Fixed Versus Disconnectable Turret Mooring System

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Case Assumptions
South China Sea

- **Water Depth: 150 meters**
- **FPSO: 1,200,000 bbls storage**
- **Offloading Tanker Parcel: 1,000,000 bbls**
- **Field Life: 20 years**
- **Oil Production Rate: 100,000 bopd**
- **Offloading Rate: 50,000 bbls/hr**
- **Parcel Size Maximum: 1 million bbls**

Design Criteria Factors

- **Environment**
- **Field Characteristics**
- **Production Criteria**
- **Field Life**
- **Flexibility**
- **Operability**
- **Risk**

Case Comparison

- **Case 1 – Fixed Internal Turret Mooring System with Tandem Offloading**

- **Case 2 – Disconnectable Internal Turret Mooring System with Tandem Offloading**

Fixed Turret for Amoco Orient Petroleum Co., People's Republic of China, Liuhua 11-1

Disconnectable Turret for JHN, People's Republic of China, Lufeng 13-1

South China Sea Area

FSO's and FPSO's in the South China Sea

- **Fixed Turret Systems 9**
- **Disconnectable Turret Systems 6**

Case Design Basis

- **Water Depth: 150 meters**
- **Service Life: 20 years**
- **Vessel: 170,000 dwt**
- **Storage: 1,200,000 bbls**
- **Maximum Offloading Parcel: 1,000,000 bbls**
- **Oil Production 100,000 bopd**
- **Gas Production: 130 MMsfd**
- **Pressure at Vessel: 285 Psig**
- **Offloading Rate: 50,000 bbls/hr**

Case-Risers

- **12” Production: 3 Lines**
- **Umbilicals: 3 Lines**

100-Year Survival Typhoon Conditions

100-YEAR SURVIVAL TYPHOON CONDITIONS				
STORMS / DIRECTIONALITY		100-YEAR TYPHOON		
		Collinear	Option 1	Option 2
CURRENT	Velocity @ Surface (m/s)	2.33	2.33	2.33
	Direction (deg)	180	210	225
WIND	Velocity (m/s, 1 minute)	52.1	52.1	52.1
	Direction (deg)	180	180	180
WAVE	Significant Height (m)	12.1	12.1	12.1
	Peak Period (s)	13.8	13.8	13.8
	Peak Parameter	3.3	3.3	3.3
	Direction (deg)	180	180	180

- **Collinear: Wind and current collinear with waves**
- **Crossed Option 1: Current acting 30 degrees to wind and waves**
- **Crossed Option 2: Current acting 45 degrees to wind and current**

Typhoons South China Sea Area 1959 – 2001 42 Years

by Naval Pacific Meteorology and Oceanography Center / Joint Typhoon Warning Center (JTWC)

Typhoon < 64 knots with sustained surface winds during its lifetime

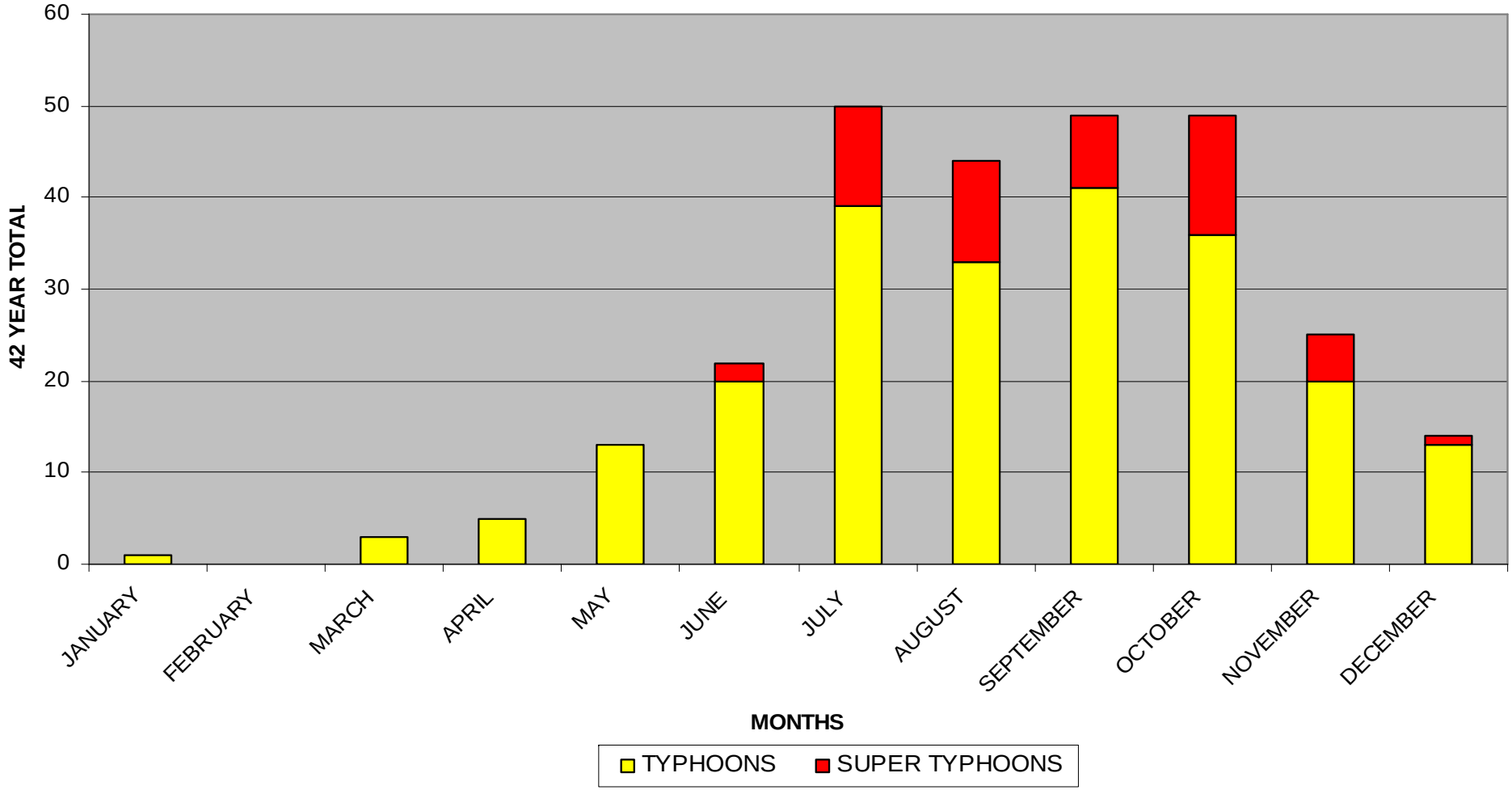
Super Typhoon < 130 knots with sustained surface winds during its lifetime

Table 2 - Typhoons South China Sea Area

1959 TO 2001 - 42 YEARS

Year	Month	Typhoon	Maximum Wind Speed Knots
1959	AUGUST	IRIS	90
	AUGUST	JOAN	170
	AUGUST	LOUISE	125
	DECEMBER	GILDA	150
	DECEMBER	HARRIET	125
1960	APRIL	KAREN	75
	JUNE	MARY	75
	JUNE	OLIVE	125
	JULY	SHIRLEY	125
	OCTOBER	KIT	90
	OCTOBER	LOLA	80
1961	MAY	ALICE	65
	MAY	BETTY	100
	JUNE	CORA	80
	JULY	ELSIE	100
	AUGUST	JUNE	110
	AUGUST	LORNA	150
	AUGUST	ELAINE	175
	SEPTEMBER	OLGA	75
	SEPTEMBER	PAMELA	170
	SEPTEMBER	SALLY	60
1962	MAY	HOPE	85
	MAY	IRIS	65
	JULY	KATE	85
	JULY	OPEL	150
	AUGUST	PATSY	65
	AUGUST	WANDA	95
	SEPTEMBER	CARLA	75
	SEPTEMBER	DINAH	100
	NOVEMBER	JEAN	90
	NOVEMBER	LUCY	100
1963	JUNE	TRIX	70
	JULY	WENDY	135
	JULY	AGNES	85
	JULY	CARMEN	125
	SEPTEMBER	FAYE	110
	SEPTEMBER	GLORIA	90
	DECEMBER	PHYLLIS	75
1964	MAY	VIOLA	70
	MAY	WINNIE	100
	JULY	ELSIE	100
	AUGUST	IDA	135
	SEPTEMBER	RUBY	120
	SEPTEMBER	SALLY	170
	SEPTEMBER	TILDA	110
	SEPTEMBER	VIOLET	75
	OCTOBER	CLARA	80
	OCTOBER	DOT	90
	NOVEMBER	IRIS	65
	NOVEMBER	JOAN	70
	NOVEMBER	KATE	80
1965	MAY	BABE	80
	JULY	FREDA	140
	JULY	HARRIET	100
	AUGUST	MARY	150
	SEPTEMBER	ROSE	100
1966	MAY	IRMA	120
	JULY	MAMIE	85
	JULY	ORA	85
	AUGUST	SUSAN	80
	SEPTEMBER	ELSIE	115
	DECEMBER	PAMELA	90
1967	MARCH	SALLY	85
	APRIL	VIOLET	120
	JUNE	ANITA	80
	AUGUST	KATE	70
	AUGUST	NORA	70
	OCTOBER	CARLA	160
	NOVEMBER	EMMA	140
1968	AUGUST	SHIRLEY	65
	AUGUST	WENDY	140
	AUGUST	BESS	65
	SEPTEMBER	ELAINE	150
	NOVEMBER	MAMIE	65
	NOVEMBER	NINA	70
1969	JULY	TESS	70
	JULY	VIOLA	130
	AUGUST	DORIS	65
	SEPTEMBER	ELSIE	150
1970	SEPTEMBER	GEORGIA	140
	OCTOBER	IRIS	100
	OCTOBER	JOAN	150
	OCTOBER	KATE	130
	NOVEMBER	PATSY	135
1971	APRIL	WANDA	75
	MAY	DINAH	90
	JUNE	FREDA	65
	JUNE	GILDA	90
	JULY	HARRIET	125
	JULY	JEAN	85
	JULY	LUCY	130
	JULY	NADINE	150
	AUGUST	ROSE	120
	SEPTEMBER	AGNES	75
	SEPTEMBER	DELLA	70
	OCTOBER	HESTER	90
1972	JUNE	ORA	80
	JULY	SUSAN	65
	AUGUST	CORA	65
	SEPTEMBER	FLOSSIE	75
	SEPTEMBER	LORNA	75
	OCTOBER	PAMELA	110
	NOVEMBER	SALLY	80
	DECEMBER	THERESE	105
1973	JULY	ANITA	70
	JULY	DOT	85
	AUGUST	GEORGIA	70
	SEPTEMBER	LOUISE	75
	SEPTEMBER	MARGE	80
	SEPTEMBER	NORA	160
	OCTOBER	OPAL	75
	OCTOBER	PATSY	140
	OCTOBER	RUTH	90
1974	JUNE	DINAH	70
	JULY	IVY	95
	OCTOBER	BESS	65
	OCTOBER	CARMEN	75
	OCTOBER	DELLA	90
	OCTOBER	ELAINE	95
	NOVEMBER	GLORIA	120
	NOVEMBER	IRMA	115
1975	JANUARY	LOLA	70
	JULY	NINA	135
	SEPTEMBER	ALICE	75
	SEPTEMBER	BETTY	95
	OCTOBER	ELSIE	135
	OCTOBER	FLOSSIE	70
1976	JUNE	RUBY	120
	AUGUST	BILLIE	125
	SEPTEMBER	IRIS	75
1977	JULY	SARAH	75
	JULY	THELMA	85
	JULY	VERA	110
	SEPTEMBER	DINAH	75
1978	APRIL	OLIVE	85
	AUGUST	ELAINE	65
	SEPTEMBER	LOLA	75
	OCTOBER	RITA	155
1979	JULY	ELLIS	85
	AUGUST	HOPE	130
	SEPTEMBER	MAC	70
	OCTOBER	SARAH	110
	NOVEMBER	VERA	140
1980	JULY	JOE	105
	JULY	KIM	130
	AUGUST	NORRIS	90
	SEPTEMBER	RUTH	65
	SEPTEMBER	PERCY	125
1981	JUNE	KELLY	75
	SEPTEMBER	CLARA	120
	NOVEMBER	HAZEN	100
	DECEMBER	LEE	95
1982	MARCH	NELSON	105
	JULY	ANDY	120
	AUGUST	DOT	80
	SEPTEMBER	IRVING	90
	OCTOBER	NANCY	115
1983	JULY	TIP	65
	JULY	VERA	90
	JULY	WAYNE	135
	AUGUST	ELLEN	125
	OCTOBER	JOE	65
	OCTOBER	LEX	70
	NOVEMBER	PERCY	70
1984	AUGUST	IKE	125
	OCTOBER	WARREN	65
	NOVEMBER	AGNES	120
1985	JUNE	HAL	100
	SEPTEMBER	TESS	75
	SEPTEMBER	ANDY	85
	OCTOBER	CECIL	100
	OCTOBER	DOT	150
1986	JUNE	PEGGY	140
	AUGUST	WAYNE	90
	OCTOBER	ELLEN	80
1987	AUGUST	BETTY	140
	AUGUST	CARY	85
	SEPTEMBER	GERALD	105
	OCTOBER	LYNN	140
	NOVEMBER	NINA	145
	DECEMBER	PHYLLIS	100
1988	MAY	SUSAN	75
	JULY	WARREN	115
	OCTOBER	PAT	75
	OCTOBER	RUBY	125
	NOVEMBER	SKIP	125
	NOVEMBER	TESS	65
1989	MAY	BRENDA	75
	MAY	CECIL	75
	JUNE	DOT	100
	JULY	GORDON	140
	OCTOBER	ANGELA	130
	OCTOBER	BRIAN	80
	OCTOBER	DAN	70
	OCTOBER	ELSIE	140
	NOVEMBER	HUNT	90
1990	MAY	MARIAN	90
	JUNE	PERCY	115
	AUGUST	YANCY	90
	AUGUST	BECKY	90
	SEPTEMBER	DOT	80
	SEPTEMBER	ED	90
	NOVEMBER	MIKE	150
1991	JULY	ZEKE	80
	JULY	AMY	125
	JULY	BRENDAN	70
	AUGUST	FRED	95
1992	JUNE	CHUCK	80
	JULY	ELI	75
	JULY	GARY	65
	AUGUST	OMAR	130
	NOVEMBER	FOREST	125
1993	JUNE	KORYN	130
	JULY	LEWIS	85
	AUGUST	TASHA	80
	SEPTEMBER	ABE	110
	SEPTEMBER	BECKY	65
	SEPTEMBER	DOT	80
	OCTOBER	IRA	120
	NOVEMBER	KYLE	95
	NOVEMBER	LOLA	105
	DECEMBER	MAUNY	120
	DECEMBER	NELL	65
1994	MARCH	OWEN	75
	JULY	TIM	125
	AUGUST	GLADY	105
	OCTOBER	TERESA	80
	DECEMBER	AXEL	115
1995	JULY	GARY	65
	AUGUST	HELEN	70
	AUGUST	KENT	130
	AUGUST	LOIS	65
	SEPTEMBER	RYAN	130
	SEPTEMBER	SIBYL	95
	OCTOBER	TED	70
	OCTOBER	YVETTE	65
	OCTOBER	ZACK	95
	OCTOBER	ANGELA	155
1996	JULY	FRANKIE	90
	JULY	GLORIA	90
	JULY	HERB	140
	AUGUST	NIKI	95
	SEPTEMBER	SALLY	140
	SEPTEMBER	WILLIE	65
	OCTOBER	BETH	90
1997	JULY	VICTOR	65
	AUGUST	AMBER	110
	SEPTEMBER	FRITZ	75
	OCTOBER	LINDA	65
1998	AUGUST	OTTO	100
	OCTOBER	BABS	135
	DECEMBER	FAITH	90
1999	APRIL	LEO	110
	JUNE	MAGGIE	105
	AUGUST	SAM	75
	SEPTEMBER	YORK	70
	OCTOBER	DAN	110
2000	JULY	KA-TAK	75
	AUGUST	BILIS	140
	SEPTEMBER	WUKONG	95
	OCTOBER	XANGSANE	90
	OCTOBER	BEBINCA	85
2001	JUNE	CHEBI	100
	JUNE	DURIAN	75
	JUNE	UTOR	80
	JULY	YUTU	85
	JULY	TORAJI	100
	SEPTEMBER	NARI	100
	SEPTEMBER	LEKIMA	95
	NOVEMBER	LINGLING	115
	DECEMBER	VAMEI	75

TYPHOONS SOUTH CHINA SEA AREA
1959 TO 2001 - 42 YEARS



Subtotal Average Typhoons Year	5.2
Subtotal Average Super Typhoons Year	1.2
Total Average Typhoons Year	6.4

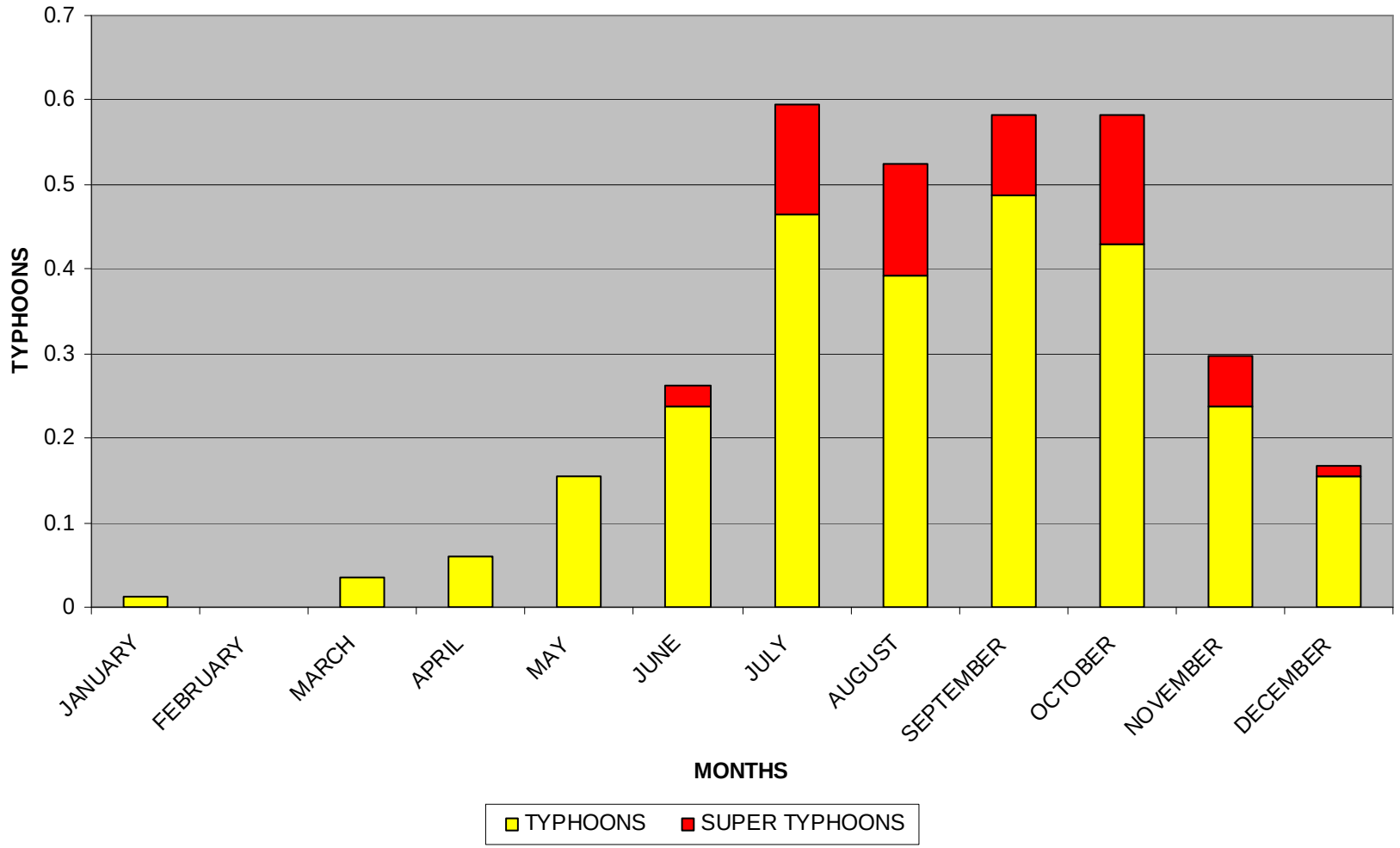
FSO and FPSO Typhoon Evacuation

- **First Alert: Typhoon within 400 nautical miles**

- **Second Alert: Evacuate FSO or FPSO when typhoon within 350 nautical miles**

Second Alert happens approximately 50% of the time for typhoons entering the South China Sea

TYPHOONS SOUTH CHINA SEA AREA
ANNUAL AVERAGE 50% EVACUATION



Subtotal Typhoons	2.6
Subtotal Super Typhoons	.6
Total Typhoons	3.2

Note: Over 85% occurring in the last six months of the year

Case 1 – Fixed Internal Turret Mooring System with Tandem Offloading

Anchor Legs: 9 Leg 3x3 Grouping

Top Chain – 117mm R4 Studless: 10m

Riser Wire – 111mm Spiral Strand: 160m

Dip Zone Chain – 117mm R4 Studless:100m

Excursion Limiter

Primary Chain – 127mm R4 Studless: 100m

Attached Chain – 152mm Any Grade: 151m

Ground Wire – 111mm Spiral Strand: 900m

Ground Chain – 127mm R4 Studless: 100mm

Case 1 – Fixed Internal Turret Mooring System with Tandem Offloading (Contd.)

Pull-in Winch:	**200mm**
Anchors:	**9**
Drag Anchors:	**27mt**
Chain Stoppers:	**9**
Offloading Lines:	
1 x 20” Offloading Hose System from FPSO	**520m**

Case 2 – Disconnectable Internal Turret Mooring System with Tandem Offloading

Anchor Legs: 8 Leg Symmetrical
Top Chain – 87mm R4 Studless: 10m
Riser Wire – 81mm Spiral Strand: 160m
Dip Zone Chain – 87mm R4 Studless: 100m
Excursion Limiter
Primary Chain – 100mm R4 Studless: 100m
Attached Chain – 142mm Any Grade: 155m
Ground Wire – 81mm Spiral Strand: 900m
Ground Chain – 87mm R4 Studless: 100mm

Case 2 – Disconnectable Internal Turret Mooring System with Tandem Offloading (Contd.)

Pull-in Winch:	**150mt**
Anchors:	**8**
Drag Anchors:	**16mt**
Chain Stoppers:	**8**
Offloading Lines:	
1 x 20” Offloading Hose System from FPSO	**520m**

CAPEX Cost Estimates

Cost: +1 – 15% Accurately

- **Mooring**
- **Fluid Transfer**
- **Hull Systems**
- **Topside System**
- **Installation**
- **Service and Administration**

OPEX Cost Estimates

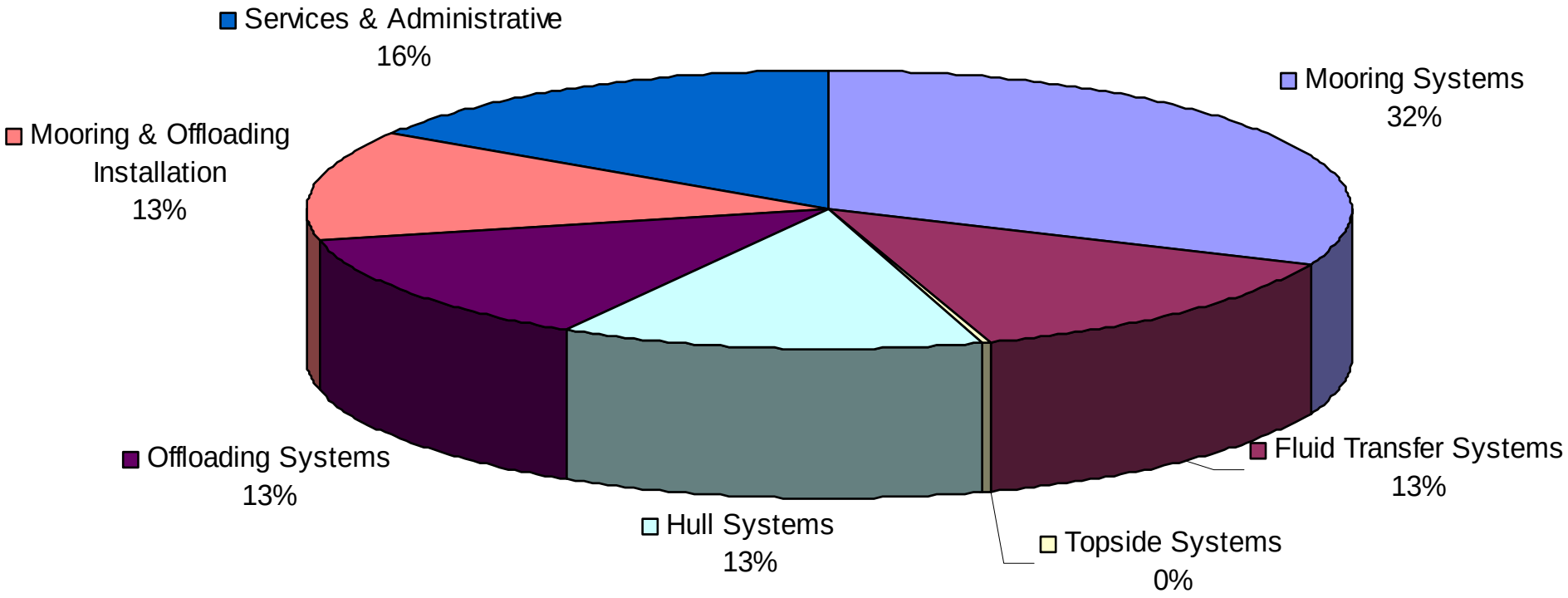
Cost: **+1 – 15% Accurately**

Inflation Rate **270 per Year**

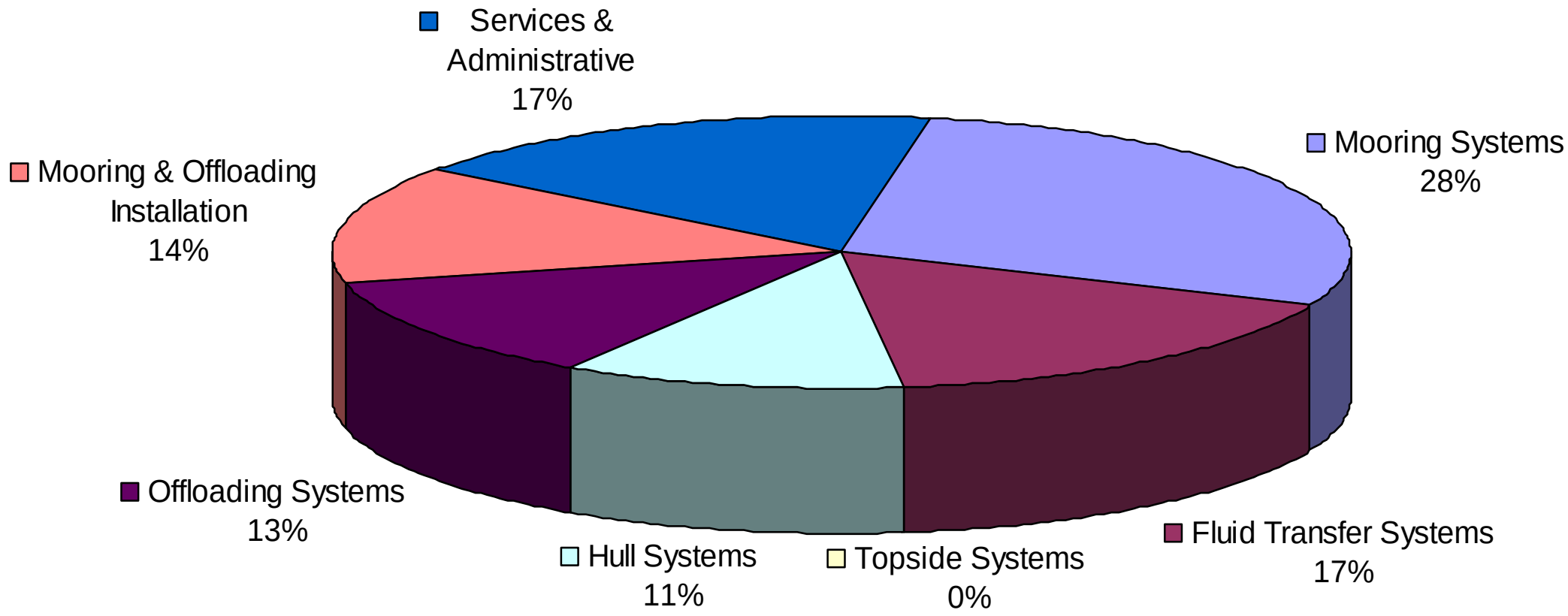
Present Value (PV) **10.5% Discount rate computed from first oil milestone**

- **Demurrage**
- **Offloading Tug and Pilots**
- **Offloading Hoses and Hawsers**
- **Typhoon Shutdown Helicopter Evacuation**
- **Maritime Crew Requirements**
- **Turret Maintenance**

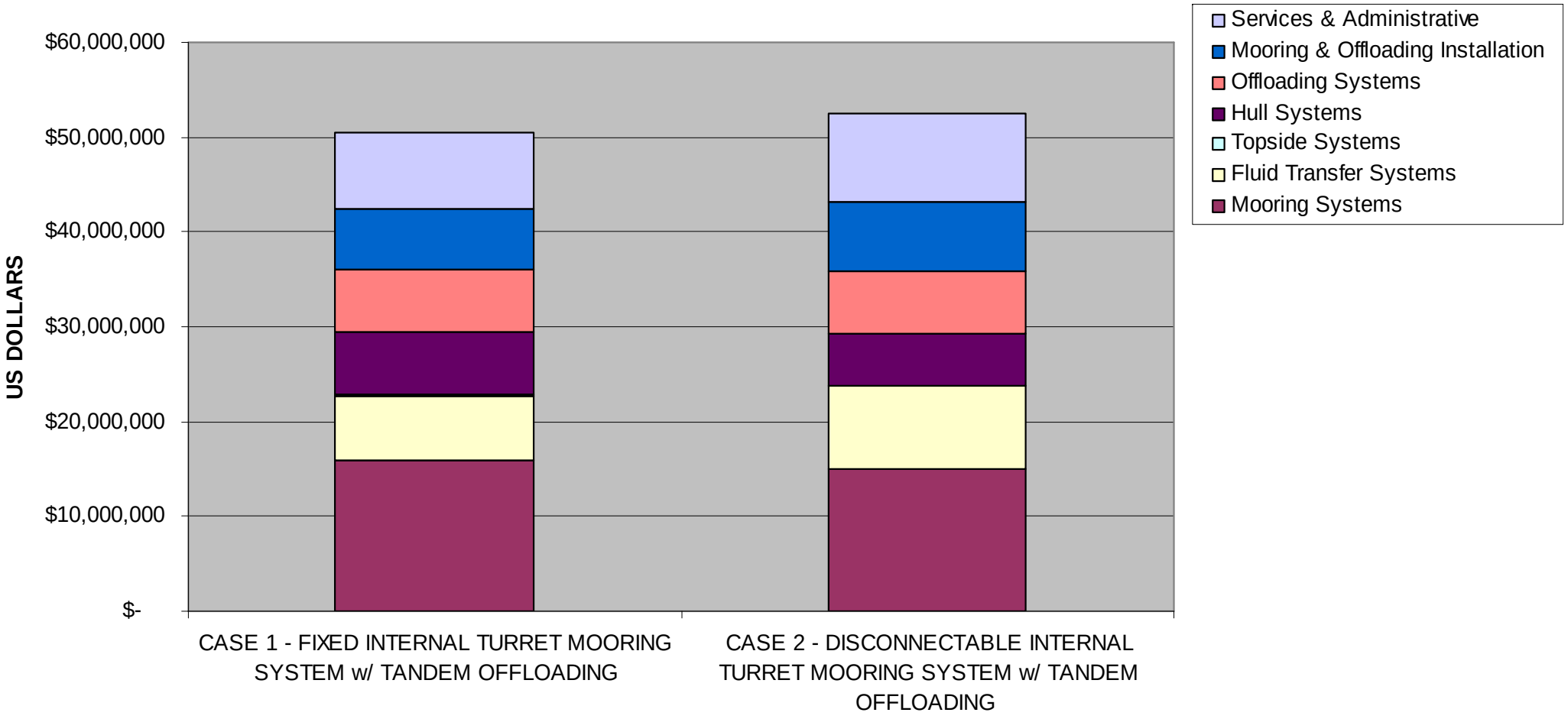
CAPEX - CASE 1 SOUTH CHINA SEA
FIXED INTERNAL TURRET MOORING SYSTEM w/ TANDEM OFFLOADING



CAPEX - CASE 2 SOUTH CHINA SEA DISCONNECTABLE INTERNAL TURRET MOORING SYSTEM w/ TANDEM OFFLOADING

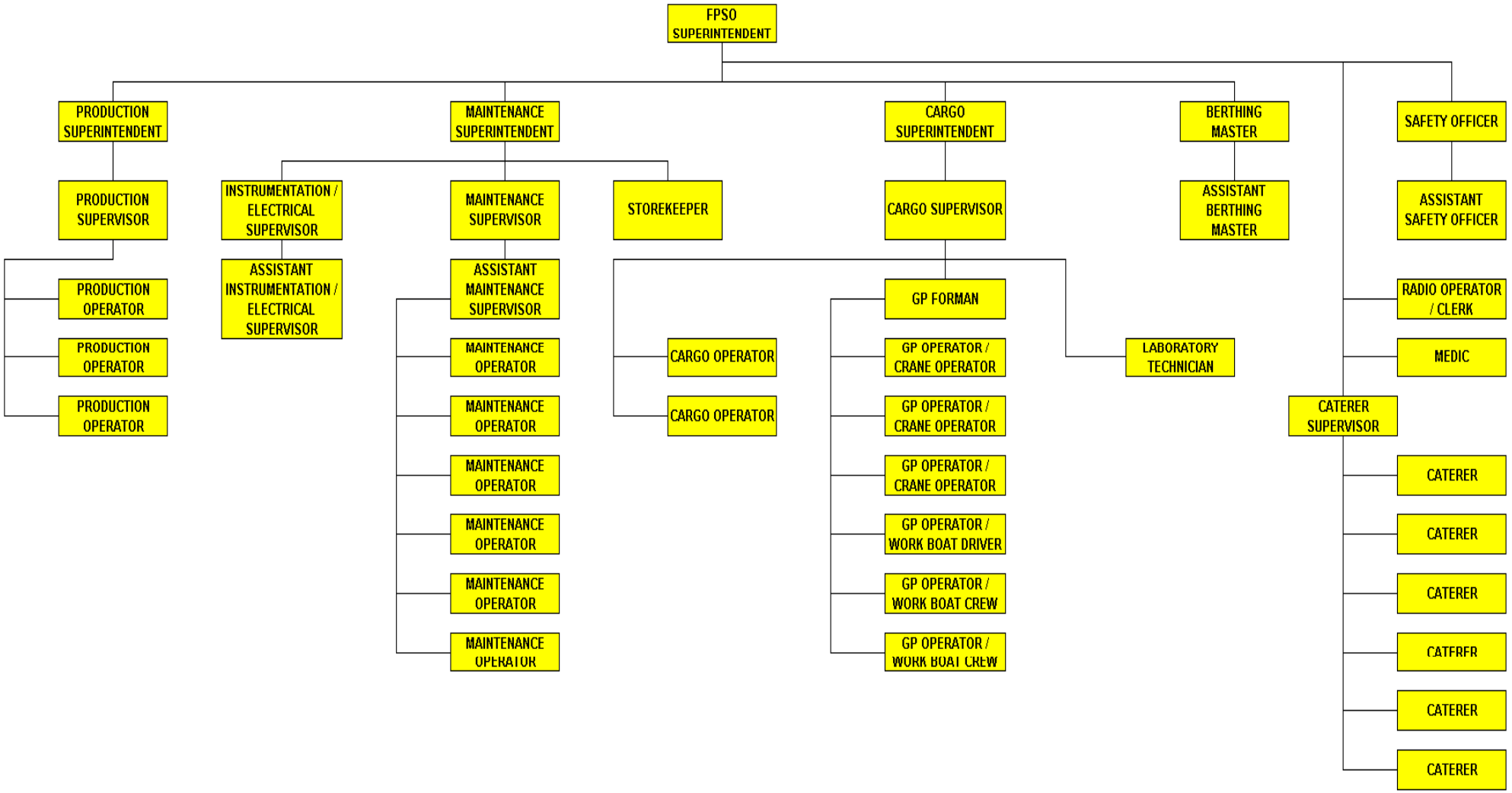


CAPEX - CASE SOUTH CHINA SEA



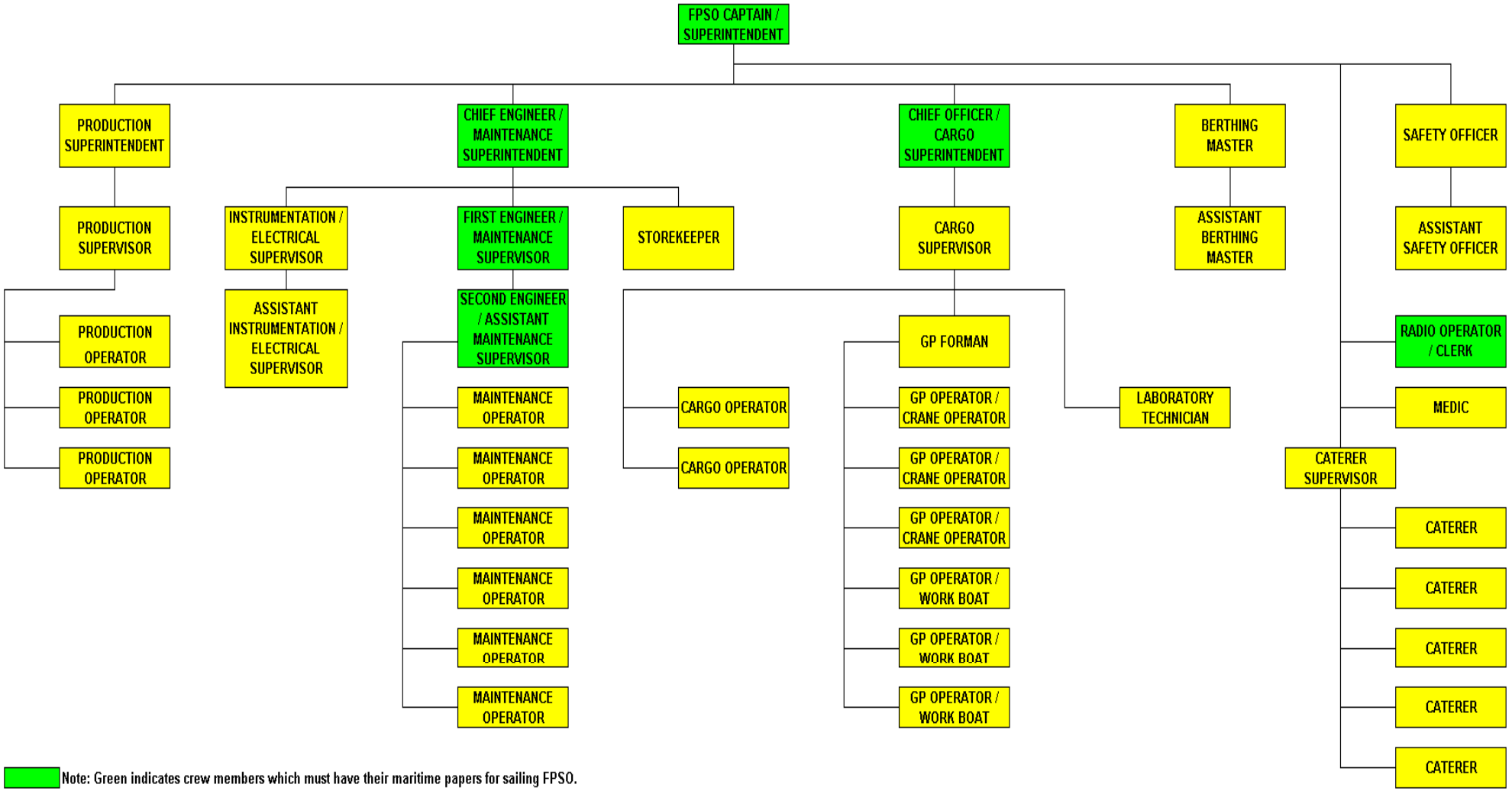
CASE 1 - FIXED TURRET SYSTEM

FPSO CREW COMPLEMENT (43)



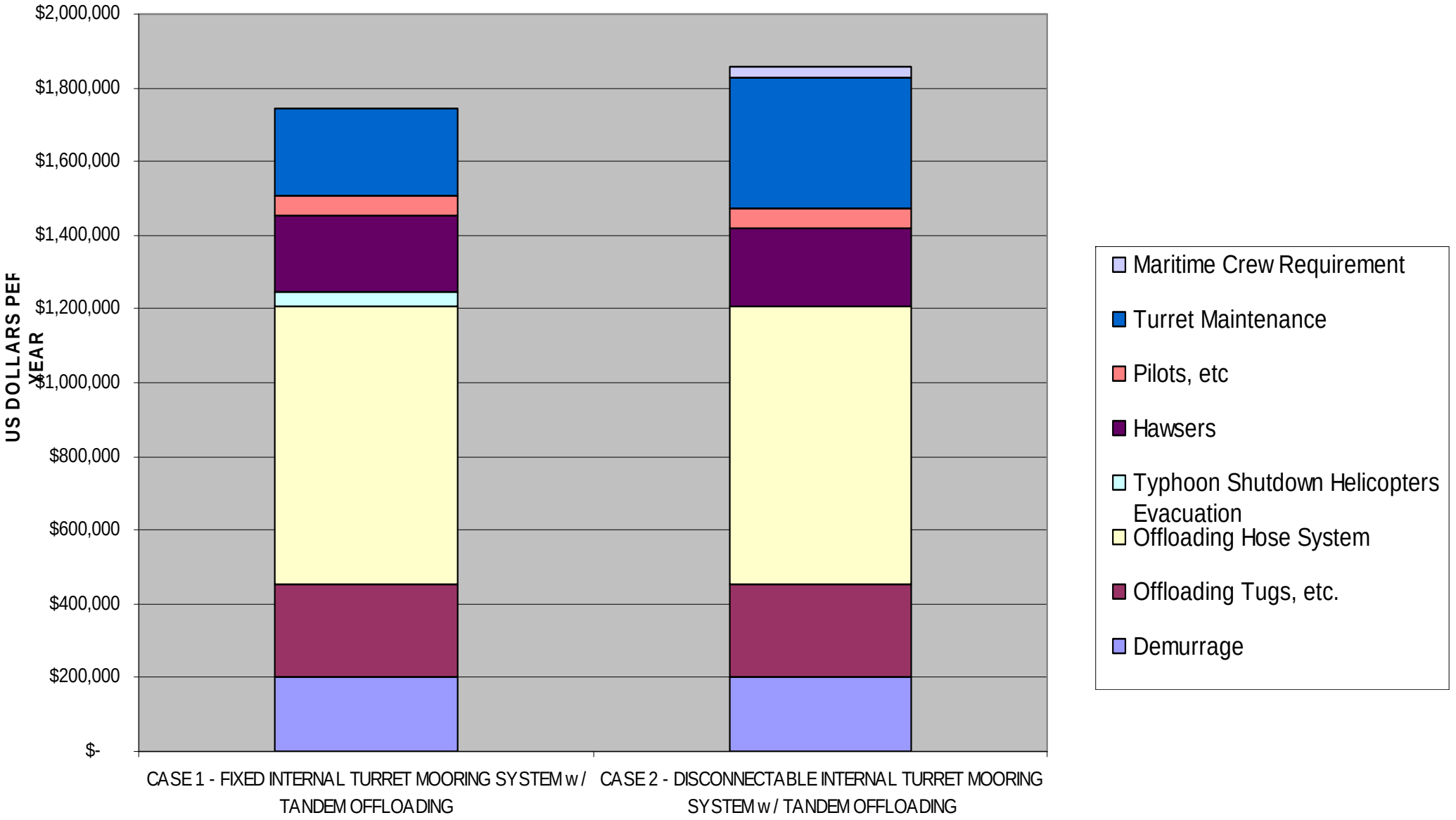
CASE 2 - DISCONNECTABLE TURRET SYSTEM

FPSO CREW COMPLEMENT (43)

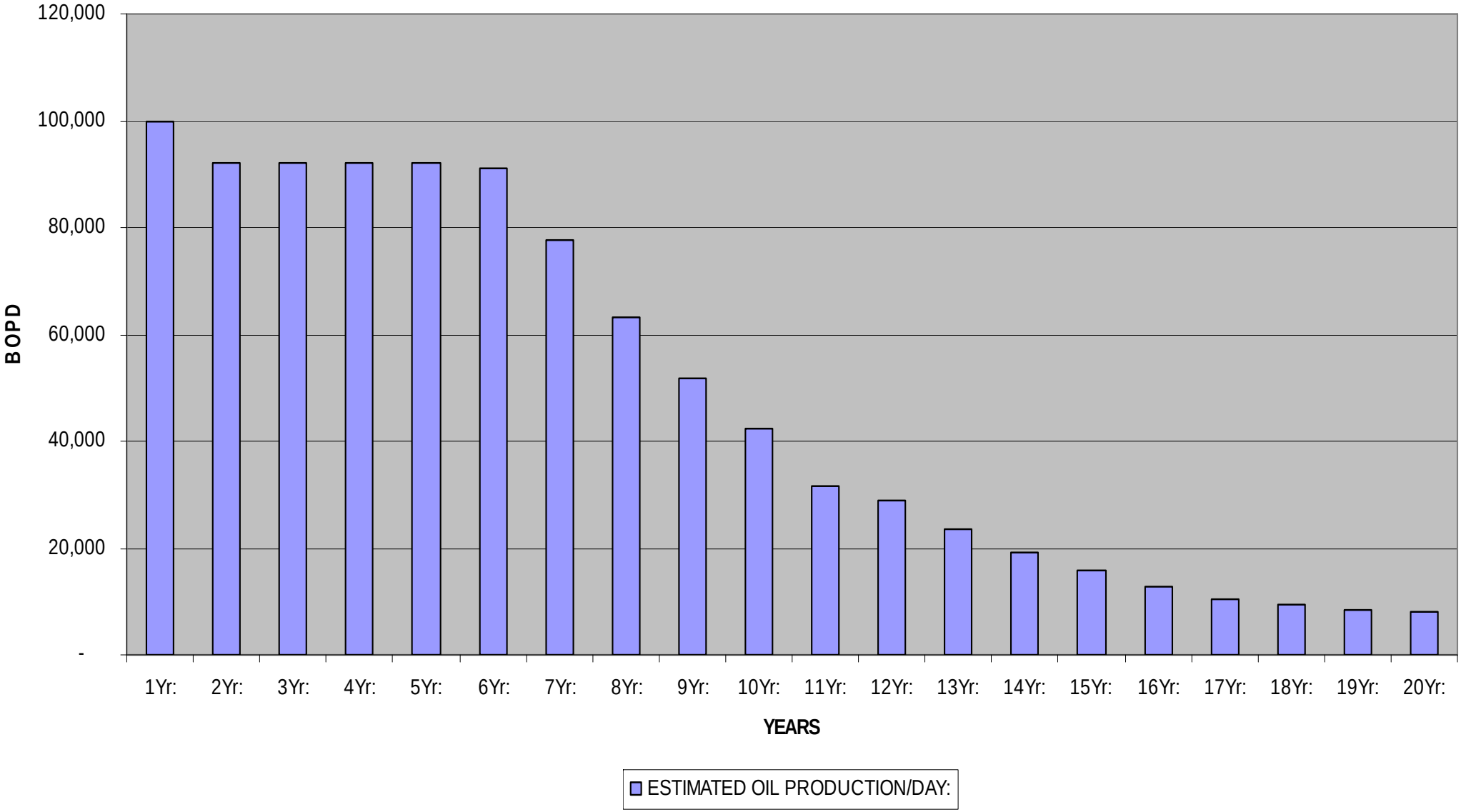


Note: Green indicates crew members which must have their maritime papers for sailing FPSO.

OPEX
AVERAGE TWENTY YEAR OPERATION



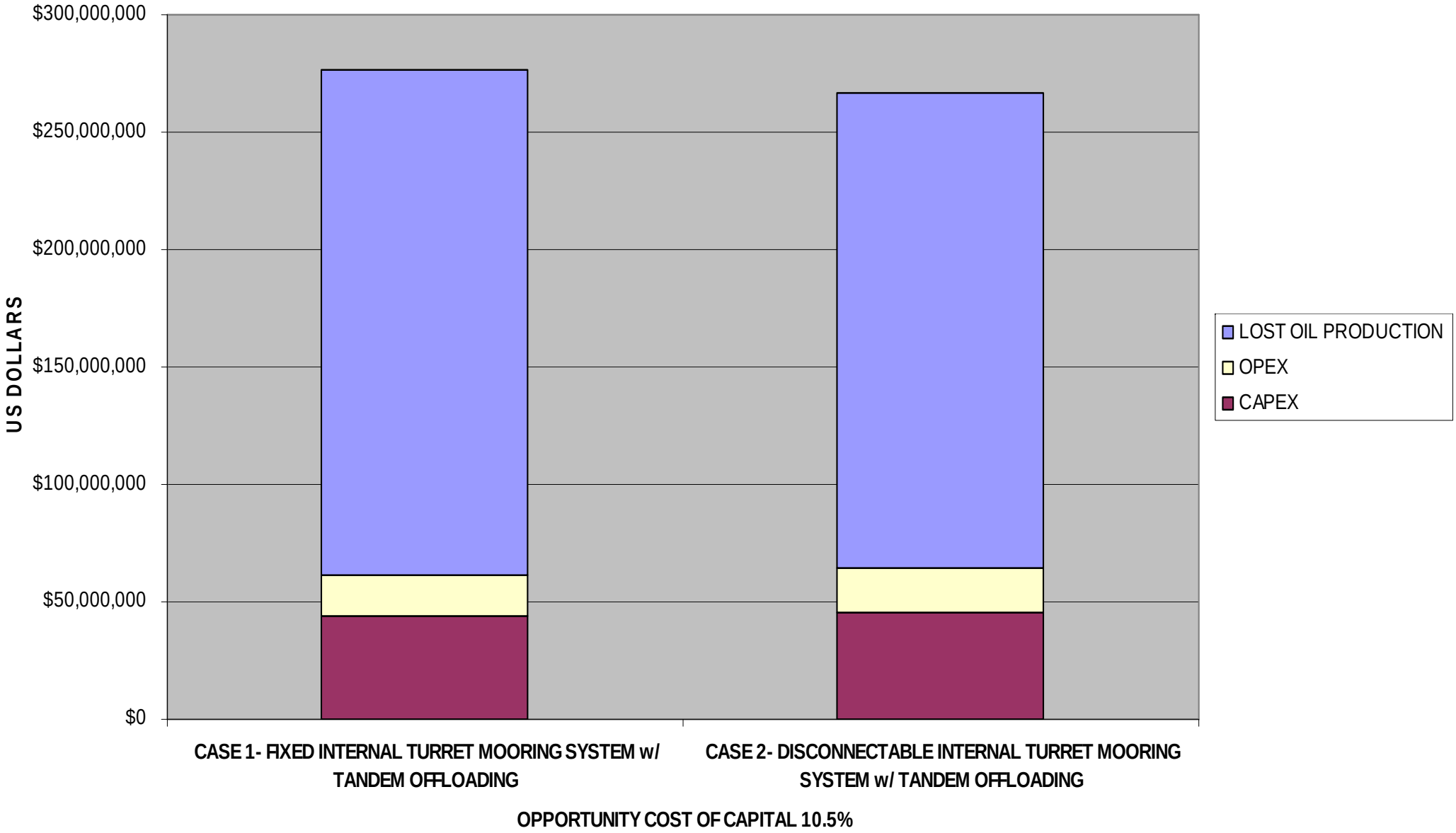
CASE OIL PRODUCTION - SOUTH CHINA SEA
100,000 BOPD OVER 20 YEARS



Lost Production

	Case 1 – Fixed Turret System	Case 2 – Disconnectable Turret System
Process Facilities Maintenance	4 Days	4 Days
Well Major Workover	.5 Days	.5 Days
Downtime Due to Shortage Limitations	4 Days	4 Days
Downtime Due to Typhoons (3 Times)	10 Days	9 Days
Annual Average Lost Production	18.5 Days	17.5 Days

Present Value at First Oil



RISK FACTORS

Description	Case 1 – Fixed Internal Turret System	Case 2 – Disconnectable Internal Turret System
FSO or FPSO	Hull, topside equipment and mooring system must be designed for 100-year survival typhoon conditions and stay on location for 15 years with all maintenance done offshore.	Since the vessel leaves the site as the typhoon approaches, the hull, topside equipment and mooring system will be designed for much lower load conditions than the 100 year typhoon conditions. Also the vessel has the additional option of leaving for drydock maintenance such as every five years or in an unexpected maintenance requirement.
Crew	Crew must be evacuated by helicopters as the typhoon approaches.	Crew will sail on vessel as the typhoon approaches.

Conclusion

- **Cost: Case 1 Fixed Internal Turret System has the lowest cost for both CAPEX and OPEX by approximately 4% for this case.**

  Case 2 "Disconnectable Internal Turret System" has the least lost production by approximately 5% for this case

Conclusion (Contd.)

- **Risk: Case 2 “Disconnectable Internal Turret System” has the lowest risk on design, crew safety and the flexibility of possible drydocking over the field life**

Conclusion (Contd.)

Note:

- **As the field you are evaluating water depth increases the turret mooring system CAPEX for the fixed system will increase significantly faster than the disconnectable system**

- **For each crew evacuation for a fixed turret system how many helicopters are required and the distance they must travel and what other offshore facilities are they also committed to evacuate**