CLAIMS

What is claimed is:

1. A subsea production system for conducting hydrocarbon recovery operations in a marine environment, the marine environment comprising a body of water having a surface and a seabed, and the production system comprising:

an elongated trussed frame having a first end and an opposing second end, the first end comprising a base residing proximate the seabed;

a landing deck at the second end of the trussed frame, the landing deck being configured to receive and releasably attach to a floating drilling unit, and the landing deck residing below the water surface a sufficient distance to avoid contact with a floating ice sheet;

one or more fluid storage cells residing at the seabed proximate the base of the trussed frame, at least one of the one or more fluid storage cells being a hydrocarbon fluids storage cell for receiving hydrocarbon fluids; and

subsea production operational equipment residing above the seabed and proximate the second end of the trussed frame, the subsea production operational equipment being in fluid communication with the at least one hydrocarbon fluids storage cell.

2. The subsea production system of claim 1, wherein the subsea operational equipment comprises (i) power generation equipment, (ii) pressure pumps, (iii) control valves, (iv) a production manifold, (v) fluid separation equipment or (vi) combinations thereof.

3. The subsea production system of claim 1, further comprising:

a hydrocarbon transport line providing fluid communication between the subsea production equipment and the at least one hydrocarbon fluids storage cell.

4. The subsea production system of claim 1, further comprising:

a plurality of wellheads disposed on the trussed frame, each wellhead receiving production fluids from a subsurface reservoir through a surface casing that extends from the seabed and into the trussed frame; and

a production flowline for delivering production fluids from the wellhead to the subsea production equipment.

5. The subsea production system of claim 1, further comprising:

a production riser for transporting hydrocarbon fluids from the at least one hydrocarbon fluids storage cell to a transport vessel at the surface, the production riser being in selective fluid communication with the transport vessel.

6. The subsea production system of claim 1, wherein:

the subsea production operational equipment receives production fluids from a plurality of wellheads located on the seabed; and

the subsea production system further comprises production flowlines for transporting production fluids from the respective subsea wellheads to the subsea production operational equipment proximate the second end of the trussed frame.

7. The subsea production system of claim 1, wherein the trussed frame is generally frustum-shaped.

8. The subsea production system of claim 1, wherein the trussed frame has a substantially constant width between the first end and the second end.

9. The subsea production system of claim 1, further comprising:

a gravity base structure comprising the one or more fluid storage cells.

10. The subsea production system of claim 1, wherein the first end of the trussed frame comprises a gravity base.

11. The subsea production system of claim 1, further comprising:

a plurality of mooring lines circumscribing the production tower, with each line having a first end connected to the trussed frame, and a second end connected to an anchor at the seabed.

12. The subsea production system of claim 11, wherein each of the anchors comprises a weighted block held on the seabed by gravity, or a frame structure with a plurality of pile-driven pillars or suction pillars secured to the seabed.

13. The subsea production system of claim 11, wherein the first end of each of the plurality of mooring lines is connected to the trussed frame proximate the second end of the trussed frame.

14. The subsea production system of claim 11, wherein each of the mooring lines is fabricated from chains, wire ropes, synthetic ropes, eyebars or pipes.

15. The subsea production system of claim 1, further comprising:

one or more buoyancy tanks within the trussed frame.

16. The subsea production system of claim 15, wherein the landing deck resides at least about 20 meters (66 feet) below the water surface.

17. The subsea production tower of claim 1, wherein the trussed frame defines an articulated structure comprising:

a substantially rigid lower section extending upwardly from the seabed to a pivot point located intermediate the first end and the second end of the trussed frame; and

a compliant upper section extending upwardly from the pivot point to the landing deck such that the compliant upper section is able to pivot relative to the lower section in response to wave energy and currents.

18. The subsea production tower of claim 17, wherein the substantially rigid lower section comprises:

a plurality of pile sleeves attached to the trussed frame; and

a plurality of piles passing through the pile sleeves to permit relative pivoting motion between the substantially rigid lower section and the compliant upper section.

19. The subsea production tower of claim 18, wherein:

each of the plurality of pile sleeves is attached to the lower section; and

each of the corresponding piles is attached to the compliant upper section.

20. The subsea production tower of claim 18, wherein:

each of the plurality of pile sleeves is attached to the compliant upper section; and

each of the corresponding piles is attached to the lower section.

21. The subsea production tower of claim 18, wherein the substantially rigid lower section comprises a gravity base at the seabed.

22. The subsea production tower of claim 1, wherein the drilling unit comprises:

a platform for conducting operations in the marine environment;

a tower configured to provide ballasting and stability below the surface; and

a base for attaching to the landing deck.

23. A method for installing components for a subsea production system in a marine environment, the marine environment comprising a body of water having a surface and a seabed, and the method comprising:

identifying a location in the marine environment for hydrocarbon recovery operations;

placing one or more hydrocarbon fluids storage cells on the seabed at the selected location;

transporting an elongated trussed frame to the selected location, the trussed frame having a first end and an opposing second end;

installing the trussed frame in the marine environment such that the first end is placed on the seabed proximate the one or more hydrocarbon fluids storage cells;

transporting a frame structure containing the subsea production operational equipment;

installing the frame structure proximate to the second end of the trussed frame;

installing a landing deck to the second end of the trussed frame;

transporting a floating drilling unit to the selected location;

releasably attaching the floating drilling unit to the landing deck of the trussed frame;

connecting a hydrocarbon transport line so as to provide fluid communication between the subsea production operational equipment and the one or more hydrocarbon fluids storage cells.

24. The method of claim 23, wherein the operational equipment comprises (i) power generation equipment, (ii) pressure pumps, (iii) control valves, (iv) a production manifold, (v) fluid separation equipment or (vi) combinations thereof.

25. The method of claim 23, further comprising:

drilling a plurality of wells through the seabed and into a subsurface reservoir; and

producing hydrocarbon fluids.

26. The method of claim 25, further comprising:

placing a plurality of wellheads for each well on the trussed frame, each wellhead receiving production fluids from the subsurface reservoir through a surface casing that extends from the seabed and into the trussed frame; and

installing production flowlines for delivering production fluids from the respective wellheads to the subsea production operational equipment.

27. The method of claim 26, wherein all production fluids received by the subsea production operational equipment flows through the plurality of wellheads disposed on the trussed frame.

28. The method of claim 25, further comprising:

placing a plurality of wellheads for each well on the seabed; and

installing production flowlines for delivering production fluids from the respective wellheads to the subsea production operational equipment.

29. The method of claim 25, further comprising:

placing a first end of a production riser in fluid communication with the one or more hydrocarbon fluids storage cells; and

transferring hydrocarbon fluids from the one or more hydrocarbon fluids storage cells to the transport vessel.

30. The method of claim 23, further comprising:

lowering a plurality of anchors onto the seabed, the anchors circumscribing the trussed frame;

providing a corresponding plurality of mooring lines, each mooring line having a first end and a second end; and

connecting the first end of each mooring line to an anchor at the seabed, and a second end of each mooring line to the trussed frame.

31. The method of claim 30, wherein each of the anchors comprises a weighted block held on the seabed by gravity, or a frame structure with a plurality of pile-driven pillars or suction pillars secured to the earth proximate the seabed.

32. The method of claim 23, wherein the trussed frame defines an articulated structure comprising:

a substantially rigid lower section extending upwardly from the seabed to a pivot point located intermediate the first and second ends of the trussed frame; and

a compliant upper section extending upwardly from the pivot point towards the landing deck such that the compliant upper section is able to pivot laterally relative to the lower section in response to wave energy and currents.

33. The method of claim 23, further comprising:

attaching a floating drilling unit to the landing deck of the trussed frame.

34. The method of claim 23, further comprising:

identifying a moving ice sheet within the marine environment;

disconnecting the floating drilling unit from the landing deck of the trussed frame; and

temporarily moving the floating drilling unit to a new location in the marine environment to avoid the moving ice sheet.

35. The method of claim 23, further comprising:

determining an anticipated maximum depth of moving ice sheets within the marine environment; and

dimensioning the elongated trussed frame such that the landing deck is below the maximum depth when the trussed frame is erected.

36. The method of claim 35, wherein the landing deck resides at least 20 meters (66 feet) below the surface.

37. A method of moving a floating drilling unit in a marine environment from an offshore location, the marine environment comprising a body of water having a surface and a seabed, and the method comprising:

identifying a moving ice sheet within the marine environment;

disconnecting the drilling unit from a subsea production tower, the subsea production tower comprising:

an elongated trussed frame having a first end and an opposing second end, the first end comprising a base residing proximate the seabed,

a landing deck at the second end of the trussed frame, the landing deck being configured to receive and releasably attach to the floating drilling unit, and the landing deck residing at least 20 meters (66 feet) below the surface, and

subsea production operational equipment residing above the seabed and proximate the second end of the trussed frame, the fluid separation equipment being in fluid communication with at least one hydrocarbon fluids storage cell on the seabed;

temporarily re-locating the drilling unit to a new location within the marine environment to avoid the moving ice sheet; and

returning the drilling unit to the landing deck of the production tower after the ice sheet has passed by the offshore location.

CLAIMS

1. A subsea production system for conducting hydrocarbon recovery operations in a marine environment, the marine environment comprising a body of water having a surface and a seabed, and the production system comprising:

an elongated trussed frame having a first end and an opposing second end, the first end comprising a base residing proximate the seabed;

a landing deck at the second end of the trussed frame, the landing deck being configured to receive and releasably attach to a floating drilling unit, and the landing deck residing below the water surface a sufficient distance to avoid contact with a floating ice sheet;

one or more fluid storage cells residing at the seabed proximate the base of the trussed frame, at least one of the one or more fluid storage cells being a hydrocarbon fluids storage cell for receiving hydrocarbon fluids; and

subsea production operational equipment residing above the seabed and proximate the second end of the trussed frame below the landing deck, the subsea production operational equipment being in fluid communication with the at least one hydrocarbon fluids storage cell.

2. The subsea production system of claim 1, wherein the subsea production operational equipment comprises (i) power generation equipment, (ii) pressure pumps, (iii) control valves, (iv) a production manifold, (v) fluid separation equipment or (vi) combinations thereof.

3. The subsea production system of claim 1, further comprising:

a hydrocarbon transport line providing fluid communication between the subsea production operational equipment and the at least one hydrocarbon fluids storage cell.

4. The subsea production system of claim 1, further comprising:

a plurality of wellheads disposed on the trussed frame, each wellhead receiving production fluids from a subsurface reservoir through a surface casing that extends from the seabed and into the trussed frame; and

a production flowline for delivering production fluids from the wellhead to the subsea production operational equipment.

5. The subsea production system of claim 1, further comprising:

a production riser for transporting hydrocarbon fluids from the at least one hydrocarbon fluids storage cell to a transport vessel at the water surface, the production riser being in selective fluid communication with the transport vessel.

6. The subsea production system of claim 1, wherein:

the subsea production operational equipment receives production fluids from a plurality of wellheads located on the seabed; and

the subsea production system further comprises production flowlines for transporting production fluids from the respective subsea wellheads to the subsea production operational equipment proximate the second end of the trussed frame.

7. The subsea production system of claim 1, wherein the trussed frame is generally frustum-shaped.

8. The subsea production system of claim 1, wherein the trussed frame has a substantially constant width between the first end and the second end.

9. The subsea production system of claim 1, further comprising:

a gravity base structure comprising the one or more fluid storage cells.

10. The subsea production system of claim 1, wherein the first end of the trussed frame comprises a gravity base.

11. The subsea production system of claim 1, further comprising:

a plurality of mooring lines circumscribing the production system, with each line having a first end connected to the trussed frame, and a second end connected to an anchor at the seabed.

12. The subsea production system of claim 11, wherein each of the anchors comprises a weighted block held on the seabed by gravity, or a frame structure with a plurality of pile-driven pillars or suction pillars secured to the seabed.

13. The subsea production system of claim 11, wherein the first end of each of the plurality of mooring lines is connected to the trussed frame proximate the second end of the trussed frame.

14. The subsea production system of claim 11, wherein each of the plurality of mooring lines is fabricated from chains, wire ropes, synthetic ropes, eyebars or pipes.

15. The subsea production system of claim 1, further comprising:
one or more buoyancy tanks within the trussed frame.

16. The subsea production system of claim 15, wherein the landing deck resides at least about 20 meters (66 feet) below the water surface.

17. The subsea production system of claim 1, wherein the trussed frame defines an articulated structure comprising:
a substantially rigid lower section extending upwardly from the seabed to a pivot point located intermediate the first end and the second end of the trussed frame; and
a compliant upper section extending upwardly from the pivot point to the landing deck such that the compliant upper section is able to pivot relative to the substantially rigid lower section in response to wave energy and currents.

18. The subsea production system of claim 17, wherein the substantially rigid lower section comprises:
a plurality of pile sleeves attached to the trussed frame; and
a plurality of piles passing through the pile sleeves to permit relative pivoting motion between the substantially rigid lower section and the compliant upper section.

19. The subsea production system of claim 18, wherein:
each of the plurality of pile sleeves is attached to the substantially rigid lower section; and
each of the corresponding piles is attached to the compliant upper section.

20. The subsea production system of claim 18, wherein:
each of the plurality of pile sleeves is attached to the compliant upper section; and
each of the corresponding piles is attached to the substantially rigid lower section.

21. The subsea production system of claim 18, wherein the substantially rigid lower section comprises a gravity base at the seabed.

22. The subsea production system of claim 1, wherein the drilling unit comprises:
a platform for conducting operations in the marine environment;
a tower configured to provide ballasting and stability below the water surface; and
a base for attaching to the landing deck.

23. A method for installing components for a subsea production system in a marine environment, the marine environment comprising a body of water having a surface and a seabed, and the method comprising:
identifying a location in the marine environment for hydrocarbon recovery operations;
placing one or more hydrocarbon fluids storage cells on the seabed at the selected location;
transporting an elongated trussed frame to the selected location, the trussed frame having a first end and an opposing second end;
installing the trussed frame in the marine environment such that the first end is placed on the seabed proximate the one or more hydrocarbon fluids storage cells;
transporting a frame structure containing the subsea production operational equipment;
installing the frame structure proximate to the second end of the trussed frame;
installing a landing deck proximate the second end of the trussed frame above the frame structure a distance below the water surface;
transporting a floating drilling unit to the selected location;

releasably attaching the floating drilling unit to the landing deck of the trussed frame;

connecting a hydrocarbon transport line so as to provide fluid communication between the subsea production operational equipment and the one or more hydrocarbon fluids storage cells.

24. The method of claim 23, wherein the subsea production operational equipment comprises (i) power generation equipment, (ii) pressure pumps, (iii) control valves, (iv) a production manifold, (v) fluid separation equipment or (vi) combinations thereof.

25. The method of claim 23, further comprising:

drilling a plurality of wells through the seabed and into a subsurface reservoir; and

producing hydrocarbon fluids.

26. The method of claim 25, further comprising:

placing a plurality of wellheads for each well on the trussed frame, each wellhead receiving production fluids from the subsurface reservoir through a surface casing that extends from the seabed and into the trussed frame; and

installing production flowlines for delivering production fluids from the respective wellheads to the subsea production operational equipment.

27. The method of claim 26, wherein all production fluids received by the subsea production operational equipment flows through the plurality of wellheads disposed on the trussed frame.

28. The method of claim 25, further comprising:

placing a plurality of wellheads for each well on the seabed; and

installing production flowlines for delivering production fluids from the respective wellheads to the subsea production operational equipment.

29. The method of claim 25, further comprising:

placing a first end of a production riser in fluid communication with the one or more hydrocarbon fluids storage cells; and

transferring hydrocarbon fluids from the one or more hydrocarbon fluids storage cells to ~~a~~ transport vessel.

30. The method of claim 23, further comprising:

lowering a plurality of anchors onto the seabed, the anchors circumscribing the trussed frame;

providing a corresponding plurality of mooring lines, each mooring line having a first end and a second end; and

connecting the first end of each mooring line to an anchor at the seabed, and a second end of each mooring line to the trussed frame.

31. The method of claim 30, wherein each of the anchors comprises a weighted block held on the seabed by gravity, or a frame structure with a plurality of pile-driven pillars or suction pillars secured to the earth proximate the seabed.

32. The method of claim 23, wherein the trussed frame defines an articulated structure comprising:

a substantially rigid lower section extending upwardly from the seabed to a pivot point located intermediate the first and second ends of the trussed frame; and

a compliant upper section extending upwardly from the pivot point towards the landing deck such that the compliant upper section is able to pivot laterally relative to the substantially rigid lower section in response to wave energy and currents.

33. The method of claim 23, further comprising:

attaching a floating drilling unit to the landing deck of the trussed frame.

34. The method of claim 23, further comprising:

identifying a moving ice sheet within the marine environment;

disconnecting the floating drilling unit from the landing deck of the trussed frame; and

temporarily moving the floating drilling unit to a new location in the marine environment to avoid the moving ice sheet.

35. The method of claim 23, further comprising:

determining an anticipated maximum depth of moving ice sheets within the marine environment; and

dimensioning the elongated trussed frame such that the landing deck is below the maximum depth when the trussed frame is erected.

36. The method of claim 35, wherein the landing deck resides at least 20 meters (66 feet) below the water surface.

37. A method of moving a floating drilling unit in a marine environment from an offshore location, the marine environment comprising a body of water having a surface and a seabed, and the method comprising:

identifying a moving ice sheet within the marine environment;

disconnecting the drilling unit from a subsea production tower, the subsea production tower comprising:

an elongated trussed frame having a first end and an opposing second end, the first end comprising a base residing proximate the seabed,

a landing deck at the second end of the trussed frame, the landing deck being configured to receive and releasably attach to the drilling unit, and the landing deck residing at least 20 meters (66 feet) below the water surface, and

subsea production operational equipment residing above the seabed and proximate the second end of the trussed frame below the landing deck, the subsea production operational equipment being in fluid communication with at least one hydrocarbon fluids storage cell on the seabed;

temporarily re-locating the drilling unit to a new location within the marine environment to avoid the moving ice sheet; and

returning the drilling unit to the landing deck of the production tower after the ice sheet has passed by the offshore location.

38. The method of claim 37, wherein the subsea production operational equipment includes fluid separation equipment, the fluid separation equipment residing a distance below the landing deck within about 20% of the overall height of the subsea production tower.

39. The subsea production system of claim 1, wherein the subsea production operational equipment includes fluid separation equipment.

40. The subsea production system of claim 39, wherein the fluid separation equipment is placed on the trussed frame proximate the second end.

41. The subsea production system of claim 39, wherein the fluid separation equipment is place on a separate frame structure positioned proximate the second end of the trussed frame.