Section 1
Basic Properties and Data Management

- Rock Properties
- Fluid Saturation
- Reservoir Drive Mechanisms
- Collecting and Organizing Well and/or Production Data
- Knowing Your Water Related Costs

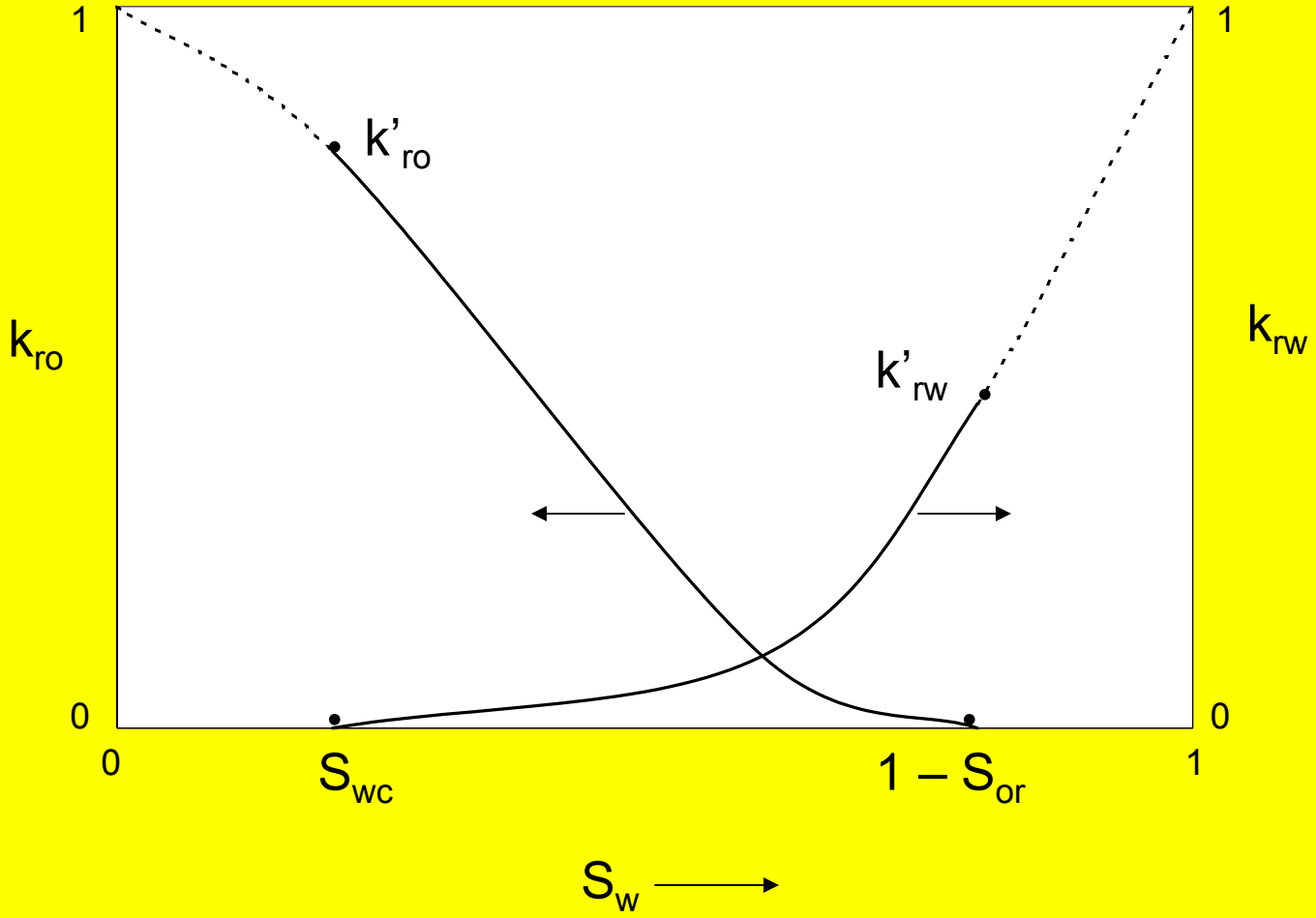
Rock Properties

- Porosity – ratio of void space to the bulk volume
  - Original – developed during deposition
  - Induced – developed by geologic process
  - Total – total void space
  - Effective – interconnected void space
- Permeability – capacity of the rock medium to transmit or conduct fluids
  - Occurs both horizontally and vertically
  - Spatial variations
  - Matrix
  - Fracture

Fluid Saturation

- Reservoir rocks normally contain both petroleum hydrocarbons and water (connate)
- Capillary Pressure
  - Pressure required to drive a fluid through a pore throat and displace the pore-wetting fluid.
- Relative Permeability
  - Ratio of the of the effective permeability of a particular fluid to the base permeability of the rock.
- Wettability
  - When two immiscible fluids (oil and water) are in contact with a rock surface, one preferentially adheres to the rock surface

RELATIVE PEMEABILITY VS. SATURATION



Reservoir Drive Mechanisms

- Solution gas or depletion drive
  - Principle energy is the expansion and dissociation of gas in solution in the oil
  - Water production minimal, rapid pressure decline and low recovery efficiency
- Solution-gas-gas-cap drive
  - Contains original free gas cap with no associated active water
  - Water production minimal, pressure maintained at higher levels, improving recovery efficiency
- Water drive
  - Associated with water-bearing formations that are so active that little or no pressure drop occurs when hydrocarbons are produced
  - Water productions varies depending on structural position and nature of water drive, most efficient in maintaining reservoir pressure, usually yields highest recovery efficiency

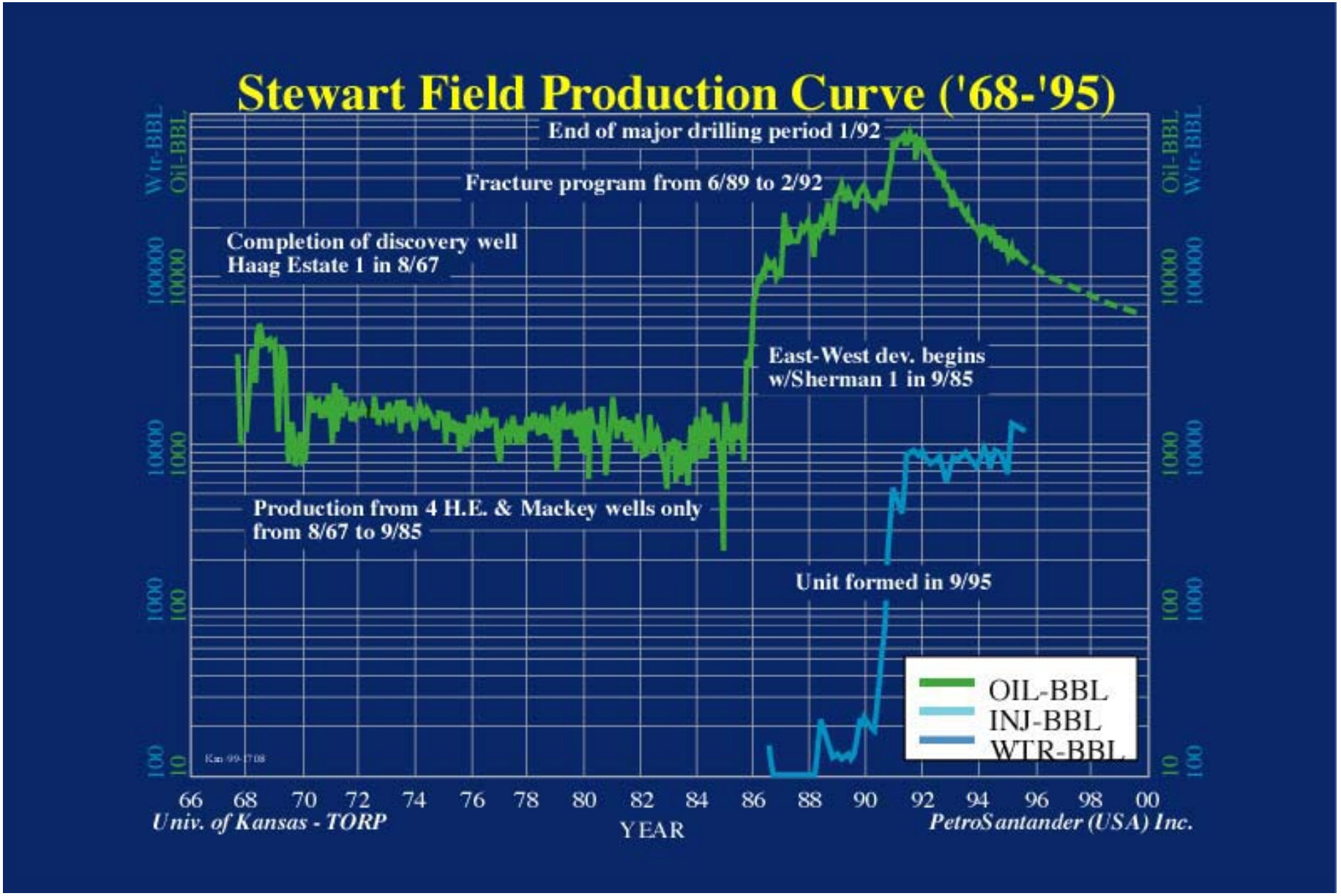
Collecting and Organizing Well and/or Production Data

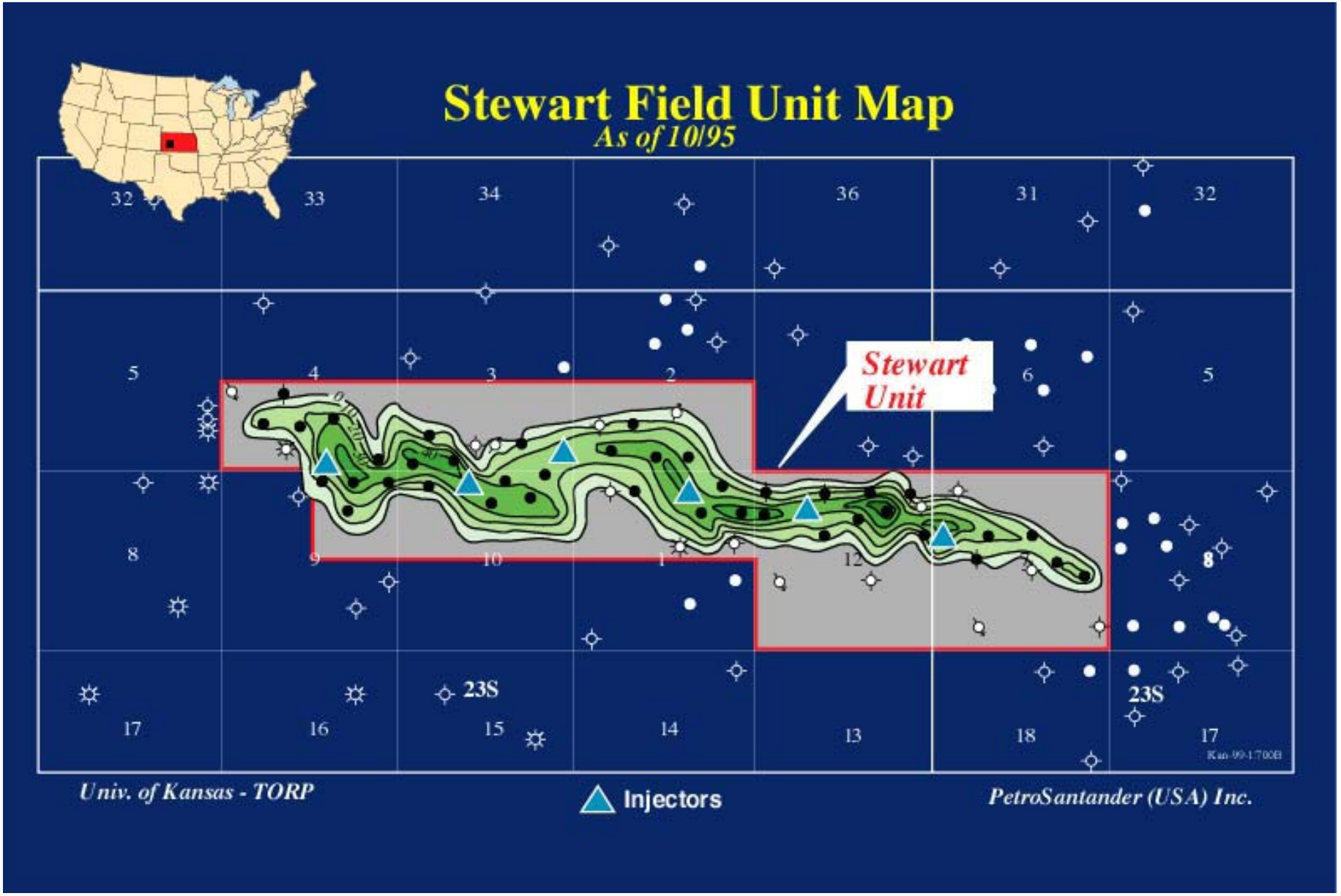
- Wellbore schematics
  - Capturing and displaying well data
  - Cannot over-emphasize keeping good individual well records
  - Individual well tests once or twice a month
- Graphical plots
  - Oil production versus time
    - Semi-log plot referred to as decline curve
  - Rates versus time
    - Different rates on same graph assist in determining relationship
    - Fluctuations in one rate can effect another

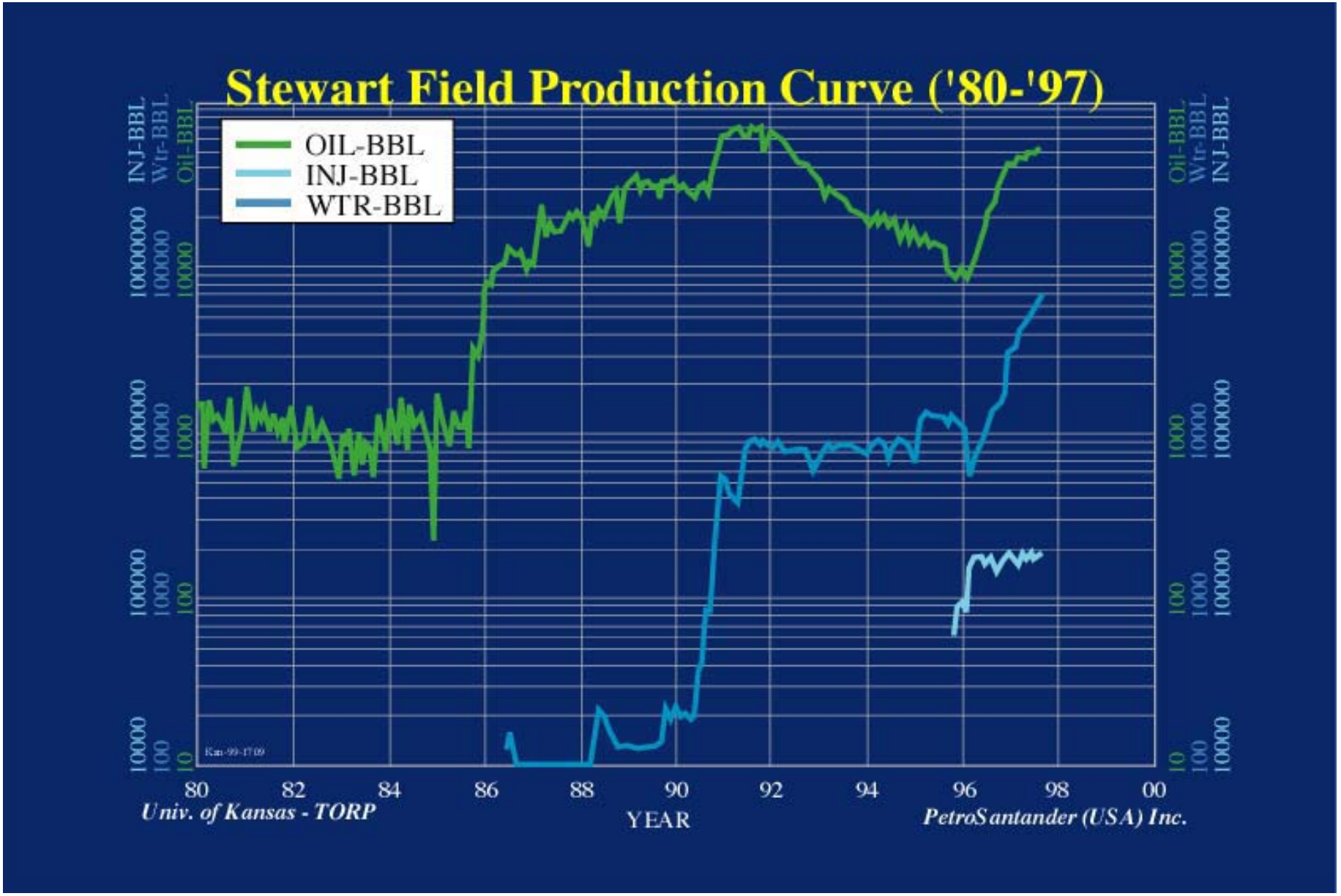
Collecting and Organizing Well and/or Production Data (cont.)

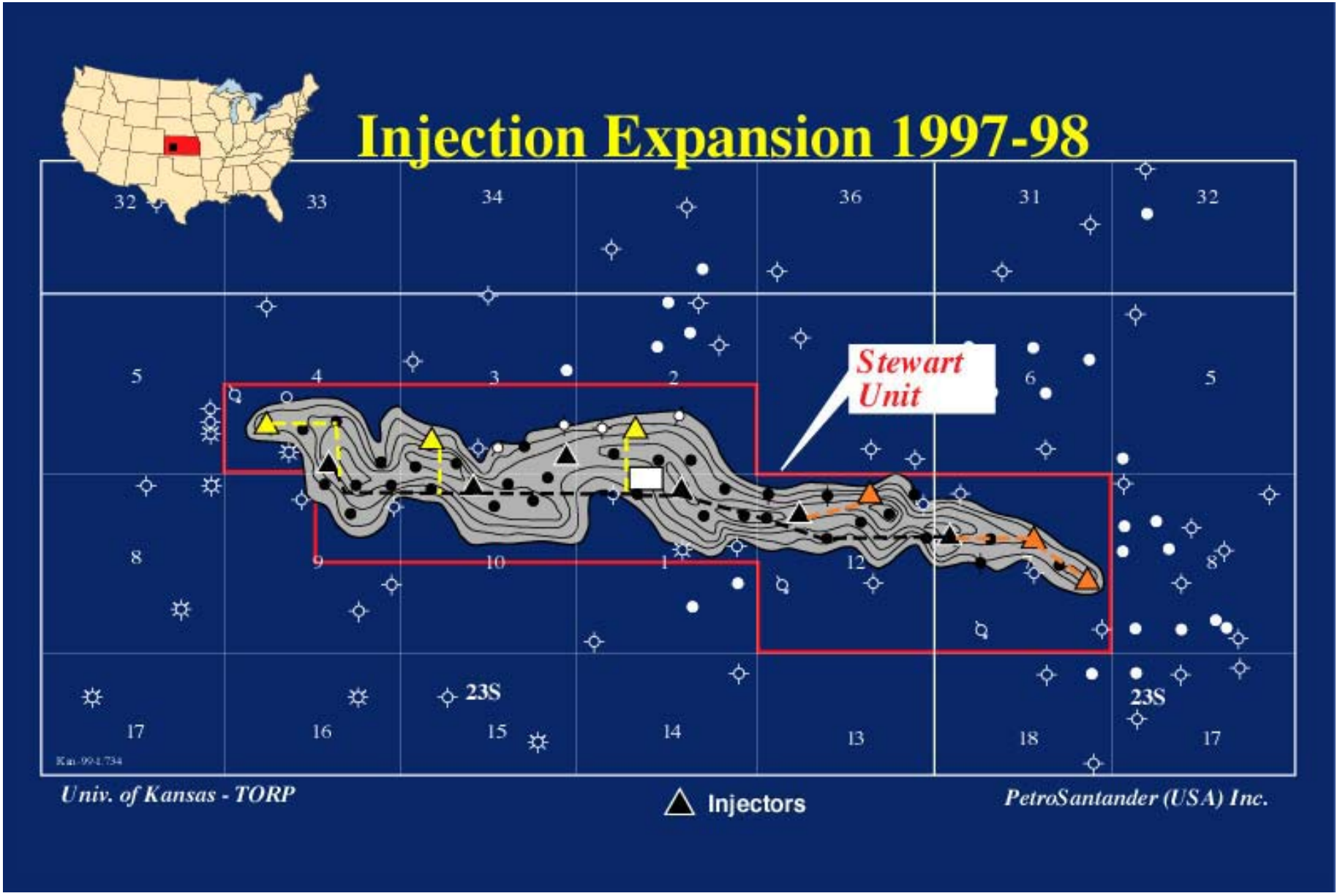
- Graphical plots (cont.)
  - Water-oil ratio versus cumulative oil production
    - Semi-log plot
    - Reveals changes in water production as a function of oil production
    - Area under curve represents total oil production
    - Sharp increases can indicate problem
  - Hall plots
    - Summation of surface or bottomhole pressure multiplied by time versus cumulative fluid injection
    - Used to analyze injection wells or fluid injection treatments
    - Changes in slope provides information associated with fluid injection

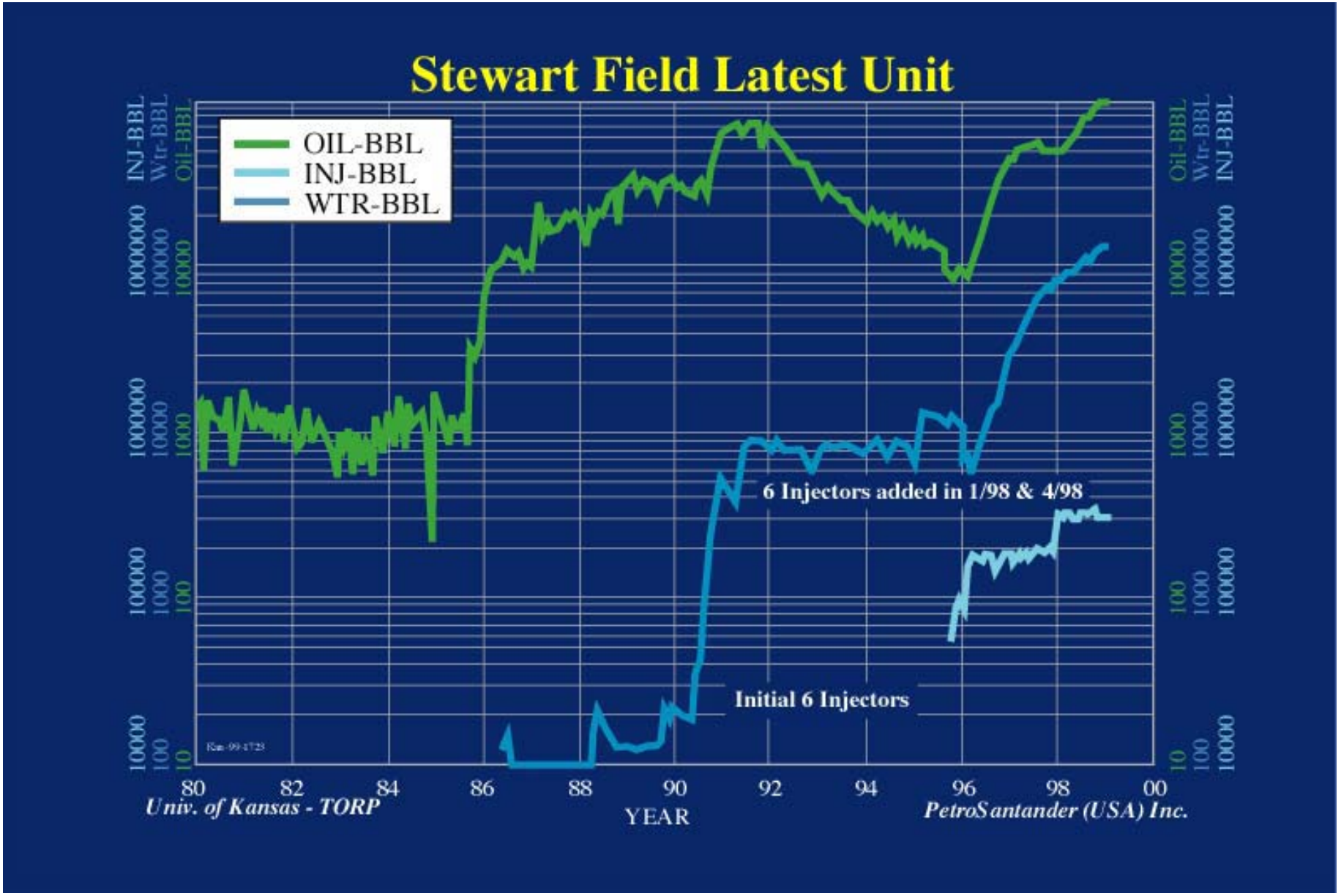
1. Completion of primary drilling
2. Start of waterflood operations
3. Theoretical economic limit of primary production
4. Formation fill-up due to waterflood
5. Start of waterflood expansion
6. Field not producing due to non-technical problems
7. Field not producing due to non-technical problems
8. Improvements in filtration and bacteria control
9. Application of polymer treatments


Stewart Field Production Curve ('68-'95)
End of major drilling period 1/92
Fracture program from 6/89 to 2/92
Completion of discovery well
Haag Estate 1 in 8/67
East-West dev. begins
w/Sherman 1 in 9/85
Production from 4 H.E. & Mackey wells only
from 8/67 to 9/85
Unit formed in 9/95
OIL-BBL
INJ-BBL
WTR-BBL
Wtr-BBL
Oil-BBL
66 68 70 72 74 76 78 80 82 84 86 88 90 92 94 96 98 00
YEAR
Univ. of Kansas - TORP
PetroSantander (USA) Inc.

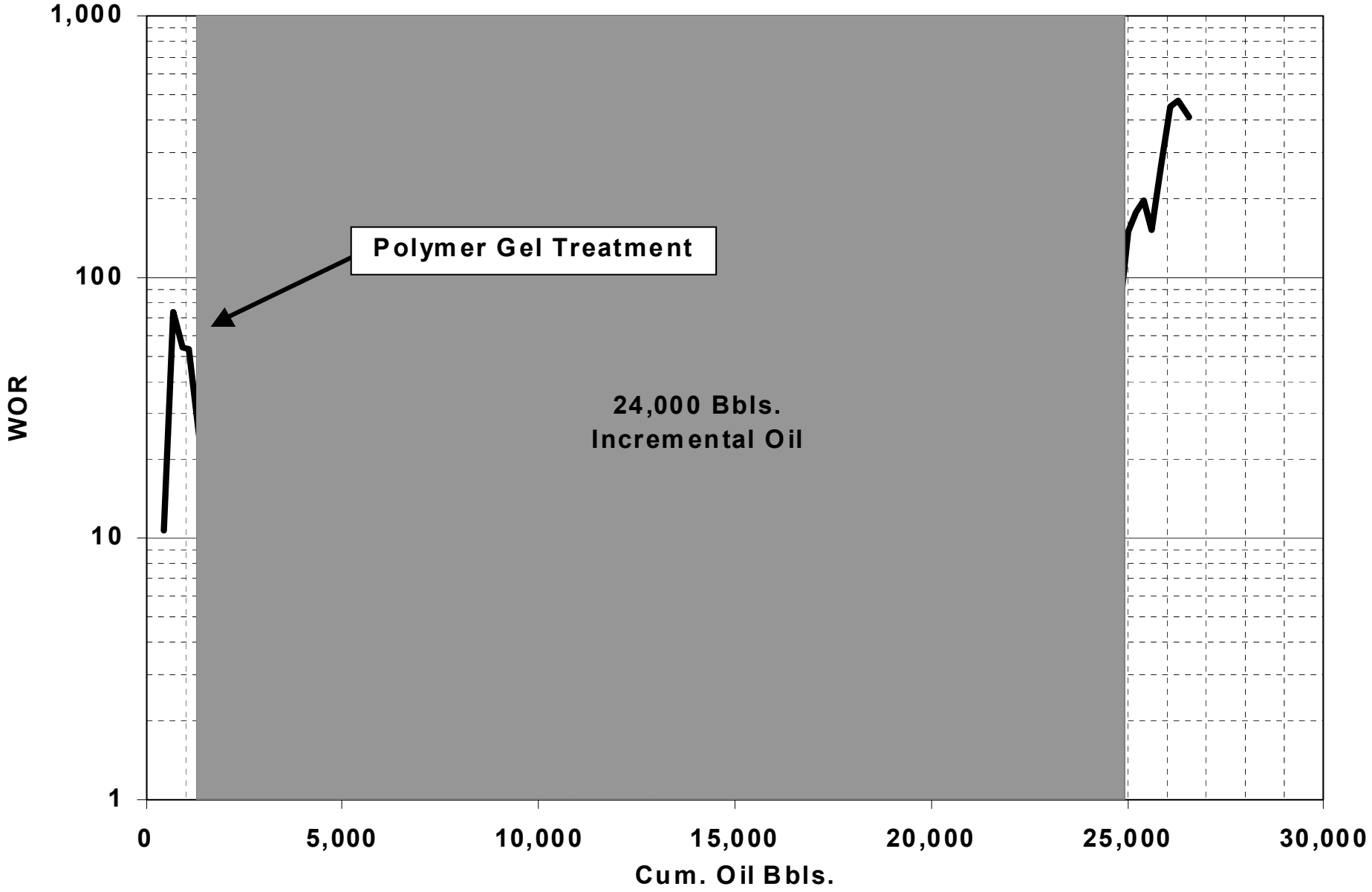

Stewart Field Unit Map
As of 10/95
Stewart Unit
32
33
34
36
31
32
5
4
3
2
6
5
8
9
10
1
12
8
23S
17
16
15
14
13
18
23S
17
Kan-99-1700B
Univ. of Kansas - TORP
Injectors
PetroSantander (USA) Inc.


Stewart Field Production Curve ('80-'97)
OIL-BBL
INJ-BBL
WTR-BBL
INJ-BBL
Wtr-BBL
Oil-BBL
10000000
1000000
100000
10000
1000
100
10
Oil-BBL
Wtr-BBL
INJ-BBL
Kan-99-1709
80
82
84
86
88
90
92
94
96
98
00
YEAR
Univ. of Kansas - TORP
PetroSantander (USA) Inc.

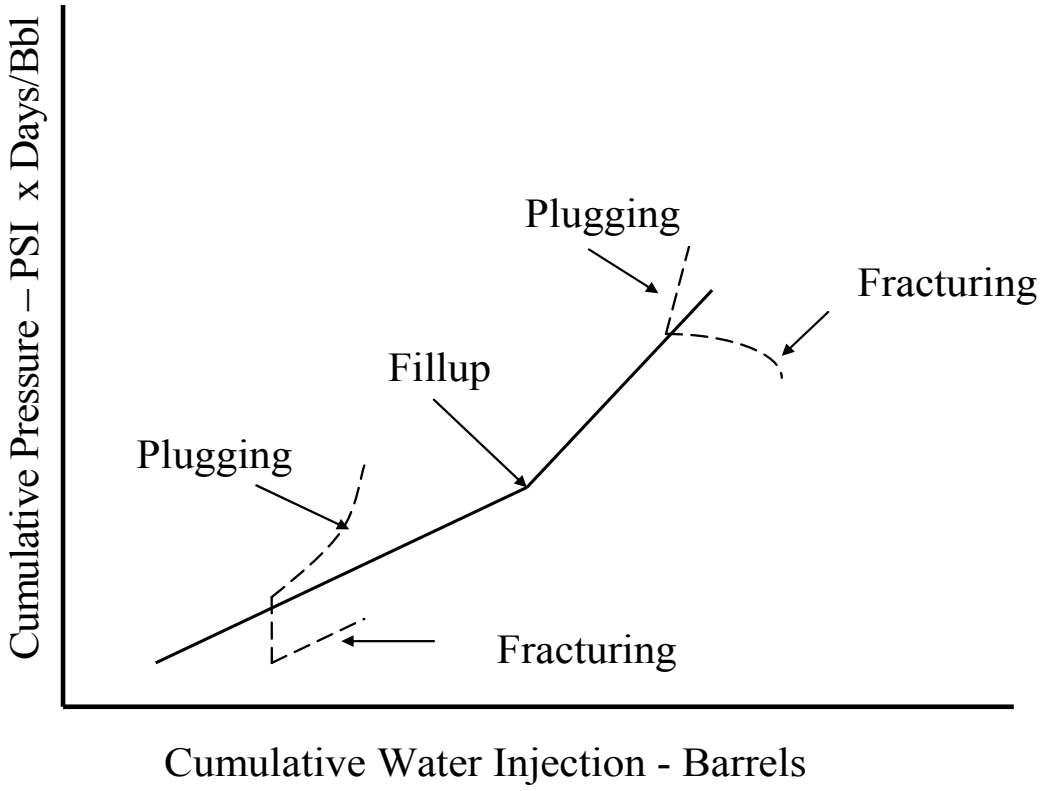

Injection Expansion 1997-98
Stewart Unit
23S
23S
Univ. of Kansas - TORP
Injectors
PetroSantander (USA) Inc.


Stewart Field Latest Unit
OIL-BBL
INJ-BBL
WTR-BBL
INJ-BBL
Wtr-BBL
Oil-BBL
Oil-BBL
Wtr-BBL
INJ-BBL
6 Injectors added in 1/98 & 4/98
Initial 6 Injectors
80
82
84
86
88
90
92
94
96
98
00
YEAR
Univ. of Kansas - TORP
PetroSantander (USA) Inc.

Hunton Dolomite Formation - Woods County, Oklahoma



Typical Hall Plot Slopes



Knowing Your Water-Related Costs

- Water production can make or break a project's performance by reducing the flow rate or ultimate recovery or by raising costs
- Water plays a role throughout the entire life cycle of a well
- Impact of water is underestimated and opportunities to implement strategies and improve inefficiencies are overlooked
- Account for the full cost of water management
- In many cases a modest gain in economic efficiencies can lead to a substantially large economic benefit

Knowing Your Water-Related Costs (cont.)

- Water related cost and impact areas
  - Accounting in estimate of economical recoverable reserves
  - Water use strategies in drilling program
  - Water control strategies in completion design
  - Water control conformance strategies in the reservoir and the wellbore
  - Water drive and choke strategies
  - Water lifting and surface handling
  - Chemical treatment
  - Water gathering and water process facilities
  - Permitting and delays
  - Transportation
  - Injection disposal and waterflood
  - Beneficial use
  - Liabilities