Appendix A

House Bill 90

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ORIGINAL HOUSE **ENGROSSED**
BILL NO. 0090

ENROLLED ACT NO. 25, HOUSE OF REPRESENTATIVES

FIFTY-NINTH LEGISLATURE OF THE STATE OF WYOMING
2008 BUDGET SESSION

AN ACT relating to carbon sequestration; providing for regulation by the department of environmental quality of the injection of carbon dioxide and associated constituents; providing for an appropriation; and providing for an effective date.

Be It Enacted by the Legislature of the State of Wyoming:

Section 1. W.S. 30-5-501 and 35-11-313 are created to read:

ARTICLE 5
GEOLOGIC SEQUESTRATION ACTIVITIES

30-5-501. Oil and gas activities at geologic sequestration sites.

Nothing in W.S. 35-11-313 shall be deemed to affect the otherwise lawful right of a surface or mineral owner to drill or bore through a geologic sequestration site as defined by W.S. 35-11-103(c)(xxi), if done in accordance with the commission rules for protecting the geologic sequestration site against the escape of carbon dioxide.

35-11-313. Carbon sequestration; permit requirements.

(a) The geologic sequestration of carbon dioxide is prohibited unless authorized by a permit issued by the department.

(b) The injection of carbon dioxide for purposes of a project for enhanced recovery of oil or other minerals approved by the Wyoming oil and gas conservation commission shall not be subject to the provisions of this chapter.

(c) If an oil and gas operator converts to geologic sequestration upon the cessation of oil and gas recovery operations, then regulation of the geologic sequestration facility and the geologic sequestration site shall be transferred to the department. If the oil and gas operator does not convert to geologic sequestration, the wells shall be plugged and abandoned according to the rules of the Wyoming oil and gas conservation commission.

(d) Temporary time limited permits for pilot scale testing of technologies for geologic sequestration shall be issued by the department based upon current rules and regulations.

(e) Permit requirements for geologic sequestration of carbon dioxide shall be as defined by department rules.

(f) The administrator of the water quality division of the department of environmental quality, after receiving public comment and after consultation with the state geologist and the advisory board created under this act, shall recommend to the director rules, regulations and standards for:

(i) The creation of subclasses of wells within the existing Underground Injection Control (UIC) program administered by the United States Environmental Protection Agency under Part C of the Safe Drinking Water Act to protect human health, safety and the environment and allow for the permitting of the geologic sequestration of carbon dioxide;

(ii) Requirements for the content of applications for geologic sequestration permits. Such applications shall include:

(A) A description of the general geology of the area to be affected by the injection of carbon dioxide including geochemistry, structure and faulting, fracturing and seals, stratigraphy and lithology including petrophysical attributes;

(B) A characterization of the injection zone and aquifers above and below the injection zone which may be affected including applicable pressure and fluid chemistry data to describe the projected effects of injection activities;

(C) The identification of all other drill holes and operating wells that exist within and adjacent to the proposed sequestration site;

(D) An assessment of the impact to fluid resources, on subsurface structures and the surface of lands that may reasonably be expected to be impacted and the measures required to mitigate such impacts;

(E) Plans and procedures for environmental surveillance and excursion detection, prevention and control programs. For purposes of this section, "excursion" shall mean the detection of migrating carbon dioxide at or beyond the boundary of the geologic sequestration site;

(F) A site and facilities description, including a description of the proposed geologic sequestration facilities and documentation sufficient to demonstrate that the applicant has all legal rights, including but not limited to the right to surface use, necessary to sequester carbon dioxide and associated constituents into the proposed geologic sequestration site;

(G) Proof that the proposed injection wells are designed at a minimum to the construction standards set forth by the department and the Wyoming oil and gas conservation commission;

(H) A plan for periodic mechanical integrity testing of all wells;

(J) A monitoring plan to assess the migration of the injected carbon dioxide and to insure the retention of the carbon dioxide in the geologic sequestration site;

(K) Proof of bonding or financial assurance to ensure that geologic sequestration sites and facilities will be constructed, operated and closed in accordance with the purposes and provisions of this act and the rules and regulations promulgated pursuant to this act;

(M) A detailed plan for post-closure monitoring, verification, maintenance and mitigation;

(N) Proof of notice to surface owners, mineral claimants, mineral owners, lessees and other owners of record of subsurface interests as to the contents of such notice. Notice requirements shall at a minimum require:

(I) The publishing of notice of the application in a newspaper of general circulation in each county of the proposed operation at weekly intervals for four (4) consecutive weeks;

(II) A copy of the notice shall also be mailed to all surface owners, mineral claimants, mineral owners, lessees and other owners of record of subsurface interests which are located within one (1) mile of the proposed boundary of the geologic sequestration site.

(iii) Requirements for the operator to provide immediate verbal notice to the department of any excursion after the excursion is discovered, followed by written notice to all surface owners, mineral claimants, mineral owners, lessees and other owners of record of subsurface interests within thirty (30) days of when the excursion is discovered;

(iv) Procedures for the termination or modification of any applicable Underground Injection Control (UIC) permit issued under Part C of the Safe Drinking Water Act if an excursion cannot be controlled or mitigated;

(v) Such other conditions and requirements as necessary to carry out this section.

(g) As soon as practical and prior to September 30, 2009, the state oil and gas supervisor, the state geologist and the director shall convene a working group for the purpose of developing an appropriate bonding procedure and other financial assurance methods to assure that adequate financial resources are provided to pay for any mitigation or reclamation costs that the state may incur as a result of default by the permit holder. The bond or other financial assurance shall be required during the operating life of the sequestration project and throughout the post-closure care period in order to abate or remedy any violation of a permit, standard or rule established under the provisions of this act. The working group shall recommend to the joint minerals, business and economic development and joint judiciary interim committees, on or before September 30, 2009, the duration of the post-closure care period. At a minimum, the bond or other financial assurance shall provide assurance for closure and reclamation costs, post-closure inspection and maintenance costs and environmental monitoring, verification and control costs.

(h) At the time a permit application is filed, an applicant shall pay a fee to be determined by the director based upon the estimated costs of reviewing, evaluating, processing, serving notice of an application and holding any hearings. The fee shall be credited to a separate account and shall be used by the division as required to complete the tasks necessary to process, publish and reach a decision on the permit application. Unused fees shall be returned to the applicant.

(j) The director shall recommend to the council any changes that may be required to provide consistency and equivalency between the rules or regulations promulgated under this section and any promulgated for the regulation of carbon dioxide sequestration by the United States environmental protection agency.

(k) The Wyoming oil and gas conservation commission shall have jurisdiction over any subsequent extraction of sequestered carbon dioxide that is intended for commercial or industrial purposes.

(m) Nothing in this section shall be construed to create any liability by the state for failure to comply with this section.

Section 2. W.S. 35-11-103(c) by creating new subparagraphs (xx) through (xxii) is amended to read:

35-11-103. Definitions.

(c) Specific definitions applying to water quality:

(xx) "Geologic sequestration" means the injection of carbon dioxide and associated constituents into subsurface geologic formations intended to prevent its release into the atmosphere;

(xxi) "Geologic sequestration site" means the underground geologic formations where the carbon dioxide is intended to be stored;

(xxii) "Geologic sequestration facilities" means the surface equipment used for transport, storage and injection of carbon dioxide.

Section 3. There is appropriated two hundred fifty thousand dollars ($250,000.00) from the general fund to the department of environmental quality for use by the working group created by W.S. 35-11-313(g) for expenses related to performing the tasks assigned it pursuant to this act. Expenses may include the costs to secure expert consultation. This appropriation shall be for the period beginning with the effective date of this act and ending June 30, 2010. Notwithstanding any other provision of law, this appropriation shall not be transferred or expended for any other purpose and any unexpended, unobligated funds remaining from this appropriation shall revert as provided by law on June 30, 2010. This appropriation shall not be included in the department's standard biennial budget request.

Section 4. Nothing in this act is intended to impede or impair the ability of an oil and gas operator to inject carbon dioxide through an approved enhanced oil or gas recovery project and establish, verify, register and sell emission reduction credits associated with the project.

Section 5. The department of environmental quality and the oil and gas conservation commission shall submit a joint written report, on or before November 1 of each year, to the joint minerals, business and economic development and joint judiciary interim committees as to all aspects of compliance with this legislation including, but not limited to, the promulgation of rules and regulations, the formation of the working group, permitting and changes to pertinent federal regulations affecting the same.

Section 6. This act is effective July 1, 2008.

(END)

Speaker of the House

President of the Senate

Governor

TIME APPROVED: _________
DATE APPROVED: _________

I hereby certify that this act originated in the House.

Chief Clerk

Appendix B

Phases of A Carbon Sequestration Project

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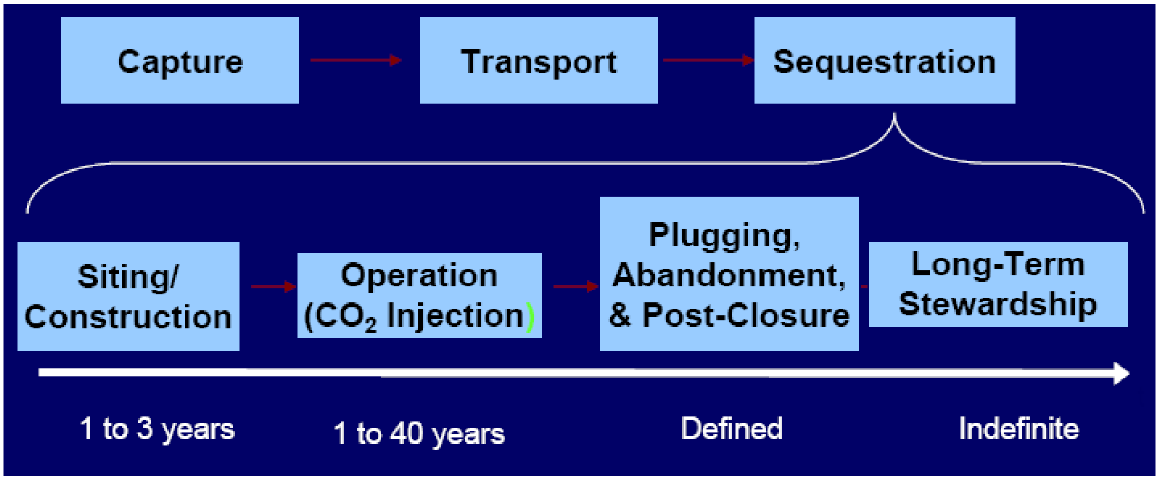
THE PHASES OF A CARBON SEQUESTRATION PROJECT

For the purposes of this program, the sequestration process is divided into four phases;

- **Site characterization and permitting Phase**
- **Operations Phase** including injection, monitoring and closure tasks
- **Post Closure Phase** including monitoring until plume stabilization is confirmed
- **Long term stewardship Phase** including periodic monitoring to confirm site remains stable



The overall framework of Carbon Capture and Storage (CCS) covers the process of capturing carbon dioxide from the original carbon source (typically a byproduct of fossil fuel combustion or a shift reaction), carbon dioxide pretreatment, compression, transportation, and ultimately the injection into deep subterranean saline aquifers or other suitable geologic structures. Although there are a number of issues that must be addressed in the process of capturing and transporting carbon dioxide, the focus of this program is to provide recommendations related to the "cradle to grave" process for permanent underground injection and storage of carbon dioxide.

The process of sequestration goes beyond injection, but must also address the different phases of the process. During each phase in the process, different financial assurance instruments must be made available to provide for the protection of health and safety, as well inadvertent trespass, or eco system impacts due to the release of carbon dioxide. To better understand the types of recommended financial assurance requirements, it is necessary to understand the various phases that sequestration covers. The overall sequestration process has been broken down into the following four phases.

I. Site Characterization and Permitting Phase

II. Operational (Injection) Phase

III. Post Closure (Plume Stabilization) Phase

IV. Long Term Stewardship (or Long Term Care) Phase

<u>Site Characterization and Permitting Phase</u>: During this phase, the owner/operator of the selected site will perform the necessary technical field studies, engineering and permitting efforts to confirm the suitability of the sequestration site. This phase is the most critical since proper site selection is key to the success of the long term sequestration.

The site will be characterized to ensure that the carbon dioxide can safely be injected into the target geologic formation and to ensure that the injected carbon dioxide remains permanently trapped either through mineralization or otherwise stabilized. This will include studies of the geology to ensure adequate geologic seals are in place. The proposed carbon dioxide injection and monitoring well locations will be identified. Above-ground facilities, including distribution piping, utility services, required auxiliary compression facilities, operating and maintenance facilities, and storage ponds are laid out. During this stage detailed computer reservoir models are developed to map the flow and impacts of carbon dioxide both during and after the operational phase. The owner/operator will be required to ensure that the injected carbon dioxide will not impact potential drinking water sources. Furthermore, the owner/operator will need to ensure that any mineral rights owners are not impacted. Agreements with pore space owners will need to put in place.

If test bore information is unavailable or insufficient, it may be necessary to drill additional wells and to perform additional analysis. During this phase, the operations plan will be developed. It may be necessary to perform small scale water and carbon dioxide injection tests to prepare the operations plan. This will require some degree of preliminary permitting effort. The site analysis will include an investigation to locate all existing and orphaned wells.

During the characterization phase, an in depth risk assessment will be performed to evaluate the various events or processes that could occur that would result in an unfavorable event or outcome. A measurement, monitoring, and verification (MMV) plan will be prepared to monitor the flow of carbon dioxide in the ground, identify any releases to the atmosphere, and to measure any surface impacts.

During this phase some of above-ground construction may be performed but will not likely include the majority of the injection and monitoring wells other than those developed for the exploratory drilling, monitoring, and mapping activities.

Much of the information will be used to prepare the overall sequestration site permit application. As part of that permitting effort, permits for the initial set of individual injection, monitoring, and relief wells will be prepared. At the completion of the Characterization and Permitting phase, the appropriate regulatory authorities would issue the site and well permits.

The duration of this phase will vary depend on a number of factors including the level to which the site has previously been drilled and geologic data is available. It is possible this phase could be as short as six months depending on the data available, but it is expected the overall process will more likely take one to two years.

Operating (Injection) Phase: During the Operating Phase the owner/operator will construct the initial injection and monitoring wells. The distribution piping and support facilities would be installed as well as any relief wells and storage ponds. After testing the integrity of the piping and wells, preliminary injection testing with water commences. Following the construction, pre-injection and commissioning activities, the operational phases would begin and the site would begin commercial operation. The owner/operator would perform periodic monitoring in compliance with the MMV plan. Monitoring techniques may include use of tracers, water analyses, pressure testing, seismic logs, soil sampling, ambient monitoring, and land contour mapping. The characteristics of the carbon dioxide plume in the reservoir would be measured and compared to the reservoir models to identify how well the computer models map the actual process. Changes in operating practices and reservoir models may be necessary. The risk assessment program would be periodically reviewed to determine if changes are needed.

As portions of the target reservoir are filled, some wells would no longer be needed. These wells would be suitably capped or plugged in compliance with the permit requirements for post closure; the owner/operator would seek a release from his financial assurance obligation associated with these wells. It is expected that for larger sequestration sites, new wells would be required and that additional permits would be required for the new wells.

At some point in time, the sequestration reservoir will reach a point where it reaches or it is no longer economic to continue operation; in either case, injection into the reservoir would cease. At this point, the injection wells and unneeded monitoring wells would be capped or plugged in compliance with the permit requirements. When all wells have been plugged, including relief wells, the Operating Phase would be considered to have ended.

The duration of the operating phase would depend on a number of factors including the time required to install the injection infrastructure, the reservoir size, the reservoir characteristics, injection rates, and life of the carbon dioxide source. It is expected that, at a minimum, a sequestration site could have a life as short as ten years. For large sites being used to sequester carbon dioxide from sources with long operating lives, such as coal-fired generating facilities, the operating phase could be as long at 35 to 40 years.

Post Closure (Plume stabilization) - This phase would begin at the point all of the carbon dioxide injection wells have been appropriately plugged and all subsurface operations and activities ceased. During the Post Closure phase, the site would still be actively monitored to establish that the site was safe and secure, the carbon dioxide plume had materially stabilized, and the site could safely be abandoned.

During the phase, the owner/operator would also have the obligation to ensure all site reclamation activities had been completed. These reclamation activities would include capping of any monitoring wells not required as part of the continuous MMV program. Underground piping would either be purged and abandoned in place or removed in compliance with the permit requirements. Above ground facilities would be removed and areas filled. Roads would be removed, re-contoured and re-seeded.

The Owner/Operator would need to submit a post injection site care and site closure plan.

At the completion of the Post Closure phase the site would be certified. This certification would establish that the site did not pose a threat to human health or the environment.

The duration of this phase would be subject to rigorous monitoring process, as it is expected that upon completion of this phase and the site was certified, the liability of the site would transfer to the care of a federal or federally sanctioned enterprise that would be responsible for assuming the long term care of the site as well as any ongoing MMV needs.

The recommendations regarding the duration of the Post Closure phase is addressed in the section entitled "**Recommendation for the Duration of the Post-Closure Care Period**"

Long Term Stewardship (or Long Term Care) Phase: This phase would follow site certification that the site no longer posed a hazard to human health or the environment. It is expected that during this phase periodic, but infrequent, MMV would be required. This may include soil measurements, water quality testing (from remaining monitoring wells), pressure tests, seismic studies, and contour mapping.

Appendix C

Summary of Legal Liability Theories

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Summary of Legal Liability Theories

Wyoming Carbon Sequestration Working Group

Lyle Witham

Our sub-group asked that I put together a summary of different kinds of legal liability and their basic elements to use as we discuss different kinds of financial assurance instruments, and what they may or may not cover. To keep this as short as possible, the discussion of basic **black-letter law** will primarily use legal citations only when discussing Wyoming law.

I. Basic Types of Liability

Three categories of legal liability cover most, if not all, potential areas that need to be covered by different forms of financial assurance instruments:

- Tort Liabilities (primarily to third parties);
- Strict Liabilities (these types of liabilities are established primarily by federal or state statute, rule, or permit, and set regulatory criteria, levels, or standards—usually numerical or objective—that must be met by the regulated person or entity subject to the standard); and
- Contractual Liabilities (in this case, the contractual liabilities are embedded in the financial assurance instruments that constitute the different forms and kinds of contracts that will be made available through the implementing statutes and rules).

Financial assurance (FA) instruments for carbon capture and sequestration (or storage) are, essentially, different kinds of contracts that cover either tort liabilities (primarily insurance contracts cover these) or strict liabilities (usually bonds or similar FA contracts cover these).

II. Tort Liabilities

Tort law originally developed under the English common law over several centuries, and is the body of law that addresses, and provides remedies for, **civil** wrongs **not** arising out of contract. Tort liability arises out of a violation of a general standard or duty of care that injures someone or something. Sometimes standards or duties of care are set or defined by law. When the law does not define a specific standard or duty of care, an implied standard of care often applies, which is usually what a reasonable and prudent person would have done under the circumstances (sometimes referred to as the "reasonable man" or "reasonable person" standard).

The common law developed four basic elements that need to be proved by specific factual evidence presented in a case to establish a *prima facie* tort-based cause of action: (1) a **duty** or standard of care owed by a responsible party to the particular person or entity who was injured; (2) a **breach** of that duty; (3) actual **injuries** or damages suffered by the person or entity making the claim; and (4) a showing of **proximate causation** between the injury suffered and the breach of duty.

Three specific kinds of **torts** cover the types of injuries that are most likely to happen to third parties as a result of carbon dioxide sequestration: **negligence, trespass,** and **nuisance.** The legal elements necessary to prove each of these specific types of tort are generally the same as the generic elements of a tort, but there are subtle but important differences.

A. Negligence

The four basic legal elements of **negligence** are:

- duty,
- breach,
- foreseeability, and
- causation.

The obvious difference between the elements of negligence from the generic elements of a tort is **foreseeability**. One of the difficulties for creating an insurance product that would insure long-tail liabilities for carbon sequestration after post-closure is the difficulty of predicting or foreseeing what those liabilities may be over such a long period of time. And because they are not easily foreseeable, it is difficult to apply traditional negligence law to them.

Contributory negligence is a common defense to a negligence claim. At one point, any kind of contributory negligence by the person making a negligence claim would bar that claim. The harshness of this to injured persons resulted in an adoption of **comparative negligence or comparative fault** statutes in most states, under which the negligence of each party is compared, and, in most jurisdictions, the person making the claim is entitled to relief if they are less than 50% responsible (or some other statutorily defined level) for the negligence causing the injury to them, and the parties responsible for the negligence must pay their share of the damages according to their comparative fault under the state comparative negligence statute where the injury occurred (these still vary significantly between states).

Wyoming's negligence law generally follows the common law, which establishes the following elements to a negligence claim:

> (1) The defendant owed the plaintiff a **duty** to conform to a specified standard of care, (2) the defendant **breach**ed the duty of care, (3) the defendant's breach of the duty of care **proximately caused** injury to the plaintiff, and (4) the **injury** sustained by the plaintiff is compensable by money damages.[1]

Although "foreseeability" is technically not an element of negligence in Wyoming, it is included within the proximate causation element. The "ultimate test of proximate cause is *foreseeability of injury*."[2] For carbon sequestration, a major factor that would trigger negligence liability likely will be the foreseeability of damages or injury *at the time it is injected*. If carbon dioxide is injected into an aquifer or other geological formation that is known to be unsound, or known to be leaking, or into a formation before taking reasonable steps to make sure it is geologically sound, then there is a significant chance for establishing the foreseeability of injury aspect of

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[1] *Glenn v. Union Pacific R. Co.*, 176 P.3d 640, 642 (Wyo. 2008).
[2] *Id.* at 644 (italics added).

proximate causation for claims related to injection of carbon dioxide. But if reasonable steps are taken to assure the geological formation is sound—and usually compliance with the relevant regulatory statute will be *prima facie* evidence that it was—then it is unlikely that the foreseeability factor will be able to be demonstrated for carbon sequestration. Such issues of foreseeability and proximate causation are questions of fact "reserved for the trier of fact's determination."[3]

Wyoming's comparative fault statute[4]

> is a "not as great as" form of comparative negligence statute (similar to an "equal to or greater than" form) as distinguished from the "pure" form, under which the plaintiff may recover part of his damages if defendant's negligence is established regardless of the percentage of his own contributory negligence such percentage being used only to determine the amount by which plaintiff's damages are reduced. The Wyoming act does not prevent contributory negligence from being a complete bar to plaintiff's recovery if his contributory negligence is "as great as" defendant's negligence.[5]

Negligence laws, like all other forms of tort law, have historically been matters subject to, and defined and regulated by, state law, rather than federal law. State tort laws tend to track the common law. But when those laws are modified, changes often are derived from a uniform state law (as state comparative negligence statutes were, when the common law contributory negligence standard was modified by statute in most states). And federal statutes have trespassed more and more into these areas traditionally subject to state law (such as tort law) over the past few decades based on "**federal nexus**" grounds when any form of **interstate commerce** is triggered by an activity that arguably makes it subject to federal jurisdiction under the **Commerce Clause** of the federal Constitution. Interstate pipelines transporting carbon dioxide for sequestration will have the federal nexus required to regulate such activities under federal law.

When such broad and sweeping federal statutes are enacted, actual or implied preemption of state law often becomes a confusing and highly litigated issue. States often have to work together when such legislation is proposed to make sure **savings clauses** are included in the legislation that preserve to states their jurisdictional and regulatory authority over areas of traditional state authority such as contract law (which includes insurance and other financial assurance documents), and negligence and other forms of tort law. So, for example, if states want to have financial assurance and other contract issues, or negligence and other tort issues, to be determined in state courts rather than federal courts, and by state regulators rather than federal regulators, then some sort of savings clause may have to be inserted into a broad and sweeping

[3] *Id.*
[4] W.S. § 1-1-109.

[5] *Danculovich v. Brown*, 593 P.2d 187, 192 (Wyo. 1979).

federal statute addressing carbon sequestration to preserve these areas of traditional state authority.

But most likely a federal carbon sequestration statute will follow the federal-environmental-statute template. Such laws generally involve an overarching federal statute, but states are given primacy over programs, subject to federal oversight, when they enact the necessary enabling state statutes and implementing rules and standards, and are approved by the federal agency for primacy over the program in their state. A similar approach is likely to be used for carbon sequestration. But states no longer fight as forcefully for preserving areas of traditional state authority as they did (for example, when the Clean Air Act was passed in stages in the late 60's and early 70's). So the likelihood that such issues will be overlooked or ignored when sweeping federal legislation is enacted is much higher now.

B. Trespass

The tort of **trespass** can involve either a direct physical interference with, or an unlawful or unauthorized physical invasion of, another's property. Trespass requires an act that actually interferes with possessory rights. The elements of trespass to real property are:

- **possession** of the property by the person claiming damages when the trespass was committed;
- an **unauthorized entry** by the responsible party; and
- **damages** resulting from the trespass to the person possessing the property.

To become liable for damages caused by trespass to real property, one must either intentionally enter another's land, or cause a thing or third person to do so, and one must either remain on the land, or fail to remove from the land a thing one has a duty to remove.

When an invasion of property rights results in harm, an essential element of damage is the monetary value of the loss of the use of the land. The measure of damages is the amount that would compensate for this loss of use or occupation. Usually this is either (1) the fair rental value of the land, (2) the reasonable value of the use of the property during the time the owner is deprived of possession, or (3) any diminution in the rental value of the property.

The above elements and determinations are relatively easy to apply to surface and near-surface invasions of property rights that result in damage. But ordinary trespass law is not extended automatically to deep injection zones, especially when it involves an injection regulated by a governmental body. The following sections of a law review article by John G. Sprankling, "Owning the Center of the Earth," 55 UCLA L. Rev. 979, 1016-1021 (2008), summarizes how trespass law is developing and being applied to deep injection wells:

> At common law, a landowner held a virtually absolute right to exclude others from his land. Even today, as the Supreme Court has observed, the right to exclude is "one of the most essential sticks in the bundle of rights that are commonly characterized as property." Consistent with this view, American courts have routinely found a trespass for intentional

physical intrusions in the near-surface zone. Typical examples include building foundations, tree roots, or pipe lines that extend from land owned by A into land owned by B, almost always within one hundred feet of the surface.

This absolutist common law right evolved in cases concerning surface intrusions. Blackstone observed that every person's land was “inclosed and set apart from his neighbor's . . . either by a visible and material fence, as one field is divided from another by a hedge; or, by an ideal, invisible boundary . . . as when one man's land adjoins to another's in the same field.” Thus, Blackstone's fence, whether tangible or imaginary, only spanned the land surface. In this setting, it was perhaps logical to insist on the surface owner's near-absolute right to exclude others in order to maximize the productive use of land.

However, the handful of decisions involving the surface owner's right to exclude in the deep subsurface reveal quite a different pattern. Increasingly, modern courts restrict or ignore this theoretical right, as reflected in a series of cases concerning (a) oil and gas operations; and (b) migrating wastes. Accordingly, as the Ohio Supreme Court explained while rejecting a trespass claim based on events that occurred about 2800 feet deep, it is appropriate to extend the concept “that absolute ownership of air rights is a doctrine which ‘has no place in the modern world,’ to apply as well to ownership of deep subsurface rights.”

a. Oil and Gas Operations

Oil and gas companies routinely inject liquids into the subsurface to enhance oil and gas production, as noted above. Suppose A injects salt water 2000 feet below his land in order to boost oil recovery. When the injected water foreseeably migrates underneath the land surface owned by B, can B sue A in trespass?

Logically, the center of the earth theory should allow B to exclude A's injectate. An actor is liable for trespass if he intentionally “enters land in the possession of the other, or causes a thing . . . to do so,” regardless of whether it causes any harm. In this context, “intent” merely means “knowledge that [an act] will to a substantial certainty result in the entry of the foreign matter.” If A injects salt water knowing that it will eventually enter strata underneath the surface owned by B, this would seem to constitute a trespass.

But a number of decisions refuse to impose trespass liability in this situation, especially where A's action is either authorized by a state agency or located within a unitized production zone. The foundation for these decisions is the public policy encouraging oil and gas production, which outweighs an owner's traditional right to exclude. As the Texas Supreme Court explained in one case, “[t]he orthodox rules and principles applied by the courts as regards surface invasions of land may not be appropriately applied to subsurface invasions as arise out of the secondary recovery of natural resources.” This approach is sometimes characterized as a “negative rule of capture.”

A few decisions have extended this principle even to physical intrusions by drilling equipment. For example, in Nunez v. Wainoco Oil & Gas Co., the plaintiff relied on the center of the earth theory to argue that a trespass occurred when the defendant oil company drilled a bore that first reached his land at a point about two miles below the surface in a unitized oil field. But the Louisiana Supreme Court rejected this claim on the basis that the statutes authorizing unitization superseded the "general concept of ownership of the subsurface by the surface owner of the land."

b. Migrating Wastes

Suppose that A disposes of liquid wastes by injecting them deep beneath her land; over time, the wastes foreseeably migrate into a zone under B's land surface. Although the center of the earth approach should allow B to exclude those wastes—or at least receive compensation for trespass—many courts provide no relief to the surface owner like B.

The leading case is Chance v. BP Chemicals, Inc., in which the defendant chemical company disposed of liquid wastes by injecting them into a sandstone formation about 2800 feet deep. The plaintiffs brought a class action on behalf of over 20,000 surface owners, raising trespass, nuisance, and other claims stemming from the underground migration of the wastes four or five miles in each direction. On appeal following a defense verdict, the plaintiffs argued that "[t]he owner of land has absolute ownership of all the subsurface property," relying on the familiar *ad inferos* maxim. But the court flatly rejected this absolutist claim, noting that "ownership rights in today's world are not so clear-cut as they were before the advent of airplanes and injection wells." Rather, analogizing to the airplane cases that restricted the *ad coelum* doctrine, it reasoned that "there are also limitations on property owners' subsurface rights." Accordingly, the court held that the plaintiffs could only "exclude invasions of the subsurface property that actually interfere with [their] reasonable and foreseeable use of the subsurface." Under this standard, the mere presence of the injectate within the plaintiffs' subsurface was not sufficient damage to sustain their trespass claim.

The Chance standard largely eviscerates a surface owner's right to exclude subsurface wastes. First, only those surface owners who are actively using the subsurface for a specific "reasonable and foreseeable" purpose are able to bring suit--a small minority. As between the idle owner of the subsurface, on the one hand, and an active intruder who devotes that subsurface to productive use, this approach favors the intruder. Second, even the rare surface owner who is actively using the subsurface has the burden of proving that the intruder has "actually interfered" with his use. Due to the complexity of subsurface geology, it will be extraordinarily difficult for any owner to make this factual showing. Chance itself demonstrates the problem: Even though plaintiffs presented expert testimony by a hydrogeologist, the court dismissed this evidence as "simply too speculative." Ultimately, Chance reflects a judicial mindset that views ownership rights in the deep subsurface as meaningless.

(Footnotes omitted.)

Wyoming's enactment of W.S. § 34-1-152 defining ownership of the pore space in the subsurface, however, will make an action for trespass for migrating carbon dioxide in the deep subsurface more likely to be successful in Wyoming than in the cases summarized by Sprankling in his article above. Those damages likely will primarily be the rental or lease value of the pore space, at least in cases where the carbon dioxide stays in the geological formation into which it was injected and it doesn't otherwise affect the surface owner. A value likely can be assigned to this occupation on a *pro rata* basis in the same way that oil and gas payments are allocated in a unitized field.

C. Nuisance

Unlike most other torts, nuisance does not focus on the nature of the conduct causing the damage, but rather on the nature and relative importance of the interests interfered with or invaded. In Wyoming, **nuisance** is defined as "a class of wrongs which arise from an unreasonable, unwarranted, or unlawful use by a person of his own property, working an obstruction or injury to the right of another."[6]

The awarding of damages for nuisance is generally limited to the following:

> A possessor of land is subject to liability for physical harm to others outside of the land caused by an activity carried on by him thereon which he realizes or should realize will involve an unreasonable risk of physical harm to them under the same conditions as though the activity were carried on at a neutral place.[7]

III. Strict Liabilities

Almost all civil environmental standards are **strict liability** laws that are defined by statute or rule, rather than by the common law. A distinguishing feature of criminal law that is not present in civil law, in general, or on the civil side of environmental law, in particular, is an assignment of moral culpability that requires an element of intent, or *mens rea*, before criminal sanctions may be imposed.

> There are several inconsistencies between environmental and criminal law … One inconsistency is that environmental standards, unlike traditional crimes, present questions of degree rather than type. Also, environmental laws are constantly evolving with technical advances, while criminal laws are fixed. However, most of the debate focuses on the fact that environmental law emphasizes actions and results, unlike criminal law, which focuses on the defendant's morally culpable mental state. This is because environmental laws are precautionary. Rather than relying on actual damage, they do not require culpability in a traditional sense.[8]

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[6] *Brown v. Johnston*, 85 P.3d 422, 430 (Wyo. 2004).
[7] *Ortega v. Flaim*, 902 P.2d 199, 205 (Wyo. 1995).
[8] Margaret Shaw, "Criminal Enforcement of Environmental Laws: Relevancy of the Public Welfare Doctrine in Determining Culpability," 27 New Eng. J. on Crim. & Civ. Confinement 337, 341 (2001).

The difference between civil environmental laws and criminal environmental laws is that most civil environmental laws are strict liability laws that require no proof of intent, whereas, in contrast, no criminal federal environmental statute imposes criminal liability absent proof of a particular state of mind.

Likewise, a distinguishing feature of tort law that is not present in strict liability laws, in general, or on the civil side of environmental law, in particular, is an assignment of a duty or care that must be violated before tort liability may be assigned.

Strict liability laws thus may be distinguished from criminal and tort laws because they do not include either an element of intent or an element of duty. A speed limit is an example of a strict liability law: no showing of *mens rea* or negligence needs to be established; only a showing that the vehicle was exceeding the established limit. Most environmental standards—whether established by statute, rule, or permit—are strict liability speed-limit-like restrictions that can be numerically or objectively measured for compliance.

And financial assurance mechanisms, other than insurance, are more typically applied to strict liability type laws where the standards to which the bond or other financial assurance mechanism is applied can be numerically or objectively measured for compliance. To make such financial assurance mechanisms affordable, those standards have to be reasonable, defined, and capable of being released when the conditions defined by the financial assurance contract have been satisfied.

IV. Contractual Liabilities

For a prima facie contract-based cause of action, a plaintiff must show the existence of four elements:

(1) the existence of a **contractual relationship**;

(2) **performance** by the plaintiff;

(3) **breach** of the contract by the defendant; and

(4) **damages** to the plaintiff as a result of the breach.

These are the four basic elements of a typical financial assurance contract such as a bond. A primary difference between bonds and generic contracts are that bonds carefully define and limit each of these elements to include, for example, a strict limit to the amount of the bond and to whom it is paid when the triggering event occurs.

Financial assurance contracts often give a governmental regulatory body the means to pay for corrective or remedial actions when a regulated person or entity fails both (1) to comply with a regulatory standard and (2) to comply with an informal or formal order or other enforcement mechanism issued by a regulatory body or agency requiring compliance and corrective action, or for other reason is unable to perform its responsibilities under the law.

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Appendix D

Carbon Sequestration Working Group Charter

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Carbon Sequestration Working Group

<u>Background:</u> HB 90 Section 1 amended the Environmental Quality Act (EQA) to provide for the regulation of carbon sequestration by the DEQ and the OGCC. A new section of the EQA, 35-11-313 (g) states: "…the state geologist, oil and gas supervisor and the director shall convene a working group for the purpose of developing an appropriate bonding procedure and other financial assurance methods to assure adequate financial resources are provided to pay for any mitigation or reclamation costs that the state may incur as a result of default by the permit holder. The bond or other financial assurance requirement shall be required during the operating life… and throughout the post-closure care period…."

Charter

Purpose: To review available technical, geological, financial, and risk management factors associated with the geologic sequestration of carbon dioxide so that an appropriate and effective bonding and financial assurance system can be recommended to the legislature.

Process:

- The working group will consist of approximately 10 members with experience and knowledge that bears on the work needed to develop the recommendation. Professions that should be represented include legal, geological, oil & gas, environmental, engineering, and financial. The group will also have representation from industry and the landowner community.
- Meetings will be open to the public, with ample time provided to receive their input and comment.
- The working group will take a phased approach to its work. The first phase will be data and information gathering. The second phase will be an idea generation and evaluation stage. The final phase will be the development of recommendations.
- Experts in the various aspects of carbon sequestration will be invited to share knowledge and perspective.
- A resource person will be retained to assist the working group in communications, meeting arrangements, and such other detail s as necessary for the group to be efficient in the use of its time.

Products:

- Identification and characterization of the environmental and other risks associated with the various phases of a carbon sequestration project.
- Identification of the reclamation, mitigation, and potential remediation requirements associated with these risks.
- Identification of other sources of liability.
- Assessment of alternatives that provide the state protection in the event of operator default.
- Review of availability of short and long term financial assurance vehicles and methods through which adequate financial resources are available throughout the project operating life, its closure and post closure care period and for an adequate period of time thereafter.
- A report will be developed and presented to the joint minerals, business and economic development and the joint judiciary committees no later than September 30, 2009. This report may include a suggested framework for legislation.

Working Group Members:

- Ron Surdam, State geologist
- Don Likwartz, State Oil and Gas Supervisor
- John Corra, Director of the DEQ
- Mark Northam, Director of the School of Energy at UW
- Ralph Brokaw, President, Wyoming Association of Conservation Districts
- Nancy Freudenthal, Attorney
- Ian Andrews, Pacificorp
- Lyle Witham, Basin Electric
- Ken Hendricks, Anadarko Petroleum
- Bob Green, Rio Tinto Energy
- Kevin Frederick, Wyoming Department of Environmental Quality

Dan Clark, DEQ Outreach Coordinator will act as a resource for our group.

Broad Action Plan

1. First Meeting:
    - Introductions and Review of Charter (see attached)
    - Discuss and agree on a work process, make assignments for future work
    - Review of legislation
    - Technical overviews; UIC programs, Geologic Sequestration, Technical aspects of carbon capture and storage
    - Broad discussion of the unique nature of CO_2 sequestration
2. Second Meeting:
    - Field Trip to Anadarko's Salt Creek field
    - Review of pertinent existing statutes and regulations (I.e. RCRA, CERCLA, Price-Anderson Act, various State of Wyoming bonding programs, etc.)
    - Bonding and financial assurance issues in the mining industry
3. Third Meeting:
    - Hear from the financial community (I.e. insurance companies who sell bonds, other financial interests who can speak to how they value risk and how they view the challenge of financial assurance for long term CO_2 storage)
    - Hear from the utilities and landowners about their concerns
    - Overview of legal issues as they pertain to the challenge
    - Hear from U.S. EPA on progress toward rule making.
    - Working group to decide on what additional information they need and map out the remainder of our work.
4. Fourth Meeting:
    - Brainstorm possibilities and develop recommendations.

Appendix E

Summary of Presentations

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Reference Materials

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Presentations to the Wyoming Carbon Sequestration Working Group

Carbon Capture and Storage – Lyle Witham, Basin Electric Power Cooperative

Key questions, needs and activities required to enable a mature carbon capture and storage system from the perspective of a company who has recently gone through technical and economic analysis of various clean coal technologies and with experience in coal gasification and enhanced oil recovery.

CO_2 Capture – Power generation – Ian Andrews, PacifiCorp

Discussion and illustration of the importance of coal to overall energy mix nation-wide and a technical review of available processes for carbon capture. Information about relative costs and challenges associated with both retrofitting exiting plants and with building new plants and a forecast of the time frame necessary to take these technologies to wide spread use was presented.

Geological CO_2 Sequestration – The Key to Economic Survival in a Carbon Constrained World – Ron Surdam, Wyoming State Geologist

A review of target formations in Wyoming for sequestration and enhanced oil recovery. Details were provided on the Rock Springs uplift and why it is an ideal location due to structural features and capacity. Details on work being conducted on modeling and geophysical characterizations that will enable good sequestration site selection were also reviewed.

Status of CO_2 Flooding and Future Options - Don Likwartz, Wyoming Oil & Gas Supervisor

An overview was presented of enhanced oil recovery operations in the U.S., existing pipeline systems, and the potential for new oil production using carbon dioxide. The presentation also contained a discussion of the potential for industry and government to cooperate and utilize experience to date as a bridge to developing optimal sequestration programs.

Underground Injection Control – Kevin Frederick, Manager DEQ Groundwater Section

Overview of the groundwater protection program and the regulatory details of the UIC program. Discussion of challenges and requirements of carbon sequestration and how these compare to existing injection programs.

UIC Financial Responsibility Requirements – Robert F. Van Voorhees, Bryan Cave

Summary of financial responsibility requirements of existing federal programs and an assessment of EPA's proposed rules that deal with financial responsibility for carbon sequestration.

Price Anderson Act – Dan Clark, WY DEQ Staff

Overview of the Nuclear Industries Indemnity Act of 1957 and subsequent amendments highlighting funding mechanism, claims procedures, constitutional/legal challenges and claims history.

RCRA and CERCLA Financial Assurance – Daniela Golden, EPA Region 8

Overview of EPA financial assurance programs currently in place for the Resource Conservation and Recovery Act and the Comprehensive Environmental Response, Compensation and Liability Act. Included information on the full range of financial assurance instruments available for these programs, including pros/cons of each.

Bonding and Financial Assurance for Coal Mining – Bob Green, Rio Tinto Energy

Overview of surface coal mining operations and financial assurance principles applied to this industry. Explanation of various bonding aspects and performance bond components including closure and post closure contingencies. Included information on CCS financial assurance considerations.

Carbon Capture and Sequestration: A Financial and Risk Management Perspective – Laura Ladd – Principal, Hewitt Ladd Inc.

Information on the financial market's perspective on carbon capture and sequestration. Major theme presented was that CCS is not an attractive investment opportunity in today's market. With current level of market uncertainty and lack of understanding of long term CCS risk, significant government support and incentives will be needed to move CCS technology forward.

Entrepreneurial Ideas & an EU Perspective on CCS – John Villar, Energy Consultant

Information presented on two potential business models to work in the CCS arena. Analysis of these models was that the field is too immature at this time to be a viable business opportunity. The European Union perspective presented was that climate change is underway and will be difficult to mitigate. However, cost of inaction would be even worse. CCS is one mitigation tool with the potential to help solve this problem. To be successful, economic incentives, a regulatory framework, improved monitoring technology and supporting human resources must be put in place.

Financial Assurance Mechanisms and CCS – Fred Eames, Hunton and Williams

Information from the Carbon Capture and Sequestration Alliance on their initiatives to develop a coordinated policy and regulatory regime at state and federal level to encourage CCS development. Good information on risk assessment from the perspective of power generation utilities and other large CO_2 emission sources.

Clean Hydrogen Power Generation With Geological Sequestration – Malcolm Anderson, Southern California Edison

Information provided on Southern California Edison's initiative to develop a clean hydrogen (integrated gasification combined cycle) power plant with carbon capture and sequestration to meet new California statutory requirement to limit green house gas emissions from power plants to not more than 1,100 lbs of CO_2/MW-Hr. Plans are already well underway to build and operate this plant somewhere in the western U.S. Additional information included on risk assessment and financial assurance issues.

Liability Risk Management Framework Options CCS – Lindene Patton, Zurich Financial Services

An overview of the risks of CS seen from the perspective of the financial services sector; non-performance, under performance, liability, property damage, ecological/natural resource damage, endangered species issues and moral hazard. Posed a management framework for CS financial assurance tailored to the phases of CS projects.

Brokers Perspective – Rick Hawkinberry, Willis Environmental Practice

Discussed the role and function of surety/insurance brokers. Stressed that CS is a very new area with little if any precedent or working business model. Explained the need for additional information such as details of projected CO_2 streams and the geology of proposed sequestration sites to make the risk of insurance acceptable to prospective investors. Advocated flexibility in developing insurance instruments for this application.

CO_2 Sequestration in Saline Reservoirs – Dwight Peters, Schlumberger Carbon Services

Outlined details of CO_2 injection based on global corporate experience with related projects such as natural gas storage, enhanced oil recovery and waste acid gas injection. Identified projected commercial scale storage timelines, the use of modeling to manage risk and a slate of data/resources needed for project implementation. Showed proposed/ongoing demonstration projects which are key to refining risk projections.

Mountain West Regional Initiative to Advance CCS – Rick Adcock, CAMCO Global

Interested in development and harmonization of regional CCS policy support mechanisms. Identifying stakeholders, supporting research and sharing information. Currently engaged in discussions on CO_2 pipelines, property law, liability and carbon credit markets.

ECO_2 Technology – Basin Electric Power Cooperative's 120 MWe Demonstration – Frank Alix, Powerspan Corp

Provided information on Powerspan's post combustion CO_2 capture technology. Compared efficiency of various technologies and outlined progress on their pilot project in conjunction with Basin Electric. Showed CO_2 pipeline layout for ongoing enhanced oil recovery project and cost basis for CO_2 capture.

Simulation and Risk Summary – Brian McPherson, Southwest Regional Partnership on Carbon Sequestration

Discussed risk evaluation methodology including identifying potential risk pathways and risk features, events and processes. Identified risk ranges during different phases of sequestration activities. Stressed the importance of quantitative risk assessments and the iterative nature of risk assessment based on monitoring and updating models with new information as it becomes available.

Notes for Presentation to the Carbon Sequestration Working Group (Wyoming CO_2 Pipelines) – Brian Jeffries, Wyoming Pipeline Authority

Provided a notional layout for a CO_2 pipeline system for the state of Wyoming. Presented the information as notional, not based on extensive research into either potential sources of CO_2 or projected optimal areas for long term CS. Identified design issues to consider for a long term CO_2 pipeline system – location of sources and sinks, quality requirements, pressure requirements, determining compression responsibility and incremental treating. Projected most likely areas of sources and reservoirs.

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Appendix F

Draft Statute

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35-11-313. Carbon sequestration; permit requirements.

(f) The administrator of the water quality division of the department of environmental quality, after receiving public comment and after consultation with the state geologist and the advisory board created under this act, shall recommend to the director rules, regulations and standards for:

(ii) Requirements for the content of applications for geologic sequestration permits. Such applications shall include:

(N) A certificate issued by an insurance company authorized to do business in the United States certifying that the applicant has a public liability insurance policy in force for the geologic sequestration operations for which this permit is sought, or evidence that the applicant has satisfied other state or federal self-insurance requirements. This policy shall provide for personal injury and property damage protection in an amount and for a duration as established by regulations;

~~(N)~~ (O)Proof of notice to surface owners, mineral claimants, mineral owners, lessees and other owners of record of subsurface interests as to the contents of such notice. Notice requirements shall at a minimum require:

(v) Requirements for bonding and financial assurance for geologic sequestration facilities and geologic sequestration sites including:

(A) Procedures to establish the type and amount of the bond or financial assurance instrument to assure that the operator faithfully performs all requirements of this act, complies with all rules and regulations, and provides adequate financial resources to pay for mitigation or reclamation costs that the state may incur as a result of default by the permit holder, provided that, any insurance instruments submitted for financial assurance purposes shall include the state of Wyoming as an additional insured, which inclusion shall not be deemed a waiver of sovereign immunity;

(B) Annual or other periodic reporting by the permittee during geologic sequestration and reclamation activities to allow the administrator to confirm or adjust the amount of the bond or other financial assurance requirements considering the site, facility, and operation-specific risks and conditions;

(C) Procedures to show proof of bond or financial assurance after notice by the administrator of the determination of any adjusted bond or financial assurance amount, including permit suspension or termination procedures following notice and an opportunity for a hearing if adequate bonding or financial assurance cannot be demonstrated;

(D) Procedures for replacement of a bond or financial assurance instrument should notice of cancellation be provided or notice that the license to do business in Wyoming of the surety or insurance company issuing a bond or other financial assurance pursuant to this act is suspended or revoked;

(E) Procedures for the director to forfeit the bond or to make a claim against any insurance instrument provided for financial assurance, including the right of the attorney general to bring suit to recover costs if bond or financial assurance is inadequate to pay for closure, mitigation, reclamation, measurement, monitoring, verification and pollution control, where recovery is deemed possible;

(F) Procedures, including public notice and a public hearing if requested, for the release of bonds or the termination of insurance instruments no less than ten (10) years after the date when all wells excluding monitoring wells have been appropriately plugged and abandoned, all subsurface operations and activities have ceased, and all surface equipment and improvements have been removed or appropriately abandoned, or so long thereafter as necessary to obtain a completion and release certificate from the administrator certifying that plume stabilization as defined by rule has been achieved without the use of control equipment based on a minimum of three consecutive years of monitoring data, and that the operator has completed site reclamation and all required monitoring and remediation to ensure that the carbon dioxide injected into the geologic sequestration site will not harm or present a risk to human health, safety, and the environment, including drinking water supplies, consistent with the purposes of this act and the rules and regulations adopted by the council;

(G) Requirements for the operator to record an affidavit pursuant to W.S. 34-11-101 in the office of the county clerk of the county or counties in which a geologic sequestration site is located, which affidavit shall be reasonably calculated to alert a person researching the title of a particular tract that such tract is underlain by a site used for geologic sequestration; and

(vi) Requirements for fees to be paid by all permittees of geologic sequestration sites or facilities, which may include a per-ton injection fee or a closure fee, commensurate with the injection of carbon dioxide and associated constituents into subsurface geologic formations in Wyoming, which fees shall be deposited in the Geologic Sequestration Special Revenue Account created by W.S. 35-11-318 for use as provided therein;

(v)(vii) Such other conditions and requirements as necessary to carry out this section.

(g) As soon as practical and prior to September 30, 2009, the state oil and gas supervisor, the state geologist and the director shall convene a working group for the purpose of developing an appropriate bonding procedure and other financial assurance methods to assure that adequate financial resources are provided to pay for any mitigation or reclamation costs that the state may incur as a result of default by the permit holder. The bond or other financial assurance shall be required during the

~~operating life of the sequestration project and throughout the post-closure care period in order to abate or remedy any violation of a permit, standard or rule established under the provisions of this act. The working group shall recommend to the joint minerals, business and economic development and joint judiciary interim committees, on or before September 30, 2009, the duration of the post-closure care period. At a minimum, the bond or other financial assurance shall provide assurance for closure and reclamation costs, post-closure inspection and maintenance costs and environmental monitoring, verification and control costs.~~

35-11-318. Geologic Sequestration Special Revenue Account.

(a) There is created an account in the special revenue fund for use by the director for measurement, monitoring and verification of geologic sequestration sites following site closure certification, release of all financial assurance instruments, and termination of the permit. Fees collected by the department shall be credited to this account, which are appropriated to be expended by the director under this section.

(b) The existence, management and expenditures from this account shall not constitute a waiver of the state of Wyoming from its immunity from suit, nor does it constitute an assumption of any liability for geologic sequestration sites or the carbon dioxide and associated constituents injected into such sites.

(c) As a special revenue account, the funds in the geologic sequestration special revenue account do not revert and are continuously appropriated.

Appendix G

Trust Fund Concept

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Trust Fund Concept

for Post-Closure and Long-term Stewardship Phases

One of the major concerns deterring commercial-scale development of carbon sequestration facilities has been the issue of long-term liability, especially during the Long-term Stewardship Phase (or at least until such time the scientific and regulatory community concludes that sequestered carbon dioxide is stabilized). It has been noted that insurance and other traditional financial assurance (FA) vehicles for the Post-closure and/or Long-term Stewardship Phases of a geologic sequestration project may be unavailable, cost prohibitive or limited in scope. These conditions present a barrier to commercial-scale deployment of geologic sequestration.

One alternative to address this issue would be to establish a trust fund to provide the financial resources that may be needed to deal with unexpected problems and for which there may not be a responsible party or FA mechanism in place. The purpose of the fund would be to provide the necessary financial resources to minimize financial risks to the entity (state, federal, private) that may be responsible for a carbon sequestration site during the Post-closure and Long-term Stewardship Phases of the project. This concept is introduced below. Discussion of the proposed funding levels, the governance structure and Fund administration is beyond the scope of this concept paper but these issues would need to be addressed prior to creation of a Trust Fund.

Funding Source

Funding for the trust would be created through tipping fees paid by each geologic sequestration operator/injector in the State during the operational phase of each project. Tipping fees are used in other material disposal arenas and generally represent charges that are calculated on a per ton or per cubic yard of material placed into disposal. The tipping fee structure (rate and unit) would need to be established by a fund administrator.

Funding Use

Funds would be reserved for remediation needs not covered by other FA instruments during the Post-closure and Long-term Stewardship Phases of a sequestration project. Through a structure of tiered pools, detailed below, assets of the fund could also be used to pay for insurance coverage on a project-specific basis, primarily in cases where the operator goes into default.

A portion of this fund, subject to specific caps, could also be made available to address significant events during other phases of a sequestration project. In this instance, the fund may be used to reduce or partially offset FA obligations during the Post-closure phase in the event that other FA instruments, including insurance, are unavailable or inadequate to cover financial assurance requirements.

Relation to other FA Mechanisms

During the Post-closure Phase, FA from the permittee/injector as required by the regulator, and not the Trust Fund, would be expected to cover all regulatory requirements and costs associated with site inspection, maintenance and any related site stabilization or mitigation.

During the Long-term Stewardship Phase, a Special Revenue Account is expected to apply. That account is expected to cover a limited scope of measurement, monitoring and verification activities during this phase.

Relation to Federal Trust Fund

There is a concern that some risk events however unlikely, may occur during the Post-closure and/or Long-term Stewardship phases and that there will not be adequate FA in place to address those potential risks. Progress toward commercial geologic sequestration will likely stall unless some form of entity or mechanism is created to address these risks. To date, the position has been that some form of federal or federal/state/industry funding mechanism will be required to deal with this risk. Except in very limited circumstances, individual states by and large have not been willing to accept this risk. Industrial companies have also not been willing to accept this risk, possessing neither the capacity nor demonstrated long term viability to do so. A Federal Trust Fund mechanism similar to the Price-Anderson Act to provide both indemnification and mitigation for nuclear events for the nuclear industry is contemplated as a template. If implemented, this fund would likely need to be established as an independent entity with a structure allowing it to be administered by the State consistent with the Funds Consolidation Act.

This fund would not be established and/or implemented prior to establishment of a comprehensive federal legal framework that satisfactorily addresses specific liabilities and responsibilities for sequestered carbon dioxide during the Long-term Stewardship phase. However, it is recommended that enabling legislation be considered to form a preparatory framework for implementing such a fund immediately upon the existence of a satisfactory federal program. That will allow the state to have a complementary program in readiness. While federal determinations on such a framework are in a state of flux, there are several vehicles within the 111th Congress (e.g., HR 2454 in the House and S.B. 1502 in the Senate) that would move toward creation of a federal program or establishment of a program under the Department of Energy with federal liability assumption during the Long-term Stewardship Phase.

Funding Pools

The fund would consist of three distinct components. The level of funding would be tiered to provide sequential funding resources as necessary to meet the specific risk. Pool #1 would be utilized first until exhausted, followed by Pool #2, and lastly Pool #3. Potential risks and related example costs of mitigation are summarized beginning on Page 52 of the Report – those are simply example costs but provide a reference for considerations of ceiling limits discussed below. References to pre-funding reflect the concept of paying tipping fees into the fund in proportion to the sequestered material throughout the operation:

- Pool #1: Pre-funding on a project level to provide for project-specific coverage to a set maximum ceiling to cover costs (over and above specific FA requirements for specifically identified activities, such as those required for measurement, monitoring and verification). This would be pre-funded by the permittee/injector, and would be dedicated for use only on the permittee/injector's project. The amount of funds under this pool would be limited to the total amount available and once exhausted would not be renewed; this essentially represents a form of pre-funded deductible self-insurance by the project permittee/injector.

- Pool #2: Pre-funding on a state level to provide for the next maximum increment ceiling level to cover additional funding requirements and to the extent the funds available from Pool #1 have been exhausted. The funding for this Pool would be pre-funded by all permittees/injectors of state sequestration sites on a per ton basis. The amount of funds under this pool would be limited to the total amount available on a per event basis; once exhausted, the Pool would be renewed by existing operational sequestration sites in the state. The maximum ceiling of funds in the pool would be established by a fund administrator.

- Pool #3: Access to a Federal program with state administration. The Federal program would provide funding for the full remaining extent of specific program costs, except in cases of gross negligence and/or misconduct, once the applicable amounts of Pools #1 and #2 have been exhausted. State access and administration of these funds is the preferred model inasmuch as it is expected that state administration would be more efficient and timely. Furthermore, state entities would ultimately be the "first on the scene" and would be the final responsible entities to address any funding requirements.

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Appendix H

Risk/Activity Matrix

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Insert Risk Activity Matrix Excel File

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Appendix I

Bond Adjustment Matrix

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Bond Adjustment Matrix

Calculated Project Risk Factor ranges would be used to determine a bond multiplication factor. This method incorporates both an event factor (assigned for any CCS project) and a site specific risk factor.

Example:

Project Risk Factor:	0-10% - Multiplication factor = 1.0
	11-20% - Multiplication factor = 1.10
	21-30% - Multiplication factor = 1.25

This factor would be used in conjunction with an adjustment for a company's credit rating (or other measure of financial strength) to determine required bonding levels.

Event Factor	High = 5
	Medium = 3
	Low = 1

Risk Factor	High = 1
	Medium = 0.5
	None = 0

1	Mineral Rights impacted			**6.62**
	Spatial Area of Interest (plume migrates larger/faster than modeled)	4	0.3	
	Leakage migrates (OR IMPACTS) recoverable mineral zone	5	0.6	
	Post injection discovery of recoverable minerals	3	0.4	
	New technology enables recovery of previously unrecoverable reserves	3	0.4	
	Acts of God affecting access to mineral rights	2	0.01	
2	Water Quality contamination			**3.43**
	Spatial Area of Interest (plume migrates larger/faster than modeled)	4	0.3	
	Leakage of CO2 contaminates potable water aquifer	5	0.15	
	Leakage of drilling fluid contaminates potable water aquifer	3	0.35	
	Rock/water (Geochemistry) interaction contaminates potable water	4	0.1	
	Acts of God affecting sub-surface water quality	3	0.01	
3	Catastrophic Release to the Surface - Asphyxiation/Health/Ecological			**6.58**
	Overpressurization (induced)	5	0.5	
	Caprock/reservoir fracture	5	0.6	
	Mechanical failure of piping or tankage above or below ground	3	0.25	
	Sabotage/Terrorist attack (on surface infrastructure)	3	0.1	
	Acts of God causing major CO2 release	3	0.01	
4	Leakage to the Surface - Ecological damage (climate change, flora/fauna) due to chronic low-level releases			**11.58**
	Seal Failure (drilling or injection equipment)	3	0.35	

	Mechanical failure of piping or tankage above or below ground	3	0.25	
	Monitoring well leakage	3	0.3	
	Well blowout (at surface or bore failure below ground)	4	0.3	
	Orphan Wells (not discovered prior to injection)	3	0.5	
	Caprock/reservoir fracture (Plume migrates along fault line/fissure to surface)	5	0.4	
	Overpressurization (induced)	5	0.5	
	Incomplete geological seal (inaccurate characterization of sub-surface geology)	4	0.3	
	Natural or induced seismicity leading to leakage	3	0.15	
	Acts of God causing chronic low-level release	3	0.01	
5	Storage rights infringement (CO2 or other gases)			**4.72**
	Spatial Area of Interest (plume migrates larger/faster than modeled)	4	0.3	
	Leakage migrates into adjacent pore space	4	0.3	
	Post injection decision to store gas in adjacent pore space	3	0.5	
	New technology makes storage of gas in adjacent pore space desirable	2	0.4	
	Acts of God affecting storage capacity of pore space	2	0.01	
6	Modified Surface Topography (subsidence or uplift resulting in Property/Infrastructure Damage)			**2.1**
	Pressure or geochemistry induced reactivation of historic fault	4	0.25	
	Modified surface topography (subsidence or uplift events)	4	0.2	

	Induced Seismicity	3	0.1	
7	Contaminant Releases			**3.85**
	Change in CO2 composition/properties (purity issue) [injected versus chemical reactions post-injection??]	4	0.45	
	Microbial activity initiated by injection process or composition	4	0.4	
	Other contaminants in injected gas or released by geochemical action in situ	3	0.15	
8	Accidents/unplanned events (Typical Process Liabilities)			**3.2**
	Surface infrastructure damage resulting in leakage	3	0.4	
	Liquid releases from surface storage impoundment	4	0.5	

Project Risk Factor **31.17%**

Appendix J

Cost Justification Background Data

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Insert 3 Cost Justification Matrix Excel Files

Print on 11 X 17 and Fold to 8 ½ X 11

POST-CLOSURE MONITORING

MONITORING FREQUENCIES DURING POST-CLOSURE

Monitoring	Years	# over 15 years
Geophysical - midpoint Year 37	37	**1**
Remote sensing - Assume every two years through year 44	32, 34, 36, 38, 40, 42, 44	**8**
Air, soil, gas monitoring - Assume listed frequencies conducted every two years through year 44	32, 34, 36, 38, 40, 42, 44	**8**
Water/brine monitoring - Assume listed frequencies conducted every two years through year 44	32, 34, 36, 38, 40, 42, 44	**8**

Assume 1 M - 4M tons CO2e per year for 30 years (4M tpy is projected level of Alberta Saline Aquifer Project)

WSGS modeling indicates a plume area factor of 0.133 mi2/Mtons CO2 (15Mtpy, 50 yrs; 750M tons total; 100 mi2 plume area) NETL suggests a plume area factor of 0.75 mi2/Mtons CO2 (1 Mtpy for 20 years; 20M tons total; 15 mi2 plume area) The NETL figure appears to be too conservative to apply to a larger project, so a figure of 0.15 mi2/MtonsCO2 has been applied here

Assume an additional 25% area for the hydrologic front, with monitoring of the front principally addressed by remote sensing and subsurface pressure monitoring

Equipment costs: It is assumed that equipment replacements are required on a 50-year cycle and that in general the original equipment for the operating phase remains in place and functional through the end of the 15-year monitoring period, 45 years after installation for the operating phase; an equipment replacement factor of 5% to 10% of total monitoring cost for the 15-year period, depending on size of operation, has been included in the total cost figures below.

Cost over 15 years of monitoring services, at frequencies listed above

Category subtotals for 15-year block (services + pro-rated costs of equipment replacement)

Remote Sensing

InSAR Avg $7,500 per square mile Annually

Plume		Cost over 15 years	Remote Sensing
If 1M tpy for 30 years, 30M tons CO2 total ~ 4.5 mi2 + 10% monitored buffer	37,125	259,875	317,625
If 2M tpy for 30 years, 60M tCO2 total ~9 mi2 + 10% monitored buffer	**74,250**	**519,750**	**637,875**
If 4M tpy for 30 years, 120M tons CO2 total ~ 18 mi2 + 10% monitored buffer	148,500	1,039,500	1,275,750
Hydrologic Front			
For 1 tpy, assume additional 1.1 mi2	8,250	57,750	
For 2 tpy, assume additional 2.25 mi2	**16,875**	**118,125**	
For 4 tpy, assume additional 4.5 mi2	33,750	236,250	

Air, soil gas tracers

						Air, soil gas monitoring
						2,343,600
Gas meter w/alarm						**4,687,200**
	Continuous	If 4.5 mi2 area then assume 18 meters				9,374,400
		If 9 mi2 area then assume 36 meters				
		If 18 mi2 area then assume 72 meters				
Eddy covariance monitors						
	Continuous	If 4.5 mi2 area then assume 18 monitors				
		If 9 mi2 area then assume 36 monitors				
		If 18 mi2 area then assume 72 monitors				
Soil CO2 monitors						
		If 4.5 mi2 area then assume 18 monitors				
		If 9 mi2 area then assume 36 monitors				
		If 18 mi2 area then assume 72 monitors				
Tracer monitors						
		If 4.5 mi2 area then assume 18 monitors				
		If 9 mi2 area then assume 36 monitors				
		If 18 mi2 area then assume 72 monitors				
Soil CO2 survey costs			Cost of each	1500		
	Monthly	If 4.5 mi2 area then assume 18 samples per month		324,000	2,268,000	

		If 9 mi2 area then assume 36 samples per month		**648,000**	**4,536,000**		
		If 18 mi2 area then assume 72 samples per month		1,296,000	9,072,000		
Isotope-atmosphere soil analyses			Cost of each	150			
	Quarterly	If 4.5 mi2 area then assume 18 samples per quarter		10,800	75,600		
		If 9 mi2 area then assume 36 samples per quarter		**21,600**	**151,200**		
		If 18 mi2 area then assume 72 samples per quarter		43,200	302,400		
Water/brine sampling	Weekly		Cost of each	60			**Water, brine sampling**
		If 4.5 mi2 area then assume 18 samples per week		56,160	393,120		393,120
		If 9 mi2 area then assume 36 samples per week		**112,320**	**786,240**		**786,240**
		If 18 mi2 area then assume 72 samples per week		224,640	1,572,480		1,572,480

Subsurface & wellhead pressure monitoring

Included in equipment replacement factor below

Subsurface & wellhead pressure monitoring

Included in equipment replacement factor below

Geophysics

						Geophysics
3D Seismic	Avg $70,000 per sq mi					1,386,000
	Quarterly	If 4.5 mi2 area + 10% monitored buffer	1,386,000	1,386,000		**2,772,000**
		If 9 mi2 area + 10% monitored buffer	**2,772,000**	**2,772,000**		5,544,000
		If 18 mi2 area + 10% monitored buffer	5,544,000	5,544,000		

	SUBTOTAL - MONITORING SERVICES	Subtotal with equipment replacement factor	TOTAL
TOTALS AND SUBTOTALS FOR 4.5 MI^2 AREA	4,440,345	4662362	4,662,362
TOTALS AND SUBTOTALS FOR 9 MI^2 AREA	**8,883,315**	**9505147**	**9,505,147**
TOTALS AND SUBTOTALS FOR 18 MI^2 AREA	17,766,630	19543293	19,543,293

WY State Geological Survey modeling of Wyoming-specific information for larger project scopes suggests a plume area factor of 0.133 mi2/Mtons CO2 (see detailed block above)

Alberta Saline Aquifer Project
A major Canadian initiative called the Alberta Saline Aquifer Project (ASAP) [12] is a consortium of 34 companies that are developing a pilot site for commercial scale carbon capture and storage in a saline aquifer. The initial pilot will sequester 1,000 tonnes per day in 2010, while the commercial phase could see 10,000 tonnes per day as soon as 2015.

Sandia Costs for a Bruel and Kjaer gas analyzer, Campbell Scientific CR-7 datalogger, pressure and temperature measurement devices, and a pressure scanning package for moniotring vadose zone (0 to 16 ft depth) is about $40,000

OPERATING PHASE MONITORING

MONITORING FREQUENCIES DURING OPERATING PHASE

		# over 30 y
Geophysical - Years 1, 2, 5, 10, 15, 20, 25 and 30 (per Benson 2004)	1, 2, 5, 10, 15, 20, 25, 30	**8**
Remote sensing - Assume every two years at and immediately prior to entering post-injection phase	1, 3, 5, 7, 9, 11, 13, 15, 17, 19, 21, 23, 25, 27, 29, 30	**16**
Air, soil, gas monitoring - Assume every two years at listed frequencies, and immediately prior to entering post-injection phase	1, 3, 5, 7, 9, 11, 13, 15, 17, 19, 21, 23, 25, 27, 29, 30	**16**
Water/brine monitoring - Assume every two years at listed frequencies, and immediately prior to entering post-injection phase	1, 3, 5, 7, 9, 11, 13, 15, 17, 19, 21, 23, 25, 27, 29, 30	**16**

Assume 1 M - 4M tons CO2e per year for 30 years (4M tpy is projected level of Alberta Saline Aquifer Project)

WSGS modeling indicates a plume area factor of 0.133 mi2/Mtons CO2 (15Mtpy, 50 yrs; 750M tons total; 100 mi2 plume area) NETL suggests a plume area factor of 0.75 mi2/Mtons CO2 (1 Mtpy for 20 years; 20M tons total; 15 mi2 plume area) The NETL figure appears to be too conservative to apply to a larger project, so a figure of 0.15 mi2/MtonsCO2 has been applied here

Assume an additional 50% area (midpoint) for the hydrologic front, with monitoring of the front principally addressed by remote sensing and subsurface pressure monitoring

Remote Sensing

InSAR — Avg $7,500 per square mile, Annually

	Equipment cost estimates (assume one full monitoring network purchased over the course of the 30 years)	Estimated Monitoring (estimated annual costs, using mid-point of area as the average over the 30-year period)	Cost over 30 years of monitoring services, at frequencies listed to the left during the years listed above	Category subtotals for 30-year block (services + one round of equipment purchases)
Plume				**Remote Sensing**
If 1M tpy for 30 years, 30M tons CO2 total ~ 4.5 mi2 (2.25 mi2 mid-point) + 10% monitored buffer		18,563	297,000	623,800
If 2M tpy for 30 years, 60M tCO2 total ~9 mi2 (4.5 mi2 mid-point) + 10% monitored buffer		**37,125**	**594,000**	**1,247,600**
If 4M tpy for 30 years, 120M tons CO2 total ~ 18 mi2 (9 mi2 mid-point) + 10% monitored buffer		74,250	1,188,000	2,438,400
Hydrologic Front				
For 1 tpy, assume additional 4.5 mi2 (2.25 mi2 mid-point)		16,875	270,000	
For 2 tpy, assume additional 9 mi2 (4.5 mi2 mid-point)		**33,750**	**540,000**	
For 4 tpy, assume additional 18 mi2 (9 mi2 mid-point)		67,500	1,080,000	

GPS — $13,000/station
+ Wireless Comm — $ 1,200/station
Continuous

Minimum 3 stations	42600
Assume 4 stations for 4.5 mi2	56,800
Assume 8 stations for 9 mi2	**113,600**
Assume 12 stations for 18 mi2	170,400

Air, soil gas tracers

				Air, soil gas monitoring
				3,632,400
Gas meter w/alarm		Cost of each	4000	**7,264,800**
Continuous	If 4.5 mi2 area then assume 18 meters		72,000	14,929,600
	If 9 mi2 area then assume 36 meters		**144,000**	
	If 18 mi2 area then assume 72 meters		688,000	
Eddy covariance monitors		Cost of each	15000	
Continuous	If 4.5 mi2 area then assume 18 monitors		270,000	
	If 9 mi2 area then assume 36 monitors		**540,000**	
	If 18 mi2 area then assume 72 monitors		1,080,000	
Soil CO2 monitors		Cost of each	30000	
	If 4.5 mi2 area then assume 18 monitors		540,000	
	If 9 mi2 area then assume 36 monitors		**1,080,000**	
	If 18 mi2 area then assume 72 monitors		2,160,000	
Tracer monitors		Cost of each	4000	
	If 4.5 mi2 area then assume 18 monitors		72,000	
	If 9 mi2 area then assume 36 monitors		**144,000**	
	If 18 mi2 area then assume 72 monitors		288,000	

Soil CO2 survey costs			Cost of each		1500		
	Monthly	If 2.25 mi2 midpoint then assume 9 samples per month			162,000	2,592,000	
		If 4.5 mi2 midpoint then assume 18 samples per month			**324,000**	**5,184,000**	
		If 9 mi2 midpoint then assume 36 samples per month			648,000	10,368,000	
Isotope-atmosphere soil analyses			Cost of each		150		
	Quarterly	If 2.25 mi2 midpoint then assume 9 samples per quarter			5,400	86,400	
		If 4.5 mi2 midpoint then assume 18 samples per quarter			**10,800**	**172,800**	
		If 9 mi2 midpoint then assume 36 samples per quarter			21,600	345,600	
Water/brine sampling	Weekly		Cost of each		60		**Water, brine sampling**
		If 2.25 mi2 midpoint then assume 9 samples per week			28,080	449,280	449,280
		If 4.5 mi2 midpoint then assume 18 samples per week			**56,160**	**898,560**	**898,560**
		If 9 mi2 midpoint then assume 36 samples per week			112,320	1,797,120	1,797,120
Subsurface & wellhead pressure monitors	Continuous						**Subsurface & wellhead pressure monitoring**
	Assume $25,000 per station	Plume					900,000
		If 4.5 mi2 area then assume 18 monitors		450,000			**1,800,000**
Solinst 4-level for 50' total depth costs average $5,000		**If 9 mi2 area then assume 36 monitors**		**900,000**			3,600,000
Assume for our depths cost would be $25,000 per station		If 18 mi2 area then assume 72 monitors		1,800,000			
		Hydrologic Front					
		If 4.5 mi2 area then assume 18 monitors		450,000			
		If 9 mi2 area then assume 36 monitors		**900,000**			
		If 18 mi2 area then assume 72 monitors		1,800,000			
Geophysics							
							Geophysics
3D Seismic	Avg $70,000 per sq mi						5,600,800
	Quarterly	If 2.25 mi2 midpoint + 10% monitored buffer			693,000	5,544,000	**11,201,600**
		If 4.5 mi2 midpoint + 10% monitored buffer			**1,386,000**	**11,088,000**	22,346,400
		If 9 mi2 midpoint + 10% monitored buffer			2,772,000	22,176,000	
Tiltmeters	$13,000/station	Minimum 3 stations		42600			
	$ 1,200/station	Assume 4 stations for 4.5 mi2		56,800			
		Assume 8 stations for 9 mi2		**113,600**			
		Assume 12 stations for 18 mi2		170,400			

	SUBTOTAL - EQUIPMENT	SUBTOTAL - MONITORING SERVICES	TOTAL
TOTALS AND SUBTOTALS FOR 4.5 MI^2 AREA	1,967,600	9,238,680	11,206,280
TOTALS AND SUBTOTALS FOR 9 MI^2 AREA	**3,935,200**	**18,477,360**	**22,412,560**
TOTALS AND SUBTOTALS FOR 18 MI^2 AREA	8,156,800	36,954,720	45,111,520

WY State Geological Survey modeling of Wyoming-specific information for larger project scopes suggests a plume area factor of 0.133 mi2/Mtons CO2 (see detailed block above)

Alberta Saline Aquifer Project

A major Canadian initiative called the Alberta Saline Aquifer Project (ASAP) [12] is a consortium of 34 companies that are developing a pilot site for commercial scale carbon capture and storage in a saline aquifer. The initial pilot will sequester 1,000 tonnes per day in 2010, while the commercial phase could see 10,000 tonnes per day as soon as 2015.

Sandia Costs for a Bruel and Kjaer gas analyzer, Campbell Scientific CR-7 datalogger, pressure and temperature measurement devices, and a pressure scanning package for moniotring vadose zone (0 to 16 ft depth) is about $40,000 ears

Risk Activity Matrix

Phases

I. Permitting/Characterization
II. Operation (Injection and permanent well closure)
III. Post-closure ("plume stabilization" - site certified closed; above ground remediation completed)
IV. Long term stewardship (Long term care)

Risk Ranking	Event Factor
1	1.0 to 3.9
2	4.0 to 6.9
3	7.0 to 10.0

		Risk Ranking by Phase						
	Major Risk (Impact) - Triggering Activity (FEP = Feature, Event, or Process)	**Permitting**	**Operation**	**Post Closure**	**Long Term**	**Event Factor (for highest Risk Phase)**	**Site Specific Risk Factor**	**Bond Adjustment Factor**
1	**Mineral Rights Infringement (Trespass)**							
1.1	Leakage migrates into mineral zone or hydraulic front impacts recoverable mineral zone, causes may include plume migration different than modeled	**0**	**3**	**2**	**1**	**8.5**	**11.0%**	**93.5%**
1.2	Post injection discovery of recoverable minerals	**0**	**1**	**1**	**1**	**2.5**	**15.0%**	**37.5%**
1.3	New technology (or economic conditions) enables recovery of previously un-economically recoverable minerals	**0**	**1**	**1**	**1**	**2.5**	**20.0%**	**50.0%**
1.4	Act of God (seismic event)	**0**	**1**	**1**	**1**	**2.5**	**7.5%**	**18.8%**
1.5	Formation fluid impact due to CO2 injection	**0**	**3**	**2**	**1**			
1.6	See also Primary Contributing Causes: 3.1, 3.2, 3.3, 3.5, 4.3 and 4.4							
2	**Water Quality contamination**							
2.1	Leakage of CO_2 outside of permitted area.	**0**	**2**	**1**	**1**	**5.5**	**21.0%**	**115.5%**
2.2	Leakage of drilling fluid contaminates potable water aquifer	**1**	**2**	**0**	**0**	**5.5**	**9.0%**	**49.5%**
2.3	Rock/acidified water (geochemistry) interaction contaminates potable water by carryover of dissolved contaminants	**0**	**2**	**1**	**0**	**5.5**	**7.5%**	**41.3%**
2.4	Act of God (seismic event)	**0**	**1**	**1**	**1**	**2.5**	**5.0%**	**12.5%**

Phases

I. Permitting/Characterization

II. Operation (Injection and permanent well closure)

III. Post-closure ("plume stabilization" - site certified closed; above ground remediation completed)

IV. Long term stewardship (Long term care)

Risk Ranking	Event Factor
1	1.0 to 3.9
2	4.0 to 6.9
3	7.0 to 10.0

		Risk Ranking by Phase						
	Major Risk (Impact) - Triggering Activity (FEP = Feature, Event, or Process)	**Permitting**	**Operation**	**Post Closure**	**Long Term**	**Event Factor (for highest Risk Phase)**	**Site Specific Risk Factor**	**Bond Adjustment Factor**
2.5	Formation fluid impact due to CO2 injection	**0**	**3**	**2**	**1**			
2.6	See also Primary Contributing Causes: 3.1, 3.2, 3.3, 3.5, 4.3 and 4.4							
3	**Single Large Volume CO2 Release to the Surface - Asphyxiation/Health/Ecological**							
3.1	Overpressurization (induced)	**0**	**2**	**1**	**0**	**5.5**	**20.0%**	**110.0%**
3.2	Caprock/reservoir failure	**0**	**2**	**1**	**1**	**5.5**	**10.0%**	**55.0%**
3.3	Well blowout (at surface or bore failure below ground), includes monitoring wells - Causes could include seal failure (well, drilling or injection equipment)	**0**	**2**	**1**	**1**	**5.5**	**15.0%**	**82.5%**
3.4	Major mechanical failure of distribution system or storage facilities above or below ground (near surface)	**0**	**2**	**1**	**0**	**5.5**	**0.15**	**0.825**
3.5	Orphan well failure (well not identified prior to injection)	**0**	**2**	**0**	**0**	**5.5**	**30%**	**165%**
3.6	Sabotage/Terrorist attack (on surface infrastructure)	**0**	**1**	**1**	**1**	**2.5**	**5%**	**13%**
3.8	Act of God (i.e. major seismic event)	**0**	**1**	**1**	**1**	**2.5**	**5%**	**13%**

Phases

I. Permitting/Characterization

II. Operation (Injection and permanent well closure)

III. Post-closure ("plume stabilization" - site certified closed; above ground remediation completed)

IV. Long term stewardship (Long term care)

Risk Ranking	Event Factor
1	1.0 to 3.9
2	4.0 to 6.9
3	7.0 to 10.0

		Risk Ranking by Phase						
	Major Risk (Impact) - Triggering Activity (FEP = Feature, Event, or Process)	Permitting	Operation	Post Closure	Long Term	Event Factor (for highest Risk Phase)	Site Specific Risk Factor	Bond Adjustment Factor
4	**Low Level CO_2 Leakage to Surface - Ecological damage (flora/fauna) due to chronic low-level releases; potential asphyxiation**							
4.1	Overpressurization (induced)	0	2	1	0	5.5	20%	110%
4.2	Caprock/reservoir fracture (Plume migrates along fault line/fissure to surface)	0	2	1	1	5.5	10%	55%
4.3	Incomplete geological seal (Inaccurate characterization of sub-surface geology)	0	2	1	1	5.5	20%	110%
4.4	Well seal failure (well, drilling or injection equipment), includes monitoring wells	0	3	1	1	8.5	15%	128%
4.5	Mechanical failure of distribution system or storage facilities above or below ground (near surface)	0	3	1	1	8.5	15%	128%
4.6	Orphan wells (well not identified prior to injection)	0	2	0	0	5.5	30%	165%
4.7	Induced seismicity leading to leakage	0	2	1	1	5.5	5%	28%
4.8	Act of God (seismic event)	0	1	1	1	2.5	5%	13%

Phases

I. Permitting/Characterization

II. Operation (Injection and permanent well closure)

III. Post-closure ("plume stabilization" - site certified closed; above ground remediation completed)

IV. Long term stewardship (Long term care)

Risk Ranking	Event Factor
1	1.0 to 3.9
2	4.0 to 6.9
3	7.0 to 10.0

		Risk Ranking by Phase						
	Major Risk (Impact) - Triggering Activity (FEP = Feature, Event, or Process)	**Permitting**	**Operation**	**Post Closure**	**Long Term**	**Event Factor (for highest Risk Phase)**	**Site Specific Risk Factor**	**Bond Adjustment Factor**
5	**Storage Rights Infringement (CO2 or other Entrained Contaminant Gases) - Form of Mineral Rights Infringement**							
5.1	Leakage migrates into adjacent pore space; cause may include plume migrates faster than modeled	**0**	**3**	**2**	**1**	**8.5**	**13%**	**106%**
5.2	Post injection decision (due to new technology or changed economic conditions) to store gas in adjacent pore space	**0**	**2**	**1**	**1**	**5.5**	**13%**	**69%**
5.3	Acts of God affecting storage capacity of pore space	**0**	**1**	**1**	**1**	**2.5**	**15%**	**38%**
5.4	Formation fluid impact due to CO2 injection	**0**	**3**	**2**	**1**			
	Will Also Require Primary Contributing Cause: 3.1, 3.2, 3.5, 4.3 and 4.4							
6	**Modified Surface Topography (subsidence or uplift) resulting in Property/Infrastructure Damage**							
6.1	Induced Seismicity - Pressure or geochemistry induced reactivation of historic fault or dissolution of material causing subsidence	**0**	**2**	**1**	**1**	**5.5**	**10%**	**55%**
6.2	Formation fluid impact due to CO2 injection	**0**	**3**	**2**	**1**			

Phases

I. Permitting/Characterization

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Risk Ranking	Event Factor
1	1.0 to 3.9
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		Risk Ranking by Phase						
	Major Risk (Impact) - Triggering Activity (FEP = Feature, Event, or Process)	Permitting	Operation	Post Closure	Long Term	Event Factor (for highest Risk Phase)	Site Specific Risk Factor	Bond Adjustment Factor
7	**Entrained Contaminant (Non-CO2) Releases**							
7.1	Change in CO2 composition/properties (concentration of contaminants in CO2 supply increases)	0	1	1	1	2.5	40%	100%
7.2	Microbial activity initiated by injection process or composition	0	1	1	1	2.5	50%	125%
	Will Also Require Primary Contributing Causes: 3.1, 3.2, 3.3, 3.5, 4.3 and 4.4							
8	**Accidents/unplanned events (Typical Insurable Events)**							
8.1	Surface infrastructure damage	1	2	1	0	5.5	25%	138%
8.2	Saline water releases from surface storage impoundment	0	2	0	0	5.5	18%	96%

	COMPLIANCE ACTIVITIES THAT WILL REQUIRE FINANCIAL ASSURANCE							
1	Well capping & permitted abandonment or removal of underground piping	x	x					
2	Removal of above-ground facilities & Site reclamation (roads, wells)			x				
3	Continuous and /or Periodic Monitoring	x	x	x	x			

7 IX Treatment Option for Hyd Front Withdrawal at July 21 09 Fnl.xls

	acre-feet	75% of Hyd Front	gallons	barrels at 55 gal/barrel	Ion Exchange treatment costs at $0.30/bbl (K Hendricks 5-12-09) At 75% Hyd Front volume	At 50% Hyd Front	At 25% Hyd Front	Cost for IX unit(s)	Total
2M tpy case	64,000	48,000	15640867200	284,379,404	$ 85,313,821	$ 56,904,319	$ 28,437,940	Assume 2 at $50,000 each	$ 28,537,940
4M tpy case	128,000	96,000	31281734400	568,758,807	$ 170,627,642	$ 113,808,637	$ 56,875,881	Assume 4 at $50,000 each	$ 56,975,881

Pumping Costs for Hydraulic Front Relief

10 mile X 10 mile area of review (similar to 90 mi2 area from 4M tpy injection rate)

Over a 30-year operational period, would be 120M tons of CO_2 injected

750M tons of CO_2 produces 1 km3 of water; equiv to 6B barrels of water	4M tpy, 120M tons is	16%	of 750M tons, 0.16 km3,	0.96B ba	128000 ac-ft in hydraulic front	
gallons of water in 6B barrels = 252B gallons	2M tpy, 60M tons is	8%	0.08km3	0.48B ba	64000	ac-ft

Costs for pumping for 5000-foot relief wells
Pumping costs est at $0.12/ac-ft/ft

100% of hyd front	75% of front	50% of front
$ 76,800,000	$ 57,600,000	$ 38,400,000
$ 38,400,000	$ 28,800,000	$ 19,200,000

Costs for pumping for 7000-foot relief wells
Pumping costs est at $0.12/ac-ft/ft

100% of hyd front	75% of front	50% of front
$ 107,520,000	$ 80,640,000	$ 53,760,000
$ 53,760,000	$ 40,320,000	$ 26,880,000

800000 ac ft = 1km3

UC-Davis says $0.20/ac-ft per foot of lift for pumping
almost all is electricity, so comparing CA to WY for elec costs:
EIA ~ 2007: WY - 7 cents/kwh CA - 12 cents/kwh

0.116667

For WY, inflated equivalent ~ $0.12/ac-ft per foot of lift for pumping

For depth of pumping, the 7000-ft level is indicated as an average
based on depth and thickness of Weber and Madison formations in
Rock Springs Uplift (roughly 6800 to 7700 feet)