ARB CCS Technical Discussion Series: Well Mechanical Integrity

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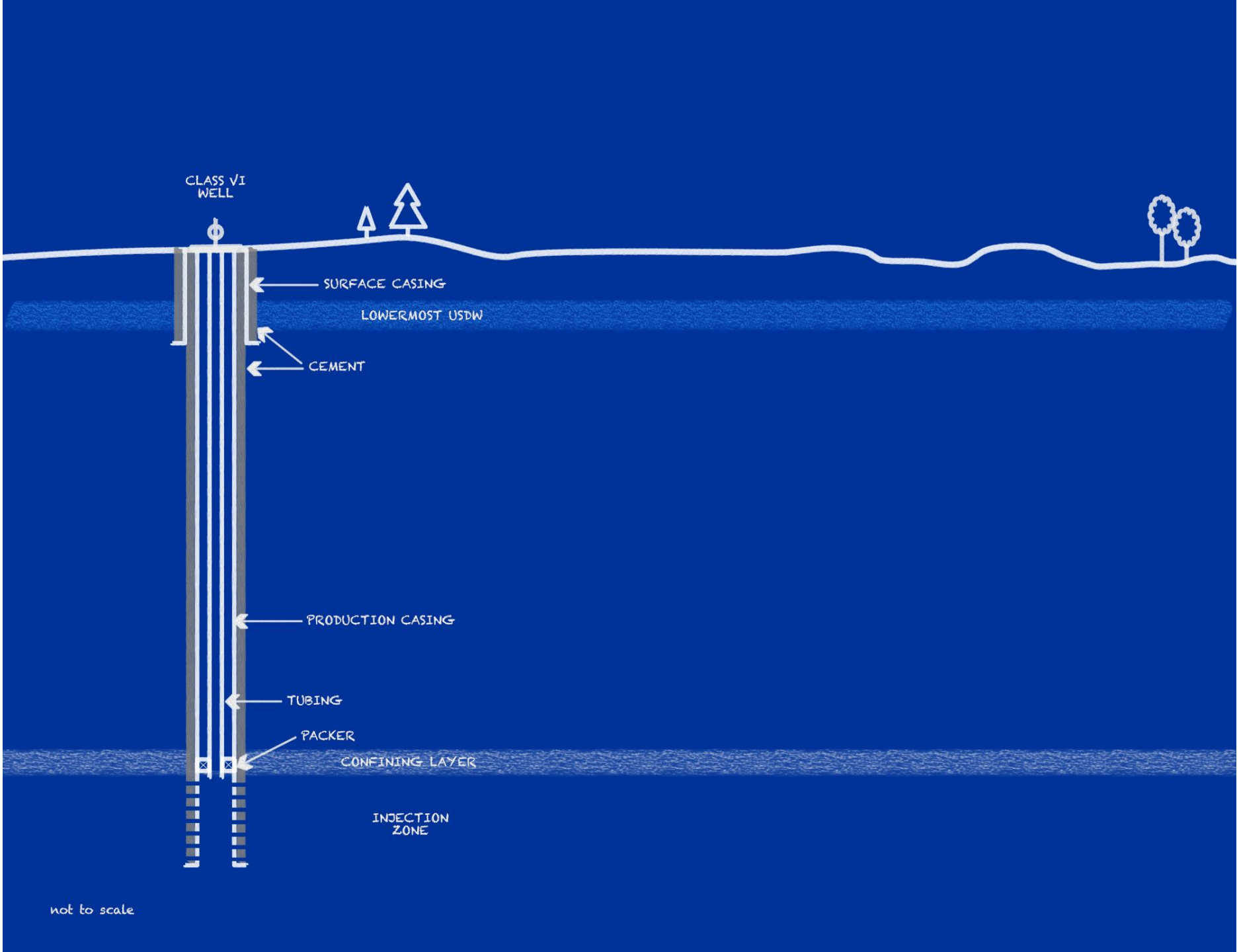
Mechanical integrity means the absence of significant leakage within the injection tubing, casing, or packer (internal mechanical integrity), or outside of the casing (external mechanical integrity).

Class VI Sequestration
vs.
Class II Sequestration

Mechanical Integrity Challenges


CLASS VI
WELL
SURFACE CASING
LOWERMOST USDW
CEMENT
PRODUCTION CASING
TUBING
PACKER
CONFINING LAYER
INJECTION
ZONE
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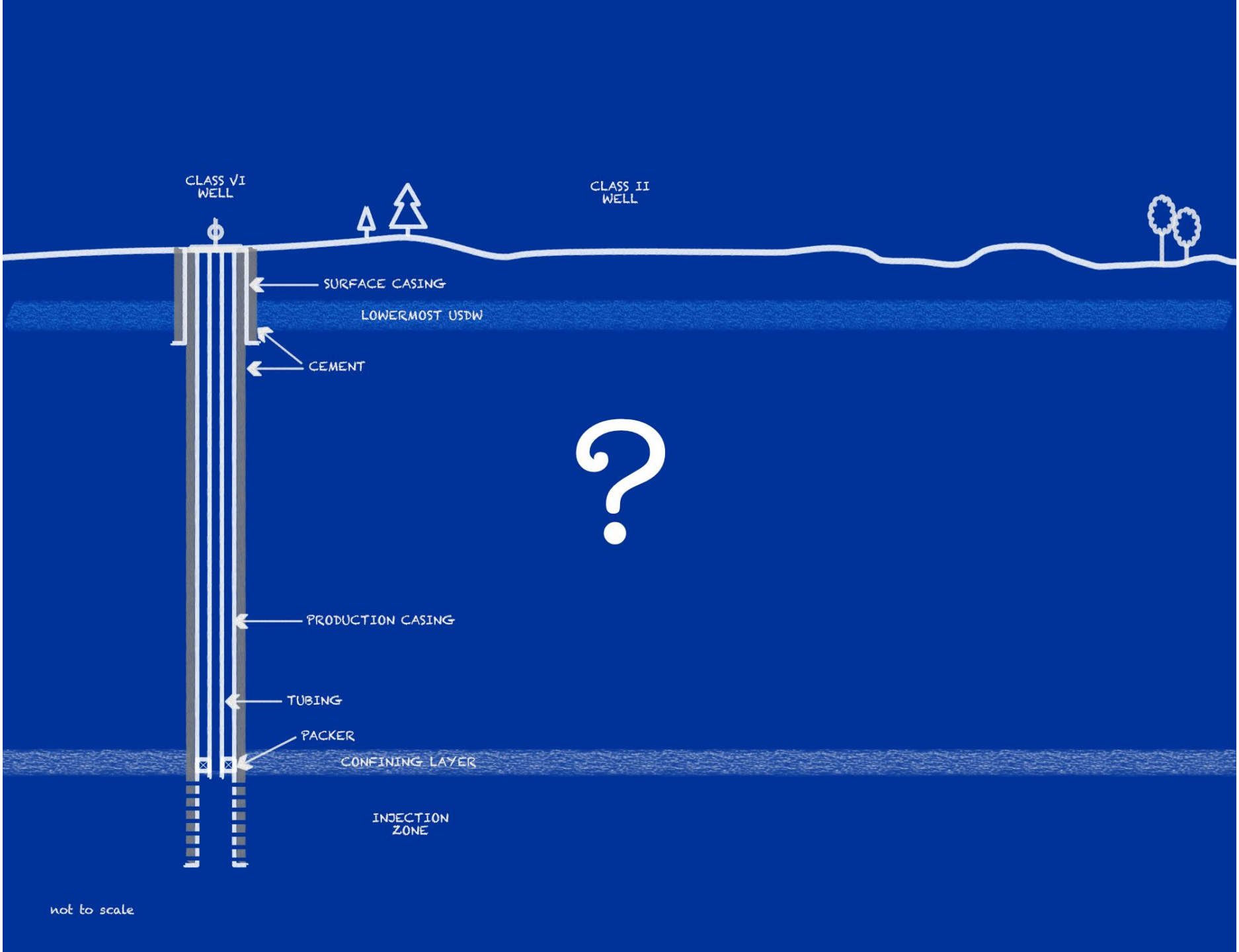
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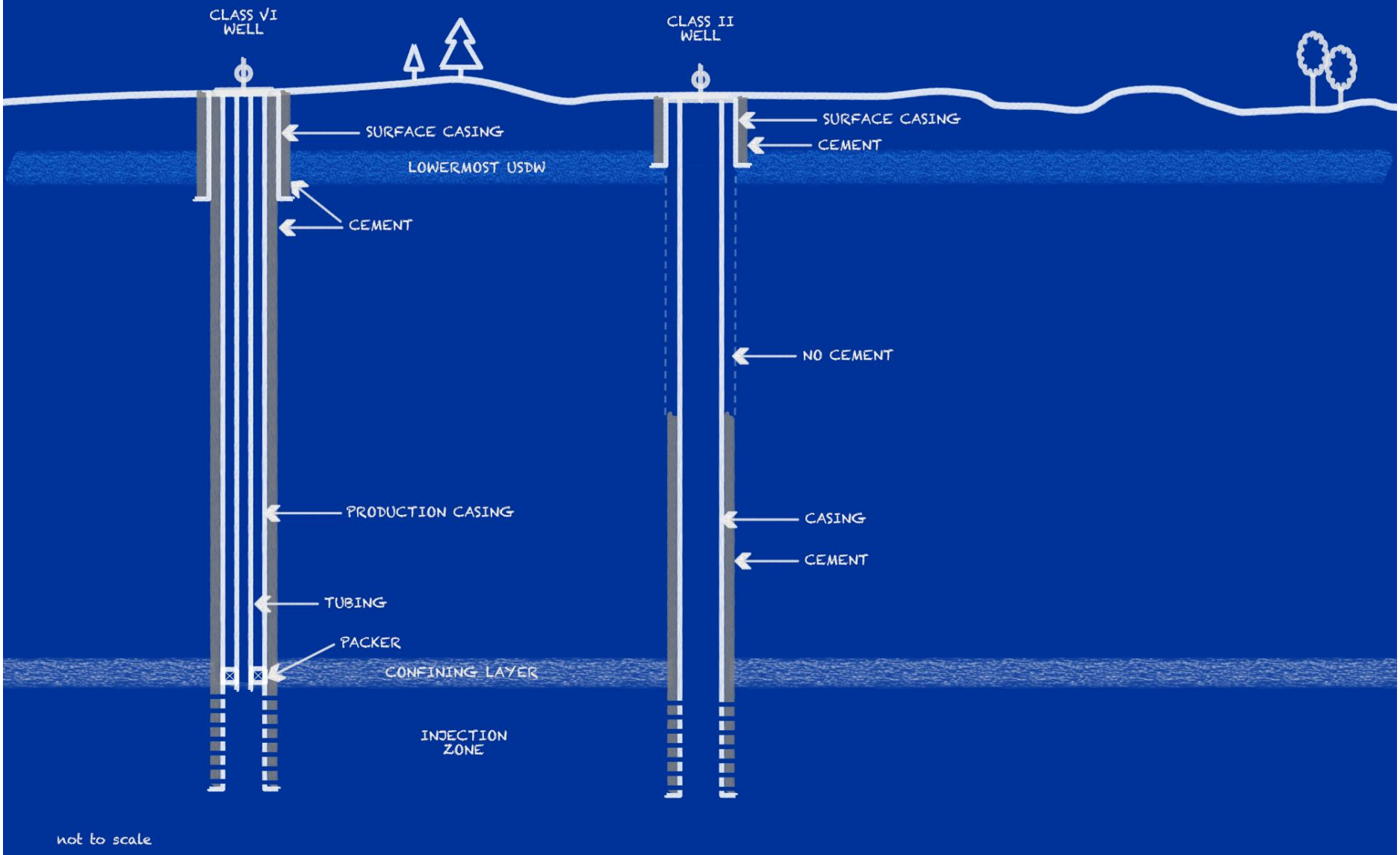
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CEMENT
NO CEMENT
CASING
CEMENT
not to scale

Converting Wells in a Mature West Texas Field for CO_2 Injection

Michael T. Power, SPE, **Monte A. Leicht,** SPE, and **Kerney L. Barnett,** SPE, Chevron U.S.A. Inc.

Summary. This paper deals with the planning, special equipment considerations, and operations necessary to convert 165 water injection wells to CO_2 injectors that will function through at least the end of the century. The paper is divided into two parts: planning and engineering (wellhead, packer, and tubular selection) and procedural operation highlights (fishing, openhole cleanout, casing evaluation and repair, stimulation, liner running, wellhead replacement, packer setting, and the reworking of tubulars). A case-history approach was used to analyze the success or failure of the various methods and techniques used in this project. All 165 wells were converted as of March 29, 1989.

Introduction

Chevron U.S.A.'s North Ward Estes (NWE) field is an 18×4-mile anticlinorium located in Ward and Winkler Counties, TX. The field is roughly 60 miles southwest of Midland and lies on the western flank of the Central basin platform.

The Yates is the dominant producing formation. It is composed of up to nine major reservoirs. The individual reservoirs are very-fine-grained sandstones to siltstones separated by very dense dolomite beds. The average depth of the Yates is 2,800 ft.

The NWE field was discovered in 1929 and to date has yielded more than 330 million bbl of oil (30% of original oil in place). Current production averages 2,849 BOPD in the project area.

Many older areas of the NWE field began to approach their economic limit in 1954. A pilot waterflood was initiated on the Hutchings Stock Assn. lease in late 1954. Expansion to cover the entire field began in mid-1955; by 1965, 26,000 acres was under waterflood.

Since 1975, a number of tertiary pilot projects have been conducted in the NWE field. These include in-situ combustion, caustic flooding, and polymer-injection-profile modification.

in its own way. "Cookbook" procedures were prepared at the beginning of the conversion work to give the drilling group a direction and objective for each well. As the work progressed, however, casing leaks were found and repaired, junk in the hole required sidetracking, and sloughing shot holes required mudding up to complete the conversion. Thus, changes in our operations from the original procedures evolved owing to monetary constraints and rethinking of what techniques were actually successful.

Casing Evaluation and Repair

Elimination of casing inspection logs is an example of both reasons for changes in operations. Evaluation of logs from more than 20 wells revealed that essentially all the wellbores were in the same condition: reasonably good casing down to the old injection packer and no casing below the packer. Also, the logs failed to locate explicitly holes in the casing (above the injection packer) where subsequent packer and retrievable-bridge-plug testing found leaks. Casing inspection logs were then deleted on most wells except where casing leaks had been detected on previous workovers. This application was an attempt to determine whether casing corrosion neces-

Area of Review and Corrective Action

Class VI

- AoR & Corrective Action Plan
- Update at least every 5 years
- Computational modeling to determine extent of CO_2 plume and identify potential migration pathways
- Identify and assess all penetrations of the confining zone

Class II

- Fixed ¼-mile radius or Zone of Endangering Influence
- No required review or update
- No requirement to predict or track CO_2 movement
- Casing diagrams for all idle, P&A, or deeper-zone producing wells and evidence that P&A wells will not have an adverse effect

Area of Review and Corrective Action

- 2011 audit of CA's UIC program found that "the quarter-mile fixed radius AOR standard has been applied historically with very few exceptions."
- 2004 EPA UIC National Technical Workgroup Report found that a fixed radius AOR may not be adequate to protect USDWs
  - The NTW recommend that AoRof all authorized injection projects nationwide be re-evaluated, stating "The majority of EPA UIC National Technical Workgroup members understands the magnitude of the suggested action and consider this proposal as a long-term solution to a **long-standing inadequate permitting practice**."

Case Study: Salt Creek CO2-EOR Field, WY

- Discovered in 1880; First well drilled in 1899; First well targeting the Wall Creek member drilled in 1906
- 1899-1926: Primary Production; 1926-1961: Gas-Injection; 1961-present: Waterflooding; 2004-present: CO2 flooding of Wall Creek II
- Stacked reservoir with 11 productive horizons, two under CO2 flood, WC2 ~1800'
- Field contains more than More than 4000 wells, with approximately 70% having been drilled prior to 1930
- At time of conversion to CO2-EOR, contained more than 3,000 plugged and inactive wells with questionable cement integrity and plugging quality; incomplete well data and numerous unknown wells

Sources: Woodruff, E. G., & Wegemann, C. H. (1911). *The lander and salt creek oil fields Wyoming*. Washington: Government Printing Office.; Wegemann, C. H. (1918). The Salt Creek oil field. *Wyoming: US Geological Survey Bulletin*, *452*, 37-82.; U.S. Bureau of Land Management, Casper Field Office. (2006). *Salt Creek Phases III/IV Environmental Assessment #WYO60-EA06-18.* Wyoming: U.S. Department of the Interior.; Hendricks, K. (2009). *Experiences in the Salt Creek Field CO2 Flood.* Calgary: 5th Annual Wellbore Integrity Network

Case Study: Salt Creek CO2-EOR Field, WY

- After onset of CO2 injection in 2004, CO2 seeped to the surface over an approximately one-quarter square mile area
- Estimated rate of leakage averaged 12 thousand cubic feet per day but estimate very uncertain
  - ~150 million cubic feet per day of CO2 was being injected into the field at the time
- Operator determined that some leaks were the result of improperly constructed or maintained wells
- Remediation of these wells failed to completely eliminate the seeps

Sources: Bureau of Land Management, Casper Field Office. (2006). *Salt Creek Phases III/IV Environmental Assessment #WYO60-EA06-18.* Wyoming: U.S. Department of the Interior.; Cameron-Cole. (2005). *Air Dispersion Modeling in Support of Risk Analysis, Howell Petroleum Corporation, Salt Creek Field*

Case Study: Salt Creek CO2-EOR Field, WY

- Operator developed containment plan to collect CO2, restrict access to seep sites, and communicate with regulators and the public
- Operator also developed a series of steps to identify abandoned wells throughout the field and perform corrective action in advance of CO2 injection into a new phase
  - Aeromagnetic survey, records review, field inspection, workovers, remedial cementing, mechanical integrity testing

Sources: Bureau of Land Management, Casper Field Office. (2007). *Decision Record and Finding of No Significant Impact, Howell Petroleum Corporation, Salt Creek Fieldwide Expansion of the CO2 Enhanced Oil Recovery Project EA # WY-060-EA7-067 Natrona County, Wyoming*. Wyoming: U.S. Department of the Interior.; Hammack, R. W., Veloski, G. A., and Hodges, G. (2006). *Helicopter Surveys for Locating Wells and Oilfield Infrastructure*. 13th Annual International Petroleum Environmental Conference: San Antonio, TX October 17-20, 2006.; Meyer, J.P. (2007). *Summary of Carbon Dioxide Enhanced Oil Recovery (CO2EOR) Injection Well Technology*. Prepared for the American Petroleum Institute.

Case Study: Salt Creek CO2-EOR Field, WY

BEFORE THE

DEPARTMENT OF ENVIRONMENTAL QUALITY

STATE OF WYOMING

FILED

AUG 14 2012

Jim Ruby, Executive Secretary
Environmental Quality Council

IN THE MATTER OF THE NOTICE OF VIOLATION AND ORDER ISSUED TO:	)	
Anadarko Petroleum **PO Box 10** **Midwest, WY 82643**	)	**DOCKET NUMBER 5030-12**

NOTICE OF VIOLATION AND ORDER

NOTICE IS HEREBY GIVEN THAT:

1. Anadarko Petroleum (Anadarko) is the owner/operator of numerous oil and gas operations in the Salt Creek Field, Natrona County, Wyoming. Some of the operations include re-injecting carbon dioxide (CO2) into geological formations to assist in oil and gas recovery processes.

2. On July 30, 2012 Wyoming Department of Environmental Quality personnel met with Anadarko personnel and visited a site where gas was observed bubbling into Castle Creek (class 3B). Anadarko personnel informed DEQ the bubbles were possibly the result of the injected CO2 gas. During the site visit water samples were collected and field tests were conducted with results indicating pH levels below the water quality standards for Wyoming surface waters. Chemical reactions resulting from changes in pH in water can cause death to fish and other organisms.

3. The U.S. Fish and Wildlife Service also visited the site prior to the DEQ and collected six dead ducks to be analyzed for the possible cause of death.

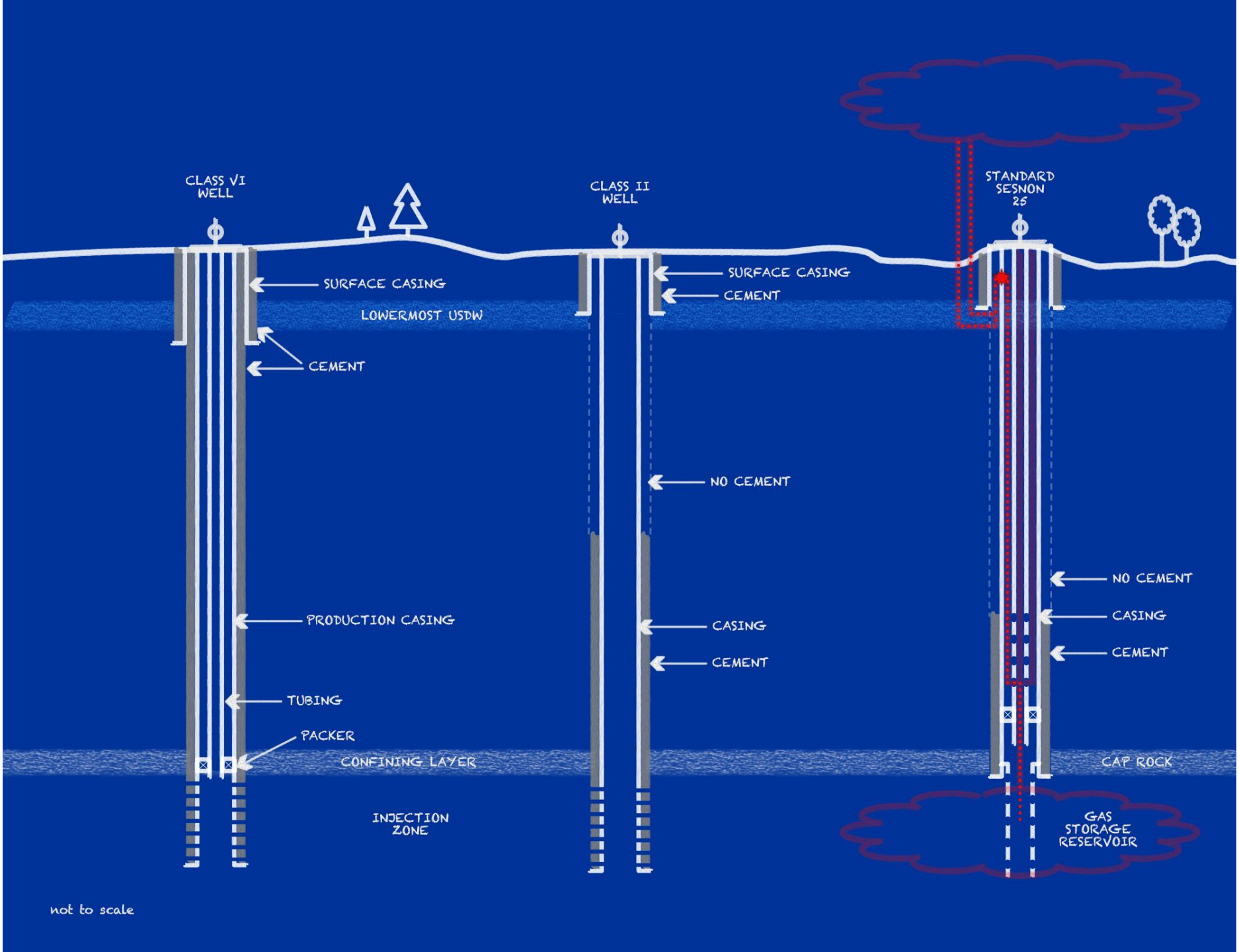
High Level Solutions

- Detailed site characterization to determine geologic suitability
- Site-specific AoR and Corrective Action plans that take into account field data and operating history
- Robust methods for identifying existing wells, including
  1. Historical Record Review
  2. Site Reconnaissance
  3. Aerial and Satellite Imagery Review, and;
  4. Geophysical and Air Emissions Surveys
- Ensuring MI of existing wells, including
  1. Well Record Review
  2. Field Inspection and Testing, and;
  3. Corrective Action
- Best practices for new well construction and conversion of existing wells
- Robust leak inspection, detection, reporting, and repair standards
- Comprehensive Mechanical Integrity Testing Plan, including post-closure

NRDC

Historical MI Performance of UIC Wells

- Determining the precise number mechanical integrity incidents and the consequences of those incidents is not possible with existing data but research indicates cause for concern, see, e.g.
  - U.S. General Accounting Office, 1989;
  - Smith, J. B., & Browning, L. A.,1993;
  - Koplos et al., 2006;
  - Browning, L.A. and J.B. Smith,1993;
  - U.S. Government Accountability Office, 2016
  - Watson, T., & Bachu, S., 2009;
  - Dusseault, M., Gray, M. & Nawrocki, P., 2000;
  - Dusseault, M.B., Jackson, R.E., & MacDonald, D., 2014.
  - Duguid et. al, 2010 ;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CAP ROCK
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