TRANS-TASMAN RESOURCES LIMITED

IMPLICATIONS OF LOOSE TAILINGS SEABED MATERIAL ON FUTURE JACK-UP DEPLOYMENT IN THE SOUTH TARANAKI BIGHT

by

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1. INTRODUCTION

Trans-Tasman Resources Limited (TTR) is proposing to undertake iron ore (iron sands) extraction processing operations in an area between 22 and 36 kms offshore from Patea in the South Taranaki Bight. The iron sand material will be dredged from the seabed down to a depth of 11 m below seabed level using a remotely operated seabed crawler machine and pumped up to the support vessel a Floating Processing Storage and Offloading (FPSO) vessel. The extracted seabed sediment will be processed onboard the FPSO into iron ore concentrate (approximately 10% of the extracted material) with the residual material (90%) returned directly to the seabed as de-ored sediment via controlled discharge at depth below the FPSO.

It is understood that the thickness of the tailings deposit on the seabed in the previously mined areas will be up to 10 m. The tailings will be in loose condition as deposited.

The purpose of this document is to provide comment and analysis on the implications of the tailings for any future deployment and founding of mobile jack-up drill rig platforms on the seabed. Jack-up rigs have previously been used in the South Taranaki Bight for oil and gas exploratory drilling. The comments also cover the case of foundations for fixed platforms, well head or production platforms. There are existing offshore structures at Kupe.

OCEL Consultants NZ Limited (OCEL), in conjunction with NZ Diving and Salvage Limited (NZDS) has undertaken a total of 5 geotechnical investigations and founding evaluations for jack-up drill rig deployments off the West Coast of the North Island of NZ. NZDS have undertaken the geotechnical investigation work using OCEL designed, diver operated, subsea geotechnical drilling rigs.

2. TAILINGS DESCRIPTION

The black iron sands found on the continental shelf seabed in the South Taranaki Bight were derived from Quaternary age Mt Taranaki volcanic lahar that was eroded and washed down rivers from Mt Taranaki and the Central Plateau out to the sea.

The sands to be mined, processed and returned to the seabed consist mainly of fine sand with a maximum particle size of just over 2 mm. For the purposes of the calculation of the depth of penetration of a jack-up spudcan into tailings the tailings will be taken as fine, non-cohesive, relatively high specific gravity sand material deposited in a loose condition on the seabed in previously mined areas.

The seabed prior to mining has been identified as very dense sand on the basis of some investigation work undertaken by NZDS to determine the dredgeability - or dredging effort required - to dredge the seabed. The work consisted of a borehole down to 6.5 m penetration with Standard Penetration Testing (SPT) - at 1.5, 3, 4.5 and 6.5 m penetration into the seabed - the results of which were interpreted and reported by OCEL. The dredging target material is non-cohesive sand underlying a thin soft, silty, weakly cohesive surface layer.

3. JACK-UP RIGS

Most offshore drilling in shallow to moderate water depths is undertaken from self elevating mobile jack-up units also known as Mobile Offshore Drilling Units (MODU). They are also used as production support and for fixed platform workovers. The cover photograph shows a jack-up platform in the workover mode. Typical jack-up rig units comprise a buoyant triangular platform supported by three independent truss structure legs with the weight of the deck and equipment more or less equally distributed. The legs are jacked up and down by a rack and pinion system.

Bearing pads in the form of shallow angle (15° to 30°) large inverted cones known as spudcans are attached to the base of each truss leg structure. Typically circular in plan the shallow cone on the underside terminates in a sharp protruding spike or spigot.

The jack-up rig is typically towed to site floating, from relatively close range, with the legs elevated out of the water. Photograph No 1 shows a jackup production platform being transported to location by a submersible barge on an SBM offshore project OCEL were involved with off Newfoundland. The barge was used for trans ocean transport, from a fabrication yard in the Middle East.

Once on location the legs are lowered down into contact with the seabed and jacked to have the hull clear of the water. The foundations of the spudcans are then pre-loaded by pumping seawater into ballast tanks in the hull so the foundations then take the weight of the jackup unit plus the additional ballast water weight (between 30 – 100% of the weight of the jack-up). This constitutes a proof loading of the foundations by exposing them to a higher vertical load than would be expected during service. On completion of the pre-loading the ballast water is dumped and the jack-up hull is jacked up on its legs clear of the water surface and wave action.

4. GEOTECHNICAL INVESTIGATIONS PRIOR TO JACK-UP DEPLOYMENT

Prior to the deployment of a mobile jack-up drilling rig at an offshore location a seabed geotechnical investigation has to be undertaken and an evaluation made of the footing/spudcan penetration at that location.

The American Society of Naval Architects and Marine Engineers (SNAME) has developed a Recommended Practice (RP) document for the safe emplacement of jack-up rigs, Recommended Practice for Site Specific Assessment of Mobile Jack-Up Units, that has been adopted by Mobile Offshore Drilling Unit (MODU) operators for jack-up rig deployments in NZ waters.

OCEL has undertaken a total of 5 geotechnical investigations and spudcan penetration evaluations for jack-up drill rig deployments in NZ, all in conformance with the SNAME RP, the subsea boreholes having been drilled by NZDS. The NZDS owner operated Mark1 subsea geotechnical drilling rig is shown in Photograph No 2. The drill rig platform floor is elevated above the seabed both to reduce diver decompression time and to keep it above the seabed turbidity layer.

The SNAME RP, clause 3.16, calls for a minimum of one borehole per location to a depth equal to 30 m or the anticipated footing penetration plus 1.5 to 2 times the footing diameter, whichever is greater. This is the minimum. For the locations investigated by OCEL supplementary data in the form of geophysical information giving strata depth and inclination has also been available.

For any deployment over a previously mined area a borehole will be established prior to the deployment of the jack-up and this investigation will determine the nature of the tailings at that time. Whether the seabed material remains loose will depend on the time since it was dumped, natural consolidation will have occurred, assisted by the high specific gravity of the tailings, and the seabed will have been subject to wave influence. The South Taranaki Bight is a high wave energy environment and the persistent long period swell from the south west can affect the seabed. The deep water wavelength of a 12 second period swell is 225 m, 200 m in 45 m water depth. Waves have seabed influence for depths less than half the deepwater wavelength - 100 m for 12 second period swell waves.

The geotechnical investigation will establish the soil strength parameters for the seabed strata to allow a prediction of the extent to which the jack-up spudcans will penetrate into the seabed and identify any potential for a 'punch through' type bearing capacity failure which could jeopardise the safety of the rig. The principal concern is with the presence of soft or loose layers within the bearing pressure bulb developed by the spudcan load. The presence of soft or loose bearing layers on the seabed is less a concern, the weight of the jack-up will typically force the spudcans well into or through soft top layers.

5. JACK-UP APPLIED LOADS

The bearing loads exerted by a jack-up rig are high, of the order of 400 kPa, and as a consequence the spudcans will penetrate into the seabed other than for relatively rare very dense or high bearing capacity seabed conditions. In loose or soft seabed conditions the penetration can be several metres. The spudcans typically have a water jetting system incorporated into the spudcans to assist with reducing the resistance to pullout on completion of the work at the location.

The ENSCO 56 jack-up drill rig used to drill the Kahu well offshore North Taranaki in 2008 applies a maximum load of 44.95 MN (4580 tonne) per spudcan. This is the normal preload used to test the spudcan capacity. The spudcans were taken as cylinders 12.1 m diameter by 4.57 m high for the purpose of calculating the leg penetration. The actual spudcan shape, shown in Appendix A, shows a typical spudcan geometry with a point underneath a shallow angle, truncated cone shape.

The ENSCO 56 MODU will be taken as representative of the type of jack-up that may be used for any drilling in previously mined areas covered by a tailings seabed layer in order to predict the possible penetration of the spudcans into loose tailings. The details of the rig are given in Appendix A of this report.

Some jack-ups use a mat support structure that connects all three legs and has a bearing area comparable to the water plane area of the rig itself. These have application in very soft cohesive seabed material, conditions that do not apply in the South Taranaki Bight.

6. CALCULATION OF SPUDCAN PENETRATION INTO LOOSE TAILINGS

The calculation of the depth to which the spudcans of the ENSCO 56 will penetrate into the seabed was carried out in accordance with the methods given in Section 6 of the SNAME Recommended Practice for Site Specific Assessment of Mobile Jack-Up Units, 2002.

Predictions of spudcan penetration are based on a direct application of conventional bearing capacity formulae for shallow flat circular foundations. However the analysis methods for shallow foundations and spudcan penetration predictions are fundamentally different. Conventional foundation analyses for a circular footing at depth or penetration D into the seabed firstly comprise the determination of the ultimate bearing capacity, F_v, at this depth followed by a computation of the vertical displacement of this footing, z_u, which is required to mobilize this resistance. The analyses consist of a strength analysis followed by a deformation analysis.

For a spudcan penetration analysis the deformation at ultimate resistance, D in this case, is taken as an input and from this the associated soil resistance is directly computed. The analysis is then one step using the same bearing capacity criteria as for the shallow foundation analyses. The incompatibility between these approaches is generally accounted for by the application of empirical corrections – achieved through the selection of appropriate soil strength parameters - to classical bearing capacity formulations.

The Brinch Hansen bearing capacity equation was used to determine the bearing capacity at a range of penetrations into the seabed – penetration depths corresponding to the depths at which SPT N values were determined.

$$F_v = A.(0.5\gamma'.B.N_\gamma.d_\gamma s_\gamma + p_o'.N_q.s_q.d_q) \quad \text{for non-cohesive material}$$
$$F_v = A.(C_u.N_o.s_c.d_c+.\ p_o') \quad \text{for cohesive material}$$

Where:

A	is the area of the spudcan
N	is a bearing capacity factor
s	is a shape factor
d	is a depth factor
B	is the diameter of the spudcan
Φ	is the angle of internal friction for the sand
p_o'	is the effective overburden pressure at spudcan base level
c_u	is the undrained cohesive shear strength (0 in this case for sand)
D	is the penetration into the seabed

For the case of a circular footing

$N_\gamma = 1.5(N_q - 1)\tan\varphi$
$d_\gamma = 1$
$s_\gamma = (1 - .4B/L)$
$s_c = 1 + N_q/N_c$

$N_q = e^{\pi\tan\varphi}\tan^2\varphi(45^o + \varphi/2)$
$s_q = 1 + B/L\sin\varphi$
$d_q = 1 + 2\tan\varphi(1 - \sin\varphi)^2 D/B$
$d_c = 1 + 0.4\,(D/B)$

Based on observed in the field penetrations for actual spudcans – spudcans are an order of magnitude larger than most conventional foundations – the penetrations were found to be significantly larger than the laboratory test derived φ values would indicate. For that reason the SNAME RP recommend that the laboratory triaxial φ should be reduced by 5° for the prediction of large diameter footing penetrations in silica sands. If laboratory test data are unavailable – as in this case – the SNAME Guidelines give suggested values, reference Table No 1.

DESIGN PARAMETERS FOR COHESIONLESS SILICEOUS SOIL				
Density	**Soil Description**	**Φ°des**	**N_γ**	**N_q**
Very Loose Loose Medium	Sand Sand-silt Silt	15	2.6	3.9
Loose Medium Dense	Sand Sand-silt Silt	20	5.4	6.4
Medium Dense	Sand Sand-silt	25	11	11
Dense Very Dense	Sand Sand-silt	30	22	18
Dense Very Dense	Gravel Sand	35	48	33

Table No 1

The calculated penetration of the spudcan into the tailings in the loose condition was estimated at 6 m. Calculation of the ultimate vertical bearing capacity of a spudcan foundation in uniform soils is influenced by the geometry of the foundation (spudcans are usually idealised as circular with a conical underside) as indicated by the shape factors, s_γ, s_c, and s_q. The penetration measured to the tip of the spudcan will probably be more than 4 m given that the calculation assumed – in the absence of any detailed spudcan geometry – that the bottom of the spudcan is flat and the spudcan is a simple cylinder. That assumption will not have any significant effect on the result.

7. LIQUEFACTION POTENTIAL

The identification of the tailings as being in the loose condition following deposition on the previously mined areas raises the issue of potential liquefaction in seismic events and loss of foundation support. However the high bearing loads imposed by the jack-up spudcans and the nature of the descent to the founding depth will change the condition of the soil. The spudcans will end up deep into the tailings layer and will consolidate the foundation.

The penetration velocity of the spudcans into the seabed is likely to be of the order of 1 m/hour. The drainage conditions of the soil as the spudcans sink into the seabed has a bearing on of the ultimate vertical bearing capacity of each spudcan foundation in uniform soils. The sand tailings foundation would be expected to exhibit drained behaviour. The high bearing capacity, 390 kPa, obtained at the final penetration depth and the 'drained', dense nature of the sediment under the spudcan makes it less susceptible to any potential for seismically induced liquefaction associated with loose sediment.

8. FIXED PLATFORM FOUNDATIONS

The presence of the tailings will have no influence on the design of the foundations for any fixed platform structures. These structures would be expected to have pile foundations extending deep into the seabed, the nature of the seabed layer being close to insignificant.

9. CONCLUSION

Irrespective of whether the seabed consists of loose, re-deposited sand tailings over previously mined areas or untouched seabed geotechnical investigation work (normally a borehole, one minimum) will be required at the site of any proposed jack-up deployment for exploration or development work. This will identify the nature of the tailings at the time of the jack-up deployment - consolidation (enhanced by the high specific gravity of the tailings) and some seabed densification of the tailings due to wave action will have occurred - and the soil strength parameters of the strata below the seabed. A spudcan penetration analysis will be required.

The presence or otherwise of the tailings and their potentially loose nature doesn't change anything or have any significant implications for any future deployment and founding of mobile jack-up drill rig platforms on the seabed. The spudcans will sink further into the seabed than for the untouched seabed case before they attain the ultimate bearing capacity resistance required but this is not of significance given that jack-ups are setup to recover spudcans that have sunk well into the seabed.

Photograph No 1

Photograph No 2

APPENDIX A

ENSCO

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ENSCO 56

GENERAL INFORMATION
Flag Liberian
Owner Ensco Oceanics International Company
Previous Name(s) Bonito II; Miss Clementine
Year Built 1982 **Builder** Ingalls Shipbuilding, Pascagoula, Mississippi, USA **Upgrade** 2006
Design Friede & Goldman L-780 Model II Cantilever Jackup
Classification ABS A-1 Self-elevating Drilling Unit

MAIN DIMENSIONS
Length 180'
Breadth 175'
Depth 25'
Legs 3 x 417' triang/truss; 368' leg below hull
Leg Spacing Longitudinal leg spacing 115'; transverse leg spacing 120'
Cantilever 50' x 24' (with 10' drop in extensions)
Spud Cans 39.66' diameter x 15' deep
Deck Area

DRAFT AND DISPLACEMENT
Transit Draft 16'
Transit Displacement 9,981 ton

MACHINERY
Main Power 5 x Cat D-399 engines (1215 HP each), 5 Kato 800 Generators (800 Kw each)
Power Distribution Ross-Hill SCR power units with controls for 8 x dc drilling motors
Emergency Power 1 x Cat D-379, diesel engine, rated 600 HP at 1200 rpm, driving 1 x Kato 400 KW 480V generator

OPERATING PARAMETERS
Water Depth 300' (20' – 300')
Maximum Drilling Depth 25,000'
Leg Penetration
Air Gap
Transit Speed 4.5 knots
Survival Conditions wind: 100 knots; waves: 50'; wave period: 13.5 sec; temperature: 32 F
Criteria Design wind: 70 knots; waves: 35'

DRILLING EQUIPMENT
Derrick DSI 160' x 30' x 30' beam leg; rated 1,300 kips static hook load
Drawworks National 1625-DE; 3,000 HP; Elmagco 7838 brake
Rotary National C-375, 37½" opening, independent electric drive – 1,000 kips max load
Top Drive Varco TDS-4S
Travelling National, 650 ton
Handling PH-85 Pipe Handler, ST-80 Iron Roughneck, PS-21 hydraulic slips
Cementing Halliburton (free placement only)
Mud Pumps 2 x National 12-P-160 triplex, 1600 Hp, equipped with P-Quip Rod & Liner Retention System

HOISTING EQUIPMENT
Cranage 1 x NOV Dreco DNS48 120 (Port) / 1 NOV Dreco DNS48 100 (Stbd.), 35 ton at 30' radius

CAPACITIES
Variable Deck Load 3,150 ton (Includes Drilling Load) 6,300 Kips
Cantilever Load Total combined load: 1,250,000 lbs.
Tubulars in Pipe Rack 750 kips on cantilever.
Liquid Mud 1,516 bbls
Bulk Mud / Cement 4,575 / 4,110 cu. ft.
Sacks 3,400 sacks
Drillwater 5,198 bbls
Potable Water 1,348 bbls
Fuel Oil 2,470 bbls
Others

WELL CONTROL SYSTEMS
BOP 1 x Shaffer 13-5/8" 5,000 psi spherical annular; 1 x Cameron U 13 5/8" 10,000 psi double ram; 1 x Cameron 13 5/8" 10,000 psi single ram, 1 x Cameron 13 5/8" 10,000 psi single ram with large bore tandem boosters and BSRs.
BOP Handling 2 x 25 ton hoist and trolley handling system
Control System 1 x 420 gallon, ABB Vetco
Diverter Vetco KFDJ 2000 37-1/2 RT
Drill pipe 5" S-135, Range 2, 19.5 lbs/ft, 15,000 ft
Drill collars 9½"; 8 ¼:, 8"; 6½"
TV System 2 pan & tilt cameras in Derrick, Screen at Driller console
Choke and Kill 3 1/16" x 10,000 psi with 2 x hydraulic and 2 x manual chokes

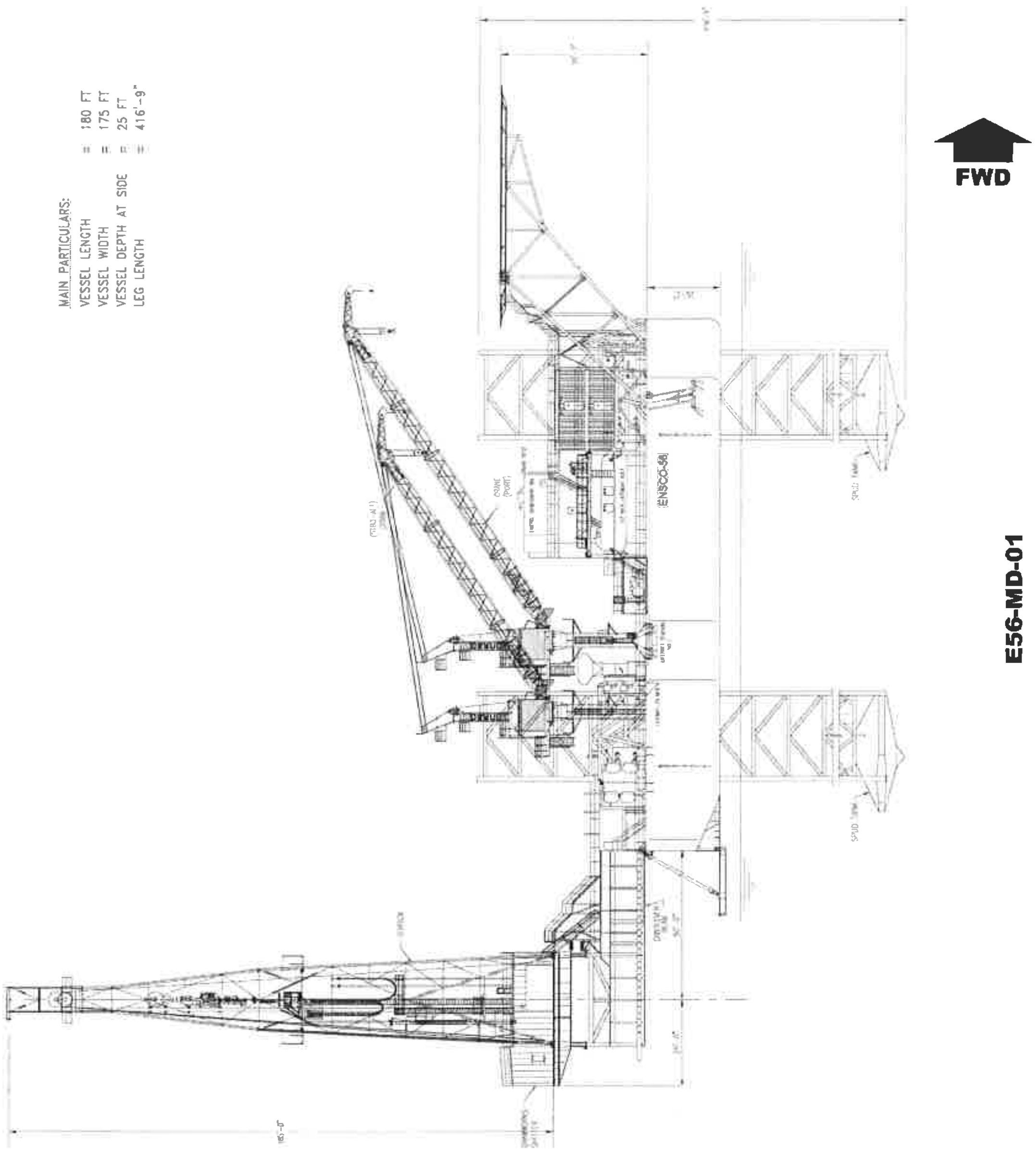
MOORING
Anchor Winches Not applicable
Wire/Chain Not applicable
Anchors Not applicable

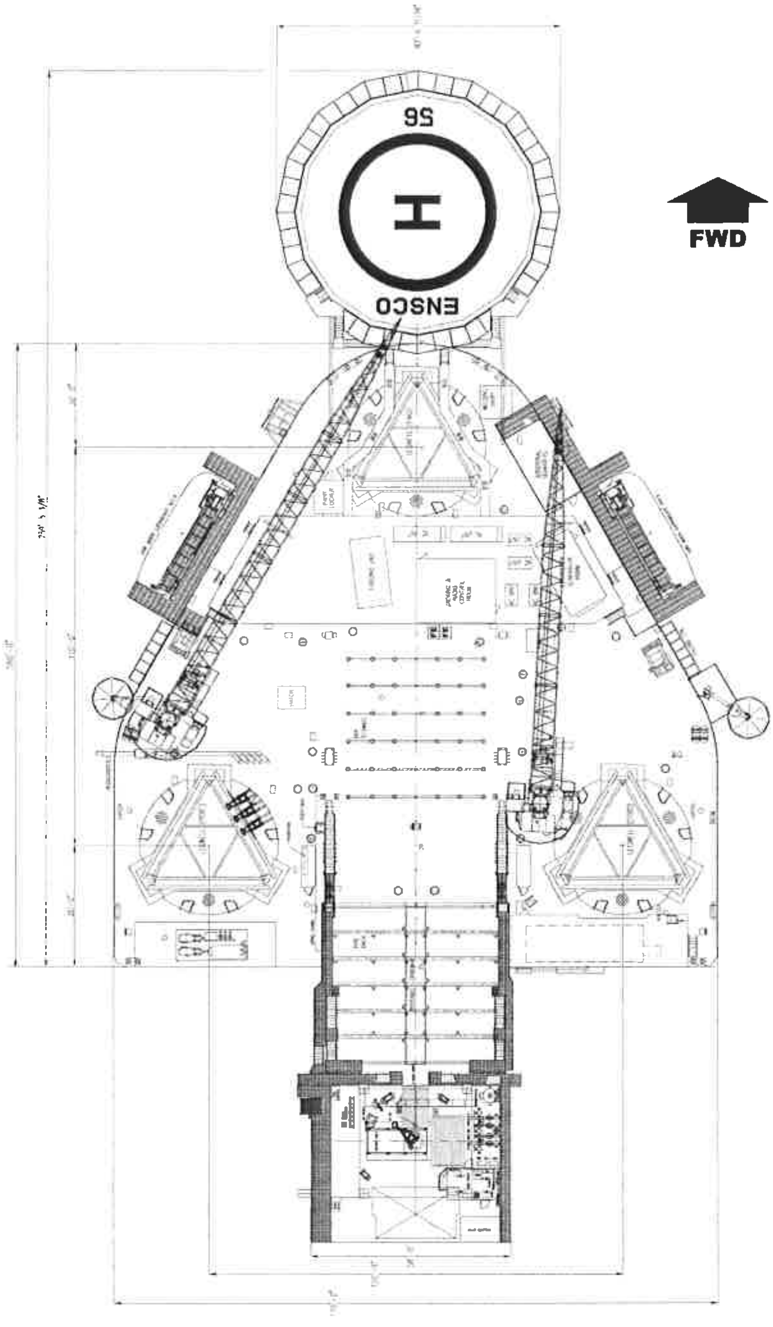
HELIDECK S-76; 70' diameter, 20,500 gross lbs
JACKING AND SKIDDING SYSTEM Bissonneau & Lotz Marine jacking system
ACCOMMODATION 98 berths

ADDITIONAL DATA
Mud cleaning facilities: 4 x Brandt VSM Shakers. Desander: Derrick, 3 x 10" cones; Mud Cleaner 12 x 4" cones, Zero Discharge (single point), Plimsoll hydraulic rack chock system. Capability to store grey/black water on board.

CANTILEVER CAPACITY (kips)

Max Combined Load	Reach	S12'	0	P12'
Max set back: 450kips Max cant piperack: 750kips	50'	421	1112	482
	40'	803	1250	876
	≤32'	1250	1250	1250


MAIN PARTICULARS:
VESSEL LENGTH = 180 FT
VESSEL WIDTH = 175 FT
VESSEL DEPTH AT SIDE = 25 FT
LEG LENGTH = 416'-9"
ENSCO-56
FWD
E56-MD-01



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