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UIC CLASS VI GEOLOGIC STORAGE OF CO_2 PERMIT APPLICATION

Loving CCS Hub

[redacted]

Loving County, Texas

Section 2: Area of Review (AoR) and Corrective Action (CA) Plan

[40 CFR §146.82, §146.84]

Prepared for:

EPA Region 6

Underground Injection Control Section

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2.0 AREA OF REVIEW (AoR) AND CORRECTIVE ACTION (CA) PLAN [40 CFR 146.82 (a)(13), 146.84 (B)(1)]

2.1 AoR Plume Modeling and Delineation Introduction

The Area of Review (AoR) is the region surrounding the geologic sequestration project where USDWs may be endangered by the injection activity. The Area of Review is delineated using computational modeling that accounts for the physical and chemical properties of all phases of the injected carbon dioxide stream and is based on available site characterization, monitoring, and operational data.

Milestone has prepared a geologic model (Model) that predicts future behavior of injectate in all phases, and elevated pressure associated with injection. This Model delineates the AoR for the proposed geologic sequestration project. Milestone anticipates revising the Model once a stratigraphic test well is drilled, and then at least once every five (5) years during the injection period and post injection site care (PISC) period, and in response to the re-evaluation criteria found later in this document.

The Model was constructed using all available public information and includes data from well logs, cores, 2-D/3-D seismic data, pressure readings from offset water injection wells, RRC documentation, and an extensive literature review.

The plume and pressure model predicts the projected lateral and vertical migration of the CO_2 plume and pressure in the subsurface from the commencement of injection activities until the plume movement ceases[1] and there are no longer pressure differentials sufficient to cause the incremental movement of injected fluids or formation fluids into a USDW. The results of this Model demonstrate that the Well will be sited in an area with a suitable geologic system that includes a sufficient injection unit and an appropriate confining zone, as required by 40 CFR §146.83(a).

- The Model is based on detailed geologic data collected to characterize the Injection Interval, confining zone (Top Seal) and any additional zones; and anticipated operating data, including injection pressures, rates, and total volumes over the proposed life of the geologic sequestration project
- Takes into account any geologic heterogeneities, other discontinuities, data quality, and their possible impact on model predictions
- Considers potential migration through faults, fractures, and artificial penetrations.

[redacted]

The Monitoring Plan (**Section 6**), Post Injection Site Care Plan (**Section 9**), Emergency and Remedial Response Plan (ERRP) (**Section 10**) and Financial Assurance Plan (FA) (**Section 11**) take the AoR into account.

[redacted]

[1] Ceases is defined as <1% change in plume AoR area per year.

2.2 Computational Modeling Approach

Static geologic modeling and dynamic reservoir simulation provide an estimation of key subsurface parameters affected by the injection of supercritical CO_2 into [redacted]

The modeled parameters provide critical insights across the project area and help define the extent of the resulting injection plume, pressure propagation, and operating conditions, which are then utilized to determine the Project's Area of Review (AoR).

To provide accuracy and reliability in handling the complex nature of the simulation, Milestone used industry-standard software tools, including SLB's Petrel™ 3-D modeling software and Computer Modelling Group's (CMG) Generalized Equation-of-State Model™ (GEM™) reservoir simulator.

2.3 Model Background

A representation of the storage reservoir was constructed from available well logs, interpreted formation tops (**Table 2-1**), interpreted 3-D and 2-D seismic data, and fault interpretations from literature [redacted] SLB's Petrel™ software was used to construct a static geocellular model comprised of discrete layers that span from the [redacted]

[redacted]

[redacted]

The dynamic grid from the static geologic model was used as an input to GEM™ a commercial compositional finite difference reservoir simulation, maintained and distributed by CMG. GEM ™ is considered one of the most technically sound reservoir-simulation software packages and is best suited to the compositional nature of the modeling objectives. GEM™ utilizes equation-of-state (EOS) algorithms and advanced computational methods to evaluate key characteristics of fluid flow in the reservoir to produce accurate and reliable simulation models for carbon sequestration. Numerical simulations were conducted to forecast the subsurface behavior of supercritical CO_2, pressure buildup from CO_2 injection, and output parameters used in the evaluation of the AoR boundary.

[redacted]

[redacted]

In order to model the subsurface behavior of supercritical CO_2, a compositional isothermal simulation was run to predict the diffusion of the injectate at pressures less than 90% of the fracture gradient.

The selected model describes the movement and trapping of CO_2 with the data available. To evaluate the extent of the AoR, the model was run to evaluate the incremental change in reservoir pressure and CO_2 saturation within the model domain. [redacted]

2.4 Static Model Summary

[redacted]

The cell size used is adequate to account for lateral heterogeneity as it is significantly less than the average distance between wells used for petrophysical property distribution.

[redacted]

[redacted]

[redacted]

2.4.1 Structural Framework

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]


[redacted]

[redacted]

[redacted]

2.4.2 Layering

Model layers ("K-layers") were generated using proportional layering with the number of layers added [redacted]

[redacted]

2.4.3 Porosity Model

The total pore volume in the injection units [redacted]) controls the volume of CO_2 that can be stored in the reservoir and is fundamentally related to permeability. Porosity logs including density, neutron, and sonic from [redacted] within the regional static model domain were used to determine the injection unit's total porosity. Porosity and permeability were calculated using Milestone's petrophysical software Geolog™. Log analysis and [redacted]

[redacted]

[redacted]

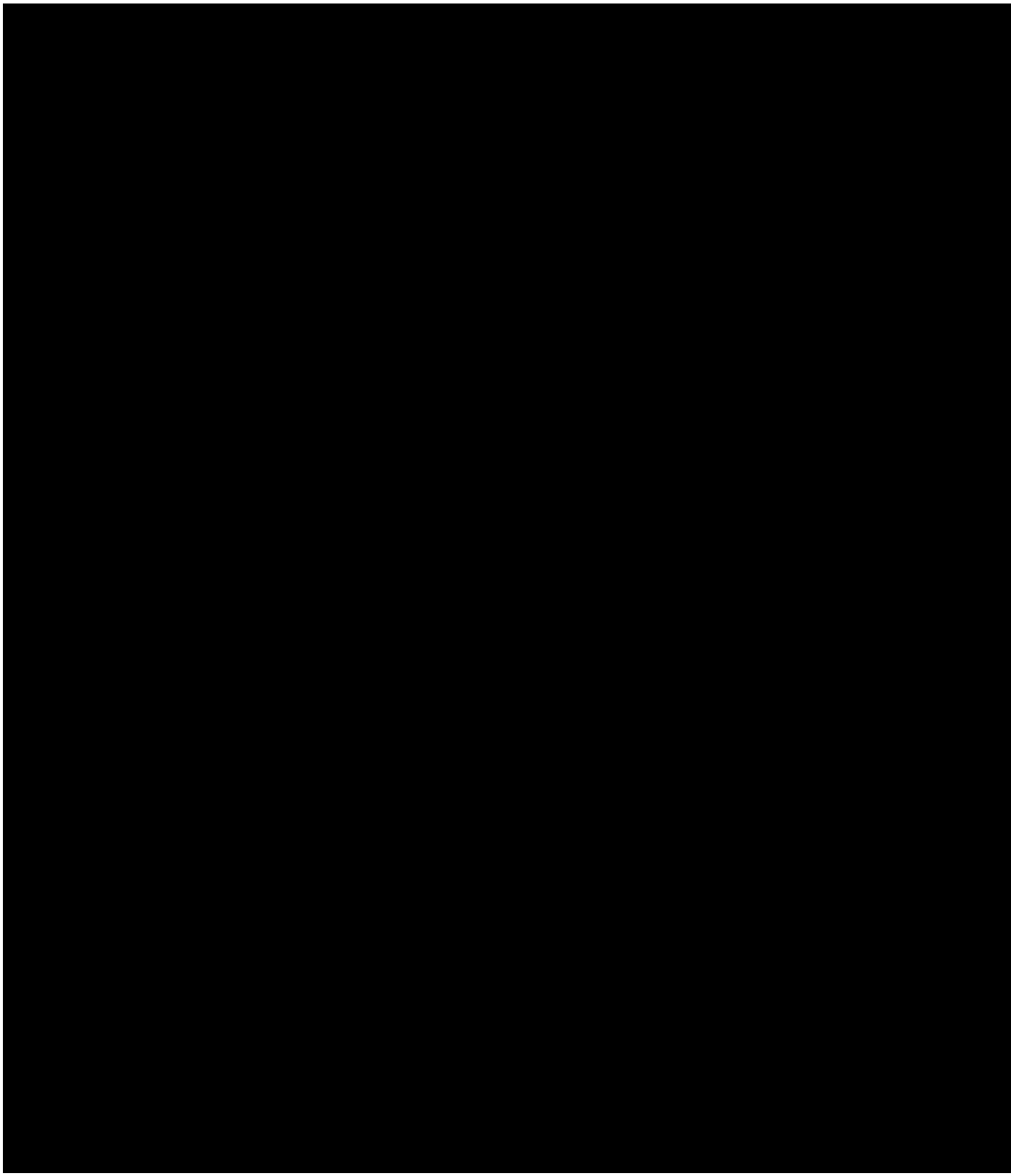
[redacted]

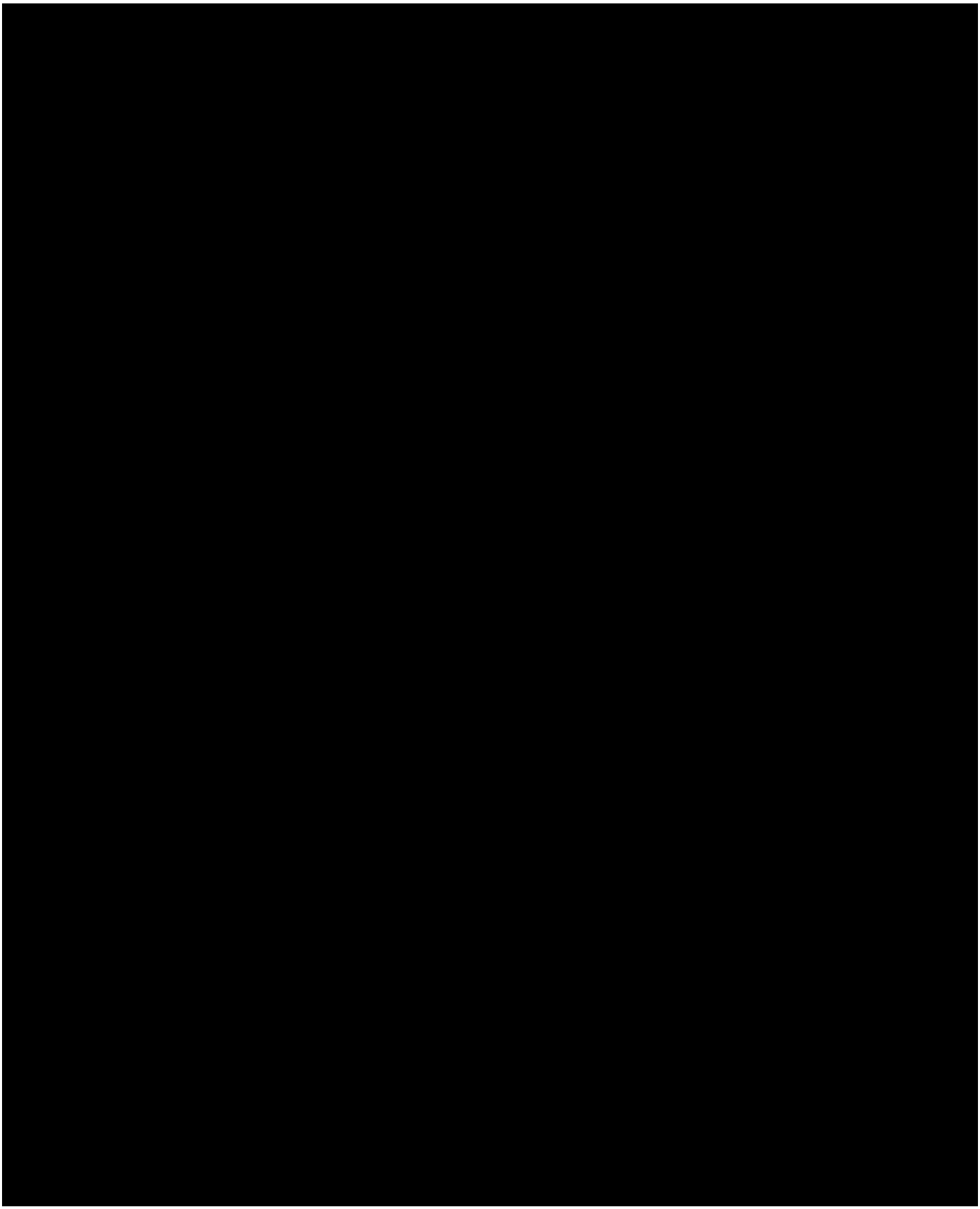
[redacted]

[redacted].

[redacted]

[redacted]





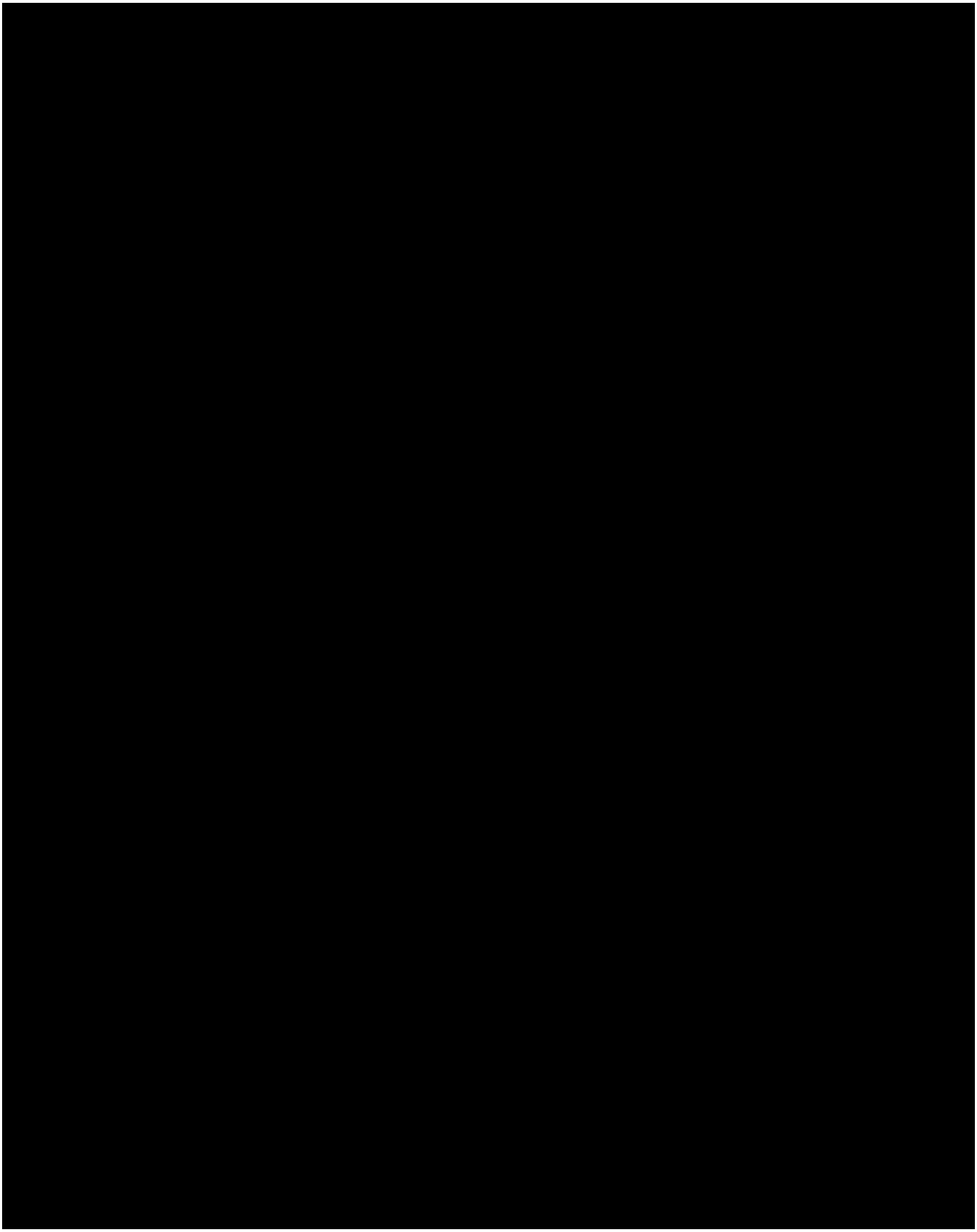
2.4.4 Permeability

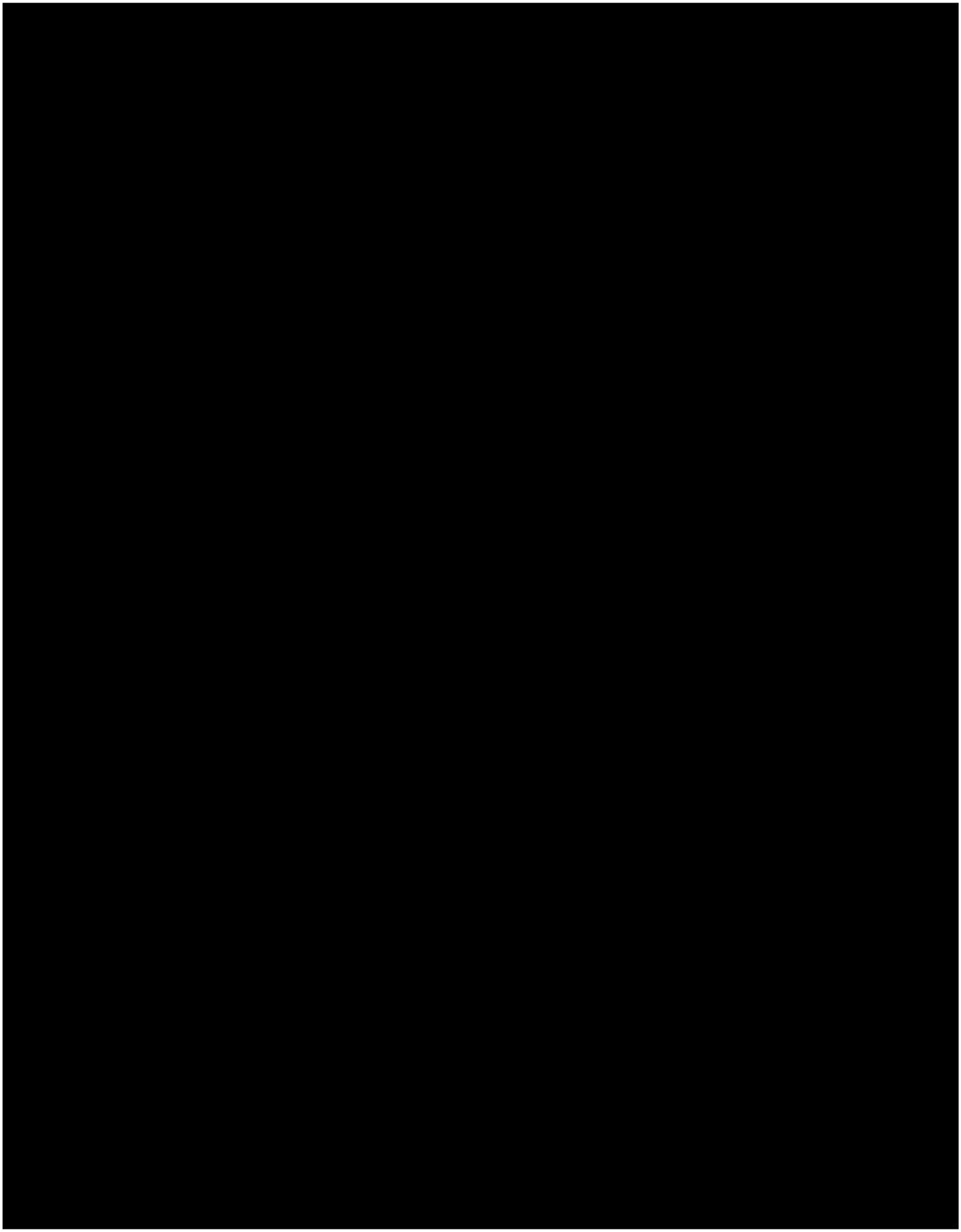
Permeability is a key subsurface parameter in porous media and impacts the rate of fluid flow and resulting injection pressure. Intrinsic permeability is related to changes in porosity, pore size, pore structure and the presence of natural fracturing. [redacted].

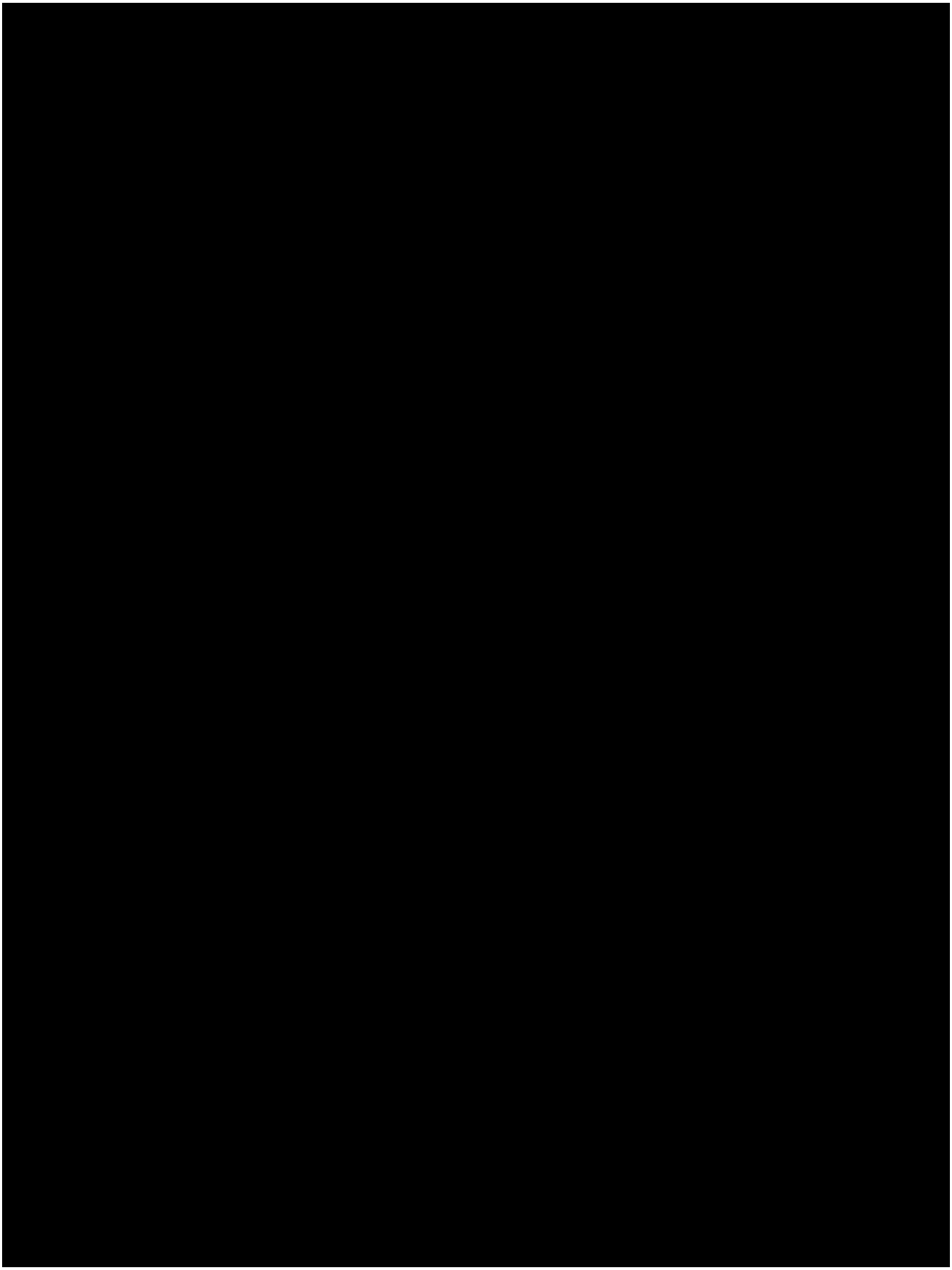
[redacted]

[redacted]

[redacted]







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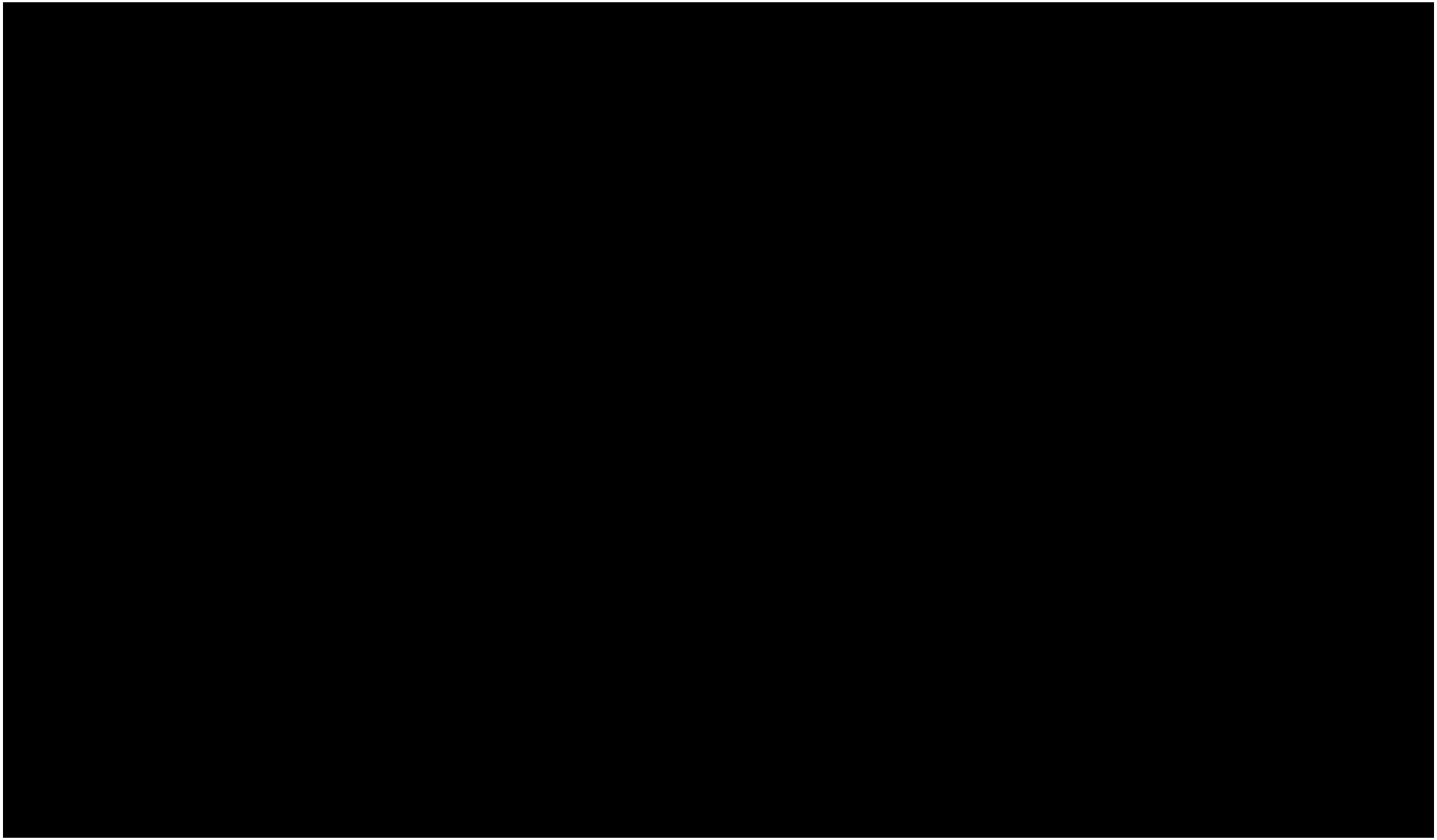


[redacted]

[redacted]

[redacted]

2.4.5 Relative Permeability and Other Rock Properties

[redacted]

[redacted]

[redacted]

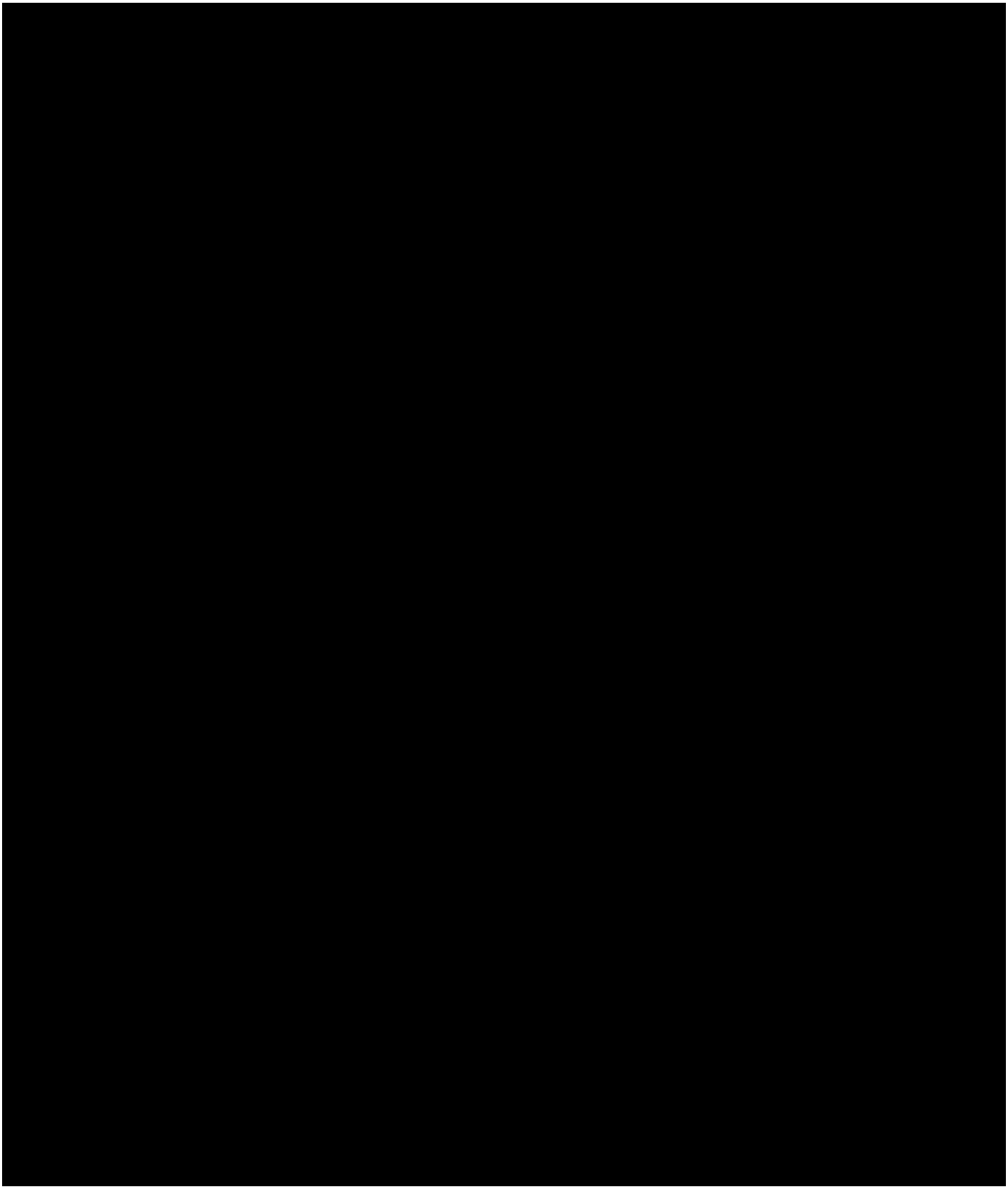
[redacted]

[redacted]

[redacted]

[redacted]

[redacted]



[redacted]

[redacted]

[redacted]

[redacted]

2.4.14 Potential for Future Updates

Both the static geologic model and dynamic reservoir simulation represent a baseline to which measured laboratory data and field observations can be added. In addition to incorporating field and laboratory data, the models can be systematically adjusted with each measurement to quantify the incremental changes across the static model of the [redacted] project area.

Once initialized with each new parameter, the model can be history-matched to the recorded injection pressures and volumes to further fine tune each parameter to field conditions.

[redacted]

2.6 Computational Modeling Results

2.6.1 Predictions of System Behavior

Milestone generated a dynamic reservoir model to delineate the CO_2 plume size, characterizing the extent and geometry of the AoR. Milestone identified the extent of the pressure disturbance in the reservoir, and the corresponding point at which the change in pressure and diffusion become nominal. In addition to calculating the plume size and AoR, [redacted]

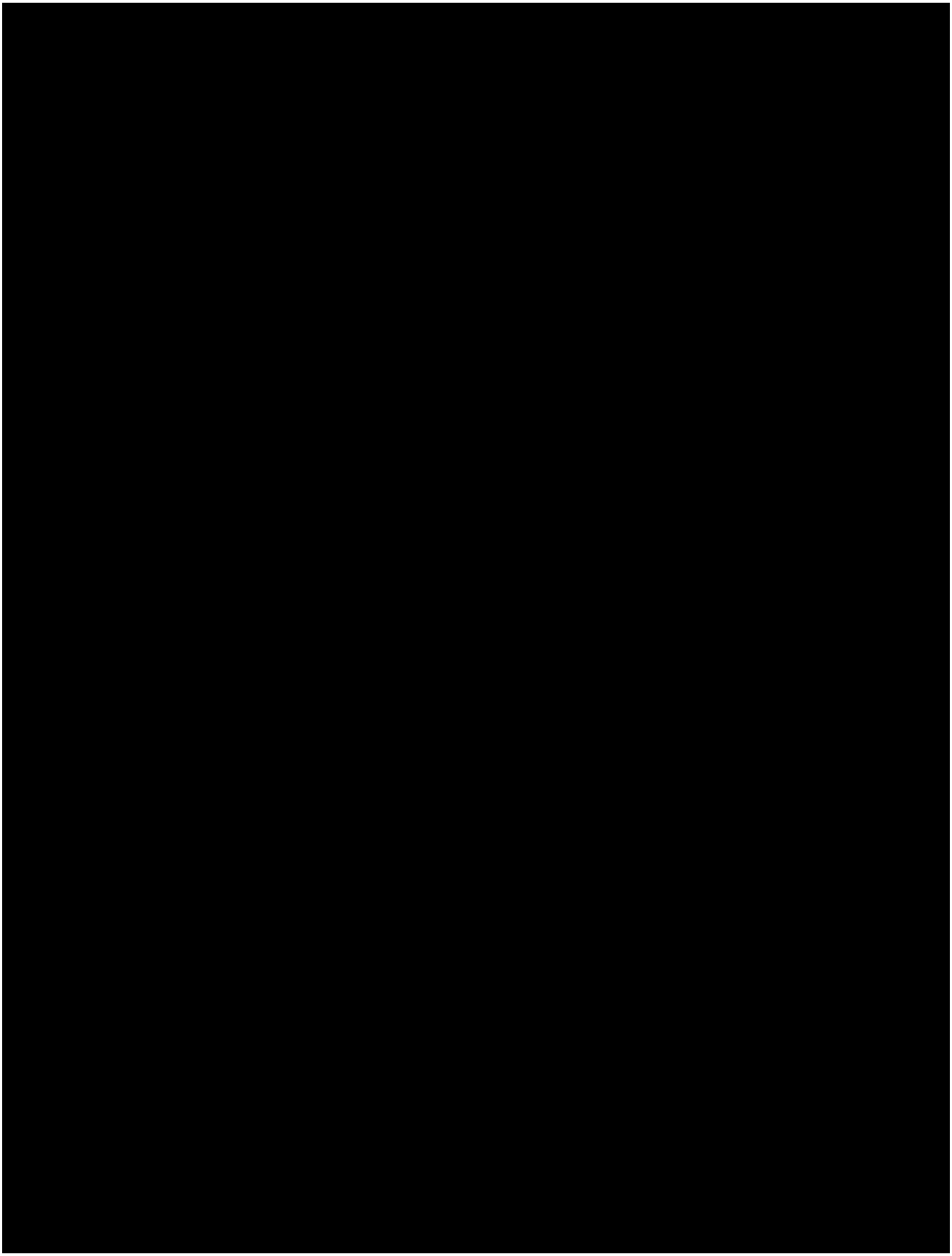
[redacted]

[redacted]

[redacted]

[redacted]

[redacted]



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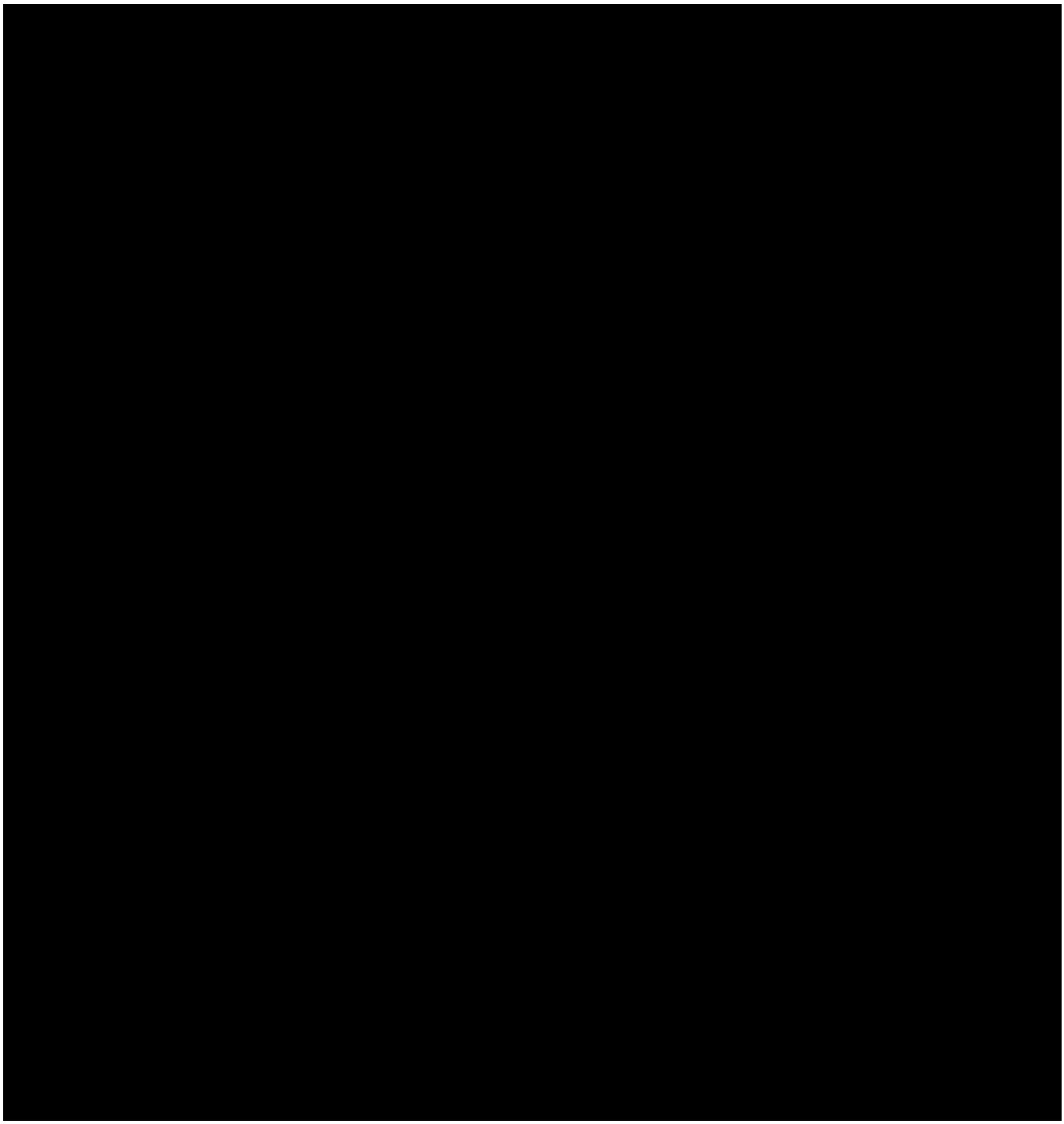

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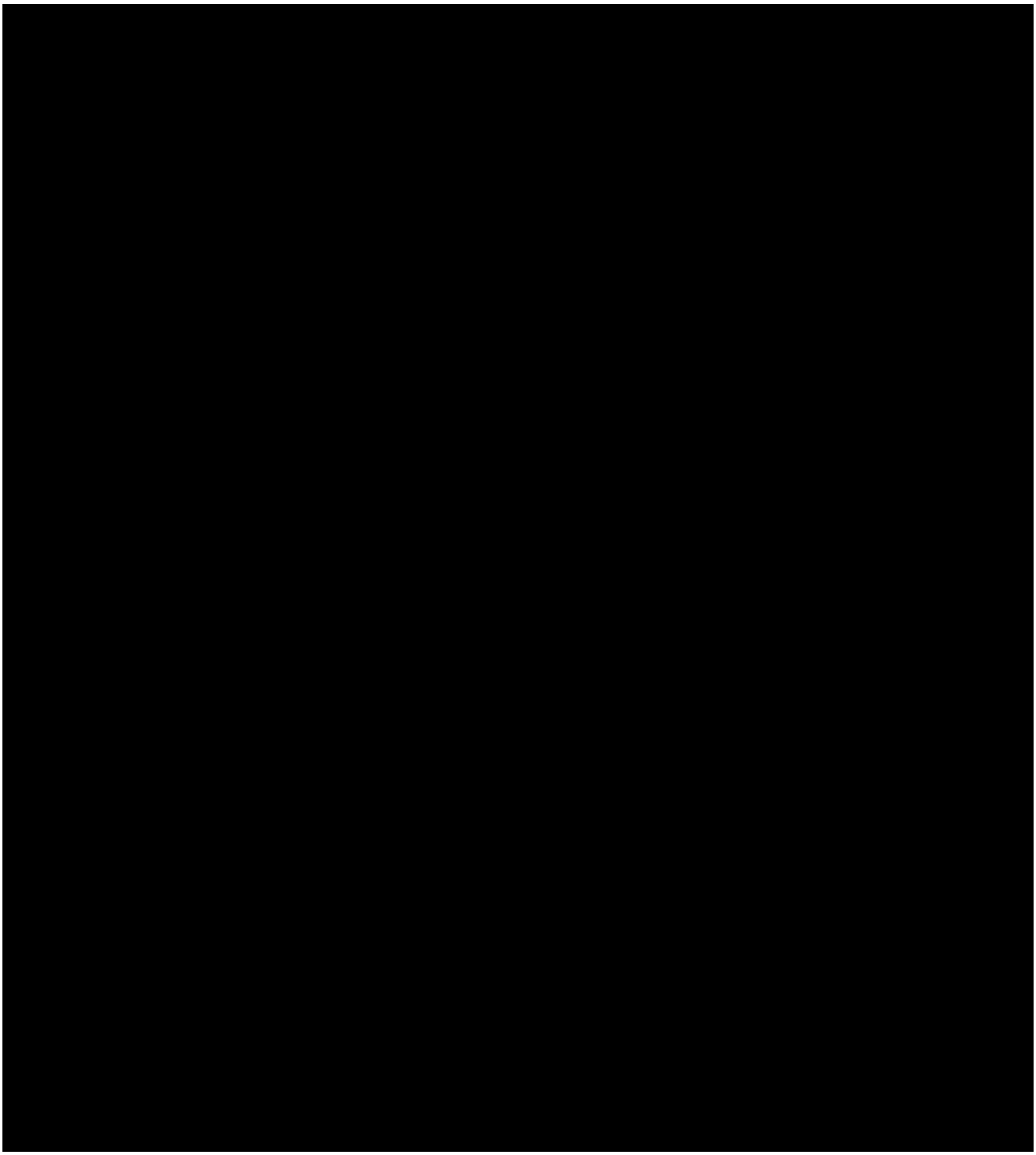


[redacted]

[redacted]

[redacted]

2.7.3 Model Calibration and Validation

Milestone used the extensive publicly available data compiled from the New Mexico OCD to calibrate its dynamic model using sensitivity analysis [redacted]

[redacted]

[redacted]

[redacted]

[4] Oil Conservation Division regulates oil and gas activity in New Mexico

[redacted]

[redacted]

[redacted]

[redacted]

2.8 Corrective Action Introduction

Milestone delineated the AoR for the [redacted] Based on the critical pressure calculations described below, the AoR is equal to the area of elevated supercritical CO_2 gas saturation Milestone then identified, and carefully examined, each well and deep stratigraphic borehole within the AoR to determine whether corrective action is necessary. [redacted]

At least once every 5 years, as specified in **Section 2.12**, or when monitoring and operational conditions warrant, Milestone will:

1) Reevaluate the Area of Review consistent with previous modeling efforts
2) Identify all wells in the reevaluated Area of Review that may require corrective action
3) Perform corrective action on wells requiring corrective action in the reevaluated Area of Review
4) Submit an amended Area of Review and corrective action plan or demonstrate to the Director through monitoring data and modeling results that no amendment to the Area of Review and corrective action plan is needed. Any amendments to the Area of Review and corrective action plan must be approved by the Director, must be incorporated into the permit, and are subject to the permit modification requirements at 40 CFR § 144.39 or § 144.41, as appropriate.

2.9 Critical Pressure Calculations

The methodology for determining critical pressure was sourced from the EPA's *Underground Injection Control (UIC) Program Class VI Well Area of Review Evaluation and Corrective Action Guidance*, [redacted]

[redacted]

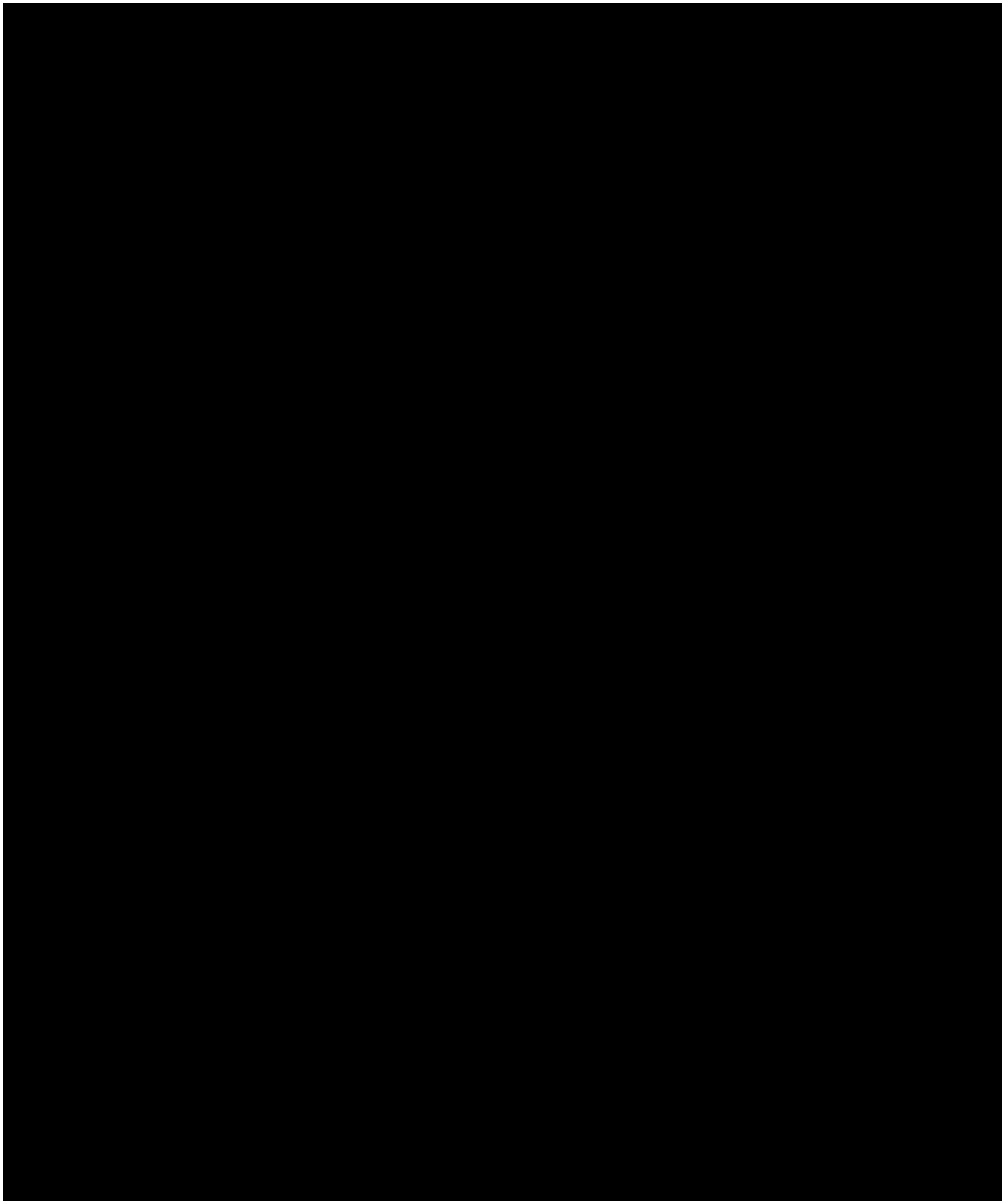
[redacted]

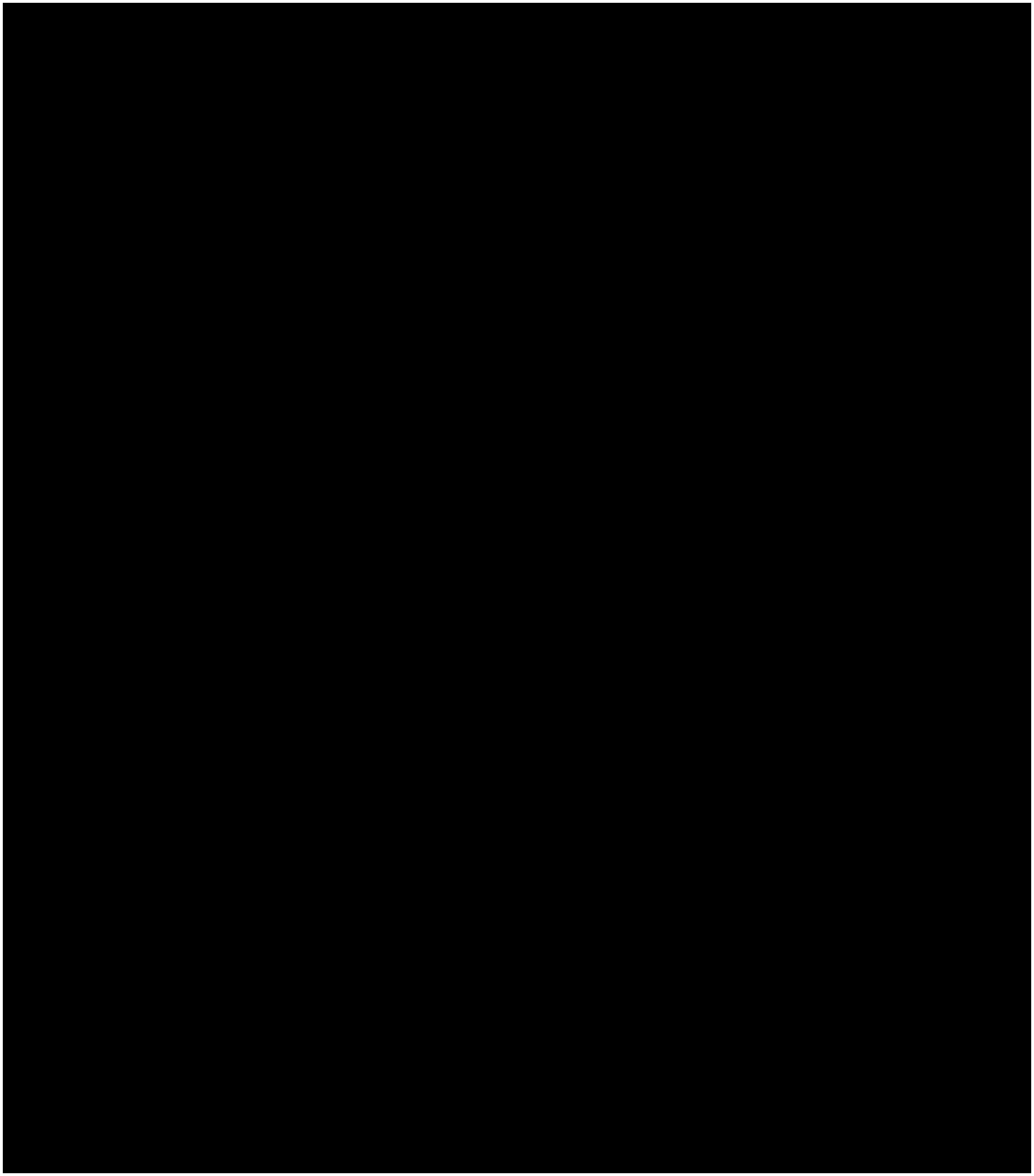
[redacted].

[redacted]

[redacted]

[redacted]





[redacted]

[redacted]

2.11 Tabulation of Wells within the AoR [40.82(a)(4); 146.84(c)(2)]

Milestone evaluated all oil and gas wells, water disposal wells, stratigraphic boreholes, dry holes and plugged and abandoned wells within the AoR based on data from proprietary and commercially operated databases. [redacted]

For all wells identified, available files from the RRC were downloaded and reviewed to confirm total depth and zones penetrated. Milestone also submitted a request to the RRC for non-digital records and reviewed records that exist on microfilm/microfiche at the RRC to confirm no other artificial penetrations exist within the AoR. Based on Milestone's review, [redacted] Not all wells within the AoR had complete records available.

[redacted]

2.12 Re-evaluation Schedule and Criteria

Milestone will reevaluate the above described AoR at least every five (5) years during the injection and post-injection phases.

The procedure used to reevaluate the AoR will be based upon the data collected between reevaluations and the well conditions at the time of reevaluation. Measured data will include injection rates, pressures, indirect pressure and plume measurements and relevant operating conditions of the [redacted] that will inform the dynamic model.

History-matching the dynamic model to measured data, where recorded rates are used as an input to the dynamic model and the input parameters adjusted to match the recorded pressures will be performed. By history matching the recorded data at the Injection Wells, a process of calibration and validation of the model to recorded data will be established. History matching the Injection Wells will continue to inform the dynamic simulation.

Future sensitivity analysis will help to identify model parameters that drive the largest changes in the AoR and plume size. Changes to the input parameters will be entered into the model and the impact to the AoR and plume size calculated incrementally from each change. AoR reevaluations will discuss the following:

- Changes to the monitoring and operational data prior to the scheduled reevaluation date.
- How monitoring and operational data (e.g., injection rate and pressure) have been used to update the geologic model, the computational simulations to determine the AoR.
- Triggers for AoR reevaluations prior to the next scheduled reevaluation.
- Any required corrective action from the new model

Any observations or measured data that are believed to have a material impact on the size of the plume and AoR will trigger a reevaluation of the model and inputs. Any newly-identified wells in the new AoR will be evaluated to determine if corrective action is required. If necessary, corrective action will be performed following federal, state, and local regulations. An amended AoR and corrective action plan will be submitted, or the data and modeling results that indicate no change to the AoR is needed. Milestone will discuss any such events with the UIC Program Director to determine if an AoR reevaluation is required. If an unscheduled reevaluation is triggered, Milestone will perform the following steps:

1. Evaluate the static model assumptions and compare them to any new data or measurements.
2. Evaluate the impact of any changes to the static model by running the simulation and comparing the results to the prior predictions.
3. Evaluate the dynamic model assumptions and compare them to any new data or measurements.
4. Evaluate the impact of any changes to the dynamic model by running the simulation and comparing the results to the prior predictions.

See permit **Section 6** for more information on the testing and monitoring program.

See permit **Section 10** for more information on emergency criteria and response.

Examples of events that may trigger an unscheduled AoR reevaluation, with guidance from the UIC Program Director:

1) [redacted]

2.13 Model Input and Data Retention

Milestone will retain all modeling inputs and data used to support Area of Review evaluations for at least ten (10) years.