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Efficiency and Equity of Alternative Well Interference Policies in Semi-Arid Regions

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Introduction

During the 1970's, well interference emerged as a highly volatile policy issue in the allocation of groundwater in states bordering the humid East and the arid West. Well interference is the lowering of water levels of wells adjacent to or neighboring a high capacity well during and shortly after the period in which the high capacity well is being pumped. It is generally a temporary hydraulic phenomenon, as distinguished from long term overall lowering of the water level in an aquifer caused by pumping exceeding recharge.

States such as Iowa, Minnesota, and South Dakota, bordering humid and arid regions, have experienced dramatically increased groundwater irrigation in the last decade. Although the actual number of cases of interference in these states is relatively small, and aggregate economic damages thus far are slight, the political impact has been significant. Under these conditions, the problem, whether actual or perceived, becomes a major factor in shaping the future course of groundwater policy.

The political impact of the problem resulted largely from widespread public unease about the adequacy of water supplies during the drought period of 1974-76. Most of the conflicts arose from new irrigation

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wells interfering with existing domestic wells. The drought, combined with rapidly increasing use of groundwater for irrigation, caused all three states to review, and to some extent, revise their groundwater allocation policies. Most of the revised rules have emerged since the easing of the drought, and have not been subject to the degree of public scrutiny to which they might have been exposed a few years before. Nor have they been tested to any great extent in actual practice or litigation. Thus, it is appropriate to examine these policies in light of economic effects they are likely to have. Specifically, the purpose of this paper is to examine efficiency and equity implications of the well interference policies of South Dakota, Iowa, and Minnesota, and to draw implications for rational policy to deal with well interference in semi-arid states.

Effects in Semi-Arid Regions

There are several physical, economic, and social reasons why well interference is a greater problem in "border" states than in the more arid West. Natural precipitation is greater in the border states, and evapotranspiration is generally lower, making traditional non-irrigated agriculture a much more viable alternative to irrigation than is usually the case in the west. Irrigation is of a supplemental nature in the border states, usual water applications are less than 12 inches per year. A relatively small percentage of farmers irrigate, and the practice of irrigation is not regarded with the same degree of legitimacy as in the West.

There are also hydrologic differences. Western aquifers tend to be large, thick outwash formations of relatively uniform composition.

Aquifers in the states of Iowa, Minnesota, and South Dakota are often relatively small aquifers located in a jumble of glacial till material. They are often severely limited in area and thickness, and may vary widely in transmissivity and other characteristics within a very short distance. While many aquifers may produce wells with sufficient yields for irrigation, and may receive enough recharge to support irrigation, their physical characteristics are such that severe well interference or other short term drawdown problems result from such use. Population density is usually higher in border states than in the West, and distances between irrigation wells and neighboring wells are often shorter.

In these border states, interfering wells are nearly always irrigation wells. Interfered wells are usually used for domestic supply, and livestock watering. Serious problems usually occur only when the interfered well is completely dried out, at least for some period of time. There may be other cases where well interference results in higher pumping costs in the interferred well, but total quantities pumped are usually so low that the costs are negligible. The VMP of water produced by the interferred wells is usually high however. Moreover, economic losses from well interference are seldom limited to foregone production. There may be costs from other damages such as burned out pump motors and health or production losses to livestock. For example, dairy cows which are forced to go without water for relatively short periods early in their lactation may suffer from decreased production for the rest of the lactation period.

Well Interference as an Externality

Well interference is a classic example of an economic externality of production, an activity of one economic unit that unintentionally affects the utility or well-being of another. When the pumping of a high capacity well, such as an irrigation well, causes interference with neighboring wells, the owners of existing neighboring wells incur costs that they would not have incurred if the high capacity well were not used. These costs may be higher energy costs resulting from pumping from a greater depth, or in more serious cases, the cost of installing a new pump, or construction of a new and deeper well.

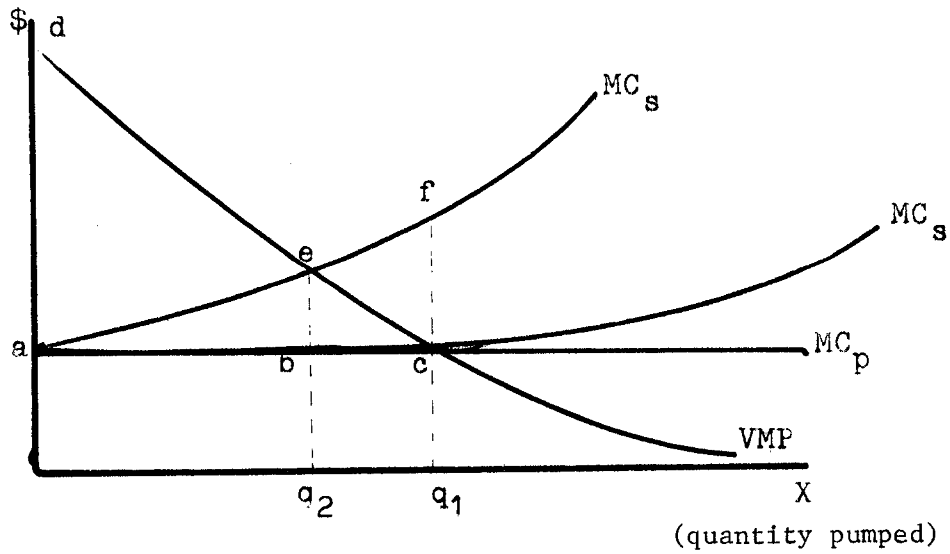
There are both equity and efficiency effects from this phenomenon. There is net efficiency gain to society insofar as the value of the marginal product exceeds the marginal social cost of pumping the water. However, there is an efficiency loss because the irrigator using the high capacity well does not bear all the costs to society of pumping. Hence, he will pump more than is optimal from a resource efficiency standpoint. There will be a dead weight lost to society from the supra-optimal use of resources.

The equity effect is that the irrigator gains the value of the marginal product of the water, a portion of which is at the expense of the owner of the existing neighboring well who bears higher pumping costs and perhaps experiences temporary water shortages. This phenomenon can be illustrated with a simple graphic model.

In this model the producer faces two economic parameters. One is his marginal cost of pumping water, MC_p. This cost is determined by fuel and variable labor costs, and is nearly horizontal within the

FIGURE 1.

Economic Transfers and Losses
Caused By Well Interference.



relevant range. The producer also faces a value of marginal product curve, VMP.[1/] This is the potential value that could be produced, at each level of water use, by using one more unit of water. For many water using activities, particularly agricultural irrigation, the value of marginal product is a decreasing function which may decline to zero or even become negative.

As a rational profit maximizer, the producer pumps until the value produced by the last unit of water he uses is equal to the cost of pumping it. In our diagram that quantity of water is q_1. The producer realizes a surplus of value produced over costs equal to the triangular area acd. Unfortunately, the producers pumping costs are not the only costs to society of this activity. Well interference occurs, and while nearly costless at low levels of pumping, it becomes rapidly more costly at higher levels of pumping. These external costs of well interference, when added to the producers pumping costs, form the total costs to society as a whole. The marginal costs to society at each level of water use are represented by the curve MC_s. The marginal cost of well interference at any point is the vertical distance between MC_p and MC_s.

We can see that part of the producer's surplus acd was in fact a transfer from persons affected by well interference. The amount of this transfer is equal to the area of trangle ace. This is made up of triangles abe and bcd. The triangle abe represents the pure equity effect of well interference. The remaining portion of the transfer, bce, has

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[1/] VMP = $\left(\frac{\Delta \text{Total revenue}}{\Delta \text{ input}}\right)$, or Marginal physical product multiplied by the price of the product.

has both equity and efficiency implications.

From the point of view of society as a whole, the optimum level of water use does not occur at q_1, but rather at q_2 where the VMP is equal to marginal cost to society rather than marginal cost to the producer. Producing at level q_1 rather than at q_2 has two effects, a transfer from society, or in this case, neighbors, to the producer equal to triangle bce, and a dead weight loss equal to triangle cfe. The triangle bce and cfe represent the efficiency effect of well interference, bce being a transfer to the irrigator, and cfe being a dead weight loss to society.

In this model, the difference between the producer's marginal cost, MC_p and the marginal cost to society MC_s consists of the additional cost of pumping water in affected wells and the damages caused by temporary water shortages during one pumping season. In the long run, these costs may be reduced or eliminated by constructing new, deeper domestic wells. This action would shift the seasonal marginal cost to society to MC_s. This would allow the producer to continue to pump q_1 units of water without causing appreciable transfers or losses. This solution would be preferable for society if the cost of the new wells is less than the present value of the external costs represented by area ace, assuming that pumping was restricted by rules or administrative procedures to q_2. If pumping were allowed to q_1, the new well, allowing costs to shift to MS_s would be preferable if the cost of the new well were less than the present value of area acf. Area ace represents the dead weight loss no longer occuring.

Based on these equity and efficiency characteristics of well interference, one can derive several criteria by which to evaluate well interference policies. With respect to efficient resource allocation, laws and administrative regulations should minimize dead weight losses to society while enabling real income gains that may result from high capacity pumping. With respect to equity; laws, rules and regulations should recognize the transfers which may occur under high capacity pumping, and depending on the value judgements of society, reduce or compensate for the transfers that take place.[2/] This has implications for efficiency since failure to provide for compensation may prevent irrigation benefits from occuring. Finally, policies, and procedures that are adopted should not be cause equity or efficiency effects that are more severe than those which are intended to alleviate. For example, cumbersome administrative procedures and/or lengthy litigation are real costs to society and may have undesirable equity effects.

With this background, we now turn to an analysis of specific state policies.

Analysis of State Policies

Groundwater use in Minnesota is regulated by its Department of Natural Resources (DNR). The high visibility of well interference as an issue is evidenced by the fact that about 20 percent of the text of the DNR's agency rules governing water appropriation deal with procedures to avoid or abate the problem of well interference.

The basic intent of Minnesota's policy appears to be to force large users to provide compensation for any damages caused by their

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[2/] Most observers would agree that the party who irrigates should compensate the party who is injured. However, some writers argue that there is no a priori reason why the party that stands to lose by an action should have a favored position over the party who loses by not being allowed to undertake any action.

pumping. The pumper "shall be responsible for all costs necessary to provide an adequate supply with the quality and quantity as prior to the applicants or permittee's interference."[3/]

Applicants for a permit to pump groundwater for irrigation are required to submit detailed information about the location of their well. If the aquifer is not one for which the DNR has "adequate" information from which to estimate drawdown and effect on existing wells, the applicant is required to conduct a test. This test consists of pumping the well for at least 24 hours while observing drawdown and subsequent recovery in one or more observation wells.

The information produced from the test is used in a computer analysis to predict interference effects in nearby wells. If it appears likely that one or more neighbor will be deprived of water at any period of time, the DNR may not issue the permit until the applicant reaches an agreement with all affected parties detailing the abatement or compensation the application will offer to the party potentially damaged.

After the permit to pump is issued, any party who realizes changes presumably caused by the new irrigator can register a complaint to the DNR. The DNR is required to investigate all complaints. If a complaint to substantiated, the DNR is required to restrict or suspend the permit until the permittee reaches an agreement with the affected parties.

[3/] MCAR 1. 5053A. 3C (1) (a)

How does Minnesota's policy rate with respect to the criteria for efficiency and equity described above? Regarding efficiency, because the irrigator is forced to compensate neighbors for damages to their wells, the irrigator effectively faces the maximum cost to society, the MC_s curve illustrated in Figure 1. Thus, the irrigator has the incentive to operate at q_2 and the deadweight loss to society is likely to be minimal. Further, the gains to society resulting from increased real product from irrigation are allowed to accrue insofar as provision is made for the irrigator to negotiate with owners of neighboring wells regarding compensation.

With respect to equity, the irrigator is forced to absorb the cost represented by the area a b e in Figure 1, and no transfers will occur.

Another advantage of the policy regarding both efficiency and equity is that the usually difficult task of estimating marginal costs is left to be resolved by the affected parties on the basis of approximately equal bargaining power. Parties in the bargaining process are prevented from exhibiting a monopoly or veto power by a provision which allows appeal to impartial arbitration by any party who feels his/her opponents are unreasonable.

The policy can be criticized on the basis of administrative and transaction costs. If the ultimate result; liability on the part of the water user, with negotiated compensation, remains the same, we can question the justification of the time consuming and expensive permit application and evaluation process. The current practice does little to reduce any uncertainty on the part of the producer. He must incur most of his ultimate investment costs as part of the application process, and issuance, of a permit is no guarantee that subsequent problems will not result in its being suspended. However, one can argue that the pumping test may permit the affected parties and the DNR to anticipate problems which may later arise. Furthermore, the transaction costs are much cheaper than those which would result from litigation in the courts at a later time.

It might be argued that the aquifer test requirement has some external benefit to society in that information is generated which will reduce uncertainty for future potential water users. This argument can be countered on two points. The same information could be generated over time by systematic lower-cost data collection during normal use of the well. Secondly, requiring initial developers to bear all the costs of generating information that later developers will benefit from, tends to discourage such development. This is a variant of the classic questions of copyrights and patents. The resulting disincentive to development could result in efficiency losses equal to the value of foregone production.

South Dakota's procedures are in some respects similar to those of Minnesota. Applicants for high capacity well permits are required to submit information about the location and the geologic characteristics of their proposal wells to the Department of Natural Resources Development (DNRD). DNRD staff members evaluate the application on several grounds, including the likelihood of well interference. The information required and analysis made are not as detailed as in Minnesota. However, the body of collected hydrologic information is greater in South Dakota than in Minnesota, thereby providing a rationale for not requiring many of the hydrologic details required in Minnesota. The DNRD staff recommends to the state Water Right Commission whether to approve or disapprove the application.

If it appears that a domestic well will be interfered with, and that well is an "adequate" well, the Commission will not approve the application. The key question here is what constitutes an adequate well. While Minnesota protects all existing wells, South Dakota protects only those wells that meet standards of adequacy. Generally, an adequate well must fully penetrate the aquifer and have its pump set just above the screen. Many existing wells do not meet these standards since the statuatory requirements are in excess of what would be needed to construct an aequate well in the absence of irrigation. Water wells typically have long lives, and most existing domestic wells were constructed before the development of large scale groundwater irrigation.

If the interfered well does not meet the adequacy standards, there is no protection to the owner, and the owner of the interfered well must bear all the costs of the interference. If the well is adequate, the permit is not issued, and the high capacity well owner has no recourse. If he is able to reach an agreement with the interfered party, the WRC may issue the permit. However, no state agency is authorized to encourage or require such a bargaining process. The domestic well owner holds a near absolute veto power. If he is not satisfied with any offer of compensation, the high capacity well remains shut down. Similar procedures are followed in cases of interference that are not predicted during the permit application process, but which do materialize later.

How does this policy rate with respect to efficiency and equity criteria? This policy results in an all or nothing situation. If the affected well is "adequate", and interference there may be no use of water at all, resulting in an efficiency loss through the loss of real product that could have been produced with irrigation. If the well is not adequate, and interference occurs, the results are the same as in Figure 1, where production occurs to point q_1, and both efficiency and equity effects occur. There is a supra-optimal use of resources, a resulting dead weight loss, and a transfer of income from the owner of the interference well to the irrigation.

South Dakota has at least one other policy designed to reduce interference problems. This is a well spacing requirement. All high capacity wells must be located at least 660 feet from any domestic wells. This provision may have some justification in that it precludes the worst possible cases of well interference.

This rule, being rather "cut and dried", has relatively low administrative costs. Other than this, it has few effects. It has no effects on any interference of wells located more than 660 feet apart which is still a highly possible occurrence. While it precludes the transfers and efficiency losses that would occur a distance less than 660 feet, it also precludes any production from cases where interference would not occur even at short distances. There appears to be little or no economic justification for such a policy since it precludes the possibility of society benefitting from the economic product which would be realized from irrigation. To the extent that well interference can cause undesirable efficiency and equity effects, an attempt to reconcile these with the efficiency gains from irrigation is certainly worthy of efforts by policy makers.

The impact of well interference as a political issue in the mid 1970's was perhaps greater in Iowa than in any neighboring states.

Public concern about groundwater development led to a three year near-moratorium on the issuance of new permits. Permits issued during this period were limited to a term of one year.

At present, Iowa has no formal policy for dealing with well interference. Surprisingly, in spite of the "near moratorium on irrigation permits", the problem is not specifically mentioned in any Iowa statute or agency rules. The Iowa Natural Resource Council deals with approximately ten cases that occur each year on an ad hoc basis.[4/] If there are indications that well interference may occur, permit applications may be denied on the grounds of inadequacy of water supply. No formal investigation of the probability of occurrence is made, however. If interference actually occurs, the parties involved are informally urged to reach a private agreement. If this effort is not successful, the INRC may investigate the complaint. If it is substantiated, the Council may terminate the permit. There is no formal mechanism for arbitration or determination of compensation. The INRC can either terminate or not terminate the permit, but it cannot order abatement procedures or compensation. If either party to the dispute is dissatisfied with INRC actions, their recourse is to proceed with litigation under common law in the state courts. This generally is a viable although costly, alternative for the party damaged by interference. The high capacity groundwater user may be denied access to the resource on grounds that he feels are unreasonable.

Another component of the state policy is the groundwater irrigation development has been effectively banned in many areas by moratoria on the issuance of new permits for a number of aquifers. Justification

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[4/] Interview with Louis Gieseke, Water Commissioner. Iowa Natural Resource Council, March 5, 1980.

given is the prevention of groundwater mining, but avoiding well interference disputes was also a factor in the policy decision.[5/]

There appears to be a number of efficiency effects of Iowa's policy. The lack of a defined policy increases uncertainty and acts as a disincentive to irrigation development. Litigation itself is costly. The amount by which the costs of litigation exceed the costs of alternative methods of resolving disputes can be viewed as a deadweight loss to society. The policy of limiting the INRC to the "either-or" options of no action or total shutoff encourages the INRC to condone small transfers from the owners of domestic to irrigators.[6/] The high minimum cost associated with litigation also forces damaged parties to absorb substantial costs, as long as these costs are below the threshold of litigation costs.

On the other hand, when interference is substantiated by the INRC, and permit suspension threatened, the interfered party holds a virtual veto power and is able to extract a form of "monopoly rent" from his position. He still may force the irrigator to pay more than the actual damages incurred to in order to obtain his consent for the well.

Iowa's policy can be summarized as undefined and ad hoc with heavy reliance on traditional legal remedies through litigation. The policy is a low cost one for the regulatory agency, but it involves high transaction costs for the parties involved.

In conclusion, the Iowa policies produce indeterminate results, have high transaction costs, and produce considerable uncertainty which

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[5/] IBID

[6/] IBID

is a formidable barrier to groundwater development and use. The results appear to be potentially large losses in efficiency.

Summary and Conclusions

The states of Minnesota, South Dakota, and Iowa have distinct differences in their procedures for dealing with the volatile problem of well interference. It is economically desirable to obtain the real gains resulting from irrigation, and to prevent the deadweight loss to society from a supra-optimal use of resources, consistent with reasonable transaction costs. The authors assert that administrative regulations are preferable to litigation in terms of transactions costs. With respect to equity, the authors place a value judgment leaning toward minimizing transfers from one party to another.

It appears from the analysis that Minnesota law is efficient in permitting irrigation to take place. Deadweight losses from supra-optimal resource use and transfers do not occur because of the approximately equal bargaining power of affected parties. The relatively explicit administrative procedures minimize the chances of costly and wasteful litigation.

South Dakota policies leave open the possibility of efficiency loss through the 660 foot spacing law, and possible impediment to irrigation development if well interference is likely. Provisions for negotiation are not apparent. Deadweight losses may occur if an "adequate" well is interfered with. This possibility is likely to open the door to wasteful litigation.

Iowa's policies also have aspects contributing to inefficiency. This stems largely from lack of formal mechanisms to negotiate prior to commencement of irrigation. There tends to be a lack of certainty of continuation of a permit, once issued. This serves to impede development, and the lack of prior procedures is more likely to result in litigation of differences.

As states in semi-arid regions develop well interference policies, greater attention needs to be given to efficiency and equity aspects discussed in this paper. Examination of the experience of states with diverse procedures, and comparison with the tenets of economic theory, can lead to efficiency gains and to equitable solutions which conform to the values of society.