

▶ SHALE GAS SERVICES





INNOVATIVE SOLUTIONS FOR UNCONVENTIONAL GAS RESERVOIRS

The rapid expansion and development of the economic reserves of shale gas in North America have major implications for long-term natural gas supply and pricing, growth of gas markets, pipeline infrastructure and climate change strategies in addition to local, basin-specific issues relating to shale gas exploration and production.

At Golder, we understand the criteria, challenges, and regulatory environment required for successful shale gas development. We offer an innovative, multidisciplinary approach to shale gas development, bridging the gap between engineering design and environmental planning and permitting. We provide solutions for the full cycle of development for exploration and characterization, through regulatory and permitting services, reservoir and hydraulic fracturing engineering, production optimization, and pipeline infrastructure. Our integrated shale gas team can assist with project approvals, help maximize production, and reduce overall cost.

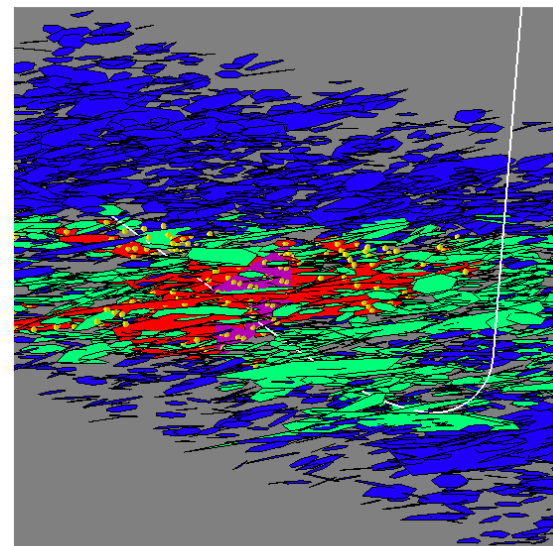
RESERVOIR ENGINEERING AND GEOLOGY

Shale gas production depends on flow controlled by the combination of hydraulic fractures and reactivated natural fracture networks. With over 25 years of experience, Golder's FracMan Technology Group is the world leader in analyzing and evaluating fracture-controlled oil and gas production. Golder applies this experience to shale gas and tight gas using our FracMan® technologies that simulate hydraulic fracturing within the shale, including interaction with the natural fracture network.

Golder's geologists and engineers develop models of the natural and hydraulic fracture system through a quantitative integration of geological, geophysical, and engineering data.

The model provides:

- Characterization of the natural fracture network
- 3-D modeling of hydrofrac propagation through fractured rock
- Mapping of fracture characteristics throughout the reservoir
- Hydrofracture geomechanics and hydrodynamics
- Tributary drainage volume, connectivity, and compartmentalization
- Upscaling to multiphase flow simulators



Results of hydraulic fracture simulation in FracMan

ENVIRONMENTAL PERMITTING

- Permitting for seismic exploration, well siting, and development infrastructure including well pads, roads, pipelines, impoundments, and other related facilities
- Development of bid specifications, well design, and construction
- EIA and NEPA regulatory process management and permitting
- Terrestrial and aquatic habitat surveys and monitoring
- Mitigation and reclamation design, oversight, and monitoring
- Groundwater withdrawal permitting
- Permitting of surface water intake, surface discharge and re-injection
- Aquifer testing
- Water quality testing, treatment alternative analyses and selection and well system engineering
- Client support for interaction with federal, state, county, and city stakeholders.
- Long-Term NORM Management Strategy Development

WATER MANAGEMENT SERVICES Planning and Regulatory

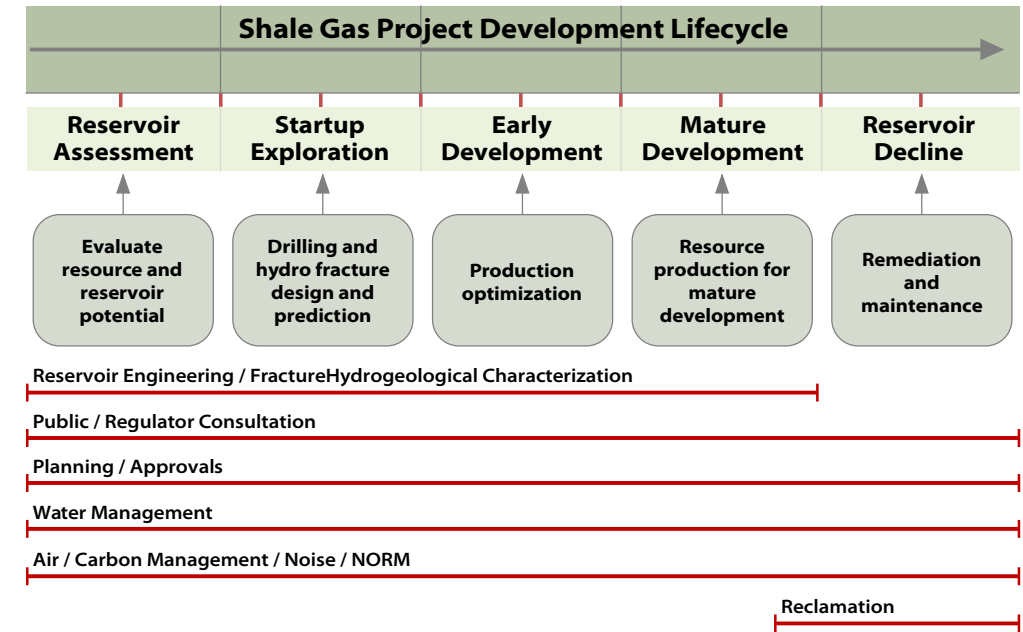
- Hydrology and hydraulic studies
- Water treatment, reuse, deep injection, and conservation
- Water quality assessment
- Permit application and regulatory liaison

Design and Construction

- Pipelines, pump stations, hydraulic transient analysis
- Dams, impoundments, and on and off stream reservoirs
- Water intakes

Hydrogeological Services

- Aquifer and aquitard characterization
- Water supply siting and permitting
- Production and injection well design
- Well-head protection analyses
- De-watering design and analysis
- Groundwater modeling
- Contaminant assessment
- Hydraulic and tracer testing, including two phase flow, low-permeability, at depth (up to 2000'), and fractured rock
- Baseline and long-term groundwater quality monitoring
- In situ stress measurement
- Hydrodynamic and well test analysis
- Tool design, including wells up to 14" diameter
- Allocation modeling and system optimization suite



AIR QUALITY MANAGEMENT, NOISE AND ACOUSTIC ENGINEERING

Air Permitting and Compliance Management

- Regulatory applicability determination
- Agency negotiation and litigation support
- New source review, Title V and PSD permitting
- Compliance management program development

Ambient Monitoring and Field Assessment

- Criteria pollutant, air toxics, and noise monitoring
- Dispersion meteorology monitoring
- Odor and indoor air exposure assessment

Project Impact Analysis

- Emissions inventory development
- Air quality and acoustic modeling
- Accidental release simulation and exposure assessment
- Emission Control Engineering
- BACT/RACT/LAER/MACT/BART/CAIR/CAMR studies

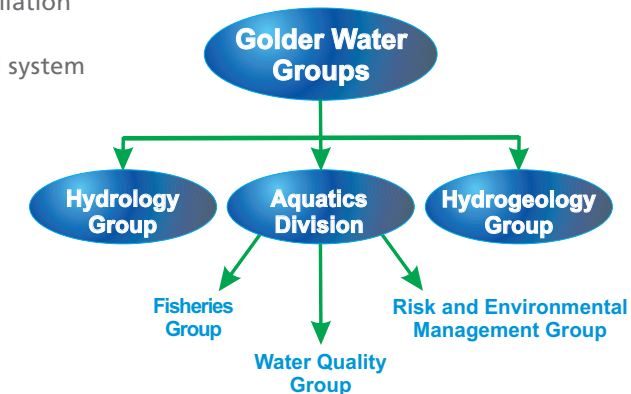
Emissions Control Specification and Design

- System procurement and installation management
- Source monitoring and control system performance assessment

SUSTAINABLE SOLUTIONS

- We work with our clients on the interaction between people, the environment, and economics to arrive at sustainable solutions. Golder's social and stakeholder engagement specialists have wide-ranging experience in achieving social and economic project outcomes to maximize community benefits in often contentious and technically complex projects.
- Sustainable development policy and planning, audits, and certification
- Metrics and reports
- Stakeholder engagement
- Environmental and social impact assessment
- Canadian First Nation and Native American cultural awareness training

Golder provides seasoned experience, proven technologies, and a commitment to bringing your gas from shale to market.



MAKE YOUR BUSINESS DECISIONS ON A SOLID FOUNDATION.
CHOOSE A COMPANY WITH THE TECHNICAL EXPERIENCE AND COMMITMENT
TO SERVICE EXCELLENCE AND SUSTAINABILITY THAT YOU NEED TO BE SUCCESSFUL.

JUST ASK GOLDER



ENGINEERING EARTH'S DEVELOPMENT, PRESERVING EARTH'S INTEGRITY.

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