SPE Distinguished Lecturer Program

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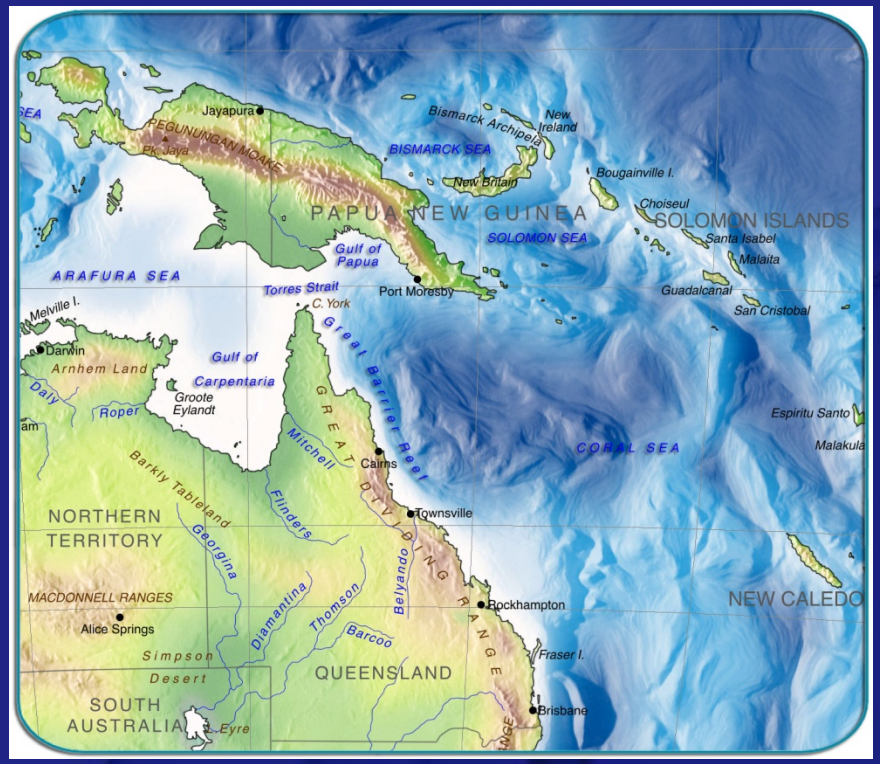
Mature Fields : Keep Revisiting the Fundamentals

Dr. Neil Williams

Oil Search Limited



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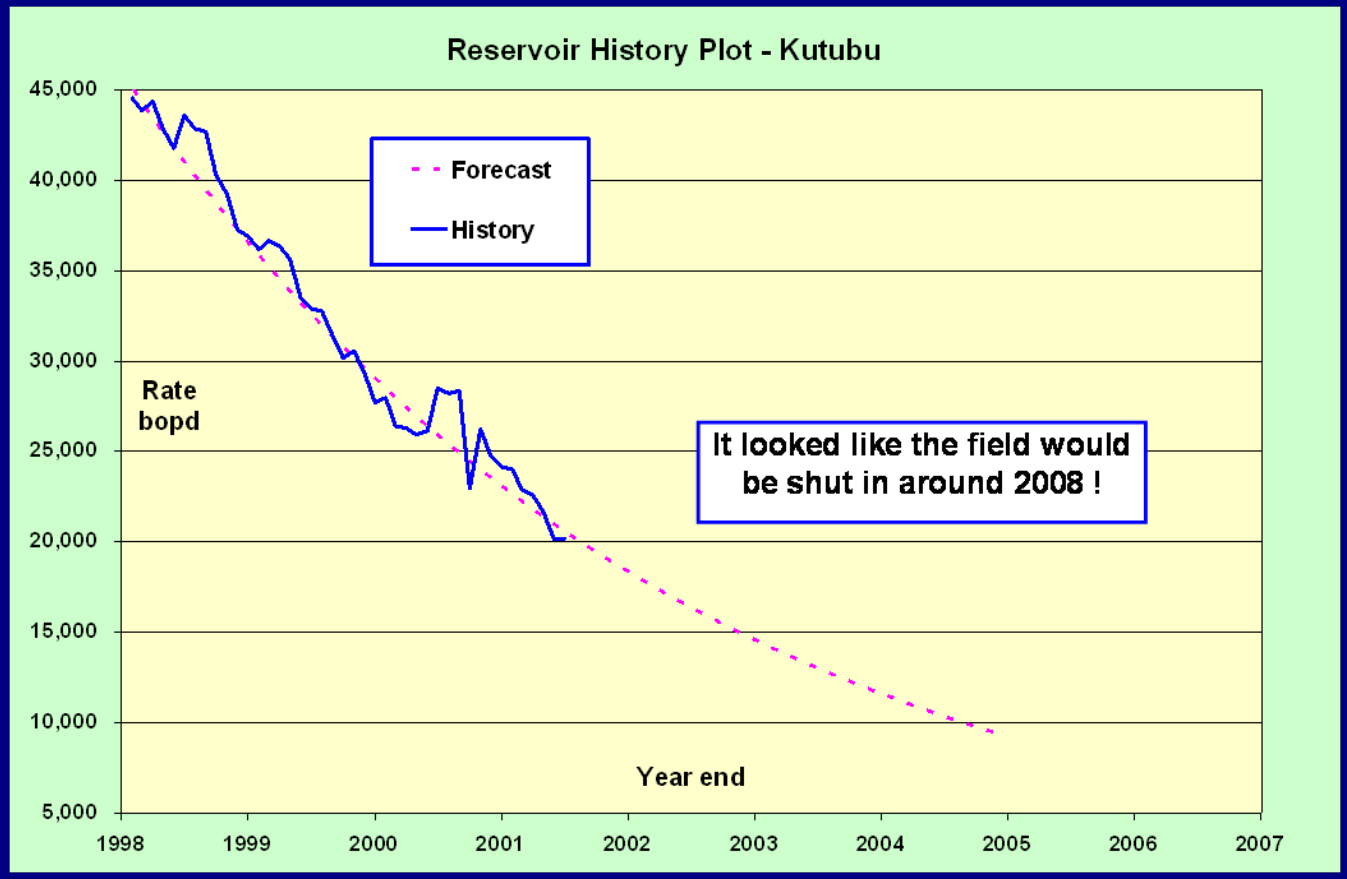
Introduction

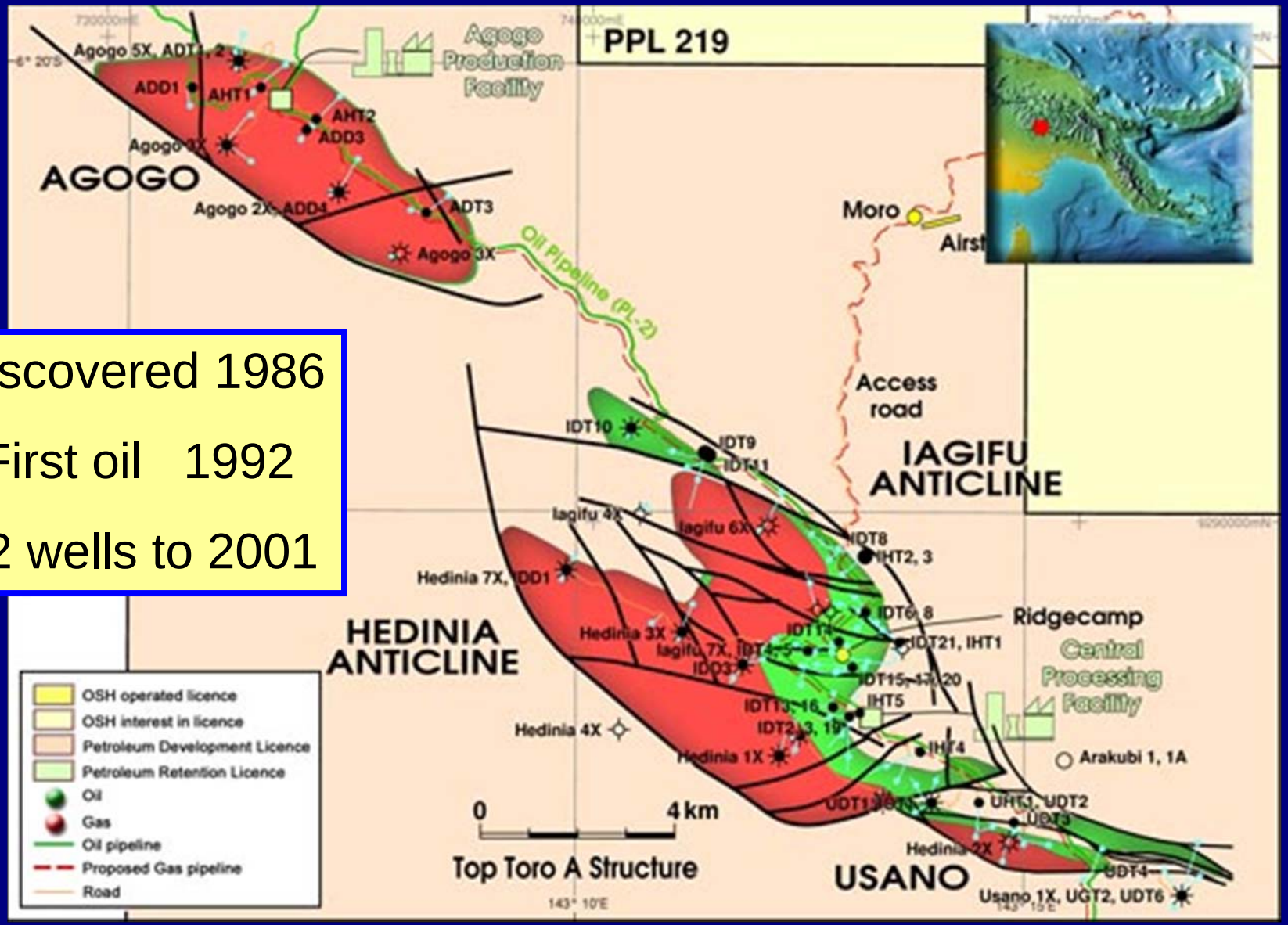
This is the story of a field most people thought was in terminal decline:-

- **Drilling had ceased**
- **Rapid production decline**
- **Some partners had sold out**
- **Shut in looking not far off**

In 2001 things were looking grim !



Greater Kutubu Area – Toro A

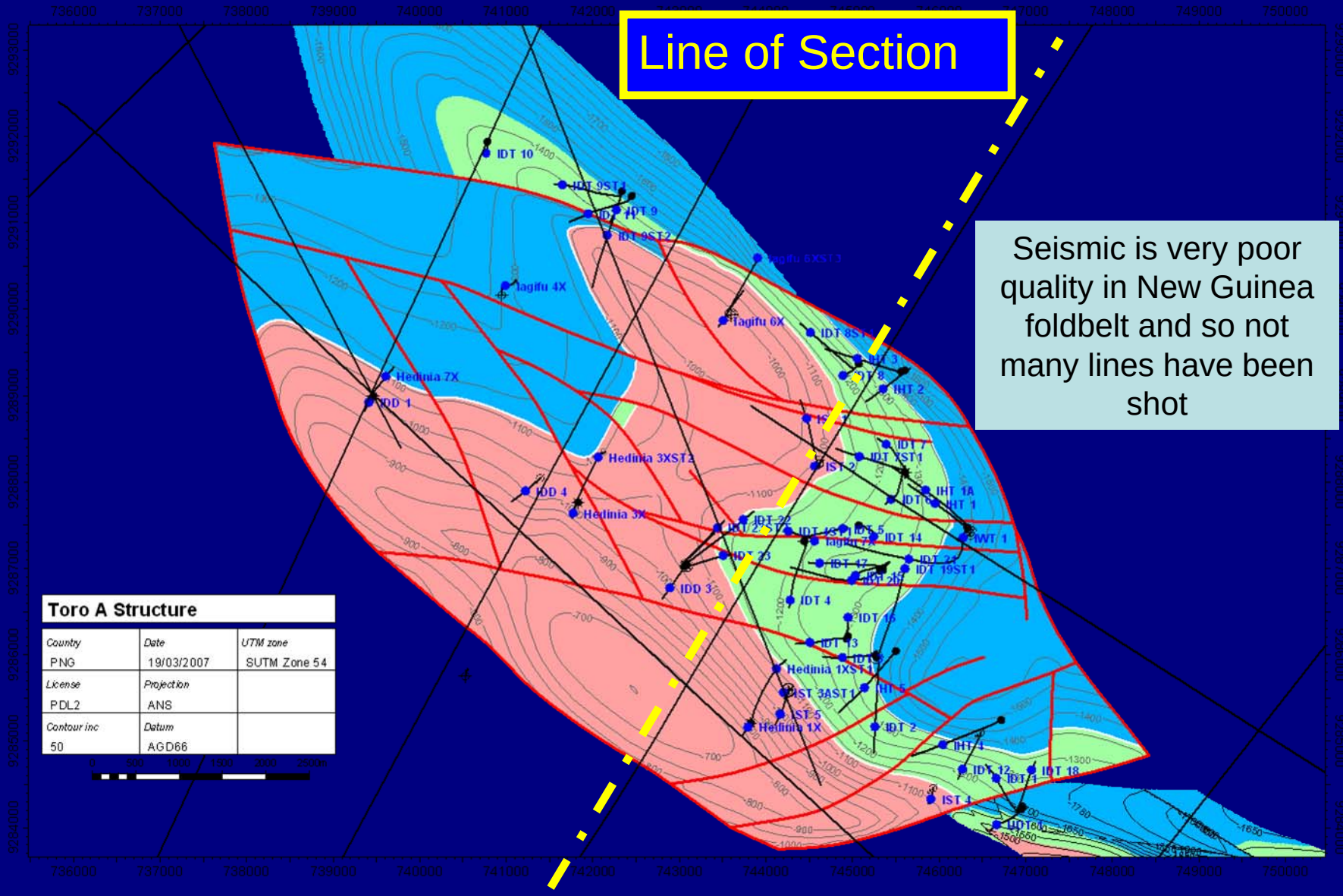


Discovered 1986

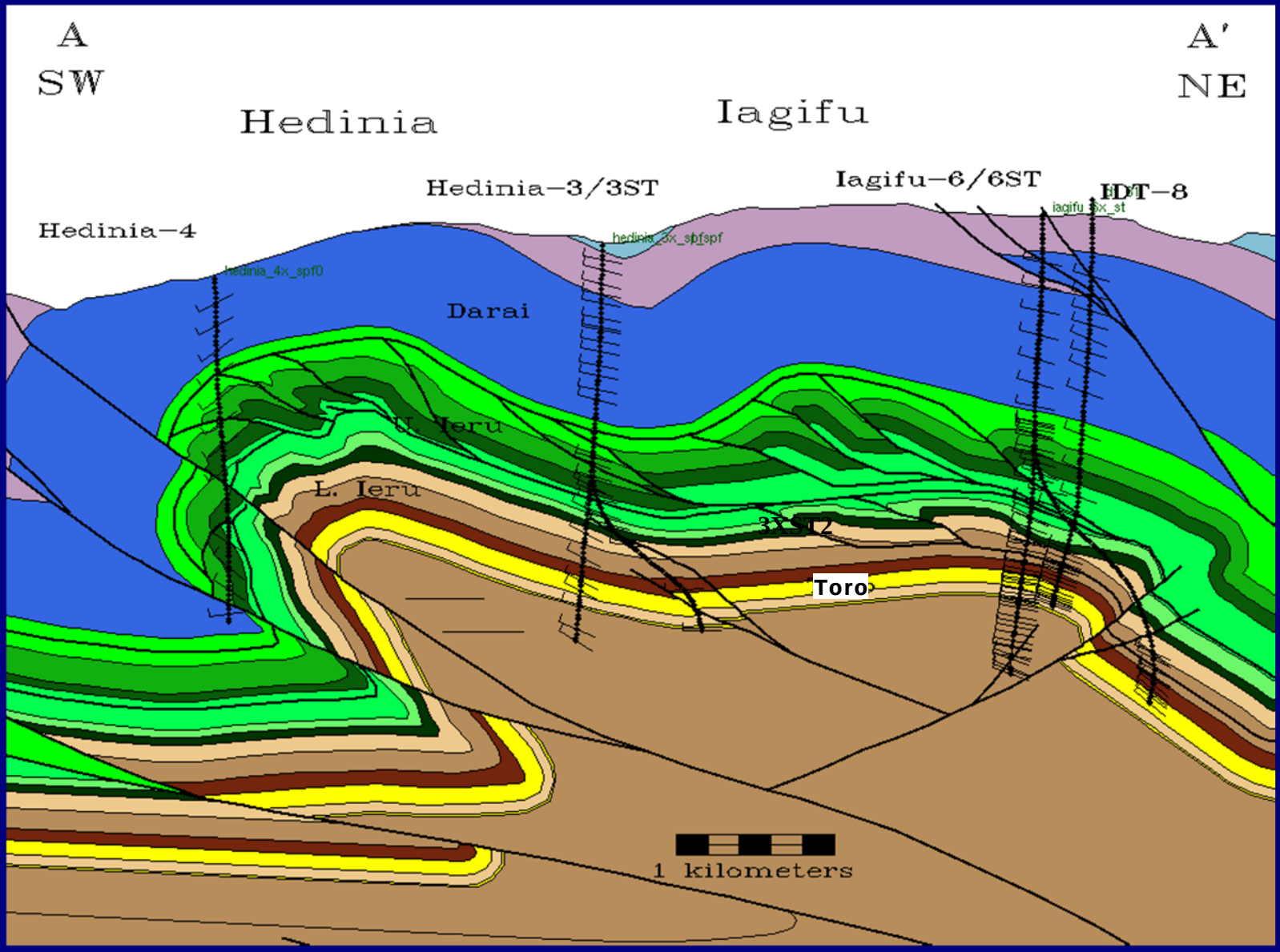
First oil 1992

72 wells to 2001

Iagifu Hedinia – Toro A Structure



Crestal Cross Section



Kutubu Vital Statistics

- **Papua New Guinea's largest oil field**
- Main formations — Toro A,B,C sands
- STOOIP — about 600 MMstb
- EUR — about 350 MMstb
- Peak oil rate — 130,000 stb/d
- Gascap — about 1.2 TCF OGIP
- Permeability — 400 md
- Porosity — 13%
- Viscosity — 0.3 cP

Gas Drive or Water Drive ?

- Large gascap
- Gascap expansion throughout field life
- Wells gas out, rather than water out
- The highest wells, those nearest the gascap, *should* gas out first……
- Hence placed wells downdip near OOWC
- Very little water production

Melbourne SPE Conference 1994:-

- **3 papers on Papua New Guinea development**
- **1 paper on aquifer hydrodynamics**
- **Emphatic conclusion that region dominated by powerful aquifer flows**

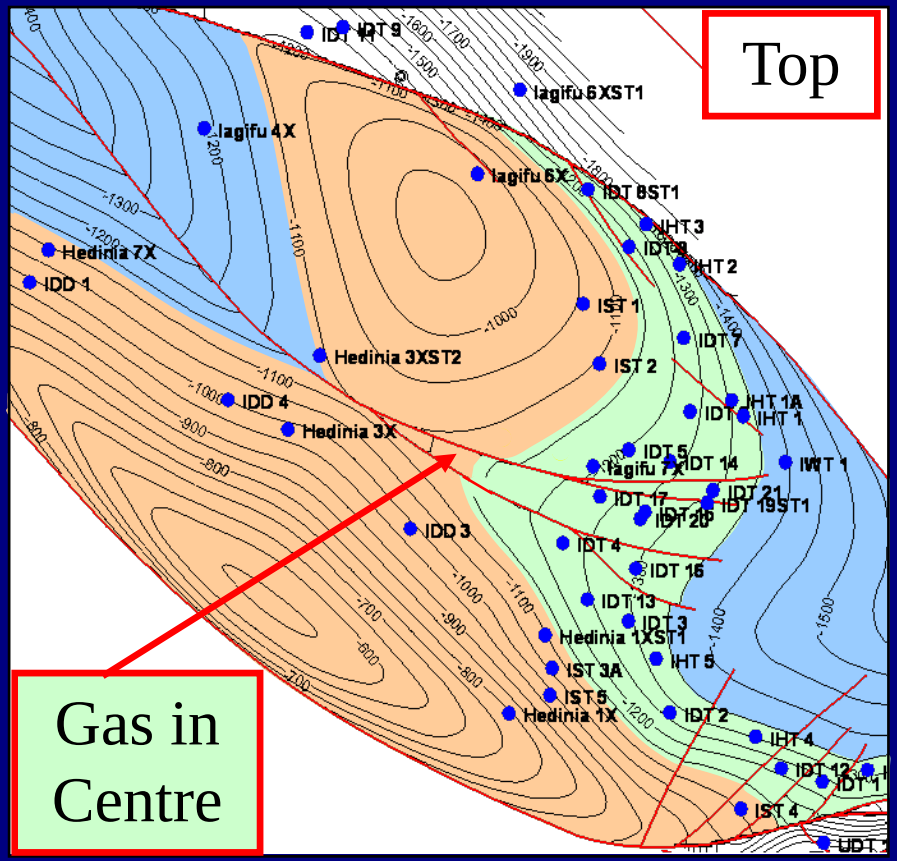
Evidence for the Strong Aquifer

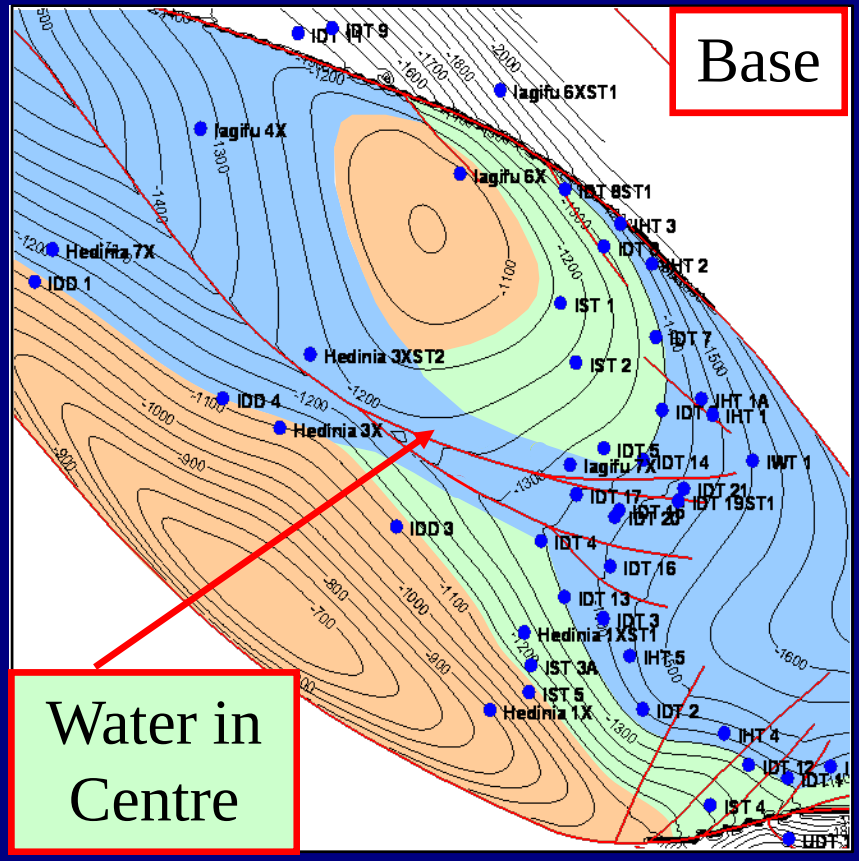
- Strong aquifer should cause a tilted contact
- Some variation in OWC depth across field
- Some pressure anomalies
- Some water found in a well nearest the centre of the field
- It looked like all the oil had been swept to the east and SE side of the field

Conclusion

- A large part of the field, the centre, was considered to have been water swept and was therefore not a drilling target !!

The Feared Central Water Channel





The Beginning of the Rethink

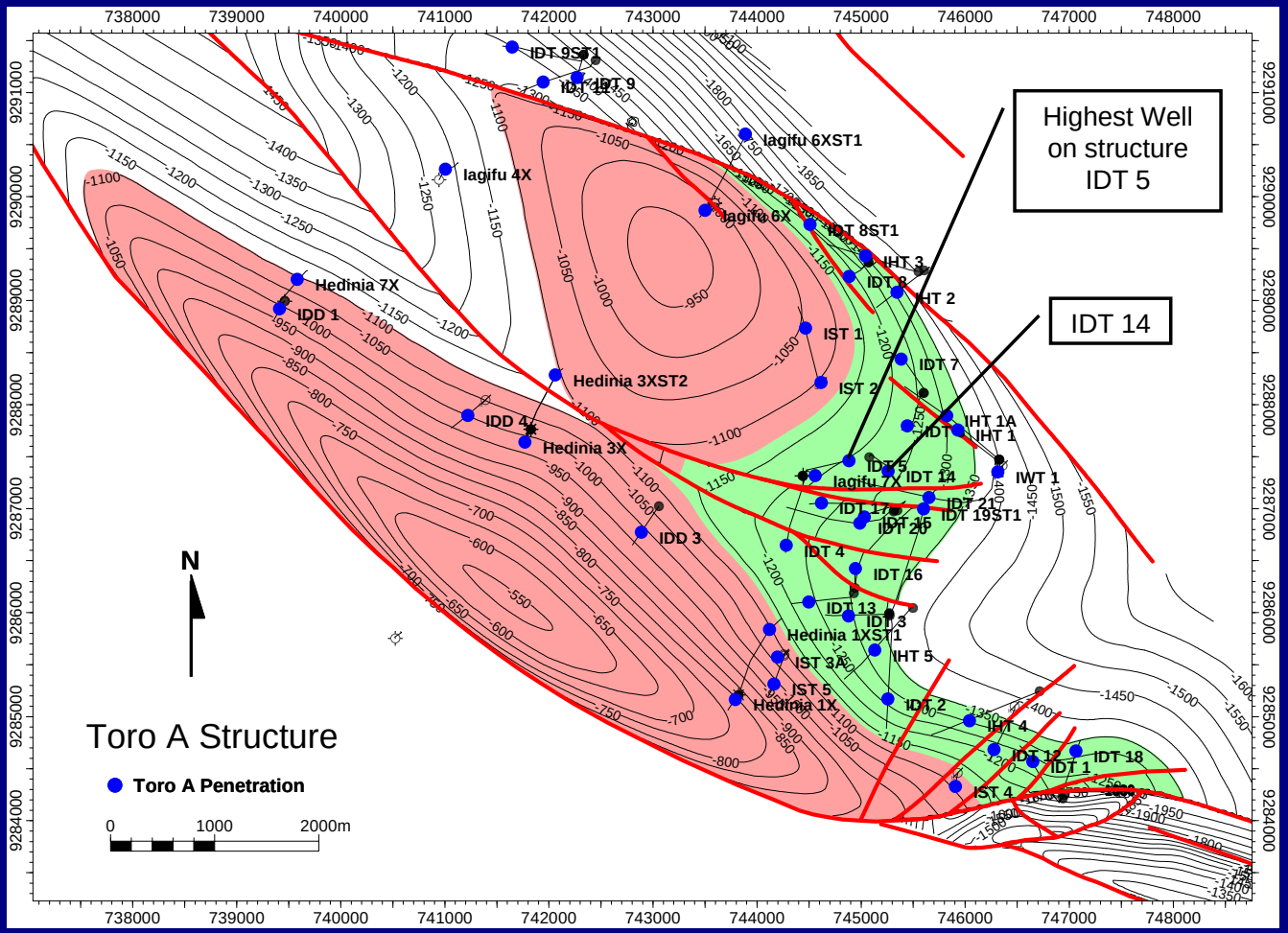
- A full petrophysical review
- A full facies study
- All the above fed into simulation
- New simulation built
- A seismic review

Rethink - continued

- A full RFT review:-
  - All the original data was on the one straight line
  - All the post production data was not
  - Huge amount of detail in the post production RFT data revealing subdivisions within sands
  - This data had major implications :-
    - changed our completion philosophy, leading to more zone splitting
    - needed more layering in the simulation

Well Performance Review

- This is a gas drive system
- However the highest well on the structure had not gassed out
- Instead it was the best well in the field



Alternative Theories to the Dynamic Aquifer Model

Compartmentalisation

Measurement uncertainties

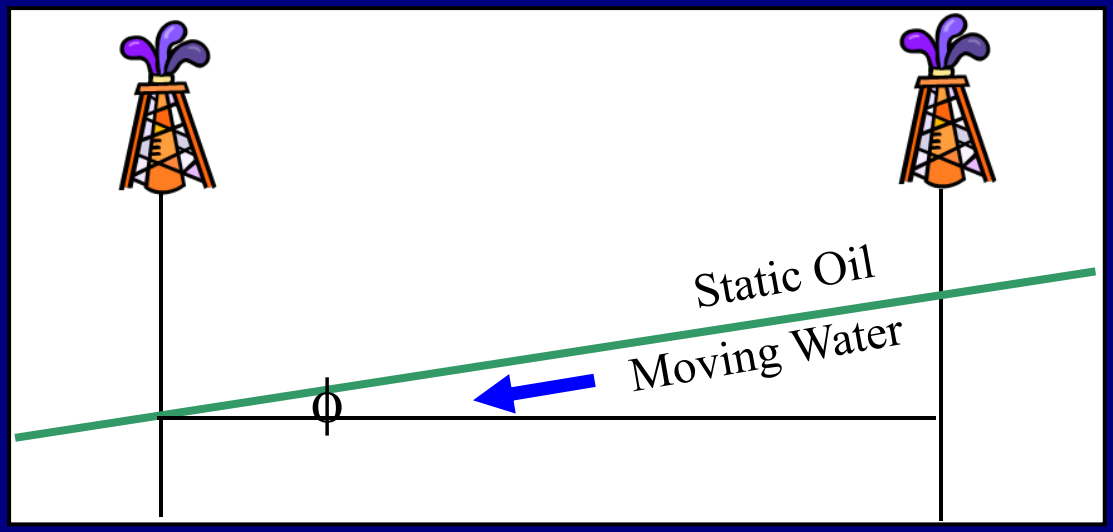
Permeability variations

} Unlikely in this case

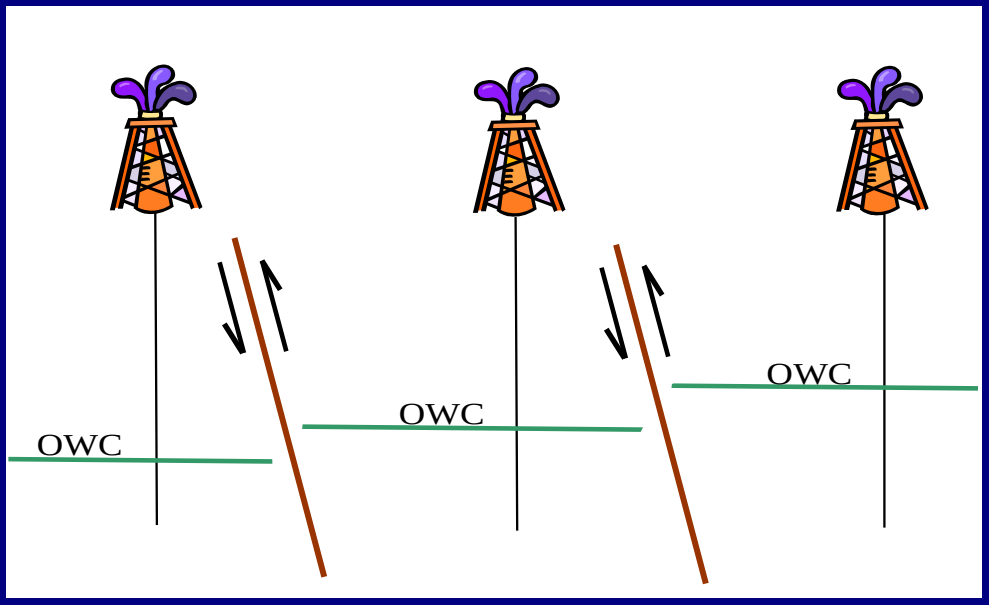
Compartmentalisation ??

- Compartment behaviour had been observed in the other New Guinea Highlands oil fields
- This applies to Moran and Gobe fields – no dynamic aquifer needed to explain their performance
- Did we really want a different theory for Kutubu ? Was it a *special case* ?

Competing Theories



Strong aquifer with tilted contact

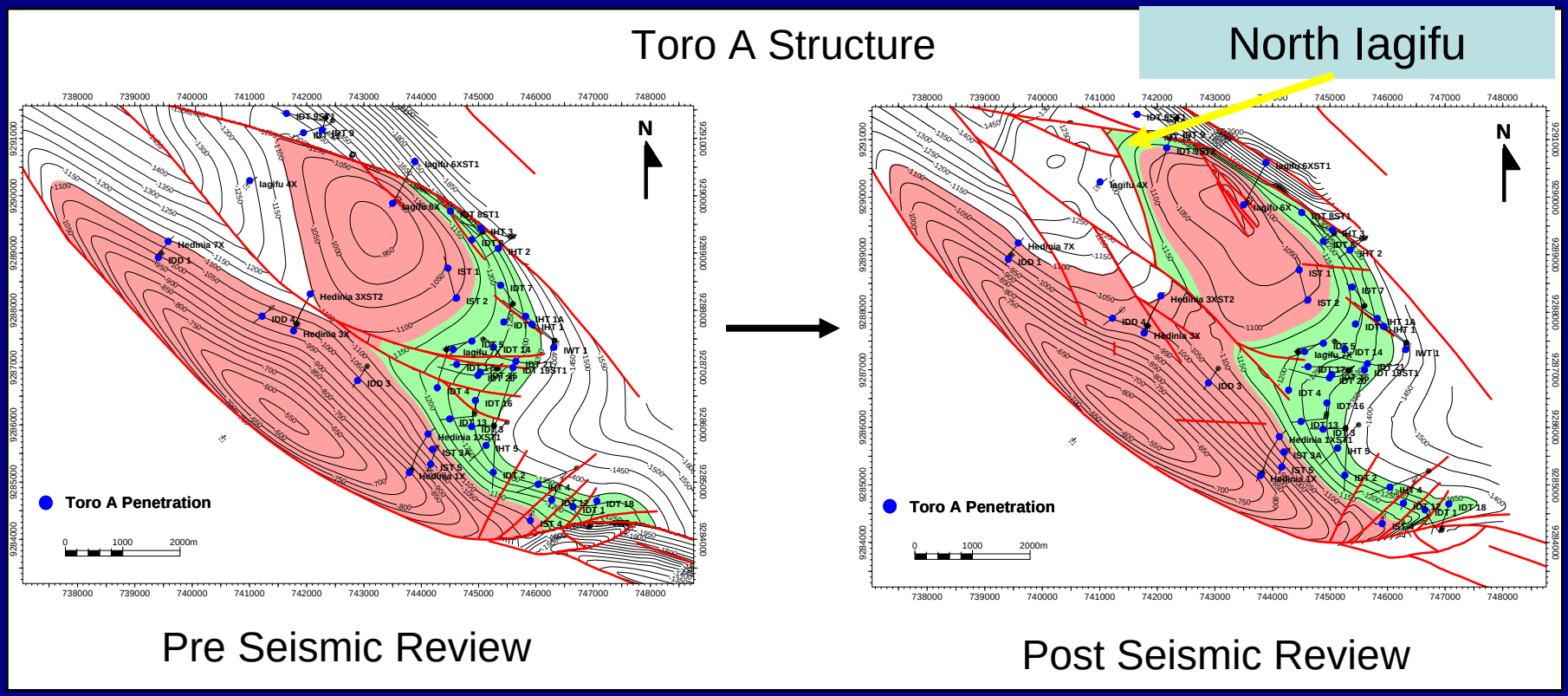


Compartmentalised System

Reasons against Tilted Contact

- Compartment behaviour obvious in nearby fields Moran and Gobe
- Worried about having a different theory for Kutubu
- Some parts of Kutubu obviously compartmentalised so why not all ?
- Seismic data and well performance suggested potential compartmentalising faults exist
- Intriguing anomalous performance of well IDT5
  - Highest well on structure
  - Would be expected to gas out first
  - Instead it's best well in field !!
  - Second best well was nearby
- No water production in centre of field near where dynamic aquifer might be
- Simulation suggested oil in the centre of the field

Seismic Review – Identifying Compartments

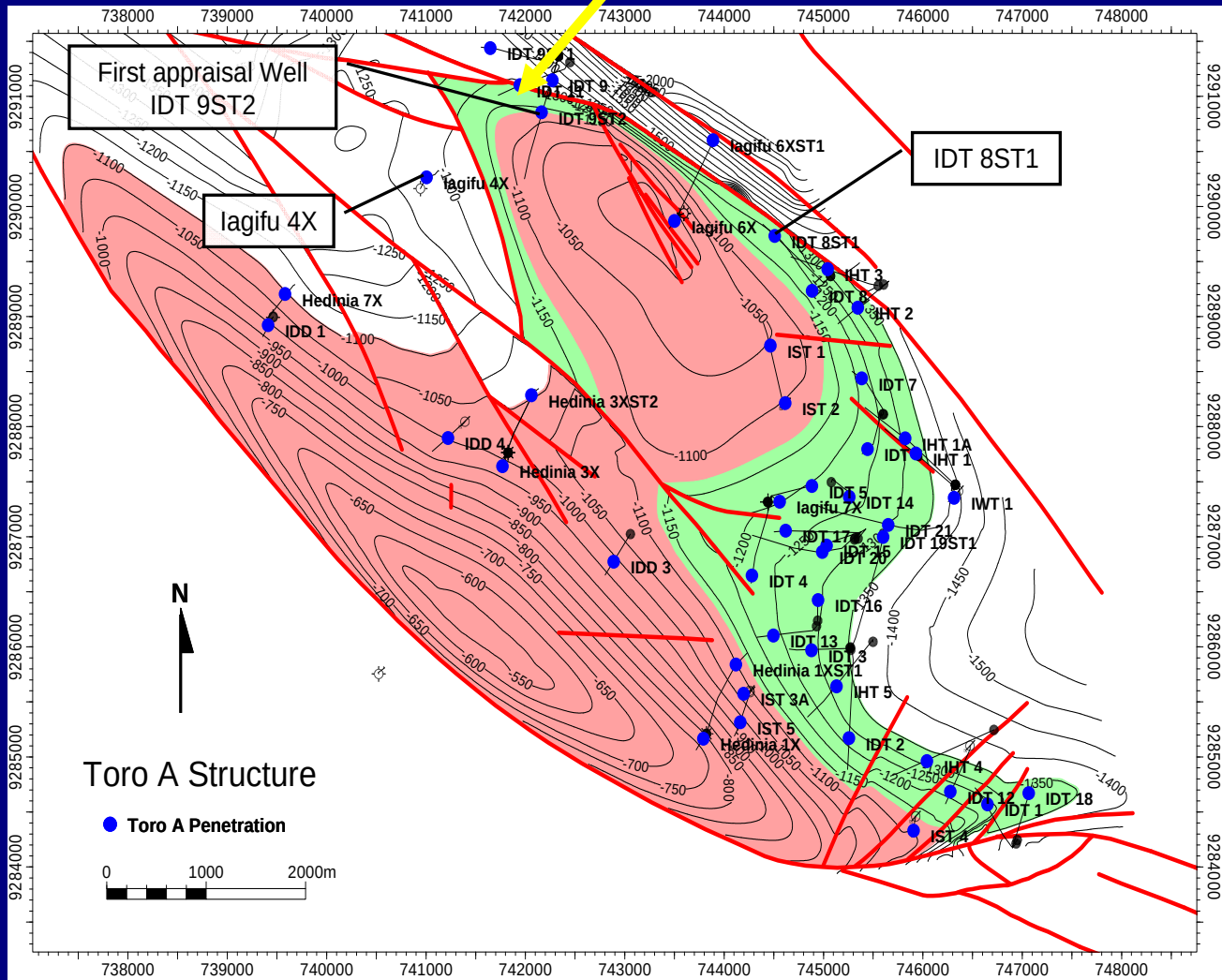


A review of available seismic data pointed to the fact that significant, potentially compartmentalising, faults exist that had not been previously recognised

- It soon became apparent that the North Iagifu region was unappraised and may contain significant volumes of unaccessed oil

The First Appraisal Well – IDT 9ST2

- **Drilled IDT-9ST2 in North Iagifu region**
  - **Found water in the Toro !**
  - ***BUT*……**
  - **Unusually high water confirmed compartment theory !**
  - **However also discovered a deeper reservoir**

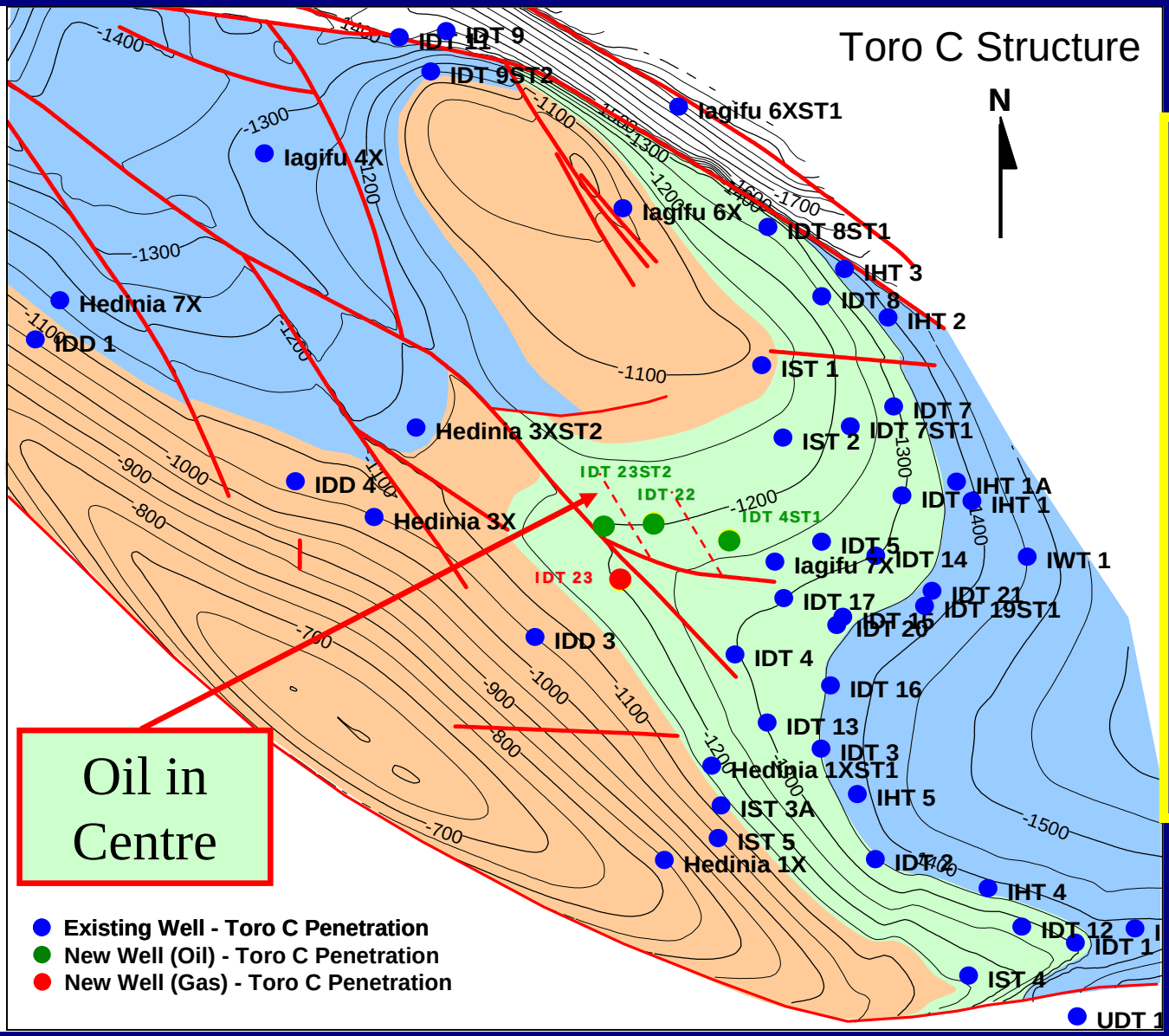


Action

- **It was decided to drill *<u>updip of the highest well</u>* in a mature gascap drive field !!!**

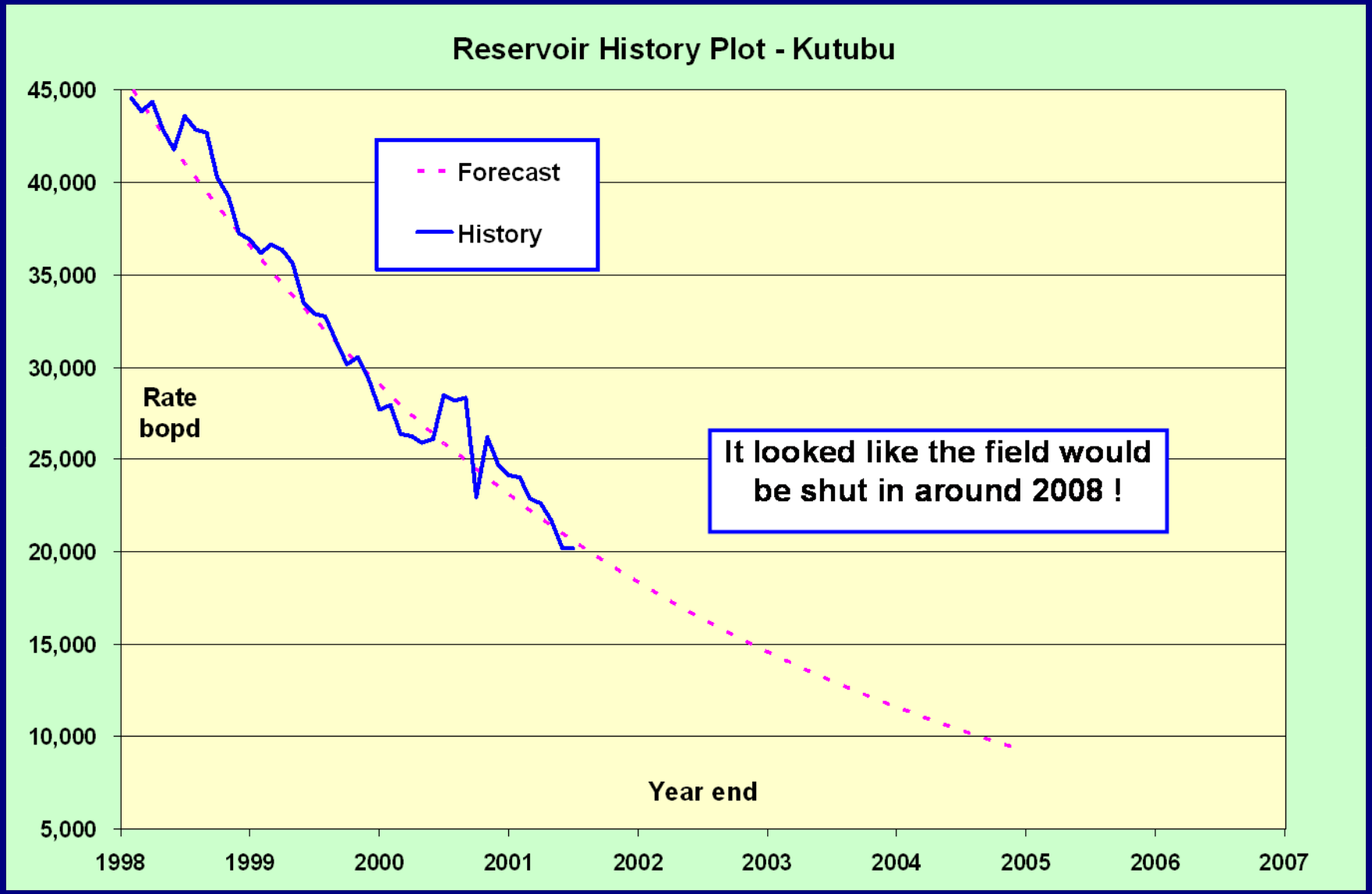
- Drilled 4 updip deviated wells into the central “water-prone” region :-
  - Drilled IDT-4ST1
    - Found oil in Toro A, B, C and no water
  - Drilled IDT-22
    - Found more oil and no water
  - Drilled IDT-23
    - Gas swept, no water
  - Drilled IDT-23ST2
    - Found more oil, some trapped or “perched” water

New Top Toro C Structure

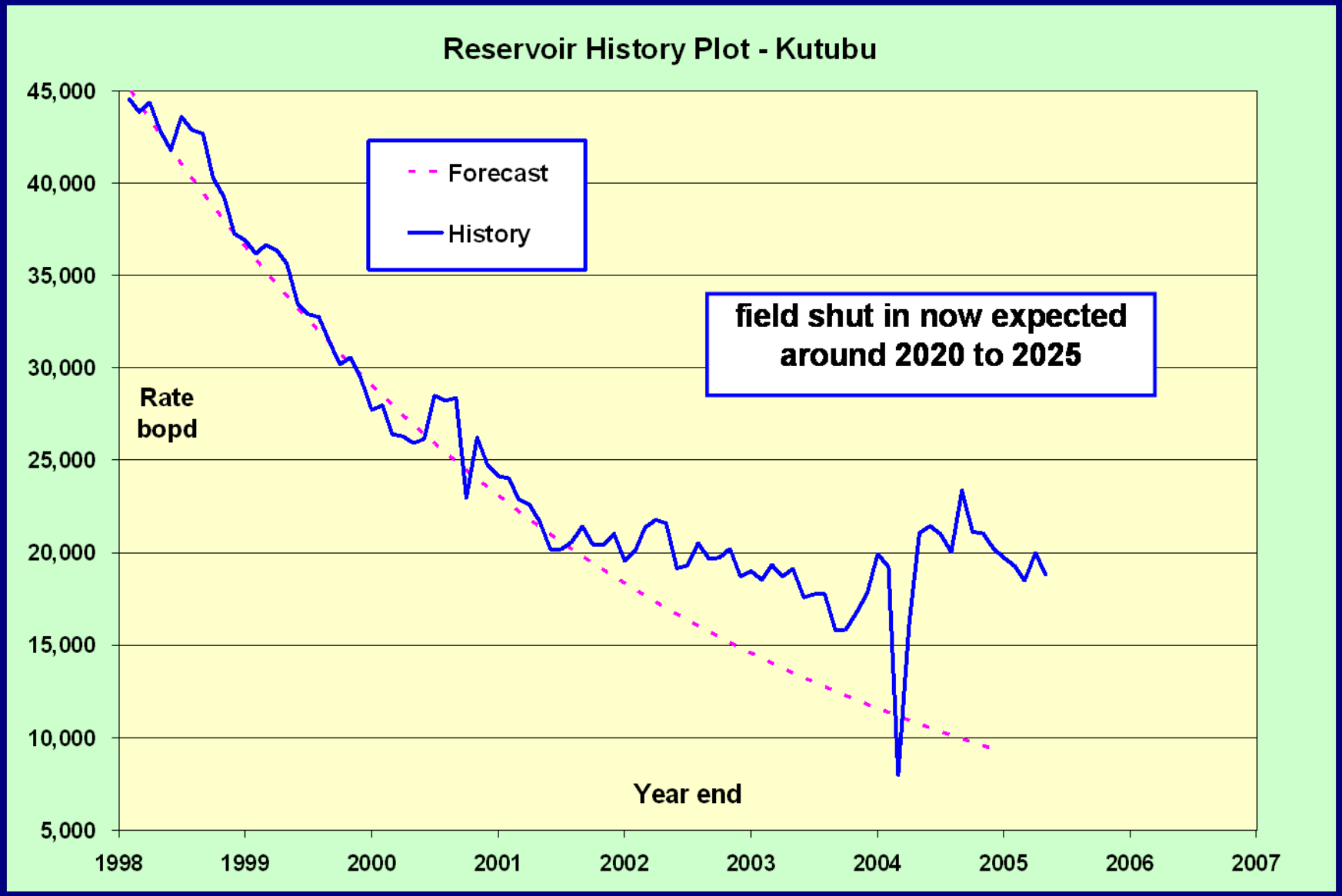


- *All 4 central wells were found to be in separate compartments !!!*
- The central oil pool extension had been supporting the structurally high wells which had not gassed out as early as expected

In 2001 things were looking grim….



By 2006 things were looking good



Other Actions

- Resurrection of old wells shut in and forgotten
  - Do not forget “watered out wells”
- Workovers
  - Often a low cost, high return activity
- Wireline
  - Keep checking all zones
  - Imbalance of reinjection can create opportunities
- Development of undeveloped zones
  - You need to break the ice…..

Highlights

- At the end of the round of drilling discussed above Kutubu production levels had recovered to 24,000 bopd, the highest capacity since late 2001 / early 2002
- Have added over 10,000 bopd of capacity
- Have added 10 to 20 MMstb reserves

Lowlights

- The severe tectonic stresses which create the compartments also cause occasional collapsed casing
- Need to keep doing things else field goes back onto decline

Conclusions

- Beware of “dynamic aquifers” and tilted contacts
- Step back from the detail and look at the regional issues occasionally
- Performance of “outlier” wells is often an omen
- Keep going back to basics:-
  - Are all zones perforated ?
  - Wells change, even “dead” wells
  - Keep testing old wells
- Simulation
  - If it tells you there has to be more oil there, that’s good
  - If it can’t see more oil maybe there’s a new compartment, which is even better
- Keep revisiting the fundamentals !!

A Final Note

- **Interesting to note that IDT 23ST2, our newest well, *the highest well on structure*, is the only well still producing at solution GOR…**

- Many appraisal opportunities remain in Kutubu

This presentation was based on

SPE paper 101123
“Kutubu - A Rethink”

which was presented at the

Adelaide SPE Conference
September 2006

by

Neil Williams & David Lund

Oil Search Limited