Optimal Gridding Selection for Field-Scale Reservoir Simulation of a Channelized Deepwater System*

Casey Meirovitz¹, Lisa Stright², Stephen M. Hubbard³ and Brian W. Romans⁴

Abstract

Sub-seismic scale heterogeneity in channelized deepwater reservoirs can lead to significant uncertainty in reservoir connectivity and predicted performance. Though bed-scale heterogeneity can influence reservoir performance, reservoir simulation typically requires cell sizes much greater than the scale of internal channel architecture. Fine-scale sector models consisting of two stacked channel segments were used previously to quantify the influence of bed-scale heterogeneity and channel stacking on reservoir performance. Systematic upscaling and local grid-refinement are utilized here to optimize model construction for field-scale reservoir performance prediction while preserving key flow behaviors observed in fine-scale sector modeling.

Outcrop characterization of deepwater channels from the Tres Pasos Formation of the Magallanes Basin in Chile provided the framework (internal architecture and cross-sectional geometry) for each dynamic simulation. Twelve fine-scale sector models (cells 2 m x 2 m x 0.25 m) representing a range of potential offset angles and distances between two straight channel segments served as the “base-case” for upscaled model performance evaluation. Flow was induced between a single injector-producer well-pair completed 500 meters apart in opposing channel margins. Two different styles of gridding were tested for each of the 12 scenarios: (1) cartesian; and (2) conformable gridding. A range of vertical (0.25 to 2 m) and lateral (2 to 100 m) cell sizes were tested for each gridding style. Effective reservoir properties were calculated initially using flow-based averaging. History matching of upscaled and fine-scale results evaluated cumulative production, well flow rates, pressure, recovery efficiency, water breakthrough timing, and simulation runtime. Conformable gridding with cells 30 m x 30 m x 1 m most efficiently replicated high resolution simulation results for all 12 stacking scenarios. To obtain greater flexibility in defining channel fill architectures (a deterministic fill pattern was used previously), observed trends and distributions were used to geostatistically define net sand on the 30 m X 30 m x 1 m grids. Porosity and directional permeability were then assigned using the distributions of these properties and relationship to net sand taken from earlier upscaled models. Simulated results from the non-deterministic upscaled models match earlier fine-scale simulation results within 5% error. The methodology and results presented here provide the framework for future efforts to evaluate the influence of inter- and intra-channel architecture on reservoir performance prediction at the field-scale.
References Cited


Casey Meirovitz1, Lisa Stright2, Brian W. Romans3, and Stephen M. Hubbard4
1Geology and Geophysics, University of Utah, 2Colorado State University, 3Geosciences, Virginia Tech, 4Geoscience, University of Calgary

Geologic Background and Study Area
The Late Cretaceous Tres Pasos Formation consists of a turbidite-dominated succession that records the terminal phase of deep-water deposition in the Magallanes foreland basin, southern Chile. Slope channel deposits accumulated along a high-relief margin (>1 km relief) along a depositional profile ~40 km long (Hubbard et al., 2010). This study focuses on a 120 m thick and 2.5 km long sandstone-rich succession of slope channel strata located adjacent to Laguna Figueroa. 3D exposures along a depositional dip oriented transect enables well constrained mapping of channel architecture.

Objectives
1) Systematically upscale a deep-water channelized turbidite reservoir for field-scale reservoir performance prediction while preserving key flow behaviors observed in high-resolution sector modeling.
2) Utilize detailed outcrop characterization and statistics to represent observed internal channel fill heterogeneities, facilitating future investigation of variations in fill geometries and facies proportions.
3) Quantitatively assess error introduced through upscaling methods.
4) Create and test a field-scale dynamic model of the Lower Laguna Figueroa channel complex set.

“Fine-Scale” Geologic Heterogeneity and Reservoir Performance Prediction
Reservoir performance is strongly impacted by heterogenous marginal facies, especially when channels are laterally stacked. Upscaling trends to under-represent marginal facies resulting in overprediction of reservoir volumes and intra-channel dynamic connectivity.

High resolution sector modeling (Meirovitz et al., 2016) shows oil production and water breakthrough are slowed by the baffling effect of marginal facies. Introducing 1.5 meters of vertical offset increases the average production rate by 20%, also resulting in water breakthrough 284 days earlier. Upscaling of the simulation grid and reservoir properties must be designed to capture these effects.

High Resolution Sector Models As “Base Case” for Upscaling
Sector models capture twelve stacking patterns designed to represent a range of possible channel migration behaviors. Offset angle varies from 0° (lateral) to 90° (vertical). Offset distance is either short (1/4 channel width) or long (1/2 channel width).
Multiple options for grid upscaling were investigated before arriving on an "optimal" grid design. Reservoir properties are upscaled to the new grid using flow-based upscaling and arithmetic averaging.

All 12 sector models are treated as a single case with adjustments to reservoir properties applied across all 12 realizations.

Geostatistical realizations of internal channel architecture are created using geometric trends and property distributions/relationships extracted from the upscaled deterministic models.

Porosity, permeability, and Net:Gross sand distributions are adjusted to match simulated results to the "base-case" simulations.

Upscaling methods and statistics are applied to the 600m cell field-scale geologic model and results verified. This upscaled model provides the basis for ongoing investigation.

Multiple grid options are shown for a single model realization. A combination of qualitative criteria (preservation of channel form/growth/internal fill architecture) and flow simulation results were employed in selecting an "optimal" channel cell size. A conformable grid with 30m x 30m cell size best met these criteria considering all 12 stacking patterns.

A range of cell thicknesses (0.25 to 2 m) were explored using the same selection criteria as above. Ultimately a 1 m cell thickness was selected. Upscaling to a 30m x 30m x 1 m grid reduces the total number of cells by a factor of 900.

Development of Geostatistical (Non-Deterministic) Realizations

Above and Right: Flow-chart outlining process for developing geostatistical, non-deterministic upscaled simulations consistent with original high-resolution sector models. A non-deterministic representation of observed internal channel architecture is required for future field-scale simulations designed to capture channel fill asymmetry and variations in Net:Gross sand.

Conclusions and Next Steps

1) A process of systematic upscaling has been demonstrated which makes possible field-scale reservoir modeling of the Laguna Figueroa outcrop while preserving simulated fine-scale reservoir behaviors.

2) Process derived statistics make possible stochastic representation of internal fill architecture, facilitating future efforts to quantify the influence of asymmetric channel fill and variable channel-scale Net:Gross sand on 3D reservoir volumetrics/performance prediction.

3) The ability to fully capture the baffling effect of marginal facies in purely laterally offset channel elements remains elusive and is a topic for future research.

4) Ongoing efforts to extract facies geostatistics/trends from the Laguna Figueroa outcrop (Tres Pasos Fm.) promises to provide improved outcrop-based detail for future modeling.

A Special Thanks

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