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Review paper

Selection of Exploration Strategy

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PROCEEDINGS

Key words: Exploration, Reserves replacement, Highly explored area, Offshore, Onshore, Risk of exploration, Turnover, Production cost, Public company.

Abstract

The exploration of oil and gas depends on investments and prospective area to be explored. Exploration as a risky business, has to be financed from company's resources, not through loan. Basically, exploration provides oil and gas producers, who are financed through actual production.

Our prospective area is well explored and there is a diminished probability of discovering large deposits. Production has a decreasing trend.

This is why the strategy of exploration needs to be checked and redefined. Especially as this coincides with political and economic changes and with changes in ownership. Owners and/or their representatives are ready to invest in exploration if the target is clear, the cost defined and there is a high probability of finding oil and/or gas.

Ključne riječi: istraživanje, obnova zaliha, visoka istraženost, podmorje, ozemlje, istraživački rizik, ukupni prihod, trošak proizvodnje, javno poduzeće.

Sažetak

Programiranje istraživanja nafte i plina prvenstveno ovisi o veličini sredstava za istraživanje i raspoloživom i perspektivnom istražnom prostoru. Budući je istraživanje rizičan posao, ono se u pravilu financira iz vlastitih sredstava. To uvelike određuje politiku gospodarenja zalihama, odnosno proizvodnju.

Naš nacionalni prostor je visokoistražen i mala je vjerojatnoća nalaza velikih zaliha. Proizvodnja je ušla u trend pada.

To su dovoljni razlozi da se vrednuje i nađe i/ili potvrdi strategija istraživanja. Tim više što to u nas koincidira s novim vlasničkim odnosima, a ovlaštenici prosuđuju strategiju koja, u odnosu na druga ulaganja, sadrži neuobičajeno velik rizik, doduše i profit, ali sve zastire jednako neuobičajeno udaljen vremenski horizont - desetak i više godina. Nasuprot tome, uspjeh ulaganja u proizvodnju cipela vidite u jednoj sezoni, u građevinarstvu u jednoj godini, a u većini složenijih projekata unutar pet godina.

1. INTRODUCTION

The transformation of the social and political system, together with the consequences of war, have forced the oil industry of Croatia to redefine its business strategy including that of exploration. This strategy shall remedy negative trends and it has to be convincing enough for the owner's representatives to make decisions on investment in exploration.

Forecasting production and the state of reserves indicates the required volume of replacement reserves (over a given period). However, restrictive factors include the accessibility of a quality exploration area under acceptable conditions and the availability of capital for exploration.

2. RESERVES AND PRODUCTION AS CRITERIA FOR DEFINING EXPLORATION STRATEGY

As production depends both on reserves and the policy of exploitation, it therefore makes sense to consider the influence of both parameters on defining the scope of exploration. On the basis of reserves, the minimal objective in both the medium-term and particularly long-term periods, is to discover such reserves and to prevent the decrease of existing ones over a certain period of time. This means that the replacement coefficient should be at least equal to 1 or greater than 1.

Production depends not only on the state of reserves but also on the market. Therefore, if production has an increasing trend, exploration would have to provide for reserves, while the economic base for financing the exploration would grow as well. Although, generally, it depends on the continuity of exploration successes, percentage of field depletion and production costs.

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	Total sources	Reserves by conventional methods		Additional reserves after the application of EOR	
		proven reserves	potential reserves	proven reserves	potential reserves
North America	(223)	45	67	74	37
South America	(223)	74	45	81	23
Europe	(75)	30	15	15	15
Africa	(259)	59	103	30	67
Middle East	(848)	268	170	251	59
Asia	(443)	96	96	192	59
Far East	(149)	30	59	23	37

Table 1 Estimate of the volume of sources and possibilities of conversion into reserves (in 10^9 bbl).

According to the production criterion alone (without possible market sales), in the present exploatation policy replacement reserves are required for covering some 4 million TOE/y[1] of current annual production.

3. THE SCOPE OF EXPLORATION AND AREA QUALITY AS CRITERIA FOR NEW STRATEGY

In terms of exploration for oil and gas, the territory of Croatia is a highly explored area. Throughout some fifty years the oil and gas production expanded until the mid-eighties, which was largely a consequence of successful exploration. From the discovery of the Gojlo and Križ oil fields to that of the Podravina gas fields, in each decade discoveries have been at ever increasing depths, and deposits (of oil and gas) have been found under progressively more complex conditions of pressure, temperature and fluid composition.

Analyzing the results of exploration in Texas and Wyoming in the USA (IVANHOE, 1996), it has been noted that on a sample of over 750 wells there is a statistical regularity of inverted proportionality of layer thickness and permeability as well as permeability and porosity, and a direct proportionality of depth and production cost. To some extent this is also confirmed in Croatia in the discoveries of the Molve, Kalinovac and Stari Gradac fields. Deeper and deeper exploration objectives require more extensive investments, simultaneously with the stagnant low price of oil and gas. Besides, as mentioned earlier, Croatia represents a highly explored area, the probability of finding a large quantity reserves has to be inversely proportional to the explored level. This aspect has been dealt with in the literature, periodically and mainly statistically, with the intention of establishing the volume of remaining reserves, their price, etc.

During 1987, after the prices dropped precipitously from 30 to 10 US$/bbl and then seemingly stabilized at US$ 18, the President of Elf Aquitaine stated that with a price of 20 US$/bbl it would be possible to convert 82% of resources into proven reserves (OGJ, 1987a), which at the time amounted to 2200 billion bbl and this would cover 85% of annual consumption from 1987. The current estimates of the time were those based on the regional distribution of resources and reserves, shown in Table 1.

According to the same source, with the price of 12 US$/bbl it was possible to discover and bring to production only 58% of the potential world reserves i.e. resources, while with a price of up to 30 US$/bbl, as much as 95%.

In OGJ Report (OGJ, 1987b), there were mentioned almost 1000 fields discovered in offshore areas of the world, but they were not put into production because of the high cost. Most of the fields (293) were found in the area of Far East, 264 in the region of Africa, and even 263 in the area of Europe. In South America 98 fields were discovered, but only 51% in the offshore. Approximately one third of these fields were found at sea depths of up to 30 m - 271 fields, and 554 fields were discovered at depths from 30 to 120 m; at depths from 120-300 m - 118 fields, and over 300 m - 24 fields.

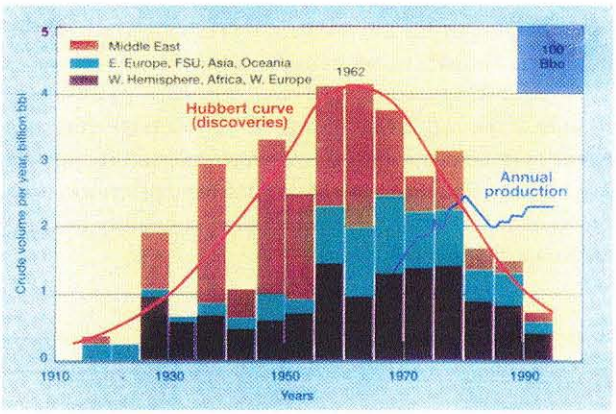

Fig. 1 History of oil production growth and forecasts of the further course. From IVANHOE, 1996 (Hubbert curve added by Ivanhoe is weighted average of global oil discovered 1915-1992).

[1] Tons of oil equivalent per year.

Year	1987	1988	1989	1990	1991	1992	1993	1994	1995*
Total number of rigs in operation in the United States of America	1050	900	860	1000	850	750	650	1000	1000

Table 2 Number of drilling rigs in operation in the period from 1987 to 1993 (after KVINNSLAND, 1993 and GALOVIĆ, 1996). * - data for the first 6 months.

Year	1982	1983	1984	1985	1986
Number of deep wells drilled	1205	577	614	566	391
Average depth (m)	5290	5175	5099	5170	5198
Average price per well (1,000 US$)	6636	6095	5817	5574	5394
Number of producers	600	301	288	284	174

Table 3 Developments in the USA at the beginning of the eighties, until the drop of prices (from KVINNSLAND, 1993).

It must be stressed that through exploration, Croatia can discover new reserves but at the present price of oil the cost of new reserves has to be acceptable. According to this, the general philosophy of life reserve confirms the justifiability of exploration even in highly explored areas.

IVANHOE (1995), by updating the Hubbert curve attempts to answer a number of complex questions and presents statistically based arguments for constructing the oil life curve (Fig. 1). According to these results the world reserves will reach their maximum at the end of this century.

World oil exploration, particularly drilling, has been considerably reduced since 1986, until the present. From Table 2 it can be observed that, with the exception of 1990 when the number of rigs in operation was somewhat increased, until 1993 there were less rigs in operation than in 1987.

The exploration forecast in the offshore area as well as the production estimate were given by KVINNSLAND (1993) on the basis of samples in 89 countries. A number of wells were analysed and not the number of rigs, but only the wells in the world offshore areas. According KVINNSLAND (1993), in the four years following the decrease of activity in 1986/7, the number of drilled wells worldwide was increasing (to over 1200/year during 1988-1991), with a simultaneous decrease of wells in both the Americas (less than 900). In 1993 there appeared an increasing trend of drilled wells with an expected further increase in the following years, in all the regions.

Accessible papers on future world exploration refer to a few general conclusions, which can be useful in our business strategy and especially in the strategy of exploration.

1. The forecasting of a increase in exploration and development in the context of oil and gas prices encourage our own explorational complex;
2. Regional forecasting of exploration and development suggests that no extensive operations in the Mediterranean are foreseen (this renders more difficult the marketing of our services, that is, of our free equipment and manpower;
3. With respect to our foreign exploration, besides Community of Independent States and in particular Russia, efforts should be focused on the western coast of Africa, especially Angola where we have already been involved.

The US data presented in Table 3 indicate the developments at the beginning of the eighties, until the drop of prices.

4. SOURCES OF EXPLORATION FINANCING

It is well known that the possibility of exploration financing depends on current production. The financing of oil and gas exploration, due to the risks involved, is sourced as a rule, from the proper equity of the company or from the pooled assets of a partner. Credit financing should not be used. The international accounting system applied in Croatia since 1994 has brought about considerable changes in the method of exploration financing, and now requires that special care be taken over expenditure, in order to provide continuity in exploration (under the current or even declining oil prices).

Positive discovery and revival of production shall increase the turnover. Table 4 shows that between 1960-1981 Naftaplin surpassed, in oil production, the limit of 0.8 mil. t per year in 1960 and in 1970 it surpassed 2 mil. t and in 1980 3 mil. t. Natural gas production started vith 100 mil. m^3 in 1964, 500 mil. m^3 in 1971 surpassing 1 bil. m^3 in 1981. The turnover and particularly income, due to the price policy and to constant economic changes do not completely follow the increasing production although the turnover (and the economic power of the company) do follow, to a certain degree, the curve of a pretty regular production increase.

In the eighties (Table 5), increased investment into exploration resulted from a large share of the offshore

Year	Oil (t)	Gas (1000 m^3)	Tons of oil equivalent (TOE)
1960	768,028	38,564	806,592
1961	1,125,034	55,472	1,080,506
1962	1,156,476	61,419	1,234,313
1963	1,151,005	77,837	1,228,842
1964	1,285,362	130,602	1,415,965
1965	1,415,921	151,106	1,567,027
1966	1,545,110	188,826	1,733,936
1967	1,702,005	232,359	1,934,364
1968	1,818,336	329,728	2,148,064
1969	1,931,641	408,624	2,340,265
1970	2,055,248	477,671	2,532,919
1971	2,136,791	547,537	2,684,328
1972	2,326,456	569,162	2,895,608
1973	2,422,930	611,723	3,034,653
1974	2,470,197	573,796	3,143,993
1975	2,669,751	751,310	3,421,061
1976	2,812,779	911,185	3,723,964
1977	2,828,717	1,009,052	3,837,779
1978	2,931,166	934,294	3,865,460
1979	2,971,006	805,668	3,776,674
1980	3,056,388	983,241	4,039,629
1981	3,140777	1,168,926	4,309,703
1982	3,047,194	1,244,541	4,291,735
1983	2,860,466	1,195,127	4,056,595
1984	2,853,327	1,231,493	4,084,820
1985	3,020,189	1,463,594	4,483,783
1986	3,006,856	1,699,388	4,706,244
1987	2,946,648	1,973,458	4,922,126
1988	2,844,668	2,122,910	4,967,578
1989	2,705,166	2,176,657	4,881,923
1990	2,496,794	1,982,287	4,479,081
1991	1,902,956	1,838,876	3,741,832
1992	1,742,852	1,820,397	3,563,249

Table 4 Production of oil, gas and conditional oil in Naftaplin from 1960-92 (KOLUNDŽIĆ, 1995).

exploration as well as from the exploration and development of deep gas wells in Podravina. In such a way, the expenditure was increased from 1/2 of the total revenue to more than 2/3.

The most rapid increase of material and energy costs (as well as of foreign services) can be observed as a consequence of addressing more costly forms of exploration: greater depths, offshore drilling area and an increase in the number of production fields. Exploration and development expenditure was being increased at lower rates. Besides, the material and energy costs were increased quite surely as a consequence of a great number of wells, particularly for oil. During a great reduction of oil and gas prices (as in 1986), there shall be determined the limit of profitable production per well and those wells which by their production do not cover the production costs will be excluded from production.

Table 6 shows a trend of increasing share of costs in the total revenue. Around 1980 that share was between 39-40% whereupon it started to increase.

Such a progressive increase of costs after 1985 was conditioned by the decrease in oil price in 1986, but it also shows that the costs were not reduced.

To estimate exploration financing from 1989, in view of the production potential (Fig. 2) over a fifteen-year period, the resource will decrease with no significant price increase.

Such an estimated profile affects the cash flow. With respect to the basic products, oil and gas, these projections are shown in Figs. 3 and 4.

If, in principle, we expect ever reducing financial resources for oil and gas exploration, then these should be focused on the elements of efficiency regarding both our own services and the quality of concessions as well as the efficiency of the operators' activities.

The exploration of oil and gas of INA-Naftaplin shows a growth of the efficiency coefficient from 1945 to 1985. as shown in Table 7. The growth of drilling efficiency has an intrinsic value, due to the fact that the efficiency is being increased although the structures are consistently deeper, drilling conditions increasingly more difficult, and the explored level indicator is ever higher. However, the correlation between the number of exploration metres and tons of new production is, of course, not linear and it considerably depends upon the explored level indicators of the area concerned.

The productivity as a rate of efficiency, suggests a decline. Through the combined influence of a price drop and further growth (instead of reduction) of the number of employees, the productivity has tended to decline since the beginning of the eighties, and in the second half of the decade became dramatic. The time disparity of the inflection points for the base activities of INA arises out of constant changes of external and internal conditions of business activities. A series of key indicators from 1970-1990 show a break of continuity in the middle of the eighties.

It may be stated that from 1970 to 1990 the production of natural gas increased and the production of oil after 1986 has been in gradual decline. The total production of oil and gas, as shown in tons of oil equivalent is in constant growth; however, due to a faster growth of the number of employees, the production in TOE per employee since 1970 has declined (Table 8).

In addition, the natural production of oil equivalent increased from 1970-1980 by 37%, from 1980-1985 by 11.4% and from 1985-1990 by 3.6%. The reserves of oil and associated gas have decreased, and the reserves of natural gas have increased (Table 8).

The absence of adequate reactions in the eighties, (by 1986 at the latest), should be attributed to the established economic and political system in Croatia. The rationalization and reduction of the number of employ-

Year	Material and energy	Services of others	Depreciation	Investment maintenance	Invest. into explor. & development
1970	100	100	100	100	100
1975	332	462	559	395	524
1980	1,485	1,369	6,544	202	4,113
1985	28,964	17,428	30,088	6,068	49,111
1989	552,409	172,398	176,991	85,227	274,123

Table 5 Review of a relative increase of certain financial indicators in INA-Naftaplin (from KOLUNDŽIĆ, 1995).

Year	Share of costs in total revenue (%)
1981	39.6
1982	46.4
1983	46.0
1984	44.8
1985	58.8
1986	77.9
1987	80.6
1988	82.6
1989	96.2

Table 6 Share of costs in the total revenue (from KOLUNDŽIĆ, 1995).

ees as one aspect of cost reduction was not possible, and a number of protective mechanisms depended thereupon (Table 9).

In the ten-year period between 1984-1994 a sample of oil companies from the United States shows a growth of effectiveness, both through reduction of discovery costs of ≥50% (Fig. 5) and through a high reserve replacement rate (Fig. 6).

However, for the overall improvement of efficiency in the field of oil and gas exploration and production, cost cutting measures combined with organizational adaptation (Down-sizing) will not give results unless this is undertaken in conjuction with a reasonable exploration level.

What is a reasonable level? The data supporting exploration efficiency and requirements for replacement of reserves suggest that an investment of 6 US$ per BOE produced is necessary in order to halt the decrease in production.

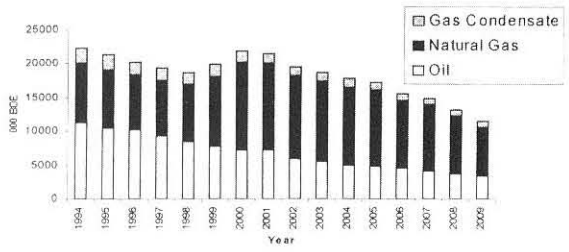

Fig. 2 Estimate of the production profile (from KOLUNDŽIĆ, 1995).

Naftaplin planned to invest 49 million US$ for exploration within Croatia and abroad and 40.5 million US$ for development in 1995. In the relation to the total production of oil and gas and the value obtained at actual prices the planned investments make 3.8 US$ per produced BOE or 1.9 US$/bbl for oil and gas exploration. In compliance with some data, 2.4 US$/bbl was spent on exploration in 1994.

The relevant world literature reiterates the necessity for investment into new reserves from 6 to 8 US$/bbl. The data of the well-known auditing house Arthur Andersen showed on a model of several international companies that the investments amounted to 5.6 US$/bbl in the year 1994.

However, investments should be increased in relation to the actual ones within the realm of possibility and continuity should be provided. The quality of exploration and efficiency should be assured, through the possibility of selecting an exploration objective.

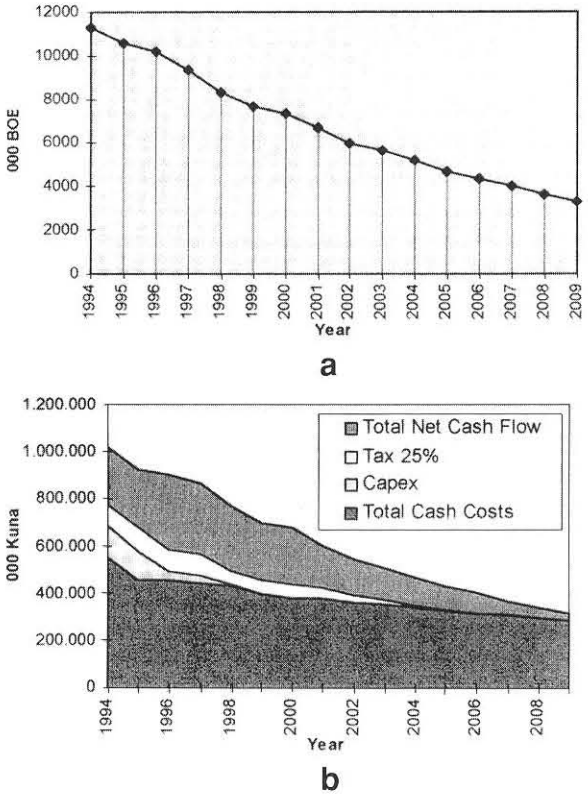

Fig. 3 Forecasts of oil production and revenue: a) oil production; b) cash flow. Kuna (Kn) is Croatian money unit (1 Kn ~ 0.2 US$). From KOLUNDŽIĆ (1995) and GALOVIĆ (1996).

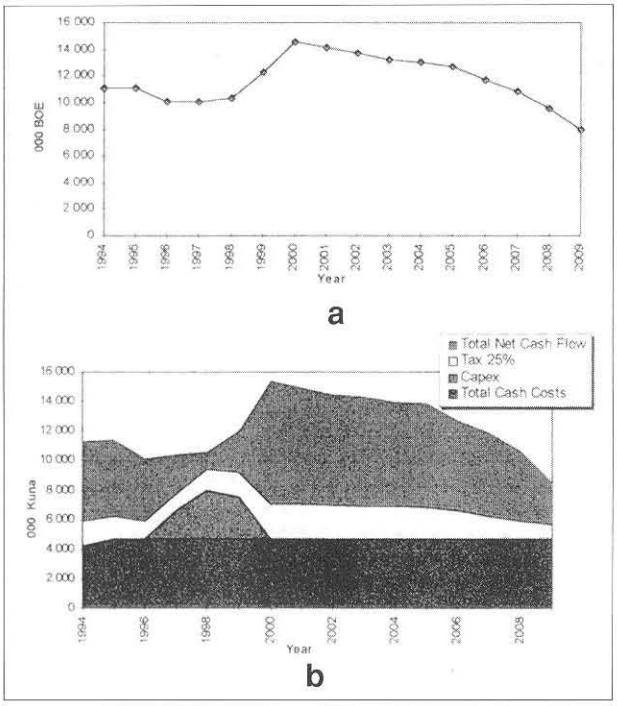

Fig. 4 Forecasts of gas production and revenue: a) gas production; b) cash flow. From KOLUNDŽIĆ (1995) and GALOVIĆ (1996).

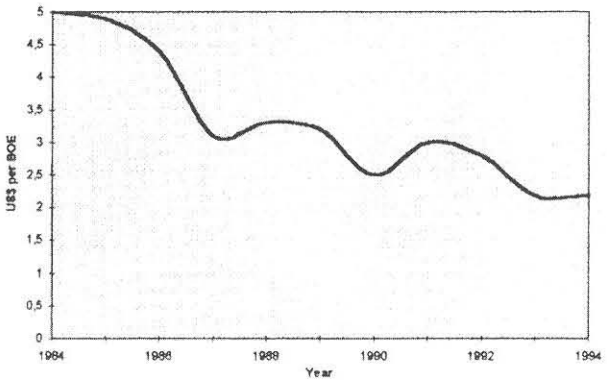

Fig. 5 Trend of reduction of exploration and development costs in USA (from Artur Andersen & Co., Sc: Hydrocarbon Value Chain Analysis.- Unpublished Report, Sept. 1995, INA-Naftaplin Archive).

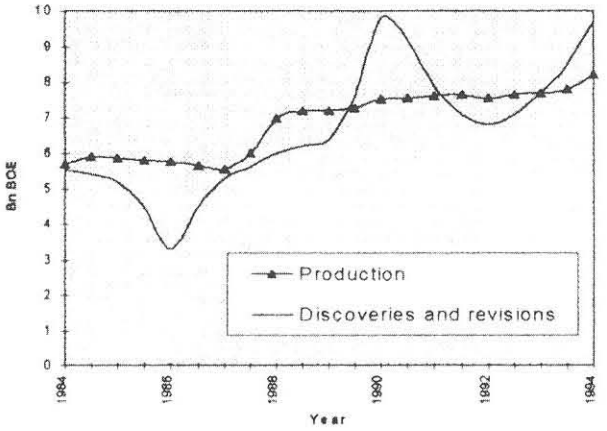

Fig. 6 Curves of growth for production and discovery of reserves (from Artur Andersen & Co., Sc: Hydrocarbon Value Chain Analysis.- Unpublished Report, Sept. 1995, INA-Naftaplin Archive).

5. CONCLUSIONS

Exploration is a multidimensional problem. The explorers consider it from a professional, geological, developmental, technological and user's point of view. The management reach their final decisions on the basis of value and scope of investment, rate of return and evaluation of risk.

The owner or his representative is not usually an oilman. He rarely has any exploration and/or mining sentiment and is additionally perplexed by the time component in the oil business. A time horizon ranging from 5 to 20 years, necessity of investment continuity, the scope of investment - all these are the characteristics which obstruct the vision.

Through providing a greater selection of exploration objectives (both within Croatia and abroad) than the planned scope of exploration, it is possible to establish, by comparative analysis, a priority between objectives. Such basic data also enable comparative analyses with the prices of discovered reserves being offered for sale. In addition to this, by past analysis, it can be easily proven that both exploration and production were a profitable business. Through better organization, and a choice of exploration objectives, the efficiency of exploration will be increased, probably with a new strategy of exploration as follows:

- intensify exploration abroad;
- increase the number of concessions to 5-10;

Period	TOE	Drilling meters (m)	Efficiency coeff.
1945-1954	727,370	232,492	3.13
1955-1964	7,668,120	989,662	7.751
1965-1974	25,856,600	1,681,043	5.38
1975-1984	40,913,982	1,922,339	21.28
1945-1984	75,167,431	4,825,536	15.58
1985	4,606,911	239,646	19.22
1945-1985	79,774,342	5,065,182	15.75

Table 7 Efficiency of drilling (from KOLUNDŽIĆ, 1995).

	1970	1975	1980	1985	1990	Change (%) 70-75	75-80	80-85	85-90
Explor. drilling, m	48,863.0	71,319.0	60,379.0	89,282.0	82,000	7.9	3.3	8.1	-1.7
Oil production, 10^3 t	2,057.1	2,669.7	3,056.4	3,059.2	2,696	5.4	2.7	0.0	-2.5
Gas product., 10^6 m^3	477.7	751.3	983.2	1,441.0	1,966	-	-	9.9	0.7
Local prod. TOE	2,534.8	3,421.0	4,039.6	4,500.2	4,662				
Product./employee ("TOE")/employee	600	-	597	519	515				
Oil reserves									
A + B + C_1 10^6 t	35	35	35	25	20				
Natural gas reserves									
LPG 10^9 m^3	15	12	7	6	5				
NG 10^9 m^3	12	15	30	22	40				

Table 8 Production of some basic products in the period from 1970 to 1990 and production per employee (from KOLUNDŽIĆ, 1995).

	1970	1980	1985	1989	1990
INA - Total	22.3	163.6	223.2	118.6	87.4
INA JP (Public Company)*	12.0	199.8	280.8	139.8	101.1
I. Upstream	10.3	126.3	176.4	89.6	61.1
II. Processing	32.4	418.8	369.0	162.7	126.4
III. Petrochem.	21.6	62.0	81.2	71.2	48.0

Table 9 Economic indicators of productivity (1,000 US$) total revenue per employee (average value). * INA JP (Public Company) was engaged in the core business of INA Group.

- define methods of evaluating a concession as well as the maximum and minimum participation;
- define (or delimit) the exploration as agreed with the owner including a proposal of reinvesting the entire profit to the year 2000.

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