Petroleum & Coal
ISSN 1337-7027

**Available online at www.vurup.sk/petroleum-coal**
Petroleum & Coal 56(4) 383-394, 2014

# EVALUATING THE INVESTMENT AND EXPECTED REVENUE IN AN OIL DEPLETED UNDERGROUND GAS STORAGE RESERVOIR WITH WATER INFLUX

C. I. C. Anyadiegwu[1], C. M. Muonagor[2]

[1] *Department of Petroleum Engineering, Federal University of Technology, Owerri, Nigeria.* drcicanyadiegwu@yahoo.com

[2] *Institute of Petroleum Studies, Port Harcourt, affiliated to Institut Francais du Petrole (IFP), France.* tissadeking@yahoo.com

Received May 19, 2014, Accepted July 28, 2014

**Abstract**

Evaluating the investment and expected revenue in an oil depleted underground storage reservoir with water influx is analysed in this work. Data on a depleted oil reservoir located in the Niger Delta were used for the analysis. An economic analysis on the reservoir was performed by considering water influx in case 1 and no water influx in case 2. Economic factors as NPV, IRR, Pay-out and Break-even point were determined using model equations and Microsoft Visual Basic Computer Programs. From the analysis and computations made, it was shown that the water influx into the reservoir often reduces the storage capacity of the reservoir, and subsequently affects the internal rate of return on the investment.

***Keywords:*** *economics, net present value, internal rate of return, pay-out, storage capacity, depleted reservoir*

## 1. Introduction

The water inflows resulting from gradual expansion of the aquifer continue in transient conditions over a relatively long period. The recovery from many oil/gas reservoirs is affected by water influx, either from the perimeters of the reservoirs or from below, or from both. An understanding of the interplay between aquifers and the oil/gas reservoirs is important to properly perform recovery calculations [13].

Water influx results from a reservoir pressure following oil/gas production. Water influx tends to maintain, either partially or wholly, the reservoir pressure. In general, both effectiveness of the pressure support system and the water influx rates are governed by the aquifer characteristics, which principally include permeability, thickness, areal extent and the pressure history along the original reservoir/aquifer boundary [6].

Before the effects of water influx on oil/gas reservoir behavior were completely understood, early derivations from a straight line on a plot of P/Z vs $G_p$ often were attributed to measurement errors. In some instances, errors in the field pressure measurements can mask the effects of water influx, especially if a weak water drive is percent [4].

In the effort to understand the fundamentals of natural gas storage, and the underlying motivations of the owners, it is often asked how much does the project cost and what is the profit [3].

Natural gas storage unit cost for various storage systems are [7]:

- UGS in depleted fields: 0.70 – 1.75 dollars per $m^3$.
- Gas storage in water layers: 1.88 dollars per $m^3$.
- Gas storage in salt cavern (formation): 5.00 dollars per $m^3$.
- LNG storage: 4.60 dollars per $m^3$.
- Gas storage in propane: 1130 dollars per $m^3$.
- Natural gas storage in pipeline at 1600 psia: 1700 dollars per $m^3$.

## 2. Procedure

### *2.1 Costs Analysis*

The economic flow chart for underground gas storage in depleted oil reservoir consists of the various costs at different stages: acquisition cost, development cost, cost of gathering facilities and cost of cushion gas, which are summed up to get the total cost of investment which will be added to the annual storage cost to get the total storage cost as shown in Fig 2.1 below

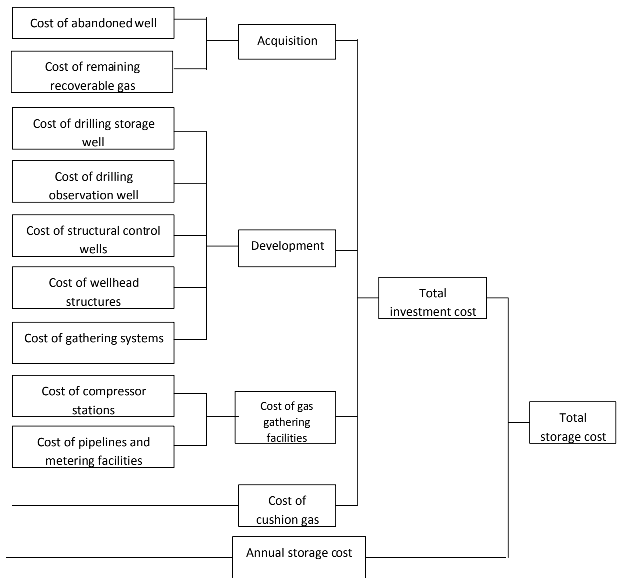


Fig 2.1 Economic flow chart for natural gas storage in depleted reservoir

As with all infrastructural investments in the energy sector, developing storage facilities is capital intensive. Investors usually use the return on investment as a financial measure for the viability of such projects. It has been estimated that investors require a rate of return between 12 percent to 15 percent for regulated projects, and close to 20 percent for unregulated projects. The higher expected return from unregulated projects is due to the higher perceived market risk. In addition significant expenses are accumulated during the planning and location of potential storage sites to determine its suitability, which further increases the risk [1].

The capital expenditure to build the facility mostly depends on the physical characteristics of the reservoir. First of all, the development cost of a storage facility largely depends on the type of the storage field. As a general rule of thumb, salt caverns are the most expensive to develop on a billion cubic feet (Bcf) of working gas capacity basis. However one should keep in mind that because the gas in such facilities can be cycled repeatedly, on a deliverability basis, they may be less costly. The wide price range is because of some region difference which dictates the geological requirements.

According to American Gas Association [1], these factors include the amount of comprehensive horsepower required, the type of surface and the quality of the geologic structure to name a few. A depleted reservoir costs between 800 million naira ($5million) to 1.12 billion naira ($7million) per Bscf of working gas capacity.

The conversion rate from naira to dollar as at October, 2012 is given as:

$$\$1 = N\ 160 \tag{2.1}$$

Finally, another major cost incurred when building new storage facilities is that of base gas. The amount of base gas in a reservoir could be as high as 50% for depleted reservoirs making them unattractive to develop when gas prices are high. The expected cash flows from such projects depend on a number of factors. These include the services the facility provides as well as the regulatory regime under which it operates. Facilities that operate primarily to take advantage of commodity arbitrage opportunities are expected to have different cash flow benefits than the ones primarily used to ensure seasonal supply reliability. Rules set by regulators can on one hand restrict the profit made by storage facility owners and on the other hand guarantee profit depending on the market model.

Several items contribute to the total investment necessary to put an underground storage field into operation, [16]. They include:

i. Cost of acquisition of the old well and/or reservoir, Acquisition cost involves the: cost of acquiring the abandoned well, cost of purchase of the remaining recoverable gas or oil in the formation, cost of acquiring the right to use the formation for storage.
ii. Cost of development of the storage facility, consisting of: cost of drilling storage wells, cost of drilling observation wells, cost of structural control wells, cost of wellhead structures, cost of gathering system.
iii. Cost of gas gathering system.
iv. Cost of base or cushion gas.

The total investment cost is given by the equation below:

Total investment cost = Acquisition cost + Development cost + Gas gathering cost + Cost of cushion gas (2.2)

It is represented mathematically as:

$$I = A + D + G + C \tag{2.2a}$$

The total storage cost = initial investment cost + annual storage cost (2.3)

This is represented mathematically as:

$$S = I + N = A + D + G + C + N \tag{2.3a}$$

The price of Natural Gas as at October, 2012 was \$4.06/MMBtu = \$4.06/1000scf [8]

A Microsoft Visual Basic Program was developed using eqs 2.2 – 2.17, and was used to perform the economic analysis of the storage reservoirs, considering the different costs ranging from the cost of drilling a well to cost of installation of surface facilities. The results of the economic analysis are presented in this work.

### *2.1.1 Acquisition cost, (A)*

Acquisition cost is the cost of acquiring the abandoned oil/gas well from the oil/gas producing company. It is always negotiable between the gas storage system operator and the oil producing company that produced oil from the well. The agreement is always on a lease arrangement. Acquisition cost is the sum of the cost of abandoned well and cost of the remaining gas in formation. It is expressed mathematically as:

$$A = C_{Wa} + C_{Grem} \tag{2.4}$$

#### *2.1.1.1 Cost of acquiring abandoned well, ($C_{Wa}$)*

This equals salvage value of 20% of initial well cost.

Initial cost of well = Drilling cost (\$/ft) * Depth (2.5)

Salvage value of remaining oil well = 20% of Initial cost of well (2.6)

#### *2.1.1.2 Cost of purchase of remaining recoverable gas in formation, ($C_{Grem}$)*

$$C_{Grem} = \text{Gas price} * \text{amt of remaining recoverable gas} \tag{2.7}$$

### *2.1.2 Development cost, (D)*

The development cost is the cost of drilling new wells and related activities like installation of wellhead structures required for the reconditioning of the depleted reservoir for underground storage facility. Six new wells are to be drilled in the course of developing the storage facility. One storage well would be needed: for injection withdrawal.

Five observation wells are also necessary, observation wells permit the measurements to verify that injected gas is confined to the designated area and has not migrated away. They control gas bubble evolution from the storage wells and observe leakage if gas leaks from the storage reservoir.

The development cost covers: i. Drilling cost, ($C_D$), ii. Cost of installing wellhead structures, $C_{ws}$, and iii. Cost of installing gathering systems, $C_{gs}$. It is mathematically expressed as: For developing one well,

$$D = C_D + C_{ws} + C_{gs} \quad (2.8)$$

### 2.1.3 Cost of Gas Gathering System

Gathering systems are defined as the flowline network and process facilities that transport and control the flow of oil or gas from wells to a main storage facility, processing plant or shipping point.

A gathering system includes some or all of these put together: pumps, headers, separators, emulsion treaters, tanks, meters and regulators, compressors, dehydrators, valves, pipelines and other associated equipment [2].

The cost of gas gathering system in this text is the sum of the costs of compressor stations, pipelines and metering stations. It is represented mathematically as:

$$C_{ggs} = C_{comp} + C_{pipeline} + C_{meter} \quad (2.9)$$

#### *2.1.3.1 Compressor station:*

A reciprocating compressor of 200 - 1000billion hp whose daily input and output is 50 MMscf/day is chosen.

#### *2.1.3.2 Pipelines and metering stations:*

Pipeline diameters of 12’, 14’ and 18’ and length of about 40 miles are commonly used, and 4 metering stations are installed [9].

### *2.1.4 Cost of cushion gas*

Cost of cushion gas is estimated using 50cent/MMscf of working gas volume [15].

Cost = 50cent/MMscf working storage gas * working gas volume (2.10)

## 2.2 Financial Analysis

Based on the Energy Information Administration (EIA) standards, 1031Btu of average heat content is equivalent to 1 ft$^3$

Average gas price = \$4.06/MMBtu

1031Btu = 1scf (2.11)

According to Zachmann and Neumann [16]:

Reservoir Storage Cost per MMBtu = \$0.48 (2.12)

Annual Operating cost = Labour costs + Maintenance costs + Management costs (2.13)

Annual storage cost = Annual reservoir storage cost + Annual Operating cost (2.14)

Total storage cost = total investment cost + annual storage cost (2.15)

Gross Revenue = \$4.06 * Working gas capacity, Bcf/1000scf (2.16)

Net revenue for subsequent years of operation =Gross revenue – Annual Storage cost (2.17)

# 3. Results

## *3.1 CASE 1: Reservoir Z-16T without Water Influx*

The storage capacity of reservoir Z-16T with $W_e - W_p = 0$, $N_p = 0.5825$ MMstb, $N = 1130000$, $B_o = 1.405$, $B_g = 0.004156$, $R_p = 3200$, $R_s = 847$ was estimated as 8.8 Bscf and the total storage capacity was also estimated as 17.07 Bscf [3].

### *3.1.1 Storage Economics*

According to Philips [10];

- Cost of drilling a well per foot = \$150
- Cost of wellhead structures = \$10 000

- Cost of gas gathering system = $50 000

Cost of compressor station = $9 600 000 [11].
Cost of pipeline and metering stations = $10 400 000 [9].
According Latvian Business Guide, [5] (2006);

- Annual labour costs = $4 800 000
- Annual maintenance costs = $7 240 000
- Annual management cost = $804 000

The storage economics for reservoir Z-16T is computed using Microsoft Visual Basic Program as shown in Figs 3.1 and 3.2 (see Amendment) and the results summarized in Table 3.1.

Table 3.1 Summary of the cash flows for reservoir Z-16T

| YEAR | INV | REV | EXP | NCR | CUM. NCR | PV @ 5% | PV @ 10% |
|---|---|---|---|---|---|---|---|
| 0 | $59.1M | - | - | ($59.1M) | ($59.1M) | ($59.1M) | ($59.1M) |
| 1 | - | $35.7M | $17.15M | $18.55M | ($40.55M) | $17.67M | $16.86M |
| 2 | - | $35.7M | $17.15M | $18.55M | ($22.0M) | $16.82M | $15.33M |
| 3 | - | $35.7M | $17.15M | $18.55M | ($3.45M) | $16.02M | $13.94M |
| 4 | - | $35.7M | $17.15M | $18.55M | $15.1M | $15.26M | $12.67M |
| 5 | - | $35.7M | $17.15M | $18.55M | $33.65M | $14.53M | $11.52M |
| 6 | - | $35.7M | $17.15M | $18.55M | $52.2M | $13.84M | $10.47M |
| 7 | - | $35.7M | $17.15M | $18.55M | $70.75M | $13.18M | $9.52M |
| 8 | - | $35.7M | $17.15M | $18.55M | $89.3M | $12.56M | $8.65M |

#### 3.1.1.1 Calculation of Net Present Value and Internal Rate of Return

Net Present Value, NPV is a measure of profitability of any project. The net present value (NPV) or net present worth (NPW) of a time series of cash flows, both incoming and outgoing, is defined as the sum of the present values (PVs) of the individual cash flows. NPV compares the value of a dollar today to the value of that same dollar in the future, taking inflation and returns into account. If the NPV of a prospective project is positive, it should be accepted. However, if NPV is negative, the project should be rejected because cash flows will also be negative [14].

NPV = PV at 1yr + PV at 2yrs + PV at 3yrs + PV at 4yrs + PV at 5yrs + PV at 6yrs + PV at 7yrs + PV at 8yrs - PV at 0yr (3.1)

From Table 3.1, the Net Present Value, NPV at an expected rate of return/discount rate of 10% which is the sum of all the Present Values in that column = $8.65M + $9.52M + $10.47M + $11.52M + $12.67M + $13.94M + $15.33M + $16.86M - $59.1M = $39.86M

The internal rate of return (IRR) on investment for a project is the rate of return that makes the net present value of all cash flows from a particular investment equal to zero. The higher the IRR of a project, the more desirable it is to undertake the project. Table 3.2 is a table of the net present values for reservoir Z-16T at various discount rates, which was used in generating a plot of NPV against discount rate as shown in Fig 3.3 for the determination of the IRR which is 26.8%. This value is the discount rate at which the NPV equals zero.

Table 3.2 NPV at various discount rates, reservoir Z-16T

| Discount Rate (%) | NPV ($) | Discount Rate (%) | NPV ($) |
|---|---|---|---|
| 5 | 60.79M | 25 | 2.65M |
| 10 | 39.86M | 30 | (4.85M) |
| 15 | 24.14M | 35 | (10.90M) |
| 20 | 12.08M | | |

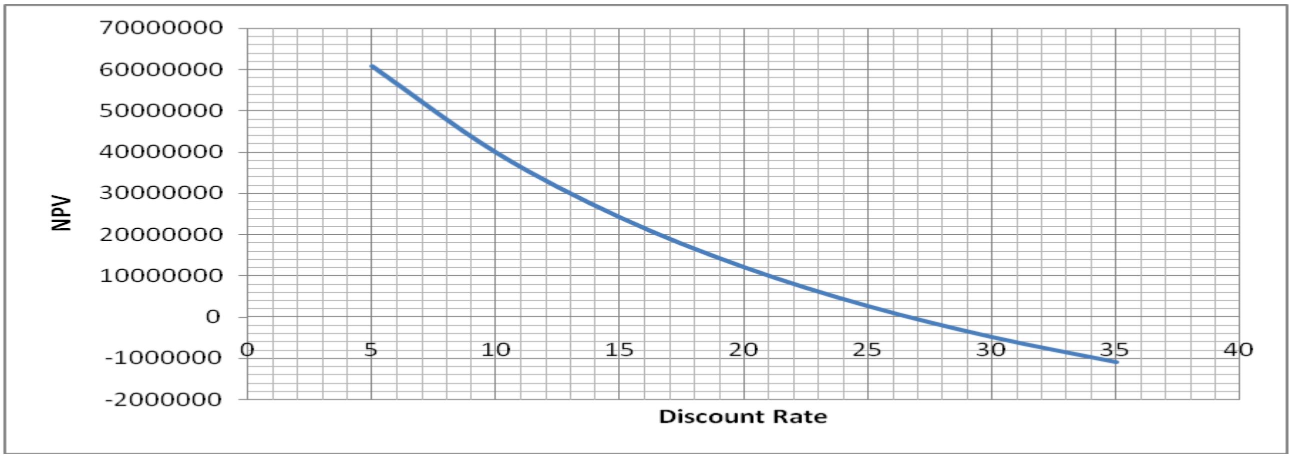


Fig 3.3 Plot of NPV against Discount rate, reservoir Z-16T

### *3.1.1.2 Pay-out, PO, for Reservoir Z-16T*

The pay-out for a project refers to the time (years) at which the initial investment on the project is just recovered. It is the time at which cumulative NCR becomes zero. From Table 3.1, cumulative NCR becomes zero between the 3$^{rd}$ and 4$^{th}$ year. In this project work, 3 and 4 years were used as the initial point (IP) and final point, (FP) respectively. Applying interpolation:

(PO – IP) / (FP – IP) = (0 – CUM NCR at IP) / (CUM NCR at FP – CUM NCR at IP (3.2)

(PO – 3yrs) / (4yrs – 3yrs) = (0 – ( - 3.45)) / (15.1 – ( - 3.45)) PO
= 3.19yrs which is also shown in Fig 3.4 below.

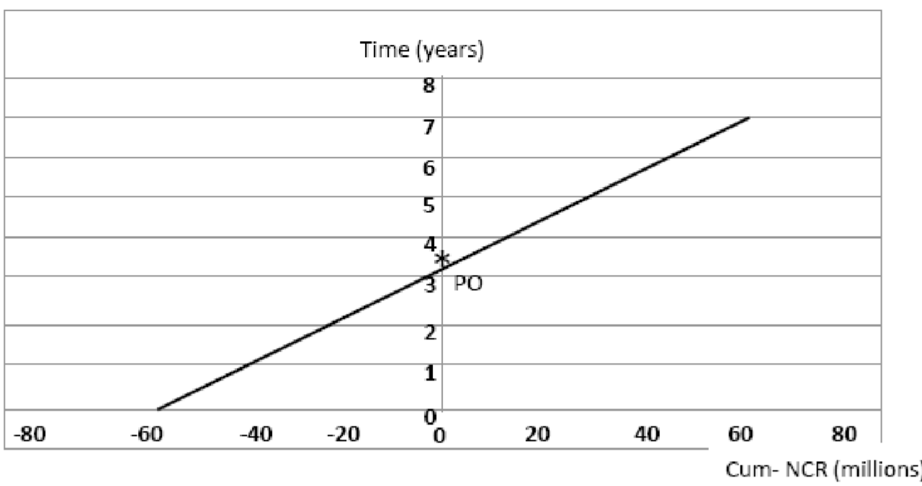


Fig 3.4 Plot of Time in Years Against Cum-NCR in Millions of Dollars, Reservoir Z-16T

### *3.2 CASE 2: Reservoir Z-16T with Water Influx*

The storage capacity of reservoir Z-16T with $W_e - W_p = 0$, $N_p = 0.5825$ MMstb, N = 1130000, $B_o = 1.405$, $B_g = 0.004156$, $R_p = 3200$, $R_s = 847$, $W_e = 17.55$MMscf, $W_p = 1.56$MMscf was estimated as 6.69 Bscf and the total storage capacity was also estimated as 13.7 Bscf [3].

### 3.2.1 Storage economics of reservoir Z-16T with water influx

The storage economics of reservoir Z-16T with water influx has been evaluated to determine the NPV, Break-even point and Pay-out using Figs. 3.5 and 3.6 (see amendment). The values generated thereof were used to make plots of time against cumulative NCR and time against cumulative Net Revenue as shown in Figs. 3.7 and 3.8 respectively.

Table 3.3 Summary of the cash flows for reservoir Z-16T (in millions $)

| YEAR | INV | REV | EXP | NCR | CUM. NCR | PV @ 5% | PV @ 10% |
|---|---|---|---|---|---|---|---|
| 0 | 59 | 0 | 0 | (59.00) | (59.00) | (59.00) | (59.00) |
| 1 | 0 | 27.14 | 16.11 | 11.03 | (47.97) | 10.50 | 10.02 |
| 2 | 0 | 27.14 | 16.11 | 11.03 | (36.94) | 10.00 | 9.11 |
| 3 | 0 | 27.14 | 16.11 | 11.03 | (25.91) | 9.52 | 8.27 |
| 4 | 0 | 27.14 | 16.11 | 11.03 | (14.88) | 9.07 | 7.54 |
| 5 | 0 | 27.14 | 16.11 | 11.03 | (3.85) | 8.64 | 6.84 |
| 6 | 0 | 27.14 | 16.11 | 11.03 | 7.18 | 8.23 | 6.22 |
| 7 | 0 | 27.14 | 16.11 | 11.03 | 18.21 | 7.83 | 5.66 |
| 8 | 0 | 27.14 | 16.11 | 11.03 | 29.24 | 7.46 | 5.14 |

**3.2.1.1 Pay-out, PO, for Reservoir Z-16T**

The pay-out for a project refers to the time (years) at which the initial investment on the project is just recovered. It is the time at which cumulative NCR becomes zero. From Table 3.3, cumulative NCR becomes zero between the 5th and 6th year. In this project work, 5 and 6 years were used as the initial point (IP) and final point, (FP) respectively. Applying interpolation:
(PO – IP) / (FP – IP) = (0 – CUM NCR at IP) / (CUM NCR at FP – CUM NCR at IP) (PO – 5yrs) / (6yrs – 5yrs) = (0 – (- 4020681)) / (6985971 – ( - 4020681)) PO = 5.37yrs which is also shown in Fig 3.7 below.

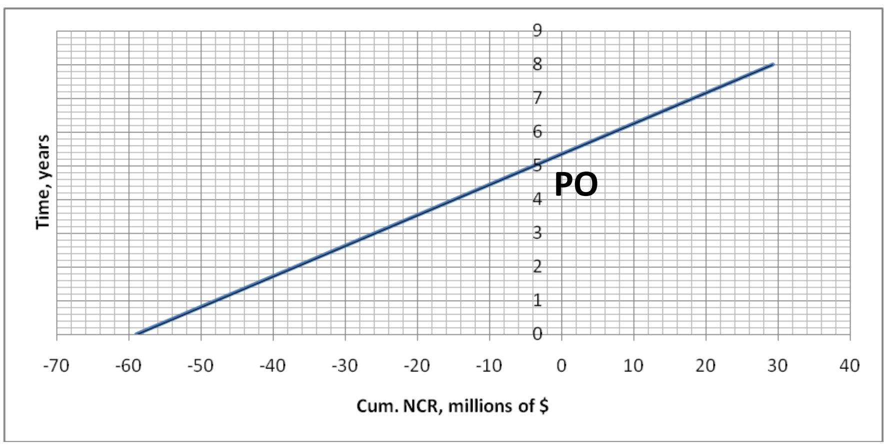


Fig 3.7 Plot of Time in years against Cum NCR in millions of dollars for reservoir Z-16T with water influx

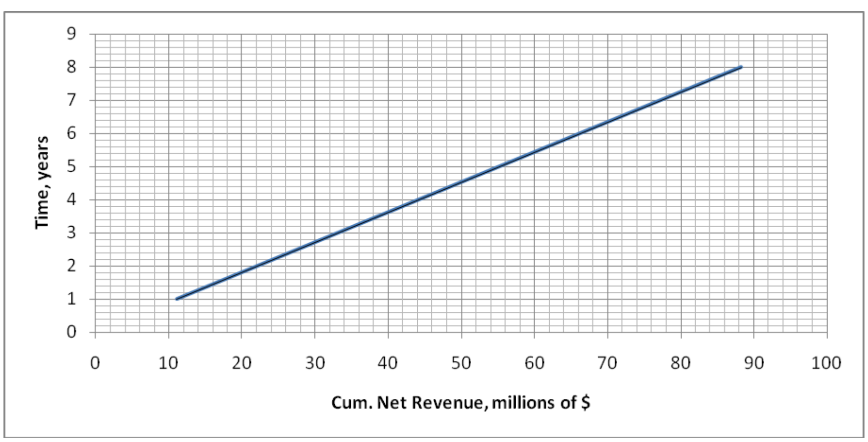


Fig 3.8 Plot of Time in years against Cum Net Rev in millions of dollars for reservoir Z-16T with water influx

### 3.2.1.2 Calculation of Net Present Value and Internal Rate of Return

From Table 3.3, the Net Present Value, NPV at an expected rate of return/discount rate of 5% which is the sum of all the Present Values in that column = \$10.5M + \$10M + \$9.52M + \$9.07M + \$8.64M + \$8.23M + \$7.83M + \$7.46M - \$59M = \$12.29M

The Net Present Value, NPV at an expected rate of return/discount rate of 10% which is the sum of all the Present Values in that column = \$10.02M + \$9.11M + \$8.27M + \$7.54M + \$6.84M + \$6.22M + \$5.66M + \$5.14M - \$59M = (\$0.156M)

The internal rate of return (IRR) on investment for a project is the rate of return that makes the net present value of all cash flows from a particular investment equal to zero. The higher the IRR of a project, the more desirable it is to undertake the project. Table 3.4 is a table of the net present values for reservoir Z-16T at various discount rates, which was used in generating a plot of NPV against discount rate as shown in Fig 3.9 for the determination of the IRR which is 9.93%. This value is the discount rate at which the NPV equals zero.

Table 3.4 NPV at various discount rates, reservoir Z-16T

| Discount Rate (%) | NPV (\$) |
|---|---|
| 5 | 12.29M |
| 10 | (0.16M) |
| 15 | (9.51M) |
| 20 | (16.68M) |

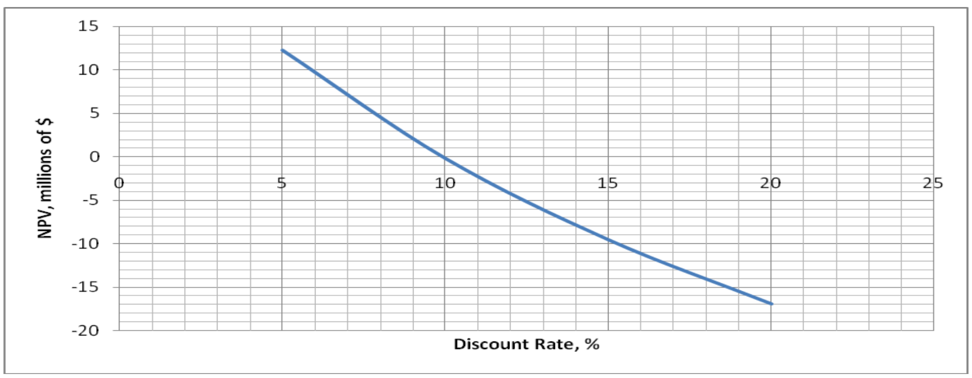


Fig 3.9 Plot of NPV in millions of dollars against Discount Rate in % for reservoir Z-16T with water influx

Table 3.5 Result of Storage Economics for Z-16T

| | Reservoir Z-16T without Water Influx | Reservoir Z-16T with Water Influx |
|---|---|---|
| Total Storage Capacity | 17.07 Bscf | 13.7 Bscf |
| Working gas capacity | 8.8 Bscf | 6.69 Bscf |
| Acquisition cost | \$28.79 million | \$28.79 million |
| Development cost | \$10.26 million | \$10.26 million |
| Cost of gathering facilities | \$20 million | \$20 million |
| Cost of cushion gas | \$4 400 | \$3 345 |
| Annual storage cost | \$17.15 million | \$16.16 million |
| Total investment cost | \$59.1 million | \$59.1 million |
| Gross Revenue | \$35.7 million | \$27.16 million |
| Annual Net Revenue | \$18.55 million | \$11 million |
| IRR | 26.8% | 9.93% |
| Pay-out | 3.19 years | 5.37 years |
| Break-even point | \$59.1 million | \$59.1 million |
| NPV @ 10% after 8 years | \$39.86 million | \$12.29 million |

## 4. Conclusion

The result of the economic analysis in this work has shown that reservoir Z-16T is suitable for conversion to underground storage purpose. From the economic indicators considered, the following conclusions are made:

1. The storage capacity of reservoir Z-16T reduced from 8.8Bscf to 6.69 Bscf without and with water influx respectively.
2. The cushion or base gas required for the pressure maintenance already exists in both cases.
3. A potential investor in gas storage business can check the profitability of any depleted reservoir using the computer models developed in this work.
4. The internal rate of return (IRR) which is used as profit indicator was 26.8% and 9.93% without and with water influx respectively.
5. The Net Present Values at expected rate of return of 5% without and with water influx are $39.86 million and $12.29 million respectively.
6. The pay-outs without and with water influx are 3.19 years and 5.37 years respectively.

## Nomenclature

| | |
|---|---|
| *A* | *Acquisition cost* |
| *B* | *Constant 2πR2ihΦ(Cw + Cp)* |
| *Bo* | *Oil formation volume factor* |
| *Bg* | *Gas formation volume factor* |
| *Bgi* | *Initial Gas formation volume factor* |
| *Bw* | *Water formation volume factor* |
| *Bscf* | *Billion standard cubic foot* |
| *Bcf* | *Billion cubic foot* |
| *Btu* | *British thermal unit* |
| *C* | *Cost of cushion gas* |
| *Cwa* | *Cost of acquiring abandoned well* |
| *Cgrem* | *Cost of purchasing remaining gas in formation* |
| *CD* | *Drilling cost* |
| *Cws* | *Cost of installing wellhead structures* |
| *Cgs* | *Cost of gas gathering system* |
| *Ccomp* | *Cost of Compressor stations* |
| *Cpipeline* | *Cost of pipelines* |
| *Cmeter* | *Cost of metering facilities* |
| *Cum NCR* | *Cumulative Net Cash recovery* |
| *C* | *tabulated aquifer function (from time t to time t i)* |
| *D* | *Development cost* |
| *DP i* | *half pressure drop at interface from time (i-1) to (i+1).* |
| *EIA* | *Energy Information Administration* |
| *EXP* | *Expenses* |
| *FP* | *Final point* |
| *Ft3* | *Cubic foot* |
| *I* | *Initial Investment cost* |
| *INV* | *Investment* |
| *IP* | *Initial Point* |
| *IRR* | *Internal Rate of Return* |
| *MMBtu* | *Million British Thermal Unit* |
| *MMscf* | *Million standard cubic foot* |
| *N* | *Annual storage cost* |
| *N* | *Initial Oil in place* |
| *Np* | *Cumulative Oil Production* |
| *NPV* | *Net Present Value* |
| *NPW* | *Net Present Worth* |
| *NCR* | *Net cash recovery* |
| *PO* | *Pay-out* |
| *PV* | *Present value* |
| *REV* | *Revenue* |
| *Rp* | *Gas oil ratio* |
| *Rs* | *Gas solubility* |

*S* *Total storage cost*
*V* *Storage capacity*
*Vinj* *Volume of gas injected*
*Vw* *Estimated volume of aquifer water*
*We* *Water encroachment*
*Wp* *Water Production*

**References**


[1] American Gas Association (1997): AGA Monograph on Underground Gas Storage, Arlington, V.A.

[2] Anyadiegwu C.I.C. (2004): Examining the prospects of Natural Gas Liquids Extraction from Nigerian Gas flare stream. Int'l Research Journal in Engineering, Science and Tech (IREJEST) Vol. 1, No 2, pp 60 - 69.

[3] Anyadiegwu C.I.C. et al., (2012): Estimation of Storage Capacity of an Underground Gas Storage Reservoir, International Journal of Academic Research, Vol 4 No 4, July, 2012, pp 116 – 122, Azerbaijan.

[4] Bruns J.R., Fetkovich M.J. and Meitzen V.C., (1965): The Effect of Water on P/Z – Cumulative Gas Production Curves, JPT pp. 287-91.

[5] Latvian Business Guide, (2006): Geological and Economic Study on Possible Underground Natural Gas Storage Development in Latvia, Dubele District, Nr.2006-G130/06-TREN/06/TEN-E-S07.68968, Executive Summary, Final Report, November, 50 pp.

[6] Lee J. and Wattenbarger R.A., (2002): Gas Reservoir Engineering, SPE Text Book Series Vol 5, Texas, U.S.A.

[7] Medici M., (1974): The Natural Gas Industry: A Review of World Resources and Industrial Applications, London, Newness – Butterworths, SPE Reprint Series No13 Gas Technology 81, 1977.

[8] Nigerian Gas Report, (2011): Nigerian Energy Digest, Vol 1, pp. 6-7, 64

[9] Oilserve Nigeria Limited (Jan, 2004): Ongoing Power Plant Stations and Pipeline Projects Listing, Port-Harcourt, Nigeria.

[10] Phillips O. (2009): Profitable Carbon dioxide, presented on May 13, at the University of Wyoming Carbon dioxide Conference, U.S.A.

[11] Revak Amy, (May 26, 2011): Commissioners Advance Lease for Natural Gas Compressor Station, Herald Standard, Posted: Friday, May 27, p.1

[12] United States Energy Information Administration, (EIA), (2004): The Basics of Underground Natural Gas Storage, Natural Gas Storage Report, August 2004 Update, Retrieved from http://ir.eia.gov/ngs/ngs.html, pp. 1-7.

[13] William E.B. (1997): Water Influx and it's Effect on Oil Recovery, Part 1, Supri Tr. 103 Report, prepared for U.S. Department of Energy, Tulsa, U.S.A.

[14] Woodside Petroleum, (2010): Perth, Western Australia, Retrieved from http://en.wikipedia.org/wiki/natural.gas.storage.

[15] World Bank Publications, (2010): The Future of The Natural Gas Market In Southeast Europe, 1818 H Street, NW., Washington DC 20433, U.S.A.

[16] Zachmann G. and Neumann A., (2007): Natural Gas Storage, Tales From Two Countries, Drafted May 31, DIW, Berlin.

**Amendment: Figures**

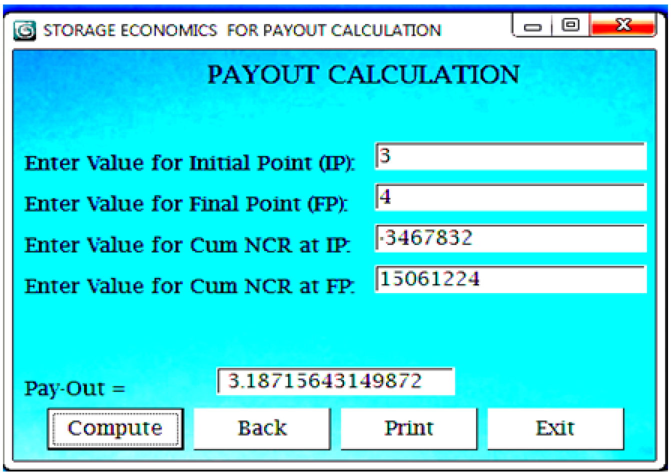


Fig 3.1 Payout Calculation for reservoir Z-16T


Fig 3.2 Computed Storage Economics of reservoir Z-16T


Fig. 3.5 Storage Economics of reservoir Z-16T with water influx

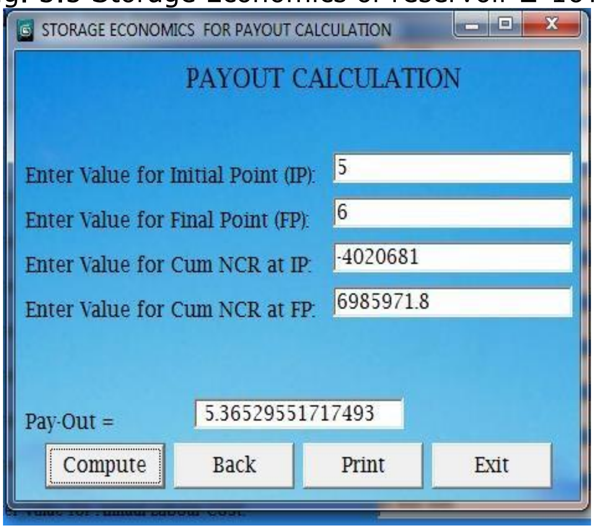


Fig 3.6 Pay-back calculation for reservoir Z-16T with water influx