TITLE: ECONOMIC RECOVERY OF OIL TRAPPED AT FAN MARGINS USING HIGH ANGLE WELLS AND MULTIPLE HYDRAULIC FRACTURES

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Objective

This project attempts to demonstrate the effectiveness of exploiting thin-layered, low-energy deposits at the distal margin of a prograding turbidite complex through the use of hydraulically fractured horizontal or high-angle wells. The combination of a horizontal or high-angle well and hydraulic fracturing will allow greater pay exposure than can be achieved with conventional vertical wells while maintaining vertical communication between thin interbedded layers and the wellbore.

A high-angle well will be drilled in the fan-margin portion of a slope-basin clastic reservoir and will be completed with multiple hydraulic-fracture treatments. Geologic

modeling, reservoir characterization, and fine-grid reservoir simulation will be used to select the well location and orientation. Design parameters for the hydraulic-fracture treatments will be determined, in part, by fracturing an existing test well. Fracture azimuth will be predicted by passive seismic monitoring of a fracture-stimulation treatment in the test well using logging tools in an offset well.

Summary of Technical Progress

The long radius, near horizontal well was drilled during the first quarter of 1996. Well conditions resulted in the 7 in. production liner sticking approximately 900 ft off bottom. Therefore, a 5 in. production liner was necessary to case this portion of the target formation.

Swept-out sand intervals and a poor cement bond behind the 5 in. liner precluded two of the three originally planned hydraulic fracture treatments. As a result, all pay intervals behind the 5 in. liner were perforated and stimulated with a non-acid reactive fluid.

Following a short production period, the remaining pay intervals in the well (behind the 7 in. liner) were perforated. The well was returned to production to observe production trends and pressure behavior and assess the need to stimulate the new perforations.

Completion Operations

Production Performance

Yowlumne Unit B 91X-3 was originally completed by perforating all pay intervals behind the 5 in. production liner. This primarily included Sand C and a small interval at the base of Sand B (Fig. 1). The perforations were then stimulated with a non-acid reactive fluid consisting of a blend of KCl water, iron chelating agents, mutual solvents, and surfactants.

The initial production rate was 220 BOPD and 20 BWPD. However, in less than two and one-half months oil production had declined to 160 BOPD, and water cut had increased to 35% (Fig. 2). The gas-oil ratio (GOR) remained fairly constant at 450 SCF gas per STB oil.

Additional Wellwork

Because of production decline, additional pay intervals were perforated in Sands A and B, behind the 7 in. production liner, in November 1997 (Fig. 1).

The well was returned to production without stimulation. The initial production rate was approximately 220 BOPD and 20 BWPD. However, after a month and a half the well had declined to 150 BOPD and 150 BWPD, similar to the pre-wellwork rate (Fig. 2).

Inflow performance relationship (IPR) curves were established by layer (Fig. 3). The 240 BPD total liquid rate for Sand C represents the initial production rate from the lower perforations. Perforating Sands A and B were expected to add 170 BPD, however the actual increase was only 80 BPD.

After production peaked at approximately 150 BOPD and 150 BWPD, a decline in oil production set in. An attempt was made to change the hydraulic jet pump, which was last changed in January 1998. This attempt was unsuccessful when the pump became stuck in the bottomhole assembly. The well continued to produce until a rig was available for service. Late in the third quarter, with the rig on the well, another attempt was made to fish the pump. Fishing operations were unsuccessful, requiring the tubing to be pulled. The bottomhole assembly and pump where changed out, and the well was returned to production. This service job accounts for the change in production (Figure 1).

Future Plans

Production surveillance seems to indicate the upper perforations added in November 1997 are performing poorly and will not clean up thorough continued production. Stimulation will be necessary to remove wellbore skin.

Subject to economics associated with current low oil prices, one stimulation alternative being evaluated is similar to an earlier stimulation of the lower perforations. A non-acid reactive fluid consisting of a blend of KCl water, iron chelating agents, mutual solvents, surfactants, and nitrogen was pumped through coiled tubing into the lower perforations. This treatment of the original completion interval successfully increased production from a trace of oil and 40 BWPD to 220 BOPD and 20 BWPD.

Following stimulation of the upper perforations, the well would be produced for a period of time to clean up and observe production trends and pressure behavior. Based on these results, a hydraulic fracture treatment may be considered for these perforations.

Technology Transfer

Open File

An "open file" was established at the beginning of this project with the California Division of Oil, Gas, and Geothermal Resources (DOGGR). It is updated a minimum of every quarter with technical reports and other pertinent data. The open file is available to the public, and is intended to be useful to operators of slope-basin clastic reservoirs, particularly in California.

Technical Papers, Presentations, Workshops

Technical Papers and Presentations

Dr. M.S. Clark presented the geologic framework and reservoir description of the Yowlumne field on November 11, 1997 at the Pacific Coast Oil Show in Bakersfield, California.

Dr. M.S. Clark published the following paper: *Characterization and Exploitation of the Distal Margin of a Layered, Low-Permeability Turbidite Reservoir, Yowlumne field, San*

Joaquin Basin, California, Houston Geological Society Bulletin, v. 40, pp. 12-15, December 1997.

Dr. M.S. Clark presented a paper titled *Reservoir Characterization of a Fan-Shaped Turbidite Complex in an Active-Margin Basin, Miocene Stevens Sandstone, Yowlumne Field, San Joaquin Basin, California* at the EAGE/AAPG Third Research Symposium on DEVELOPING AND MANAGING TURBIDITE RESERVOIRS: CASE HISTORIES AND EXPERIENCES in Almeria, Spain on October 4-9, 1998.

Workshops

A public workshop was held on August 20, 1998 in Bakersfield, California. The workshop addressed three major aspects of this project: 1) project area geology, 2) hydraulic fracturing operations of the test well, and 3) objectives, planning, drilling operations, and completion operations of the new well.

A compact disc containing information about this project was distributed at the workshop and to those unable to attend. Information on the disc can be viewed utilizing a web browser.

Invitations to the workshop were mailed to 114 oil and gas professionals. There was a good response to this technology transfer session, with 71 people attending. The attendees represented 26 operators and agencies from four different states.

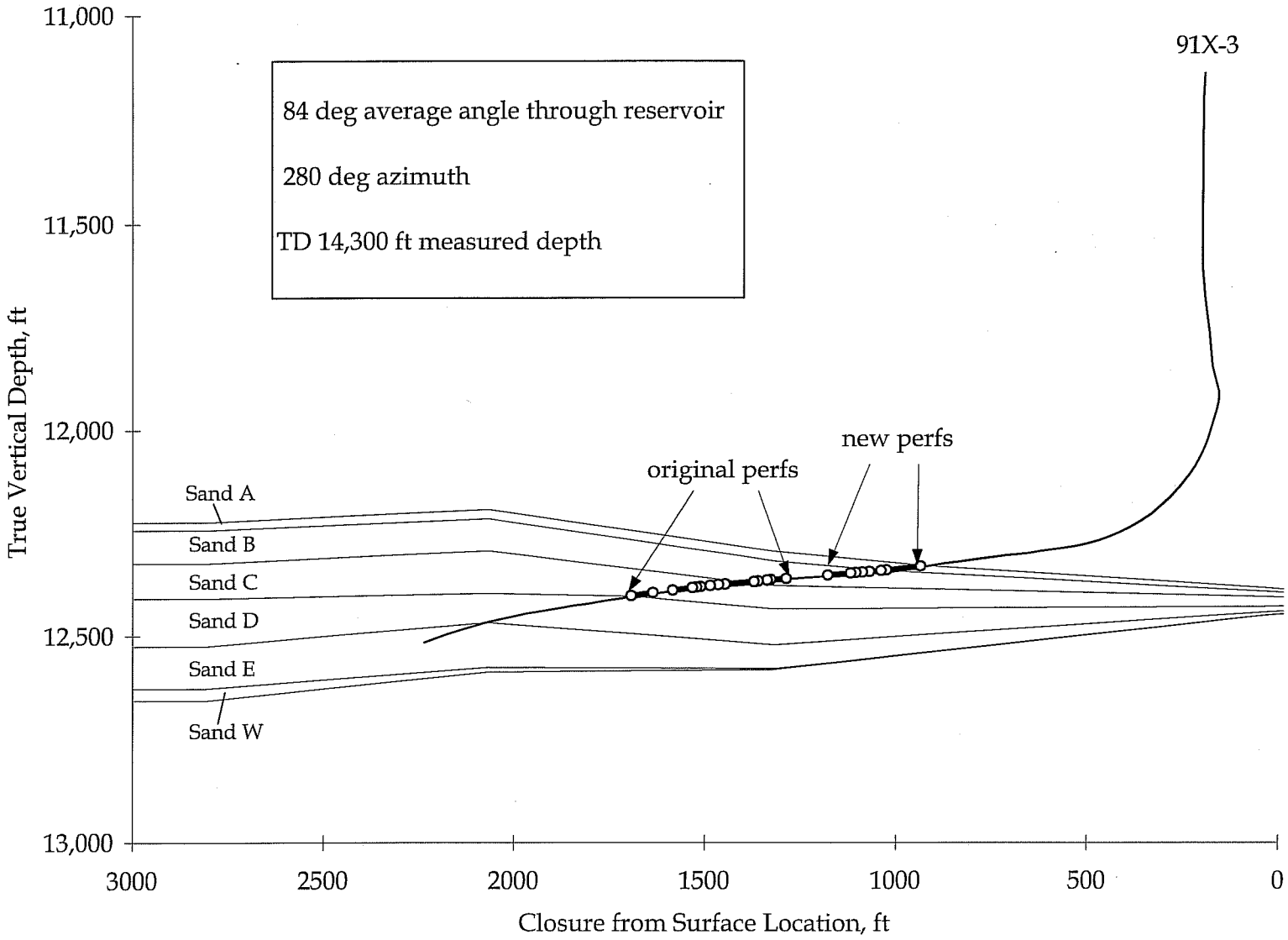

Figure 1. Actual well path relative to major Yowlumne sand intervals. Also shown are existing perforated intervals.

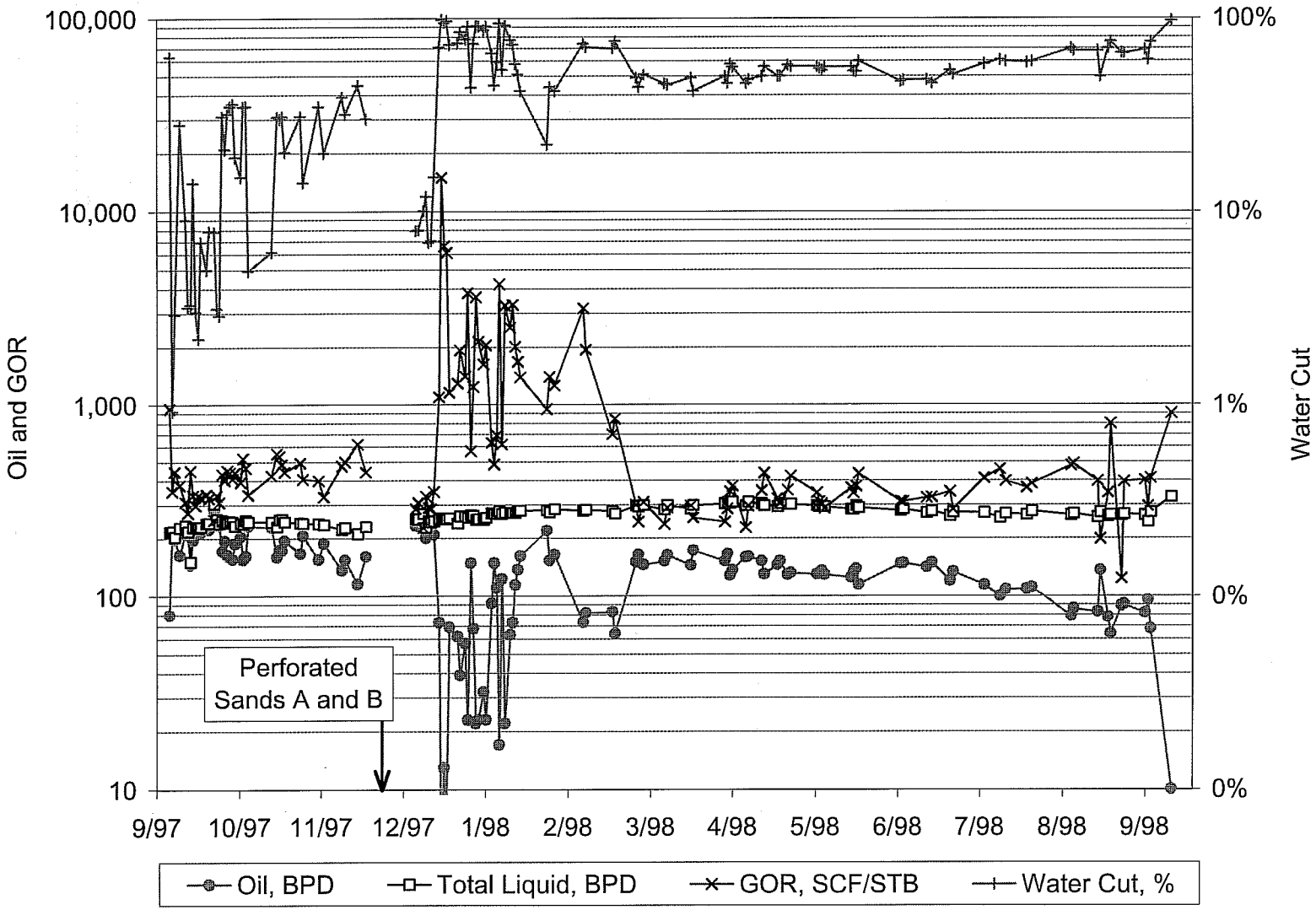

Figure 2. Yowlumne Unit B 91X-3 well tests.

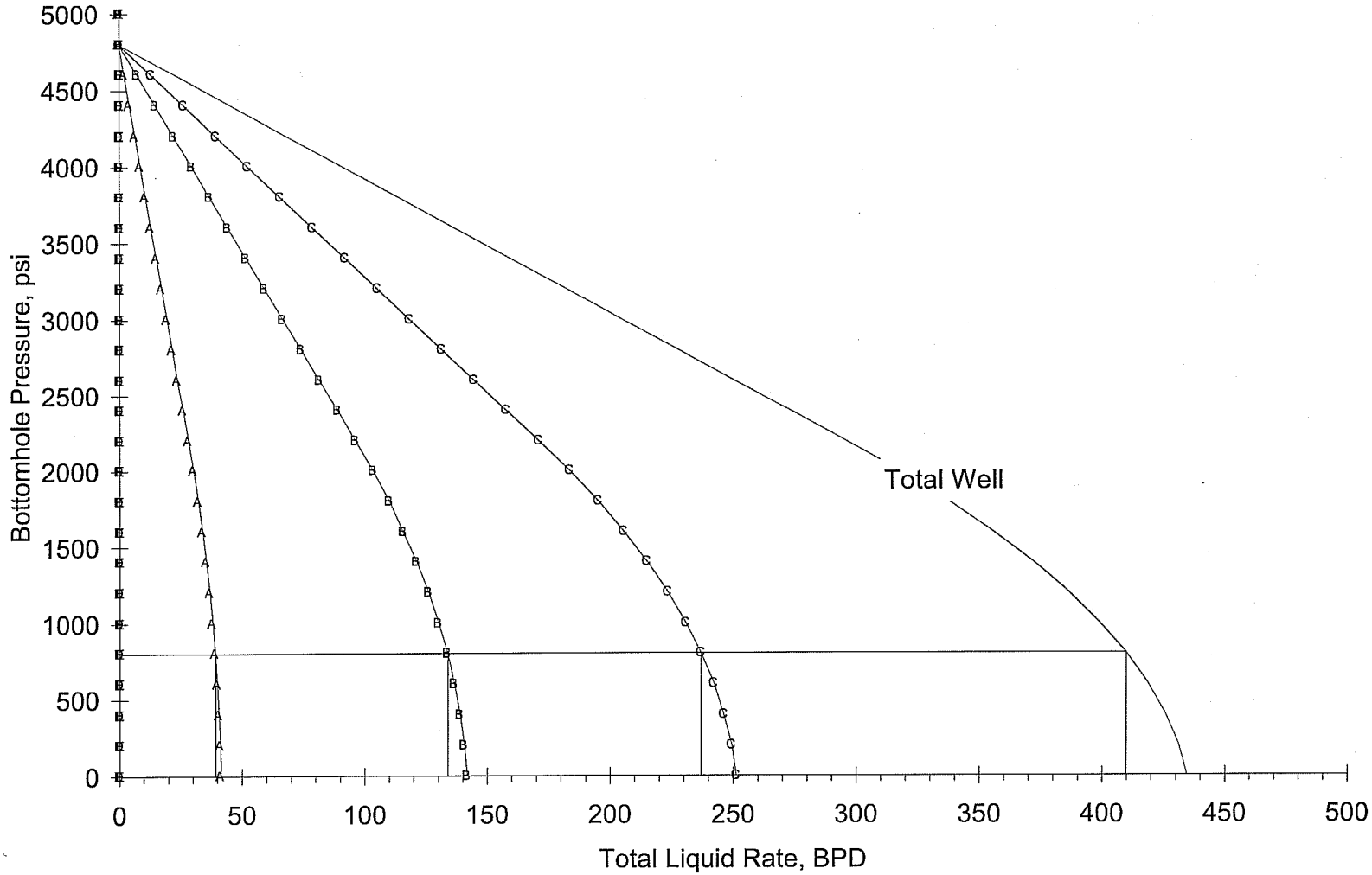

Figure 3. Vogel IPR curve for Sand C and expected IPR curves for Sands A and B.