

APPENDIX C

SUMMARY OF DIRECTIONAL DRILLING WITHIN THE PROJECT AREA

This appendix and the information contained herein was provided as part of the Operators' Proposed Action. The BLM has not verified the information, nor has it validated the conclusions presented. Information regarding potential cost savings of directional drilling is not included in this appendix.

Directional Drilling as Part of the Proposed Action

Directional Drilling of 20 acre offset development from surface locations on 40 acre spacing is a viable alternative to intensive, vertical well placement on 20 acre patterns, and is proposed by the operators as a mitigation measure to reduce surface impacts. Such an alternative is made feasible by the limited lateral offset distance of approximately 330 feet. This relatively short horizontal displacement from the surface hole location to the bottom hole location means that the two curves needed in the wellbore will be much less severe than those in a well where the horizontal displacement is greater than 500 to 600 feet. The operators have found that the risks, both mechanical and economical, rise exponentially when the lateral reach exceeds 500 to 600 feet, and become extremely high as distances approach 1,000 feet (see discussion below). These risks are operationally acceptable, however, when the lateral reach is less than 500 feet. The incremental costs associated with each such directional well would be approximately \$78,300.

Summary of Directional Drilling Problems Encountered Within the Project Area

Directional drilling has been used in the Cave Gulch/Bullfrog Units in the past with limited success.

Barrett Resources Corporation

Barrett Resources Corporation has drilled three wells within the Cave Gulch-Bullfrog-Waltman project area directionally. These were the CGU#8, CGU#13, and SCG#B1 wells.

The CGU#8 well was programmed to be drilled directionally to a point 1015' wsw of the surface location at a depth of 9000'. The drillstring became stuck while drilling at 7326'. During efforts to free the drillstring, a blowout occurred. In order to regain control of the well, the drillstring and hole below 5000' was abandoned and the drillpipe above 5000 feet was cemented in place and the basal Fort Union sands were completed. Costs directly attributable to the directional drilling, the stuck drillstring and blowout were \$717,000.

The #13 well was drilled as a replacement well for the #8 in order to develop the Lance formation from 5000' to 9000'. This well also encountered hole problems and spent 3 days freeing stuck drillstring as well as having to repeatedly make short trips to wash and ream tight intervals. Cost to drill (excludes casing, cement and completion costs) this replacement well was \$525,000. None of this cost would have been necessary if the #8 well had been successfully drilled to it's proposed depth.

The SCG#B1 well required building over three times the angle required to drill the #8 and #13 wells. Structural data on the basal Fort Union sands made it mandatory that the wellbore reach

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a point some 1100' from the surface location by the time the wellbore reached a depth of 4500' if there was any hope of encountering productive sands. At that point it had to be brought back to vertical and kept vertical through the Lance to a projected depth of 9000'. The drillstring repeatedly got stuck in this well and it consequently took 50% longer to drill the well. The resulting cost to drill was more than double the cost of the other vertically drilled wells.

In addition, no open hole logs could be obtained due to sloughing shales in the deviated part of the wellbore. This means there is no definitive data available for completion operations and more incremental costs will be incurred. Of potentially even greater impact, is the potential for lost reserves. Due to not having the log data needed to project what a particular sand or interval should be capable of producing, there is no way to know whether the actual production obtained from a completion interval is representative of what the interval should have been capable of producing.

It is therefore not possible to estimate the true ultimate incremental cost of this well. Before consideration of any lost reserves, the well will, at minimum, cost some three times what it should have cost. The incremental cost to date of the directional drilling is over \$300,000 and the well has yet to be completed. The incremental cost of the completion operation will easily add another \$250,000. This \$550,000 nearly represents the cost of two vertically drilled wells.

Chevron U.S.A Production Company

Chevron U.S.A. Production Company has drilled four directional wells in the Waltman area in the past two years. Waltman #42 was drilled in 1995 and Waltman #43, #38, and #20 have been drilled during 1996. All four wells were successfully drilled and cased. The openhole logging program for Waltman #42 had to be canceled due to hole problems. The incremental cost of directionally drill the subject wells was \$599,750 (approximate cost to drill an additional straight hole).

Attached is a table summarizing the costs associated with directionally drilling the four Waltman wells. The costs for Waltman #42 and #43 were significantly higher than Waltman #38 and #20 due to the difference in "directional severity". For the purpose of this analysis, the complexity of the directional plan dictates the degree of directional severity. Three classes of directional severity were defined (Table C-1). To date all of the wells which have been drilled have been either Class "1" or Class "2" wells.

Waltman #42 was the first directional well drilled in the Waltman area. The well was drilled utilizing the standard casing program for the Waltman area (+/-500' of surface casing and no intermediate string) with a fairly aggressive, Class "2", "S" shaped directional profile. Hole stability and keyseating problems developed early on in the project and became so severe by total depth that the well required 18 days of reaming prior to running casing. Hole conditions were so severe that openhole electric logs were not even attempted.

One additional impact resulting from the hole problems encountered due to directionally drilling the Waltman No. 42 well was a 4 month delay in production from both the Waltman #37 and Waltman #42 wells. These wells were drilled from the same location, and were scheduled to be completed prior to the implementation of seasonal raptor stipulations. Due to the significant delays in drilling the # 42 well, neither well was completed in time to avoid seasonal raptor stipulations. The wells were therefor shut-in until approval was granted to resume activities. The economic impact from

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this delay in production over the winter months when gas prices are usually highest is calculated to be in excess of 3.3 million dollars.

Additionally, when completion operations were resumed on the Chevron Waltman #37 well, it was discovered that during the time the well was shut-in, the Fort Union Formation was damaged to the extent that a replacement well was required to be drilled. It is postulated that the reservoir damage occurred from the reaction of the drilling fluids that invaded the formation during drilling activities with clays in the reservoir. In a more typical field development scenario, these fluids would not have remained in contact with the formation for such a prolonged period of time. When perforating and formation fracturing take place, the fluids that invade the formation during drilling operations are displaced and recovered. Because of the damage to the reservoir in the Chevron Waltman #37 well, a replacement, twin well was required to be drilled at a cost of approximately \$500,000. to produce the Ft. Union reserves. There is a further economic impact associated with the additional 8 to 9 month delay in production of the Ft. Union reserves in the original #37 well while a replacement well was drilled and completed.

Waltman #43 was the second Class "2" well drilled in the Waltman area. The build, hold, and drop sections of the well were cased with an intermediate string of casing to alleviate the hole stability and keyseating problems that were encountered on Waltman #42. The well was drilled without the same severe hole stability and keyseating problems experienced in the Waltman #42 well. Future Class "2" wells will be designed in this manner. The incremental cost of future Class "2" wells will be in the \$160,000 to \$180,000 range.

Waltman #38 and #20 are located in areas of the reservoir where it was possible to "adjust" the directional targets in such a manner as to reduce the complexity of the directional plan. The Class "1" wells were drilled, logged, and cased relatively trouble free. The incremental cost of future Class "1" wells will be in the \$80,000 to \$100,000 range.

To date, Chevron has not drilled a Class "3" well. Depending on the outcome of the Environmental Impact Study it may be necessary to drill Class "3" wells in the future. Class "3" wells will be very aggressive "S" shaped wells requiring +2000' of horizontal displacement or long reach build and hold wells requiring +2500' of horizontal displacement. It is projected that the incremental cost to drill a Class "3" well is in the \$250,000 to \$300,000 range, assuming no hole problems are encountered. Depending on the severity, Class "3" wells may not be economically feasible.

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Table C-1. Incremental Costs Associated with Drilling 1995 and 1996 Waltman Directional Wells.

Well	Directional Severity	Directional Services	Drilling Mud	Rig & Personnel	Casing & Cement	Hole & Logging Problems	Total Incremental
Waltman #42	Class "2"	\$72,000	\$44,000	\$21,200	--	\$130,400	\$267,600
Waltman #43	Class "2"	\$59,000	\$11,200	\$23,700	\$62,400	\$9,500	\$165,850
Waltman #38	Class "1"	\$49,700	\$9,100	\$17,100	--	\$4,100	\$80,000
Waltman #20	Class "1"	\$61,900	\$8,000	\$8,200	--	\$8,200	\$86,300
	TOTAL	\$242,600	\$72,300	\$70,200	\$62,400	\$152,200	\$599,700

DEFINITIONS:

Directional Severity

- Class "3" "S" shaped wells with aggressive build and drop rates with a +30 degree tangent angle, or a "build and hold" plan with a +40 degree tangent angle.
- Class "2" "S" shaped wells with aggressive build and drop rates with a 20-30 degree tangent angle. Additional string of casing incorporated in 1996 and future wells.
- Class "3" "S" shaped wells with a moderate build rate and a mild drop rate with a 10-20 degree tangent angle.

Directional Services

Costs associated with Directional Driller, MWD, and other associated equipment.

Drilling Services

Incremental mud cost to maintain a "lighter" mud system for additional hole stability.

Drilling Mud

Incremental cost associated with additional time required to directionally drill.

Rig & Personnel

Incremental cost associated with running a intermediate casing string on post 1995 Class "2" wells.

Hole & Logging Problems

Incremental cost associated with hole stability and logging problems associated with Waltman directional wells.