ECONOMIC ISSUES AND POLICIES AFFECTING RECLAMATION IN WYOMING'S OIL AND GAS INDUSTRY[1]

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Abstract This study examines economic issues that affect the decision to reclaim land disturbed by oil and gas development. We start with a discussion of the current reclamation bonding requirements in Wyoming, which are intended to insure the proper reclamation of disturbed land. Next, a simple economic framework is proposed for modeling reclamation decision making by oil and gas producers. The most important issue affecting the decision to reclaim is the cost of reclaiming the disturbed land; therefore, we use a dataset provided by the Wyoming Oil and Gas Conservation Commission to conduct a detailed analysis of reclamation costs for orphaned oil and gas wells. We also consider issues concerning the timing of reclamation costs and some environmental considerations. Finally, we discuss some deficiencies in the current bonding system, and offer some suggestions on how the current system could be improved in terms of providing more economic incentives for operators to fully reclaim disturbed lands.

Additional Key Words: bonding requirements, reclamation costs.

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Introduction

This study examines economic issues that affect the decision to reclaim land disturbed by oil and gas development. We begin by providing a brief description of the current regulatory setting that governs the oil and gas industry in Wyoming and focus our attention on reclamation bonding requirements, which are intended to insure the proper reclamation of disturbed land. Next, a simple economic framework is proposed for modeling reclamation decision making by oil and gas producers. The most important issue affecting the decision to reclaim is the cost of reclaiming the disturbed land (although other factors such a clear reclamation guidelines and standards set by land management agencies are important as well). Therefore, we provide a detailed analysis of reclamation costs for orphaned oil and gas wells in Wyoming using a dataset provided by the Wyoming Oil and Gas Conservation Commission.[1] We also consider issues concerning the timing of reclamation costs and some environmental considerations. Finally, we discuss some deficiencies in the current bonding system, and offer some suggestions on how they could be improved in terms of better representing the actual cost of reclamation, as well as providing more economic incentives for operators to fully reclaim disturbed lands.

Booms and busts in the energy sector are common and expected events for Wyoming's economy. Notably there have been two major boom cycles since the 1970s, the first beginning in 1981 and the second in 1998. However, development in the most recent boom represents a substantial increase from previous years (Figure 1). Since 1998, the annual growth in new wells averaged approximately 40 percent per year, in contrast to the decade before 1998 in which the annual growth averaged approximately 15 percent per year. The fact that the most recent development is substantially higher than previous booms suggests that reclamation issues will become increasingly important in the future as these wells are plugged and abandoned.

[1] Most of the cost analysis is focused on orphaned wells, which are wells that have been reclaimed by the state because the last owner filed for bankruptcy or ceases to exist. This represents a small percentage of wells in Wyoming; however, there exist a large number of wells that can be classified into an area we call under-reclaimed, which are inactive wells that are not fully reclaimed that may or may not be placed back under production in the future.

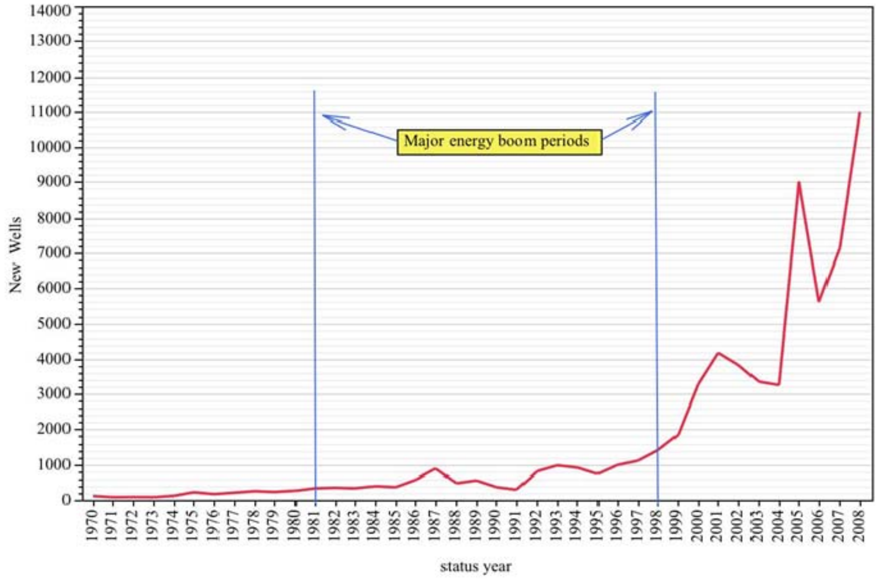

Figure 1. Newly Developed Oil and Gas Wells, 1970 - 2007. Source: *WOGCC*.

In addition to the cost of reclamation, other factors that become important in successful reclamation include the regulatory environment, industry structure, and environmental factors associated with the specific location of the field or well. Given the difficult growing conditions that exist in most of Wyoming, environmental factors are especially important to reclamation. The overwhelming majority of active wells are located in a semi-arid to arid regions of the state, with approximately 62 percent of active wells in regions that receive between 11-15 inches of precipitation per year, and 15 percent in desert regions that receive less than 10 inches of annual precipitation.[2] The ecology of these regions suggests that re-vegetation will be a long and difficult process.

There is also a clustering of wells by land cover category. For example, 58 percent of the active wells are located in sagebrush steppe regions. Almost two thirds are located in sagebrush steppe or desert shrub areas, both areas that present challenges to successful reclamation.[3] Many of the wells located in the mountain grassland prairie areas are the coal bed methane fields in the northeast part of the state. Given the distribution across varying ecological and precipitation regimes, and the growth in the number of new wells, an important question to ask when

[2] Figures compiled by authors from the WOGCC database.

[3] Figures compiled by authors from the WOGCC database.

considering the factors that affect the decision to reclaim disturbed land is, "*what is going to be the future cost of reclamation when production ceases*," when the public may have to pay for the reclamation.

Therefore, after discussing the bonding requirements and presenting our economic model, we provide a detailed examination of the cost of reclaiming orphaned oil and gas wells in Wyoming in the period 1997-2002. Given accurate cost estimates, appropriate bonding requirements can be established that fully account for the cost of reclamation. The current bonding system can be improved upon from the perspective of both the public as well as the oil and gas operators. From some of the public's perspective, the current bond amounts are set too low and the system is poorly designed. This is primarily because the bonding requirements are not linked to production, but are instead a fixed cost that is essentially a sunk cost from the perspective of the operator. We illustrate how the current bonding system does not properly account for the time value of money using some simple examples. Properly accounting for the time value of money and linking the bonding requirements to production are two examples of methods we propose for improving the current requirements.

Bonding Requirements

An environmental bond represents a guarantee against the failure to cure environmental damage from mining (Webber, 1985).[4] A study conducted by the Political Economy Research Center (Gerard, 2000) concluded that bonding "is a market-based enforcement mechanism that relies on financial incentives and reputation effects to deliver site reclamation at the lowest possible cost." Some of the potential advantages of reclamation bonds include increasing the probability of reclamation and regulatory flexibility in monitoring and enforcement activities. Bonding mechanisms also have inherent limitations such as the opportunity costs associated with investment of firm resources in bonds, administrative costs, and legal restrictions (Shogren, 1993).

Bonding can occur through various instruments: Cash outlays, capital liens, or surety bond companies who pay the bond on promise that the reclamation will be completed by the Oil and Gas Company. The latter approach allows companies to minimize cash outlays to cover bonds,

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[4] Webber, BS "Promoting economic incentives for environmental protection in the Surface Mining Control and Reclamation Act of 1977: An analysis of the design and implementation of reclamation performance bonds." Natural Resources Journal 389 (1985).

and is a common practice in the industry. However, recent reports on the surety bond market suggest that a market approach to bonding may be limited (Kirschner and Grandy, 2002). Surety bonds are increasingly difficult to secure because of general market conditions and higher risk.

The current bonding requirements for oil and gas development in Wyoming depend on the type of land under development, with slightly different regulation covering federal land as opposed to state and private fee land. The Bureau of Land Management (BLM) has authority to require a bond under the Mineral Leasing Act (MLA), and the current fees range from $10,000 for a single lease that may cover multiple wells to $150,000 for a national blanket bond that covers all production activities (across state-lines) and often cover hundreds of wells under a single blanket bond. In addition, producers can apply for a blanket bond of only $25,000 to cover all the wells drilled within one state. It is important to note that the Wyoming Oil and Gas Conservation Commission (WOGCC) has the authority to set additional bonding requirements for fee lands, among which includes the option of imposing an additional fee of $10 per foot of drilling depth for idle wells.[5]

The other current policy mechanism that is used to regulate disturbance by oil and gas development is a maximum allowable disturbed area rule. In the BLM's preferred alternative for development in the Atlantic Rim area, the proposal is to cap the allowable disturbed area to 7,600 acres total, and no more than 6.5 acres / well.[6] The cap forces larger producers to continually reclaim previously disturbed land as new development cannot occur above the 7,600 acre limit. However, producers may also transfer ownership of well sites to other entities in order to remove them from their maximum allowable disturbed area, which is a potential issue with this policy. The cap does not limit total area disturbed by all producers, only what any individual producer may disturb. The maximum allowable disturbed area policy is probably the best enforcement mechanism for insuring reclamation for large producers who rarely default on final reclamation duties, and for whom the bonding requirements are negligible.

One of the big shortcomings of the current bonding system is that it does not properly handle the time value of money. The average life of an oil and gas well can be decades, and the value of

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[5] WOGCC Rules and Statutes, revised Chapter 3, Section 4(c). Available on line http://wogcc.state.wy.us/rules-statutes.cfm?Skip='Y'.

[6] BLM Record of Decision: Environmental Impact Statement for the Atlantic Rim Natural Gas Field Development Project (March 2007) page 12

having a small bond returned at the end of the production period is negligible from the operator's standpoint. Furthermore, under current policy the bond can be withheld for up to an additional 10 years after production ceases in order to insure that the reclamation is adequate. The problem boils down to one of investing the bonds in an interest bearing account so that accrued interest is available to cover the increasing cost of reclamation over time.

Consider the problem from the perspective of a hypothetical oil and gas operator, who posts a $25,000 bond today for a well that will be producing for 20 years. Assuming they perform reclamation in year 20, the bond is returned in year 30. The present value (today) of a $25,000 bond returned 30 years from now is $1,245 (at a continuously compounded discount rate equal to 10 percent). Compare this to more than $2 million in development costs for a typical well, and the present value of the bond is negligible. Now consider the land manager's perspective. An oil and gas well that is developed today will cost substantially more in the future to reclaim because of general price inflation. Now assume the producer defaults on the reclamation in year 20 and the state has to pay for the reclamation. At an annual rate of inflation of 3 percent, $25,000 in reclamation cost today will cost the state $45,553 in 20 years.

A more economically rational system would require a cash bond at the start of development that is deposited into an interest bearing reclamation account. The funds in this account could be invested in low-risk government securities such as government bonds. As long as the real interest rates on these government securities are positive, the future cost of the reclamation would be covered (accounting for general price inflation). Furthermore, this system provides some interesting options for increasing the incentive of producers to perform the final reclamation. One possibility is to share the accrued interest on the bond between the state and the producer.

Consider the following example, suppose a large producer posts a cash bond today at a cost of $100,000. The state then deposits this money in a reclamation account that is invested in low risk government securities. Assuming a 5 percent interest rate on the government security, the future value of this bond in year 20 would be $271,828. When production ceases in year 20, the state would have $271,828 to perform the reclamation in case of default by the producer. Additionally, under an interest sharing arrangement between the producer and the state, the producer has more economic incentive to perform the reclamation. If the state and the producer were to share the accrued interest, the producer would receive their initial bond amount

($100,000) plus half of the $171,828 of accrued interest. The state could retain half of the accrued interest for a reclamation fund to help cover unexpected reclamation costs as they arise. Perhaps part of the reason that the current system does not properly account for the time value of money is because of the fact that many oil and gas producers use surety bonds to fulfill their bonding requirements, where they pay a surety company an annual premium to insure final reclamation. In this case the surety companies benefit by collecting the annual premiums they can reinvest over the productive life of the well.

One final note concerning current reclamation policy is that it does not properly account for the loss of surface land values. Oil and gas producers pay severance taxes and royalty payments that are intended to account for the loss of sub-surface value of mineral resources, but they may not pay for the total loss of ecosystem services such as lost grazing allotments, wildlife uses, and aesthetic values. One way to account for these opportunity costs associated with oil and gas production is to increase bonding rates to reflect the loss of surface values.

Economic Model of Reclamation Decision Making

We propose the following framework for modeling the decision to reclaim land disturbed by oil and gas development following similar work on coal mining (Sult, 2004). The model is represented by a three-stage decision making process. It is useful for focusing attention on the important issues that affect reclamation decision making and the potential policy mechanisms that could be used to improve the current system of bonding requirements.

First Stage – *Exploration and Development*

The oil and gas operator decides on the number of wells to drill and the location of wells depending on economic, regulatory, and environmental factors. The decision on the number and location of wells is assumed to be independent of the environmental bond for three primary reasons. First, the bond amount is very small relative to exploration and development costs. Second, most firms operate under a blanket bond that is by design independent of the number and location of wells. Third, many firms use surety bonds, and never actually post a cash bond at the start of development, so we assume the small surety premiums are absorbed into the substantial development costs.

Second Stage – *Production*

Assume an oil and gas well has been developed. The operator must now decide on a level of regulatory compliance during the life of the well that includes interim reclamation and final reclamation activities. A cost-minimizing operator will have the following objective function related to the optimal level of regulatory compliance:

$$\min_{e} C = I(e) + R(e) + F(e) \qquad (1)$$

Where C = cost of compliance, I = interim reclamation, R = final reclamation, F = fines, and e = regulatory compliance effort. Interim reclamation costs include any reclamation costs incurred prior to the end of production. Final reclamation costs include down-hole reclamation, plugging, and surface reclamation activities performed after production has ended. The choice variable in this model is the level of regulatory compliance effort denoted by, *e*. This could include labor hours and equipment hours devoted to compliance activities. The following diagram (Figure 2) shows the assumed shape of the *C, I, R,* and *F* functions with effort plotted on the horizontal axis.

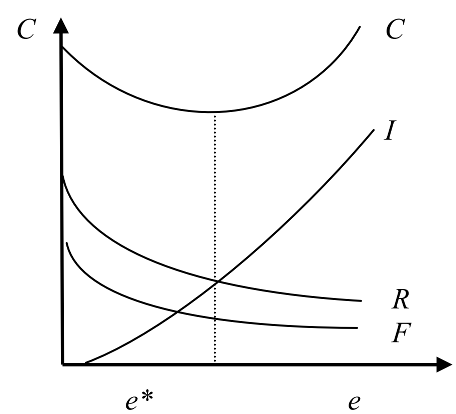

Figure 2: Cost-minimization Problem[7]

Third Stage – *To Reclaim or not to Reclaim*

At time $t=T$ production is complete, and the operator makes a decision to fully reclaim the abandoned well, or leave an 'orphan' well that is not reclaimed. This decision depends on the

[7] This figure was adapted from Sult (2004) figure 1: *Optimal Compliance Effort.*

cost of final reclamation, $R(e)$, relative to the sum of the environmental bond, *B*, and reputation costs, *D*. The objective function is:

$$C\big|_{t=T} = \min\left(R(e), B+D\right) \tag{2}$$

$$C\big|_{t=T} = \begin{cases} R(e) & (B+D=0) \\ B+D & (R(e)=0) \end{cases} \tag{3}$$

$$\begin{aligned} R(e) > B+D &\;\Rightarrow\; \text{do not reclaim} \\ R(e) < B+D &\;\Rightarrow\; \text{reclaim} \end{aligned} \tag{4}$$

It is obvious from this model that an increase in either *B* or *D* will increase the incentive to reclaim, and that the final cost of reclamation relative to the bond and reputation cost is the determining factor affecting the decision to reclaim. Another implication of the model is that reputation effects matter, and in the case of large oil and gas producers the reputation effects are large. Also, larger companies are far less likely to declare bankruptcy and terminate their operations than are smaller operators. This means that for most if not all larger producers the threat of suspending operations under the aforementioned "Maximum Allowable Disturbed Area" policy is probably the binding enforcement mechanism and not the small bonding requirement.

Reclamation Costs for Orphaned Wells

The following analysis of the cost of reclaiming land disturbed by oil and gas development in Wyoming was conducted using data from the Wyoming Oil and Gas Conservation Commission (WOGCC).[8] The cost figures represent the actual costs incurred by WOGCC in the process of fully reclaiming a total of 48 separate locations on fee lands that included a total of 255 orphaned

[8] The data in this analysis were provided by Don Likwartz, *State Oil and Gas Supervisor*, WOGCC (Fall 2008). The first database includes: Date, Number of Wells, Depth of well (feet), Total Cost ($), $/foot, $/well, Bond ($), Bond ($)/well, Bond ($)/foot, and Bond Variance ($), for 48 orphaned well locations in Wyoming from 1997 to 2007. The database includes a total of 255 wells, with 30 single well locations and 18 multiple well locations (total of 225 wells on multiple well locations). The database includes 23 locations with no environmental bond posted, and 25 locations where an environmental bond was posted and retained by the state. The second database includes a sub-sample of 10 observations (locations) from the previous database that provided more detail on cost estimates by various reclamation activities, including 1) plugging services; 2) tank, equipment, and fluid removal; 3) battery removal; and 4) pit and dirt work. The third database includes 7 observations on reclamation locations (some from the previous database and some not in that database) with a total of 58 wells and additional information on the cost of reclaiming the land area (soil, topography, and roads).

wells in Wyoming from 1997-2007.[9] Full reclamation activities can be broadly classified into plugging services and ecological restoration, which includes such things as equipment removal, fluid removal, soil and topography restoration, re-vegetation, and road removal.

The locations of orphaned wells are mostly split between ecological areas with higher or lower precipitation regimes than the active wells discussed in the introduction. Fifty-four percent of the wells are located in precipitation areas that receive between 25 and 50 inches of precipitation annually, a category higher than 62 percent of the active wells described above. A substantiallly higher percentage (39 percent) are located in low precipitation arid areas that receive less than 10 inches of precipitation per year. In terms of land cover zones the comparisons are very similar to active wells. As with the active wells, the majority (80%) of the orphan wells are located on big sagebrush steppe areas. This suggests that our cost estimates for reclaiming orphaned wells are representative of the eventual costs of reclaiming the current group of active wells in Wyoming (allowing for price inflation).

The database used in the analysis that follows includes single-well locations and multiple-well locations, and in some of the analysis we cluster the sample by single and multiple well locations and compare differences. A sub-sample of the larger database included additional information about the cost of reclamation by various activities, including: 1) plugging services; 2) tank, equipment, and fluid removal; 3) battery removal; and 4) pit and dirt work. Therefore, we use this sub-sample to examine reclamation costs for these specific activities. Finally, we have another set of data on the cost of 'dirt work,' for a sample of seven different reclamation locations with a total of 58 wells. Dirt work includes soil and topography restoration, and re-vegetation (this may also include road removal).

In the analysis that follows we convert all of the cost data into constant 2007 dollars using the Gross Domestic Product Implicit Price Deflator (GDP – IPD), U.S. Government (2009). The data span the years 1997-2007 so it was important to control for the effects of inflation and put all of the years on a comparable basis. The data are analyzed in terms of 1) the full 48 observations with 255 total wells; 2) the 25 bonded locations; and 3) clustered by single-well locations (30 total) and multiple-well locations (18 total). As a starting point, Table 1

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[9]It is important to note that the funds for reclaiming orphaned wells in Wyoming come from a mill-levy paid by the oil and gas industry, and do not come from the general tax fund.

shows the actual cost, bond amount, and variance (difference between cost and bond) for the full set of 255 wells: 1) per foot of drilling depth; and 2) per well.

Table 1. Orphaned Oil & Gas Wells in Wyoming (1997-2007)

	Actual Cost	Bond	Variance
Per foot	10.81	1.79	9.02
Per well	$29,136	$5,989	$23,147

a. Averages from full database (48 locations and 255 wells).
b. Figures are constant 2007 dollars (deflated using GDP - IPD).
c. Includes orphaned wells with no bond posted.

The actual cost of the full reclamation of the 255 wells was $10.81 per foot of well depth, and approximately $29,136 per well. The bond per foot of well depth was $1.79, and per well was $5,989. Part of the reason why the bond amount per foot of well depth and per well seems low is because the full sample includes some wells that had no bond posted, as their development likely pre-dated the bonding regulations. However, this gives a good indication of the variance that likely currently exists in Wyoming because there is a mix of older wells with no bond posted, and newer wells that are fully bonded. The existence of the older un-reclaimed wells with no bond posted places an added financial burden on the state, above and beyond insuring that funds are available in the future to reclaim current development.

Table 2 shows descriptive statistics for two sub-samples of the full dataset, the first including all single-well locations and the second including all multiple-well locations. The third column in the table is the difference between the single-well and multiple-well locations. The first thing to note is that on a depth-per-well basis, single-well locations are statistically significantly deeper than multiple-well locations at the one-percent level of significance.[10] Single-well locations averaged 4,602 feet / well, and multiple-well locations averaged 2,038 feet / well. It is important to note that reclamation is a capital-intensive process and that moving heavy machinery and equipment to and from reclamation locations is a costly enterprise; therefore, it is cost effective to have a number of wells to reclaim in a given location. Because of

[10] We assumed unpaired data and unequal variances in a two-sided *t*-test. The null hypothesis is H_0: mean of single-well = mean of multiple-well (on depth/well basis), and the alternative hypothesis is H_a: mean of single-well ≠ mean of multiple-well (on a depth/well basis). The *p*-value of the test statistic is 0.0041, indicating rejection of the null hypothesis at the 1 percent level of significance in favor of the alternative.

the capital-intensive nature of reclamation activities, our *a-priori* expectation is that the economies of scale exist with regards to reclamation activities, and one implication is that we expect that the cost of reclaiming single-well locations to be higher than the cost per well for multiple-well locations.

Table 2. Orphaned Oil & Gas Wells in Wyoming 1997-2007 (Clustered by Single Well and Multiple Well Reclamation Sites)

	Single Well	Multiple Well	Difference
Number of wells	1	12.5	
Depth (feet)	4,602	35,751	
Depth per well (feet)	4,602	2,038	2,564
Total cost ($)	$38,165	$227,620	
Cost per foot ($)	$10.44	$11.43	-$0.99
Cost per well ($)	$38,165	$15,347	$22,818
Bond ($)	$6,470	$33,011	
Bond per foot ($)	$1.01	$3.09	-$2.09
Bond per well ($)	$6,470	$5,161	$1,309
Variance ($)	$31,695	$194,609	
Variance per well ($)	$31,695	$15,569	$16,126

a. All figures are simple averages and include locations with no bond posted.
b. Single well averages include 30 observations (30 wells).
c. Multiple well averages include 18 observations with a total of 225 wells.
d. Costs are constant 2007 dollars (deflated using GDP - IPD).

Based on our *a-priori* expectations we performed a one-sided *t*-test of the hypothesis that the single-well locations are more costly to reclaim than the multiple-well locations (per well).[11] The results indicate rejection of the hypothesis that the costs per well are equal for single-well and multiple-well locations at the 10 percent level of significance. Because of the apparent scale economies single-well locations simply cost more to reclaim and perhaps this means that

[11] We assumed unpaired data and unequal variances in the one-sided *t*-test. The null hypothesis is H_0: mean of single-well = mean of multiple-well (on a $/well basis), and the alternative hypothesis is H_a: mean of single-well > mean of multiple-well (on a $/well basis). The *p*-value of the test statistic is 0.0696, indicating rejection of the null hypothesis at the 10 percent level of significance in favor of the alternative.

bonding rates should be increased for single-well permits relative to blanket bonds. Finally, note that the cost per foot of drilling depth is fairly even across the different groupings, with no statistically significant difference in these measures. The approximate cost of reclamation is $10.50 per foot of well depth.

In Table 3 we show the average reclamation costs by activity from a sample of 10 single-well reclamation locations. This sub-sample represents a costly group of reclamation sites, as the average cost per-well for these locations is $82,628, far above the full sample of single-well average of $38,165. This is indicative of the variable nature of reclamation costs. Plugging services were by far the largest share of the total costs, and averaged $55,440 / well for this particular group of wells. Tank, equipment, and fluid removal come in a distant second at an average of $24,384 / well. Battery removal combined with pit and dirt work accounted for an average of $16,614 / well.

Table 3. Reclamation Costs for Single-Well Locations by Activity

	Mean	S.d. mean
Plugging Service	$55,440	$34,326
Tanks, equipment, and fluid disposal	$24,384	$8,458
Battery removal	$6,043	$1,100
Pit and dirt work	$10,571	$3,182
Reclamation cost per well	$82,628	$41,064
Reclamation cost per foot	$18.62	$5.71

a. Note that not all reclamation activities were required at each location.
b. Figures are the Mean and the S.d. of mean of 10 single well reclamation locations.
c. Figures are constant 2007 dollars (deflated using GDP - IPD).

The WOGCC database also includes a sample of seven reclamation locations (58 wells) with detailed cost estimates for dirt work and road removal. Recall that dirt work includes soil and topography restoration, and re-vegetation. Table 4 shows the estimated cost of dirt work, which is $2,551 per acre, and the estimated cost of road removal, which is $2,986 per mile, or $0.57 per linear foot.

Table 4. Land and Road Reclamation Cost Estimates

	Dirt work	Road removal
Cost per acre	$2,551	
Cost per mile		$2,986
Cost per foot		$0.57

a. Figures based on a sample of 7 reclamation sites.
b. Cost estimates are constant 2007 dollars.
c. Figure deflated using GDP – IPD.

Table 5 shows the simple-correlation coefficients between certain key variables in the dataset. We treated each reclamation location as a separate observation, and therefore the estimates reflect a sample of 48 observations. The correlation between the total well depth in a location (sum of all wells) and the actual cost of reclamation is 0.985. The correlation is less on a per-well basis, but still a substantive 0.611. The correlation between total reclamation cost for a location and the bond amount posted is 0.732, but the correlation is essentially zero on a per-well basis, which is a result of the existence of fixed-cost blanket bonds that can cover hundreds of wells under a single bond. The relationship between well depth and the cost of reclamation is important because it provides a convenient and effective way to link bond rates to production. As previously indicated, the reclamation of orphaned wells by the state averaged approximately $10.50 per foot of well depth.

Table 5. Correlation Coefficients Between Given Variables

	Reclamation Cost ($)
Total	
Depth (feet)	0.985
Bond ($)	0.732
Per Well	
Depth (feet)	0.611
Bond ($)	-0.093

a. Includes multiple and single well reclamation locations.
b. 48 observations for each variable.
c. Variables under Total include the total depth, bond, and reclamation cost for all wells in a location.
d. Per Well estimates divide the totals by the number of wells reclaimed.

Finally, we used the evidence of the strong relationship between the cost of reclamation and well depth as a basis to estimate what the current outstanding reclamation costs are for the state of Wyoming. To do this we used additional data from WOGCC that includes all of the active wells in Wyoming, and all wells that are inactive but un-reclaimed (or under-reclaimed). The data includes the status of each well and the drilling depth for 68,163 wells under various classifications that are not reclaimed.[12] The cumulative feet drilled for all 68,163 wells is 300,390,704 feet, and the average drilling depth among all wells is 4,407 feet/well. Using our estimate of $10.50 / foot, we calculated the current potential total outstanding reclamation costs for Wyoming as: (300,390,704 feet of total well depth)×($10.50 / foot) = $3.154 billion when measured in constant 2007 dollars. It is important to note that we are not implying that the state of Wyoming will pay for this reclamation cost as most of these costs will be paid by legitimate oil and gas producers. However, the number is a good indication of the size of the reclamation task ahead. Furthermore, we are also not suggesting that oil and gas producers should pay a bond rate of $10.50 / foot of drilling depth. The calculation of an optimal bonding rate depends on other factors that are outside of the scope of this paper. The question of an optimal rate should be determined in a dynamic economic framework that fully accounts for both private and public values.

Conclusions

The three primary issues with the current bonding system include: 1) not properly accounting for the time value of money; 2) charging a flat bond rate instead of linking bonding rates to production; and 3) not properly accounting for the loss of surface land values. As we illustrated in section 2 of this paper, the lengthy production horizon associated with oil and gas development necessitates consideration of the time value of money. One way to accomplish this is to require producers to pay cash bonds, and have the land management agencies set-up an

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[12] All data used in this analysis are available to download on-line from the WOGCC website: http://wogcc.state.wy.us/. Active and un-reclaimed well status comes from the following WOGCC well status classifications: Producing Oil Well, Producing Gas Well, Dry Hole, Shut – In, Temporarily Abandoned, Active Injector, Dormant, Notice of Intent to Abandon, Subsequent Report of Abandonment, Permit to Drill, Well Spudded, Suspended Operations, Flowing, Gas Lift, Pumping Rods, Pumping Submersible, Pumping Hydraulic, and Plunger Lift.

interest-bearing state reclamation account. This has the two-fold benefit of insuring sufficient funds to meet the future cost of reclamation accounting for price inflation, as well as increasing the incentive of producers to do the reclamation themselves by offering to return the initial bond plus some of the accrued interest. The cost analysis for orphaned wells in section 4 of the paper indicated that reclamation costs are closely related to the depth of a given well, and therefore this provides a convenient method of linking bonding rates to production. The current system also does not account for the loss of surface land values. Oil and gas operators pay severance taxes for the extraction of underground mineral resources, but may not completely compensate the public for the loss of ecosystem services they create while in production. Given the life of most wells this loss can be significant. Including these opportunity costs in bonding rates is one method of accounting for this loss. The majority of oil and gas producers in Wyoming will continue to fully comply with their reclamation duties, and not because of the current bonding system. The best enforcement mechanism to insure reclamation for large producers is the maximum allowable disturbed area policy; however, a properly designed bonding system would be effective in insuring reclamation by smaller producers as well. Any changes to the current bonding system should target problem producers and allow the legitimate producers to continue to function without significant changes to their operations.

There are other factors that influence completion of reclamation. Our intent is to explore these in future work. This includes incorporating geospatial and environmental attributes into the analysis to better predict what causes orphan well status in different environmental situations. We will also look at ownership and development/production characteristics as well as agency goals, and their relationship to successful reclamation completion. Finally we will look at role interim reclamation strategies play in lowering costs of the final reclamation bill.

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