use of 100 percent available reservoir capacity (Table 4), analysis of the runoff catchment basins above individual reservoirs indicates that there is sufficient capacity in the proposed reservoirs to contain CBM inflow plus the following storm events (Table 6, Part C):

- Amy Reservoir can contain CBM water plus storm water through a 10-year probability, 24-hr duration storm (begins to overflow by 25-yr storm);
- Anna Reservoir: contain CBM + storm water through a 25-yr, 24-hr storm (begins to overflow by 50-yr storm)

Water mixing was analyzed to predict the resulting water quality in the event of storm-induced overflow and is discussed below in Section 1.6.

Basin hydrologic characteristics were used to estimate 24-hour duration annual peak flow runoff rates, volumes, and resulting reservoir capacities for eight different storm event probabilities. For basin characteristics (Table 6), a Geographic Factor of 1.6 was assumed (Lowham, 1988), and the Basin Slope was determined from the area topographic contours using the method detailed in Lowham (1988).

1.6 WATER QUALITY

Water will be produced from the Big George coal. CBM water has been sampled from this coal from the one existing well on this project (Corsair #2) and from nearby Dry Creek CS State lease (Dry Creek #1) (Table 7 and Appendix C) within a 20-mile radius. Dry Creek #1 and Corsair #2 samples are presented as the geographically closest available samples, although they were collected during short-term initial start-up pump testing, which may not be as representative as long-term production.

Chlorides exceeded the typical end-of-pipe effluent limit of 46 milligrams per liter (mg/L) that WDEQ has established for the Powder River Basin (WDEQ, July and December 2001) in two of the three CBM water samples presented in Table 7. However, these chloride concentrations are all less than the chloride Aquatic Life Chronic Value of 230 mg/L intended to be protective of stock and aquatic life. If these reservoirs were to overflow in response to a storm, the overflow chloride concentration should be further diluted by storm water.

Total radium concentrations exceeded the typical effluent limit of 1 picoCurie per liter (pCi/L) in two of the three samples presented in Table 7. However, the two samples reporting radium in excess of 1 pCi/L are from this same project well (Corsair #2). The sample from the well northeast of this project (Dry Creek #1) did not report radium in excess of 1 pCi/L. Further, the radium limit is currently under review by WDEQ and may be raised above 1 piC/L.

CBM water from the Big George coal typically exhibits a high (with respect to irrigation water quality) sodium adsorption ratio (SAR) and electrical conductivity (EC). Table 8 compares CBM groundwater to (a) pre-CBM surface water quality from U.S. Geological Survey (USGS) monitoring station No. 06313665 on Dead Horse Creek just above its confluence with the Powder River (data collected between 1978 and 1989), and (b) recent mainstem (Powder River) water quality from two Petroleum Association of Wyoming (PAW) monitoring stations upstream of Indian Creek. The medians of the pre-CBM data (Appendix D) and the series of samples from the PAW stations (Table 8) were determined to derive a single concentration for each constituent. Data plotted on the U.S. Department of Agriculture irrigation water quality characterization scheme (see plot on Table 8) shows that the pre-CBM main stem surface water, current main stem surface water, and CBM groundwater all exhibit very high salinity hazard, indicating that CBM water has not contributed to salinity.

However, the current main stem and CBM water quality show a very high sodium (alkali) hazard as compared to pre-CBM main stem water quality plotting in the high alkali hazard zone. The Dead Horse Creek USGS monitoring station No. 06313665 was chosen as being the nearest representative of surface water quality flowing over the same surface geology (Wasatch Formation) as the Corsair project. Comparison of the ions on Table 8 indicates that the higher SARs reported by the current main stem and CBM water are likely due to the relatively higher sodium concentrations and the much lower concentrations of calcium and magnesium as compared to the pre-CBM water concentrations.

1.6.1 Storm Overflow Mixing Analysis

An analysis of CBM groundwater mixed with storm water concentrations indicates that if a sufficiently large storm event were to cause reservoir overflow, the quality of the resultant mixed water (Tables 9a and 9b) will be within typical WDEQ effluent limits of 6 SAR and 2000 micromhos per centimeter (umhos/cm) electrical conductance (EC).

To relate the predicted mixed water quality to potential effects on soil permeability of consequence to irrigation, these values plot within the "slight to moderate reduction in infiltration" zone of the Hanson EC vs. SAR chart (plots on Tables 9a and 9b). Lesser probability storms with greater storm water flow volumes would result in further dilution of the CBM water and contribute additional calcium and magnesium, further decreasing both the EC and SAR of the resultant mixed water. Lastly, these production estimates are conservatively high and assume constant maximum production rates maintained over a year. CBM groundwater production rates are expected to decrease exponentially over time, further decreasing overflow probability.

<u>Mixing Estimation Methods</u>

The mixing analyses of storm runoff and CBM water included runoff that would be generated within the watershed surrounding the channel on which each reservoir will be located above the confluence with Indian Creek (Map 3). Runoff volumes were determined based on flow rates generated from different magnitude storm events. Storm water runoff rates and volumes are estimated using a combination of solutions developed by the USGS (Lowham, 1988) and the Soil Conservation Service (Kent, 1973). Storm water quality is estimated using correlations relating 2-year storm flow-normalized rates to storm water quality using data from USGS station No. 06316400 (Crazy Woman Creek at Upper Station near Arvada, summary statistics in Appendix D) to represent basin-wide storm water runoff quality. This USGS station data was used, rather than Station No. 0631665, because there are many flow measurement records from which to develop the flow vs. concentration correlation; station No. 0631665 had only two flow measurement records.

Water quality concentrations from nearby CBM discharge samples were mathematically "mixed" with historical storm water concentrations from USGS monitoring station No. 06316400 to represent storm water quality. Complete mixing of storm runoff with the CBM product water was assumed. The following summation equation was used to estimate the resulting mixed water quality:

$$\mathbf{RQ = \sum(SW_{us} + RW + SW_{ds})_i + SW_{basin}}$$

where:

RQ	=	resultant water quality, such as EC, [Na], [Mg], [Ca], or SAR
SW_{us}	=	quality contribution of storm water upstream of reservoir i
RW	=	quality contribution of CBM water in reservoir i
SW_{ds}	=	quality contribution of storm water downstream of reservoir i to next stream order
SW_{basin}	=	quality contribution of storm water from the remaining intermittent tributary basin area
i	=	individual reservoir

Potential Area CBM and Other Water Contribution

No other CBM discharges were identified upstream within un-named tributaries on which the un-named tributaries in which the Corsair reservoirs would be located. Draft discharge permits identified from researching the WDEQ NPDES permit database (Table 10) indicate potential outfalls to be located both upstream and downstream of where the Corsair reservoir tributaries join Indian Creek. However, only limited discharge volume information was found for these draft permits.

The area topographic map (USGS, 1972) shows three "Flowing Wells" mapped west of and just above the Powder River floodplain and downstream of Yates' project (SE NW NW-2-T48-R78; NE NW SW-32-49-77). This suggests the potential for natural groundwater discharges into Indian Creek.

1.6.2 Downstream Water Quality Monitoring

Yates proposes to monitor water quality originating from their facility at points just above Indian Creek from the intermittent tributaries that would contain the upstream Corsair reservoirs. In the event that discharges occur from either of the on-channel reservoirs on either tributary, Yates will monitor downstream surface water quality just above its confluence with Indian Creek (proposed TRIBs 1 and 2) to ensure protection of mainstem Indian Creek water quality. The basin analysis (Table 6) indicates the storm events that are expected to cause overflow of the individual Corsair reservoirs. The proposed downstream monitoring conditions and locations (Table 3 and Maps 2 and 4) are as follows:

> (1) If either reservoir within the individual defined watersheds overflows, TRIBs on the watershed channel just above the confluence with Indian Creek will be sampled for water quality, if the overflow water reaches the TRIB, to determine Corsair CBM water quality potentially entering Indian Creek and the Powder River.
>
> (2) If either reservoir overflows, surface water samples will be collected from one upstream mainstem monitoring point on the Powder River above the confluence with Indian Creek (WQMS-UP), and one downstream mainstem monitor point on the Powder River below the confluence with Indian Creek (WQMS-DOWN).

No active irrigation was observed and no irrigation rights from Indian Creek or the adjacent un-named tributaries were identified downstream of the Corsair project watersheds. The nearest surface water irrigation rights identified are from the Powder River, not from Indian Creek or these intermittent tributaries (Table 11). Further, the Powder River irrigation right identified dates from 1903 and is recorded as abandoned.

1.7 SUMMARY & CONCLUSIONS

Yates Petroleum Corporation is committed to the environmentally responsible management of their CBM-produced waters. Water budget estimates indicate that the proposed two interconnected on-channel reservoirs can contain CBM water produced annually. In the event a storm event of sufficient volume exceeds existing reservoir capacity, a mixing analysis predicts resultant water quality at the confluence of the reservoir watersheds with Indian Creek will be within typical effluent water quality limits established by WDEQ for other Powder River Basin permits. Monitoring of surface water quality at a series of monitoring locations will ensure compliance with limits required in the NPDES permit.

1.8 REFERENCES

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