PNGE 480
Petroleum Engineering Design

West Virginia University
Lab Friday 3:00-5:20 (ESB-EG3)

Instructor
Dr. Ebrahim Fathi
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TA
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Office Hours: M W R 11:00-13:00 or by appointment

Course Definition:

Comprehensive problems in design involving systems in unconventional gas reservoir characterization, drilling and completion and production

Pre- and co-requisites:

You must have the following pre- and co-requisites to be eligible to attend in this course:

Co-req: PNGE 450

Pre-req: PNGE 420 and PNGE 434 and PNGE 441

Expected Learning: Outcomes: Upon successful completion of this course:

a. Student will learn how to Apply knowledge of Math, Science, and Engineering 10.0% Projects
b. Student will learn how to Design & Conduct Experiments, Analyze & Interpret Data 10.0% Projects
c. Student will learn how to Design a System or Component 20.0% Projects
d. Student will be able to Function on Multi-Disciplinary Teams 10.0% Projects
e. Student will be able to Identify, Formulate and Solve Engineering Problems 15.0% Projects
f. Student will learn Professional & Ethical Responsibility 3.0% Projects
g. Student will learn how to Communicate Effectively 2.0% Projects
h. Student will be able to quantify the Impact of Engineering Solutions in Global and Social Context 5.0% Projects
I. Student will learn how To Engage in Life-Long Learning 5.0% Projects
j. Student will learn Knowledge of Contemporary Issues 5.0% Projects
k. Student will Use Modern Engineering Tools Necessary for Engineering Practices 15.0% Projects Total 100.00%

Policy:

- Progress reports/presentations:40%
- Midterm presentation: 20%
- Final Project Report: 20%
- Final Project Presentation: 20%
- Late projects: Not accepted.
- Attendance: Required.

(Attendance in laboratory and lecture sessions are required, however if you cannot attend in class you need to inform instructor prior to the class. More than two unauthorized absents results in %5 deduction from your final grade, if you miss more than 3 sessions you will lose %10 from your final grade and more than 4 unauthorized absents results in failing the course with grade F.)

- Only Team leaders will be directing the questions regarding the project to TA or instructor.
- Only Team leader submits the reports other submissions are will not be considered.

Grade Assignment:

100 – 96	A+	95.99 – 90	A
89.99 – 87	A-	86.99 – 84	B+
83.99 – 80	B	79.99 – 77	B-
76.99 – 74	C+	73.99 – 70	C
69.99 – 65	C-	64.99 – 60	D
59.99 – 0	F		

Course Outline

Week	Subject
1-2	**PHASE I**
	Perform a literature review and have summary report on current knowledge of best practices for reservoir modeling, completion design, and forecasting based on published information and your field engineers' experience. Petrophysics and well logging- Application of Petra IHS (Petra® is a solution software for data management, manipulation, visualization and integration of geological, geophysical and engineering data).
	Progress Report 1
3-4	**PHASE II**
	Developing Shale reservoir Model using CMG GEM Compositional model

	Data Collection and Preparation Initial Reservoir Conditions Well Information PVT Information and Fluid Properties Developing the Model Using Builder Pre Processor from CMG Drilling a horizontal well Performing multi-stage hydraulic fracturing of the horizontal well
	Progress Report 2
5	**PHASE III**
	Performing sensitivity analysis for determining the overall variation of simulation results under different parameter values and/or which parameters have the greatest effect on simulation results (well bottom-hole Pressure; cumulative Oil, Gas and Water production, etc).
	Progress Report 3
6-7	**Phase IV**
	Performing History matching to match the field production and rates and to generate a proxy model for forecasting and development purposes using CMG **CMOST**
	Progress Report 4
8-9	**PHASE V**
	Performing Rate Transient Analysis RTA using conventional and advanced analysis techniques for unconventional reservoirs using **IHS HARMONY**
	Progress Report 5
10	**PHASE VI**
	Evaluate the basic reservoir and fracture properties from a diagnostic fracture injection test (DFIT) that was conducted in the field and obtain pore pressure and fracture closure pressure and use these values for running your model
	Progress Report 6
11-12	**PHASE VII**
	Performing hydraulic fracture analysis in the case of slick water frac job for various sand schedules using **FRACPRO**
	Progress Report 7
13	**PHASE VIII**
	Economic analysis/
14	**Final presentation (20 minutes each group)**

Text Book:

It is highly recommended to have Hydraulic Fracturing in Unconventional Reservoirs
Theories, Operations, and Economic Analysis
Authors: Hoss Belyadi Ebrahim Fathi Fatemeh Belyadi

References:

All the textbooks used in Petroleum Engineering courses that you have taken so far.

Academic Integrity

The integrity of the classes offered by any academic institution solidifies the foundation of its mission and cannot be sacrificed to expediency, ignorance, or blatant fraud. Therefore, I will enforce rigorous standards of academic integrity in all aspects and assignments of this course. For the detailed policy of West Virginia University regarding the definitions of acts considered to fall under academic dishonesty and possible ensuing sanctions, please see the Student Conduct Code http://studentlife.wvu.edu/office_of_student_conduct/student_conduct_code. Should you have any questions about possibly improper research citations or references, or any other activity that may be interpreted as an attempt at academic dishonesty, please see me before the assignment is due to discuss the matter. You also need to go to the http://www.libraries.wvu.edu/instruction/plagiarism/ and pass the test and report your passing grade to the instructor.

PNGE 480 Final Project

You are a project manager of Marcellus North division and you have been assigned to optimize your field by defining the optimum hydraulic fracture sand schedule followed by obtaining the net present value of the well in order to provide guidance to the analyst on the true intrinsic value of the well. The purpose of this project is as follows:

1. Find the optimum economic sand design schedule
2. Find the BTAX and ATAX NPV of the well using various pricing provided at the end of this project

Below are the steps that must be taken to complete this project:

a) Perform a literature review and have summary report on current knowledge of best practices for reservoir modeling, completion design, and forecasting based on published information and your field engineers' experience.
b) Perform petrophysical analysis on your well to find the basic reservoir properties.
c) Build a shale gas reservoir model using CMG GEM and perform horizontal well drilling and multi-stage hydraulic fracturing.
d) Perform sensitivity analysis and uncertainty quantification (CMG CMOST).
e) Perform history-matching to match the filed production data (CMG CMOST).
f) Perform well performance analysis (IHS HARMONY).
g) Evaluate the basic reservoir and fracture properties from a diagnostic fracture injection test (DFIT) that was conducted in the field and obtain pore pressure and fracture closure pressure and use these values for running your model. (Refer to chapter 14 of the book)
h) The formation in focus is brittle with high young's modulus and low Poisson's ratio and is ideal for slick water frac job. Therefore, use the workflow for designing a slick water frac job for various sand schedules of 1000 lb/ft, 1500 lb/ft, 2000 lb/ft, 2500 lb/ft, 3000 lb/ft, 3500 lb/ft, and 4000 lb/ft using 40% 100 mesh, and 60% 40/70 mesh sand size. The type of 40/70 mesh sand type must be determined using the closure pressure obtained from the DFIT. When creating these sand/ft schedules, keep your sand concentrations the same across all sand stages (e.g. 0.25 ppg, 0.5 ppg, 0.75 ppg, etc.) and only change the amount of clean water volume for each sand stage to obtain the aforementioned sand/ft loadings. (Refer to chapter 10 Fracture Treatment Design)
i) Once each sand schedule is created, take these sand schedules into preferred commercial fracture software such as FracPro and run these sand schedules in the fracture software to obtain fracture geometry for each design (propped half-length, propped width, propped conductivity). After obtaining fracture geometry for each design, write down a summary of the fracture geometry of each design. Finally, take the fracture geometry of each design and obtain

production rate vs. time for each scenario that was obtained numerically using CMG GEM compositional simulator. The propped half-length obtained from each design must provide some guidance on well spacing. For the sake of time, run each numerical simulation (7 cases) for 10 years only, as the first 10 years are the most important value creation during the life of a well.

j) Next, take the production rate vs. time for each scenario and perform BTAX and ATAX economic analysis following the step-by-step workflow in chapter 18. Plotting ATAX NPV vs. various sand schedules of 1000, 1500, 2000, 2500, 3000, 3500, and 4000 lb/ft, there is an optimum sand schedule based on the highest NPV of all sand designs (use $3/MMBTU gas price and the assumptions listed at the end of this project).

k) Next, run a modified hyperbolic decline curve fit through the optimum sand schedule production volume vs. time that was obtained numerically to obtain the production rate vs. time for 50 years instead of the first 10 years that was obtained numerically. Assume a terminal decline rate of 5% and use a hyperbolic exponent (b value) of between 1.0 and 1.7 to fit your decline curve to the numerical decline curve that was obtained for the optimum sand design schedule. Record the modified decline curve parameters and use the monthly volumes generated from this decline curve to run all your economic analysis going forward.

l) Obtain the BTAX and ATAX NPV at each pricing below from the modified hyperbolic decline fit and obtain the well NPV at various pricing listed below):

- $2.5/MMBTU gas pricing escalated using a monthly stair step fashion at 3%/year
- $3.0/MMBTU gas pricing escalated using a monthly stair step fashion at 3%/year
- $3.5/MMBTU gas pricing escalated using a monthly stair step fashion at 3%/year
- $4/MMBTU gas pricing escalated using a monthly stair step fashion at 3%/year
- Using NYMEX provided with this project followed by 3%/year monthly stair step fashion at the end of the last provided NYMEX pricing

Economic assumptions below can be used for the above tasks:

1- BTU= 1060 BTU/SCF (dry gas)

2- Shrinkage= 1% (or 0.99 shrinkage factor due to line losses and fuel at the compressor station) Use the numerical 10-year decline curve (rate vs. time and use the modified hyperbolic decline curve obtained by fitting through the numerical data for 50 years.

3- Variable lifting cost= $0.22/MCF escalated using a monthly stair step fashion at 3%/year

4- Fixed lifting cost= $100/month/well escalated using a monthly stair step fashion at 3%/year

5- Variable gathering cost= $0.3/MMBTU escalated using a monthly stair step fashion at 3%/year
6- Firm transportation (FT) cost= $0.2/MMBTU escalated using a monthly stair step fashion at 3%/year
7- WI= 100%
8- NRI= 85%

For your NYMEX use the info from Henry Hub Natural GAs Future quotes and use the average price, for after July 2019 use 3 percent escalation (http://www.cmegroup.com/trading/energy/natural-gas/natural-gas.html)
For your tax assume 38% of cooperation tax
11% Tangible
89% intangible
Discount rate of 10%

Sand/ft (lb/ft)	Total Capex ($)
1000	$5,200,000
1500	$5,572,794
2000	$5,940,054
2500	$6,306,902
3000	$6,667,476
3500	$7,024,782
4000	$7,374,492