The Gulf of Mexico Decommissioning Market

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Abstract: The Gulf of Mexico offshore decommissioning market is the most diverse and competitive service contract environment in the world. The purpose of this paper is to describe the business, engineering, and market environment of decommissioning services in the Gulf of Mexico, and to provide a first-order approximation of the number of structures expected to be removed over a 25 year time horizon. Decommissioning activities associated with offshore production are an important and specialized segment of marine construction that has received limited attention in the academic literature, yet is compelling because few industrial sectors have such well-understood and widely adopted abandonment requirements. This paper should appeal to practitioners and researchers interested in learning the processes involved in deconstruction and the basic structure of the industry. The regulatory requirements and primary stages of decommissioning are reviewed, and the management, bid/tender process, and negotiation strategies are described. A life expectancy model of the number of structures expected to be removed from the Gulf of Mexico is presented, along with a discussion of the model uncertainty and the limitations of the analysis.

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Introduction

The outer continental shelf (OCS) of the Gulf of Mexico (GOM) is the most developed and mature hydrocarbon basin in the world. The federally regulated offshore waters of the GOM begins seaward 3 nautical miles (1 nautical mile is approximately 6,076 ft) from the Louisiana, Alabama, and Mississippi shorelines, and 9 nautical miles from the Texas and west Florida shorelines, and extends 200 miles through the exclusive economic zone (EEZ). The EEZ was established by the 1982 United Nations Convention on the Law of the Sea, which allows each coastal nation to establish an EEZ adjacent to its territorial sea, extending a maximum of 200 miles seaward from the shoreline (U.S. Commission on Ocean Policy 2004).

A wide variety of structures are used in the GOM to develop hydrocarbons, ranging from simple caissons and well protectors supporting one or more wells in shallow water (Fig. 1), to complex fixed platforms that support drilling and production operations up to 457 m (1,500 ft) (Fig. 2), to mammoth floating structures such as tension-leg platforms and spars in deep water. There are currently approximately 4,000 structures in the federal waters of the GOM in depths ranging from less than 3 m (10 ft) to over 2,200 m (7,000 ft).

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At the end of 2003, there were 2,175 active (producing) structures, 898 idle (nonproducing) structures, and 440 auxiliary (never-producing) structures on 1,356 active leases; and 329 idle structures and 65 auxiliary structures on 273 inactive leases (Table 1). A few dozen deepwater structures are not considered in Table 1 because they are small in number, relatively recent installations, and are expected to serve as deepwater hubs for hydrocarbon production for many years to come. An active structure produced hydrocarbons in the year 2003; an idle structure once produced hydrocarbons, but has not been productive over the past year; and an auxiliary structure has never produced hydrocarbons, but serves in a support role, as a quarter facility, flare tower, storage platform, or similar nonproductive role. A total of 2,175 active structures, 1,227 idle structures, and 505 auxiliary structures, or 3,907 total structures, currently reside in the GOM.

Decommissioning operations are generally routine, involving standard, low-technology methods performed over distinct stages and relatively short time horizons. Operating offshore is more uncertain and costly than onshore, however, due to the hostile ocean environment and the remote nature of operations. A greater potential for harm to human and sea life also exists since the marine environment is more sensitive and dynamic than land-based operations. Decommissioning does not generate revenue unless the asset can be divested or the property farmed out, and so for nearly all producing companies, decommissioning is primarily viewed as a noncore activity that is best handled outside the organization. Since 1947, over 2,200 structures have been removed from the GOM, and over the past decade, 125 structures on average have been removed annually. The number and type of structures removed can vary considerably from year to year (Fig. 3), and although extreme weather events have not played a large role in the removal of offshore infrastructure, during the 2005 hurricane season, Hurricanes Katrina and Rita destroyed an unprecedented 132 structures and damaged 52 others, the worst since Hurricane Andrew in 1992.

Structures are installed to produce and process hydrocarbons,

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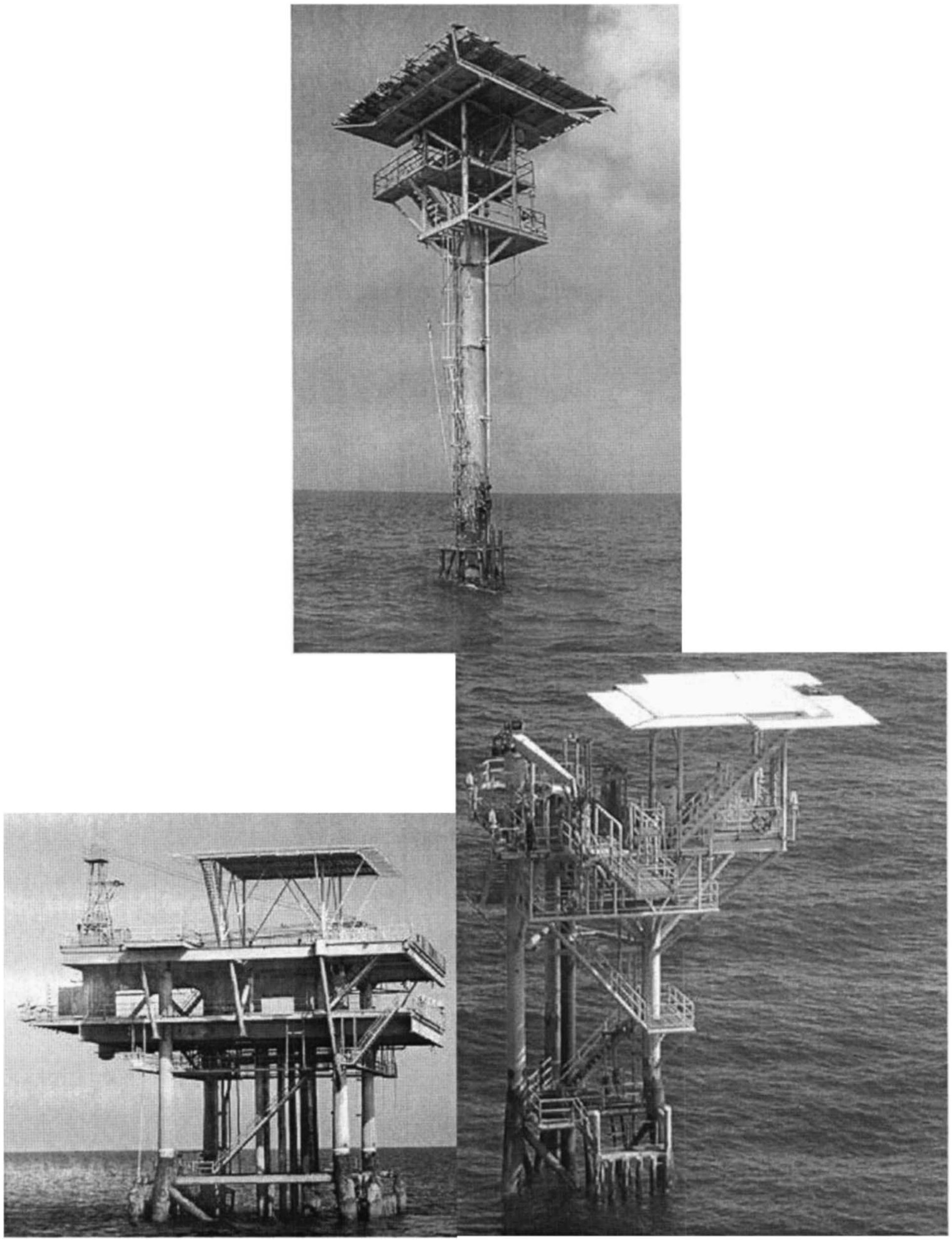

Fig. 1. Caisson and well protector structures (photographs courtesy of Twachtman Snyder and Byrd, used with permission)

and when the time arrives that the cost to operate a structure (maintenance, operating personnel, transportation, etc.) exceeds the income from the hydrocarbons under production, the structure exists as a liability instead of an asset and becomes a candidate for divestiture or abandonment. When the operating cost of a structure equals the income from production, the economic limit is said to be reached, and a decision to abandon the structure and shut-in production is made. The timing of decommissioning is somewhat flexible, however, and depends upon operator preference, strategic opportunity, and regulatory requirements. There are usually no commercial incentives for early removal and operators have no incentive to “fast track” decommissioning unless required by regulatory time limitations.

Strategic objectives play a significant role in decision making. Delaying decommissioning has an economic value since it defers expenditure while allowing the deferred funds to be invested in productive activities. Operators may postpone decommissioning to delay incurring the cost of decommissioning, to see if new extraction technology will increase a field’s life, to achieve economies of scale in the operation (i.e., remove all the structures on the lease and on nearby leases at once), or to hold (requalify) infrastructure for new (or marginal) field development plans or alternative uses such as offshore wind power or mariculture operations. Operators may also remove structures on a lease earlier than suggested by the economic limit if the rate of return in the investment does not meet a minimum threshold or the strategic goals of the operator change. If the field is still profitable it may be purchased and operated by another firm with lower operating cost and/or a lower required return on investment. The impact of divestiture—which is a very common practice in the GOM—acts to extend lease life, delay the “expected” structure decommissioning date, and shift the time of removal into the future.

Federal regulations require that all structures on a lease be

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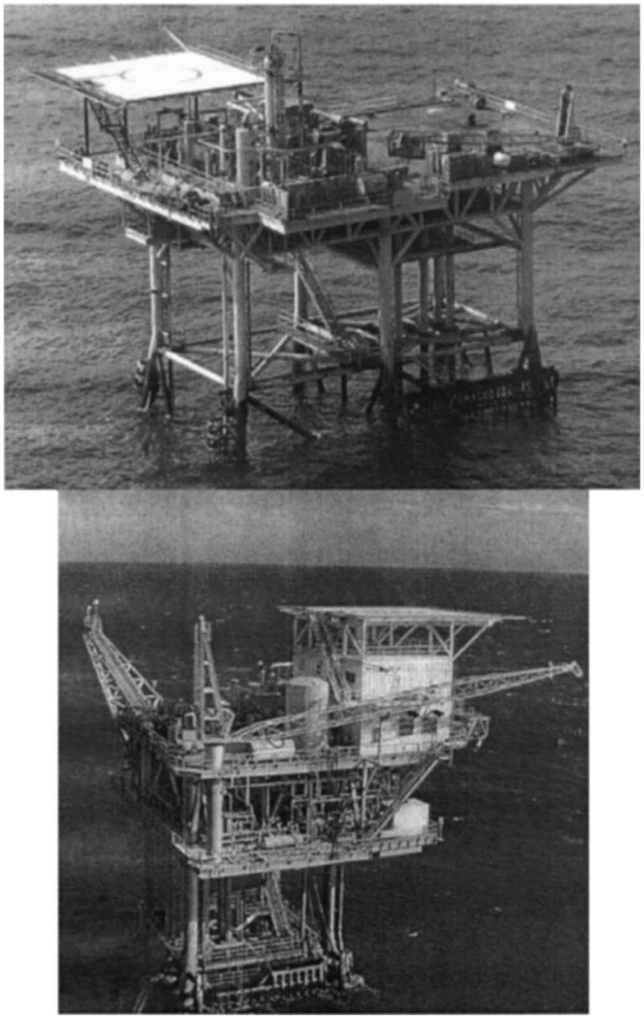

Fig. 2. Fixed platform structures (photographs courtesy of Twachtman Snyder and Byrd, used with permission)

completely removed and all wells permanently plugged and abandoned within one year after the lease is terminated. Typically, a lease is terminated when production on the lease ceases, but special circumstances may arise that allow the operator to maintain structures on nonproducing leases. If the operator intends to

Table 1. Active, Idle, and Auxiliary Structures[a] in the Gulf of Mexico (2003)

Water depth (ft)	WGOM			CGOM			GOM
	CAIS	WP	FP	CAIS	WP	FP	Auxiliary
0–20	1	0	0	200	10	35	79
21–100	79	25	119	767	268	710	318
101–200	3	17	82	48	63	490	73
201–400	1	4	85	1	12	320	31
400+	0	0	13	0	3	43	4
Total	84	46	299	1,016	356	1,598	505

[a]Structures are classified as caissons (CAIS); well protectors (WP); and fixed platforms (FP) across the Western and Central Gulf of Mexico (WGOM, CGOM) planning areas. Active and idle structures are aggregated. Active structures are currently producing. Idle structures are no longer producing. Auxiliary structures are associated with oil and gas production but do not produce hydrocarbons.

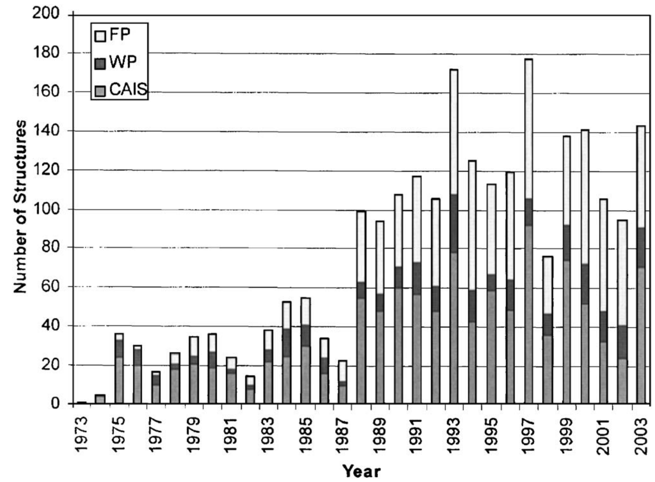

Fig. 3. Structures removed in outer continental shelf of the Gulf of Mexico (1973–2003)

rework well(s) or pursue additional drilling activity on the lease, for instance, or the lease contains an active pipeline or a gathering system for the production from other structures, conditions may warrant an extension of the lease termination. Further, since several structures may be contained on a lease, it is only when production from the *last* productive structure ceases that *all* the structures on the lease are required to be removed. Operators typically plug and abandon nonproducing wells and may remove simple structures such as caissons, flare piles, and storage facilities on a productive lease early, but it is really only after the lease is terminated that all the structures are required to be removed.

A forecast of the number of structures expected to be removed from the GOM is a useful indicator for a number of purposes. Structures need to be constructed, delivered, installed, and equipped prior to production, operated and serviced during production, and then eventually decommissioned and removed after production. Each of these activities has both a direct and indirect impact on the communities in which the service facilities and manufacturing operations are located, and induce a "spill-over" effect on the economic growth of regions which serve the development (Coffman et al. 2001). An entire industry has been built in the GOM around constructing and installing production equipment and structures, servicing those structures (maintenance, repairs, supply), and then removing the structures when production ceases. Decommissioning is the least glamorous stage in the life cycle of a field, but it is an important segment, and perhaps because few sectors in the construction industry have such well understood and widely adopted removal requirements, this discussion may have wider implications to the end-of-use phase of other projects.

The number of offshore structures removed with explosives is of particular concern, as using explosives may place marine mammals, sea turtles, and other sea life at risk (U.S. Dept. of the Interior 2005). The negative impact of explosive removals on fish populations is well known (Gitschlag et al. 2000; Continental Shelf Associates 2004), and regulatory safeguards have been enacted to help ensure the protection of marine mammals and sea turtles (Federal Register 2002). Explosive severance activities are subject to regulations promulgated under the OCS Lands Act, Endangered Species Act, and the Marine Mammal Protection Act. The Minerals Management Service (MMS) issued a Notice to Lessees and Operators, No. 24-G06 (http://www.gomr.gov/

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homepg/regulate/regs/ntls/ntl04-g06.html), that summarizes all of the current regulations and conditions for explosive severance activities.

The outline of the paper is as follows. The regulatory requirements of decommissioning are first outlined followed by a brief description of the basic stages of the operation. Decommissioning management, the bid/tender process, and standard negotiation strategies are then described. The scale of the decommissioning market is estimated using a first-order approximating life expectancy and probabilistic removal model. The results of the model and a description of the limitations of the analysis are discussed. Conclusions complete the paper.

Regulatory Requirements

Different government bodies regulate the decommissioning and abandonment of offshore structures and the regulatory body with primary responsibility is dependent on the physical location of the structure. State agencies are responsible for structures located in state waters, while the MMS is the federal agency responsible for decommissioning activities in the OCS of the United States.

The basic aim of a decommissioning project is to render all wells permanently safe and remove most surface/seabed signs of production activity. The general requirements for decommissioning are specified in Federal Registry 30 CFR Sec. 250.1703 and require that all wells be permanently plugged and abandoned, all platforms and other facilities be removed, and the seafloor cleared of all obstructions created by the operations within one year after the lease or pipelines right-of-way terminates (Federal Register 2002).

Federal regulations for well plugging and abandonment are written to have general application to all wells and specify the minimum requirements necessary. The operator is required to receive approval for plug and abandonment operations and submit information on the reason the well is being plugged, a description of the work requirements, an assessment of the expected environmental impacts of the operation, and the procedures and mitigation measures taken to minimize such impacts. Before beginning operations, the MMS district supervisor is required to be notified at least 48 h prior to the operation.

All wellheads and casings are required to be removed to a depth at least 5 m (15 ft) below the mudline unless the district supervisor approves an alternative depth. The District Supervisor may approve an alternate removal depth if the wellhead or casing would not become an obstruction to other users of the seafloor or area; the use of divers and the seafloor sediment stability pose safety concerns; or the water depth is greater than 800 m (2,640 ft). The requirement for removing subsea wellheads or other obstructions may be reduced or eliminated when, in the opinion of the district supervisor, the wellheads would not constitute a hazard to other users of the seafloor.

A pipeline may be abandoned in place if it does not constitute a hazard to navigation, commercial fishing operations, or unduly interferes with other uses in the OCS. Pipelines abandoned in place need to be flushed, filled with seawater, and plugged with the ends buried at least 1 m (3 ft) below the mudline.

To remove a platform from OCS waters, a structure removal application and site clearance plan must be submitted to the MMS, and if explosives are to be used for cutting, it is necessary to receive an Endangered Species Act Sec. 7 consultation. Strict regulations govern the manner in which explosives are employed in severance operations (Kaiser et al. 2002). The piles, conductors, and caissons that attach the jacket to the seafloor and serve as a conduit to the hydrocarbon reservoir must also be severed and removed at least 5 m (15 ft) below the mudline.

Fig. 4. Derrick barge arrives on site and removes deck module (source: National Marine Fisheries Service—Galveston)

All abandoned well and platform locations in water depths less than 91 m (300 ft) must be cleared of all obstructions present as a result of oil and gas activities. Platforms and single-well caissons in water depths less than 91 m (300 ft) are trawled for clearance verification over a radial circle the size of which depends on the structural element. The MMS preferred verification technique is to drag a standard trawl net across 100% of the site in two directions. In some cases, alternative site verification techniques, such as side scan sonar or documentation of sweep assembly results, have been used. At the conclusion of the operation, a completion report is submitted to the MMS detailing the removal operation and certifying that the site has been cleared.

Stages of Decommissioning

The main stages of decommissioning and the primary equipment involved in the operation are depicted in Figs. 4–10. For more detailed descriptions of the stages and the technical requirements of the process, see Byrd and Velazquez (2001), Hakam and Thornton (2000), Manago and Williamson (1997), Pulsipher (1996), Thornton and Wiseman (2000), and National Research Council (1985). For a risk assessment perspective of decommissioning options, see Faber et al. (2002).

Planning and Permitting

The engineering planning phase of decommissioning typically consists of a review of all contractual obligations and requirements from lease, operating, production, sales, or regulatory agreements. A plan is developed for each phase of the decommissioning project, and the process of surveying the market for equipment and vessels is initiated. Engineering personnel are sent to the site to assess the work requirements, and the project management team will report on the options available to the operator, including the scope of work that needs to be performed and how best to prepare the bid.

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Fig. 5. Deck module and heliport placed on cargo barge for transportation to shore (photographs) courtesy of Twachtman Snyder and Byrd, used with permission)

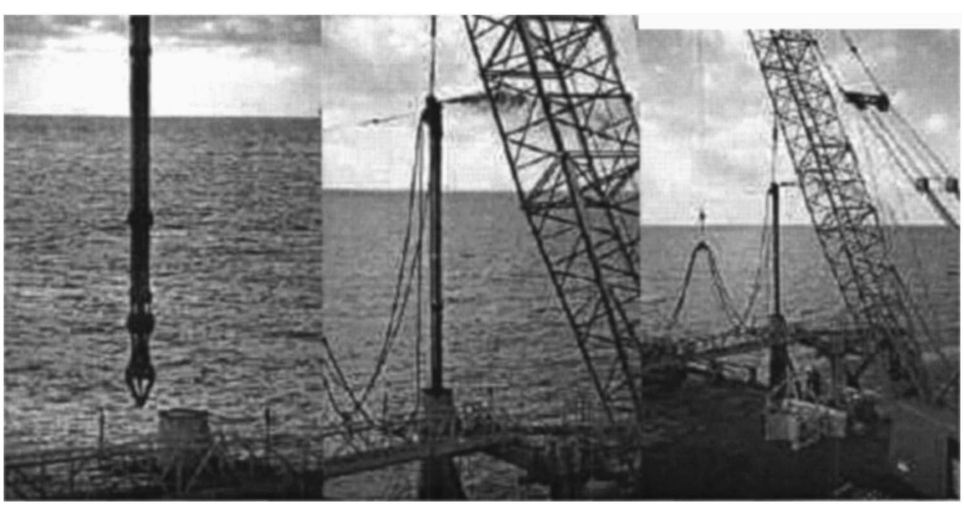

Fig. 6. Water jet used to clear mud from within each platform leg (source: National Marine Fisheries Service—Galveston)

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Fig. 7. Explosives technicians prepare and load charges into conductors and legs (source: National Marine Fisheries Service—Galveston)

Plug and Abandonment

The purpose of plug and abandonment (P&A) is to destroy the permeability within the formation and stabilize the wellbore and its associated annuli until geologic forces can reestablish the natural barriers that existed before the well was drilled. Isolation of the hydrocarbon-bearing intervals and uncemented annuli is critical to successful abandonment. P&A activities essentially involve setting various cement plugs in wells to ensure downhole isolation of hydrocarbon zones which prevents the migration of formation fluids within the wellbore or to the seafloor. Plugging and abandoning wells may occur before, during, or after removal preparation activities are complete—depending on the scope of work and contractor requirements—but all wells must be P&A prior to cutting and removing the conductors.

Preparation

The structure is prepared for removal and an inspection is made to determine the condition of the structure and identify potential problems with the salvage. Depending on the water depth, inspections are performed using divers or a remotely operated vehicle. On deck, the crew flushes and cleans all piping and equipment that contained hydrocarbons. All modules to be removed separately from the deck are cut loose, and the piping, electrical, and instrumentation interconnections between modules are cut. Work needed to prepare the modules for lifting is also performed. The fluids and agents used to purge and clean the vessel must be disposed by pumping them downhole through an injection well or to storage in tanks and onshore disposal in accord with MMS regulations. Equipment and other metallic debris are sent onshore to recycle or scrap, while nonmetallic debris is sent as waste to a landfill.

Pipeline Abandonment

Most pipelines in the GOM are abandoned in place, with the pipeline flushed, filled with seawater, cut, and then plugged with the ends buried at least 1 m (3 ft) below the mudline (Pulsipher 1996).

Structure Removal

The removal of the topside facilities, deck, conductors, piles, and jacket is the core of the decommissioning project and typically the most expensive stage (Kaiser et al. 2003).

Deck Removal

The deck is normally cut from the jacket using torches. The deck is then lifted (Fig. 4) and placed on a cargo barge (Fig. 5), secured, and returned to shore for scrap or reuse. The interior of the piling is then cleared using water jets to remove the mud from

Fig. 8. Aerial view of job site before blast and detonation (source: National Marine Fisheries Service—Galveston)

Fig. 9. Jacket structure rigged and lifted from water (photograph courtesy of Twachtman Snyder and Byrd, used with permission)

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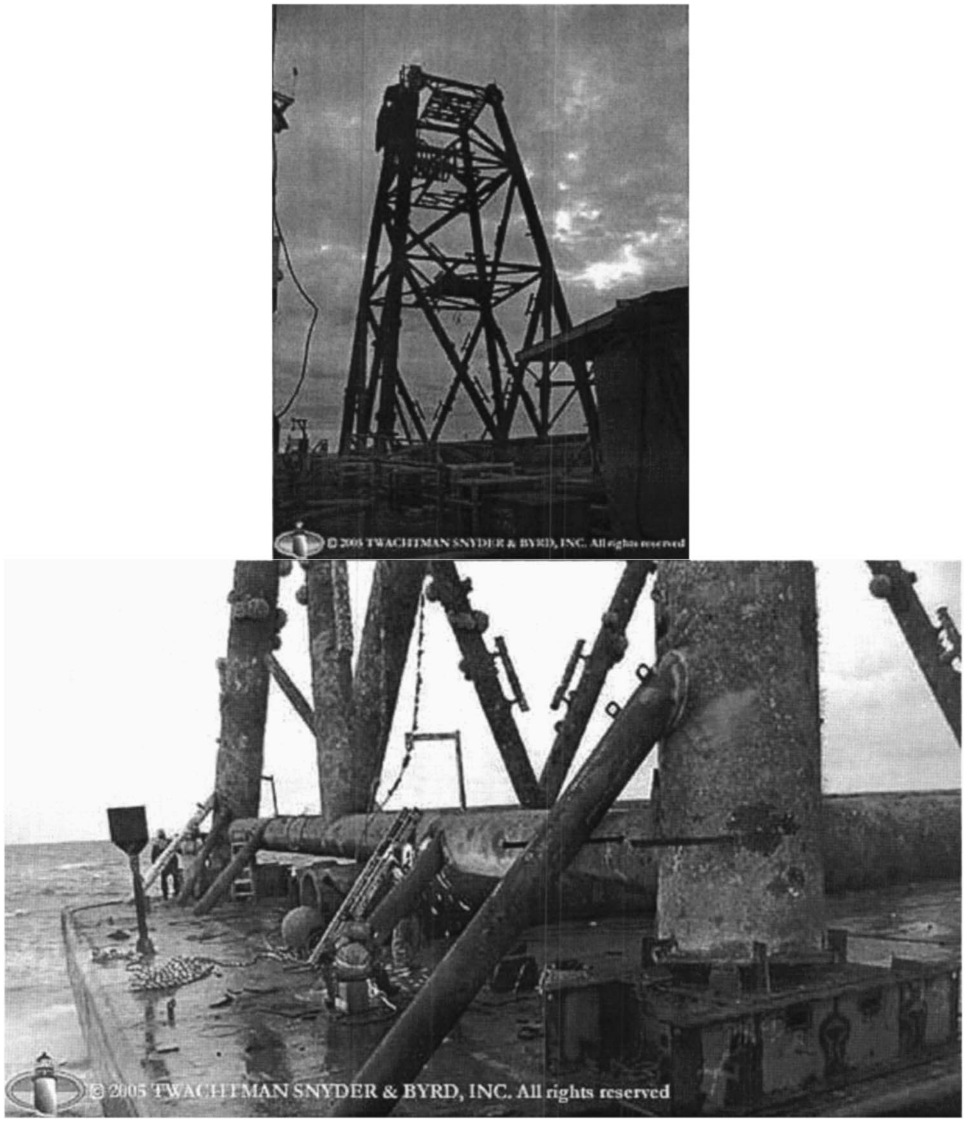

Fig. 10. Jacket secured on cargo barge and transported to shore (photographs courtesy of Twachtman Snyder & Byrd, used with permission)

within the platform legs so that the explosives (or other cutting device) can be lowered below the mudline (Fig. 6).

Pile and Conductor Removal

Conductors, casing string, and piling are cut at least 5 m (15 ft) below the mudline, pulled, and removed. Conductor severing and removal may take place as part of P&A activity or during the structure removal operation. Mechanical casing cutters, abrasive water jets, or explosives are used to cut conductors at the designated elevation. Piles are frequently severed using explosives, although abrasive water jet technology is also employed up to 76 m (250 ft) water depth. The explosives technician prepares and loads the charges into the legs and conductors (Fig. 7), the derrick barge is backed off a safe distance, and the explosives are detonated in accord with federal regulations (Fig. 8). Piling and conductors are pulled using the derrick barge crane.

Jacket Removal

After the conductors and piles have been removed, the jacket structure is lifted out of the water (Fig. 9) and welded to a materials barge for transport to shore or a reef site (Fig. 10). In some cases, the jacket is toppled-in-place after the piling has been cut, while in other cases, the jacket is cut in half in the water column and the top-half of the structure is placed on the seabed near the bottom half. A structure "toppled-in-place" proceeds much like a complete removal, except that after the piles are cut and removed, the structure is pulled over and placed on its side on the seafloor. In a "partial removal," the bottom-half section of the structure is left standing vertically in the water column, whereas the top-half section of the jacket is severed and placed next to the base or removed to shore.

Site Clearance and Verification

The last stage in decommissioning is site clearance and verification. Site clearance is the process of eliminating, or otherwise addressing, potentially adverse impacts from debris and seafloor disturbances, while verification is used to ensure that the site is clear of obstructions. According to MMS regulations, for clearance purposes, all abandoned well and platform locations in water depth less than 91 m (300 ft) must be cleared of all obstructions present as a result of oil and gas activities. After the jacket has been removed, the site is cleared with a trawling vessel or divers deployed with scanning sonar, and then clearance is verified with

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a trawler. Specialized, heavy-duty trawling gears with reinforced mesh, commonly known as "gorilla nets," are used in the operation. The nets are dragged over the seafloor in four directions to provide 100% coverage of the area. Waivers for site clearance and verification are sometimes granted for structures reefed in place.

Business of Decommissioning

Management Options

Operators have essentially two options available to manage their decommissioning projects. The operator can devote resources to manage the decommissioning activities within the company or contract out the requirement to a third party which specializes in project management or provides decommissioning management as part of an integrated service package. The choice of which management option is selected depends upon the business model of the operator and the size of the operator's offshore inventory. Offshore structures have been removed for decades and almost all of the early removals were performed in-house using company personnel or an outside contractor under the operator's control. This business model still makes sense for a company like Chevron which maintains several hundred structures in the GOM. It is logical and cost effective for companies with "enough steel" to manage their own decommissioning activities to take advantage of scale economies, to ensure the quality and cost of service, to provide flexibility to field management teams, and to control liability. In-house project management teams embody significant expertise that is expected to contribute to additional cost savings over time. For the majority of GOM operators, however, removal requirements are sporadic and decommissioning activities are typically contracted out to an independent project management team.

Business Models

In the standard business model, the operator maintains the structure until it is no longer economic, and then a third party project management team plans the decommissioning activities acting as the agent of the operator. The operator can also divest the structure to a third party some time before the economic limit is reached. In this manner, the third party operator (presumably with lower operating cost or required rate of return), can enjoy revenue for a time before decommissioning is required, and as long as the third party is financially stable and performs decommissioning activities in a sound manner, the operator can transfer the liability risk and cost of decommissioning with the divestiture of the asset. By maintaining a portfolio of marginal structures, it is possible for the third party to schedule decommissioning activities to balance the cash flow of the operation.

Construction contractors such as Cal Dive and Tetra Applied Technologies maintain subsidiaries which actively seek the acquisition of sunset properties for production and decommissioning. Cal Dive subsidiary Energy Resource Technology, Tetra Technologies subsidiary Maritech, Superior Energy Services subsidiary SPN Resources, and Global Industries subsidiary Global Production Services are offshore service/construction companies that acquire mature and end-of-life properties. The subsidiaries are expected to generate a profit while also serving as a "feeder" to increase the utilization of the parent company's rigs, barges, diver crews, and other equipment. Service/construction companies integrate many of the facets of P&A and decommissioning to streamline the process and provide a cost effective and cohesive safety/environmental operation.

Bid and Tender Process

Decommissioning activities are performed in accord with the business model of the operator, but regardless of the model employed, each decommissioning job requires a dedicated project management team to oversee the operation. The project management team will review the blueprints and history of the structure and send engineering personnel to the site to assess the work requirements. The project management team will then report on the options available to the operator, including the scope of work that needs to be performed and how best to prepare the bid. A request for quotation is then created.

The project management team specifies the work requirements of the bid based upon the best available information at the time. Normally, the information required to write a bid include the job specification (location; deck weight, layout, padeye location, leg size, center of gravity; jacket weight, size, center of gravity; number, size, type of piles and wells; module weights; and coordinates and dimensions of equipment) and special requests such as platform and jacket disposition, preference for severance methods, if any, and any other relevant information.

In most cases, the contractor is responsible to furnish all labor, equipment, and material, including a crane vessel with sufficient capacity, cargo barges, tugs, and necessary construction equipment to perform the operation. The contractor generally will specify the severance procedure to be used in the operation and may provide various options if requested by the operator. If the operator specifies the severance method, this may result in the contractor qualifying the bid to transfer the severance risk to the operator.

Typically, a lump sum (base) bid is specified that includes weather downtime, except downtime due to named tropical storms, for work during the prime season (May 15–October 15). The base bid will normally assume that the contractor will dispose of all platform components and the operator will accept the cost of the National Marine Fisheries Services (NMFS) observers and aerial survey, required for the use of explosives, and delays associated with the severance method specified by the operator, if any. A lump sum optional bid may also be offered which gives the contractor the ability to quote an alternative decommissioning method not specified in the scope of work but which still meets all specifications and goals of the job.

The contractor may be required to perform extra work not covered in the scope of work and not included in the base bid. If extra work is required that alters the critical path crane vessel time, the operator is charged at "extra work rates." Extra work may result from obstructions and/or bent stabbing guides in casings or piles, or anything other than soil that prevents the placement of jetting systems, explosives, or cutting tools. If extra work is required that does not alter the critical path crane vessel time, the operator is normally charged an hourly composite rate for all personnel and material required to correct the problem. The cost of extra work is normally passed through to the operator.

Contractors submit their bid based upon the job specification, the supply/demand for construction services in the GOM, and the manner in which the job can be scheduled with the contractor's other work activities and obligations. Heavy lift vessel contractors are typically involved with installation activities during the decommissioning season and bid on jobs to increase the utilization

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Table 2. Average Age of Structures Upon Removal by Water Depth, Configuration Type, and Planning Area in the Gulf of Mexico (1947–2002)

Water depth range (m)	Caisson		Well protector		Fixed platform	
	WGOM	CGOM	WGOM	CGOM	WGOM	CGOM
0–60	(7.1, 4.7)	(15.9, 10)	(16.3, 11.3)	(17.4, 10.2)	(9.3, 5.3)	(17.1, 10.8)
61–200			(7.3, 3.8)	(17, 10.9)	(10.4, 6.2)	(12.6, 7.9)

Note: The data entries are denoted by the coordinate pair (μ, σ), where μ= mean and σ= standard deviation of the structure data per water depth and planning area category.

of their equipment and improve the efficiency of their operations. For activities that the contractor cannot perform directly—such as severing, diving, surveying, and catering services—the contractor will solicit quotes when preparing their bids. Some of these services may already be under contract, whereas other services—especially severance and site clearance and verification—are contracted out on a job-by-job basis. The extent to which a contractor requires subcontractor services depends upon the size, experience, and financial resources of the contractor and its alliance network. Site verification is required by federal law to be performed by an independent subcontractor.

Contractor Selection

The project management team, in consultation with the operator, examines the received bids and then selects the bid that represents the best value for the operator based upon the job specification, the past performance of the contractor, and other conditions, such as the timing of the operation. After selecting the preferred contractor, it is not unusual for additional negotiation to occur between the operator (through the project management team) and contractor, as the job specification becomes more clearly defined. The project management team acts as the representative of the operator and is responsible to ensure that the operator is treated fairly. To minimize cost overruns, the operator should clearly specify the scope of the job and perform as much planning and preparatory work as possible.

Final Negotiation

Each contract is site, time, and operator specific, and so it is difficult to generalize the final negotiation process that occurs, but generally speaking, the operator will try to write a contract as specific as possible to eliminate contingencies and minimize the cost/risk of unforeseen events (Hinze 2001). Contractors prefer operational flexibility, a wide time window, and contingencies when uncertainty exists. A wide time window allows contractors to integrate the job with other operations, which allows them to bid more competitively and ensure extra time for unforeseen events. Contractors prefer the operator to accept any unexpected cost/risk associated with the operation. For example, if explosive methods are used, the operator is expected to incur all the cost associated with NMFS observers, aerial surveys, diver surveys, as well as any delays associated with the presence of sea turtles/mammals, nighttime restrictions, pile flaring, or any other problems that result from the use of explosives. The final negotiation is thus a give and take process based upon the contract terms, precedence, market conditions, negotiation strategy, and the history of the relationship between the operator, project management team, and contractor.

Removal and Severance Forecast Models

Historic Statistics

The average age of structures that have been removed in the GOM along with their standard deviations is shown in Table 2. Since the standard deviation statistics are greater than half the value of the reported means, it is clear that there is a wide variability in removal age across water depth and configuration type. Structures in the western GOM tend to be removed earlier than central GOM structures, due to the widespread occurrence of natural gas fields which tend to undergo quick depletion rates.

The application of explosive techniques varies widely throughout gulf waters (Table 3). Caissons are the most likely to be removed using nonexplosive methods, and as water depth increases, the chance of using explosives increase across all configuration types.

The percentage of structures removed using explosive techniques is depicted in Table 4 according to age upon removal, configuration type, and water depth. The use of nonexplosive methods is most common within the 0–10 year category, and as the age and water depth of a structure increases, roughly speaking, a structure is more likely to be removed using explosives.

Life Expectancy Removal Module

The removal date of a structure is estimated through the relation

$$r(s) = i(s) + a(\Gamma) + k\sigma(\Gamma)$$

where $r(s)$=year of removal of structure s; and $i(s)$=year of first production. The average age upon removal for elements within the category Γ is described by $a(\Gamma)$ and $\sigma(T)$=standard deviation.

Table 3. Number of Structures Removed (R), Structures Removed by Explosive Technique (R_E), and the Percentage of Explosive Removals (p_E) as a Function of Water Depth and Configuration Type for the Gulf of Mexico (1986–2002)

Water depth range (m)	Caisson			Well protector			Fixed platform			All		
	R	R_E	$p_E(\%)$	R	R_E	$p_E(\%)$	R	R_E	$p_E(\%)$	R	R_E	$p_E(\%)$
0–60	749	381	51	193	119	62	595	387	65	1537	887	58
61–200				6	5	83	81	61	75	87	66	76
200^+										2	1	50
Total	749	381	51	199	124	62	676	448	66	1626	954	59

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Table 4. Percentage of Explosive Removals by Configuration Type and Age Upon Removal in the Gulf of Mexico (1986–2002)

Age upon removal (Year)	Caisson		Well protector		Fixed platform	
	0–60 m	61–200 m	0–60 m	61–200 m	0–60 m	61–200 m
0–10	39		52	100	55	76
11–20	56		67	67	68	76
21–30	53		58		77	67
30^{+}	72		77	100	73	100

The value for $a(\Gamma)$ and $\sigma(\Gamma)$ is defined according to configuration type, water depth and planning area (Table 2). The value of k is a user-defined parameter.

The removal model adopted is a heuristic approach modified from a National Research Council (NRC) report (National Research Council 1985). In the NRC report, $a(\Gamma)$ was determined from user-defined values: "Smaller structures in shallow waters, such as caissons and well protectors, tend to be removed after 20–25 years; larger structures with more wells, such as 4- and 8-pile platforms, have a useful life of 25–30 years, and larger structures in deepwater should have a useful life of at least 30 years." The NRC approach is recalibrated using the historic values of age classified according to configuration type and water depth, and then these values are combined with the standard deviation statistics and a user-defined perturbation term to ensure all structures in the GOM are removed.

Life expectancy removal Model I is defined by setting $k=1$ and applying $a(\Gamma)$ and $\sigma(\Gamma)$ from Table 2. If $r(s)\geqslant 2003$, the removal time of structure s is "accepted"; otherwise, set $k=3$ and repeat the calculations. Model II is defined by determining the smallest integer value of k such that $r(s)\geqslant 2003$ and then using this value to estimate removal. Both of these models are heuristic and subjective. Models I and II both ensure that all installed structures will be removed based upon their installation date, average age of removal, and a user-defined perturbation term. Model I represents a slow removal scenario, while Model II presents an accelerated removal schedule.

Explosive Severance Module

The decision to employ explosive techniques in cutting operations depends upon a number of factors, and to the extent that the decision can be proxied by configuration type, water depth, and age upon removal, the probability that a structure will be removed using explosives is written as $p_E(s)$. Structure s belongs to category Γ and is estimated to be removed at the time $r(s)$. Since the age upon removal is known when $r(s)$ is determined, the probability the structure will be removed with explosives is estimated from Table 4.

Model Output

The forecast output predicts the number of structures expected to be removed using explosive technology categorized by configuration type, water depth, and planning area across 5 year time blocks, where the block $200X$–$200(X+4)$ is interpreted as January 1, $200X$–December 31, $2000(X+4)$. A summary of the number of active structures expected to be removed with explosives is depicted in Tables 5 and 6. A reasonable planning level suggests that between 94 and 159 structures per year will be removed in federal waters in the near term. Major structures will play an increasingly important role both in terms of the absolute number of structures that will need to be removed as well as the expected cost of removal.

Table 5. Medium-Term Forecast of the Number of Structures Removed in the Gulf of Mexico by Explosive Technique (Model I)

Water depth range (m)	Forecast horizon	Caisson		Well protector		Fixed platform		Total	
		W	C	W	C	W	C	W	C
0–60	2003–2007	14	97	4	64	52	155	70	316
	2008–2012	18	133	4	57	35	255	57	445
	2013–2017	8	104	5	41	62	222	75	367
	2018–2022	0	98	7	30	5	215	22	343
	2023–2027	0	115	9	29	0	203	9	347
Subtotal		40	547	29	221	165	1052	234	1818
61–200	2003–2007	0	0	5	0	19	62	24	62
	2008–2012	1	0	2	0	31	65	35	65
	2013–2017	1	1	0	0	15	83	16	84
	2018–2022	0	1	0	0	3	53	3	54
	2023–2027	0	2	0	17	0	17	0	36
Subtotal		2	4	7	17	69	278	78	301

Note: "W" denotes the Western Gulf of Mexico and "C" the Central Gulf of Mexico.

Limitations of the Analysis

There are significant uncertainties associated with all structure removal forecasts, and forecasting should be viewed in terms of the "potential" of the likely impact, under current conditions, rather than as a predictive indicator of the actual number of structures that will be removed in the future. The assumptions that provide the framework to perform a forecast also dictate the manner in which the model results are interpreted. Since operator behavior is too complex to model on an aggregate basis without the use of production profiles or private information (e.g., nomination schedules, operational cost, development plans, strategic objectives), all nonproduction based forecasts are considered to have comparable levels of uncertainty and to be roughly equivalent in their predictive ability.

Table 6. Medium-Term Forecast of the Number of Structures Removed in the Gulf of Mexico by Explosive Technique (Model II)

Water depth range (m)	Forecast horizon	Caisson		Well protector		Fixed platform		Total	
		W	C	W	C	W	C	W	C
0–60	2003–2007	30	168	10	91	89	250	129	509
	2008–2012	10	221	11	83	62	317	83	621
	2013–2017	0	132	8	47	14	280	22	459
	2018–2022	0	26	0	0	0	205	0	231
Subtotal		40	547	29	221	165	1052	234	1820
61–200	2003–2007	1	0	4	0	48	107	53	104
	2008–2012	1	0	3	9	26	97	30	106
	2013–2017	0	2	0	8	0	77	0	87
	2018–2022	0	2	0	0	0	0	0	2
Subtotal		2	4	7	17	69	278	83	299

Note: "W" denotes the Western Gulf of Mexico and "C" the Central Gulf of Mexico.

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Heuristic methods hold advantage in terms of ease of implementation and focus on the model drivers, but it is often desirable to investigate more advanced techniques to refine and improve the methodological structure. A life expectancy and probabilistic removal model is considered a first-order approximation of removal times. More sophisticated models can be constructed; e.g., (Kaiser 2005), but are considerably more difficult to implement, are subject to their own set of uncertainty, and fall outside the discussion of this paper.

The primary assumptions employed in the life expectancy and explosive severance model are as follows:

1. Structures are differentiated into "reasonably" homogenous categories according to configuration type, water depth, and planning area, and are removed based on the time history of their installation and their estimated age at the time of decommissioning.
2. The removal of structures to be installed in the future are not considered.
3. The probability that a structure is removed with explosives is assumed to be described through historic statistics, and depend on the configuration type, water depth, and age upon removal.
4. The operating costs and production revenue associated with a structure, complex, leasehold, or field are not considered.
5. Operator-specific conditions such as investment strategy, field development options, removal scheduling, regulatory constraints, and divestiture opportunity that may influence structure removal times are not considered.
6. Exogenous events such as extreme weather are not considered.

Since all active structures are differentiated on a configuration type, water depth, and planning area basis and are removed according to the time history of their installation (Assumption 1), the categorization and removal relation ensures a structured and transparent methodology.

Most structures that will be removed over the next two decades will come from the population of existing structures. Structures expected to be installed in the future may need to be removed at a time which overlaps with the current time horizon, but most structure removals associated with future installations is expected to occur outside or near the end of the time horizon of the forecast. Assumption 2 is thus considered reasonable over a medium term horizon.

The life expectancy removal relation serves as a heuristic to the expected removal time. The removal relation is a simple, nonproduction based model, and in view of the sources of uncertainty governing the problem, is presented as a first-order approximation. In the absence of company-level economic criteria or engineering estimates of field life, the values of the parameters used with this relation are based on historic data for elements classified within reasonably homogeneous categories.

The probability of an explosive removal is characterized using aggregate statistics categorized according to configuration type, water depth, and age upon removal. More advanced regression-based methodologies could be used to predict the removal method as a function of these variables, but data limitations usually constrain the generality of more sophisticated approaches. Assumption 3 is thus considered appropriate relative to the constraints of the model and the manner in which the decision to use explosive technology is made by operators.

It is desirable to build a model that mimics the economic decision criteria of the operator, but at an aggregate level such a procedure is difficult to construct and is also a source of a large amount of uncertainty. The primary factor that drives operator decision-making, namely, profit, is not incorporated within the current model framework (Assumption 4), and other operator-specific and environmental conditions are also not considered (Assumptions 5 and 6). To determine the profit of a given structure or field, the model must account for the expected future values of hydrocarbon price, production, operator cost, reserve estimates, and investment decision making. Unfortunately, these variables are highly uncertain, and in most cases, unobservable, and so when developing more advanced models, we are usually simply exchanging one set of uncertain factors for another set of uncertainty of the same, or possibly, lesser magnitude.

Conclusions

Decommissioning activities are driven by economics and technological requirements and governed by federal regulation. Decisions about when and how a structure is decommissioned involve issues of environmental protection, safety, cost, and strategic opportunity, and the factors that influence the timing of removal as well as the manner in which the structure is severed are complicated and depend as much on the technical requirements and cost as on the preferences established by the contractor, the scheduling of the operation, and federal regulations. Our description of the decommissioning market and business segments of the industry are practice-oriented, and offer a window into industry operations in a condensed and direct manner. The regulatory requirements of decommissioning were reviewed and first-order removal forecasts for the GOM developed using a life expectancy and probabilistic removal model. The forecast model is simplistic, but it is carefully and concisely developed, with assumptions clearly stated. Model building allows the process drivers to be better understood, and the approach is considered a first-order approximation to more complex modeling schemes. Forecasts were provided for structure data partitioned according to configuration type, water depth, age, and planning area. A description of the modeling process and a summary of the results and limitations of analysis were outlined.

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