



# United States Department of the Interior

## FISH AND WILDLIFE SERVICE

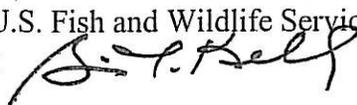
Ecological Services  
5353 Yellowstone Road, Suite 308A  
Cheyenne, Wyoming 82009

In Reply Refer To:  
ES-61411/W.02/WY07FA0129

APR 06 2007

### Memorandum

To: Dennis Stenger, Field Manager, Bureau of Land Management, Pinedale Field Office, Pinedale, Wyoming

From: Brian T. Kelly, Field Supervisor, U.S. Fish and Wildlife Service, Wyoming Field Office, Cheyenne, Wyoming 

Subject: Comments on the Draft Supplemental Environmental Impact Statement for the Pinedale Anticline Oil and Gas Exploration and Development Project

Thank you for the opportunity to comment on the Draft Supplemental Environmental Impact Statement (DSEIS) for the proposed Pinedale Anticline Oil and Gas Exploration and Development Project located in Sublette County, near Pinedale, Wyoming. The proposed action includes year-round drilling, completion and production of up to 4,399 wells and associated facilities in addition to the existing development approved under the 2000 Record of Decision for the Pinedale Anticline Oil and Gas Exploration and Development Project. The Pinedale Anticline Project Area (PAPA) encompasses 198,034 acres of combined federal, state and private surface ownership.

The U.S. Fish and Wildlife Service (Service) has reviewed the DSEIS and is providing the following comments pursuant to the Endangered Species Act (Act) of 1973, as amended (16 U.S.C. 1531 *et seq.*), Migratory Bird Treaty Act (MBTA), 16 U.S.C. 703, and the Bald and Golden Eagle Protection Act (BGEPA), 16 U.S.C. 668. Wetlands are afforded protection under Executive Orders 11990 (wetland protection) and 11988 (floodplain management), as well as section 404 of the Clean Water Act (CWA). Other fish and wildlife resources are considered under the Fish and Wildlife Coordination Act (FWCA), 48 Stat. 401, as amended, 16 U.S.C. 661 *et seq.*, and the Fish and Wildlife Act (FWA) of 1956, as amended, 70 Stat. 1119, 16 U.S.C. 742a-742j.

1. Page vii, Threatened, Endangered Species and Special Status Species: The DSEIS states that there will be surface water and groundwater withdrawals; however, Colorado River fish species will not be affected and there may be a net contribution of water to the system. The Service believes that some water withdrawal plans may meet certain parameters and may no longer meet the definition of a depletion. However, the Bureau of Land Management (Bureau) must be prepared to demonstrate the timeframe, discharge point, and methods to clearly show that there is no effect or a beneficial effect to Colorado River fishes. The

Bureau should work with the Service to review the characteristics of this proposal in terms of the water usage and the Service will assist the Bureau in making a decision regarding whether a depletion exists. As with any no effect determination, the Bureau is not required to consult with the Service under the Act, but in the case of possible depletions we recommend that the Bureau assume there to be a depletion and provide the water withdrawal plan to the Service for review before authorizing the action.

2. Page 1-8, Section 1.6, Proposed Action: The DSEIS states that the operators are proposing to implement Tier 2 equivalent emission controls on 60 percent of the drilling rig engines within the PAPA. The Service recommends that the Bureau require that the Operators implement Tier 2 equivalent emission controls on 100 percent of the drilling rig engines as is required on the engines in the Jonah Infill Drilling Project (Jonah 2006).
3. Page 1-11, Table 1.9-1: Table 1.9-1 indicates that the Service's authority includes the Endangered Species Act. For clarification, the Service also provides recommendations for protective measures for migratory birds in accordance with the MBTA, BGEPA, Executive Orders 11990 and 11988, CWA, FWCA and the FWA.
4. Page 2-10, 2.3.2.6 Anticline Disposal Facility: The DSEIS discusses a produced water disposal facility which will dispose of produced water by evaporation and surface discharge. The Service recommends that the DSEIS include the following additional information regarding the Anticline Disposal Facility:
  1. The produced water handling capacity of the facility;
  2. surfactants and other chemicals present in the wastewater stored at the facility;
  3. concentrations of salts in the evaporation ponds;
  4. measures implemented by the facility to prevent migratory bird mortality; and
  5. if this facility will be capable of handling the additional volume of produced water generated during the development of up to 4,400 additional natural gas wells.

Large evaporation ponds at oil field wastewater disposal facilities, like oil field production pits, pose a significant risk to migratory birds and other wildlife if they contain oil on the surface. The following conditions make oil field wastewater disposal evaporation ponds a risk to the environment and migratory birds:

1. Accumulation of oil on the surface and berms of evaporation ponds;
2. presence of visible sheens on the surface of evaporation ponds;
3. oil and water separation occur in the main evaporation pond;
4. skim ponds or open topped separation tanks are not equipped to prevent entry by birds and other wildlife; and
5. concentrations of salts in the evaporation ponds may eventually cause hypersaline conditions which could pose a risk to migratory birds and cause mortality.

Migratory bird mortality has been documented in oil field wastewater disposal facilities in Wyoming due to the presence of oil, paraffin, and sheens in evaporation ponds. The presence of visible sheens on wastewater ponds are just as deadly to birds that come into contact with them. A light sheen will coat the bird's feathers with a thin film of oil. Although a sheen of oil on the bird may not immediately immobilize the bird, it will

compromise the feathers' ability to insulate the bird. Furthermore, the affected bird will ingest the oil when it preens its feathers and suffer chronic effects. The bird could suffer mortality depending on the severity of the chronic effects and the amount of oil ingested. Any oil or sheens remaining in the ponds in between the removal actions has the potential of coating birds or other wildlife coming into contact with it. Mortality or morbidity may result depending on the amount of oil coating the animal, the species, prior condition of the animal, the amount of stress incurred by the animal after oiling, and weather conditions.

High concentrations of salts can also pose a risk to migratory birds. Birds entering ponds with hypersaline water can ingest the brine and die from sodium toxicity. Salt toxicosis has been reported in ponds with sodium concentrations over 17,000 milligrams per liter (parts per million) (Windingstad et al. 1987). Ingestion of water containing high sodium levels can also pose chronic effects to aquatic birds, especially if a source of freshwater is not available nearby. Aquatic birds ingesting hypersaline water can be more susceptible to avian botulism (Cooch 1964). During cooler temperatures, sodium in the hypersaline water can crystallize on the feathers of birds landing in these waterbodies. The sodium crystals destroy the feathers' thermoregulatory and buoyancy functions causing the bird to die of hypothermia or drowning. Sodium intoxication can cause neurological impairment resulting in the bird's inability to hold its head upright (Meteyer et al. 1997). The bird's head will droop into the water and cause it to drown.

Oil and gas production chemicals, such as corrosion inhibitors and surfactants, could be present in the produced water and could pose a risk to migratory birds. When a bird comes into contact with water containing surfactants, the surfactant will reduce the surface tension of the water; thus, allowing water to penetrate through the feathers and onto the skin. This compromises the insulative properties of the feathers and subjects the bird to hypothermia (Stephenson 1997). The loss of water repellency by the feathers due to reductions in surface tension will cause the bird to become water logged and the loss of buoyancy will cause the bird to drown. The MBTA prohibits any "take" of migratory birds. The definition of take includes the killing, possessing, or collecting of migratory birds.

5. Page 3-73, 3.15.1.3 Groundwater Quality: The DSEIS states that produced water is discussed further in Appendix C. However, Appendix C does not provide adequate information on the quality of produced water generated from the proposed natural gas wells. Although Appendix C contains a list of metals, trace elements and radionuclides that could be present in the water, it does not provide information on the concentrations likely to be present in the water. The DSEIS should provide data on metal, trace element and radionuclide concentrations in produced water if available from nearby existing natural gas wells to assess the probable water quality of produced water from the proposed wells.
6. Page 3-75, 3.15.1.4 Groundwater Quantity: The Service recommends that the DSEIS provide information on the salinity of the water used for dust control and the potential or lack thereof for impacts to adjacent vegetation.
7. Page 3-79 3.16.1.2 Surface Water Quality: The DSEIS states that Total Dissolved Solids (TDS) increases in the New Fork River are due to Alkali Creek and other drainages entering the anticline section. However, this section does not discern whether the TDS in Alkali

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Creek and other drainages are due to natural gas development. The Service recommends that this section discuss the source of TDS in these drainages (i.e. natural, due to natural gas development, other causes, and or unknown).

8. Page 3-82, 3.16.1.6 Produced Water: The Service recommends that this section provide the following information:
1. The quantity and quality of produced water generated by the increased number of natural gas wells;
  2. an assessment of hazards to migratory birds from the disposal of produced water into large evaporation ponds;
  3. an assessment of other disposal options, such as deep-well injection, for produced water;
  4. the quantity of produced water disposed of by deep-well injection versus the quantity disposed of by evaporation ponds; and
  5. the number of additional produced water wastewater disposal facilities (with evaporation ponds) needed in the future to dispose of produced water.

Salts in the produced water evaporation ponds will increase over time due to evaporative concentration. The DSEIS should assess the long-term salt concentrations in the evaporation ponds and whether the increased concentrations will pose a risk to migratory birds landing on these ponds. Sodium concentrations in water greater than 17,000 ppm can cause toxicity in aquatic birds.

Concentrations of surfactants in the produced water should also be assessed. As mentioned previously, surfactants will reduce the surface tension of the water; thus, allowing water to penetrate through the feathers and onto the skin. This compromises the insulative properties of the feathers and subjects the bird to hypothermia (Stephenson 1997). The loss of water repellency by the feathers due to reductions in surface tension will cause the bird to become water logged and the loss of buoyancy will cause the bird to drown.

9. Page 4-112, 4.19 Threatened, Endangered, Special Status Species: The DSEIS states that under the Bureau's Sensitive Species Policy and List in Wyoming, the Bureau is committed to maintain vulnerable species and habitat components in functional ecosystems a prevent a need to list species under the Endangered Species Act. The Service recommends that the Bureau consider how these goals will be met for sensitive species, such as greater sage-grouse, with the amount of oil and gas development in the PAPA and a DSEIS that states "continued loss of habitat function is likely...under all alternatives."

10. Page 4-113, 4.19.3.1, Bald Eagle: The DSEIS discusses wellfield disturbances on private lands and the possibility that some actions may be interrelated and interdependent to actions on Bureau lands. It also states that potential conflicts between such disturbance and bald eagles on private lands has been addressed through voluntary Best Management Practices (BMP) recommended by the Service in coordination with several development companies.

The Service understands that although the BMPs are an important component of ensuring the continued recovery of the bald eagle, the Service reminds the Bureau of their obligation to analyze effects to bald eagles from actions on private land where those actions are interrelated and interdependent to actions on Federal lands. The Bureau may include the

private land owner and/or the operator in their section 7 consultation under the Act, but at minimum the Bureau is obligated to inform the private land owner and the operator of their obligation to comply with the Endangered Species Act.

11. Page 4-115, Black-footed Ferret: The DSEIS states that surveys will be conducted on prairie dog towns where development is proposed. To ensure that surveys are conducted only in areas where the likelihood of finding a black-footed ferret is high (e.g. those towns or portions of towns where densities of prairie dogs are moderate to high), the Service recommends that the Bureau and/or their designated representative contact the Service if prairie dog towns will be impacted to discuss survey needs.
12. Page 4-115, Ute ladies' -tresses: The DSEIS states that the orchid has not been detected in the PAPA and there are no known occurrences in southwest Wyoming. Because there are known occurrences in northeast Utah as well as eastern Wyoming the Service recommends that the Bureau evaluate suitable habitat (i.e. seasonally moist soils and wet meadows of drainages below 7000 feet elevation) for possible occurrence of the orchid.
13. Page 4-116, Colorado River Fish: The DSEIS discusses adverse effects to the four Colorado River fish species affected by depletions to the Colorado River system. It states that produced water, that is surface discharged, would be returned to the Colorado River system. Please see comment 1 above. Also see the attached "Data Needs for Aging Deep Ground Water Aquifers to Evaluate Hydrological Connection to Shallow Aquifers and River Basin Flows."
14. Page 4-120, Colorado River Fish: The DSEIS states that approximately 245 acre-feet of water would be required during construction of the R6, PBC and Opal pipelines; however, because the water would be returned to the Colorado River Basin "actual depletion would be minor." Please see comment 1 above. Also see the attached "Data Needs for Aging Deep Ground Water Aquifers to Evaluate Hydrological Connection to Shallow Aquifers and River Basin Flows."
15. Page 4-133, Upland Game Birds: The DSEIS states that greater sage-grouse reproduction and lek attendance has declined in the PAPA and the Bureau expects continued loss of habitat under all of the alternatives considered. However, page 4-112 (Threatened, Endangered, Special Status Species) states that the Bureau's Sensitive Species Policy and List in Wyoming will ensure that vulnerable species and habitat components are maintained in functional ecosystems and will prevent a need for listing species under the Act. The population of greater sage-grouse in the Green River Basin, which includes the PAPA, is 1 of the 5 largest extant greater sage-grouse populations within the species' entire range (Connelly et. al., 2004). The Service is extremely concerned that existing and continued oil and gas development within the PAPA at the current rate will contribute to the extirpation of this population. Holloran (2005) suggests that current stipulations are inadequate to protect greater sage-grouse, and his data are supported by similar research also on the PAPA (Lyon, and Anderson 2003) as well as on gas field developments in the Powder River Basin (Naugle et al. 2006) and Alberta, Canada (Aldridge and Brigham 2003). Holloran goes on to state that mean extirpation time for the population of birds in his 2005 study that was present before gas field development was estimated at 19 years.

To protect and maintain greater sage-grouse populations, Anderson and Holloran (2005) recommend that managers minimize or halt actions that reduce suitability of nesting habitat within 5 kilometers (3.1 mile) of a lek and protect all potential nesting habitat regardless of proximity to lek locations. The Service understands that the data presented by Holloran (2005) and others were unavailable when the Bureau approved the initial Pinedale Anticline project. However, we are concerned about why the Bureau is not incorporating this new information into the PAPA SEIS plan of development when the potential outcome could have significant effects on the perpetuation of the Green River Basin sage-grouse population.

The Service reminds the Bureau of the 2000 Memorandum of Understanding (MOU) it signed on to with the U.S. Forest Service and the U.S. Fish and Wildlife Service with the Western Association of Fish and Wildlife Agencies (WAFWA) to conserve the greater sage-grouse and its habitat. This MOU outlined the participation of Federal and State wildlife agencies, including the Wyoming Game and Fish Department, in greater sage-grouse conservation, and these commitments should be considered in project planning in sage-grouse habitat. Additionally, unless site-specific information is available, greater sage-grouse habitat should be managed following the guidelines by Connelly et al. 2000 (also known as the WAFWA guidelines). The Service strongly encourages the Bureau to not authorize actions that may exacerbate greater sage-grouse declines on either a local or range-wide level

16. Appendix C, Page C-4, fourth paragraph: This section states that if oil enters reserve pits, it would be removed pursuant to Wyoming Oil and Gas Conservation Commission (WOGCC) or Bureau regulations and the pit would be flagged overhead or covered with netting to prevent waterfowl use. The Service recommends that flagging be excluded from consideration as a protective measure as it is ineffective at deterring birds from oil production skim pits and reserve pits. Additionally, songbirds are also at risk, not just waterfowl. Songbirds and mammals may approach oil-covered pits to drink, and can fall into the reserve pits. Insects entrapped in the oil can also attract songbirds, bats, and small mammals. Hawks and owls in turn become victims when they are attracted by struggling birds or small mammals. The DSEIS should state that the pit would be covered with netting to prevent bird and other wildlife access if oil or sheens are present in the reserve pit. The specific WOGCC regulation should be included in this section: "Reserve pits shall be completely fenced and, if oil or other harmful substances are present, netted or otherwise secured at the time the rig substructure has been moved from the location in a manner that avoids the loss of wildlife, domestic animals, or migratory birds."

The presence of visible sheens on reserve pits are deadly to birds that come into contact with them. A light sheen will coat the bird's feathers with a thin film of oil. Although a sheen of oil on the bird may not immediately immobilize the bird, it will compromise the feathers' ability to insulate the bird. Furthermore, the affected bird will ingest the oil when it preens its feathers and suffer chronic effects. The bird could suffer mortality depending on the severity of the chronic effects and the amount of oil ingested. Mortality or morbidity may result depending on the amount of oil coating the animal, the species, prior condition of the animal, the amount of stress incurred by the animal after oiling, and weather conditions.

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- W-8  
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17. Appendix C, Page C-5, second paragraph: This section states that fracture fluid additives would be contained in pits or tanks. The DSEIS should assess whether if the storage of fracture fluid additives in pits or open tanks would pose a hazard to migratory birds or other wildlife.
- W-10  
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18. Appendix C, Page C-5, third paragraph: This section states that operators would remove fluids from reserve pits within one year of all wells on the pad being put into production. Oil present in reserve pit fluids can entrap and kill migratory birds and other wildlife. The Service has documented bird mortality in reserve pits. This section should specify that fluids containing oil or oil-based products will be removed as soon as possible from the reserve pits after well completion to prevent migratory bird mortality or the reserve pit will be closed. The DSEIS should state that if fluids containing oil or sheens cannot be removed from the reserve pit, then the pit will be covered with netting to prevent bird and other wildlife access.
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19. Appendix C, Page C-5, fourth paragraph: This section states as produced water production declines smaller tanks may be used to accommodate the reduced storage requirements. This should be reworded to state that smaller closed-top tanks will be used to store the produced water. Open-topped tanks can pose a hazard to migratory birds.
20. Page C-27, Wildlife and Habitat Mitigation Plan, Scope: The DSEIS states that a 0.25-mile “no surface occupancy” restriction will be placed around active greater sage-grouse leks. Please see comment 15 above regarding the Service’s concern with existing stipulations.
- FA-3-18
21. Page C-28, Proponent Committed Measures, bullet 2: The DSEIS states that the consolidated development areas will leave 92 percent of the PAPA undisturbed by natural gas development. However, the Bureau fails to identify how much of the directly impacted area is important and/or limiting wildlife habitat. Also, in reviewing the chapter on Affected Environment (pages 3-33, 3-36) it is clear that a significant portion of the PAPA is directly or indirectly affected by oil and gas development through the indirect effects of traffic, noise, lighting, hazardous materials, negative effects to wildlife movement and habitat. As we identified in our 12-month finding on the greater sage-grouse (70 FR 2244) fragmentation of sagebrush habitats has been cited as a primary cause of the decline of sage-grouse populations since the species requires large expanses of contiguous sagebrush. Powerlines, roads, and other corridors associated with oil and gas development can significantly contribute to sagebrush fragmentation, even if a large proportion of the habitat is not directly removed (Knick et al. 2003; Connelly et al. 2004). Lyon and Anderson (2003) suggested that roads on the PAPA may be the primary impact of oil and gas development to sage-grouse, due to their persistence and continued use even after drilling and production have ceased. Other potential indirect impacts to sage-grouse and sagebrush habitats from the development of oil and gas resources include noise, gaseous emissions, changes in water availability and quality, and increased human presence (70 FR 2244). We recommend that the Bureau consider the direct and indirect impacts of intense and perhaps year-round development over the entire PAPA especially areas of importance to wildlife.
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22. Page C-33, Restoration of Impacts: The DSEIS states that “impacts will be rectified by repairing, rehabilitating or restoring the affected environment.” The Service is concerned that sagebrush habitats will not be restored at or near pre-disturbance quality. Knick et al.

(2003) indicate that areas previously dominated by sagebrush may not be completely restorable due to alterations in vegetation, nutrient cycle, topsoil, and other disturbance processes which may result in disturbance from which the habitat can not recover. For most oil and gas developments, the return of greater sage-grouse to pre-disturbance population levels is not expected due to a net loss and fragmentation of habitat (Braun et al. 2002). For example, after 20 years, sage-grouse have not recovered to pre-development numbers in Alberta, even though well pads in these areas have been reclaimed (Braun et al. 2002). In some reclaimed areas, sage-grouse have not returned (Aldridge and Brigham 2003).

23. Page C-33, Reduction and Elimination of Impacts: The DSEIS states that the proponents will utilize computer assisted remote monitoring of producing wells but anticipate that each pad will be visited once per day. The Service recommends that the SEIS clarify why each well will require daily visits when remote monitoring is in place.

24. Page E-5, Reclamation Monitoring: The DSEIS states that the Operator is responsible for monitoring reclamation to determine if certain criteria has been met and to develop and implement remedial actions if not met. The Bureau is responsible for evaluating the reports and providing concurrence with the assessments. Because oil and gas development is a temporary use of public lands, the Service recommends that the Bureau conduct some portion of the reclamation monitoring to ensure that it meets with the Bureau's objectives for fish and wildlife resource needs and multiple use needs.

In Summary, the Service is extremely concerned that implementation of the proposed action and/or alternative-C may contribute to the extirpation of one of the largest populations of greater sage-grouse in the species entire range. The Service is also concerned with the quantity of produced water generated by the proposed action that will be disposed of into large evaporation ponds which could pose a risk to migratory birds and other wildlife. This increase in produced water generation could lead to the construction of additional oilfield wastewater disposal facilities with large evaporation ponds which would increase the risk to migratory birds and other wildlife if not designed and managed properly. The Service is also concerned with the potential for migratory bird and other wildlife mortality in reserve pits with oil or sheens after drilling operations cease. Pitless or closed loop systems should be used when drilling with oil-based muds.

We look forward to working with you throughout the planning process for this project. If you have further questions regarding our comments or your responsibilities under the Act or other policies mentioned, please contact Kathleen Erwin of my staff at the letterhead address or phone (307) 772-2374, extension 228.

Enclosure (1)

cc: FWS, National Environmental Policy Coordinator, Denver, CO (C. Young-D)  
 BLM, Statewide Listed Species Coordinator, Cheyenne, WY (J. Carroll)  
 WGFD, Statewide Habitat Protection Coordinator, Cheyenne, WY (V. Stelter)  
 WGFD, Non-Game Coordinator, Lander, WY (B. Oakleaf)

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**Data Needs for Aging Deep Ground Water Aquifers to Evaluate their Hydrological  
Connection with Shallow Aquifers and River Basin Flows**  
U.S. Fish and Wildlife Service

**Background**

For several years the U.S. Fish and Wildlife Service (Service) has consulted with U.S. Bureau of Land Management (BLM) under section 7 of the Endangered Species Act (ESA), as amended (16 U.S.C. 1531 *et seq.*), regarding potential effects to federally listed species from natural gas development. Increased development resulting in an increased risk of impacts to federally listed species, coupled with an increase in section 7 consultation for project related impacts, prompted the Service in February, 2002, to develop guidelines regarding information needed to aid our evaluation of potential impacts to federally listed species and their habitat (e.g., water quality variables, stratigraphic profile including major geologic layers).

In particular, the Service has expressed concern that pumping water from deep coal bed aquifers may result in depletions to the Colorado or Platte River Basins because of the potential hydrological connection between gas wells and shallow basin aquifers. Providing information for determining the extent of hydrological connection is the responsibility of the project proponent, for which results of isotopic analyses have typically been employed. The extent to which the results of these analyses may be extrapolated broadly across project areas is, however, largely determined by major local geological features (e.g., confining layers or aquitards, presence of major faults). Because details of these features may be poorly understood, and because of the real possibility of hydrological connection between gas wells and shallow aquifers, extrapolating such data must be approached cautiously and methodically as the Service has expressed in previous consultation with BLM.

For several projects over the past year, the BLM has determined that no demonstrable hydrological connection exists between particular gas wells and shallow basin flows; consequently, BLM made a no effect determination regarding downstream species within the Colorado River Basin. While it is not necessary for BLM to obtain concurrence from the Service for no effect determinations under section 7 of ESA, the BLM has requested concurrence from the Service on several such determinations. The Service has not, however, concurred with such determinations and we have stated the need for more information in order for us to do so. To this end, the Wyoming Field Office and the Service's Mountain-Prairie Regional Office have developed the following guidelines.

**Data Needs for Evaluating Hydrological Connection**

Natural gas development may involve pumping large quantities of water from deep aquifers. Because significant natural gas development is projected to occur within the Colorado River and Platte River Basins and consumptive use of water within each basin must be consulted on under section 7 of the ESA, it is necessary to establish whether or not a hydrological connection exists between gas wells and active flow systems. If no demonstrable connection exists, it is assumed that withdrawing water from the aquifer does not constitute consumptive water use to the

respective river basin, and therefore has no effect on downstream federally listed species due to depletions.

From the viewpoint of the Service and section 7 depletion analysis, there are two aspects to evaluating impacts of groundwater pumping on surface water:

- (1) Is the groundwater part of an active hydrologic system that eventually contributes to surface flows?
- (2) If so, how much of a depletion will groundwater pumping cause in the river system of interest, and over the time period of interest (e.g., life of project)?

The purpose of language below is to provide guidelines and suggestions to project proponents for addressing these questions. The burden of proof for answering these questions will be the responsibility of the project proponent. Proponents are encouraged to submit whatever data, analyses and professional evaluations they consider relevant to meeting these informational needs.

#### Determining Hydrological Connection

Because the understanding of hydrogeological characteristics within areas identified for natural gas development is generally poor, ascertaining the extent of hydrological connection between deep water aquifers and shallow basin flows is difficult. In the past, the Service has accepted tritium isotopic analyses alone as a basis for determining the relative date of deep aquifer recharge and, by extension, the degree of hydrological connection with shallow basin flows. However, inconclusive analytical results reviewed by the Service have called into question the reliability of such methods. Considering the recent boom in oil and gas development and the increased risk of impacts associated with the enormous quantities of produced water extracted from deep aquifers, the Service has reviewed the reliability of several methods used to determine mean residence time of ground water.

Based on this review, the Service has determined that at least three lines of evidence may provide useful information in characterizing the relative date of ground water recharge and the potential for hydrological connection with active flow systems: (1) tritium analysis, (2) stable isotopic analysis, and (3) complete water chemistry. Unfortunately, because of the relatively large margin of error often associated with these analyses, none of these types of data, by themselves, adequately addresses questions concerning the relative age of ground water and provide a scientifically reliable characterization of mixing between the deep and shallow water aquifers. Multiple lines of evidence will be considered reliable.

***Tritium Analysis:*** Tritium is a heavy isotope of hydrogen ( $^3\text{H}$ ), the atoms of which are unstable and decay radioactively. Tritium is measured in ground water as a ratio of tritium atoms to hydrogen atoms (i.e.,  $\text{T}/\text{H} = 10^{-18}$  is defined as 1 tritium unit (TU))( Mazor 1991). Tritium concentrations in ground water are useful indications of “modern” (post hydrogen bomb testing in 1952) versus “submodern” recharge. Scientific literature suggests that ground water

containing  $\geq 0.8$  TU is, at least partially, of modern origin and is mixing with shallow water aquifers; tritium concentrations  $< 0.8$  TU suggest that recharge to the ground water aquifer has taken place prior to testing of the hydrogen bomb and is likely not part of an active flow system (Plummer et al. 1993, Clark and Fritz 1997, Bartos and Ogle 2002).

Tritium analytical results can vary substantially among samples taken from the same aquifer (e.g., Mazor 1991, Clark and Fritz 1997, Bartos and Ogle 2002), and lab results often involve a large margin of error making it difficult to arrive at meaningful conclusions concerning relative age of the ground water. Therefore, analytical results for one sample taken from an aquifer do not provide enough information to draw definitive conclusions concerning relative date of aquifer recharge and the potential connection with an active flow system. Multiple samples typically will be necessary to ensure that they are reasonably representative of local aquifer conditions.

**Stable Isotopic Composition:** Ratios of the stable isotopes of oxygen (oxygen-18/oxygen-16, or  $^{18}\text{O}/^{16}\text{O}$ ) and hydrogen (deuterium/hydrogen, or  $^2\text{H}/\text{H}$ ) in water samples, relative to other waters sampled in the vicinity (ground water and surface water) provide an indication of the origin and movement of water. The isotopic composition of water is expressed in per mil deviations from the Standard Mean Ocean Water, written as  $\delta^{18}\text{O}\%$  and  $\delta\text{D}\%$ . Isotopic composition can provide information about climatic conditions under which recharge occurred since a positive relationship exists between temperature and isotopic composition: i.e., as temperature declines, isotopic composition becomes lighter (more negative) (Mazor 1991, Clark and Fritz 1997).

However, a large degree of variability can occur between samples taken from the same aquifer, and isotopic composition varies seasonally and with the altitude of recharge water (e.g., Mazor 1991, Peters et al. 1993, Ogle 1996, Clark and Fritz 1997, Bartos and Ogle 2002, Frost et al. 2002). Therefore, analytical results for one sample taken from an aquifer do not provide enough information to draw definitive conclusions concerning relative date of aquifer recharge. Common use of stable isotopes is to plot values for  $\delta^{18}\text{O}\%$  and  $\delta\text{D}\%$  taken from ground water, springs, streams or other local sources, alongside the meteoric line of local or regional precipitation as a reference with which to compare (e.g., Mazor 1991, Bartos and Ogle 2002, Frost et al. 2002, ). The grouping of values taken from various sources, relative to each other and to the meteoric line, indicate the origin, movement, and relative age of the water sources.

**Water Chemistry:** Major ion and general mineral characteristics provide important information regarding the origin and development of ground water. By examining the concentrations of these constituents in aquifers relative to shallow basin aquifers or surface flows, meaningful conclusions can be drawn regarding the relative age of produced water. Specifically, the following information is needed:

Total Dissolved Solids  
 Total Hardness (mg/L as  $\text{CaCO}_3$ )  
 Sodium Absorption Ratio (SAR)

Dissolved (mg/L): Calcium, Magnesium, Sodium, Potassium, Bicarbonate, Chloride, Sulfate, Fluoride, and Silica

The Service recommends the collection of surface and ground water samples from various sources in close proximity to the area of gas development in order for us to begin understanding the hydrological consequences of gas development. Tritium, stable isotopes, and water chemistry should be evaluated seasonally as gas development continues, providing baseline information needed to understand the local and/or regional hydrological consequences of gas development. Because of the variability of analytical results associated with field samples providing this information, we recommend collecting and analyzing duplicate samples for every 10 percent of samples collected (e.g., if 100 samples are collected, every 10<sup>th</sup> sample should be collected and analyzed in duplicate).

#### Determining Depletive Impacts to Surface Water Flows

The data identified above will provide key information the Service needs for section 7 consultations to evaluate the extent of hydrological connection in the basin between the deep coal bed aquifers and shallow aquifers and surface water flows. However, this information may not adequately describe the extent to which surface flows in regional streams and rivers, and water levels in shallow basin aquifers, will be affected by pumping large quantities of deep ground water. Other information would be needed to address such questions: for example, the stratigraphic profile, composition of major geological layers, proximity to surface water features, relative depth of deep and shallow aquifers, and regional geographical features such as confining layers and major faults. Data or models addressing the hydrologic effect of lowering the piezometric surface within confined aquifers, or lowering the water table in unconfined aquifers, also would help us determine whether there will be impacts to waters of concern.

The Service recommends monitoring seasonal water levels, hydrostatic pressure, and isotopic or chemical data for dating ground water in a subset of local wells including those being drilled by the developer: this would provide invaluable information concerning the long term effects of gas development locally. Because of the variability of analytical results associated with field samples providing this information, we recommend collecting and analyzing duplicate samples for every 10 percent of samples collected as recommended above.

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