ELR
NEWS & ANALYSIS

Geologic Carbon Dioxide Sequestration: An Analysis of Subsurface Property Law

by Elizabeth J. Wilson and Mark A. de Figueiredo

Editors' Summary: To address potential global climate change caused by rising concentrations of atmospheric carbon dioxide (CO_2), many are advocating CO_2 capture and sequestration, which involves the injection of CO_2 into geologic formations. But because of the large volumes of CO_2 that would need to be injected annually, the long storage time frames required for geological sequestration, and the monitoring and verification needs for injected CO_2, this technology presents a novel set of demands on the current legal regime for subsurface property rights. This Article focuses on the legal precedents for underground injection and examines the existing case law framework that could influence legal interpretations of future geological sequestration projects. The authors argue that clarification of property rights as they relate to geological sequestration is important from both regulatory and liability perspectives, as each can have significant impacts on the future cost, public acceptability, and feasibility of geological sequestration projects.

I. Introduction

With increasing concern in the international community over rising concentrations of atmospheric carbon dioxide (CO_2) that may lead to changes in the global climate, the political impetus for mitigating CO_2 emissions is growing. In combination with incoming solar radiation, higher concentrations of CO_2 in the atmosphere serve to trap heat and, according to scientific consensus, influence the temperature of the earth's surface.[1] Atmospheric concentrations of CO_2 have risen from a pre-industrial level of about 280 parts per million (ppm) to a current level of 372 ppm.[2] The international community, through the United Nations (U.N.) Framework Convention on Climate Change, has sought to stabilize atmospheric concentrations of CO_2 at a level that would prevent dangerous anthropogenic interference with the climate system.[3]

CO_2 capture and sequestration could play a key role in achieving the deep emissions cuts necessary to stabilize CO_2 levels. The technology involves the capture of CO_2 emitted from power plants or industrial sources[4] and sequestration of the CO_2 in deep sub-seabed or subterranean geologic formations. Potential geologic sequestration (GS) reservoirs include oil and gas fields, saline aquifers, and coal seams.[5] Because of the large volumes of CO_2 that would need to be injected annually, the long storage time frames required for GS, and the monitoring and verification needs for injected CO_2, GS presents a novel set of demands on the current legal regime for subsurface property rights.

Resolution of regulatory and legal uncertainty for GS is a key prerequisite for the technology's adoption and success.

Elizabeth J. Wilson is an assistant professor at the University of Minnesota's Humphrey Institute of Public Affairs. She holds a doctorate in engineering and public policy from Carnegie Mellon University.

Mark A. de Figueiredo is a research assistant at the Massachusetts Institute of Technology's Laboratory for Energy and the Environment. He is a J.D. candidate at the University of Virginia School of Law and a Ph.D. candidate in technology, management, and policy at the Massachusetts Institute of Technology.

1. *See, e.g.*, Climate Change 2001: The Scientific Basis 10-11 (J.T. Houghton et al. eds., 2001).

2. U.S. Environmental Protection Agency (EPA), Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2002, at 3 (2004), *available at* http://yosemite.epa.gov/oar/globalwarming.nsf/UniqueKeyLookup/RAMR5WNMGY/$File/04_complete_report.pdf (last visited Jan. 5, 2006).

3.

> The ultimate objective of this Convention and any related legal instruments that the Conference of the Parties may adopt is to achieve, in accordance with the relevant provisions of the Convention, stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system.

1992 U.N. Framework Convention on Climate Change, June 12, 1992, 31 I.L.M. 849 (entered into force Mar. 21, 1994).

4. Carbon could be captured from electric power plants, hydrogen production facilities, refineries, cement plants, upstream natural gas production, or other industrial sources.

5. *See, e.g.*, Franklin Orr, *Distinguished Author Series: Storage of Carbon Dioxide in Geologic Formations*, J. Petroleum Tech., Sept. 2004, at 90.

From this legal analysis emerge important issues that will need further resolution and clarification before large-scale GS projects can be implemented. Specific questions concerning property rights of land, minerals in place, and of the injected CO_2, as well as operational and long-term liability, emerge as particularly significant. Identification of these issues now can help to ensure that appropriate legislative and legal considerations are incorporated into state and federal policy.

In order to determine the right to compensation for any type of subsurface harm, three elements need to be further clarified. The first issue is the ownership of the pore space, the voids within the rock where the CO_2 will be sequestered. Second, ownership of the injected CO_2 and the associated liability finds precedent in natural gas storage case law; the determination of ownership could be especially important if sequestered CO_2 were to leak into potable water supplies or to the surface. Third, determining what type of mechanism, if any, would be appropriate for compensation to surface owners, as sequestration rights need to be defined, protected, and enforced for long time frames is important. Developing a clear understanding of what legal paradigm and body of case law GS will be evaluated under is the first step toward anticipating legal challenges and developing appropriate methods for managing them.

This Article focuses on the legal precedents for underground injection and examines the existing case law framework that could influence legal interpretations of future GS projects. The clarification of property rights as they relate to GS is important from both regulatory and liability perspectives, as each can have significant impacts on the future cost, public acceptability, and feasibility of GS projects. Following a brief description of the technical aspects of GS, legal concepts that could be potentially important to GS deployment are explored through analogous injection activities. In particular, relevant case law that has shaped subsurface property rights in the oil and gas, hazardous waste, and natural gas storage industries is presented. Finally, the implications of case law for GS and future research concerns and directions are explored.

It should be noted that several dimensions of importance to GS are not explored in this Article. These include scale-related issues, the impacts of injecting large quantities of CO_2 on the extent of lateral migration (such as displacement and the effect on groundwater resources), and liability considerations (such as the causal chains necessary to prove harm and the implications for liability when GS is linked to an international carbon accounting structure). In addition, the structure of GS projects, whether they occur in a large centralized operation or through smaller, dispersed projects, will also influence the overall legal regime.

II. Geologic CO_2 GS

GS is the injection of CO_2 into deep (greater than approximately one kilometer (km)) geologic formations for the explicit purpose of avoiding atmospheric emission of CO_2.

The injection of CO_2 into wells is essentially the reverse of pumping oil or water from confined aquifers in the subsurface. CO_2 is injected into the pore spaces of more porous and permeable layers of sedimentary rock, essentially trapped by less permeable rock layers that impede fluid migration (known as the confining interval). The pressure of the CO_2 being injected must be greater than the in situ pressure of the receiving formation for fluid to enter. In order to avoid potential fracturing of the confining interval, the injection pressure may not exceed the pressure on a layer of rock caused by the overlying material (known as the lithostatic pressure). To ensure the integrity of the confining interval, pressure levels of injection wells are regulated to avoid fracturing.[6] When the injection well pressure needed to inject nears the lithostatic pressure safety margin, a well is considered "full" and injection ceases.

For GS, CO_2 will be sequestered either as a gas, a dense supercritical gas,[7] or a liquid. Depending on reservoir temperature and pressure injected, in almost all circumstances, except deep ocean subsurface sequestration, CO_2 will be less dense than the brine present in the reservoir. This makes buoyancy flow an important force governing supercritical CO_2 behavior in the subsurface.[8] Generally it is assumed that the water in the receiving reservoir is at hydrostatic pressure, but this can vary significantly between different injection sites. As a rule of thumb, temperature increases 25 degrees Celsius/km underground and the pressure increases 10 megapascal (MPa)/km.[9] While these rates will vary according to the type of geologic formation, the general predictability is primarily due to the fact that over long timescales (10,000 to 1 million years), deep waters in the formation are connected to the larger hydrosphere.[10] As CO_2 is highly compressible up to pressures of roughly 8 MPa, found at approximately at a depth of 1 km below the surface, significantly more CO_2 can be stored at injection depths up to 1 km. Beyond this the density is flat, or even slightly decreasing with depth.[11] Because injected CO_2 will initially be more buoyant than the receiving waters, upwards and lateral migration within the subsurface is an important consideration. Storage will become more secure over time as geochemical reactions dissolve CO_2 in formation waters and eventually convert it to minerals such as calcium carbonate. The rates of change are slow: on the order of centuries for dissolution and millennia for mineralization.[12]

Several GS projects are currently underway or planned, as shown in Table 1. In addition to the projects injecting CO_2 for sequestration shown in Table 1, CO_2 is injected with acid gas, a waste associated with sour gas production (natural gas with high levels of hydrogen sulfide) in Abu Dhabi, Canada,

6. William R. Walker & William E. Cox, Deep Well Injection of Industrial Wastes: Government Controls and Legal Constraints 31-32 (1976).

7. CO_2 is considered a supercritical fluid at temperatures greater than 31.1 degrees Celsius and 7.38 megapascal (MPa) (critical point). CRC Handbook of Chemistry and Physics F-89 (60th ed. 1979).

8. Stefan Bachu, *Sequestration of CO_2 in Geological Media: Criteria and Approach for Site Selection in Response to Climate Change*, 41 Energy Conversion Mgmt. 953, 967 (2000).

9. 10 MPa is equivalent to ~99 atmospheres of pressure, so at a depth of 1 km, the pressure is roughly 100 times greater than it is at the surface of the earth.

10. Tianfu Xu et al., Analysis of Mineral Trapping for CO_2 Disposal in Deep Aquifers 62 (Lawrence Berkeley Nat'l Laboratory, Report No. LBNL-46992, 2000).

11. David Law, *Injectivity Studies*, *in* Aquifer Disposal of Carbon Dioxide: Hydrodynamic Mineral Trapping—Proof of Concept 59, 62 (B. Hitchon ed., 1996).

12. Karsten Preuss et al., *Numerical Modeling of Aquifer Disposal of CO_2*, 8 Soc'y Petroleum Engineers J. 49, 52-53 (2003). *See also* Xu et al., *supra* note 10, at 62.

and the United States.[13] Approximately 25 million metric tonnes (MMTs)[14] per year of CO_2 are injected for enhanced oil recovery (EOR) in the Permian Basin in Texas alone, with more projects planned worldwide.[15] GS projects could inject CO_2 in conjunction with EOR efforts for resource extraction, or they could inject directly into saline aquifers where no hydrocarbons are present. There are likely to be differing legal treatments with respect to EOR versus non-EOR storage sites; for example, the U.S. Environmental Protection Agency regulates the underground injection of fluids for the enhanced recovery of oil under a different regime from other types of underground injection.[16] Additionally, it is unclear how the legal regime could shift when CO_2 injected for EOR becomes CO_2 monitored for larger global sequestration efforts.

Table 1: CO_2 GS Demonstration Projects[17]

Project	Start	Type of Project	Participants and Location	Tonnes of CO_2 Injected Per Year	Total Tonnes of CO_2 to Be Injected
Sleipner	1996	Upstream natural gas	Statoil, North Sea	1 MMT	20 MMTs
Weyburn	2000	CO_2 from anthropogenic source, enhanced oil recovery	EnCana, Canada	1 MMT	20 MMTs
In Salah	2004	Upstream natural gas	BP and Sonatrach, Algeria	1 MMT	18 MMTs
Snohvit	Planned 2006	Upstream natural gas/liquefied natural gas (LNG)	Statoil, Petoro, TotalFinaElf, and others, Barents Sea	0.7 MMT	Unknown
Gorgon	2008-2010	Upstream natural gas/LNG	Chevron Texaco, Australia	1 MMT in Phase I	125 MMTs

III. Overview of U.S. Mineral Rights and Subsurface Ownership

With the exception of federal lands, the rules concerning mineral rights are largely governed by state law and differ significantly across jurisdictions. The construction of these rights affects property access, management, and exclusion, with mineral rights being "severed" from the surface estate spatially, temporally, and according to use.[18] Finding that an unjust subsurface "taking" of resources or property rights has occurred depends both on the degree of financial importance as well as the feasibility of future utilization of the resource. Claims of trespass and unjust takings of mineral, water, or storage resources appear in much of the case law explored here.

A. Subsurface Ownership and Mineral Formations

Under the English common-law system in use in the United States, land is divided into surface and mineral estates. A surface estate provides ownership over the entire matrix of the earth from crust to core. Mineral estates can be conveyed separately from the surface estate, and in the majority of states, such conveyance will include oil, gas, and other petroleum products.[19] These rights allow the owner right-of-way on the surface land for exploration and reasonable use of the surface estate for subsurface oil and gas extraction.

At the turn of the century, several courts viewed capture of oil and gas as similar to the capture of wild animals, *ferae naturae*, where oil and gas were considered "fugitive," and like wild game, the landowner did not possess the gas or oil until it was captured.[20] Modified versions of this rule of capture lead to the "nonownership theory" of oil and gas resources, which is practiced in roughly one-half of the United States.[21] States following nonownership theory recognize that the owner possesses the exclusive rights of mineral exploration and exploitation and is able to protect the reservoir from operations that might be harmful.[22] Further, in some "nonownership states," differentiations are made between resource stocks and resource flows.[23]

The remaining states adhere to the more easily interpretable "ownership in place" theory, where the mineral interests are severed from the surface estate and the mineral rights holder owns the oil and gas beneath his land, as is the case with solid minerals.[24] Owners have a "possessory estate" in the oil and gas in place, giving them the right to explore and produce oil and gas (and exclude others) subject to regulatory and legal restrictions, which may limit operations and protect adjacent mineral owners.[25] The mineral estate can also be conveyed separately from the rest of the land.[26] The owner of the mineral estate has the power to explore, develop, and extract oil and gas from the subsurface and has the ability to transfer these rights to another party, usually through an oil and gas lease.[27]

Both of these broad frameworks are subject to the rule of capture, where the legitimate producing party "gains title

13. International Energy Agency Greenhouse Gas R&D Programme, CO_2 Capture and Storage, *R&D Project Database*, *at* http://www.co2captureandstorage.info/co2db.php4 (last visited Dec. 2, 2005) [hereinafter *R&D Project Database*]. *See also* Interview with Stefan Bachu, Alberta Energy Utilities Board (Oct. 22-25, 2003).

14. Tonne refers to the metric tonne or 1,000 kilograms (kgs), about 2,204 pounds (lbs.). This convention is employed to differentiate it from the U.S. ton of 2,000 lbs. (907 kgs).

15. Interview with Owen Anderson, Professor of Law and Kuntz Chair in Oil, Gas, and Natural Resources, University of Oklahoma (Nov. 17, 2003).

16. 40 C.F.R. §144.6 (2005) [hereinafter Anderson Interview].

17. *R&D Project Database*, *supra* note 13.

18. Owen Anderson et al., Hemingway Oil and Gas Law and Taxation §2.1 (4th ed. 2004).

19. *Id.* §1.1-1.2.

20. Hammonds v. Central Ky. Natural Gas Co., 75 S.W.2d 204, 206 (Ky. Ct. App. 1934). *See also* Higgins Oil & Fuel Co. v. Guaranty Oil Co., 82 So. 206, 212 (La. 1919); State v. Ohio Oil Co., 49 N.E. 809, 812 (Ind. 1898); Townsend v. State, 47 N.E. 19, 21 (Ind. 1897); Westmoreland & Cambria Natural Gas Co. v. DeWitt, 18 A. 724, 725 (Pa. 1889).

21. Anderson et al., *supra* note 18, §1.3. *See also* Anderson Interview, *supra* note 15.

22. *Id.*

23. Boudewijn Bouckaert, *Original Assignment of Private Property*, *in* Encyclopedia of Law and Economics 807 (B. Bouckaert et al. eds., 2000).

24. Anderson et al., *supra* note 18, §1.3.

25. *Id.*

26. *Id. See also* Proctor v. Graham, 32 Colo. App. 102, 105 (Colo. Ct. App. 1973).

27. Anderson et al., *supra* note 18, §1.3.

to all oil and gas produced, regardless of drainage."[28] Statutes governing the conservation of oil and gas and the prevention of waste have been adopted in all fossil fuel-producing states.[29]

B. Subsurface Ownership and Saline Formations

While these provisions cover mineral estates, property rights of saline aquifers without hydrocarbons present depend on a legal regime founded on groundwater rights and ownership of the subsurface. There is an inherent uncertainty concerning the determination of property rights for a saline formation with respect to GS because of the lack of case law on point.[30] Instead, the law has focused on property rights over the taking and use of groundwater for consumption. In general, states follow one of five major doctrines with respect to ownership of groundwater rights: (1) absolute dominion; (2) reasonable use; (3) correlative rights; (4) the restatement rule; or (5) prior appropriation.

Under the absolute dominion rule, the surface owner has "absolute dominion" over everything above, on, or below the land.[31] Any water contained in an aquifer lying beneath the land is the property of the surface owner.[32] The surface owner would have the right to use the water for any purpose, with no liability for damage to an adjoining owner.[33] The absolute dominion rule holds that groundwater is the absolute property of the surface owner, as with the rocks and soil that compose the land.[34]

Under the reasonable use rule, there is no restriction on the taking of groundwater; however, any use must be in a reasonable and beneficial manner.[35] A use not connected to beneficial enjoyment of the land from which it is obtained would be an unlawful purpose with respect to groundwater. The reasonable use rule is pertinent where large quantities of water are extracted for use at a distance from the land where the water was extracted and generally applies only when there is no connection with the use, enjoyment, or improvement of the land from which it is extracted.[36]

The correlative rights rule is an extension of the reasonable use rule. Surface owners hold proportionate proprietary shares in the aquifer, with the largest landowner having the largest share of the aquifer since the owner has the largest share of the land above it.[37] During times of water scarcity, landowners are restricted to a fair and just proportion of the supply, which is determined by the proportionate share.[38] The courts may weigh and balance the rights of competing uses to determine those that are proper.[39] In California, the correlative rights rule has been extended by the doctrine of mutual prescription, allocating water by comparing reasonableness of use based on such factors as custom, social utility, safe yield, and need.[40]

The restatement rule, from §858 of the *Restatement (Second) of Torts*, is also an extension of the reasonable use rule. While the reasonable use rule requires water to be used on the land overlying the aquifer, the restatement rule allows for water to be applied outside of the overlying land.[41] Although the rule is a limitation of liability, its effect is as a rule governing property rights allocation.[42] The restatement rule states:

> A possessor of land who, in using the subterranean water therein, intentionally causes substantial harm to a possessor of other land through invasion of the other's interest in the use of subterranean water in his land, is liable to the other if, but only if, the harmful use of water is unreasonable in respect to the other possessor.[43]

As the rule has been interpreted, liability is imposed for any withdrawal that causes unreasonable harm to neighboring landowners by lowering the water table or reducing the pressure of the aquifer.[44] Liability is also imposed for any withdrawal that exceeds a reasonable portion of the annual groundwater storage for the aquifer.[45] The rule has not received widespread acceptance due to its lack of guidance and difficulties in application.[46]

Under the prior appropriation rule, temporal precedence establishes property right over the groundwater.[47] This is the so-called first in time, first in right rule. During times of water shortage, whoever drills into the aquifer first in time has priority over the taking of water contained in the aquifer.[48] In some states, the courts have imposed reasonableness restrictions on the prior appropriation rule.[49] For example, Colorado prohibits pumping if it would result in a 40% depletion of groundwater over a 25-year period, and Idaho has prohibited all groundwater mining.[50]

C. Implications for GS

The implications of these different ownership structures for GS could depend on how GS projects are structured. If CO_2 is injected for EOR and then monitored for sequestration, it

28. Anderson Interview, *supra* note 15.
29. Ana B. Schepens, *Prospecting for Oil at the Courthouse: Recovery Drainage Caused by Secondary Recovery Operations*, 50 Ala. L. Rev. 603, 606 (1999).
30. Tara L. Taguchi, *Whose Space Is It Anyway? Protecting the Public Interest in Allocating Storage Space in California's Groundwater Basins*, 32 Sw. U. L. Rev. 117, 119 (2003).
31. Alison Mylander Gregory, *Groundwater and Its Future: Competing Interests and Burgeoning Markets*, 11 Stan. Envtl. L.J. 229, 240 (1992). *See also* 78 Am. Jur. 2d *Waters* §214 (2004).
32. Gregory, *supra* note 31, at 240.
33. Bristor v. Cheatham, 255 P.2d 173, 178 (Ariz. 1953).
34. Maddocks v. Giles, 728 A.2d 150 (Me. 1999). *See also* 78 Am. Jur. 2d *Waters*, *supra* note 31.
35. *Bristor*, 255 P.2d at 178.
36. 78 Am. Jur. 2d *Waters*, *supra* note 31, §215.
37. Earl Finbar Murphy, *The Recurring State Judicial Task of Choosing Rules for Groundwater Law: How Occult Still?*, 66 Neb. L. Rev. 120, 134 (1987).
38. Gregory, *supra* note 31, at 241.
39. *Id.*
40. City of Pasadena v. City of Alhambra, 207 P.2d 17, 33 (Cal. 1949). *See also* Gregory, *supra* note 31, at 242.
41. Dylan O. Drummond, *Texas Groundwater Law in the Twenty-First Century: A Compendium of Historical Approaches, Current Problems, and Future Solutions Focusing on the High Plains Aquifer and the Panhandle*, 4 Tex. Tech. J. Admin. L. 173, 197 (2003).
42. *Id.* at 200.
43. Restatement (Second) of Torts §858 (1977).
44. *Id.*
45. *Id.*
46. Gregory, *supra* note 31, at 242.
47. Drummond, *supra* note 41, at 201.
48. Taguchi, *supra* note 30, at 125.
49. Drummond, *supra* note 41, at 201.
50. *Id.* at 202.

seems likely that legal precedents relating to secondary recovery operations will apply initially. Once the project is into the "sequestration phase," post-active oil extraction, it is unclear which legal doctrine will apply. If a GS project seeks establishment in a saline aquifer, its legality will depend on whether groundwater and the aquifer is owned privately or as a public resource. Each of these different scenarios calls for a further analysis of trespass, liability, and interpretations of reasonable use doctrines.

IV. GS and EOR: Trespass, Liability, and Damage to Hydrocarbon Resources

Through EOR, CO_2 is already injected into oil reservoirs to increase the amount of oil that can be produced.[51] It is very likely that initial GS projects will be linked with EOR projects. At the time of this writing, long-term oil futures prices of over $60 per barrel are driving a renewed interest in domestic EOR projects.[52] Additionally, increased EOR, especially if the CO_2 is captured from anthropogenic sources, will help to provide the capture and transport infrastructure necessary for large-scale GS.

By injecting fluid into the producing reservoir, "secondary recovery" operations re-pressurize the reservoir and increase oil and gas recovery, and "tertiary recovery" operations involving the injection of CO_2 serve to recover additional oil in place.[53] Secondary and tertiary recovery operations have revitalized oil production in the United States[54]; however, these operations have raised questions surrounding the operator's liability vis-à-vis reducing the amount of recoverable oil and gas from an adjacent mineral rights holder.[55] An operator has the right to a fair share of the oil and gas in place and a duty to protect the common source of supply, and the continuing physical invasion of neighboring mineral estates is forbidden.[56] As water injected for secondary recovery migrates through the subsurface, it can pass onto a neighboring lease, ultimately affecting a neighboring rights holder's oil or gas supply and affecting the ability to recover the resource. The legal ramifications of secondary recovery projects are thus significant.

A. Negative Rule of Capture

One of the first cases to deal with the implications of secondary recovery operations was *Railroad Commission of Texas v. Manziel*.[57] Manziel was the mineral rights owner in a property adjacent to a secondary recovery project approved by the Railroad Commission of Texas. Manziel brought suit against the commission for trespass of his subsurface property because injected fluids could potentially migrate across property lines. The Texas Supreme Court held that technical rules of trespass could not defeat a valid secondary recovery project, noting that secondary recovery increased total oil and gas recovery.[58] The resulting rule of nonliability has come to be known as the "negative rule of capture," which states that less valuable substances can migrate through the subsurface and replace more valuable substances without incurred liability.[59]

B. Field Unitization

Most secondary recovery activities will only take place in a field that has been unitized. With "field unitization," oil or gas field leases for resource development are combined, thereby creating a field-wide operation[60]; liability is removed as a driving concern because production and profits are shared by all unit members, and the field is managed in order to optimize resource recovery. Many oil and gas fields are not unitized, and liability has been imposed upon the operator in several subsequent cases involving mineral loss, granted on theories of trespass and nuisance.[61]

The power of state regulatory boards to grant permits for secondary recovery operations or even forced unitization, however, has consistently been upheld.[62] This discretionary power by state oil and gas boards is seen as necessary to ensure the greatest recovery and least waste of a valuable resource.[63] In *Phillips Petroleum Co. v. Stryker*,[64] where water flooding on an adjacent parcel to a producing unit had drained oil reserves, damages of $26.9 million were initially awarded to Stryker by a jury in the lower court on claims of trespass, negligence, fraud, nuisance, and punitive damages for draining the plaintiff's oil and gas reserves. After being upheld by the appeals court, Phillips Petroleum Company appealed to the Alabama Supreme Court, which reversed the lower court's judgment, finding that the plaintiff, in accordance with the Alabama Code, should have petitioned for inclusion in the unit.[65] To hold Phillips Petroleum Company liable was against the state's policy on secondary re-

51. Mark A. Klins, *Carbon Dioxide Flooding*, *in* BASIC CONCEPTS IN ENHANCED OIL RECOVERY PROCESSES 215-40 (M. Bavière ed., 1991).

52. Interview with Michael Moore, Managing Partner, Falcon Environmental Services (Jan. 9, 2006). *See also* NYMEX, Light Sweet Crude Oil Futures for December 2010 (June 24, 2005).

53. Klins, *supra* note 51, at 215-17.

54. *See* U.S. OFFICE OF TECHNOLOGY ASSESSMENT, ENHANCED OIL RECOVERY POTENTIAL IN THE UNITED STATES 234 (1978).

55. Schepens, *supra* note 29, at 608.

56. Hastings Oil Co. v. Texas Co., 149 Tex. 416, 430-31 (1950).

57. 361 S.W.2d 560, 562 (Tex. 1962).

58. *Id.* Interestingly, a later Railroad Commission of Texas Oil and Gas Proposal for Decision and Orders speculates that the result of *Manziel* may have been different had the secondary recovery project "drowned" one of Manziel's producing wells, thereby increasing the total damage of the secondary recovery operation. M. KAWAGUCHI & T. RICHTER, APPLICATION OF LASMO ENERGY CORPORATION FOR AN EXCEPTION TO CONVERT THE FOLLOWING PRODUCING WELLS TO INJECTION WELLS: J.D. HANSBOROUGH UNIT NO. A-1, W.W. WINGFIELD UNIT NO. 2, AND THE J.R. LUSK UNIT NO. 1 IN THE ALABAMA FERRY (GLENROSE "D" FIELD), LEON AND HOUSTON COUNTIES, TEXAS (No. 5-95279) (Railroad Comm'n of Tex. 1990).

59. HOWARD R. WILLIAMS ET AL., OIL AND GAS LAW §204.5 (2001). *See also* Schepens, *supra* note 29, at 617.

60. ANDERSON ET AL. *supra* note 18, §7.13.

61. Schepens, *supra* note 29, at 622. *See also* Boyce v. Dundee Healdton Sand Unit, 560 P.2d 234, 237 (Okla. Ct. App. 1975) (recovery granted based on theory of nuisance for damages caused by water flooding); Greyhound Leasing & Fin. Corp. v. Joiner City Unit, 444 F.2d 439, 440 (10th Cir. 1971) (recovery was granted on private nuisance for damage caused by salt water encroachment caused by secondary recovery); Tidewater Oil Co. v. Jackson, 320 F.2d 157, 164-65 (1963), *overruled in part by* Fransen v. Conoco, Inc., 64 F.3d 1481, 1495 (10th Cir. 1995) (granted recovery based on trespass and nuisance in action from water flooding).

62. Schepens, *supra* note 29, at 614, 616.

63. *Id.*

64. 723 So. 2d 585 (Ala. 1998).

65. *Id.* at 591.

covery.[66] As a result of the reversal, no damages were awarded on the grounds that "an owner of interests outside a unit should not be entitled to damages from the operator of the unit if the circumstances are such that he can protect himself by engaging in an independent operation, or if he has been extended a fair opportunity to participate in the Unit."[67] The importance of administrative powers to create units and the role in unitization protecting an operator from liability is highlighted in this decision.

C. Implications for GS

While clear on the importance of secondary recovery for field maintenance and the right of state oil and gas boards to approve it, judicial rulings on the associated liability are inconsistent. Liability for resulting mineral damage has been found in many secondary recovery cases, and fields that are not fully unitized could be especially vulnerable. If CO_2 were injected for sequestration, the operator could, theoretically, be held liable if neighboring mineral rights that were not part of the same producing unit were harmed. Many secondary recovery operations take place only in fully unitized fields because of this potential liability. Injecting CO_2, initially for hydrocarbon recovery and eventually for GS, within a fully unitized field could avoid potential liabilities associated with mineral owners resulting from the operation. It is unclear if post-recovery longer term liabilities associated with the sequestration of CO_2 would also be covered. It should be noted that all of the case law discussed dealt specifically with the injection of water for secondary recovery, not other fluids, such as CO_2, which are used in subsequent recovery projects. Overall, considerations of other mineral and surface rights holdings should be thoroughly reviewed to avoid compromising resource production and potentially litigious situations resulting from GS.

Additionally, the role of administrative law in both supporting the creation of units and protecting parties against future liabilities is a key consideration for GS; ensuring that the regulatory structure is appropriate is a crucial component for success. Creating a large reservoir for resource recovery or storage is not a new concept, and there is an inherent tension between individual and collective rights when unitizing oil or gas production fields or establishing a natural gas storage site. Information on oil and gas leases, storage documents, pooling agreements, surface leases, easements, rights of way, and royalty and surface owner interests need to be assembled to determine interests and project stakeholders.

Creating a field unit for secondary oil recovery may take months to years of negotiating to secure all necessary rights and reach an agreement, as understanding the shares of risk and production from operations is complicated.[68] Statutes allow for voluntary unitization, and most producing states also have a "compulsory joinder of interest": once a certain percentage of owners have agreed to unitization (50% to 85%), then the unit is created.[69] It is much more difficult in states without this provision, due primarily to the liability associated with potential resource damage of conjoiners.[70] State oil and gas or natural resource commissions review the application and then approve the unitization. Combination GS and EOR projects will benefit greatly from the reduced liability, but once the operation ceases to be active and the sequestration phase begins, surface owners may have rights as well.

While the experience with secondary oil recovery provides a rich body of case law, the goals of secondary recovery are inherently different from those of GS. Many early GS projects will probably be linked to CO_2-EOR; however, the fundamental goal of EOR is not to sequester CO_2, and a fair amount of injected CO_2 is produced with the pumped oil. In contrast, the goal of GS is to sequester the injected CO_2 underground for time periods that extend hundreds to thousands of years beyond the 25- to 35-year time frame of tertiary oil recovery projects. Additionally, the laws, property rights, statutes, and regulations that specifically govern oil and gas production may not apply to GS injection into saline aquifers without hydrocarbon resources.

V. Subsurface Property Rights: The Case of Hazardous Waste Injection

Compared to the needs for large-scale GS, the amount of hazardous waste injected annually is small (about 34 MMTs per year),[71] but these underground injection wells dispose of approximately 50% of the liquid hazardous waste in the United States.[72] There are approximately 120 hazardous waste wells operating in 19 states, most injecting at depths of about 1,400 meters (4,500 feet).[73] The subsurface property issues surrounding hazardous waste injection are exemplified by *Chance v. BP Chemical, Inc.*,[74] and *Mongrue v. Monsanto*.[75] In both cases, neighboring citizens sued the operator of a hazardous waste injection facility; in neither of the cases did the court uphold the plaintiffs' claims.

A. Curtailing Subsurface Ownership Rights

In the class action suit of *Chance*, plaintiffs-appellants charged that injectate from BP Chemical's injection well had laterally migrated below the plaintiff's property, violating their rights as property owners.[76] The plaintiffs sought recovery for trespass, nuisance, negligence, and fraudulent concealment and claimed damage to their substrata for other uses, but the trial court limited the cause of action to trespass due to lack of standing for the other claims. As underground injection is less costly than other ways of handling hazardous waste, plaintiffs also claimed unjust enrichment on the

66. *Id.*

67. *Id.*

68. U.S. Office of Technology Assessment, *supra* note 54, at 86.

69. *Id.*

70. *Id.*

71. Elizabeth Wilson et al., *Regulating the Ultimate Sink: Managing the Risks of Geologic CO_2 Storage*, 37 Envtl. Sci. & Tech. 3476, 3480 (2003).

72. *See* Francoise M. Brasier & Bruce J. Kobelski, *Injection of Industrial Wastes in the United States*, *in* Deep Injection Disposal of Hazardous and Industrial Waste 1-8 (1996). *See also* Paul S. Osborne, Technical Program Overview: Underground Injection Control Regulations 3 (2001). Hazardous waste definitions are discussed at 40 C.F.R. §261 (2005).

73. Wilson et al., *supra* note 71, at 3478.

74. 670 N.E.2d 985 (Ohio 1996).

75. 249 F.3d 422 (5th Cir. 2001).

76. *Chance*, 670 N.E.2d at 986.

basis that BP Chemical was able to dispose of toxins below their subsurface at a lower cost. BP Chemical cited the relevance of *Manziel* and its "rule of negative capture,"[77] but the court found the holding of that case to be irrelevant because *Manziel* concerned the extraction and storage of hydrocarbons.[78] For that same reason, the court also rejected *Columbia Gas Transmission Corp. v. Exclusive Natural Gas Storage Easement*,[79] which affirmed that surface owners should be compensated for use of the pore space and outlined various compensation schemes for surface property owners overlying natural gas storage projects.

The Supreme Court of Ohio held that even though BP Chemical "operates the wells pursuant to the permits, that fact in and of itself does not insulate [BP Chemical] from liability."[80] Yet the court held that the plaintiffs had the burden of proving that a trespass had occurred.[81] The court applied *United States v. Causby*[82] to resolve the question of subsurface property ownership. Reasoning that "absolute ownership of air rights is a doctrine which 'has no place in the modern world,' to apply as well to ownership of subsurface rights," the court effectively truncated subsurface property ownership, though no specific depth was cited.[83] In this interpretation, subsurface rights to exclude invasions are only valid as long as the invasions actually interfere with "reasonable and foreseeable" use of the subsurface.[84] Thus, physical damage or interference with use must be shown to be associated with any alleged trespass.[85] The plaintiffs'/appellants' trespass case was found to be too speculative.[86] The court did surmise that there was possibly a valid trespass claim against BP Chemical for one class member who had supposedly abandoned plans to drill for natural gas and, thus, was "prevented from enjoying the reasonable and foreseeable use of its property" by the injection operations.[87] Ownership of mineral rights might have conferred a claim of trespass (and damages) that mere surface property ownership did not. The dissent argued that *Columbia Gas Transmission* was relevant and that the rental value of plaintiff's properties should have been determined by the jury.

Chance seems to truncate ownership of the subsurface pore space, affirm the operator's liability associated with injected fluid, and, largely because of the lack of standing, not find any need to compensate surface owners for disposal below their surface estates. The acceptance of such logic supporting a ruling would, assuming no leakage, allow GS projects to proceed without significant threat of legal action for trespass from surface owners, while still making the operator liable for damage caused by the injectate.

77. Railroad Comm'n of Tex. v. Manziel, 361 S.W.2d 560, 568 (Tex. 1962).
78. *Chance*, 670 N.E.2d at 991.
79. 620 N.E.2d 48, 49 (Ohio 1993).
80. *Chance*, 670 N.E.2d at 990.
81. *Id.* at 991.
82. 328 U.S. 256 (1946).
83. *Chance*, 670 N.E.2d at 992 (citing Willoughby Hills v. Corrigan, 278 N.E.2d 658, 664 (1972).
84. *Id.*
85. *Id.* at 993.
86. *Id.*
87. *Id.*

B. Liability and Full Subsurface Property Rights

In *Mongrue*, the U.S. Court of Appeals for the Fifth Circuit affirmed a decision by the U.S. District Court for the Western District of Louisiana that wastewater injected by Monsanto onto Monsanto property, but possibly migrating under Mongrue's subsurface property, did not constitute a taking without just compensation.[88] The plaintiffs/appellants had originally charged trespass as well, but later dropped this charge in the appeal even though under Louisiana law, "the ownership of a tract of land carries with it the ownership of everything that is directly above or under it."[89] Both the district court and the appeals court assumed, arguendo, that Monsanto's injected wastewater had migrated into the plaintiff's subsurface property and that the plaintiff did have ownership rights to the strata, though Monsanto filed an affidavit disputing the physical presence of its injectate under the plaintiff's property.[90] The Fifth Circuit, in an opinion written by Judge Jane A. Restani, held that "appellants may recover under a state unlawful trespass claim against Monsanto regardless of the permit allowing for injection," but because plaintiffs dismissed their trespass claim, the court did not rule on this issue.[91]

The Fifth Circuit considered only the question of an unconstitutional taking. Plaintiffs did not include a federal claim in their case. Under Louisiana law, only private agents authorized by the government can be held liable for an unconstitutional taking from the expropriation of property.[92] As Monsanto had received no such delegation of authority, the court held that Monsanto could not be implicated in an unconstitutional taking. Although the Louisiana Commissioner of the Office of Conservation had the power to delegate permits for injection and issue unitization orders affecting property rights, there was no evidence that the rights of the property owners could be "redefined or limited."[93] The court seemed willing to grant, or assume, trespass in this case, though it was unclear if any damages would have been found or any compensation granted.

For GS projects, the underlying logic to this ruling could have more significant ramifications in terms of the subsurface use rights of surface estate owners and the need to compensate them for occupying their subsurface property.

C. Implications for GS

Operator liability was affirmed in both cases; holding a valid permit to inject does not exempt the operator from liability. The burden of proof, however, is on the plaintiff. In *Chance*, the subsurface depth of the surface property holder's interest was truncated, yet in *Mongrue*, the court affirmed the subsurface ownership by the surface property holder. While it might have been possible to prove trespass in the latter case, it is unlikely that any damages would have been awarded as no harm to existing or future interests could be proven. Whether compensation could have been demanded is unclear.

88. *Mongrue*, 249 F.3d at 425.
89. *Id.* at 432 n.15.
90. *Id.* at 429 n.9.
91. *Id.* at 432 n.17.
92. *Id.* at 429.
93. *Id.* at 432.

The implications for GS are significant; while surface property owners were found to have ownership, or limited ownership, of the subsurface, trespass claims that resulted in damage awards were not upheld. These cases highlight the plaintiff's difficulty in proving trespass (especially when no monitoring wells are required) and subsequently highlight the lack of material interest that surface property holders have been determined to have in the subsurface. Unlike hazardous waste injection, however, the quantities that will be injected for GS projects are large; injected CO_2 could migrate toward or to the surface; and conceivably, subsurface trespass could be more easily proven.

The cases were argued, in large part, by experts with dueling hydrogeologic models. Much of the testimony focused on the validity of the specific model parameters and underlying assumptions. Uncertainties in the subsurface geology and the ability of the different models to capture these were the focus of much of the argument. Because of the large quantities of CO_2 and large area influenced by GS injection, modeling the heterogeneous subsurface features over such a large area would be a challenge.

VI. Subsurface Property Rights: The Case of Natural Gas Storage

Natural gas storage provides another relevant analog for understanding the evolution of subsurface property rights. Natural gas is stored underground in depleted oil and gas reservoirs, salt caverns, or suitable natural aquifers to provide for the increased market demand during the winter months. U.S. natural gas storage capacity is approximately 230 billion cubic meters (8.1 trillion cubic feet).[94] Differentiating between the ownership of the pore space and ownership of the stored gas and associated rights and liabilities between them is a major theme running through this body of case law.

A. Ownership of Injected Gas

One of the first cases on the subject of ownership of injected gas was *Hammonds v. Central Kentucky Natural Gas Co.*[95] The court held that gas lost its title once it was injected for storage and, therefore, trespass did not occur because the injected gas had no owner.[96] This rule was widely criticized and is not currently followed in the United States.[97] In subsequent cases,[98] individual state courts have ruled that the injecting company holds title to the re-injected natural gas and that third parties would be liable for production of the stored gas.

In both *Lone Star Gas Co. v. Murchison*[99] and *Oklahoma Natural Gas Co. v. Mahan & Rowsey, Inc.*,[100] stored gas had migrated to other parts of the receiving reservoir, where the gas storage company had not acquired storage rights, or to adjoining formations that were not known to transmit with the storage formation.[101] The storing party was found to have retained ownership rights even though the gas had migrated to production wells that were on the third party's land not within the designated storage area.[102] Mere ownership does not protect the operator from liability of potential claims of trespass or damage to subsurface resources and the injector of gas must therefore obtain control of storage rights for the full area of the reservoir, contracting with all parties that have mineral or surface rights.[103] These cases highlight the difficulty of anticipating where injected gas will flow within the subsurface and could be of special interest to GS.

B. Storage Space Property Rights

Numerous courts have held that after the removal of underground minerals, oil, or gas, the surface owner retains the right to use the remaining space for storage (known as the American rule). This is different from the English rule (also practiced in much of Canada) where the mineral owner owns the subsurface space even after the minerals have been removed.[104]

While surface owners retain the right to the storage space, mineral rights holders have also been found to have a continued property interest or right to the space in cases where the underground storage facility was constructed in an "ownership in place" state such as Texas.[105] Other parties that may have an interest in the subsurface storage of natural gas include mineral lessees (who have leased the mineral rights for a defined term and might need to be compensated for the taking of the exploratory rights) and future interest owners (who have a vested right in the future estate).[106]

The judiciary interprets storage rights and mineral rights differently.[107] In several cases, storage rights were found not to preclude exploration or production of mineral rights. A storage operator would be unable to prevent the issuance of production leases for zones beneath the storage forma-

94. Jason Heinrich et al., Environmental Assessment of Geologic Storage of CO_2 21 (Massachusetts Institute of Technology Laboratory for Energy and the Environment Working Paper No. 2003-002, 2004).

95. 75 S.W.2d 204 (Ky. Ct. App. 1934).

96. *Id.* at 206.

97. Robert J. McKinnon, *The Interplay Between Production and Underground Storage Rights in Alberta*, 36 Alberta L. Rev. 400, 405 (1998). In Kansas, the rule is qualified, and while *Hammonds* has never officially been overturned, natural gas public utilities have been granted the power of eminent domain. This statutory right allows natural gas public utilities to condemn subsurface formations for the purpose of storage. Philip DeLaTorre, *Survey of Kansas Oil and Gas Law (1988-1992)*, 41 Kan. L. Rev. 691, 716-20 (1993).

98. "[T]itle to natural gas once having been reduced to possession is not lost by the injection of such gas into a natural underground reservoir for storage purposes." White v. New York State Natural Gas Corp., 190 F. Supp. 342, 349 (W.D. Pa. 1960). *See also* Oklahoma Natural Gas Co. v. Mahan & Rowsey, Inc., 786 F.2d 1004, 1005 (10th Cir. 1986); Lone Star Gas Co. v. Murchison, 353 S.W.2d 870, 880 (Tex. Ct. App. 1962).

99. 353 S.W.2d 870 (Tex. Ct. App. 1962).

100. 786 F.2d 1004 (10th Cir. 1986).

101. *Lone Star*, 353 S.W.2d at 871; *Oklahoma Natural Gas*, 786 F.2d at 1006.

102. *Lone Star*, 353 S.W.2d at 880; *Oklahoma Natural Gas*, 786 F.2d at 1005.

103. McKinnon, *supra* note 97, at 405.

104. Adam Stamm, *Legal Problems in the Underground Storage of Natural Gas*, 36 Tex. L. Rev. 161, 168 (1957). *See also* Jack L. Lyndon, *The Legal Aspects of Underground Storage of Natural Gas—Should Legislation Be Considered Before the Problem Arises?*, 1 Alberta L. Rev. 543, 545 (1955).

105. Mapco, Inc. v. Carter, 808 S.W.2d 262, 277 (Tex. Ct. App. 1991).

106. Roger Scott, *Underground Storage of Natural Gas: A Study of Legal Problems*, 47 Okla. L. Rev. 27, 62 (1966).

107. McKinnon, *supra* note 97, at 406-11.

tion.[108] While the storing party would be able to observe the production to ensure that it did not harm her operation, she would not be able to stop it; however, natural gas storage operators usually contract with mineral owners so the storage integrity is not compromised.[109]

C. Access to Storage Rights

The Natural Gas Act of 1938 provides for eminent domain for the construction of interstate natural gas pipelines.[110] The judiciary later interpreted the Act to include the construction of underground storage facilities.[111] Thus, if a gas company is unable to directly contract with property owners for storage rights, it can still obtain subsurface rights for storage by initiating condemnation procedures in a state or federal court.[112] For storage operations that are not interstate, state legislation must grant eminent domain power to establish storage operations. Mineral rights owners often own a "cushion" of remaining gas in the formation and therefore must be compensated.[113] When a property owner overlying a natural gas storage project does not voluntarily enter into a contract with the storage company, the remaining patchworks of property are termed "windows" in the storage field.[114] If the owner of a window property threatened to drill into the storage formation or was not included in the original project boundary because of geologic uncertainties, the storage company could file a condemnation action in court.[115] The owner of the window property can file an inverse condemnation claim and possibly "obtain compensation as of the date of the taking." The property owner could then counterclaim for trespass under state law, a claim that potentially allows for compensation as well as punitive damages.[116] With deregulation of the gas market, many of the firms now managing natural gas storage are private. Moreover, legal definitions of just compensation and public good are still evolving in this field.

Formulas for granting compensation for storage of natural gas under land were explored in *Columbia Gas Transmission*.[117] In an effort to clarify Ohio law on compensation for natural gas storage projects, the federal district court asked the Ohio Supreme Court to clarify "a measure of just compensation for the appropriation of an underground gas storage easement."[118] The court held that the methods outlined by a commission appointed by Judge David D. Dowd Jr., were appropriate for examining this issue.[119] Several methods of determining the value of a natural gas storage easement were described. The commission's analysis suggested that one must consider the "fair market value," which could be based on one of the following methods: comparable sales of easements for natural gas in the particular formation; present value calculation (if sufficient natural gas exists for commercial recovery) of the "foreseeable net income flow from the property for its foreseeable life"[120]; capitalization of rental income for the right to store gas, calculated by multiplying the area to be rented with the value of comparable storage rights; calculation of the depreciation of the entire tract from the taking of the easement used for storage; calculating the difference of the market value of the property before and after the taking; mineral lease value; and viewpoint of value, i.e., the value calculated from the point of the view of the landowner.[121]

While Ohio law is now clear at both the state and federal levels, the same cannot be said for other jurisdictions within and outside of the U.S. Court of Appeals for the Sixth Circuit. For example, while state law is followed in the Sixth Circuit, state laws affecting valuation in Kentucky, Michigan, and Tennessee are not necessarily clear, and in other jurisdictions outside of the Sixth Circuit, the issue is largely undecided.[122]

D. Implications for GS

Unlike the case of hazardous waste injection, natural gas storage law largely affirms that the surface estate owner also owns the subsurface storage pore space. Mineral owners, however, could also have a substantial future interest, even after presently recoverable minerals and gas have been removed. In developing natural gas storage projects, both surface and mineral rights holders are traditionally included.[123] This is in marked contrast with Canadian and English law,

108. *Id.*

109. Anderson Interview, *supra* note 15.

110. The Natural Gas Act provides:

> When any holder of a certificate of public convenience and necessity cannot acquire by contract, or is unable to agree with the owner of property to the compensation to be paid for, the necessary right-of-way to construct, operate, and maintain a pipe line or pipe lines for the transportation of natural gas, and the necessary land or other property, in addition to right-of-way, for the location of compressor stations, pressure apparatus, or other stations or equipment necessary to the proper operation of such pipe line or pipe lines, it may acquire the same by the exercise of the right of eminent domain in the district court of the United States for the district in which such property may be located, or in the State courts. The practice and procedure in any action or proceeding for that purpose in the district court of the United States shall conform as nearly as may be with the practice and procedure in similar action or proceeding in the courts of the State where the property is situated: Provided, That the United States district courts shall only have jurisdiction of cases when the amount claimed by the owner of the property to be condemned exceeds $3,000.

15 U.S.C. §717f(h) (2005).

111. Columbia Gas Transmission Corp. v. An Exclusive Gas Storage Easement, 776 F.2d 125, 128 (6th Cir. 1985). *See also* Steven D. McGrew, *Selected Issues in Federal Condemnations for Underground Natural Gas Storage Rights: Valuation Methods, Inverse Condemnation, and Trespass*, 51 Case W. Res. L. Rev. 131, 138-40 (2000).

112. McGrew, *supra* note 111, at 133.

113. Anderson Interview, *supra* note 15.

114. McGrew, *supra* note 111, at 142.

115. *Id.*

116. *Id.* at 142, 149-51. Steven McGrew provides a series of arguments as to why the unauthorized storage of natural gas should constitute trespass and argues that the federal Natural Gas Act does not preempt state law trespass claims, which, he concedes, could vary significantly by jurisdiction. He posits that an amendment to the Natural Gas Act could provide the best overall solution for clarifying the roles and responsibilities of the operator and property holder.

117. *Columbia Gas Transmission*, 620 N.E.2d at 49.

118. *Id.*

119. *Id.*

120. *Id.*

121. "The yardstick is what the landowner has lost, not what Columbia has gained." *Id.*

122. McGrew, *supra* note 111, at 146.

123. Anderson Interview, *supra* note 15.

where the mineral rights owner (the Crown for UK energy minerals and government-owned for 90% of Canadian mineral resources) is also considered the owner of the pore space remaining after mineral exploitation.

The judiciary has clarified that ownership of injected natural gas rests with the operator injecting the stored natural gas. If the same principle applies for GS, the operator injecting the CO_2 would retain property rights as well as the associated liability that this implies. Stored natural gas, however, is a valuable commodity that is injected and then recovered seasonally while injected CO_2 would be sequestered for hundreds to thousands of years.

Natural gas storage rights are secondary to those of mineral production. Possible mineral extraction below GS storage strata, however, could conceivably lead to compromising the integrity of the storage reservoir.[124] Additionally, as many of the cases found extensive lateral movement of stored natural gas, it will be incumbent upon any GS project to characterize the reservoirs thoroughly and to contract with all associated property interests. This will be especially challenging given the long time frames for GS projects; thus, the greater importance of future interest holders.

Finally, with ownership of the injectate comes liability. Trespass is tolerated and eminent domain is granted for natural gas storage projects; the gas is a valuable commodity and the activity is considered necessary for the common good. No power of eminent domain yet exists specific to GS projects. Proving an immediate "public good" could be challenging and would need to be established by state legislation. The Interstate Oil and Gas Compact Commission Geologic Sequestration Task Force's *A Regulatory Framework for Carbon Capture and Geological Storage*[125] suggests a legislative framework on the grounds that "[t]he geologic storage of CO_2 provides a mitigation strategy aimed at reducing CO_2 emissions into the atmosphere, which has been shown to be a contributing actor in global warming, thereby promoting the public interest and the general welfare." The document also outlines legislation for establishing the rights of eminent domain for GS projects.[126] In the absence of such legislation, it is unclear how "window properties" overlying the storage reservoir will be handled. As GS requires underground storage for long time periods, the implications of the different types of compensation methods outlined in *Columbia Gas Transmission* should be further explored.

VII. Conclusion

The preponderance of case law presented here suggests that both surface and mineral owners will have a legitimate claim to subsurface strata used for GS projects. Many actors will have interests in GS projects, including the injector, owner of injected material, surface owner, mineral owner, mineral lessee, neighboring surface and mineral owners, and neighboring mineral lessees. As property rights are governed by state laws and interpreted by state courts, any legal opinion on GS projects will be influenced by jurisdictional differences. Inconsistencies between different jurisdictions could affect the siting, operation, and long-term care of future GS projects. Several issues that could directly affect GS projects include subsurface property ownership, potential liability, ownership of injected CO_2, and methods for evaluating potential compensation for utilization of the subsurface.

In most of the case law explored here, the ownership of the subsurface pore space seems to rest with the owner of the surface estate. This is different from Canadian and English law, where the pore space ownership remains with the mineral estate owner. Though it has been theoretically explored in several texts,[127] the court in *Chance* truncated subsurface rights of surface owners in the case of hazardous waste injection wells. Efforts at initiating GS projects in the United States need to be aware of both surface estate ownership as well as mineral estate ownership, as both are important stakeholders.

It is unclear which legal paradigm will be employed for GS projects not associated with hydrocarbon recovery. While hazardous waste is injected for long-term disposal, natural gas is injected expressly for the purpose of storage. The direct applicability of this guidance is limited, however, due both to the small quantities involved in hazardous waste injection and to the seasonal nature of natural gas storage.

As in the case of natural gas storage, explicit "storage or disposal rights" could be granted for GS projects. Both surface and mineral estates will need to be involved in this process. Additionally, compensation for subsurface use and royalties for mineral rights owners has regularly been paid for natural gas storage projects. Further study on the impacts of compensation schemes on GS costs should be undertaken. The GS project's time frame is an important consideration for leasing versus purchasing subsurface interests. Theoretically, competing GS projects could create a market for storage strata.

The title of injected natural gas remains with the storage operator, a finding upheld by the courts. This is true even if the gas migrates out of the defined boundaries of the storage area. Natural gas, however, is a valuable commodity that will be recovered and sold. For other fluids, this issue is not as certain, and no case law deals directly with injected CO_2. It seems that CO_2 injected under a GS scheme could also remain the property of the injecting party, but further clarification would help, especially if injected CO_2 has no positive economic value and liability associated with leakage is significant. Cases of multiple operators injecting into the same reservoir would need to be clarified as well.

Because of the large size of many proposed GS projects, care needs to be taken to ensure that adjacent mineral rights owners' holdings are not compromised. As mineral rights have been found to trump both storage uses and surface holdings,[128] any GS project needs to carefully examine mineral, water, and surface uses of the land that will be influenced by an injection project. Migration of CO_2 from the storage or disposal zone could inadvertently affect mineral rights. Mineral extraction in adjacent strata could compromise the formation's storage integrity. Likewise, pressure

124. Storck v. Cities Serv. Gas Co., 575 P.2d 1364, 1367 (Okla. 1977); Rayl v. East Ohio Gas Co., 348 N.E.2d 390, 392 (Ohio Ct. App. 1975).

125. Kevin Bliss, Final Report: A Regulatory Framework for Carbon Capture and Geological Storage 75 (Interstate Oil & Gas Compact Comm'n 2005).

126. *Id.* at 77.

127. *See* William A. Thomas, *Ownership of Subterranean Space*, 3 Underground Space 155, 160 (1979).

128. In addition to the right of reasonable access on the surface.

increases in the substrata could affect lateral movement of waters in the subsurface and affect groundwater quality.

If the programmatic goal is to ensure safe, economic, and effective GS, these issues should be examined more fully to understand their ramifications on GS. As litigation is costly and time consuming, substantial efforts made up front to understand the legal framework and implications of legal precedents on GS projects could help to avoid costly future litigation. The legal framework is likely to vary significantly between states and among specific project sites, as will the important geophysical characteristics. Despite the legal hurdles, geologic carbon sequestration could significantly reduce the transition costs to a carbon managed energy system and enable deep emission cuts while allowing for continued use of fossil fuel resources, technology, and infrastructure.